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

REPLY TO
ATTENTION OF

CEMVN-ED-H

30 April 2014

MEMORANDUM FOR Commander, Mississippi Valley Division (CEMVD-PD-N/ Mr. Rayford Wilbanks)

SUBJECT: Independent External Peer Review of Greater New Orleans Hurricane and Storm Damage Risk Reduction System (GNOHSDRRS): Design Elevation Report and Addendum

1. Reference Battelle Memorial Institute's "Final Independent External Peer Review Report Hurricane and Storm Damage Risk Reduction System - Design Elevation Report, December 6, 2010" (Encl 1) and "Final Independent External Peer Review Report for the Hurricane and Storm Damage Risk Reduction System - Design Elevation Report Addendum, September 4, 2012" (Encl 2). This memo summarizes the results of both reviews.

2. IEPR Review 1 of the Greater New Orleans Hurricane and Storm Damage Risk Reduction System (GNOHSDRRS) Design Elevation Report was conducted by the Battelle Memorial Institute. The independent team assembled by Battelle consisted of two (2) panel members with broad-ranging experience in hydraulic and civil engineering. The IEPR team provided subject report to recap and summarize review comments and recommendations which was submitted to USACE. As stated in the final report, "The HSDRRS Design Elevation Report is generally technically defensible for its purpose to document the analyses performed to develop preliminary design elevations. Because levee resiliency directly affects the actual level of protection achieved by the HSDRRS, the Panel thought that the HSDRRS Design Elevation Report should provide more discussion of levee resiliency, including backslope armoring, where the average overtopping rate exceeds the resiliency criterion of 0.1 cfs/ft for extreme events, including the 0.2% annual exceedance probability event. The Panel also thought that additional discussion regarding the relative sea level rise (RSLR) assumption of 1 foot in 50 years that was used to establish future surge and wave characteristics is needed to justify what appears to be a RSLR value on the low end of predicted RSLR ranges."

The final report of the IEPR panel is entitled, "Final Independent External Peer Review Report – Hurricane and Storm Damage Risk Reduction System – Design Elevation Report, December 6, 2010". Overall, six final panel comments were identified and documented. Of those five had medium significance and one had low significance. The six comments were successfully closed and concurred upon by the USACE and the IEPR panel. The USACE written response for all comments, including concurrence, are documented in Encl 1.

The six comments are listed below:

1. The HSDRRS Design Elevation Report should provide more documentation of the levee resiliency that results from the design elevations and average overtopping rates currently in the HSDRRS Design Elevation Report where the average overtopping rate exceeds 0.1 cfs/ft for the 0.2% annual exceedance probability event.

2. Additional documentation regarding the relative sea level rise (RSLR) assumption of 1 foot in 50 years that was used to establish future surge and wave characteristics is needed in the HSDRRS Design Elevation Report to justify what appears to be a value on the low end of predicted RSLR ranges.

3. Documentation for levee certification needs to be presented in the HSDRRS Design Elevation Report, including numerical parameters for certification requirements.

4. More documentation on input parameters for estimating wave overtopping rates is needed in the HSDRRS Design Elevation Report to clarify how the design elevations were calculated and how the future engineering implications will be implemented.

5. Portions of the HSDRRS Design Elevation Report describing the wave characteristics and calculations need improved clarity and documentation.

6. The HSDRRS Design Elevation Report needs to fully document the basis for wave forces on hard structures.

3. IEPR Review 2 of the Greater New Orleans Hurricane and Storm Damage Risk Reduction System (GNOHSDRRS) Design Elevation Report was conducted by the Battelle Memorial Institute. The independent team assembled by Battelle consisted of two (2) panel members with broad-ranging experience in hydraulic and civil engineering. The IEPR team provided subject report to recap and summarize review comments and recommendations which was submitted to USACE. As stated in the final report, "The panel was generally satisfied with the Design Elevation Report (DER) Addendum. The DER addendum was technically defensible for their purpose to update the HSDRRS DER and document the analysis performed to develop the resulting preliminary design elevations. The panel believes that the technical quality of the DER Addendum could be improved by providing a more explicit and unified discussion of the key issues of resilience, redundancy, robustness and system performance."

The final report of the IEPR panel is entitled, "Final Independent External Peer Review Report for the Hurricane and Storm Damage Risk Reduction System – Design

Elevation Report Addendum, September 4, 2012". Overall, five final panel comments, all of low significance, were identified and documented. The five comments were successfully closed and concurred upon by the USACE and the IEPR panel. The USACE written response for all comments, including concurrence, are documented in Encl 2.

The five comments are listed below:

1. The computed wave overtopping rates for the Seabrook Sector Gate Complex presented in the Design Elevation Report (DER) Addendum exceed the design criteria.

2. The redundancy associated with the interfaces between structures, materials, members, and project phases is not discussed in the DER or the Addendum.

3. The DER and Addendum do not specifically address how the various HSDRRS components work as an effective system.

4. The model analysis for surge levels does not include an update on quantification of the differences with the Federal Emergency Management Agency (FEMA) flood insurance study for the 100-year return period.

5. The DER Addendum does not discuss HSDRRS resiliency and robustness to the extent warranted given their importance to system performance.

4. The point of contact for this action is Stacey Frost, P.E. at (504) 862-2993.

2 Encls
as

MARK R. HOAGUE, P.E.
Chief, Engineering Division

CF:
CEMVN Commander, Colonel Richard L. Hansen
Chief, TFH, Michael F. Park, CEMVN-TFH
Chief, PRO Thomas J. Podany, CEMVN-PM-O
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Enclosure 1

Final Panel BackChecks on

USACE Evaluation Responses

on the

HSDRRS Design Elevation Report

Review 1

Enclosure 1

Final Panel Comment 1:
The HSDRRS Design Elevation Report should provide more documentation of the levee resiliency that results from the design elevations and average overtopping rates currently in the HSDRRS Design Elevation Report where the average overtopping rate exceeds 0.1 cfs/ft for the 0.2% annual exceedance probability event.
Basis for Comment:
Levee resilience affects the actual level of protection that will be achieved by the Hurricane Storm Damage Risk Reduction System (HSDRRS). While the HSDRRS Design Elevation Report does state (p.10) that additional research and modeling is needed to establish resiliency guidance, in its present state, the HSDRRS Design Elevation Report is not completely consistent on resiliency issues. Specifically, for many levee segments (e.g., NO10 and NO01), the 50%-assurance overtopping rate (or "q50") computed in the resiliency analysis for the 0.2% event exceeds, and sometimes greatly exceeds, the 0.1 cubic feet per second per foot (cfs/ft) maximum allowable average overtopping rate that was interpreted from the literature as discussed in Appendix E. The 0.1 cfs/ft criterion appears to contain much inherent uncertainty. It therefore appears that those levee segments having q50 much greater than 0.1 cfs/ft may not be resilient under the 0.2% event. This seems problematic because the 0.2% annual exceedance probability event used in the residency analysis is reported to represent the approximate recurrence of a Hurricane Katrina-level event (HSDRRS Design Elevation Report, page10), where levees breached and frequently failed to provide protection because of severe backslope erosion due to overtopping and inadequate backslope protection. Furthermore, the HSDRRS Design Elevation Report does not address the use of backslope armoring to provide levee resiliency where it could be appropriate. The Panel considers armoring to be an important issue relevant to the HSDRRS Design Elevation Report that should be addressed at some level, if only to reference where armoring is addressed and how it is addressed. Additionally, the HSDRRS Design Elevation Report does not explain how resiliency relates to robustness, redundancy or system effectiveness, which the Panel understands are part of the design intent. Ideally, levee resilience would provide an appropriate margin of safety against: (a) the uncertainty of future surge and wave overtopping rates (i.e., future levee "demand"), and (b) the uncertainty of levee resistance to overtopping by surge or waves (i.e., future levee "capacity"). While the HSDRRS Design Elevation Report deals with uncertainty in future surge and wave overtopping, an unquantified residual risk remains — that residual risk which requires levee resiliency. One element of residual risk is suggested by the American Society of Civil Engineers (ASCE) comments (USACE, 2007b; page 15) that the White Paper on Estimating Hurricane Inundation Probabilities (Resio, 2007) "leaves an overly optimistic impression of the state-of-the-art in computing storm surges and their statistics with Joint Probability Method (JPM) methodology." This suggests that future surge estimates included in the HSDRRS Design Elevation Report are more uncertain than quantified. The Joint Surge Study (JSS) response strongly agreed and indicated "the need for further research to clarify many of the questions and nagging concerns embedded within the overall effort" (USACE, 2007b). Again, it appears that levee resiliency is

a major aspect in dealing with these, and other, uncertainty gaps.
Significance – Medium:
The HSDRRS Design Elevation Report would benefit from additional discussion on levee resiliency issues because levee resilience is a critical element of the HSDRRS that affects the actual level of protection that will be achieved by the HSDRRS, and is directly affected by the design elevations and average overtopping rates determined in the HSDRRS Design Elevation Report.
Recommendation(s) for Resolution:
1. Provide clarifying discussion of the apparent inconsistency of the condition where the 50%-assurance overtopping rate, q50, computed in the resiliency analysis exceeds the adopted 0.1 cfs/ft maximum allowable average overtopping rate. As appropriate, update the maximum allowable average overtopping rate to include an update of the Appendix E evaluation, based on subsequent information that is now available. 2. Add discussion regarding the use of backslope armoring to provide levee resiliency where it could be appropriate. 3. Consider including for all reaches the example resiliency-analysis table for St. Charles Parish included in the comment response section 5.2 at page 45 in the June 19, 2007 JSS Response to the ASCE External Peer Review (USACE, 2007b). This kind of table (showing q50 and q90 for both the 1% and 0.2% events) is not included in the HSDRRS Design Elevation Report, but would be a useful addition for reader understanding and to serve as a kind of sensitivity/resiliency analysis. These tables would also provide for a more complete resiliency analysis. 4. Consider and discuss the related concepts and functions of redundancy, resilience, robustness, and system effectiveness in a holistic fashion in a subsection of the HSDRRS Design Elevation Report. 5. Discuss or reference “The Risk and Reliability Analysis” that will be integrated into a full systems analysis, as stated at pp. 40-41 in USACE (2007b), in the HSDRRS Design Elevation Report. 6. Discuss residual risk. For example, the ASCE comment on the Estimating Hurricane Inundation Probabilities White Paper (Resio, 2007) should be explicitly addressed in the HSDRRS Design Elevation Report.
USACE Final Evaluator Response (#1):
Concurred. Comment response is attached as file comment1response.pdf
Final BackCheck Response (#1):
Concur.

Literature Cited

Resio, D.T. (2007). White Paper on Estimating Hurricane Inundation Probabilities. Probability Methodology – Optimal Sampling. January 29, 2006. Vicksburg, MS: U.S. Army Corps of Engineers.

USACE (2007b). USACE/FEMA Southeast Louisiana Joint Surge Study: Responses to ASCE External Peer Review. June 19, 2007.

Final Panel Comment 2:
Additional documentation regarding the relative sea level rise (RSLR) assumption of 1 foot in 50 years that was used to establish future surge and wave characteristics is needed in the HSDRRS Design Elevation Report to justify what appears to be a value on the low end of predicted RSLR ranges.
Basis for Comment:
The HSDRRS Design Elevation Report makes it apparent that relative sea level rise (RSLR) is an important, but uncertain, variable for estimating future surge and wave overtopping rates used in the HSDRRS design. The HSDRRS Design Elevation Report uses a RSLR of 1 foot in 50 years based on USACE (2004; as cited on HSDRRS Design Elevation Report page 57). The Panel understands that the RSLR range estimated for the Louisiana Coastal Area Ecosystem Restoration Projects Study Area ranged from a low of 1.5 feet/50 years to a high of 3.2 feet/50 years with an intermediate rate of 1.9 feet/50years based on local historic subsidence rates plus estimated eustatic sea level rise. The National Research Council (NRC) has reportedly estimated an intermediate RSLR of 1.6 ft in 50 years. The HSDRRS Design Elevation Report says that the RSLR will be revisited and updated as part of the expected 10-year reviews. However, it may not be cost-effective or even practicable to delay dealing with RSLR that proves to be significantly greater than the 1-ft per 50 yrs presently assumed in the HSDRRS Design Elevation Report. Therefore, because there is so much uncertainty in future RSLR, and 1 foot in 50 years appears to be toward the lower end of the potential range, the HSDRRS Design Elevation Report needs a more thorough discussion of the justification for adopting a RSLR of 1 foot in 50 years and explaining how the HSDRRS would be retrofitted if RSLR proves to be significantly greater than presently assumed. The Panel also notes that the subsidence discussion at HSDRRS Design Elevation Report page 11 is not clear regarding long-term levee soil-consolidation settlement due directly to levee construction. This levee-caused settlement is distinct from regional or local long-term subsidence in the absence of levee construction.
Significance – Medium:
RSLR directly affects the future (year 2057) surge elevations and wave characteristics used in the HSDRRS Design Elevation Report, and, therefore, the actual level of protection that will be achieved by the HSDRRS.
Recommendation(s) for Resolution:
1. Provide a more thorough discussion of the justification for adopting a RSLR of 1 foot in 50 years. 2. Explain the implications for HSDRRS performance if RSLR proves to be significantly greater than presently assumed. 3. Explain how the HSDRRS would be retrofitted if RSLR proves to be significantly greater than presently assumed.
USACE Final Evaluator Response (#2):
Concurred. See attached file comment2response.pdf for response.
Final BackCheck Response (#2):

Concur.

