Final Independent External Peer Review Report Hurricane and Storm Damage Risk Reduction System – Armoring Research Summary and Armoring Guidance Manual

Prepared by
Battelle Memorial Institute

Prepared for
Department of the Army
U.S. Army Corps of Engineers
Coastal Storm Damage Reduction Planning Center of Expertise
Baltimore District

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SHORT-TERM ANALYSIS SERVICE (STAS)

on

Final Independent External Peer Review Report
Hurricane and Storm Damage Risk Reduction System – Armoring Research Summary and Armoring Guidance Manual

by

Battelle
505 King Avenue
Columbus, OH 43201

for

Department of the Army
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FINAL
INDEPENDENT EXTERNAL PEER REVIEW REPORT
Hurricane and Storm Damage Risk Reduction System – Armoring Research Summary and Armoring Guidance Manual

EXECUTIVE SUMMARY

The Hurricane and Storm Damage Risk Reduction System (HSDRRS) – Armoring Research Summary and Armoring Guidance Manual (hereinafter Armoring Manual) is a compilation and explanation of armoring research and development (R&D) performed for the HSDRRS program. The manual is intended to provide guidance to armoring designers such that an economical, yet flexible, solution to control protected-side wave overtopping erosion can be implemented for greater than the 100-year and up to the 500-year storm surge.

The U.S. Army Corps of Engineers (USACE) is conducting an Independent External Peer Review (IEPR) of the Armoring Manual. Independent, objective peer review is regarded as a critical element in ensuring the reliability of scientific analyses. Battelle, as a 501(c)(3) non-profit science and technology organization with experience in establishing and administering peer review panels for USACE, was engaged to coordinate the IEPR of the Armoring Manual. The IEPR was external to the agency and conducted following USACE and Office of Management and Budget (OMB) guidance described in USACE (2010), USACE (2007a), and OMB (2004). This final report describes the IEPR process, describes the panel members and their selection, and summarizes the Final Panel Comments of the IEPR Panel (the Panel) regarding the Armoring Manual.

Four panel members were selected for the IEPR. Battelle followed the criteria for selecting the candidate panel members specified in the USACE Statement of Work to (1) contact candidate panel members to evaluate technical skills, potential conflicts of interest (COIs), availability, and hourly rates, and (2) identify four experts from the pool of candidates to serve on the IEPR Panel. Based upon these criteria the final panel members were selected for their technical expertise in the key areas of hydraulic engineering, civil/geotechnical engineering and agronomy. Although the candidates for Panel were disclosed to USACE, Battelle made the final selection of panel members.

The Panel received electronic versions of the Armoring Manual documents, totaling approximately 538 pages (with approximately 200 supplemental pages), along with a charge that solicited comments on specific sections of the documents to be reviewed. The charge was prepared by USACE according to guidance provided in USACE (2010) and OMB (2004). Charge questions were provided by USACE and included in the draft and final Work Plans.

The USACE Project Delivery Team briefed the Panel and Battelle during a kick-off meeting held via teleconference prior to the start of the review. Other than this teleconference, there was no direct communication between the Panel and USACE during the peer review process. The Panel produced more than 45 individual comments in response to 15 charge questions.

IEPR panel members reviewed the Armoring Manual documents individually. The panel members then met via teleconference with Battelle to review key technical comments, discuss charge questions for which there were conflicting responses, and reach agreement on the Final Panel Comments to be provided to USACE. Each Final Panel Comment was documented using a four-part format consisting of (1) a comment statement, (2) the basis for the comment, (3) the significance of the comment (high, medium, or low), and (4) recommendations on how to resolve the comment. Overall, 16 Final Panel Comments were identified and documented. Of these, one had high significance, nine had medium significance, and six had low significance.

Table ES-1 summarizes the Final Panel Comments by level of significance. Detailed information on each comment is contained in Appendix A of this report.

USACE guidance (2010) states the final report will contain the Panel's “assessment of the adequacy and acceptability of the economic, engineering, and environmental methods, models, and analyses used.” However, for the Armoring Manual IEPR, the Panel focused solely on the hydraulic engineering, civil/geotechnical engineering, and agronomy (e.g., soil scientist/turf expert) analysis of the project; no economic or other environmental assessment was conducted. The Panel agreed on its assessment of the adequacy and acceptability of the engineering methods, models, and analyses used in the Armoring Manual documents. However, the Panel expressed concern about the intended use of the manual and was informed during the March 8, 2012 teleconference with USACE that the Armoring Manual is limited to preliminary designs of earth levees protecting against coastal flood hazards in the HSDRRS in Louisiana.

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. 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. 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 Panel understands the importance of the levees and T-walls for meeting the objectives of the overall design of the HSDRRS. Because of the importance of the levees and T-walls in providing the first line of defense towards potential erosion of these components, the Panel recommends that the Armoring Guidance Manual be reviewed by the same American Society of Civil Engineers (ASCE) Panel that reviewed the HSDRRS Design Guidelines. This ASCE Panel will provide a needed layer of consistency that will ensure the Armoring Guidance Manual allowable overtopping thresholds do not conflict with the basis for similar recommendations previously determined during the HSDRRS Design Guidelines review, or raise new concerns because of the changes in criteria and designs. The following statements summarize the Panel’s findings.

Table ES-1. Overview of 16 Final Panel Comments Identified by the HSDRRS Armoring Research Summary and Armoring Guidance Manual IEPR Panel

No.	Final Panel Comments
	Significance – High
1	The actual dimensions of flood-side erosion may be greater than those reported in the Armoring Guidance Manual.
	Significance – Medium
2	The Armoring Guidance Manual does not provide guidance for armoring around T-walls because there is no stability analysis or supporting documentation.
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.
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.
5	The Armoring Guidance Manual does not provide the appropriate geotechnical guidance.
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.
7	The turf reinforcement testing did not include the characteristics of the embankment subgrade and the wave overtopping that would load the subgrade.
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.
9	A potential weakness in the conclusions drawn from the CSU modeling may be the wave parameters used as input for the CSU WOS.
10	The Armoring Guidance Manual does not consider an “importance factor” or “localized condition variable factor” when determining sufficient armoring for a location.
	Significance – Low
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.
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.
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.
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.
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.
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.

Hydraulic Engineering: The hydraulic engineering panel members were encouraged to read that USACE had reached out to the Dutch regarding armoring as they are very experienced in this type of work. They noted that some very well respected individuals (e.g., Jentsje W. van der Meer and Steven Hughes) developed information that went into the Armoring Manual, and judged the use of two large-scale model tests a wise approach because of the complex hydraulics and theory. However, 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 recommendations in the manual rely on an unproven concept that erosion potential resulting from wave overtopping can be gauged by an average overtopping flowrate, similar to prior work on rivers and reservoirs, but notably very different from the pulses associated with waves. 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. 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 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.

Civil/Geotechnical Engineering: The civil/geotechnical engineering panel member noted the Armoring Manual benefitted from Dr. Hughes' excellent job of providing supporting documents for the entire project by preparing theses or dissertations on wave loading of levees. However, the Manual suffered from a lack of emphasis on the CSU Wave Overtopping Simulator (WOS) Testing and the extrapolation of that data to much higher loading values. As such, the Manual provides a confusing directive to design engineers. 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 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. This will provide the designers with the background information necessary to determine if they need to make adjustments for the project section they are working on.

Agronomy: The Agronomist is concerned that the bermudagrass was tested in a region to which it is not adapted. It is likely that the bermudagrass was dormant when tested and results would likely differ from that on actively growing turf. However, results collected from dormant bermudagrass would likely be a worst-case scenario and thus would be useful data.

Battelle posted the Final Panel Comments into the Design Review and Checking System (DrChecks) on January 18, 2012. USACE Project Delivery Team (PDT) evaluated and reviewed the IEPR panel comments and provided draft Evaluator Responses to Battelle (using a template provided by Battelle) on February 16, 2012. Battelle immediately provided the draft Evaluator Responses to the IEPR Panel and directed the panel members to develop draft BackCheck Responses. The USACE draft Evaluator Responses and the Panel draft BackCheck Responses were discussed during the Final Panel Comment teleconference with USACE (which included the non-federal sponsor) on March 8, 2012. During the teleconference, Battelle facilitated discussions between the USACE PDT and the Panel on each Final Panel Comment with the goal of reaching consensus (e.g., concurrence between USACE and the Panel). At the end of the teleconference, USACE and the IEPR Panel had reached concurrence on six of the 16 Final Panel Comments, and for most of the remaining comments the Panel indicated they would concur with the intended USACE PDT draft Evaluator Response based on discussions during the teleconference. Following the teleconference, USACE developed final Evaluator Responses and uploaded them into DrChecks on April 30, 2012. Battelle downloaded these responses, provided them to the Panel, and directed the Panel to prepare final BackCheck Responses. The panel members considered the final Evaluator Responses and concurred with the USACE PDT on 14 of the 16 Final Panel Comments. The final BackCheck Responses were uploaded to DrChecks and the comments were closed. Detailed information on the USACE PDT Evaluator and Panel BackCheck Responses posted in DrChecks is contained in Appendix B of this report.

After closing the comments in DrChecks and during preparation of the final report, Battelle was notified that the PDT had obtained new information that could be helpful to the Panel in understanding some reported results pertaining to Final Panel Comments 6 and 8. This information was not available prior to or during the March 8 teleconference. The PDT asked that the Panel review the new information and additional final Evaluator Responses to determine whether they addressed the Panel’s concerns. On May 17, 2012 Battelle received the information from USACE and directed the Panel to review their original final BackCheck responses based on their assessment of the additional Evaluator Responses provided by the PDT in DrChecks and the new information. Battelle received the Panel’s additional final BackCheck Responses on June 7, 2012, uploaded them to DrChecks on June 7, and closed the comments. Although the new information provided support to some of the conclusions in regards to the larger overtopping wave volumes, it did not result in a change to the BackCheck responses to these Final Panel Comments (see Appendix B).

This final report details the IEPR process, describes the IEPR panel members and their selection, and summarizes the findings of the IEPR, including the post-Final Panel Comment response process and results.

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TABLE OF CONTENTS

EXECUTIVE SUMMARY i

1. INTRODUCTION 1

2. PURPOSE OF THE IEPR 1

3. METHODS 2
   - 3.1 Planning and Schedule 2
   - 3.2 Identification and Selection of IEPR Panel Members 2
   - 3.3 Preparation of the Charge and Conduct of the IEPR 5
   - 3.4 Review of Individual Comments 5
   - 3.5 IEPR Panel Teleconference 6
   - 3.6 Preparation of Final Panel Comments 6

4. PANEL DESCRIPTION 7

5. SUMMARY OF FINAL PANEL COMMENTS 12

6. POST–FINAL PANEL COMMENT RESPONSE PROCESS 15

7. REFERENCES 16

Appendix A. Final Panel Comments on the HSDRRS Armoring Research Summary and Armoring Guidance Manual

Appendix B. Record of USACE PDT Evaluator Responses and Panel BackCheck Responses to Armoring Manual IEPR Final Panel Comments

Appendix C. Final Charge to the Independent External Peer Review Panel on the HSDRRS Armoring Research Summary and Armoring Guidance Manual

LIST OF TABLES

Table ES-1. Overview of 16 Final Panel Comments Identified by the HSDRRS Armoring Research Summary and Armoring Guidance Manual IEPR Panel iii

Table 1. HSDRRS Armoring Research Summary and Armoring Guidance Manual IEPR Schedule 3

Table 2. HSDRRS Armoring Research Summary and Guidance Manual IEPR Panel: Technical Criteria and Areas of Expertise 8

Table 3. Overview of 16 Final Panel Comments Identified by the HSDRRS Armoring Manual IEPR Panel 13

LIST OF ACRONYMS

ACB	Articulated Concrete Blocks
ASCE	American Society of Civil Engineers
ATR	Agency Technical Review
CEW	Cumulative Excess Work
COI	Conflict of Interest
CSU	Colorado State University
DrChecks	Design Review and Checking System
EC	Engineering Circular
ERDC	Engineer Research and Development Center
HPTRM	High Performance Turf Reinforcement Material
HSDRRS	Hurricane Storm Damage Risk Reduction System
IEPR	Independent External Peer Review
IPET	Interagency Performance Evaluation Task
LSU	Louisiana State University
NRC	National Research Council
NTP	Notice to Proceed
O&M	Operations and Maintainability
OMB	Office of Management and Budget
PDF	Project Delivery Tam
PI	Plasticity Index
R&D	Research and Development
SDF	Spillway Design Flood
SOW	Statement of Work
TRM	Turf Reinforcement Material
USACE	United States Army Corps of Engineers
WOS	Wave Overtopping Simulator

1. INTRODUCTION

The Hurricane and Storm Damage Risk Reduction System (HSDRRS) – Armoring Research Summary and Armoring Guidance Manual (hereinafter Armoring Manual) is a compilation and explanation of armoring research and development (R&D) performed for the HSDRRS program. The manual is intended to provide guidance to armoring designers such that an economical, yet flexible, solution to control protected-side wave overtopping erosion can be implemented for greater than the 100-year and up to the 500-year storm surge.

The objective of the work described here was to conduct an Independent External Peer Review (IEPR) of the Armoring Manual. Independent, objective peer review is regarded as a critical element in ensuring the reliability of scientific analyses. Battelle, as a 501(c)(3) non-profit science and technology organization with experience in establishing and administering peer review panels, was engaged to coordinate the IEPR of the Armoring Manual. Battelle conducted the IEPR in accordance with procedures described in the Department of the Army, U.S. Army Corps of Engineers Engineer (USACE) Circular *Civil Works Review Policy* (EC No. 1165-2-209) (USACE, 2010), USACE CECW-CP memorandum *Peer Review Process* (USACE, 2007a), and Office of Management and Budget (OMB) bulletin *Final Information Quality Bulletin for Peer Review* (OMB, 2004).

