REPLY TO
ATTENTION OF

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

CEMVD-TFH

June 4, 2014

MEMORANDUM THRU Commander, New Orleans District, U.S. Army Corps of Engineers, (CEMVN-ED/Mr. Mark Hoague) ~~Houe~~

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): Armoring Research Summary and Armoring Guidance Manual

1. Reference subject Final Independent External Peer Review (IEPR) Report, 29 June 2012. This memo summarizes the results of the IEPR and provides the final responses to comments offered by the IEPR team.

2. The IEPR of the Greater New Orleans Hurricane and Storm Damage Risk Reduction System (GNOHSDRRS): Armoring Research Summary and Armoring Guidance Manual was conducted from January 18, 2012 to June 29, 2012 by the Batelle Memorial Institute. The independent team assembled by Batelle consisted of four (4) Panel Members with broad-ranging experience in civil/geotechnical, hydraulics and agronomy. The IEPR effort included orientation kick- off teleconferences, the development of a critical items list, the development of comments, initial responses by USACE to comments, the IEPR team's backcheck of comments and closeout of comments. The IEPR team provided subject report to recap and summarize review comments and recommendations which was submitted to USACE.

3. A total of 16 comments were submitted by the IEPR Team. 14 of the 16 comments were either closed, resolved or withdrawn with 4 comments concurred with and revisions made, and the panel members requesting further information or clarification on 10 comments. 2 comments were unresolved but later became 'not applicable' due to deletions required by the Risk Management Center during the Agency Technical Review. The final IEPR report was submitted without any further action regarding these unresolved comments.

4. The Executive Summary (shown in italics) contained several statements that necessitated the following clarification responses (in bold):

ENCL 3

a) *Overall, the Panel agrees that USACE needs to clarify the content of the Armoring Manual and how it will be used. In its current form, it is more of a summary of the Colorado State University (CSU) and Louisiana State University (LSU) research than a guidance manual.*

The purpose of this document has been revised by the Risk Management Center (RMC) to only document the R&D performed to determine the erosion resistance of various armoring materials and configurations. This research was done to technically support the armoring of HSDRRS levees and not offer any specific design recommendations. Armoring is necessary to prevent breaches from extreme storm surges (500-yr) in the Greater New Orleans HSDRRS, with its unique combination of soil, grass, climate, wave, storm and slope conditions, and is not intended for direct application to any other region. The RMC performing the Agency Technical Review (ATR) put together a team in the summer of 2012 to edit the entire Armoring Manual, which decided that the word 'Manual' was inappropriate and renamed the document the HSDRRS 'Levee Armoring Research and Recommendations Report' or 'LARRR'. This document is not a design guidance manual for all locations and all conditions, hence the removal of the word, 'Manual' from its title. Later it was renamed the Levee Armoring Research Documentation Report (LARDR) after all specific design recommendations removed, per the recommendation of the RMC .

b) *In most instances, the Armoring Manual leaves the decisions up to the designer after providing vague and unsupported engineering guidance. In particular, the Panel is concerned about some of the assumptions made in the reported studies and the Armoring Manual, as well as some of the specific guidance that is provided within the Armoring Manual.*

All of the specific armoring recommendations and engineering guidance, supported by full scale wave overtopping research performed using HSDRRS soil, grass, climate, and wave conditions, has been removed from this document. The research was performed using the world's largest wave overtopping simulator to model a highly conservative worst case combination of high waves and high overtopping flow conditions to provide a high degree of confidence in the test results. All armoring recommendations will be developed and placed in an Engineering Alternative Report (EAR) to provide the designer with the necessary engineering guidance, which is supported by the R&D described in this document.

c) *In some instances, the Armoring Manual conflicts with the HSDRRS Design Guidelines (USACE, October 2007 with revisions dated 12 June 2008) and in other instances, it conflicts with USACE engineering guidelines used throughout the country for flood control projects.*