Enclosure 1

Final Panel Comment 3:
Documentation for levee certification needs to be presented in the HSDRRS Design Elevation Report, including numerical parameters for certification requirements.
Basis for Comment:
Section 1.3, page 10, of the HSDRRS Design Elevation Report identifies that levee certification is a critical requirement of the hydraulic system design. The HSDRRS Design Elevation Report indicates, "Use of a risk based approach in the design of the HSDRRS ensures that the design elevations meet certification requirements" (page 10). Although the hydraulic design approach in Section 2 includes a brief description of hydraulic and geometric parameters, it is not evident from the current description which parameters are relevant to levee certification. Because levee certification criteria have been in a state of developmental flux for some time, the Panel believes that an explicit identification and explanation of the current hydraulic requirements for levee certification is necessary. Furthermore, an example explaining how the HSDRRS Design Elevation Report addresses the levee certification requirements would be useful in the HSDRRS Design Elevation Report. Sections 3 through 6 present applications of the risk based approach to Lake Pontchartrain and Vicinity, West Bank and Vicinity, Mississippi Coincident, and New Orleans to Venice, respectively. However, these design applications do not describe the levee certification requirements and how were they satisfied. The tabular presentation of results for the design applications in Sections 3 through 6 is fragmented making it difficult to relate and compare the results to the specific application. The parameters and results presented in the HSDRRS Design Elevation Report (Sections 3 through 6) would be more useful if they were provided in a manner that made verification of the results with the certification requirements obvious. The Panel did a few spot checks of levee heights for two levee segments. They compared the final levee crest heights with the Federal Emergency Management Agency (FEMA) requirements of 44 CFR 65.10, specifically regarding freeboard for coastal levees. The 44 CFR 65.10 part (b)(1)(iii) indicates "freeboard must be established at one foot above the height of the one percent wave or the maximum wave runup (whichever is greater) associated with the 100-year stillwater surge elevation." The two levee segments included in the spot checks were the New Orleans Lakefront Levee (NO01) and Topaz St (NO10), both of which were part of the Orleans Parish Lakefront Metro. These levee segments had crest heights (elevations) exceeding "the height of the 1% wave associated with the 100-year stillwater surge elevation" which was assumed to be equivalent to the "mean surge level plus the mean significant wave height" for the 1% hydraulic boundary conditions as presented in Table 21 on page 78, Section 3 of the HSDRRS Design Elevation Report. The spot check evaluation could not be completed using the "maximum wave runup" because that value depends on parameters that could not be located in this section of the HSDRRS Design Elevation Report, although the maximum wave runup typically exceeds the significant wave height. To ensure the guidelines are followed, the HSDRRS Design Elevation Report should present such information in a clear and concise manner.
Significance – Medium:
The levee certification is a direct outcome of the information contained in the HSDRRS Design

Elevation Report, which also serves as the basis of satisfying the certification requirements, however, the HSDRRS Design Elevation Report does not clearly indicates what is needed to meet the certification requirements.
Recommendation(s) for Resolution:
1. Consider adding a new sub-section in Section 2 with a self-describing title such as "Levee Certification." This sub-section should provide some explanation on how design elevations are addressed in the context of meeting levee certification requirements, both now and in the future. This sub-section may include information such as levee certification requirements, list of parameters needed, free board criteria for certification along with statistically based performance target, cross-reference to other sections from which the necessary parameters could be derived. 2. Include an example of how the levee certification requirements are satisfied for one of the levee segments and how it would be helpful in demonstrating how the guidelines are applied. 3. Include a dedicated sub-section on levee certification as it applies to Sections 3 through 6 to clearly identify specific parameters, their values, and sources.
USACE Final Evaluator Response (#3):
Concurred. See attached response file comment3response.pdf
Final BackCheck Response (#3):
Concur.

Final Panel Comment 4:
More documentation on input parameters for estimating wave overtopping rates is needed in the HSDRRS Design Elevation Report to clarify how the design elevations were calculated and how the future engineering implications will be implemented.
Basis for Comment:
While the design approach in Section 2 adequately presents the design concepts and background, the HSDRRS Design Elevation Report needs better documentation of several elements regarding the assumptions, input parameters, and results for overtopping calculations. In addition, the Panel recommends that more transparency is needed regarding implementation of future engineering investigations. The following elements do not constitute a complete list of desired documentation, but serve only as examples. • Section 1.3 of the HSDRRS Design Elevation Report briefly indicates that future engineering analyses would be performed at 10-year intervals. Further elaboration is needed of the proposed schedule, future engineering investigations, monitoring, maintenance, time frame, and quantification of subsidence . • The example overtopping calculation presented in Appendix F is unclear in how it has been presented and needs more complete documentation regarding input parameters and results output. • The documentation of various assumptions used in the HSDRRS Design Elevation Report needs to be further clarified. For example, the numerical values of all parameters used in Eq 1 and 2 (page 30) to calculate average overtopping rate, q, are not specified in the report. Therefore, it is difficult to independently calculate q for given design segments as reported in the “Hydraulic Design Heights” sections and tables. In other words, calculations of q are not completely transparent and the report does not provide complete documentation of how the design elevations were calculated. For complete transparency, all the Eq 1 and 2 parameters used in the q calculations should be included in the report. Ideally, the report should include an adequate but brief (appropriate) justification or rationale for each of the parameters used in the calculations for each segment in Sections 3 through 6. • The methods for determining wave overtopping and wave forces are appropriate at the current level of technological knowhow. The HSDRRS Design Elevation Report, however, needs to document further clarification on the assumptions and their application to levee designs in Section 2, followed by presentations in Sections 3 through 6. For example, Section 2 of the HSDRRS Design Elevation Report on page 21 states that errors generated by the probabilistic model for the best estimate of the 1% surge level are generally in the range of 1 to 2 feet (based on frequency analysis from ADCIRC and STWAVE). However, Sections 3 through 6 present the standard deviation of 10% of the best estimates (as stated on page 21), which is quite often less than 1 foot (Table 1 Input for Monte Carlo Analysis on page 33). This needs clarification on the basis of accepting a standard deviation (SD) value less than the expected best estimate error. • The Monte Carlo Analyses (MCA) and imbedded Van der Meer equations (Eq 1 and 2, page 30) used to estimate average overtopping rate q at 50% and 90% confidence levels recognize and consider both model uncertainty and parameter uncertainty, which is

appropriate. However, it appears that there are judgments required in assessing overtopping input parameters, which introduces uncertainty that does not appear to be explicitly included in the MCAs. These apparently unaccounted for parameter uncertainties and their potential effects on estimation errors should probably be introduced and discussed in Section 2.3.5. Some discussion of total uncertainty could also be added, and perhaps even tied into the 10-year reviews. • Issues relevant to armoring, on either the flood side or the protected side (backslope), are not addressed in this HSDRRS Design Elevation Report. Hopefully, they are addressed somewhere else or they may be addressed in the final version. If armoring is outside the scope of the HSDRRS Design Elevation Report, the report should provide a reference to where armoring would be addressed. • Appendix E of the HSDRRS Design Elevation Report presents a concise summary of overtopping effects, but it is not clear how recent it is (appears to be circa 2007) and does not discuss additional studies that may be currently in progress or planned as indicated in Section 8 pages 56 through 58 of USACE (2007b).
Significance – Medium:
A clear understanding of the overtopping rate calculation and proper implementation of the assumptions and procedure are critical elements of the HSDRRS. It is necessary to be transparent on the limitations, the schedule of potential improvement, and monitoring and maintenance of the relevant elements.
Recommendation(s) for Resolution:
1. Improve documentation and transparency on the assumptions and estimation of overtopping rates in Section 2 and in Sections 3 through 6 for each levee and floodwall segment. 2. Provide complete details on the example in Appendix F describing the input parameters and results output. 3. Provide clarification on the status of the procedure updates documented in Appendix E.
USACE Final Evaluator Response (#4):
Concurred. See attached file comment4repsonse.pdf
Final BackCheck Response (#4):
Concur.

Final Panel Comment 5:
Portions of the HSDRRS Design Elevation Report describing the wave characteristics and calculations need improved clarity and documentation.
Basis for Comment:
The section describing wave characteristics in Section 2.3.6 (Step 2 of the Step-Wise Approach) on page 35 along with the Hydraulic Boundary Condition Tables found throughout the text need better clarification. The implementation of Step 2, as presented in Tables in Sections 3 through 6, causes some confusion in the "Hydraulic Boundary Conditions" sections of the report. This is because it is not always clear if the reported "Significant wave heights" (H_s) in the tables are (a) 1% wave heights at 600-ft from the levee toe or structure toe, based on the JPM-OS method, or (b) reduced wave heights due to shallow foreshores, where H_{max} = 0.4h for H_s/h > 1/3 and h = water depth of the 1% surge at the levee toe. Where the reported H_s are reduced, it is not always readily apparent that they are reduced and what the "unreduced" wave heights were, making it difficult to check or evaluate results. For transparency of the report, both the "unreduced H_s" (i.e., the 1% wave heights at 600-ft from the levee toe or structure toe, based on the JPM-OS method) and "reduced H_s" at the levee toe should be included in the report. The rationale and calculation for reduction should also be clear and transparent for each levee segment in Sections 3 through 6, particularly where H_s is between the unreduced H_s and H_{max}=0.4h. It is also cautioned that the 2.3.3 Breaker Parameter used for wave height reduction not be confused with the "surf similarity parameter," ξo, in Eq 1 and 2 on page 30, from TAW (2002) because ξo is called the "breaker parameter" in TAW (2002) Eqs 22 and 23. Further, it is not always clear how the breaker parameter is calculated for a given segment. The interpretations of analyses and conclusions are reasonable; however, all of the interpretations are not obvious from the current document. Sections 2.4 and 2.5 represent two examples of sections that lack the necessary details, causing a perception of incompleteness. This is also carried over to Sections 3 through 6. Sections 3 through 6 do not adequately document the implementation of the design approach. The actual assumptions of special conditions and options for each segment of the levee/wall as presented are not clear. The results presented in Tables in these sections need more clarification as to their basis of the computations and need improved documentation. The Panel found it difficult to compare segment-specific information across the tables showing "1% Hydraulic Boundary Conditions," "1% Design Heights," and "Resiliency Analysis" located on separate pages in the HSDRRS Design Elevation Report. Ideally, all this information would be summarized in one table so that all the values could be easily compared for a given segment, and between segments in a given section. Presentation of maps of 1% still water levels, wave heights, and wave periods in Appendix A may be supplemented with further details on the procedures and assumptions. Figures A.1 shows the 1% still water levels at the west end (St. Charles Parish) as higher than the values at the east end (Orleans Parish) despite the landward existence of St. Charles Parish. An

explanation for this seemingly counterintuitive result could not be found in the HSDRRS Design Elevation Report. Ideally, there would be a way to independently verify the accuracy of these calculations, including provision of adequate documentation for future evaluation and changes as the HSDRRS evolves.
Significance – Medium:
Clear and sufficient documentation of the basis for calculations is essential for the hydraulic design. The information documented for design elevations should allow for independent verification and future evaluation as the HSDRRS evolves. The difficulty of comparing results found in separate tables affects the readability and understanding of the DER and thus decreases the functional quality of the guidelines.
Recommendation(s) for Resolution:
1. Provide additional clarification on assumptions and computations of wave characteristics in Sections 2.3, 2.4, and 2.5. 2. Provide additional details on assumptions and calculations for each design segment in Sections 3 through 6. 3. Provide additional clarification and enhancement to the results presented in the tables in Sections 3 through 6. Add reader-friendly “summary tables” with all the tabular information from the “1% Hydraulic Boundary Conditions,” “1% Design Heights,” and “Resiliency Analysis” consolidated into the same table, one table for each HSDRRS section (as presented in the report). 4. Clarify Figures A.1 through A.9 with minor additions. At a minimum, these figures need north indicators. The 1% still water levels at the west end (St. Charles Paris) of Figure A.1 are higher than the values at the east end (Orleans Paris) despite the landward existence of St. Charles Parish. The reason for this counterintuitive result should be explained.
USACE Final Evaluator Response (#5):
Concurred. Response is in attached file comment5response.pdf
Final BackCheck Response (#5):
Concur.

Final Panel Comment 6:
The HSDRRS Design Elevation Report needs to fully document the basis for wave forces on hard structures.
Basis for Comment:
The analysis methodology for calculating wave forces on hard structures is limited to a short discussion in Section 2.2.5 which references the Goda formulations and EM 1110-2-1100 (Part VI), Chapter 5, 1 June 2006. Details, such as a brief presentation of the equations of analysis, are not documented in the report. The Panel was unable to verify the accuracy of this methodology using documentation in the current version of the HSDRRS Design Elevation Report. The HSDRRS Design Elevation Report refers to a CD-ROM which may have the necessary information, but the CD-ROM was not available for review.
Significance – Low:
Wave forces and load calculations are important components of the system design, which is a function of the hydraulic and geometric features, including the hydrostatic pressures and pressure differentials.
Recommendation(s) for Resolution:
1. Enhance documentation on the basis for calculating wave forces on hard structures to support independent verification of the calculations and provide a basis of understanding for future evaluation and updating of the HSDRRS. 2. Provide a copy of the CD-ROM containing the information on details of the wave force calculation and the load results with the HSDRRS Design Elevation Report.
USACE Final Evaluator Response (#6):
Concurred. The pertinent page from the EM is attached. (comment5response.pdf). A new Appendix will be added - (see document comment6response.pdf) A CD-ROM containing information for the final designs is available and will be furnished to the reviewers. Please note that the report being reviewed by the IEPR is the initial report. The final designs are presented in the addendum that has not yet been reviewed. Therefore, some of the design information for the designs presented in the CD-ROM may not have been furnished to the IEPR.
Final BackCheck Response (#6):
Concur.