This final report details the IEPR process, describes the IEPR panel members and their selection, and summarizes the Final Panel Comments of the IEPR Panel on the existing engineering and agronomy analyses contained in the Armoring Manual. Detailed information on the Final Panel Comments is provided in Appendix A. Detailed information on the USACE Project Delivery Team (PDT) Evaluator and Panel BackCheck Responses to the Final Panel Comments posted in the USACE Design Review and Checking System (DrChecks) is contained in Appendix B of this report.

2. PURPOSE OF THE IEPR

To ensure that USACE documents are supported by the best scientific and technical information, USACE has implemented a peer review process that uses IEPR to complement the Agency Technical Review (ATR), as described in USACE (2010) and USACE (2007a).

In general, the purpose of peer review is to strengthen the quality and credibility of USACE decision documents in support of its Civil Works program. IEPR provides an independent assessment of the economic, engineering, and environmental analysis of the project study. In particular, the IEPR addresses the technical soundness of the project study's assumptions, methods, analyses, and calculations and identifies the need for additional data or analyses to make a good decision regarding implementation of alternatives and recommendations.

The IEPR of the Armoring Manual was conducted and managed using contract support from Battelle, which is an Outside Eligible Organization under Section 501(c)(3) of the U.S. Internal Revenue Code with experience conducting IEPRs for USACE. In this instance, only the engineering and agronomy analyses were assessed; the economic and other environmental analyses were not evaluated.

3. METHODS

This section describes the method followed in selecting the members for the IEPR Panel (the Panel) and in planning and conducting the IEPR. The IEPR was conducted following procedures described by USACE (2010) and in accordance with USACE (2007a) and OMB (2004) guidance. Supplemental guidance on evaluating conflicts of interest (COIs) was obtained from the *Policy on Committee Composition and Balance and Conflicts of Interest for Committees Used in the Development of Reports* (The National Academies, 2003).

3.1 Planning and Schedule

After receiving the notice to proceed (NTP) on September 14, 2011, Battelle was placed on hold, as the Armoring Manual was not ready to be reviewed. In October, Battelle was informed that the documents would be forthcoming in the next month or so, and therefore recruiting of panel members was initiated and submitted to USACE. USACE provided draft charge questions in early November and Battelle held a kick-off meeting with USACE to review the preliminary/ suggested schedule, discuss the IEPR process, and address any questions regarding the scope (e.g., clarify expertise areas needed for panel members) in late November. After the kickoff meeting, Battelle drafted and finalized the Work Plan and charge including revisions to the schedule based on revised receipt dates of the Armoring Manual documents. Table 1 presents the schedule followed in executing the IEPR. Due dates for milestones and deliverables are based on the date the final documents were received and the date that information pertinent to the IEPR was received from USACE PDT.

3.2 Identification and Selection of IEPR Panel Members

The candidates for the Panel were evaluated based on their technical expertise in the following key areas: hydraulic engineering, civil/geotechnical engineering, and agronomy. These areas correspond to the technical content of the Armoring Manual.

To identify candidate panel members, Battelle followed the criteria specified in the USACE Statement of Work (SOW) to (1) contact candidate panel members to evaluate technical skills, potential COIs, availability, and hourly rates, and (2) identify four experts from the pool of candidates to serve on the IEPR Panel. Battelle chose four of the most qualified candidates and confirmed their interest and availability. All candidates were proposed as primary reviewers. Information about the candidate panel members, including brief biographical information, highest level of education attained, and years of experience, was provided to USACE for feedback. The four proposed primary reviewers constituted the final Panel.

The candidates were screened for the following potential exclusion criteria or COIs.[1] These COI questions were intended to serve as a means of disclosure, and to better characterize a potential

[1] Battelle evaluated whether scientists in universities and consulting firms that are receiving USACE-funding have sufficient independence from USACE to be appropriate peer reviewers. See OMB (2004, p. 18), "….when a scientist is awarded a government research grant through an investigator-initiated, peer-reviewed competition, there generally should be no question as to that scientist's ability to offer independent scientific advice to the agency on other projects. This contrasts, for example, to a situation in which a scientist has a consulting or contractual arrangement with the agency or office sponsoring a peer review. Likewise, when the agency and a researcher work together (e.g., through a cooperative agreement) to design or implement a study, there is less independence from the agency. Furthermore, if a scientist has repeatedly served as a reviewer for the same

Table 1. HSDRRS Armoring Research Summary and Armoring Guidance Manual IEPR Schedule

Task	Action	Due Date
1	Notice to Proceed (NTP)	September 14, 2011
	Final Review documents available	December 12, 2011
	Battelle submits draft Work Plan and charge [a]	December 2, 2011
	USACE provides comments on draft Work Plan and charge	December 7, 2011
	Battelle submits final Work Plan and charge [a]	December 9, 2011
	USACE approves final Work Plan and charge	December 13, 2011
2	Battelle recruits and screens up to 4 potential panel members; submits selected panel members' summary information [a]	October 27, 2011
	USACE confirms the panel members have no Conflict of Interest (COI)	November 22, 2011
	Battelle completes subcontracts for panel members	December 13, 2011
3	USACE/Battelle Kick-off Meeting	November 21, 2011
	USACE/Battelle/Panel Kick-off Meeting	December 13, 2011
4	Monthly Progress Updates and Conference Call Discussions	monthly
5	Battelle sends review documents to panel members	December 13, 2011
	IEPR panel members complete their review	January 2, 2012
	Battelle convenes panel review teleconference	January 5, 2012
	Panel provides draft Final Panel Comments to Battelle	January 11, 2012
	Battelle inputs Final Panel Comments to DrChecks; Battelle provides Final Panel Comment response template to USACE	January 18, 2012
	USACE provides draft responses and clarifying questions to Battelle	February 16, 2012
	USACE inputs final Evaluator Responses in DrChecks	April 11, 2012
	Battelle inputs final BackCheck Responses in DrChecks	April 30, 2012
	Battelle submits final pdf printout of DrChecks to USACE [2]	May 1, 2012
	USACE inputs additional final Evaluator Responses in DrChecks[3]	May 17, 2012
	Battelle inputs additional final BackCheck Responses in DrChecks[3]	June 7, 2012
	Battelle submits revised final pdf printout of DrChecks to USACE[2]	June 12, 2012
6	Final Panel Comment Teleconference between Battelle, Panel, and USACE to discuss Final Panel Comments, draft responses, and clarifying questions	March 8, 2012
7	Battelle submits Final IEPR Report to USACE [2]	June 29, 2012
	Project Closeout	August 15, 2012

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agency, some may question whether that scientist is sufficiently independent from the agency to be employed as a peer reviewer on agency-sponsored projects."

[2] Deliverable

[3] Additional Final Evaluator and BackCheck Responses provided for two Final Panel Comments

candidate's employment history and background. Providing a positive response to a COI screening question did not automatically preclude a candidate from serving on the Panel. For example, participation in previous USACE technical peer review committees and other technical review panel experience was included as a COI screening question. A positive response to this question could be considered a benefit. The following outlines the screening inquiry for assessing the peer reviewer candidates:

- Previous and/or current involvement by you or your firm[4] in the HSDRRS Armoring Research Summary and Armoring Guidance Manual and technical appendices.
- Previous and/or current involvement by you or your firm[4] in HSDRRS Armoring Research Summary and Armoring Guidance Manual-related projects.
- Current employment by the U.S. Army Corps of Engineers (USACE).
- Previous and/or current involvement with paid or unpaid expert testimony related to the HSDRRS Armoring Research Summary and Armoring Guidance Manual**.**
- Past, current, or future interests or involvements (financial or otherwise) by you, your spouse, or your children related to coastal Louisiana.
- Current personal involvement with other USACE projects, including whether involvement was to author any manuals or guidance documents for USACE. If yes, provide titles of documents or description of project, dates, and location (USACE district, division, Headquarters, ERDC, etc.), and position/role. Please highlight and discuss in greater detail any projects that are *specifically* with the Mississippi Valley Division.
- Current firm[4] involvement with other USACE projects, *specifically* those projects/contracts that are with the Mississippi Valley Division. If yes, provide title/description, dates, and location (USACE district, division, Headquarters, ERDC, etc.), and position/role.
- ***Any*** previous employment by USACE as a direct employee or contractor (either as an individual or through your firm[4]) within the last 10 years, *notably* if those projects/contracts were with the Mississippi Valley Division Mississippi Valley Division. If yes, provide title/description, dates employed, and place of employment (district, division, Headquarters, ERDC, etc.), and position/role.
- Previous experience conducting technical peer reviews. If yes, please highlight and discuss any technical reviews concerning coastal storm damage or involving the review of guidance manuals, and include the client/agency and duration of review (approximate dates).
- Pending, current, or future financial interests in HSDRRS Armoring Research Summary and Armoring Guidance Manual-related contracts/awards from USACE.
- A significant portion (i.e., greater than 50%) of personal or firm[4] revenues within the last three years came from USACE contracts.

[4] Includes any joint ventures in which your firm is involved and if your firm serves as a prime or as a subcontractor to a prime. Please clarify which relationship exists.

- Any publicly documented statement (including, for example, advocating for, or discouraging against) related to the HSDRRS Armoring Research Summary and Armoring Guidance Manual.
- Participation in relevant prior Federal studies relevant to the HSDRRS Armoring Research Summary and Armoring Guidance Manual.
- Previous and/or current participation in prior non-Federal studies relevant to the HSDRRS Armoring Research Summary and Armoring Guidance Manual.
- Is there any past, present, or future activity, relationship, or interest (financial or otherwise) that could make it appear that you would be unable to provide unbiased services on this project? If so, please describe.

The four candidates proposed were affiliated with consulting companies and universities, determined to fit the expertise areas, and did not have any actual or perceived COIs. Battelle established subcontracts with the panel members when they indicated their willingness to participate and confirmed the absence of COIs through a signed COI form. Although the Panel was disclosed to USACE, Battelle made the final selection of panel members. Section 4 of this report provides names and biographical information on the panel members.

Prior to beginning their review and on the day their subcontracts were being finalized, all members of the Panel attended a kick-off meeting via teleconference planned and facilitated by Battelle in order to review the IEPR process, the schedule, communication, and other pertinent information for the Panel.

3.3 Preparation of the Charge and Conduct of the IEPR

Charge questions were provided by USACE and included in the draft and final Work Plans. In addition to a list of 15 charge questions/discussion points, the final charge included general guidance for the Panel on the conduct of the peer review (provided in Appendix C of this final report).

Battelle planned and facilitated a final kick-off meeting via teleconference during which USACE presented project details to the Panel. Before the meeting, the IEPR Panel received an electronic version of the Armoring Manual documents and the final charge. A full list of the documents reviewed by the Panel is provided in Appendix C of this report. The Panel was instructed to address the charge questions/discussion points within a comment-response form provided by Battelle.

3.4 Review of Individual Comments

At the end of the review period, the Panel produced approximately 45 individual comments in response to the charge questions/discussion points. Battelle reviewed the comments to identify overall recurring themes, areas of potential conflict, and other overall impressions. As a result of the review, Battelle was able to reduce the 45 comments into a preliminary list of 18 overall comments and discussion points. Each panel member's individual comments were shared with the full Panel in a merged individual comments table.

3.5 IEPR Panel Teleconference

Battelle facilitated a 5-hour teleconference with the Panel so that the panel experts could exchange technical information. The main goal of the teleconference was to identify which issues should be carried forward as Final Panel Comments in the IEPR report and decide which panel member would serve as the lead author for the development of each Final Panel Comment. This information exchange ensured that the final IEPR report would accurately represent the Panel's assessment of the project, including any conflicting opinions. The Panel engaged in a thorough discussion of the overall positive and negative comments, added any missing issues of high-level importance to the findings, and merged any related individual comments. In addition, Battelle confirmed each Final Panel Comment's level of significance to the Panel.

At the end of these discussions, the Panel identified 16 comments and discussion points that should be brought forward as Final Panel Comments.

3.6 Preparation of Final Panel Comments

Following the teleconference, Battelle prepared a summary memorandum for the Panel documenting each Final Panel Comment (organized by level of significance). The memorandum provided the following detailed guidance on the approach and format to be used to develop the Final Panel Comments for the Armoring Manual:

- Lead Responsibility: For each Final Panel Comment, one panel member was identified as the lead author responsible for coordinating the development of the Final Panel Comment and submitting it to Battelle. Battelle modified lead assignments at the direction of the Panel. To assist each lead in the development of the Final Panel Comments, Battelle distributed the merged individual comments table, a summary detailing each draft final comment statement, an example Final Panel Comment following the four-part structure described below, and templates for the preparation of each Final Panel Comment.
- Directive to the Lead: Each lead was encouraged to communicate directly with other IEPR panel members as needed and to contribute to a particular Final Panel Comment. If a significant comment was identified that was not covered by one of the original Final Panel Comments, the appropriate lead was instructed to draft a new Final Panel Comment.
- Format for Final Comments: Each Final Panel Comment was presented as part of a four-part structure:
    1. Comment Statement (succinct summary statement of concern)
    2. Basis for Comment (details regarding the concern)
    3. Significance (high, medium, low; see description below)
    4. Recommendation for Resolution (see description below).
- Criteria for Significance: The following were used as criteria for assigning a significance level to each Final Panel Comment:
    1. High: Describes a fundamental problem with the guidelines that could affect the suggested methods used.
    2. Medium: Affects the completeness or understanding of the guidelines.

3. Low: Affects the technical quality of the guidelines, but will not affect the recommendation of the methods used.

- Guidance for Developing the Recommendation: The recommendation was to include specific actions that USACE should consider to resolve the Final Panel Comment (e.g., suggestions on how and where to incorporate data into the analysis, how and where to address insufficiencies, areas where additional documentation is needed).