The Armoring Manual focuses on R&D supporting armoring for a 500-yr storm surge. It does not conflict with the HSDRRS Design Guidelines, because the Guidelines focus mainly on levee elevation design for the 100-yr storm surge for much lower allowable wave overtopping flows, which were assumed before the CSU R&D testing. Armoring guidance within the Armoring Manual was based on testing which was engineered specifically to evaluate performance of armoring alternatives subjected to the unique characteristics of the HSDRRS, thus it is reasonable that the armoring guidelines would differ from USACE engineering guidelines developed for broad flood control application.

d) *The panel members noted that the wave overtopping simulator was limited to a certain intensity (about 2 cubic feet per second per foot (cfs/ft)), yet the Manual provides recommendations that go beyond what could be simulated or modeled (over 4 cfs/ft).*

The CSU WOS is capable of discharging an average flow of 2 cfs/ft, as governed by the size of the water inflow pipeline although this does not constrain the apparatus in simulation of the largest waves characteristic of HSDRRS hydraulic conditions (8 foot high waves with 9 second periods) and also this does not constrain the simulation of flows higher than 2 cfs/ft. Furthermore, to simulate an average flow of 4.0 cfs/ft, test durations were doubled and included an increased incidence of the largest wave volumes (170 ft3/ft). Refined calculations of the capacity of the WOS based on new R&D by Lander Victor and other leading world experts have assessed that the WOS does have the capability to model wave parameters corresponding to overtopping volumes of 4.0 cfs/ft, which exceeds the highest wave overtopping flow in the HSDRRS (2.5 cfs/ft) by a multiple of at least 1.5.

e) *The recommendations in the manual rely on an unproven concept that erosion potential resulting from wave overtopping can be gauged by an average overtopping flow rate, similar to prior work on rivers and reservoirs, but notably very different from the pulses associated with waves.*

The rate of flow is only one descriptor of the average wave overtopping flow. The design of wave overtopping simulations conducted as part of this research

also considered the maximum wave height, the wave period, and the maximum wave volume required to simulate the average wave overtopping flow to adequately describe the erosion potential. For example, to simulate an average overtopping volume of 4.0 cfs/ft, waves varying in size from 20 cf/ft to 170 cf/ft were discharged from the simulator in a random sequence engineered to emulate the naturally occurring hurricane induced wave climate.

f) *The manual falls short of accurately representing the uncertainty of the tests and theory, and does not clearly state that the findings and recommendations in the manual are based on the judgment of the authors rather than direct supporting analysis.*

The actual test results are documented in the manual, such as the establishment of an erosion resistance capability for flow rates of 2.0 cfs/ft for dormant Bermuda and flow rates up to 4.0 cfs/ft for green Bermuda grass and for dormant Bermuda reinforced with HPTRM. The overtopping flows in all HSDRRS reaches were recalculated based on actual cross sections reducing the maximum 500-yr overtopping flow from 4.2 cfs/ft to 2.5 cfs/ft and in addition, newly developed science indicated that the CSU wave overtopping simulator could almost produce the maximum wave volumes necessary to simulate a real 4.0 cfs/ft. Therefore, the hydraulic uncertainty of the simulator has been virtually eliminated and the findings are now based entirely on actual test results rather than judgment.

g) *Similarly, the manual claims that the flood side of levees (exposed to wave attack) does not require armoring beyond controlled soil and grasses even though the available test data and equations were developed for much less severe wave exposures than those associated with the HSDRRS.*

The IPET investigation commissioned by the Corps following Hurricane Katrina found that erosion on the flood side of the levees was not the cause of breaches. Per IPET: "No levee breaches occurred without overtopping. The degree of erosion and breaching of overtopped levees was directly related to the character of the in-place levee materials and the severity of the surge and wave action." Available test data and equations cited in this comment are presumed to reference analyses of erosion resistance for European earthen levee systems. The European research is based upon smaller waves, but longer storm durations and less erosion resistant soil and grass. Consideration of these differences in conditions, coupled with the evident cause of actual breaches

from Hurricane Katrina, supports the recommendation of the ERDC 'Flood-side Wave Erosion of Earthen Levees: Present State of Knowledge and Assessment of Armoring Necessity" dated August 2010 that no flood side armoring is required for HSDRRS levees.