Enclosure 1

Contents of Comment1response.pdf from USACE

Enclosure 1

1. To clear up any apparent inconsistency of the application of the overtopping criteria, the paragraph in section 2.3.4 Overtopping Criteria will be changed as follows:

However, it is difficult to assess the adequacy of applying criteria for the New Orleans area without a good understanding of the overall quality of the levees following many different periods of construction and the effects of stresses of past hurricanes. The actual field evidence supporting these criteria is limited. After consultation with the ASCE External Review Panel, the following wave overtopping rates have been established for the New Orleans District hurricane protection system for the authorized level of risk reduction:

- For the still water, wave height and wave period determined for the authorized level of risk reduction, the maximum allowable average wave overtopping of 0.1 cfs/ft at 90% level of assurance and 0.01 cfs/ft at 50% level of assurance for grass-covered levees;
- For the still water, wave height and wave period determined for the authorized level of risk reduction, the maximum allowable average wave overtopping of 0.1 cfs/ft at 90% level of assurance and 0.03 cfs/ft at 50% level of assurance for wall type structures with appropriate protection on the back side.

It should be noted that Congress has not provided the USACE authority to design for 0.2% level of risk reduction.

2 Through 5.

We agree, the issue of armoring is an important issue relative to the design of the HSDRRS. The issue of resiliency and design features to incorporate resiliency into the system, such as armoring, will be addressed in two documents, a separate document prepared by the Armoring project delivery team of USACE and the HSDRRS design guidelines. The Armoring project delivery team document will address the use of backslope armoring, provide a resiliency-analysis table for all HSDRRS reaches, include the “Risk and Reliability Analysis”, as stated at pp 40-41. The HSDRRS design guidelines will be updated to provide design criteria for design features, such as armoring.

The section on armoring and resiliency in Chapter 8 will be revised. Beginning at paragraph 5 of page 295, the section will be deleted and replaced with the following:

This report includes the calculation of surge elevations, waves and overtopping flow from the 0.2% annual exceedence surge elevation. The 0.2% annual exceedence was selected as a starting point for assessing damage thresholds and establishing design criteria. For urban areas, such as New Orleans, the 0.2% exceedence probability is considered an appropriate minimum level of evaluation of resiliency. Corps experts, academia, and ASCE external review members attended a resiliency workshop held in New Orleans on 4-5 September, 2007. The participants strongly recommended a focused Resiliency Team be formed to develop concepts, methods, and tools for incorporating resiliency into the design. The draft resiliency workshop report, New Orleans Hurricane Protection System, Resiliency and Overtopping Workshop, outlines possible goals and charter for the Resiliency Team.

Enclosure 1

As noted in written comments on presentation of the IPET draft final report, Dr. Ed Link noted that resiliency

> *" is time-dependent, due to changes in requirements for protection (i.e., changes in potential consequence) or changes in the hazard (climate dynamics or changes in the nature of the protection system and subsidence). Resilience must be part of the adaptive nature of a system and be reviewed frequently as a fundamental character of the design and capacity of the system. Three main principles are suggested:*
>
> • *Designs conservative* enough to appropriately account for the unknown and flexible enough to be augmented as hazards or requirements change.
> • *Performance redundancy* such as armoring to prevent scour from overtopping that leads to failure and breaching.
> • *Integrated systems approach* to protection, from design, construction, operation, maintenance, and emergency operations perspectives. *Pumping resilience* as a component of the system is one example.

USACE Mississippi Valley Division has issued DIVR 1110-1-16, Resiliency and Structural Superiority Requirements for Hydraulic Structures within or Adjacent to Levees and Floodwalls. The DIVR provides the resiliency and structural superiority requirements to be applied to design and construction of all water resource projects containing hydraulic structures within the Mississippi Valley Division. Structural superiority provides some measure of resilience regarding design conservatism and managing consequences from failure in system performance. Structural superiority has been developed for those structures that would be very difficult to rebuild, if damaged, because of disruption in services. Examples are major highway and railroad gates that require detours, pumping station fronting protection that requires reductions to pumping capacity, sector gated structures, etc.

Additional measures of resiliency that have been incorporated into the HSDRRS include:

- For the LPV and WBV project areas of the HSDRRS, the 1% design elevation is checked against the 0.2% exceedence still water elevation. If the design elevation is lower, the elevation is raised to prevent free flow over the levee or wall.
- Structures include hardening where erosion of the material behind the structure is likely should overtopping occur; the area behind an I-wall has been hardened by providing a splash pad or other means to provide scour protection.
- Replace I-walls with T-walls, where possible.
- Pump resiliency has been added to the system through fronting protection, safe houses for pump operators, and other measures.
- Load cases are set so that water to the top of wall is checked, with a required factor of safety of 1.3.

Research is needed to understand the full performance limits of structures and to discover new approaches for creating adaptive designs. In particular, research is needed for floodwalls on levee berms; while protection can be provided for wave overtopping adjacent to the wall, how the water moves down the levee berm slope.

Enclosure 1

Design methods should be clearly based on physical behavior of engineering components and systems and should be reviewed periodically to determine if they represent the latest knowledge, practice, and technology.

Similarly, existing projects should be periodically reviewed to ensure that their original design has not been compromised by changing hazard or changing knowledge base.

Since the 2007 meeting, resiliency has been incorporated into the armoring program. The armoring program covers all aspects of armoring the system for resiliency against storms which result in surge elevations greater than the 1% exceedence values as well as armoring of the system's protected sides slopes and transistion areas between levees and structural features, and floodside slopes surges less than the 1% exceedence values. The scope of the armoring program is to provide recommendations on armoring materials, placement, and designs for the HSDRRS. Key components of the system which may require armoring are levee protected-side slopes (backslopes), especially at the inflection point where the levee slope meets the levee toe or a stability berm, and transition areas where hardened structures such as floodwalls meet earthen levees. Armoring solutions will vary with location and with site specific physical and environmental conditions. Critical areas for armoring within the system are likely to be those identified as receiving the highest overtopping flow rates and/or velocities. Deterministic and probabilistic processes will be used in the determination of system armoring needs and the development of armoring recommendations.

An Armoring Council has been established to provide oversight, recommend and monitor policies, practices and procedures to assure effective integrated quality management in support of armoring within the HSDRRS. The recommendation to the Armoring Council, on the type of Armoring to be constructed in each reach, will be driven by full scale testing and a risk assessment (including an AEP process). The Full Scale Testing will determine the velocity capacity thresholds when subjected to wave-only overtopping. Using a wave overtopping simulator, constructed and operated at CSU (with quality assurance by ERDC), empirical data will be collected and analyzed. This analysis will allow the development of protected side levee armoring design guidance.

The Armoring Program Delivery Team (PgDT) will determine overtopping velocities at each reach of the system for selected storm events greater than the 1% annual exceedence event. Utilizing the results of the full scale wave overtopping testing, the team will compare the armoring material capabilities with the overtopping velocities and determine which armoring materials are necessary for protecting each reach of the system for a given set of storm events. With this information the team will prepare three or more armoring alternatives for use in the risk assessment model.

The Risk Assessment will determine which armoring alternative provides the biggest reduction in risk for the available funds. The Risk Assessment will assess the overtopping velocities for a range of return period exceedence levels. Cost estimates for armoring the system based on the selected armoring alternatives will be developed and used to compare risk reduction to armoring cost in order to establish the optimum return period.

The output of the risk assessment will be a recommendation as to which return period exceedence event, or level of resiliency, the armoring should be designed for. The output of the CSU-based Design Guidance will be used in conjunction with the output of the risk assessment to develop the recommendation to the Armoring Council (using the AEP process).

Enclosure 1

The Armoring Program shall make recommendations as to the minimum amount and type of armoring required at transitions. Scaled overtopping tests have been performed at Texas A&M on typical levee slope and floodwall transition configurations to determine the required armoring footprint and type of armoring materials required in those areas.

The Armoring Team shall also make recommendations as to the type of flood side armoring required on levee and floodwall structures. The recommendation will draw on a USACE report commissioned by the Armoring Team to study and recommend domestic and international practices in the analysis and design of flood side protection.

All technical information developed and used in support of the recommendation to the Armoring Council will be compiled and issued in the form of an Armoring Manual. This will describe the general approach and engineering theories appropriate to the type of armoring applications required in the HSDRRS. Actual armoring decision processes and recommendations will be compiled into an Armoring Report which will describe the basis of all armoring decisions taken in support of the HSDRRS.

The Armoring Program will implement armoring programmatically at the end of the final levee construction of the HSDRRS which will be on or about June of 2011. Plans and Specifications will be prepared by CEMVN Engineering Division, or by A-E's, for each reach indentified to be armored.

The Armoring Program will deliver the following products.

<u>Flood side Wave Erosion Guidance:</u> The purpose is to identify available research that can guide flood side armoring requirements specific to the 1% HSDRRS system design. A white-paper was produced that provides the results of the research and includes recommendations for flood side armoring and/or further investigation. The guidance derived from this work will be incorporated with the Armoring Manual. Interim guidance will be issued upon completion of the ATR and before completion of the Armoring Manual. Decisions taken will be included in the Armoring Report.

<u>Transition Design Guidance</u>: This project provides a numerical model to be used to support the design of levee to floodwall transition features of the New Orleans HSDRRS. The numerical model will be verified with a scaled physical model. The results of this study are documented in a Texas A&M Report. Based on this report, the Armoring PgDT will assess the required footprint of the transition armoring and will develop a recommendation on the footprint and type of armoring required at these features. This guidance will be documented in a report and will also be incorporated in the Armoring Manual.

<u>Full Scale Wave-only Overtopping tests:</u> In order to analyze the performance of classes of armoring materials (under hydraulic loading and environmental conditions which are appropriate to the New Orleans area for extreme event loading conditions) Colorado State University (CSU) will perform Full Scale Wave Overtopping tests. CSU will produce a report on the testing with interpretative information on overtopping velocities, overtopping flow rates, and armoring material performance. Based on this report the Armoring PgDT will analyze and interpret the Full Scale Overtopping Tests in order to develop applicable design guidance. The results of this effort will be part of the basis of the AEP and the Armoring Council Recommendation, and will be documented in the Armoring Report and incorporated in the Armoring Manual.

Enclosure 1

Risk Assessment for Armoring: The Armoring Program will utilize risk methods based on the work developed by the Interagency Performance Evaluation Task Force (IPET) to achieve the maximum risk reduction for the system as a whole for a range of extreme events greater that the 100-year event. As a part of this effort a tool will be established through which different armoring alternatives can be assessed. The methodology through which armoring alternative combinations are identified is documented in the 'Velocity White Paper'. The applied risk methodology, in addition, to the results of the risk assessment (the RAA model runs), will be documented in an Optimization Report. The results in this report will then be used by the Armoring PgDT to formulate a recommendation on the optimization of armoring.

Armoring Manual: The Armoring Manual will provide levee armoring designers with design guidance (consistent with MVN Design Guidelines). The Armoring Manual will document the design methodology and analyses required to design the appropriate armoring features of all components of the HSDRSS. The Armoring manual will largely be an amalgamation of technical design guidance documents as previously described in this section.

> Armoring Report: The Armoring Report will contain a summary of all the Armoring Program Activities and Deliverables; the AEP; and Armoring PgDT Recommendations to the counsel. The Armoring Report is largely a compilation of technical documentation produced under the Armoring program.

.6. Residual risk assessment for the completed HSDRRS cannot be finalized at this time because armoring has not been implemented. It must also be noted that no risk assessment of the New Orleans area has completely considered risk from other hazards besides hurricanes. Some residual risk determinations with the 100 year protection in place have been made for Task Force Hope using methodologies employed for the IPET work. Depth maps have been posted on the USACE web page at http://www.mvn.usace.army.mil/hps2/

The DIVR has been attached (DIVR1110-1-16.pdf) – Dr Links comments are attached (IPET-final-DrLink-writtenstatement)

DEPARTMENT OF THE ARMY
Mississippi Valley Division, Corps of Engineers
Vicksburg, Mississippi 39181-0080

CEMVD-PD-WW/CEMVD-RB-T

Regulation
No. 1110-1-16

Engineering/Construction
RESILIENCY AND STRUCTURAL SUPERIORITY REQUIREMENTS FOR HYDRAULIC STRUCTURES WITHIN OR ADJACENT TO LEVEES AND FLOODWALLS

1. Purpose. This constitutes a statement of policy that defines the resiliency and structural superiority requirements to be applied to design and construction for all water resource projects containing hydraulic structures (elsewhere in this DIVR referred to as "structures" or "structure") within or adjacent to levees and floodwalls. It is furnished to provide general guidance and to define the regional oversight responsibilities of the Mississippi River Commission/Mississippi Valley Division on the subject matter.