At the end of this process, 16 Final Panel Comments were prepared and assembled. Battelle reviewed and edited the Final Panel Comments for clarity, consistency with the comment statement, and adherence to guidance on the Panel's overall charge, which included ensuring that there were no comments regarding USACE policy. There was no direct communication between the Panel and USACE during the preparation of the Final Panel Comments. The Final Panel Comments are presented in Appendix A of this report. Sections 5 and 6 summarize the results of the Final Panel Comments, as well as the post Final Panel Comment response process.

4. PANEL DESCRIPTION

Candidates for the Panel were identified using criteria specified in the USACE SOW to (1) contact candidate panel members to evaluate technical skills, potential COIs, availability, and hourly rates, and (2) identify four experts from the pool of candidates to serve on the IEPR Panel. Battelle chose four of the most qualified candidates and confirmed their interest and availability. All candidates were proposed as primary reviewers for the final IEPR Panel. Battelle prepared a draft list of primary candidate panel members (screened for availability, technical background, and COIs), and provided it to USACE for feedback. Battelle made the final selection of panel members.

An overview of the credentials of the final four primary members of the Panel and their qualifications in relation to the technical evaluation criteria is presented in Table 2. More detailed biographical information regarding each panel member and his or her area of technical expertise is presented in the text that follows the table.

Table 2. HSDRRS Armoring Research Summary and Guidance Manual IEPR Panel: Technical Criteria and Areas of Expertise

Technical Criteria	Battalio	Philips[5]	Marks	Guertal
Hydraulic Engineering (two experts needed)				
Hurricane wave expertise	X	X		
Experience in coastal hydraulic design	X	X		
Experience in erosion caused by storm-generated overtopping waves on the protected side of levees armored with grass only	X	See waiver[6]	X[6]	
Experience in erosion caused by storm-generated overtopping waves on the protected side of levees armored with grass with turf reinforcement mats	See waiver[6]	See waiver[6]	X[6]	
Experience in erosion caused by storm-generated overtopping waves on the protected side of levees armored articulated concrete blocks	See waiver[6]	X	X[6]	
Experience in research and development of extreme storm generated overtopping waves causing erosion on the protected side of earthen levees	X	X		
Civil/Geotechnical Engineering (one expert needed)				
Broad civil engineering experience in levee design			X	
Design experience in grass			X	
Design experience in turf reinforcement mats			X	
Design experience in articulated concrete blocks			X	
Experience with erosion control of protected side slopes and levee crowns against storm-generated wave overtopping of earthen levees			X	
Experience in the design and analysis of levee slopes and levee crowns for wheel loads from mowers and inspection vehicles			X	
Minimum 10 years of experience in the operation and maintenance (O&M) of levees, especially levee slopes in a coastal environment armored with grass			X	

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[5] The statement of work (SOW) states that the panel members have 20 years experience in their field of expertise. Mr. Shane Phillips is a registered P.E. in LA, TX, FL, WA, and CA with 19 years of experience. He has extensive hydraulic and civil engineering experience with coastal and marine construction projects and has applied his coastal engineering design expertise to a variety of coastal shore protection projects along the Pacific and Gulf Coasts. Battelle's request for a waiver of the SOW qualifications was approved.

[6] The SOW states that the hydraulics and civil/geotechnical engineering experts have design experience with grass, turf reinforcement mats, and articulated concrete block. Due to the highly specific levels of expertise required, Battelle is proposing that each of the hydraulics engineers have design experience using either grass or articulated concrete block (one each). In addition, the civil/geotechnical engineer has vast experience in all three areas. Battelle's request for a waiver of the SOW qualification was approved.

Table 2 HSDRRS Armoring Research Summary and Guidance Manual IEPR Panel: Technical Criteria and Areas of Expertise, continued

Technical Criteria	Battalio	Philips[3]	Marks	Guertal
Minimum 10 years of experience in the operation and maintenance of levees, especially levee slopes in a coastal environment armored with grass-reinforced mats			X	
Minimum 10 years of experience in the operation and maintenance of levees, especially levee slopes in a coastal environment armored with articulated concrete blocks			X	
Agronomy (one expert needed)				
Experience with robust bermudagrass growth for preventing soil erosion on levee slopes from extreme storm surge-generated waves, causing erosion on the protected side and crown of earthen levees covered with:				X
grass only				X
grass with turf reinforcement mats				X
Experience in the analysis and characterization of grass roots as it relates to erosion resistance from water flow, especially from wave overtopping				X[7]

Robert Battalio, P.E.

Role: This panel member was chosen primarily for his hydraulic engineering experience and expertise.

Affiliation: ESA PWA (previously known as Philip Williams & Associates)

Mr. Robert Battalio is a principal engineer with ESA PWA and is a registered professional engineer in Louisiana, California, Washington, and Oregon. He earned his M.E. in civil engineering (coastal engineering) from the University of California at Berkeley in 1985, and has over 25 years of experience with flood management, restoration design, coastal engineering, and project management. His primary focus has been on coastal and estuarine areas, wetland and creek restoration design, and waterfront civil engineering projects.

Mr. Battalio has directed all phases of waterfront and restoration Civil Works projects, including field data collection, conceptual design, preliminary design/feasibility analysis, final design/construction documents, and construction management. His experience in hurricane wave and coastal hydraulic design and erosion includes wind wave generation, wave transformations analysis, wave run-up and overtopping, overland flows, and statistical analysis methods for multi-parameter coastal flood events. Mr. Battalio led development of the Pacific Coast Guidelines for Federal Emergency Management Agency (FEMA) flood studies (2005) in

[7] Experience in the analysis and characterization of grass roots as it relates to erosion only

these areas. He has extensive experience in the design of water front structures with capabilities including coastal geomorphology analyses such as profile and shore changes in response to storms and long-term evolution that are important to establishing realistic design conditions for overtopping.

Mr. Battalio's expertise in erosion caused by storm-generated overtopping waves on the protected side of levees is reflected in his experience with the physical model study of wave overtopping of breakwaters and armor unit stability; modeling of wave run-up and overtopping and comparing to field observations for a coastal flood study; estimation of future shoreline and profiles over time and in response to sediment supply deficits, storms and sea level rise. He has investigated erosion of vegetated, uncertified earth levees in San Francisco Bay using field measurements spanning years and synthetic wave and water level time series.

Co-author of numerous papers and published reports investigating wave and tidal processes in nearshore environments and the related physical processes, Mr. Battalio has participated in the technical peer review of a variety of engineering projects.

R. Shane Phillips, P.E.

Role: This panel member was chosen primarily for his hydraulic engineering experience and expertise.
Affiliation: Coast and Harbor Engineering, Inc.

Mr. R. Shane Phillips is a principal civil engineer at Coast and Harbor Engineering, Inc. in Edmonds, WA. He earned his B.S. in civil engineering at Washington State University, Pullman, Washington in 1993, and is a registered professional engineer in Louisiana, Texas, Florida, Washington, and California. He has 19 years of experience in marine and coastal engineering , specifically in feasibility evaluation, preliminary design, and final design of geotechnical, structural and civil components of coastal and marine construction projects.

Mr. Phillips has applied his coastal engineering design expertise to a variety of coastal shore protection projects along the Pacific and Gulf Coasts. His experience in hurricane wave and coastal hydraulic engineering and design includes feasibility evaluations, preliminary and final design of hydraulic, civil, and structural components of marine and coastal construction projects along the Gulf Coasts. For these projects, he was responsible for overseeing all project and client coordination from feasibility through final design and construction.

As a civil/hydraulic design engineer, Mr. Phillips is experienced in coastal/hydraulic design and has worked on water resource engineering projects in the specialized areas of hydraulic, coastal, and river engineering. His expertise in erosion caused by storm-generated overtopping waves on the protected side of levees includes the armoring of levees with articulated concrete block and rock on projects such as the Port of Port Arthur Shore Protection Alternatives Analysis, Port Arthur, Texas. For this project he identified concrete block as one of the feasible project alternatives. He is also an experienced technical peer reviewer for engineering projects.

B. Dan Marks, Ph.D., P.E.

Role: This panel member was chosen primarily for his civil/geotechnical engineering experience and expertise.
Affiliation: Marks Enterprises of NC, PLLC.

Dr. B. Dan Marks is the owner and manager of Marks Enterprises of North Carolina, PLLC in Arden, NC and is a registered professional engineer in North Carolina, Georgia, and South Carolina. He earned his Ph.D. in civil engineering from Oklahoma State University in 1970 and has over 44 years experience as a geotechnical and dam safety engineer.

Dr. Marks is an expert in the administration and management of geotechnical engineering projects; analysis and design of dams and water retention structures, and earth retaining structures; analysis of landslide and slope stability; design of remediation; stabilization of soil; control of erosion and sedimentation; preparation of mine disposal plans; and use of geosynthetics and geotextiles in drainage and reinforcement. He is also experienced in failure analyses and remediation consulting; and has been an expert witness for arbitration testimony.

He has direct experience with levee design and the O&M of levees in coastal environments armored with grass, grass–reinforced mats and articulated blocks. He served as a project consultant for the Congaree River Levee System evaluation and remedial repair design (Columbia, South Carolina) and was a member of the IEPR Panel for the USACE Policy Review of Vegetative Growth on Levees (2008). Dr. Marks is particularly experienced in O&M of levees on the lower Mississippi River. He presented “Geogrid Reinforcement for Remedial Slope Repairs” at the 1999 American Society of Civil Engineers Spring conference and “Dam Monitoring and Data Evaluation” at the Mississippi Dam Safety Workshop in Tunica, Mississiippi (1999). He is experienced with erosion control of protected side slopes and level crowns against storm-generated wave overtopping. He has evaluated numerous earthen dams for traffic loads including the design and analysis of levee slopes and crowns for wheel loads from mowers and inspection vehicles. He co-authored the “Technical Manual for Dam Owners: Impacts of Trees and Woody Vegetation on Earthen Dams” for the FEMA and the first Erosion & Sedimentation Control Manual used by the Federal Highway Administration. He has authored 20 publications, more than 15 reports, and over 75 presentations in the geotechnical field including stabilization, remediation, and erosion control.

Elizabeth Guertal, Ph.D.

Role: This panel member was chosen primarily for her agronomy experience and expertise.
Affiliation: Auburn University

Dr. Elizabeth Guertal is a professor of Turfgrass Soil Fertility at Auburn University and is both a state and national Certified Crop Advisor. She earned her Ph.D. in soil science from Oklahoma State University in 1993 and has more than 27 years of teaching and scientific research experience in the soil science and turfgrass field including extensive experience with bermudagrass growth and its effect on erosion. She teaches both Turfgrass Management and Introductory Soil Science at Auburn University and recently served as a Fulbright Fellow at the University of Mauritius (on the island of Mauritius), teaching soil science.

Dr. Guertal's expertise includes conducting research supporting the development of specifications for establishment of bermudagrass and vegetation establishment on steeply sloped, disturbed, and poorly prepared slopes. She conducted research for the National Turfgrass Evaluation Program Bermudagrass Trial. Dr. Guertal was (through 2011) the Sports Turf Managers Association (STMA) university/voting representative to ASTM meetings, where turfgrass establishment standards are discussed. She conducts extensive work in the area of nitrogen fertility and other management inputs for bermudagrass establishment with extensive experience with both seeded (common) and vegetative bermudagrasses (hybrid and common selections).

She has authored or co-authored more than 100 publications, technical papers, and abstracts and is currently the technical editor for a top agronomy scientific publication, Crop Science. She is a member of numerous professional societies including Soil Science Society of America, American Society of Agronomy, and American Society of Horticultural Science. Dr. Guertal is a Fellow of the American Society of Agronomy and the Crop Science Society of America.

5. SUMMARY OF FINAL PANEL COMMENTS

USACE guidance (2010) states the final report will contain the Panel's "assessment of the adequacy and acceptability of the economic, engineering, and environmental methods, models, and analyses used." However, for the Armoring Manual IEPR, the Panel focused only on the hydraulic engineering, civil/geotechnical engineering, and agronomy analyses of the project, and did not assess any economic or other environmental aspects. The Panel agreed on its assessment of the adequacy and acceptability of the engineering methods, models, and analyses used in the Armoring Manual documents. However, the Panel expressed concern about the intended use of the manual and was informed during the March 8, 2012 teleconference with USACE that the Armoring Manual is limited to preliminary designs of earth levees protecting against coastal flood hazards in the HSDRRS in Louisiana.

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. 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. 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 Panel understands the importance of the levees and T-walls for meeting the objectives of the overall design of the HSDRRS. Because the levees and T-walls provide the first line of defense against potential erosion, the Panel recommends that the Armoring Guidance Manual be reviewed by the same American Society of Civil Engineers (ASCE) Panel that reviewed the HSDRRS Design Guidelines. This ASCE Panel will provide a needed layer of consistency to ensure that the Armoring Guidance Manual allowable overtopping thresholds do not conflict with the basis for similar recommendations previously determined during the HSDRRS Design Guidelines review, or raise new concerns because of the changes in criteria and designs. The following statements summarize the Panel's findings.

Hydraulic Engineering: The hydraulic engineering panel members were encouraged to read that USACE had reached out to the Dutch regarding armoring as they are very experienced in this type of work. They noted that some very well respected individuals (e.g., Jentsje W. van der Meer and Steven Hughes) developed information that went into the Armoring Manual, and judged the use of two large-scale model tests a wise approach because of the complex hydraulics and theory. However, 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 recommendations in the Manual rely on an unproven concept that erosion potential resulting from wave overtopping can be gauged by an average overtopping flowrate, similar to prior work on rivers and reservoirs, but notably very different from the pulses associated with waves. 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. 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 panel members also noted 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.