h) *The panel members also noted that the overtopping rates recommended in the Armoring Manual are substantially larger than what current standards recommend and their corresponding effects on adjacent infrastructure need to be assessed. Specifically, the design overtopping rates (over 4 cfs/ft) are very high relative to practice standards such as FEMA's use of 1 cfs/ft as a high velocity coastal flood zone and expected wave erosion thresholds for grass erosion capacities of less than 1 cfs/ft.*

The purpose of armoring is to implement measures to reduce the risk of breaching due to wave overtopping from extreme storm surges up to a 500-yr surge. The HSDRRS levee system was designed for the 1% annual chance exceedance (a.c.e.) storm surge which sets the levee crown elevation such that no greater than 0.1 cfs/ft wave overtopping occurs. The levee crown is not set to limit the maximum wave overtopping rate (now assessed at 2.5 cfs/ft) to any particular limiting flow (i.e. FEMA's standard of 1.0 cfs/ft) from a 0.2% a.c.e. storm surge. The overtopping flow rates are derived from hydraulic analyses of the 500-yr storm surge wave overtopping potential, which form the basis for armoring material selection. The allowable wave overtopping flow rate for Bermuda grass in the document was based on the SME recommendations which are based on actual test results (up to the limit of max. flow tested) of several armoring materials using HSDRRS standard quality clay, wave and climate conditions, which are much more representative than the generally applied FEMA standards.

i) *The Manual is presented in the form of a research report rather than of the high standard USACE publications that have been used by design engineers for many years. The Manual in its present form should more aptly be titled Preliminary Guidelines for Design of HSDRRS Levee Systems in the New Orleans District. The wide range of wave erosion loading values could then be evaluated as levee armoring systems designed by the Preliminary Guidelines are evaluated under loading conditions less than those associated with the 100-year return frequency design storm event.*

The Risk Management Center (performing the ATR) put together a team in the

summer of 2012 to edit the entire Armoring Manual, and the Team agreed that the word 'Manual' was inappropriate and renamed the document the HSDRRS 'Levee Armoring Research and Recommendations Report' or 'LARRR'. The LARRR was later re-titled the Levee Armoring Research Documentation Report (LARDR) to reflect that it is now a research documentation report after all specific armoring design recommendations for the 500-yr storm surge loading conditions were removed per the recommendation of the RMC during the ATR.

j) The civil/geotechnical engineering expert noted that there is significant relevant information from dam projects that should be reviewed to gain further insight applicable to the HSDRRS project, and recommends that the Armoring Manual specify, at a minimum, the design flood that the information relates to and why that particular flood was used.

All known information for dam projects was investigated and it was determined that none of these references contained any information that could be utilized for our unique combination of grass, soil, storm duration, climate and wave overtopping conditions. The 500-yr storm surge, was selected as the design condition for Armoring in order to comply with the HSDRRS Design Guidelines.

5. Each of the 16 IEPR comments (in italics) are followed by the USACE response (in bold):

a. *IEPR Comment no. 1: The actual dimensions of flood-side erosion may be greater than those reported in the Armoring Guidance Manual.*
This comment was of high significance. One recommendation was adopted.

Response: USACE non-concurred and explained that the higher erosion estimates from Hughes' report were not applicable because the extremely long storm duration and soil conditions assumed in the studies were uncharacteristic of the HSDRRS. Specifically, the erosion estimates assumed in Hughes' report were based on conditions characteristic of the coastal wave environment, soil types and grass species of the Netherlands and Europe. The reviewer did not concur, saying that the erosion estimates were based on model studies of wave conditions less severe (smaller waves) than the HSDRRS wave conditions and closed the comment. While we acknowledge that Hughes' erosion estimates were based on smaller waves, we submit that the more cohesive soils, more robust grass species and shorter storm