2. Applicability. This regulation is applicable to all organizational elements within the MVD/MRC Headquarters and its Districts.

3. References.

a. Memorandum, 1 May 74, subject: Design Elevations for Appurtenant Structures, Red River Backwater Area (encl).

b. ER 1110-2-1405, Hydraulic Design for Local Flood Protection Projects, 30 Sep 82.

c. ETL 1110-2-299, Overtopping of Flood Control Levees and Floodwalls, 22 Aug 86.

4. Background. Resiliency of structures refers to the structures ability to survive overtopping events without major damage or loss of function. Structural superiority refers to adding structure height to prevent overtopping of structures before levees or floodwalls in other locations away from the structure are overtopped. Methods of resiliency may include armoring or hardening of the structures and transitions to the levees and floodwalls to enable these structures to survive overtopping events. Structural superiority in overtopping of levees/floodwalls is a concept dealing with the survivability of structures within or adjacent to the levees/floodwalls. Higher top elevations are provided to structures within or adjacent to levee/floodwall alignments to ensure any overtopping event will first overtop the adjacent levees/floodwall system in such a manner as to not endanger the structures and assure an adequate tailwater at the structure to prevent damage should the top elevation of the structure be exceeded by a high-water event. Ensuring the survivability of these structures is warranted as repair/replacement of structures damaged by overtopping is generally more expensive and difficult to achieve than repair/replacement of adjacent levee/floodwall systems.

5. Policy. Provisions (i.e., structural superiority or structural resilience) to prevent damage or failure from overtopping will be provided for all structures within or adjacent to levees and floodwalls to ensure survivability of the structures. Types of structures covered by this DIVR include, but are not limited to, drainage structures and pump stations within levees and floodwalls as well as navigation locks and other structures within or adjacent to levees and floodwalls. Overtopping resiliency may consist of structural superiority, armoring, hardening, or other methods which will ensure structural survival from overtopping events. Where methods other than structural superiority are used, the top elevations of the structures will be no lower than the adjacent levees or floodwalls unless the structures are by function designed for overtopping (such as weirs and spillways). In cases of weirs, spillways, or other structures designed to be overtopped, the adjacent levee, floodwall, or other bound will be so designed as to have structural superiority or resilience to overtopping damage. For

pre-construction planning and design, measures to provide structural superiority or overtopping resiliency should be evaluated and applied as early in the process as practical. Completed projects or projects under construction which do not meet the superiority or overtopping resiliency requirements will be modified to meet these requirements subject to the engineering practicability of such modifications, a risk assessment (including resulting damage to the structure) of overtopping, and upon available authorities and appropriations. This DIVR does not provide such authorities or appropriations.

6. Where structural superiority is applied, a minimum of two (2.0) feet of structural superiority above the design grade of the adjacent levees/floodwalls will be provided for these structures unless such structures are, by their function, designed to withstand significant overtopping (such as weirs, spillways, etc.), in which case the adjacent bounds will have the superiority. Additional structural superiority should be considered if the risk of failure of the structure(s) from overtopping is still considered probable with only the minimum two foot superiority. Design of the structures should consider water to the top of and over the structure with superiority using applicable USACE guidelines. Design of the transition from the top of the structures back to the design grade of the adjacent levees/floodwalls should ensure that an overtopping event which scours the adjacent levees/floodwalls will not endanger the structures. A minimum transition of 100 feet from the ends of the structures to the design grade of the adjacent levees/floodwalls should be provided.

7. Deviations. Deviations to this policy are not envisioned. In the event conditions arise in which consideration of a deviation may be required, the District Commander should formally submit a request for deviation from this policy to the President, Mississippi River Commission, or Commander, Mississippi Valley Division (ATTN: CEMVD-PD-W). A deviation request should summarize the project and its existing or design conditions, the circumstances/justifications which warrant consideration of a deviation to this policy, the probability of overtopping/failure and the ramifications, alternatives in lieu of a deviation

studied, and the District Commander's recommendations. Deviations to this policy may not be made prior to written approval by the President, Mississippi River Commission, or Commander, Mississippi Valley Division.

Encl

GEORGE T. SHEPARD, JR., PE
Colonel, EN
Deputy Commander

DISTRIBUTION:
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DEPARTMENT OF THE ARMY
MISSISSIPPI RIVER COMMISSION, CORPS OF ENGINEERS
VICKSBURG, MISSISSIPPI 39180

S-1 June 1974

ADDRESS REPLY TO: LMVED-TD
PRESIDENT, MISSISSIPPI RIVER COMMISSION
CORPS OF ENGINEERS
P. O. BOX 80
VICKSBURG, MISSISSIPPI 39180

1 May 1974

SUBJECT: Design Elevations for Appurtenant Structures, Red River Backwater Area

District Engineer, Vicksburg
District Engineer, New Orleans

1. Reference LMVED-H multiple letter, dated 10 July 1973, subject: FC, MR&T Backwater Levees, copy inclosed (Incl 1). As directed in paragraph 3 of referenced letter, appurtenant structures are to be designed and constructed with backwater reservoir areas and the West Atchafalaya Floodway considered confined.

2. Extensive model tests for the project flood have recently been conducted on the Mississippi Basin Model to determine elevations at critical gaging stations within the Red River backwater area under various operational conditions. The effects of confining the Tensas-Cocodrie backwater area, the Bayou des Glaises loop area, and the West Atchafalaya floodway were determined for two conditions at Old River Structures; (1) the structures full open, and (2) the structures regulated to a maximum of 680,000 cfs. Crest elevations for these conditions are as follows:

LOCATION	CREST ELEVATION, FEET ABOVE MSL	
	OLD RIVER FULL OPEN	OLD RIVER REGULATED
Acme	67.8	65.3
Old River Tailwater	68.4	66.6
Barbre Landing	66.5	64.0
Hamburg	65.5	63.0
Simmesport	64.4	61.7

LMVED-TD 1 May 1974
SUBJECT: Design Elevations for Appurtenant Structures, Red River Backwater Area

3. Appurtenant structures in the Red River backwater area should be designed with a minimum freeboard of 3 feet above the water surface elevation obtained at the respective sites for conditions outlined above with the Old River Structures regulated. This will result in approximately 0.5 feet of freeboard above the condition with Old River Structures full open. The basis of this design is that it is impractical to consider confining these areas until such time that either dependable regulation can be achieved or the Atchafalaya River channel efficiency has improved to the extent that confining becomes practical.

4. A revised list of structures affected, including modifications required to those completed or under construction, should be submitted to this office NLT 1 June 1974.

FOR THE PRESIDENT:

1 Incl
as

R. H. RESTA
Chief, Engineering Division

Enclosure 1

LMVED-H

10 July 1973

SUBJECT: FC, MR&T, Backwater Levees

District Engineer, Memphis
District Engineer, Vicksburg
District Engineer, New Orleans

1. Reference LMVD M/L dated 13 June 1973, subject: Levee Profile.

2. The revised project design flowline for the Mississippi River, developed from 1973 flood data indicates that it is necessary to raise the main stem levees. Since the backwater levees are an integral part of the flood control system, it is also necessary that they be raised in accordance with the revised project design flowline.

3. In addition to the above, economic development in backwater areas coupled with the unreliability of any appreciable flood control storage being available to reduce flood crests, may preclude their continued use as off-river storage reservoirs. Hence, it is considered good engineering to provide sufficient freeboard for all appurtenant structures yet to be constructed to make them compatible with the levee grade and section required for complete protection of the backwater areas against the project design flood. For appurtenant structures already completed and those now under construction, alterations to achieve this end should be considered.

4. Based on the above information, you are directed to redesign and construct all backwater levees as follows:

a. Levees are to be to a grade two feet below the 1973 project design flowline for the Mississippi River.

LMVED-H 10 July 1973
SUBJECT: FC, MR&T, Backwater Levees

b. Appurtenant structures are to accommodate a levee grade and section equivalent to an additional five feet of freeboard above the levee grade determined in 4a above.

c. Levee sections will be enlarged to accommodate the levee grade determined in 4b above in those reaches where structures are involved with transition made back to the normal section on either side of the structure.

5. You are to submit to this office NLT 10 August 1973 a list of structures affected and, in the case of structures either completed or under construction, the proposed modification required. Revised design flowlines and corresponding levee grades should be furnished also.

CHARLES C. NOBLE
Major General, USA
President, Mississippi River Commission

Enclosure 1

(Written comments by Dr. Ed Link, IPET Director, on presentation of the IPET Draft Final Report)

Performance Evaluation of the New Orleans and Southeast Louisiana Hurricane Protection System

Interagency Performance Evaluation Task Force

Draft Final Report, June 1, 2006

The Interagency Performance Evaluation Task Force (IPET) today is releasing this draft final report of its performance evaluation of the New Orleans and Southeast Louisiana Hurricane Protection System during Hurricane Katrina. Our sincere hope is that the results of this report, used already in the repairs of the system, the assessments of the undamaged portions of the protection system, and being incorporated in design guidance for future protection projects in the area, will help such a tragedy from ever occurring again.

This comprehensive evaluation was conducted by the IPET, a distinguished group of more than 150 government, academic, and private sector scientists and engineers who dedicated themselves solely to this task for the last eight months. IPET applied some of the most sophisticated capabilities available in civil engineering to understand what happened during Katrina and why. This included two of the world's largest centrifuges and one of the Department of Defense's newest supercomputers. But the most important capability, by far, was the diverse experience and expertise of the many people that comprised IPET.

While IPET was created by Lt. Gen. Carl Strock, the Chief of the U.S. Army Corps of Engineers, its work was peer reviewed literally on a weekly basis by an equally distinguished review panel of the American Society of Civil Engineers. This built in quality and relevance from the beginning.

The purpose of the IPET was not just new knowledge, but immediate application of that knowledge to the repair and reconstitution of protection in New Orleans. IPET results were transferred and applied as quickly as possible to the repairs of the system. This transfer was greatly facilitated by the direct participation on IPET teams by professionals from Task Force Guardian, Task Force Hope and the New Orleans District. We believe the IPET findings and lessons learned, together with those of others, will be an effective platform for improvements to engineering practice and policies dealing with hurricane protection.

This report is being provided as a draft, offering provisional final results for the entire spectrum of the work accomplished, with the notable exception of the risk and reliability assessment, which, at the request of the ASCE External Review Panel, is undergoing validation and peer review and should be released later this month or in July at the latest.

This draft report will receive final reviews by the American Society of Civil Engineers External Review Panel and the National Research Council Committee on New Orleans

Regional Hurricane Protection Projects. The results of those reviews will be incorporated into the IPET final report, which is expected to be released in September 2006.

From the beginning, IPET was charged by the Chief of Engineers and the Assistant Secretary of the Army for Civil Works to work in an open environment and provide maximum exposure for public awareness. Report 1, published in January, presented a detailed scope of work, and Report 2, published in March, provided an update on the analysis and interim results. Since then additional interim reports were released, such as the failure mechanisms for the London Avenue Canal and the Inner Harbor Navigation Canal breaches. The majority of IPET information and documents were placed on the public Web site, *https://IPET.wes.army.mil*. At this time, there are more than 4300 documents on this site.

There are nine volumes in this draft final report. They are designed to provide a detailed documentation of IPET's technical analyses and associated findings. The volumes are organized around major technical tasks that together provided an in-depth, system-wide assessment of the behavior of the hurricane protection system and the lessons learned that were incorporated into the repairs and that are being integrated into the continuing efforts to improve the system in the future. All nine volumes are available publicly on the IPET web site.

The volumes and their individual focus areas are as follows:

- Volume I: Executive Summary and Overview – Summary of findings and lessons learned. Overview of performance evaluation activities and reports.

- Volume II: Geodetic Vertical and Water Level Datum – Update of geodetic and water level references for the region and determining accurate elevations for all critical structures.

- Volume III: The Hurricane Protection System – Documentation of the character of the hurricane protection system, including the design assumptions and criteria, as built and maintained condition.

- Volume IV: The Storm – Determining the surge and wave environments created by Katrina and the time history and nature of the forces experienced by protection structures during the storm.

- Volume V: The Performance – Levees and Floodwalls – Understanding the behavior of individual damaged structures and development of criteria for evaluation of undamaged sections. Providing input to repairs and ongoing design and planning efforts.

- Volume VI: The Performance – Interior Drainage and Pumping – Understanding the performance of the interior drainage and pumping systems with regard to extent and duration of flooding. Examination of scenarios to understand system-wide performance.

- Volume VII: The Consequences – Determination of the economic, human safety and health, environmental, and social and cultural losses due to Katrina. Examination of scenarios to understand implications of losses and possible recovery paths on future risk.

- Volume VIII: Risk and Reliability – Determination of the inherent risk for all parts of the system prior to and following Katrina. Provision of capability for risk-based decision support for continuing improvement and development of hurricane protection.

- Volume IX: Supporting Appendices – Documentation of information resources and management, program management, and communications.

The IPET did not examine organizational or jurisdictional issues that impact the effectiveness of the physical system. These issues are being examined by the Corps of Engineers initiated Hurricane Katrina Decision Chronology Study, being conducted by a separate group of investigators. Other teams of investigators outside the Corps are also examining and contributing insights to these issues.