Civil/Geotechnical Engineering: The civil/geotechnical engineering panel member noted the Armoring Manual benefitted from Dr. Hughes' excellent job of providing supporting documents for the entire project by preparing theses or dissertations on wave loading of levees. However, the Manual suffered from a lack of emphasis on the CSU Wave Overtopping Simulator (WOS) Testing and the extrapolation of that data to much higher loading values. As such, the Manual provides a confusing directive to design engineers. The Manual is presented in the form of a research report rather than 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 under loading conditions less than those associated with the 100-year return frequency design storm event. The civil/geotechnical engineering panel member noted that there is significant relevant information from dam projects that should be reviewed to gain further insight applicable to the HSDRRS project. The panel member recommends that the Armoring Manual specify, at a minimum, the design flood that the information relates to and why that particular flood was used. This will provide the designers with the background information necessary to determine if they need to make adjustments for the project section they are working on.

Agronomy: The Agronomist is concerned that the bermudagrass was tested in a region to which it is not adapted. It is likely that the bermudagrass was dormant when tested and results would likely differ from that on actively growing turf. However, results collected from dormant bermudagrass would likely be a worst-case scenario and thus would be useful data.

Table 3. Overview of 16 Final Panel Comments Identified by the HSDRRS Armoring Manual IEPR Panel

No.	Final Panel Comments
	Significance – High
1	The actual dimensions of flood-side erosion may be greater than those reported in the Armoring Guidance Manual.
	Significance – Medium
2	The Armoring Guidance Manual does not provide guidance for armoring around T-walls because there is no stability analysis or supporting documentation.
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.
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.
5	The Armoring Guidance Manual does not provide the appropriate geotechnical guidance.
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.
7	The turf reinforcement testing did not include the characteristics of the embankment subgrade and the wave overtopping that would load the subgrade.
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.
9	A potential weakness in the conclusions drawn from the CSU modeling may be the wave parameters used as input for the CSU WOS.
10	The Armoring Guidance Manual does not consider an “importance factor” or “localized condition variable factor” when determining sufficient armoring for a location.
	Significance – Low
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.
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.
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.
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.
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.

No.	Final Panel Comments
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.

6. POST–FINAL PANEL COMMENT RESPONSE PROCESS

Battelle posted the Final Panel Comments into DrChecks on January 18, 2012. USACE PDT evaluated and reviewed the IEPR panel comments and provided draft Evaluator Responses to Battelle (using a template provided by Battelle) on February 16, 2012. Battelle immediately provided the draft Evaluator Responses to the IEPR Panel and directed the panel members to develop draft BackCheck Responses. The USACE draft Evaluator Responses and the Panel draft BackCheck Responses were discussed in the Final Panel Comment teleconference with USACE (which included the non-federal sponsor) on March 8, 2012. During the teleconference, Battelle facilitated discussions between the USACE PDT and the Panel on each Final Panel Comment with the goal of reaching consensus (e.g., concurrence between USACE and the Panel). At the end of the teleconference, USACE and the IEPR Panel had reached concurrence on six of the 16 Final Panel Comments, and for most of the remaining comments the Panel indicated it would concur with the intended USACE PDT draft Evaluator Response based on discussions during the teleconference. Following the teleconference, USACE developed final Evaluator Responses and uploaded them into DrChecks on April 11, 2012. Battelle downloaded these responses, provided them to the Panel, and directed the Panel to prepare final BackCheck Responses. The panel members considered the final Evaluator Responses and concurred with USACE PDT on 14 of the 16 Final Panel Comments. The final BackCheck Responses were uploaded to DrChecks on April 30, 2012 and the comments were closed.

After closing the comments in DrChecks and during preparation of the final report, Battelle was notified that the PDT had obtained new information that could be helpful to the Panel in understanding some reported results pertaining to Final Panel Comments 6 and 8. This information was not available prior to or during the March 8, 2012 teleconference. The PDT asked that the Panel review the new information and additional final Evaluator Responses to determine whether they addressed the Panel's concerns. On May 17, 2012 Battelle received the information from USACE and directed the Panel to review their original final BackCheck responses based on their assessment of the additional Evaluator Responses provided by the PDT in DrChecks and the new information. Battelle received the Panel's additional final BackCheck Responses on June 7, 2012, uploaded them to DrChecks on June 7, 2012 and closed the comments. Although the new information provided support to some of the conclusions in regards to the larger overtopping wave volumes, it did not result in a change to the BackCheck responses to these Final Panel Comments (see Appendix B).

Detailed information on the USACE PDT Evaluator and Panel BackCheck Responses that were uploaded into DrChecks is contained in Appendix B of this report.

7. REFERENCES

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APPENDIX A

Final Panel Comments

on the

HSDRRS Armoring Research Summary and Armoring Guidance Manual

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Comment 1:

The actual dimensions of flood-side erosion may be greater than those reported in the Armoring Guidance Manual.

Basis for Comment:

Three important points associated with the flood side erosion calculations were not adequately addressed in the Manual:

1. The supporting document (Hughes, 2010) calculates that the physical extent of erosion may be greater than that reported in the Manual, which implies that the Manual may underestimate the degree to which erosion would occur.
   - Tables 14, 15, and 16 in Hughes (2010) show erosion depths greater than 5 feet for a 4-hour duration storm, and 11 feet for a 10-hour duration storm. The results for a 10-hour duration storm and results using the INFRAM method are not included in the Armoring Guidance Manual Tables 2.1, 2.2, and 2.3.
   - The Hughes Report (p. 100) indicates that erosion predictions reach the levee crest for some locations and methods, which implies some risk. However, the higher erosion results are not explicitly summarized and seem to not be supported by the author in the Case 3 results (p. 99 of the Hughes report). This omission is repeated in the Armoring Guidance Manual. However, the omission of the higher erosion estimates without explanation raises questions as to whether the omissions were an error. The designer is left with doubt regarding the risk of objectionable erosion, the basis for guidance indicating that erosion may not be a problem, and the direction being provided by the Manual.
2. The erosion computations are based on methods derived for less severe wave conditions (smaller wave heights and/or lengths) than the Hurricane Storm Damage Risk Reduction System (HSDRRS) design conditions, and hence extend beyond their applicable range.
   - The available tests for grass are for wave periods not more than 5 seconds, whereas design periods of 9 seconds are reported for the HSDRRS (Hughes, pp. 16 and 32) and up to 14 seconds (Colorado State University [CSU] report). The available tests for clay had wave periods up to 12 seconds, but only for waves up to 3.4 feet high; other tests had waves up to 5 feet high, but for periods not longer than 5 seconds. In summary, there are no test data for HSDRRS design conditions which are up to 8 feet and 9 seconds (or 14 seconds per the CSU report). Hughes states (p. 59) that the methods are known to be valid for waves up to 5 feet for 5 seconds, but are of unknown accuracy at high wave loadings such as those associated with the HSDRRS.

In addition, the findings in Section 2.8 of the Armoring Manual, Earthen Levee Flood Side Armoring, especially Finding 3, are difficult to follow:

- Findings 1 and 2 indicate that the findings hold for storm durations less than 10 hours. However, the Manual does not include the 10-hour duration tables from Hughes (2010) – only the tables for a 4-hour duration (which calculate less erosion).
- It is not clear which methods and results are being referred to in the statement that: “The maximum erosion depths for grass-covered slopes were found using equations in

which the erosion depth is directly proportional to wave height squared."

- The comment on soil structure development is qualitative and difficult to apply in design.
- The comment about minimum required levee height to attain 8-foot breaking waves is difficult to follow, and raises questions about whether the design conditions are known or realistic.

3. The Armoring Guidance Manual (top of p. 69) states the potential for erosion is on the flood side slope and recommends minimum trenching requirements (shown in Figure 3.13). The recommended minimum length of front-side armoring (measured from the crest) and the location of an anchoring trench seem to be non-conservative relative to the potential uncertainties and variabilities in computing the erosion dimensions. Extending the turf reinforcement mat (TRM) armoring farther down the flood side requires minimal cost with significant incremental benefit by reducing the risk of failure should the erosional scarp be under-predicted. If flood side anchoring were undermined or destroyed, the entire armoring system on the crest and landside slope would become compromised and potentially non-functional.

Significance – High:

Underestimating the dimensions of erosion on the flood side of the levee could lead to levee failure.

Recommendation(s) for Resolution:

1. Report all computation results, clarify which results are based on judgment, and explain why such results are valid.
2. Provide a design cross-section to be used by geotechnical and structural engineers to design flood walls.
3. Revise or remove the following sentence on p. 28: "The Design Engineer (with knowledge of the local soil, grass and wave conditions) determining whether any flood side armoring is required in any particular reach should take the above uncertainty into account and apply the appropriate factors to insure that the critical life-safety issues are adequately addressed."
4. Explain how armoring the top 2 feet of the face with turf reinforcement mat would armor against wave erosion and slope instability, and what the implications to undermining the mat anchor trench are to the protected side erosion potential.
5. Clarify what the design requirements are for the "good quality clay" to mitigate erosion, purportedly, to only 1 foot vertically with a 4-foot (or 8-foot) wave train impinging on the earth for 10 hours.
6. Consider whether conditions other than those experienced in Katrina, perhaps with a lower water level and less overtopping but more wave breaking directly on the levee face, might result in greater erosion than that experienced during Katrina.
7. Conduct physical model tests of flood side erosion.
8. Revise the surge hydrograph to consider wave setup.
9. Clarify whether raising the crest elevation increases or reduces the potential for flood side erosion.

10. Clarify whether the risk of flood side erosion could be mitigated by the designer by modifying the levee geometry to:
    a) Include an additional volume of earth to act as a sacrificial erosion buffer, and or
    b) Include a bench or flatter slope to dissipate wave action with less erosion.
11. Increase the length of minimum armoring dimensions (shown on Figure 3.13) for the flood side slope and crest to reduce risk to the project.

Literature Cited

Hughes, S.A. (2008). Flood-side Wave Erosion of Earthen Levees: Present State of Knowledge and Asseement of Armoring Necessity. Coastal and Hydraulics Laboratory, U.S. Army Corps of Engineers, Engineer Research and Development Center. ERDC/CHL TR-10-7. August.

Comment 2:

The Armoring Guidance Manual does not provide guidance for armoring around T-walls because there is no stability analysis or supporting documentation.

Basis for Comment:

Chapter 2 of the Armoring Guidance Manual states that levee failures in Hurricane Katrina were a result of the following factors:

- overtopping erosion of the land-side slope
- utilization of low-clay-content levee embankment soils
- utilization of poor quality (poorly compacted) levee embankment soils
- continuation of special erosion problems at T-walls, floodwalls, and transition zones.

Problems were found with the levee walls: structural instability of the walls, erosion at the flood-side base of the walls, and erosion during overtopping at both the land-side base of the walls and at the ends of the walls. Section 2.3 of the Manual presents the characteristics of flood-wave-induced loading, concluding that waves breaking directly on the flood-side face of the walls are the most damaging loading conditions. Section 2.7 concludes with a series of statements about the need for global stability analyses to determine the unbalanced forces on the wall foundations. However, there are no guidelines for creating an analysis model relative to depth of scour to be evaluated to determine the magnitude of unbalanced forces and to determine if these unbalanced forces create structural stability issues for the pile foundation system. Finally, the Manual states that the U.S. Army Corps of Engineers (USACE) considers additional geotechnical engineering and global stability analyses necessary to evaluate potential wall instability relative to depth of scour (erosion) at both the heel and toe of T-walls and other floodwall structures. Results of these analyses would be provided as minimum unbalanced design for various loading conditions.

There is no mention of factors of safety to be used for various loading conditions. The Manual does provide an old "rule-of-thumb" equation for predicting the depth of scour in cohesive (clayey) soils, which is approximately equal to the height of the impending waves, and an equation to determine depth of scour in cohesionless soil. It is not clear how to apply the guidance provided in the Manual for flood-side erosion and develop a design section for geotechnical and structural analyses. The Panel agrees with the USACE New Orleans District that additional geotechnical engineering and global stability analyses should be made to evaluate wall instability issues as a result of flood-side and land-side erosion. The Panel believes that a more direct connection should be made between the Design Guidelines Manual and the Armoring Guidance Manual relative to armoring requirements at T-walls, floodwalls, and other structure transition zones.

Significance – Medium:

There needs to be consistency between the Design Guidelines Manual and the Armoring Guidance Manual relative to required armoring design for structures located within the crown section of the levee. Lack of consistency is significant, but would not result in failure of the project as a whole.

Recommendation(s) for Resolution:
1. Develop a design loading condition and factor of safety based upon complete scour (erosion) of the pile-supported wall foundation, recognizing that the foundation may not actually be in contact with the levee embankment as a result of embankment settlement beneath the wall foundation. Required anchoring guidelines could then be developed to protect the wall foundation from complete scour or erosion. For example, geogrid-reinforced backfill at the heel and toe of the foundation might be anchored in such a manner as to protect the wall foundation. 2. Conduct geotechnical engineering structural and global stability analyses necessary to develop relationships between factors of safety and predicted depths of erosion (scour). Provide guidance for the design of anchoring systems that would reduce the potential for scour (erosion) to depths greater than those associated with desired factors of safety. 3. Conduct Wave Overtopping Simulator (WOS) tests for walls of varying height that are overtopped by waves of varying heights and time-averaged discharge flow rates. Evaluate the depth of scour at the heel and toe for various armoring materials. 4. Conduct model wall tests to determine the effect of different wall configurations, such as backward-sloping walls backfilled to various heights, forward-sloping walls that are completely backfilled on the flood-side of the wall, and slab-and-buttress walls that have varying degrees of front slopes and various size splash aprons on the land-side of the walls.

Comment 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.
Basis for Comment:

Proper design and quality construction of the armoring system, while important, will not be the controlling factors in the long-term performance of the levee armoring system. Long-term performance will be directly related to the proper maintenance of the armoring material (typically grass or turf slope protection). However, Section 3.11 of the Armoring Guidance Manual devotes less than two full pages (pp. 70-72) on operation and maintenance (O&M). The discussion of O&M makes no reference to the new USACE “no tree zone” policy (ETL 1110-2-571, 10 April 2009) and related documents for variances, nor does the Manual mention the use of agricultural lime as a significant ingredient in the nourishment mixture for the armoring seedbed and long-term applications. Guidance for preparation of and adherence to an O&M plan for a specific section of levee warrants a separate chapter in the Armoring Guidance Manual.