durations characteristic of the HSDRRS offset the erosion potential of the larger waves. Additional model testing would have to be performed to determine the net erosional effect of the shorter storm duration and better soil and grass conditions of the HSDRRS when combined with the greater erosional effect of the larger 8 ft waves. Nevertheless, it is doubtful that model testing could provide better evidence of flood side erosion processes and potential than was assembled by the Interagency Performance Evaluation Task Force, and other scientific and engineering bodies following Hurricane Katrina, which concluded that although confronted with robust waves during the passage of hurricane Katrina along the Lake Pontchartrain and Vicinity project perimeter, no earthen levees were breached except those that were overtopped. The preponderance of evidence supports the assessment that additional measures, beyond the revised more stringent HSDRRS design standards for levee construction and turf establishment to enhance the erosion resistance of the flood sides of levees are not warranted.

b. *IEPR Comment no. 2: The Armoring Guidance Manual does not provide guidance for armoring around T-walls because there is no stability analysis or supporting documentation.*
This comment was of medium significance. One of the recommendations was adopted.

Response: USACE concurred with the comment, and after we performed geotechnical and structural analyses of representative T-walls with 8 feet of assumed erosion on one or both sides of the floodwall, which was almost double the estimated erosion, the results indicated that there was no wall stability problem. The reviewer concurred and closed the comment.

c. *IEPR Comment no. 3: The Armoring Guidance Manual does not provide specific information regarding how each armoring method is to be inspected and maintained in the future to ensure its continued performance.*
This comment was of medium significance. Detailed recommendations were not adopted but the intent of the recommendations was adopted.

Response: Concurred. However, the specific recommendations were not adopted but the addition of O&M requirements would be documented upon completion of the Grass/HPTRM Demonstration Report, which satisfied the reviewer who concurred and closed the comment. Since this response was written the Grass/HPTRM Demonstration Report was completed and added to the document as Appendix C. Additionally, two 5000 If Pilot Projects were started which further define O&M requirements, which will be included in an Engineering Alternatives Report (EAR).

d. *IEPR Comment no. 4: Design recommendations, such as the overtopping criteria, provided in the Armoring Guidance Manual are unclear and, in some instances, contradict what has been provided in the HSDRRS Design Guidelines, which results in conflicting guidance to the designer.*
This comment was of medium significance. The recommendations were not adopted.

Response: USACE non-concurred and explained why differences between the Manual's overtopping criteria and the Design Guidelines were acceptable. This is because the allowable wave overtopping flow rates for grass in the Design Guidelines were values assumed right after Hurricane Katrina for the base levee design case, e.g. 100-yr., while the allowable wave overtopping flow rates for grass in the document were based on actual wave overtopping model test results for the extreme storm surge resiliency case, e.g. 500-yr. The reviewer concurred after additional teleconference explanations and closed the comment.

e. *IEPR Comment no. 5: The Armoring Guidance Manual does not provide the appropriate geotechnical guidance.*
This comment was of medium significance. The recommendations were not adopted.

Response: USACE non-concurred and explained that the geotechnical guidance is already provided in the construction specifications and it would not be appropriate to be included in the Armoring document. The reviewer concurred and closed the comment.

f. *IEPR Comment no. 6: The discharge rates for protected-side armoring recommendations, and the associated armoring requirements (e.g. grass, grass plus*

HPTRM, etc), are not clearly or consistently presented throughout the Armoring Guidance Manual.
This comment was of medium significance. Most recommendations were adopted.

Response: USACE concurred, revised the document to be consistent, and the reviewer concurred with the revisions and closed the comment.

g. *IEPR Comment no. 7: The turf reinforcement testing did not include the characteristics of the embankment sub-grade and the wave overtopping that would load the sub-grade.*
This comment was of medium significance. The recommendations were not adopted.

Response: USACE non-concurred with the statement that the CSU WOS design loading conditions did not result in failure and explained that additional test results were added to the document where failures did occur when the tests were run with dormant grass. The reviewer concurred and closed the comment.

h. *IEPR Comment no. 8: The wave overtopping simulator (WOS) did not replicate the design conditions for the HSDRRS, including the 500 year/50% non-exceedance conditions; therefore, the recommendations in the Armoring Guidance Manual for protected-side armoring are based on judgment.*
This comment was of medium significance. The recommendations were not adopted.