The IPET findings and lessons learned are presented in detail in the individual Volumes of the report and summarized in Volume I, the Executive Summary and Overview. A unique aspect of the IPET work is that the results are in many cases, already “in the ground” in the repairs that have been accomplished. They are also incorporated into the planning and design processes that are being used to complete the system. The analytical tools and information will be transitioned to the Louisiana Comprehensive Protection and Restoration Study and other Corps offices to develop effective approaches for higher levels of protection.

Overarching Findings

The system did not perform as a system. The hurricane protection system in New Orleans and southeast Louisiana was a system in name only. The system’s performance was compromised by the incompleteness of the system, inconsistency in levels of protection, and the lack of redundancy. Incomplete sections of the system resulted in sections with lower protective elevations or transitions between types and levels of protection that were weak spots. Given that hurricane protection is typically a series system, the failure of the weakest component causes the failure of the system. Inconsistent levels of protection were caused by differences in the quality of materials used in levees, differences in the conservativeness of floodwall designs, and variations in structure protective elevations due to subsidence and construction below the design intent (due to error in interpretation of vertical elevation datum information). Systems also need redundancy, a second tier of protection to help compensate for the potential failure of the first tier. Pumping is a form of redundancy; however, the pumping stations are not designed to operate in major hurricane conditions nor are they part of the hurricane protection system. Armoring the back sides and crests of levees and the protected side of floodwalls would have added significant redundancy and reduced breaching. Surge gates at the mouths of the outfall canals are also an excellent example of providing redundancy.

Enclosure 1

The storm exceeded design criteria, but the performance was less than the design intent. Sections of the hurricane protection system were in many ways overwhelmed by Hurricane Katrina, such as the Gulf Intracoastal Waterway levees along New Orleans East and the levees in St. Bernard and Plaquemines Parishes. The combination of record high surge and long period waves exceeded the design conditions and devastated the levees in these areas. This devastation, however, was aided by incomplete protection, lower than authorized structures, and levee sections with erodible materials. While overtopping and extensive flooding from Katrina were inevitable, a complete system at authorized elevations would have reduced the losses. The designs were developed to deal with a specific hazard level, the Standard Project Hurricane as defined in 1965; however, little consideration was given to the performance of the system if the design event or system requirements were exceeded.

At the 17th Street Canal, two sites on the London Avenue Canal and at one site within the Inner Harbor Navigation Canal, foundation failures occurred prior to water levels reaching the design levels of protection. This caused breaching and subsequent massive flooding and extensive losses. These were all I-wall structures with a common failure mode that involved the formation of a gap on the canal side of the floodwall that precipitated and accelerated the failure in the foundation materials. These structures' designs were marginal with respect to practice, the uncertainty inherent in the variable geological conditions and the hurricane hazard for the area.

Two other sites within the Inner Harbor Navigation Canal experienced I-wall breaches due to overtopping and scour behind the walls, which reduced the stability of the structures. The storm surge levels in this canal exceeded the design levels, and lower structure elevations, reduced over two feet by 35 years of subsidence, contributed to the amount of overtopping that occurred.

Another site on the west side of the Inner Harbor Navigation Canal breached from overtopping and scour of a levee. The elevation of the levee was lower than adjacent areas (another example of the incomplete system with transitions), which added to its vulnerability.

The flooding and the consequences of the flooding were pervasive, but also concentrated. Consequences of the flooding and the associated losses were greater than any previous disaster in New Orleans and, in themselves, create a formidable barrier to recovery. Loss of life was concentrated by age, with more than 75 percent of deaths being people over the age of 60. Loss of life also correlated to elevation, in terms of depth of flooding, especially with regard to the poor, elderly and disabled; the groups least likely to be able to evacuate without assistance.

The majority of the flooding, approximately two-thirds by volume in Orleans (east bank) and St Bernard Parishes, and half of the economic losses can be attributed to water flowing through breaches in floodwalls and levees. Losses, and in many respects recovery, can also be directly correlated to depth of flooding and thus to elevation. In some areas flooded by Katrina where water depths were small, recovery has been almost complete. In areas where water depths were greater, little recovery or reinvestment has taken place.

Another concentration of consequences is in the nature of the losses. Twenty five percent of residential property values were destroyed by Katrina, and this loss represents 78 percent of all direct property damages. Non-residential properties suffered a 12 percent loss in total value or half the rate of residential. Clearly, residential areas were more prone to flooding.

The repaired sections of the hurricane protection system are likely to be the strongest parts of the systems until the remaining sections can be similarly upgraded and completed. Since there are many such areas where the protection levels will be the same as before Katrina, the New Orleans metropolitan area remains vulnerable to any storm creating surge and wave conditions similar to those of Katrina. An objective of the risk and reliability analysis is to understand the relative vulnerabilities of the various drainage areas of New Orleans and to identify the primary sources of those vulnerabilities.

Overarching Lessons Learned

The IPET analysis provides broad insights into the many aspects of the New Orleans and vicinity hurricane protection system and why the system performed as it did during Hurricane Katrina. Integration of a number of these principal lessons learned provides some strategic insights for the future protection in southeast Louisiana and for hurricane and flood protection projects in general.

Resilience. It is clear that a resilient hurricane protection system provides enormous advantages. Resilience in this case refers to the ability to withstand higher than designed water levels and overtopping without breaching. Approximately two-thirds of flooding and losses were the result of breaching, i.e., the significant loss of protective elevation in structures. While overtopping and rainfall alone from Katrina would have created dramatic flooding and losses, the difference is staggering in many regards. Reductions in losses of life, property, and infrastructure, associated reductions in the displacement of individuals, families, and the workforce, coupled with reduced disruption to businesses and social and cultural networks and institutions, would have a dramatic impact on the ability of a community and region to recover. Resilience has not been easily justified using the methodologies that emphasize net economic benefits. It was not an obvious element in the New Orleans Hurricane Protection System design.

It is important to view resilience as time-dependent due to changes in requirements for protection (i.e., changes in potential consequence) or changes in the hazard (climate dynamics or changes in the nature of the protection system and subsidence). Resilience must be part of the adaptive nature of a system and be reviewed frequently as a fundamental character of the design and capacity of the system. Three main principles are suggested:

- Designs conservative enough to appropriately account for the unknown and flexible enough to be augmented as hazards or requirements change.

- Performance redundancy such as armoring levees to prevent scour from overtopping that leads to failure and breaching.

- Integrated systems approach to protection, from design, construction, operation (including pumping), maintenance, and emergency operations perspectives.

System performance. Planning and design methodologies need to allow for an examination of system-wide performance. The piecemeal development of the New Orleans Hurricane Protection System provided a system in name only. The systems approach should have a time dimension to allow consideration of the potential changes in requirements or conditions over the life of the project and to examine approaches to build in adaptive features and capabilities. Subsidence, changing population demographics, and the changing patterns of hurricane intensity and frequency are obvious examples of the time-dependent challenges hurricane protection systems face. All components that contribute to the performance of the overall system must be treated as an integral part of the system. For any given drainage basin, the protection is only as robust as the weakest component of the system and how effectively the various components that are interdependent operate together.

Risk. A risk-based planning and design approach would provide a more viable capability to make informed decisions on complex infrastructure such as hurricane protection systems. The traditional approach, used for the New Orleans protection system, is component-performance-based that uses standards to define performance and relies on factors of safety to deal with uncertainty. It is difficult to examine the integrated performance of multiple components, and standards are usually limited to past experience. Risk-based planning is systems-based, requiring that the entire system be described in consistent terms and explicitly, including uncertainty. Component performance is related to system performance as well as the consequences of that performance.

The risk-based approach uses factors such as loss of life, environmental losses, and cultural consequences in decision making without reducing all factors to one measure, such as dollars. As applied for the IPET risk assessment that will be released later, it allows aggregation and de-aggregation of information to address issues at different scales, providing a useful tool for collaborative planning between responsible agencies at different levels. Most importantly, risk and reliability allows decision makers to understand the relative levels of vulnerability that specific areas face, the nature of the consequences (e.g., loss of life, economic loss or environmental loss), and to understand the source of the vulnerability.

Knowledge, technology and expertise. The history of the planning, design, and performance of the Hurricane Protection System in New Orleans also points out a dilemma in engineering. While new pieces of knowledge were available over time that were relevant to the ultimate performance of the I-walls on the outfall canals, the pieces were not put together to solve the puzzle of the failure mechanism that occurred.

Enclosure 1

The Corps' own testing of sheetpile floodwalls (E-99 Sheet Pile Wall Field Test Report, June 1988) was not directed at the global stability of I-walls, but with hindsight, some of the behavior observed was indicative of the wall deflections that led to formation of the gap. Similarly, late in the 1990s, research published in part by the Waterways Experiment Station discussed the need to include hydrostatic water pressures with regard to a gap forming in the numerical modeling of sheetpile floodwalls. Work not directly related to levees or floodwalls in England discussed the deflection and hydrostatic water pressure problem for earth retaining walls. How do these puzzle pieces get placed together to create knowledge for designers, and how do designers and reviewers get access to this information? How does the research or testing community become aware of applications, perhaps different from their original purpose, for their new knowledge?

Part of the solution relates to the amount of overall effort and resources put into the search for new knowledge and capabilities to deliberately update design criteria and planning capabilities. The solution is not simply more research or more outreach alone, it is the ability of the design/construction and research communities to work together in an environment that enables collaboration and experimentation with new knowledge and approaches to old and new problems. There has been a distinct loss in resources expended in this area, particularly in the domain of hurricane and flood protection and specifically in the geotechnical fields that are at the heart of the levee and floodwall performance issues in Katrina. The focus on "standards" may in fact also deter this process. Standards imply stability and constancy, when in fact the concept of "guidelines" may be more appropriate, allowing and encouraging customization and adaptation as new knowledge emerges. In either case, standards and/or guidelines need to be refreshed at a greater and greater frequency as the generation of new knowledge continues to accelerate.

The other dimension to this issue is expertise. As technology accelerates and engineering practice evolves at an increasing pace, it becomes more difficult to maintain the level of technical expertise necessary to cope with the ever more complex issues, such as water resources. Significant measures are needed to re-emphasize technical expertise and renewal of that expertise as the engineering practice evolves. These measures must be part of the culture of organizations and cover the entire profession to ensure that the total team addressing priority issues, such as hurricane protection, are working from the latest knowledge and professional practice. The Corps of Engineers should be a leader in this area.

Closing

The Interagency Performance Evaluation Task Force offers this report and its findings as a contribution to the well being of the people of New Orleans and southeast Louisiana and the reconstitution of effective hurricane protection for their future. We hope that implementation of these findings will help prevent such an event from ever happening again.

Lewis E Link, Ph.D., IPET Director

Enclosure 1

Contents of Comment2response.pdf from USACE

Enclosure 1

Sea level rise and subsidence have an effect on hurricane surge elevations and wave characteristics.

Sea level rise and subsidence have been included in the ongoing hurricane modeling and calculation of levee and floodwall design elevations.

Natural subsidence rates were determined from work performed for the Louisiana Coastal Area, Louisiana, Ecosystem Restoration Study report, published in 2004. The natural subsidence rate consists of relative subsidence and sea level rise.

Relative subsidence rates were derived using the database of long-term rates maintained by the New Orleans District Corps of Engineers. Rates ranged from 0.5 ft per century to 1.0 ft per century for the Lake Pontchartrain and Vicinity and West Bank and Vicinity hurricane protection areas. See attached map. These values were determined as follows.

> Radiocarbon dating of buried peat horizons representing previous marsh surfaces at mean sea level is another commonly used technique for estimating long-term relative sea level rise rates throughout coastal Louisiana. The depth of the sample divided by its approximate age yields an estimate of the relative sea level rise rate. This technique allows estimates of relative sea level rise over the past several thousand years. However, because these rates represent long-term averages they may not reflect changes in the rates due to short term changes in the processes, such as recent sea level rise. Previous investigations of stratigraphic relative sea level rise using this technique include those of Coleman and Smith (1964), Gagliano and van Beek (1970), Gerdes (1982), Penland et al. (1988), Roberts (1985) and Kulp (2000). Rates derived using this technique vary widely depending on location, sediment age, sediment thickness, and depositional environment. In general, relative sea level rise rates are greatest where Holocene sediments are thickest. Younger sediments also have high relative rates due to the rapid dewatering which occurs after deposition. Presently, the highest rates are located at the mouth of the Mississippi River and along the axis of the infilled ancestral Mississippi River valley which runs from near Houma to Grand Isle (May 1984). Artificial drainage and subsurface fluid withdrawal can greatly increase the relative sea level rise rate experienced throughout the deltaic plain.

See attached figure Subsidencerates.jpg

The predicted sea level rise (or eustatic sea level rise), 1.3 ft per century, was taken from the Intergovernmental Panel on Climate Change Third Assessment Report, published in 2001. (Note - Fourth Assessment Report had not been published at the time of analysis; it was published later in 2007)

Enclosure 1

Adding the two values together, natural subsidence rates in the Lake Pontchartrain and Vicinity and West Bank and Vicinity hurricane protection areas ranged from 1.8 ft per century to 2.3 ft per century.

The Engineering Research and Development Center used the ADCIRC and STWAVE models to evaluate the effect of natural subsidence on still water elevations (SWE) and waves to determine how surge and waves will change in the future, 50 years from now (the year 2057).