The following examples of O&M requirements either were not included or received minor attention:

- Agronomy soil analyses should be conducted to determine which grass species would be best for consideration and what admixtures should be added to the seedbed to provide proper nourishment for initial growth and long-term health of the grass portion of the anchoring system.
- The Manual does not address means of controlling native grass overgrowth within the anchoring system if the native grasses are an undesirable armoring grass species.
- The only guidance given for maintaining the grass anchoring system is a minimum mowing length of 3 inches; however, cutting some desirable armoring grass species to 3 inches would be over-mowing and damage the armoring system;
- The Manual briefly mentions controlling weed growth but does not mention controlling woody vegetation and tree growth. Furthermore, there was no guidance on methods to control any undesirable plant growth.
- The recently established “no tree zone” policy will likely result in the shading of some portions of the toes of both levee embankment slopes. As such, some guidance should be provided for maintaining a viable armoring system in shaded areas.
- There is only a brief mention of potential wildlife damage of the levee armoring grass and rootmat. Hundreds of different wildlife species, from insects to rodents to marmots to fowl (wild geese), can cause damage. Grazing deer and rooting wild swine can cause significant embankment slope protection damage in a very short period. Animals such as voles and moles cause extensive damage while remaining completely out of sight, leaving very little evidence of damaging activity.

Significance – Medium:
Because the long-term performance of the levee armoring system depends on proper maintenance, detailed guidance in the Armoring Guidance Manual on the O&M plan for levee armoring systems is necessary.
Recommendation for Resolution:
1. Divide Chapter 3 of the existing Manual into at least three additional chapters, with the most significant chapter devoted to the subject of O&M (including inspections and monitoring) of the levee armoring system: a. The chapter on O&M should be a cooperative effort between at least two individuals: one with extensive experience in earthwork design and construction, and the other with extensive experience in agronomy and/or agriculture associated with production of hay and/or maintaining and operating significant pasture land for cattle grazing. b. The remaining two additional chapters could be used to present differing subject in more detail for clarification. For example, a chapter on project testing, a chapter on flood-side armoring, a chapter on land-side armoring, etc.

Literature Cited:

USACE (2009). Guidelines for Landscape Planting and Vegetation Management at Levees, Floodwalls, Embankment Dams, and Appurtenant Structures. U.S. Army Corps of Engineers Headquarters. Engineer Technical Letter (ETL) 1110-2-571. 10 April.

Comment 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.
Basis for Comment:
The intent, scope, and limitations of the HSDRRS Armoring Guidance Manual are not well described, and it is not clear how the recommendations will be used in the design or implementation of the elements associated with levee building and armoring. The Panel is aware that for the HSDRRS projects, a specific HSDRRS Design Guidelines document was prepared providing project-specific engineering for the levees and walls. It is not clear from the Armoring Guidance Manual whether the recommendations described in Section 5 supersede the HSDRRS Design Guidelines, or whether other considerations must be taken prior to use by the designer. As currently written, the Armoring Guidance Manual does not appear to supplement the HSDRRS Design Guidelines, and most importantly, in some instances, contradicts the HSDRRS Design Guidelines specifications. For example, the Armoring Guidance Manual provides recommendations for an average overtopping discharge of up to 1.0 cubic foot per second per foot (cfs/ft) for the grass-only protected side of the levee. However, the HSDRRS Design Guidelines Manual, which was peer reviewed by an American Society of Civil Engineers [ASCE] External Review Panel, states a maximum average overtopping discharge of up to 0.01 cfs/ft (for 50% non-exceedance). The fact that the Armoring Guidance Manual is providing a value with significant deviation from previously reported and accepted criteria is of concern to the Panel. In addition, there is no mention of the substantial difference and possible implications on the design of adjacent or supporting facilities (e.g., pumping plants, adjacent structures, etc.) impacted by the increased overtopping discharge. Another example of the Armoring Guidance Manual being unclear is the last paragraph of Section 2.8 (p. 28), which states: "The Design Engineer (with knowledge of the local soil, grass and wave conditions) determining whether any flood side armoring is required in any particular reach should *take the above uncertainty* into account and apply the *appropriate factors* to *insure* that the critical life safety issues are *adequately addressed*." This statement implies that the recommendations will be directly used by design engineers without further refinement or evaluation of the recommendations prior to implementation. The Panel is concerned about this statement because the italicized and underlined terms may cause the design engineer to be overly conservative, thus negating the effort of the studies conducted in developing the Armoring Guidance Manual. More importantly, this statement will reduce confidence that the results can be used at face value. Section 1.3 provides a short list of items that were not considered in the development of recommendations for the Armoring Guidance Manual. However, there is no mention of other important considerations such as benefit/cost analysis, importance factors, site-specific conditions, and presence of structures (pipes, culverts, and other features other than T-walls that could be constructed within the levee footprint). Section 1.3 should state that the design variables for localized conditions (which were not part of the Armoring Guidance Manual) are

not included in the Armoring Manual. This statement will forewarn the designer that the use of grass and high-performance TRM (HPTRM) may not be appropriate for all situations, even if the conditions outlined in Section 1.3 are met.

Additionally, it is not clear whether the designer has the flexibility to make decisions that may deviate from the recommendations of the Armoring Guidance Manual. If the importance factor or presence of structures warrants armoring of a levee feature (e.g., around a T-wall, on a backside slope, etc.), but armoring is not required by the Armoring Guidance Manual, it is not clear if the options are limited to grass and HPTRM or if other armoring methods (e.g., articulated concrete blocks [ACBs], rock, etc.) are available and if the design conditions (allowable overtopping rate) will still apply. The large overtopping rates (1 to 4.5 cfs/ft) may not work for the other armoring methods.

Finally, it is not clear if the recommendations presented in the Armoring Guidance Manual are intended to be used for preliminary or final engineering design. The Design Guidelines Manual clearly states (Section 1.0) that the Manual is intended for preliminary design purposes.

Significance – Medium:

The contradictions with the HSDRRS Design Guidelines and the lack of clarification could lead to misinterpretation and mis-use of the results, and correspondingly affect the performance of the designed levee facilities.

Recommendation(s) for Resolution:

1. Review the design recommendations contained in the Armoring Guidance Manual against the HSDRRS Design Guidelines criteria to ensure that the two manuals do not contradict each other and justification exists for any substantial deviation from previously established design criteria. If recommendations in the Armoring Guidance Manual maintain the current overtopping criteria, it is suggested that the ASCE Review Panel be contacted to ensure previous comments, recommendations, and concerns are captured, addressed, and incorporated into the Armoring Guidelines Manual prior to adoption as design guidance.
2. Revise the Introduction (paragraph 1.2) to include discussion and itemization of other elements that are not included or considered in the Armoring Guidance Manual evaluation and recommendations.
3. Revise the Introduction to state that the contents of the Armoring Guidance Manual are limited to the following narrowly defined conditions:
   - Grass, ACB, and TRM erosion control only. Although rock is not feasible on a larger scale (due to costs), it may still be desired within localized critical areas as erosion protection. It is not clear whether traditional methods such as rock are still an option in lieu of those outlined in the summary conclusions and recommendations.
   - Homogeneous earthen levee sections (flood side and protected side); not at locations adjacent to or at structures or facilities built on or within the levee.
   - Earthen levee to concrete T-wall transitions. Transitions to other types of structures were not evaluated.
4. Revise the Armoring Guidance Manual to provide the appropriate guidance to the designer to make final decisions on design recommendations. Discuss in greater detail the

limitations of the study results and design factors which have not been considered. This discussion would serve as a transition or “bridge” between the Armoring Guidance Manual results and the actual HSDRRS Design Guidelines Manual recommendations. Those additional design factors could include the following:

- Benefit/cost evaluation considerations
- Risk considerations
- Site-specific factors (culverts, pipes, structures, etc.)
- Adjacent infrastructure importance factors.

5. Consider rewording the statement in the last paragraph of Section 2.8 (bottom of p. 28) of the Armoring Guidance Manual to clarify for the designer how and when recommendations should be implemented. In addition, expand Section 5, Summary and Conclusions, to provide additional guidance to the designer.
6. Clarify in the document whether the guidance is for preliminary or final engineering design purposes.
7. Consider conducting a prototype analysis or simulation of Hurricane Katrina conditions which represent the recommended upper threshold of 1.0 cfs/ft for grass and 4.5 cfs/ft for HPTRM. This would include using available storm surge water level and wave height information to evaluate the performance of levees that exhibited similar high levels of overtopping and the corresponding post-storm condition assessment results (including photographs). Similarly, investigate the extent of erosion on the flood side of levees with field observations. A separate section in the report summarizing this type of evaluation would be helpful in validating the recommendations and conclusions.

Comment 5:

The Armoring Guidance Manual does not provide the appropriate geotechnical guidance.

Basis for Comment:

Chapter 2 of the Manual briefly discusses geotechnical engineering issues associated with the design and construction of levee embankments and armoring systems for the HSDRRS levees. Section 2.2 summarizes work done by Briaud (2008), which presents findings that support the proper performance of levee embankments constructed in accordance with appropriate geotechnical engineering guidance. These findings indicate the following:

- Embankment erodibility increased with decreased soil density (degree of compaction)
- Levee failures occurred at locations where embankment soils were highly erodible as a result of sand and silt content and low degrees of compaction (soil density)
- Levee failures occurred at locations where levee embankments were constructed entirely of highly erodible soils such as sands and non-plastic silts (cohesionless soils).

As such, Briaud inferred correctly that the appropriate soil type to select for levee embankment design and construction were cohesive soils (clays and plastic silts) that exhibit more resilience and are less susceptible to wave erosion. However, Briaud made no mention of the level of plasticity of the soils to be selected for levee embankment design and construction.

In Section 2.6 of the Manual, the author attempts to distinguish the performance of “good” and “bad” levee embankment soils. However, the presentation is quite confusing and indicative of possible misunderstandings of clayey soil characteristics relative to plasticity. This section of the report contains statements that grass-covered (not armored) levee embankment slopes would sustain some damage, with estimated depths of erosion in “poor” embankment soils being approximately 4 feet deep. The Manual then states that ***all*** sampled soils met the HSDRRS specifications for very “good” levee embankment soils, thus implying that the estimated depth of erosion for “poor” levee embankment soils was “*unrealistically conservative.*” Yet, on page 25 of the Manual the soil compaction specifications being referred to were stated as: “compacted to a minimum of 90 percent at -3 to +5% of optimum moisture content.”

The Panel believes that the use of these suggested design and construction compaction specifications is unsupported geotechnical engineering design guidance and notes that it is unlike any specification that USACE has made in the past relative to levee embankment design and/or construction. The Panel assumes that this is an oversight that can be corrected by editing rather than indicating a fundamental flaw in the work. No further discussion of levee embankment soil selection is made until the final chapter of the Manual, where the previously highlighted compaction specifications are again presented and Section 5.2.2, where the compaction specifications are linked to HSDRRS by stating in part: “…enhanced HSDRRS levee embankment and clay soil specifications will promote a greater level of erosive resistance and durability, even if the (armoring) grass cover is compromised”.

Use of a low-plasticity clayey soil for the design and construction of levee embankments is an appropriate geotechnical engineering recommendation. However, the incorporation of high-plasticity clayey soils into a levee embankment is disadvantageous. Some of the disadvantages of using high-plasticity clayey soils include, but are not necessarily limited to, the following:

- Difficulties associated with workability during construction, particularly when wet
- Difficulty controlling proper compaction moisture contents
- Shrinkage and/or desiccation cracking during extended drought periods
- Levee embankment settlement issues associated with secondary consolidation
- Low saturated shear strength that reduces levee embankment slope stability
- Elastic deformation and embankment creep that alter the levee configuration.

All of these disadvantages are critical long-term geotechnical engineering design, construction, and performance issues that should be carefully considered when providing geotechnical engineering guidance.

Significance – Medium:

Unclear geotechnical engineering guidance may cause confusion and incorrect use of the Manual.

Recommendation(s) for Resolution:

1. Establish specific ranges of pertinent Atterberg Limit values such as Liquid Limit, Plastic Limit, and Plasticity Index (PI) for selection of levee embankment fill soils.
2. Allow hydrated or non-hydrated lime soil modification to be used to reduce the plasticity of high-plasticity soils where clayey soils meeting the specified Atterberg Limits cannot be located within a reasonable haul distance to the levee project.
3. Increase the required degree of compaction for levee embankment design and construction to a minimum of 93 percent, and preferably 95 percent, of the standard Proctor compaction test maximum dry density (ASTM D-698).
4. Reduce the range of allowable compaction moisture from 8 percent to 4 percent, with a typical specification allowing compaction moisture contents to vary from -1 percent to +3 percent of the optimum moisture content.
5. Require the use of reasonable thicknesses of the topsoil seedbed and the cover of any turf reinforcement material that may be incorporated into the levee armoring system.
6. Require that the final compaction of the levee embankment slope and the applied armoring system be completed with a crawler tractor with a dozer blade attachment so that the track cleat marks are parallel to the slope contour and not perpendicular. This practice will prevent rill erosion along the track cleat marks.
7. Refer to other USACE manuals for geotechnical guidance, with clarification as to hierarchy of guidance.

Literature Cited:

Briaud, J.-L., Chen, H.-C., Govindsaamy, A. V., and Storesund, R. 2008. "Levee erosion by overtopping in New Orleans during the Katrina Hurricane," *Journal of Geotechnical and Geoenvironmental Engineering*, Vol 134 No. 5, pp 618-632.

Comment 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.