Response: USACE non-concurred and explained that the design conditions modeled were 8 ft waves with 9 second periods which occur on the east side of St. Bernard Parish even though the reaches with the highest overtopping rates had lower waves and low freeboard. The reviewer non-concurred and explained that the WOS could not reproduce the largest waves (~340 ft3/ft) required to simulate 4.0 cfs/ft. The USACE then presented new research by Lander Victor and others which strengthened the case that the CSU wave overtopping simulator did actually simulate 4.0 cfs/ft (500-yr/50% non-exceedance conditions) as determined by the world's leading experts in this field. The maximum wave size needed to replicate 4.0 cfs/ft (with 8 ft waves) was originally thought to be ~340 ft3/ft, but Victor's new research indicated that only a maximum wave volume of 190 ft3/ft actually was needed, which

was only marginally higher than the 170 ft3/ft capacity of the WOS. The Panel did not concur, however but closed the comment.

Subsequently, this deliberation was rendered moot when refined hydraulic overtopping analyses of the 0.2% annual chance exceedance event were adopted for the HSDRRS, which assessed that the maximum wave overtopping flow rate is 2.5 cfs/ft with 3.5 ft waves and 6.5 second periods. The overtopping flow rates for the 500-year condition were recalculated considering the actual constructed flood side embankment configuration, which resulted in the lower waves and flow rates. This lower maximum flow rate of 2.5 cfs/ft indicates that a margin for uncertainty of at least 1.5 exists for the 4.0 cfs/ft flows actually sustained during CSU tests. There is no wave flow/parameter combination in any reach that exceeds the 4.0 cfs/ft wave overtopping flow with 8 ft waves and 9 second periods that was tested with no failures at CSU on unreinforced green Bermuda and HPTRM reinforced dormant Bermuda. Therefore the worst case was tested at CSU resulting in a margin for uncertainty of at least 1.5 for the highest wave overtopping flow and extreme wave parameters.

i. *IEPR Comment no. 9: A potential weakness in the conclusions drawn from the CSU modeling may be the wave parameters used as input for the CSU WOS.*
This comment was of medium significance. The recommendations were not adopted.

Response: USACE non-concurred but added the discussion of the appropriate wave breaker parameter to the Manual. After the teleconference where we explained that only the Corps would be using the Manual and would know how the wave parameters were developed, the reviewer concurred and closed the comment.

j. *IEPR Comment no. 10: The Armoring Guidance Manual does not consider an "importance factor" or "localized condition variable factor" when determining sufficient armoring for a location.*
This comment was of medium significance. The recommendations were not adopted.

Response: USACE non-concurred and explained that we were only authorized by Congress to armor the critical elements of the HSDRRS. IPET and the ASCE External Review Panel findings provided definition of critical elements

as those that suffered breaches and severe erosion during H. Katrina, and did not include 'importance factors' for critical infrastructure considerations. The reviewer concurred and closed the comment.

k. *IEPR Comment no. 11: The term 'clay' is used in too general a sense in the Armoring Guidance Manual and does not identify the specific type of clay(s) that could be used in levee construction.*
This comment was of low significance. The recommendations were not adopted.

Response: USACE non-concurred and described the Unified Soil Classification System designated clay (CH or CL) as the only clay that can be used in HSDRRS levee construction, which is selected for geotechnical engineering considerations rather than agronomy considerations. The reviewer concurred and closed the comment.

l. *IEPR Comment no. 12: The use of a poorly adapted species (bermudagrass) to conduct tests at Colorado State University (CSU) could affect recommendations about the grasses' ability to armor levees.*
This comment was of low significance. The recommendations were not adopted.