Natural subsidence was modeled as apparent sea level rise. Five storms were selected from simulations representing today's conditions (2007). These five storms each were run with 1 ft, 2 ft, and 3 ft increased in water level. No other changes to input were made (same offshore waves, same friction, same model parameters, etc.).

Model results showed effects of apparent sea level rise are not uniform across the hurricane protection area - the effects depend on depth of water and topography of area.

From the model results, the following effects were determined:
Lake Pontchartrain, New Orleans, St Bernard, change in SWE = 1.5 ft, change in waves = 0.75 ft, change in wave period = 0.4 seconds Caernarvon and West Bank, change in SWE = 2.0 ft, change in waves = 1.0 ft, change in wave period = 0.5 seconds

The changes were added to the existing conditions (2007) SWE and wave characteristics. The resulting future conditions (2057) were used to calculate design elevations.

After the modeling and hydraulic design was completed, and HSDRRS P&S and construction underway, LACPR came out with rates of relative sea level rise. The rates were developed by ERDC and based on the Intergovernmental Panel on Climate Change Fourth Assessment Report, published in 2007. The mid range value for Pontchartrain area was 1.3 ft/50 years; the high range value for Pontchartrain area was 2.6 ft/50 years. The values were added to the statistical surface for existing condition, no modeling performed, no levee design performed, costs for levees was prorated from mid-range costs. For example, a levee of 14 ft in 2010 would be 15.6 ft in 2060 for the mid range value and 16.6 ft in 2060 for the high range value.

Compare and contrast this with the methodology performed for HSDRRS using the rate of 1 ft in 50 years. 1 ft natural subsidence was placed in ADCIRC model and a subset of storms modeled. Water level change values were developed from the model results. The water level change values were added to the 1% exceedence water level. Adjustments were made to wave characteristics. Then the height of the levee was determined using HSDRRS design guidelines.

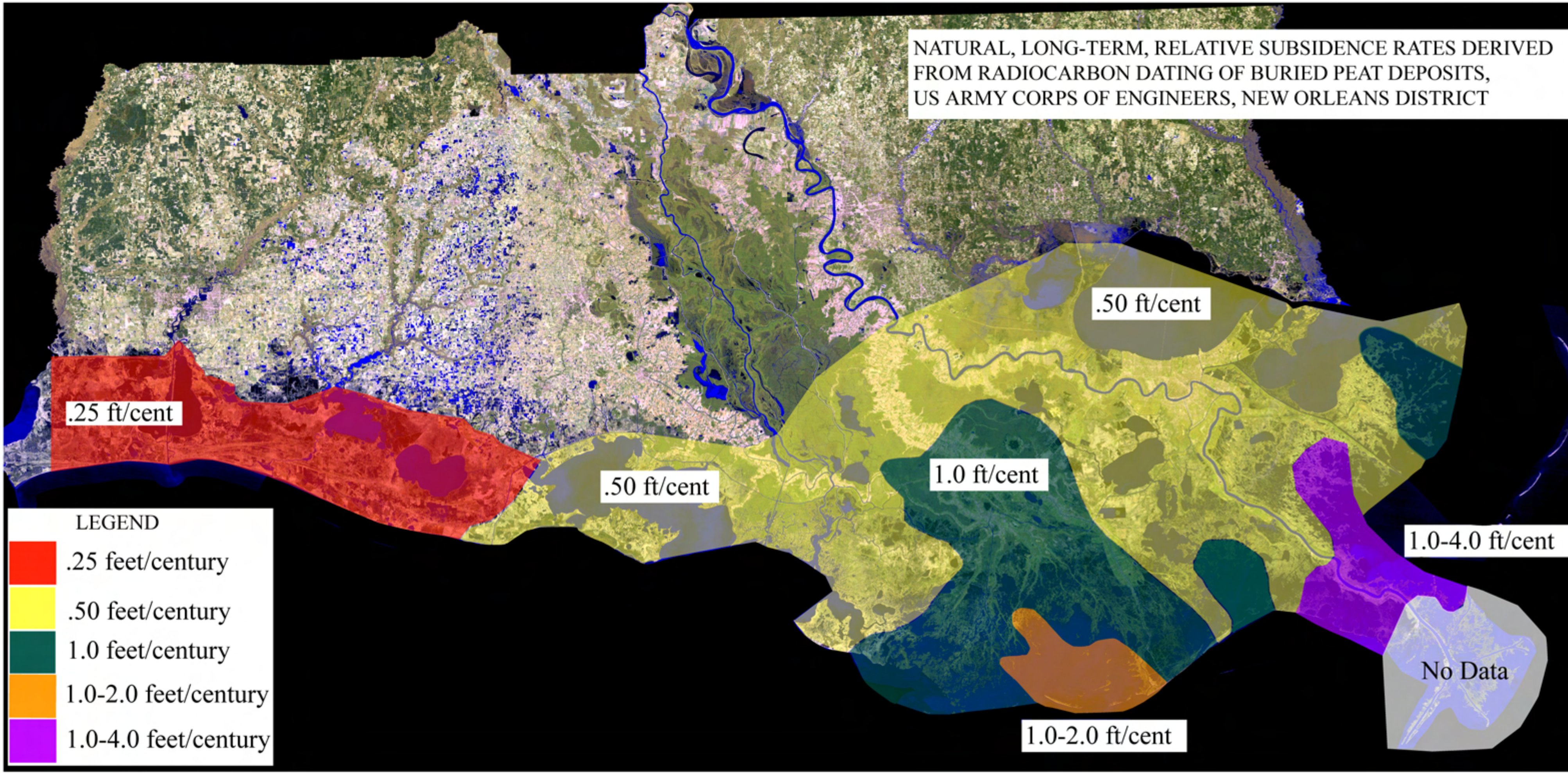
Enclosure 1

To show the difference in design elevations with the 2 methods, the LACPR levee elevation for St Bernard levees for future conditions using the mid range value would be 28.1 to 30.6 ft. Using the HSDRRS methodology, the future condition elevations are 29.0 to 31.5 ft, about 1 ft higher.

A USACE Circular was published in June 2009 prescribing the use of gage data to determine the relative sea level change, a different process than what was followed for LCA. As a result of the circular, an assessment was made regarding the design elevations in context with the three different rates of sea level change prescribed in the EC. The assessment included a description of how the HSDRRS can be modified in the event the actual change in the design water levels is greater than the predicted change.

The report, as written and reviewed by the IEPR, represents the initial work performed and reflects the best available information and guidance at the time of the work. Any additional analyses and information subsequent to that initial work relating directly to the design elevations will be added to the addendum to the design elevation report. The assessment performed after the publication of the Circular in 2009 will be added as an appendix to the addenda.

Enclosure 1



NATURAL, LONG-TERM, RELATIVE SUBSIDENCE RATES DERIVED FROM RADIOCARBON DATING OF BURIED PEAT DEPOSITS, US ARMY CORPS OF ENGINEERS, NEW ORLEANS DISTRICT
.25 ft/cent
.50 ft/cent
.50 ft/cent
1.0 ft/cent
1.0-4.0 ft/cent
No Data
1.0-2.0 ft/cent
LEGEND
.25 feet/century
.50 feet/century
1.0 feet/century
1.0-2.0 feet/century
1.0-4.0 feet/century

Enclosure 1

Contents of Comment3response.pdf from USACE

Enclosure 1

We will comply with the requirements for National Flood Insurance Program Levee System Evaluation, as set forth in EC1110-2-6067, dated August 2010. The EC is consistent with and founded on the principles of 44 CFR 65.10 while updating methods and references to current USACE practices and criteria. The first USACE national guidance related to levee system evaluation was issued in April 1997. This policy, coordinated with and accepted by FEMA, required the use of risk analysis (statistically based levee height) for levee system evaluations performed by USACE. Since then, all supplemental USACE guidance for levee system evaluation has been coordinated with FEMA. FEMA was a partner on the Project Delivery Team and the Review Team process for this EC. The EC requires that a Levee System Evaluation Report be prepared. The Levee System Evaluation Report will include all of the documentation as to the evaluation of the levee system. The Levee System Evaluation Report will have explicit identification and explanation of the hydraulic requirements for levee certification for the HSDRRS and clearly indicate how the completed HSDRRS complies with certification requirements. Any additional computations associated with the levee system evaluation will be included in the Levee System Evaluation Report.

The referenced policy letters and new EC are attached (0623-CertLetter[1].pdf, . 0623-CertAppendix[1].pdf, and EC1110-2-6067Aug2010, as well as a fact sheet and FAQ combined at end of this response). The above paragraph will be integrated into page 8 as follows:

Delete the following

In April, 1997, two policy letters addressing levee certification determinations were issued. The first letter, *Guidance on Levee Certification for the National Flood Insurance Program*, dated April 10, 1997, was issued to ensure consistency throughout USACE with the application of the policy to levee certifications. This letter was updated and reissued with the policy letter, *Guidance on Levee Certification for the National Flood Insurance Program – FEMA Map Modernization Program Issues*, dated June 23, 2006. The emphasis in this updated letter and attachments describes USACE policy in the area of freeboard criteria by providing a performance target that is statistically based, reflecting stream profile variability and uncertainty.

Use of a risk based approach in the design of the HSDRRS ensures that the design elevations meet certification requirements.

Replace with

Upon completion of the HSDRRS construction, USACE will comply with the requirements for National Flood Insurance Program Levee System Evaluation, as set forth in EC1110-2-6067, dated August 2010. The EC is consistent with and founded on the principles of 44 CFR 65.10 while updating methods and references to current USACE practices and criteria. The first USACE national guidance related to levee system evaluation was issued in April 1997. This policy, coordinated with and accepted by FEMA, required the use of risk analysis (statistically based levee height) for levee system evaluations performed by USACE. Since then, all supplemental USACE guidance for levee system evaluation has been coordinated with FEMA. FEMA was a partner on the Project Delivery Team and the Review Team process for this EC. The EC requires that a Levee System Evaluation Report be prepared. The Levee System Evaluation Report will include all of the documentation as to the evaluation of the levee system. The Levee System Evaluation Report will have explicit identification and explanation of the hydraulic requirements for accreditation of the HSDRRS and clearly indicate how the completed HSDRRS complies with accreditation requirements. Any additional computations associated with the levee system evaluation will be included in the Levee System Evaluation Report.

Enclosure 1

DEPARTMENT OF THE ARMY
U.S. ARMY CORPS OF ENGINEERS
441 G STREET NW
WASHINGTON, D.C. 20314-1000

CECW-P/CECW-E

JUN 23 2006

MEMORANDUM FOR ALL MAJOR SUBORDINATE COMMANDS

SUBJECT: Guidance on Levee Certification for the National Flood Insurance Program – FEMA Map Modernization Program Issues

References:

a. Federal Emergency Management Agency Memorandum, "Procedural Memorandum 34 – Interim Guidance for Studies Including Levees," August 22, 2005.

b. 44 Code of Federal Regulations Chapter I, Subchapter B, Part 65.

c. Engineer Regulation 105-2-101, "Risk Analysis for Flood Damage Reduction Studies," January 3, 2006.

d. Director of Civil Works Memorandum "Guidance on Levee Certification for the National Flood Insurance Program," April 10, 1997.

1. The Federal Emergency Management Agency (FEMA) has embarked upon a major program to modernize the nations' floodplain maps. Through this program, commonly referred to as the Map Modernization (MapMod) Program, FEMA will provide the nation with digital flood hazard data and maps that are more accurate, easy to use, and readily available. The MapMod Program is described in detail at *http://www.fema.gov/fhm/mm_main.shtm.* USACE MSC and district offices are encouraged to develop partnerships with their counterpart FEMA MapMod colleagues to foster close coordination and collaboration on map issues of mutual interest.

2. On August 22, 2005, FEMA issued "Procedure Memorandum 34 – Interim Guidance for Studies Including Levees". See Ref. 1a (Attachment 1). The key element of this memorandum is that if local governments wish areas behind levees to be shown on FEMA's new Digital Flood Insurance Rate Maps (DFIRMs) as protected to at least the one percent chance of flood using FEMA's guidance on levee certification, they must arrange for certification documentation to be provided to FEMA. Reference 1b includes FEMA's published guidance for levee certification. See Attachment 2. As a consequence, we expect local governments to seek certification documentation for levees within their jurisdiction from USACE offices. The purpose of this memorandum is to provide guidance on the appropriate handling of these requests.

3. USACE adopted risk analysis as the methodology for flood damage reduction studies. See Ref. 1c (Attachment 3). Subsequent to USACE adoption of the risk analysis for flood studies in 1996, USACE and FEMA agreed upon guidance for levee

certification that is founded on risk analysis as defined in ER 1105-2-101. The agreement is documented in the transmittal memorandum and guidance dated 10 April 1997 "Guidance on Levee Certification for the National Flood Insurance Program." See Attachment 4. The 1997 memorandum and guidance supplements the FEMA Code of Federal Regulation criteria for freeboard by providing upper and lower bounds of required levee performance based on specified levels of assurance of protecting against the base flood. The level of assurance performance of the levee of interest is determined by performing a risk and uncertainty analysis. The guidance requires risk analysis as the basis for all riverine and coastal levee and floodwall certification determinations performed by USACE.