Basis for Comment:

The discharge rates at which armoring is required are not stated consistently in the Armoring Guidance Manual, as follows (Tables 3.3 and 3.4, p. 59; Section 5.3.4, p. 95) :

1. The threshold below which grass is considered adequate armoring is 1.0 cfs/ft and possibly 1.4 cfs/ft;
2. The use of HPTRM only is recommended, whereas HPTRM (p. 95) or regular TRM is allowed (p.59)., The report addresses this: Section 3.10.3, pp. 61 and 62, states that the CSU-WOS testing program was unable to make a distinction between the TRM and HPTRM. The second-to-last paragraph on p. 62 then states that the HPTRM was selected based on performance of the material during normal O&M.
3. The upper limit of application of HPTRM is listed as 4.5 and 4.0.
4. The definition of "armoring" is ambiguous because grass is tested and treated as armoring and required for flow rates up 1.4 cfs/ft, but the tables indicate that no armoring is required unless the flow rate is above 1.0 cfs.
5. The TRM specifications appropriate for the identified discharges should be clarified. For instance, some of the TRM products are recommended or warranted only under conditions of full vegetation (versus no vegetation or partial vegetation). If the grass is eroded during the design event, the TRM could be rendered ineffective if the incorrect TRM product is specified. It is not clear if this was evaluated in the CSU testing and is not addressed in the recommendations. Criteria for vegetated shear capacity and vegetated velocity are mentioned at the top of p. 63, but there is no mention of unvegetated criteria.

Significance – Medium:

Unclear recommendations may cause confusion and incorrect use of the Manual.

Recommendations for Resolution:

1. Revise recommendations in Section 5.3.4 (p. 95) to clearly state the flow rate and other criteria thresholds for different armoring recommendations, specifically the flow rate thresholds for grass and grass with HPTRM, and any other requirements
2. Provide a better summary of the basis for the recommendations, specifically how guidance was developed for flow rates above 1.0 cfs/ft and 2.0 cfs/ft, which are limits of testing based on some supporting documents.
3. Clarify what conditions might allow deviation from the recommendations, and what alternatives may be appropriate. It would be better to indicate that "grass armoring" is required for flow rates below 1.0 cfs/ft rather than "no armoring" because the 1.0 cfs/ft threshold is for grass with specific minimum characteristics (Summary Table, Section 5.3.4).
4. Provide clarification as to the appropriate TRM products and specifically whether those that require an intact turf are acceptable.

Comment 7:

The turf reinforcement testing did not include the characteristics of the embankment subgrade and the wave overtopping that would load the subgrade.

Basis for Comment:

The objectives of the CSU WOS testing and the results obtained from the tests were not well connected to the levee armoring design process. The tests and design assume that the overtopping is roughly parallel to the protected-side slope in a turbulent sheet flow (Figure 3.2, condition A, wave overtopping only), but fail to recognize that the wave overtopping condition can include projectile-type water trajectories that impinge on the backslope (see, for example, the discussion in the FEMA (2005). Such a trajectory induces a different loading than that tested. A momentum-impact force is directed into the soil and can increase the shear stress within the subgrade below the turf. The thin section of soil tested, with confinement and support from the tray bottom, would have likely inhibited any such failure even if the WOS produced this flow regime. Therefore, it is not clear that the WOS addressed a design loading that could cause damage to the HSDRRS. Moreover, such damage would be synergistic with the surficial erosion of the turf, because subgrade deformations would induce surface irregularities that could concentrate hydraulic loadings on the turf.

The Manual does not provide a convenient way to relate levee embankment erosion to design conditions because the CSU WOS tests do not result in failure in terms of design criteria (that is, minimal damage at the 100-year/90% non-exceedance and no catastrophic damage at the 500-year/50% non-exceedance). Also, the average overtopping rate can apply to a range of wave conditions, and guidance is not provided to translate the "effective overtopping rate" tests which have a dubious basis (see below).

Prior to the design of any project or structure, the design engineer must establish the loading conditions upon which the project design will be based. This determination is usually represented by three loading conditions often referred to as normal or design loading condition, unusual loading condition, and extreme loading condition. In this case, a hurricane greater than that of Hurricane Katrina is used for the extreme loading condition. The unusual loading condition is often associated with the maximum loading condition than can be anticipated to occur (in this case, the loading conditions found to be associated with Hurricane Katrina). The normal or design loading condition for the HSDRRS levee system has been established based upon the 100-year return frequency storm event. This is a very realistic design loading condition if one analyzes storm events that have affected the lower Mississippi River levee system in the last 100 years.

Under the design loading condition, one does not expect significant damage to occur to the project being designed. As such, one would not expect significant damage to occur to the levee armoring systems in the HSDRRS projects. By definition, significant damage may occur to a project or structure subjected to the selected unusual loading condition. For example, subsequent to successful completion of the HSDRRS levee project design life, one would expect to see significant damage to the levee armoring system; however, there would not be total failure of the armoring system and certainly no failures of the levee embankments, floodwalls, or other appurtenant structures. In the event of a direct hit of a hurricane greater in size and intensity (category classification) than that of Hurricane Katrina, the HSDRRS levee project would be subjected to the extreme loading condition (greater than the 500-year return frequency event). The HSDRRS levee system would be in imminent danger of failure, yet failure would not occur because the factor of safety against wave and surge overtopping failure would be 1.0 or slightly larger.

Discussion of hydrodynamic loading presented in Section 3.2 is an excellent start to describing the three loading conditions described above. However, the connection was never properly made between the loading condition sketches in Figure 3.2 and the three different loading scenarios represented in this series of sketches, which progress from the normal or design loading condition to the extreme loading condition.

Even though the CSU-WOS is the largest such device ever constructed, it was unable to simulate the unusual and extreme loading conditions. Ideally, the WOS would have been run with higher and higher overtopping wave energy levels until significant damage was observed in the armoring material, and then continuing the tests at even higher overtopping wave energy levels until failure of the armoring system occurred and the levee embankment was exposed to overtopping wave erosion. With this testing, significant damage followed by failure could then be related to design loading conditions (i.e., significant damage would be associated with the unusual loading condition, and failure would be associated with the extreme loading condition when the barren levee embankment slopes would have to resist the impending overtopping wave and storm surge loading).

Significance – Medium:

Because the objectives and results of turf reinforcement testing do not correlate well with design criteria, the accuracy of the guidance and the confidence in the Manual are compromised.

Recommendation(s) for Resolution:

1. Provide a better description of design loading conditions; the actual conditions tested; the range of conditions addressed (as well as those not addressed) in the Manual, with specific guidance; and the more general guidance that may be developed for design conditions that exceed the range of testing accomplished.
2. Include clear references and connections to other pertinent design manuals such as the HSDRRS Design Guidelines. The user of this Manual must be thoroughly aware of the manner in which the Design Guidelines and the Armoring Manual are to be utilized with each other.

Literature Cited:

FEMA (2005). Final Draft Guideline for Coastal Flood Hazard Analysis and Mapping for Pacific Coast of United States, Draft Guidelines. Federal Emergency Management Administration, Washington, D.C: FEMA. (HTML).

Comment 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.
Basis for Comment:

The WOS tests were not representative of the design overtopping conditions due to the flowing factors:

1. WOS Limitations: The project documents state that the WOS could not simulate the volume of water in the larger waves of the design wave conditions. An "effective average overtopping rate" was then simulated by changing the distribution of overtopping volumes. For the "large wave and large freeboard" condition, the adjusted tests included additional smaller waves to compensate for the inability to model larger waves. In addition, the wavelength was reduced (i.e., the period was reduced from 14 seconds to 9 seconds), which would entail lower overtopping. The following is a summary of the higher design and test conditions from the review documents:
   - The design (required testing) conditions were as follows (CSU report, Appendix A by Van De Meer, pp. 1 and 9):
     - 8' 14 sec, 270 cfs/ft peak
     - 3' 6 sec, 150 cfs/ft peak
     - Texas A&M report indicated that overtopping was greater in the vicinity of the transition with flood walls. The effect on the protected side in the vicinity of flood walls and the transitions to regular levee sections were not investigated.
   - The maximum peak flows tested were between 145 and 165 cfs/ft (CSU report, p. 3, and Appendix A, p. 11), based on a reservoir capacity of about 145 cfs/ft and an additional volume based on the inflow rate of 2 cfs/ft for the duration of the discharge (e.g., 10-second discharge x 2 cfs/ft = 20 cfs/ft, added to 145 cfs /ft = 165 cfs/ft).
   - The inflow rate of 2.0 cfs/ft.
2. Maximum Conditions Tested: The Royal Haskonig "Background Report" states that the WOS could not replicate the wave overtopping time series for average rates greater than 1.4 cfs/ft, yet the Manual indicates that tests apply to rates up to 4.0 cfs/ft and provides guidance up to 4.5 cfs/ft. The following is a summary of the maximum test conditions:
   - Use of "Effective Discharge Rate" (CSU report, p. 4): Testing extended to "effective rate" of 4.0 cfs/ft by reducing design waves from 14 seconds to 9 seconds (reducing the peak wave volume) and increasing the test time to get an equivalent volume of water.
   - The "Effective Discharge Rate" concept is not supported by the Background Report (Royal Haskonig), which says that the average rate simulated by the WOS is limited to a maximum of 1.4 cfs/ft, based on the simulator's ability to simulate larger waves. A reduced value for "safety factor" recommended was 1.0 cfs/ft.

- The Armoring Guidance Manual provides guidance up to 4.5 cfs/ft, which exceeds all testing.

3. Use of Average Discharge Rate (for large allowable overtopping rates): The use of an average discharge rate is not proven to be an adequate means of evaluating wave-induced levee slope erosion because, in the Panel's opinion, wave-induced erosion is more accurately the result of the peak loadings that may not be accurately represented with an average discharge. Additionally, there is concern regarding the selection of the breaker parameter used to compute the discharge value, which could result in overtopping rates used in the WOS being underpredicted. The following is a summary of key considerations associated with use of average discharge rates:
   - The use of average discharge rate is dubious because the actual overtopping is a series of irregular pulses resulting from the irregular wave train and the local wave runup and overtopping dynamics.
   - Section 3.8.2 of the Armoring Guidance Manual (p. 55) states that "the use of q_{av} in the description of wave overtopping impacts, is not the best practice" and that despite the uncertainty, a conservative, but simplified, use of q_{av} was made possible through the use of Cumulative Excess Work Done (CEW) through a sensitivity analysis due to lack of sufficient studies.
   - The extreme wave overtopping pulses are likely the most damaging because they have higher velocities and volumes. The damage potential is usually considered to be a function of the velocity squared (this increases the importance of extremes non-linearly), and the erosion potential is usually considered to be related to intensity and duration over a threshold of incipient erosion.
   - The Texas A&M report, p. 72, indicated that erosion potential is likely proportional to velocity squared or cubed.
   - The use of an "effective average discharge rate" using more frequent, smaller pulses to compensate for below-peak pulses is not consistent with the mechanisms of wave-induced erosion, as rightly pointed out in the Background Report.
4. Assumption of No Impinging Flow: The WOS did not evaluate overtopping with a trajectory that impinges on the back side with a directional component other than parallel to the protected slope. The WOS appears to have been developed by the Dutch for much less severe overtopping, which is primarily flowing downslope in a turbulent sheet flow. The higher overtopping for the HSDRRS design conditions indicates a greater potential for a trajectory that impinges on the back slope or crest, which could result in a different and potentially greater loading than that tested. This issue is particularly significant on the back side of flood walls, which was not investigated. The following is an outline of supporting considerations:
   - The Dutch developed the WOS concept, but the CSU WOS is the largest ever constructed and still cannot replicate design overtopping for the HSDRRS. The Dutch levees are apparently designed for less overtopping.
   - The Dutch levee geometries are different, typically with a wider relative crest (relative to wavelength). This implies that the overtopping on the HSDRRS levees may not be simulated by the WOS and may have a trajectory with a greater vertical component.

Such a condition could result in impinging flow, which could impart a momentum-impact force not tested. This force could induce a different failure mechanism, associated with deformation of the levee subgrade (below turf) and possibly mass erosion due to internal shear stresses exceeding strengths. Such deformations would have a progressively supported effect toward surficial erosion and armoring instability.

- The Texas A&M model tests show very large vertical runup at flood walls, which implies a vertical trajectory component on the wall. While much of this runup was deflected back toward the flood side, some landed on the protected side – more than the theoretical methods predicted. Therefore, impinging flow is possible on the back, protected side of flood walls and transitions. Also, onshore winds should be expected in a hurricane, indicating that a greater volume of the vertical runup would be deflected to land on the protected side.

Significance – Medium:

Misrepresentation of the severity of the test conditions implies less risk than actually exists with use of the guidelines, and may affect design decisions.

Recommendation(s) for Resolution:

1. Clarify whether the designer can take steps to reduce wave overtopping damage risk by changing the levee geometry as follows:
   - Raise the levee crest
   - Add more earth to serve as a ‘sacrificial” mass to erode without compromising the critical levee cross-section.
2. Clarify the limitations of the testing so that the designer does not have to study the supporting documents to assess the appropriate use of the guidelines. State which recommendations are based on judgment, and state whether it is recommended that the designer follow this judgment.
3. Modify the WOS to include larger volumes of water releases.
4. Evaluate the potential for projectile-type overtopping that impinges on the back face. Consider the back side of flood walls, where runup is deflected vertically and may impinge on the protected side, especially with onshore winds.
5. Evaluate the hydrodynamics of overtopping using physical model results such as those from the Texas A&M model, so that the importance of impinging flow can be better evaluated.
6. Provide additional documentation and discussion on the justification for use of CEW without further study of correlation between CEW and q_{av}.

Comment 9:

A potential weakness in the conclusions drawn from the CSU modeling may be the wave parameters used as input for the CSU WOS.

Basis for Comment:

The wave parameters used as input for the CSU WOS are dependent on methods used to compute waves at the toe of the structure, which are the basis for determining the corresponding discharge over the structure crest.

Page 35 of the Armoring Guidance Manual states:

> "The WOS is continuously filled with water at a specific rate corresponding to the average overtopping discharge rate, with various volumes of water released in such a way that it forms a specific wave volume discharge".