Response: USACE non-concurred and explained that even though the Bermuda grass was grown in Vicksburg, Ms and tested in Colorado, it is well suited for the Greater New Orleans area during hurricane season, which makes warm season Bermuda grass appropriate. The reviewer concurred and closed the comment.

m. *IEPR Comment no. 13: The data from the CSU and LSU studies may not be directly applicable to HSDRRS projects because of the low number of turfgrass root samples that were collected, the type of samples used, and the lack of replication in time for that sampling.*
This comment was of low significance. The recommendations were not adopted.

Response: USACE non-concurred and explained that the second sampling of 80 core samples was conducted and the 'Grass/HPTRM Demonstration Test Report 'was completed, which nullified that comment. The reviewer concurred and closed the comment.

Subsequently, in response to non-Federal sponsor (NFS) comments, another 300 turfgrass locations were sampled around the entire HSDRRS, with 600 samples taken, which had their root quality determined, giving us a statistically significant sample size, which validates the applicability to the HSDRRS project.

n. *IEPR Comment no. 14: The Armoring Guidance Manual does not clearly state that its purpose is solely to address armoring protection for 100-year and 500-year storms, not for ongoing erosional forces.*
This comment was of low significance. One of the two recommendations was adopted.

Response: USACE concurred and added wording to make it clear that the document's primary purpose is to recommend armoring to prevent breaching from at least a 500-yr storm surge and not to prevent minor erosion from a 100-yr storm surge. The reviewer concurred and closed the comment.

o. *IEPR Comment no. 15: Valuable resources (e.g., case studies, research) associated with flood-side erosion of water-retaining embankments and back slope stability for rock breakwaters are not utilized or discussed in the Armoring Guidance Manual.*
This comment was of low significance. The recommendations were not adopted.

Response: USACE non-concurred explaining that all of the research references suggested were investigated and determined that none contained any information that could be utilized for our wave overtopping, soil and grass conditions. The reviewer concurred and closed the comment.

p. *IEPR Comment no. 16: Fertilization and liming recommendations to maintain grass on the levee are not well-documented, and other recommended agronomic maintenance practices are missing from the Manual.*
This comment was of low significance. The recommendations were adopted.

Response: USACE concurred and explained that the present armoring plan is to armor all of the HSDRRS reaches with HPTRM, so the sod, watering, and fertilizer recommendations would be included in an O&M section of the appropriate document. The reviewer concurred and closed the comment.

6. Conclusion: Only two (2) comments, numbers 1 and 8 were closed without resolution. Regarding comment 1, while USACE acknowledges the reviewer's observations, we submit that the preponderance of evidence gathered from the field by SMEs following hurricane Katrina supports the assessment that no levees were breached as a sole consequence of flood side erosion. Thus, our assessment that additional measures beyond the HSDRRS design standards for levee construction and turf establishment, to further enhance the erosion resistance of the flood sides of levees are not warranted. Comment 8 regarding whether the wave overtopping simulator (WOS) could replicate the 500 year/50% non-exceedance HSDRRS design conditions and whether the wave overtopping simulations conducted at CSU support a reasonable margin for uncertainty for HPTRM reinforced turf have been rendered moot through new science and certification of refined (lower) 500-year wave overtopping flow rates for the HSDRRS. All of the sixteen (16) comments and TFH's final responses are contained in this document. The USACE team appreciates the input of the IEPR panel during this review process and the comments and recommendations of the IEPR panel were very helpful to finalize an acceptable document. This report concludes the IEPR action for this project.

7. The point of contact for the project is Mr. Dean Arnold, TFH, at (504) 862-2674. The point of contact for IEPRs of the Greater New Orleans HSDRRS is Mr. Thomas Podany, PRO, at 504-862-2502.

MICHAEL F. PARK
Chief, Task Force Hope

CF:
CEMVN Commander, Colonel Richard L Hansen (CEMVN) (w/encl)
CEMVN-ED (Mark Hoague) (w/encl)
CEMVN-ED (Jean Vossen) (w/encl)
CEMVN-ED (Dave Beck) (w/encl)
CEMVN-PM-O (Tom Podany) (w/encl)
CEMVN-PM-OLP (Brett Herr) (w/encl)
CEMVN-PM-OLP (Soheila Holley) (w/encl)