4. Corps offices will not perform levee certifications for levees USACE did not construct, unless the levees participate in USACE's Rehabilitation and Inspection Program described in ER 500-1-1.

5. USACE will not certify a levee without, as a minimum, an on-site inspection by engineering technical staff. All inspection and certification work shall be performed by registered professional engineers. For levee systems that have been constructed within the past five years, and for which certification documentation is available, it is appropriate to briefly review the status of the levee system, verify via on-site inspections that the circumstances reflected in the published certification documentation continues to be appropriate, such as review of annual maintenance records, and re-issue a certification letter to FEMA. For levee systems that have recently undergone studies, or are in the active study phase but certification documents have not been prepared and processed, and provided timing and thoroughness of studies will support such, a certification determination can be made based on an on-site inspection and the guidance provided in the edited 10 April 1997 memorandum.

6. Final levee certification letters should be signed and submitted to the requesting local government with appropriate supporting documentation by the Chief of Engineering of the district office making the determination.

7. Funding guidance for levee certification activities described in this memorandum is expected to be issued in approximately 30 days.

8. Points of contact for this guidance are Mr. Eric Halpin, CECW-CE, telephone (202) 761-7775, Mr. Steve Durrett, CECW-CE, telephone (202) 761-5346 or Mr. Harry Kitch, CECW-CP, telephone (202) 761-4127.

FOR THE COMMANDER

P.E.

DON T. RILEY
Major General, USA
Director of Civil Works

Encl (4)

Enclosure 2

USACE Draft Evaluator Responses
to
Final Panel Comments
on the

Independent External Peer Review of the Design Elevation Report – Addenda

(Design Elevation Report Review #2)

Enclosure 2

Final Panel Comment 1:

The computed wave overtopping rates for the Seabrook Sector Gate Complex presented in the Design Elevation Report (DER) Addendum exceed the design criteria.

Basis for Comment:

The 1% chance annual exceedance criteria for wave overtopping rate (q) established in the Design Elevation Report (DER, V4.0a) include 50% and 90% non-exceedance values (q_{50} and q_{90}) of less than 0.03 cubic feet second (cfs) per foot (ft) (q_{50} < 0.03 cfs/ft) for hard structures, less than 0.01 cfs/ft (q_{50} < 0.01 cfs/ft) for grass-covered levees, and less than 0.1 cfs/ft (q_{90} < 0.01 cfs/ft) with appropriate erosion protection on the protected side. As documented in Section 8 (pp. 303-304) of the DER V4.0a, the established criteria are based on the best available information to date.

The computed wave overtopping rates for the design sections presented in this DER Addendum are reasonable and appropriate and met the above established criteria for the hydraulic design except for the Seabrook Sector Gate (SBRK-G) Complex. As documented in Table 2-19 on p. 2-104 of this DER Addendum, the computed overtopping rates for this gate structure are q_{50} = 0.078 cfs/ft and q_{90} = 0.181 cfs/ft, which exceed the above established design criteria. The basis of this exceedance, given on p. 2-102 of the DER Addendum, is stated as follows:

a) the exact location of the Seabrook gate is unknown,
b) the STWAVE model has a relatively coarse resolution, and
c) the bed geometry is relatively complicated for this particular case.

The DER Addendum (p. 2-103) presented a resolution to the STWAVE computation: a more detailed and accurate wave analysis prior to finalizing the design of the structure. This proposed resolution is reasonable as long as the computed overtopping remains within the specified criteria.

Significance – Low:

The overtopping rate exceedance is isolated due to uncertainty of the hydraulic and geometric input parameters at the proposed gate with no exact location. The proposed resolution is anticipated to remedy the inaccurate computation.

Recommendation(s) for Resolution:

1. Re-run the STWAVE model with more accurate and exact hydraulic and geometric conditions and re-compute the overtopping rates at the gate structure that satisfy the established design criteria.

USACE Draft Evaluator Response FPC#1: *The computed wave overtopping rates for the Seabrook Sector Gate Complex presented in the Design Elevation Report (DER) Addendum exceed the design criteria.*

USACE PDT please provide a single Concur or Non-Concur statement in regards to the overall Final Panel Comment here: Concur

USACE please elaborate on the reason for your Concur or Non-Concur statement here:

ERDC has performed numerical wave modeling and has prepared a report "Numerical Wave Modeling for Floodgate Design at Seabrook in New Orleans" dated December 2009. A copy of the report is attached. Estimates of wave parameters were obtained from fully nonlinear

Enclosure 2

Boussinesq-type BOUSS-2D model. The modeling results indicate for the 1% exceedence flood event, the calculated values of maximum significant wave height for the flat gate ranged from 3 ft to 3.9 ft, and the maximum wave period ranged from 5.9 to 6.2 sec. Two spectral wind-wave models, CMS-Wave and STWAVE, were also used to estimate the effect of wind on waves at the floodgate. For wind-only forcing, the maximum significant wave height estimates at the floodgate were 1.0 m (CMS-Wave) and 1.1 m (STWAVE). For the combined wind and wave forcing, the estimates increased to 1.2m and 1.3m, respectively. Additional modeling was performed using SWAN; efforts are underway to locate the documentation for this modeling.

The criteria for overtopping were developed to address the risk of scour on the floodside of grass levees or floodwalls and therefore reduce the risk of failure. Overtopping at the Seabrook gate does not flow down a levee slope or fall at the base of a floodwall; the water falls into the IHNC channel itself, with a water depth of 20 ft or more. For the tie-in walls adjacent to the gate, concrete slope paving has been incorporated into the design. Therefore, the scour potential is small.

Beginning on Page 2-102, the addendum will be revised to include information on the additional modeling and the overtopping rate exceeding the criteria. The referenced ERDC report, the report on SWAN modeling, and the DDR will be cited.

Enclosure 2

Final Panel Comment 2:
The redundancy associated with the interfaces between structures, materials, members, and project phases is not discussed in the DER or the Addendum.
Basis for Comment:
The DER Addendum does not directly address redundancy. However, system redundancy is addressed briefly in the Executive Summary of DER V4.0a (p. 5) as follows: “The existing levee/floodwall system in the Inner Harbor Navigation Canal/GIWW (IHNC/GIWW) and along the outfall canals will provide a useful measure of redundancy to the flood risk reduction system behind the primary line of protection such as the MRGO/GIWW gates, Seabrook gate, and the permanent outfall closures and pumps. Sector gage alternatives for the Harvey and Algiers Canal will also have some levee/floodwalls along the interior drainage outlets that can provide a measure of redundancy.” Although not specifically called out in the DER or the Addendum documents, the redundancy on the hydraulic design is adequately incorporated in the design process which includes still water level, surge and wave heights, and design elevation computations. For example, the friction effect is not considered in the STWAVE modeling for the 1% design elevations, which may or may not better represent the wave climate, but the absence of friction effect introduces a redundancy factor in the wave height calculation. An action plan is also being developed to determine ways to reduce uncertainty in wave characteristics and thus increase confidence in design parameters. Performance redundancy such as armoring to prevent scour and erosion from overtopping that leads to failure and breaching is recognized and acknowledged as a critical factor in the Hurricane and Storm Damage Risk Reduction System (HSDRRS). DER V4.0a states that implementation of the armoring process is currently under development and would be addressed separately from this hydraulic design. Structural superiority for difficult structures as described in the DER also contributes to redundancy, resilience, and robustness of designs. These measures address the redundancy of the hydraulic design elevations for an individual structure or for a group of structures. However, neither the DER nor the Addendum documents specifically address the redundancy with an emphasis on the interfaces between structures, materials, members, and project phases.
Significance – Low:
The redundancy of the hydraulic design is well documented and adequate. However, the redundancy of interface between structures, materials, members, and project phases needs to be defined and described.
Recommendation(s) for Resolution:
1. Define and describe the terminology associated with the redundancy of interface between structures, materials, members, and project phases, and explain the relative procedure to address this issue. 2. A separate section in the DER or Addendum may be added to address this issue (redundancy with an emphasis on interfaces between structures, materials, members and project phases), including an explanation on how this is addressed.

Enclosure 2

USACE Draft Evaluator Response FPC#2: *The redundancy associated with the interfaces between structures, materials, members, and project phases is not discussed in the DER or the Addendum.*

USACE PDT please provide a single Concur or Non-Concur statement in regards to the overall Final Panel Comment here: Concur

USACE please elaborate on the reason for your Concur or Non-Concur statement here:

The DER is a hydraulic document; the redundancy of interface between structures, material, members, and project phases is to be addressed in the Design Guidelines document, which is currently being revised. When the Design Guidelines was reviewed by an IEPR team, there was a comment specific to a system approach:

2130588 Civil Overall Document n/a n/a
While the HSDRRS is called a system, I did not see discussion in the design guidelines related to a philosophy or strategy of taking a comprehensive system perspective--e.g., similar to that taken in the draft ETL 1110-2-570 (September 12, 2007). Taking a comprehensive system perspective for the HSDRSS seems relevant and appropriate because flood-protection performance is the result of aggregate system performance, as Katrina demonstrated. A systems approach would consider all the pertinent scales of conditions and behavior that can significantly affect the overall system performance. The devils are in the many details, of course. A systematic approach would require that all the technical details be properly considered and integrated into the overall engineering process. This would be a tall order, one that would require substantial effort working out details and making the process not only practical, but also transparent and technically defensible. In particular, any systems analysis procedure must be understandable and transparent, and not so complex that it becomes an impenetrable black box. Very useful systems and risk approaches do not necessitate mind numbing complexity.
1-0 Evaluation **Concurred**
Concur. We will add a section addressing overall goals, design philosophies and the system-wide approach to the project. - TMR/mpv
Submitted By: Timothy Ruppert (504-862-2106) Submitted On: 23-Jun-09
1-1 Backcheck Recommendation **Close Comment**
Closed without comment.
Submitted By: Charles Vita (206-438-2348) Submitted On: 22-Jul-09

In addition to the Design Guidelines, a System Management Plan is being prepared that discusses the long term management of the HSDRRS system, including features such as Southeast Louisiana and storm proofing. Another document under preparation is the System Armoring PDD; this document will address performance redundancy to prevent scour and erosion from overtopping.

The DER addendum will be revised to mention that there is also redundancy of interface between structures, material, members, and project phases; the Design Guidelines, System Management Plan, and Armoring System PDD are key documents that elaborate on these

redundancies.

Enclosure 2

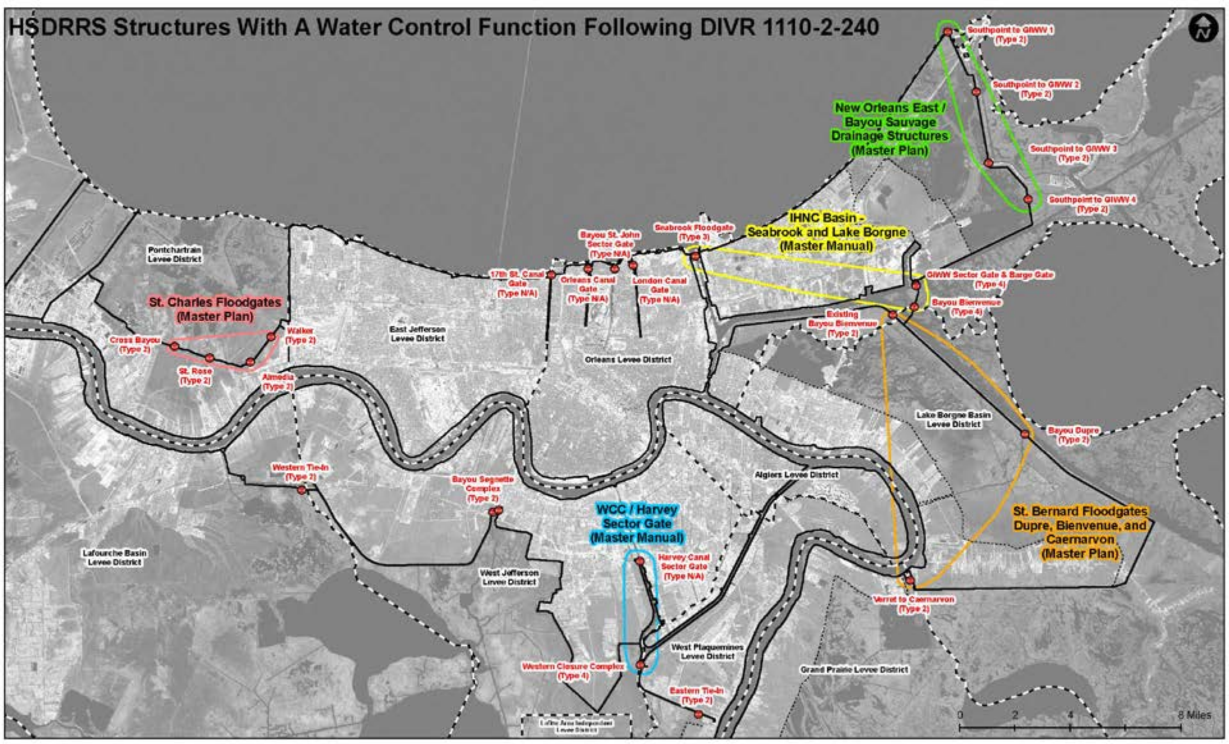
Final Panel Comment 3:
The DER and Addendum do not specifically address how the various HSDRRS components work as an effective system.
Basis for Comment:
The DER Addendum discusses the various project features, elements, and components that are intended to work effectively as a system, which is a major design intent and expectation of the HSDRRS. The DER Addendum does not, however, discuss how these components work effectively as a system that is a critical subsystem of the HSDRRS. Such a discussion, at a conceptual level of detail, would improve the technical quality of the DER Addendum. Furthermore, the DER Addendum also does not discuss the organizational and operational details associated with system performance (e.g., identifying administrative triggering action events or dates, chains and lines of intra- and extra-USACE communications and notifications, decision-making requirements and authority, oversight). Such details may be important enough to warrant discussion, perhaps as a separate appendix to the DER Addendum.
Significance – Low:
The technical quality of the DER Addendum would be increased by including a focused discussion of how the features, elements, and components presented in the DER Addendum work effectively as a subsystem of the HSDRRS.
Recommendation(s) for Resolution:
1. Include a section in the DER Addendum that explains how the features, elements and components discussed in the DER Addendum work effectively as a system, which is a subsystem of the HSDRRS. 2. Determine whether the organizational and operational details associated with system performance are important for inclusion and, if so, consider adding the discussion as a separate appendix to the DER Addendum.
USACE Draft Evaluator Response FPC#3: *The DER and Addendum do not specifically address how the various HSDRRS components work as an effective system.* ***USACE PDT please provide a single Concur or Non-Concur statement in regards to the overall Final Panel Comment here: Concur***
USACE please elaborate on the reason for your Concur or Non-Concur statement here: ***The DER is a hydraulic document; the organizational and operational details associated with system performance are addressed in the System Management Plan, a document presently being prepared. The System Management Plan discusses the long term management of the HSDRRS system, including features such as Southeast Louisiana and storm proofing. Another set of documents that address system performance are the water control documents. USACE is required to prepare water control documents for water resource projects as per***

Enclosure 2

ER1110-2-240, Water Control Management (attached.)