Page 1-13 of the 2008 HSDRRS Design Guidelines (Section 1.3.3) states:

> "To account for breaking in front of the levee or structure, the wave height from STWAVE is reduced using a breaker parameter…….A typical range for this parameter is between 0.5 to 0.78 in engineering purposes. These values are generally obtained for situations with a mild sloping bed. Laboratory experiments and Boussinesq runs suggest that the breaker parameter of 0.4 is a realistic choice for a relatively long shallow foreshore as it is the case for levees and structures within the project area."

The proper selection of the breaker parameter for transforming waves from deep water to the structure toe (described as a 600-foot distance in Section 1.3.3 of HSDRRS Design Guidelines) for use as input to the overtopping rate calculation is critical to defining a realistic overtopping discharge rate. This breaker parameter accounts for non-linear wave processes occurring in the zone in front of the levee or structure. The wave transformation within this zone is dependent on roughness, slope, and other site features, which could also have an effect on the selected breaker parameter. The recommended breaker parameter of 0.4 is approximately one-half of the upper end of the typical range used for engineering purposes. Use of a non-conservative breaker parameter and varying site conditions could result in a change in discharge values computed from the wave overtopping analysis. This deviation would change the input parameters for the WOS. The pulsating discharge used in the WOS needs to simulate the actual overtopping wave series for the design storm conditions being evaluated.

The Texas A&M model test results show a wave setup on the levee face. This wave setup increases the depth of water. Increased water depth implies that a correspondingly larger wave is possible. The effect of a setup water level therefore is likely to increase the total water level (local water level plus wave runup) and overtopping. To clarify further, while wave setup is typically included in the computed wave runup for the wave at the toe of the structure, the setup caused by larger waves breaking farther offshore is not.

Additionally, if the designer considers using the new, larger allowable overtopping rates (4.5 cfs/ft with HPTRM) and the recommended computation methods result in underprediction of the actual conditions, the result would be an underdesigned facility.

Significance – Medium:
The wave conditions developed for the WOS could have an impact on the Armoring Guidance Manual's conclusions and recommendations.
Recommendation(s) for Resolution:
1. Improve the discussion and justification for use of the 0.4 breaker parameter taken from Section 1.3.3 of the HSDRRS Design Guidelines. 2. Conduct a sensitivity analysis to determine if changes in breaker parameter have a critical impact on WOS input parameters and the corresponding results. 3. Evaluate the effect of wave setup on design wave heights.

Comment 10:

The Armoring Guidance Manual does not consider an "importance factor" or "localized condition variable factor" when determining sufficient armoring for a location.

Basis for Comment:

An "importance factor" or "localized condition variable factor" should be considered to ensure that critical infrastructure is protected from erosion and flooding. A large range of allowable overtopping (1.0 to 4.5 cfs/ft) is recommended for armoring of slopes with HPTRM. The 2008 HSDRRS Design Guidance Manual outlines a maximum overtopping rate of 0.1 cfs/ft for grass slopes. There is no mention in Section 5 of the Armoring Guidance Manual about the effects of using a larger overtopping rate on the risk to adjacent protected facilities (other than levee breach) or about the step-wise design approach required to determine if such a large overtopping rate is feasible for the infrastructure being protected.

The 2008 HSDRRS Design Guidance Manual, Section 1.0 Hydraulics, discusses development of hydraulic conditions for levee design. It states "The approach below gives a step-wise approach for determining design elevations and minimum cross sections of levees and design elevations for floodwalls." These items are:

- Use of 1% values for surge levels and waves
- Simultaneous occurrence of maxima
- Breaker parameter
- Overtopping criteria
- Uncertainties.

Two critical elements of the design approach include the breaker parameter (discussed in another comment) and the overtopping criteria (discussed in this comment). If very large overtopping criteria are allowed with other factors remaining the same, then a levee with reduced crest elevation would be provided as part of the design procedure. There seems to be a lot of uncertainty associated with the effects of the larger overtopping rate on adjacent infrastructure. It is not clear how a designer would quantify this uncertainty.

The overtopping criteria are a critical component in developing the levee geometry and could lead the designer to use the upper end of the recommended overtopping range (4.5 cfs/ft), resulting in a lower levee crest and significantly increased discharge into the protected areas. This allowable range is for the computed 50% non-exceedance overtopping event, which will result in very high instantaneous discharge rates for the larger wave conditions within the design storm wave spectrum. These larger instantaneous discharge rates could have larger impacts on the adjacent infrastructure and could result in unanticipated conditions that may be beyond the range of the experimental results, resulting in additional risk to the project.

Table 3.1 of the Armoring Guidance Manual provides criteria for tolerable wave overtopping damage criteria for grass dikes, embankments, and seawalls, but it does not consider building structures and equipment. *EurOtop -- Wave Overtopping of Sea Defences and Related Structures:*

Assessment Manual (2008) provides guidance for tolerable limits on overtopping impacts on adjacent properties. Its recommended average overtopping discharges were outlined in Table 3.4 of the EurOtop Assessment Manual as 0.4 liters/second/meter (l/s/m) for equipment set back 5 to 10 meters and 1.0 l/s/m for building structure elements. These represent thresholds that are many orders of magnitude lower than the recommended range in the Armoring Guidance Manual. Effects of overtopping on adjacent structures need to be considered.

Design Loads for Buildings and Other Structures (ASCE 7-10) outlines the use of an importance factor for calculating flood, wind, snow, seismic and ice design loads. The importance factor is a multiplier that increases or decreases the base design loads. An importance factor could also be applied to the design recommendations developed in the Armoring Guidance Manual that would result in a reduction in the allowable overtopping rate for locations of high risk, critical infrastructure, or lack of sufficient drainage or pumping capacity. The ability of critical facilities (pumping stations, hospitals, etc.) to function after a major environmental event is an important consideration in developing the need for an importance factor since it increases the need for reliability (Safety Factor).

Significance – Medium:

The design recommendations are not clear and could lead the designer to make non-conservative decisions which could result in added risk to a constructed project.

Recommendation(s) for Resolution:

1. Provide additional discussion in the summary and conclusions sections regarding the use of the recommended range (including limitations and caveats relating to the topics discussed herein) for improved clarity to the designer.
2. Review and evaluate the implications of such a large change in recommended overtopping rates and the potential impacts to the performance of constructed levees during design storm conditions. If it is determined that the larger overtopping flow rates are not feasible, consider a reduction in the allowable upper threshold (4.5 cfs/ft) regardless of the conclusions of the physical model tests.
3. Evaluate and implement the use of an importance factor for various types of structures, locations, and infrastructure for use by the designer to reduce risk to the project.

Literature Cited:

EurOtop -- Wave Overtopping of Sea Defences and Related Structures: Assessment Manual, August 2008. http://www.overtopping-manual.com/eurotop.pdf

ASCE/SEI (7-2010). Minimum Design Loads for Buildings and Other Structures. American Society of Civil Engineers Standard 7-2010.

Comment 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.
Basis for Comment:
The clay mineralogy used in levees has potential impact on the cracking/fissuring of clay soils. The mineralogical definition of clays varies widely based on their different structures. In levee construction, a major concern is whether the clay is prone to swelling, which could result in fissuring and/or cracking. Because levee construction is to some degree based upon the clay source at hand, correct definitions of clay type will aid in correct levee management. In identifying clay types, two separate issues arise. First, the term ‘clay’ refers to a soil that falls into a unique textural class (for example: ‘sand’, ‘silt loam’, ‘sandy clay’, ‘clay’), as defined by several different systems. Second, the type of clay found in the soil also needs to be defined by its mineralogy. The terminology for both of these issues should be standard and recognized. The U.S. Department of Agriculture (USDA) uses its own system to describe soil textural classes; this system clearly delineates the particle size classes into which clay falls. However, the Panel recognizes that for engineering applications, the Unified system is more often used. It, too, separates soil into distinct textural classes. Regardless of which system is used, the clay’s textural class and mineralogy are pertinent when assessing the integrity of levee construction.
Significance – Low:
Identification of the soil texture and clay mineralogy present in materials used to construct levees will aid in long-term management of the levee.
Recommendation(s) for Resolution:
1. Define clay mineralogy and describe how it affects the behavior of levees constructed from soil that contains these clays. Specific examples include (among others) smectite, kaolinite, and illite. 2. Identify which soil/clay types are most likely to occur in the New Orleans area. 3. Discuss the Unified system’s soil textural classes so that a user can determine the soil textural classes into which a given soil falls.

Comment 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.
Basis for Comment:
The apparatus used to test the armoring properties of bermudagrass is located in Colorado. Bermudagrass, a warm-season turfgrass, is not well-adapted for Colorado, particularly in cold-weather testing. It is highly likely that in cold-weather testing, the grass was not dormant but dead. Bahiagrass is also a warm-season grass with poor adaptation to Colorado. The collected information is not necessarily fatally flawed; however, the location of the testing was not particularly well-suited to the selected grass. The Panel recognizes that the adapted species for New Orleans do not grow well in Colorado. Therefore, it would be appropriate to discuss the limitations of the testing procedure (i.e., the material tested [the grass] was not well-suited to the testing location) in conjunction with the test results. The Panel also noted that bermudagrass sod was used for the CSU testing. The Manual discussed the need for sod in the testing process, and differences in bermudagrass rooting (as compared to existing levee bermudagrass) due to the use of sod are included in the Manual. While the Panel understands that time and testing constraints resulted in the need for sod (rather than seeding or sprigging), the costs and time required to sod entire levees makes such a process unlikely. Simply put, miles of levees cannot be easily and cheaply sodded. Furthermore, all of the data were collected from sodded turf installed in trays. The differences between the sodded turf and established levee turf were discussed in the Manual, but the extent of the differences may not be understood. Because bermudagrass (and bahiagrass) is well-adapted for growth in New Orleans, it will likely perform at a higher level (with regard to growth and long-term survivability) than in the Colorado tests. The established levee grasses, if they are fertilized correctly and if drought is not limiting, may very well have rooting volumes equivalent to those measured in the test trays.
Significance – Low:
The limitations of the CSU test of grass in a climate to which it is poorly adapted should be recognized, but the test results are not likely to compromise the performance of an adapted grass.
Recommendation(s) for Resolution:
1. Include a brief section that recognizes the limitations of the CSU test regarding use of the test grass in a climate to which it is poorly adapted. 2. For future research, either select adapted species or work with selected species in periods when they are actively growing (summer). 3. Explain in the Manual that sodding may be prohibitively expensive and that, while it is a best-case scenario for establishment of an instant turfgrass surface, its use may not be practical.

Comment 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.
Basis for Comment:
For the LSU work, turfgrass samples were collected on November 3, 2010 from nine levees in the New Orleans District. For the CSU sampling, grass trays were sampled on November 24, 2010, and Spring 2011. This data set is limited, especially when (as noted in the report) the levees varied in age. The data set also lacks replication in time; data would best have been collected quarterly over at least 2 years to produce a better picture of root distribution over time. If such data were submitted to a refereed scientific journal for possible publication, they would not be publishable until 2 years of data (with multiple harvests per year) were collected. Such environmental data need replication in both time and space. Additionally, bermudagrass has extensive networks of rhizomes and stolons (aboveground and belowground stem tissue), materials which are capable of producing extensive lateral growth that operates extremely well as a control against erosion and sediment loss. The Manual contains some discussion of research conducted with cool-season grasses (although exact species used are not noted); in that discussion, it is noted that there will be differences between the cool- and warm-season grasses in their growth and possible protective ability against erosion. Cool-season turfgrasses (widely used in Europe) largely do not have the prostrate growth of warm-season bermudagrass, which makes comparison with European data sets less useful.
Significance – Low:
Although the method by which root data was collected is solid and correct, additional samples should be collected to verify the study findings.
Recommendation(s) for Resolution:
1. Conduct additional sampling and data collection to obtain a sufficient number of samples and achieve replication in time and space. 2. If additional sampling is beyond the scope of the Manual, state that the number of samples taken to describe rooting characteristics of bermudagrass is low, but that the methods by which the data were collected are sound.

Comment 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.

Basis for Comment:

The Manual summarizes extreme event hydrodynamics and associated erosion armoring requirements but does not discuss other types of erosion mechanisms. These additional mechanisms could result in the requirement to armor portions of the flood-side and protected-side slopes (where it is determined to not be required for extreme hurricane conditions).

- More regular hydrodynamic conditions (daily or yearly) such as vessel pressure fields (bores), vessel wakes, locally generated wind waves, and tidal currents may require stabilization within localized areas, depending on the location of particular reaches of the levee relative to exposure to these mechanisms.
- Although most conditions associated with other erosion mechanisms will have much lower magnitude (compared to extreme hurricane events), these types of conditions can have very high frequency of occurrence and loadings, which could contribute to frequent maintenance and risk to the long-term levee stability.

Significance – Low:

Including "everyday" erosion mechanisms in the report would primarily enhance the completeness of the report and usability of the results.

Recommendation(s) for Resolution:

1. In Section 1.3, "Items Not Covered in the Scope," state that study results are limited to armoring requirements associated with extreme hurricane event conditions and do not consider requirements associated with routine hydrodynamic loading conditions (such as vessel pressure fields, vessel wakes, locally generated wind waves, tidal currents).
2. Consider including an evaluation, conducted by the design engineer, of these more routine hydrodynamics in accordance with the Coastal Engineering Manual (USACE, 2008).

Literature Cited:

USACE (2008). Coastal Engineering Manual. U.S. Army Corps of Engineers, Washington, D.C. Engineer Manual No. EM-1110-2-1100. August 1.

Comment 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 used or discussed in the Armoring Guidance Manual.