The DER addendum will be revised to mention that there is a System Management Plan that addresses the organizational and operational details associated with system performance and Water Control documents that also provide detailed organizational and operational details associated with the water control structures. Included in the revised language will be specifics on the Master Water Control Plan for systems such as the IHNC corridor, St Bernard, St Charles, New Orleans East, and Harvey-Algiers, areas with multiple structures that operate together.

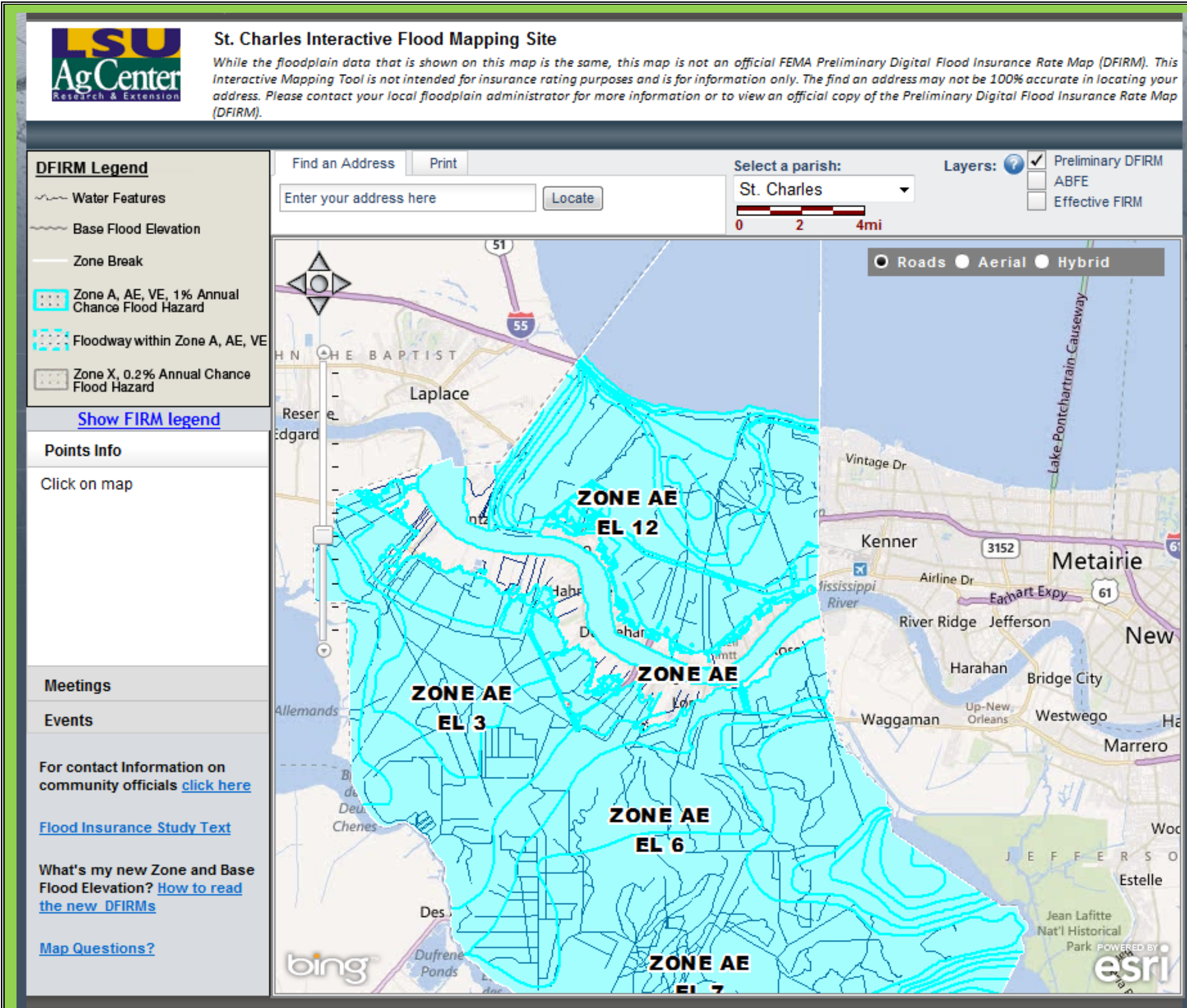
You can see these systems on the figure below.



Enclosure 2

Final Panel Comment 4:
The model analysis for surge levels does not include an update on quantification of the differences with the Federal Emergency Management Agency (FEMA) flood insurance study for the 100-year return period.
Basis for Comment:
The primary purpose of Appendix H "Investigation of ADCIRC Surge Results in St. Charles Parish; May 16, 2008" was to outline the evaluation process of the original ADCIRC model, implement the modified regional geometry and land cover characteristics into the hydraulic model, recompute the peak surge elevations after incorporating the modified regional characteristics into the ADCIRC model, and compare with the FEMA study results in the region of interest (St. Charles Parish). Appendix H adequately describes the relative modifications of the model setup (Model Resolution - refined mesh) and some of the model input parameters (bathymetry and Manning's roughness coefficient to account for land cover). Physically pertinent alterations were made to the recent FEMA analysis production grid in St. Charles Parish. USACE selected 34 storms from the original 152 Southeastern Louisiana FEMA storm suite as reflective of the most significant storms affecting the St. Charles region for implementation of the updated model and to verify the surge levels reported in the region for the recent FEMA flood insurance study. In general, surge values were lowered between 0.25 and 1.50 feet throughout the region. The comparison of surge results from the updated ADCIRC model in St. Charles Parish with the errors of the 2007 FEMA runs was adequate. However, analysis is required for St. Charles Parish to quantify differences in the 100-year return period from the values previously reported in the recent FEMA flood insurance study was not completed as part of this project. Instead, this analysis was deferred to the USACE New Orleans District Office to complete the study.
Significance – Low:
The modeling analysis process with the revised/updated geologic and hydraulic input parameters is adequate for the region of interest but is incomplete.
Recommendation(s) for Resolution:
1. Complete the model analysis in St. Charles Parish and compare the results with the recent FEMA flood insurance study for the 100-year return period.
USACE Draft Evaluator Response FPC#4: *The model analysis for surge levels does not include an update on quantification of the differences with the Federal Emergency Management Agency (FEMA) flood insurance study for the 100-year return period.* ***USACE PDT please provide a single Concur or Non-Concur statement in regards to the overall Final Panel Comment here: Concur***
USACE please elaborate on the reason for your Concur or Non-Concur statement here: ***The DER does not include specifics on the FEMA flood insurance studies for the HSDRRS area. The modeling described in Appendix H has been furnished to FEMA who can incorporate the results into the flood insurance study effort; the DFIRM maps were developed in 2008 and presently have changes pending. The following figure shows the preliminary DFIRM, indicating the zone elevation is 12.***

Enclosure 2



The table below shows the difference in the 100-year return period surge for the area, as represented by three levee reaches.

	Original ADCIRC modeling	addendum surge
SC02-A	11.3	11.0
SC02-B	10.8	10.5
SC14	10.6	10.3

SWL in ft NAVD88 2004.65

As you can see from the table, the difference is less than 0.5 ft in the modeling. The DER will be revised to include language on the comparison of the original hydraulic boundary conditions and the revised hydraulic boundary conditions.

Enclosure 2

Final Panel Comment 5:
The DER Addendum does not discuss HSDRRS resiliency and robustness to the extent warranted given their importance to system performance.
Basis for Comment:
HSDRRS resiliency is a critical project issue and major design objective. The DER Addendum addressed resiliency by computing 0.2% surge levels (50% confidence) for each hydraulic reach and showing that those surge levels were below the design elevations of the levees and other HSDRRS structures. On p. 2-2 of the DER Addendum, there is a brief introductory discussion of resiliency that specifies the minimum resiliency as being the requirement that levees and structures do not catastrophically breach when design criteria are exceeded—however, “design criteria” other than the 0.2% surge level being below design elevations are not identified. The DER Addendum references DER V4.0a (dated 12 December 2011) (Section 8) regarding the potential need for additional armoring to meet “the desired final level of resiliency” which is not defined. Resiliency is also discussed in the DER Addendum (Appendix F) where Engineering Alternative Measures (EAMs) were identified for the purpose of raising levee heights, which represents a critical aspect of resilient design. The DER Addendum appendices arguably address resiliency between project phases through the EARs (Appendix F) and Sea Level Changes (Appendix A). However, the DER Addendum (including appendices) does not: • Define or elaborate on “the desired final level of resiliency,” which remains vague in the DER Addendum. • Define the relationship and interaction between design criteria and resiliency, which should be as clear and explicit as practicable. • Discuss expected reach-specific levee or floodwall performance if the design criteria were exceeded. • Address resiliency for interfaces between structure, materials, and members, which the Panel understands was intended to be emphasized in the DER Addendum. • Discuss the vegetative reinforcement of levee backslopes or the provision of floodwall splash pads, both of which are used to provide erosion resistance (resiliency) against excessive wave overtopping or surge free flow. HSDRRS robustness, which the Panel considered to be related to HSDRRS resiliency, was not defined or well discussed. Robustness was explicitly addressed only in Appendix F of the DER Addendum, which states (p. 10) that: “The purpose of EAMs is to provide an adequately robust risk reduction against a 1% hurricane event.” The meaning of “robust risk reduction” is not clear, and there is no elaboration of robustness with an emphasis on interfaces between structures, materials, members, and project phases.
Significance – Low:
Because HSDRRS resiliency is a major performance issue and design objective, the technical quality of the DER Addendum would be increased with a clearer and more thorough discussion of HSDRRS resiliency and the related concept of robustness.
Recommendation(s) for Resolution:

Enclosure 2

1. Provide discussion in the DER Addendum that addresses the desired final level of resiliency for the HSDRRS, with more detail on interfaces between structures, materials, members, and project phases.

2. Provide discussion in the DER Addendum that addresses HSDRRS robustness, with an emphasis on interfaces between structure, materials, members, and project phases.

3. Update the programs identified in DER V4.0a Section 8, with regard to Wave Overtopping Limits, Damage Thresholds programs, and Armoring and Resiliency programs.

USACE Draft Evaluator Response FPC#5: *The DER Addendum does not discuss HSDRRS resiliency and robustness to the extent warranted given their importance to system performance.*

USACE PDT please provide a single Concur or Non-Concur statement in regards to the overall Final Panel Comment here: Concur

USACE please elaborate on the reason for your Concur or Non-Concur statement here:

The DER Addendum will be updated to include language regarding resiliency and robustness, detail on interfaces between structures, materials, members, and project phases, and reference the Design Guidelines, System Management Plan, and System Armoring PDD for additional information.

The comments of the IEPR team are appreciated and will help focus the System Armoring PDD and the update to the Design Guidelines to include language regarding:

1. ***The desired final level of resiliency and how it was developed***
2. ***The relationship and interaction between the design criteria, as presented in the Design Guidelines, and resiliency***
3. ***The expected reach-specific levee or floodwall performance when the design parameters are exceeded***
4. ***Resiliency for interfaces between structure, materials, and members***
5. ***The vegetative reinforcement of levee backslopes or the provision of floodwall splash pads.***

Section 8 of the DER V 4.0a will be revised to add any updates to the programs identified in this section. Note - At this time, there is no change to the wave overtopping limit used in design; should the criteria for wave overtopping change, the Design Guidelines will be revised to include the change.