Basis for Comment:

Many methodologies, procedures, and analyses used in the design of earthen dams are also used in the design of levee embankments. Furthermore, the number one mechanism of earthen dam failures in the United States is overtopping failure as a result of inadequate spillway capacity to safely pass the Spillway Design Flood (SDF). That condition is also considered to be the unusual loading condition, similar to that associated with a specified hurricane or hurricane category in the design of levee embankments. As such, there is a large volume of literature (including that located at the USACE Engineer Research and Development Center in Vicksburg, Mississippi) associated with wave erosion of the upstream slope and overtopping erosion of the downstream slope that may be of value in preparing the Armoring Guidance Manual.

In cases where there are similarities in embankment overtopping erosion failures, the available dam performance literature could be used if the user of the Armoring Guidance Manual is provided with adequate background information that clearly explains the similarities and differences (i.e., the magnitude of typical waves and the potential difference in potential overtopping surge). Some additional resources are as follows:

- Association of State Dam Safety Officials
- Federal Emergency Management Agency
- National Inventory of Dams Program
- National Performance of Dams Program
- USDA/Natural Resources Conservation Service,

Furthermore, at least one other USACE project has investigated flood-side erosion of earth levees: the Hamilton Wetland Restoration Project in the San Francisco District. That project analyzed wave-induced erosion of earthen levees in support of the design of levees around the perimeter of a wetland restoration site in San Francisco Bay. This design used a benched cross-section and additional "sacrificial" earth to mitigate the risk of wave-induced erosion breaching.

A significant volume of literature and information is also available from coastal management organizations and coastal engineering publications. These sources focus on the stability and erosion of armored breakwater structures and jetties. An example is the guidance provided in the U.S. Navy Coastal Engineering Design Manual 26.2 (U.S, Navy 1982) for armor unit sizing on the back side of breakwaters, which is based on the technical paper by Walker et al., (1975).

Significance – Low:

Review and/or use of other resources could assure design engineers and Manual users that all available sources of information on embankment erosion have been synthesized in preparing the Manual.

Recommendation(s) for Resolution:
1. Contact individuals at some or all of the literature resources and at each USACE District Office and request a literature search (or permission to conduct a literature search) of earthen embankment dam overtopping information. 2. Review and include pertinent information from these other sources at appropriate locations in the Manual as the document is being reorganized, rewritten, edited, and reviewed.

Literature Cited:

U.S. Navy (1982). Coastal Protection. Design Manual 26.2, Naval Facilities Engineering Command. Alexandria, VA. April.

Walker, J.R., Palmer R.Q., and Dunham, J. W. (1975). Breakwater Back Slope Stability. Proceedings, Civil Engineering in the Oceans III, 9-12 June 1975, VOl 2. ASCE, New York, 1975, pp 879-898.

Comment 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.
Basis for Comment:
Keys to long-term grass survival include (1) proper fertilization and liming via soil testing, (2) proper nitrogen (N) fertilization via crop response recommendations, (3) management of broadleaf and grassy weeds, and, (4) proper mowing, including both frequency and height of cut. Only cursory comments about nitrogen fertilization and mowing are included in the Manual.
Significance – Low:
Although maintenance information is not an integral part of the Manual, such information would ensure that levees are properly maintained.
Recommendation(s) for Resolution:
1. Include a detailed turfgrass management section in the Manual. This section should discuss the following: • Recommendations for N fertilization rate with application timing • Soil testing guidelines (yearly or every other year is probably fine) and use of the soil test for phosphorus, potassium, and lime recommendations • Guidelines for mowing frequency and height, and mower type (including tire type to minimize tracking and rutting) • Weed control for grass and broadleaf leaves, or for possible woody species • Varmint control measures to prevent digging or other damage to the levee.

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APPENDIX B

Record of USACE PDT Evaluator Responses and Panel BackCheck Responses to Armoring Manual IEPR Final Panel Comments

Note: Attachments to the entries in DrChecks are not included as part of this appendix, but are available from USACE upon request

Comment Report: All Comments
Project: Armoring Manual IEPR 2012
Review: Armoring Manual IEPR 2012
Displaying 16 comments for the criteria specified in this report.

891 ms to run this page

Id	Discipline	Section/Figure	Page Number	Line Number
4385074	Hydraulics	n/a'	Comment 1	n/a

(Document Reference: High)

The actual dimensions of flood-side erosion may be greater than those reported in the Armoring Guidance Manual.

(Attachment: Armoring_II_IEPR_Comment_01-_Final.pdf)

Submitted By: Lynn McLeod (781/952-5381). Submitted On: 18-Jan-12

1-0 Evaluation **Non-concurred**
The actual dimensions of flood-side erosion will not be greater than those reported in the Armoring Manual. However, the largest dimensions of flood-side erosion from Hughes' supporting report were not reported in the Armoring Manual because they did not apply to the HSDRRS. So to explain that the highest erosion rates were not deliberately omitted or were omitted in error, the following statement was added to Section 2.6 of the Armoring Manual stating: 'Some of the higher estimates of erosion depth (Hughes (2010)) were omitted from Table 2.1, 2.2, and 2.3 because these high erosion estimates assumed a 10 hour duration storm surge and/or a 'bare structured clay', both of which are unrealistic for the HSDRRS. Also as a result of teleconference input from the NFS, the following was added to section 2.8, no.1 and 2, and in the last paragraph of 2.8, as the first sentence: 'Sand core levees require a more detailed analysis to determine that flood side armoring is not required.' Also as a result of discussions at the teleconference, in Section 3.10.7 i, 2nd sentence on) The following was revised/added: "Therefore, it is important that the HPTRM is secured sufficiently in the flood side anchor trench as to avoid unraveling of the HPTRM on the landside, in the interim period until the grass roots down sufficiently. Therefore, the HPTRM should be trenched to a depth of 2 ft, a distance of 2' down the flood side slope, which will assure that the landside HPTRM armoring is sufficiently anchored. The anchor trenches are only necessary until the grass roots down sufficiently, perhaps in 60 to 90 days. After that, all of the anchor trenches are redundant:" Recall that we did not have any HPTRM anchors for the testing at CSU and the grass and roots held the HPTRM down very well, even with dormant grass.

Submitted By: Dean Arnold (504-862-2674) Submitted On: 10-Apr-12

1-1 Backcheck Recommendation **Close Comment**
Do not concur. The Final Evaluator Response includes text changes to the Armoring Manual that are helpful but do not completely address the IEPR Panel's concerns expressed in the "Basis of Comment". The proposed changes to the Manual fall short of indicating that actual flood-side erosion could exceed the values in the Armoring Manual, for the following reasons: 1.The erosion estimates in the manual, derived from the Hughes (2010) report, are based on model studies of wave conditions much less severe than the design conditions (e.g. Case 3). This means that there is uncertainty due to the equations being "out of bounds" beyond their empirical basis. The statement in the source document (Hughes, 2010 (page 88)) addresses this issue, but a similar statement is not included in the Manual "...the various erosion estimate methodologies were extrapolated and applied well outside the range of full-scale experiment parameters used to establish the guidance." 2. A T-wall could increase scour on the flood side due to increased wave reflection, impinging rundown, and turbulence. The HPTRM anchoring recommendations are too specific in terms of geometry, and do not state that the design objective is to anchor below and away from the design flood-side erosion. The designer (user of Manual) should be told that a different anchoring geometry of the HPTRM (e.g. greater than 2' depth) may be appropriate if the design scour on the flood side could release the mat (e.g. erosion greater than 2' at the anchor location).

Submitted By: Lynn McLeod (781/952-5381) Submitted On: 30-Apr-12

Current Comment Status: **Comment Closed**

Id	Discipline	Section/Figure	Page Number	Line Number
4385079	Geotechnical	n/a'	Comment 2	n/a

(Document Reference: Medium)

The Armoring Guidance Manual does not provide guidance for armoring around T-walls because there is no stability analysis or supporting documentation.

(Attachment: Armoring_II_IEPR_Comment_02_-_Final.pdf)

Submitted By: Lynn McLeod (781/952-5381). Submitted On: 18-Jan-12

1-0	Evaluation **Concurred** Since this review began, we have performed geotechnical and structural analyses of flood walls. We have determined that there is no wall stability problem, even with a max. of 4 to 5 feet of flood side erosion expected, since up to 8 ft of flood side and/or landside erosion could occur and not cause a stability problem. We will add wording that states that no armoring is required around T-walls to the last paragraph of section 2.7. Submitted By: Dean Arnold (504-862-2674) Submitted On: 30-Mar-12
1-1	Backcheck Recommendation **Close Comment** Concur Submitted By: Lynn McLeod (781/952-5381) Submitted On: 30-Apr-12
	Current Comment Status: **Comment Closed**

4385087	Operations	n/a'	Comment 3	n/a

(Document Reference: Medium)

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.

(Attachment: Armoring_II_IEPR_Comment_03_-_Final.pdf)

Submitted By: Lynn McLeod (781/952-5381). Submitted On: 18-Jan-12

1-0	Evaluation **Concurred** Specific O&M information regarding how each armoring method is to be inspected and maintained in the future to ensure its continued performance will be added to the Armoring Manual now that the Grass/HPTRM Demonstration Report has been completed. Submitted By: Dean Arnold (504-862-2674) Submitted On: 30-Mar-12
1-1	Backcheck Recommendation **Close Comment** Concur Submitted By: Lynn McLeod (781/952-5381) Submitted On: 30-Apr-12
	Current Comment Status: **Comment Closed**

4385092	Hydraulics	n/a'	Comment 4	n/a

(Document Reference: Medium)

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.

(Attachment: Armoring_II_IEPR_Comment_04_-_Final.pdf)

Submitted By: Lynn McLeod (781/952-5381). Submitted On: 18-Jan-12

1-0	Evaluation **Non-concurred** The overtopping rates provided in the Armoring Guidance Manual contradict what has been provided in the HSDRRS Design Guidelines, but this is acceptable since the allowable

	overtopping flow rates for grass in the Design Guidelines are for the base levee design case, e.g. 100-yr., while the allowable wave overtopping flow rates for grass are the resiliency case for an extreme event, such as a 500-yr storm surge. In Section 2.8, last paragraph, the words '(or landside)' were added after the word 'flood side'. Submitted By: Dean Arnold (504-862-2674) Submitted On: 29-Mar-12
1-1	Backcheck Recommendation **Close Comment** Concur. Based on the discussions with USACE during the teleconference on March 8, 2012 and the PDT Final Evaluator Response, it appears the majority of the comments and concerns were addressed. The Panel does believe that additional commentary and clarification of the interrelationship of the Armoring Manual with other design documents and limitations of the Manual would be helpful for future new users of the document. Submitted By: Lynn McLeod (781/952-5381) Submitted On: 30-Apr-12
	Current Comment Status: **Comment Closed**

4385095	Geotechnical	n/a'	Comment 5	n/a

(Document Reference: Medium)

The Armoring Guidance Manual does not provide the appropriate geotechnical guidance.

(Attachment: Armoring_II_IEPR_Comment_05_-_Final.pdf)

Submitted By: Lynn McLeod (781/952-5381). Submitted On: 18-Jan-12

1-0	Evaluation **Non-concurred** The Armoring Manual was meant to provide recommendations for armoring on existing levees that were constructed to strict geotechnical specifications (attached).These technical specifications were developed by the NOD's geotechnical experts and are appropriate for this area. The focus of the Armoring Manual is not to provide this type of geotechnical engineering guidance, but were quoted for the following reasons: a. to give the reader an indication of the much higher quality of levee embankment that can be expected as compared to some of the failed levees that were found after Hurricane Katrina by Dr. Briaud, who stated that levees raised or constructed to these specifications exhibit more resilience, which we can surmise that this adds an added factor of safety against breaching to whatever armoring material is used. b. for informational purposes as to the soil and foundation quality that armoring would be placed on. c. to state that the clay placed in the test trays that were tested at CSU met the same strict geotechnical requirements as the clay used in HSDRRS levees. The minor geotechnical inconsistancies in the various documents referenced do not directly impact the discussion of armoring. The geotechnical recommendations concerning increased compaction, moisture content, and compaction equipment are more appropriate for the HSDRRS Design Guidelines to construct the levees and not to armor the levees after the levees are completed. Submitted By: Dean Arnold (504-862-2674) Submitted On: 30-Mar-12 (Attachment: 31_24_00_12.pdf)
1-1	Backcheck Recommendation **Close Comment** Concur Submitted By: Lynn McLeod (781/952-5381) Submitted On: 30-Apr-12
	Current Comment Status: **Comment Closed**

4385099	Hydraulics	n/a'	Comment 6	n/a

(Document Reference: Medium)

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.

(Attachment: Armoring_II_IEPR_Comment_06_-_Final.pdf)

Submitted By: Lynn McLeod (781/952-5381). Submitted On: 18-Jan-12

1-0	Evaluation **Concurred** 1. Changed the threshold below which grass is considered to be adequate armoring to 1.0 cfs/ft and deleted an allowable of 1.4 cfs/ft for grass throughout the Armoring Manual. 2. Only the use of HPTRM is recommended, with no TRM allowed since the results of a late test was received which indicated a failure of TRM with dormant grass. The Armoring Manual was revised throughout accordingly. 3. The upper limit for application of HPTRM was revised to 4.5 cfs/ft throughout the Armoring Manual. 4. The definition of "armoring" was clarified as requiring Quality Grass Armoring up to 1.0 cfs/ft and deleted the row with 1.4 cfs/ft. 5. Revised to exclude the use of TRM due to a recent CSU test where TRM with dormant grass failed at much lower overtopping flows than HPTRM with dormant grass, Recommendation for Resolution: 1. -- revised the table accordingly. 2. – since the critical armoring areas (> 1.0 cfs/ft) are low wave, low freeboard conditions, the CSU WOS can effectively model flow rates up to 4.0 cfs/ft and this is stated in the Armoring Manual. 3.– revised accordingly 4. – no TRM products will be used due to the failure of TRM at CSU with dormant grass whereas there was no failure of HPTRM with dormant grass run at 4.0 cfs/ft. Submitted By: Dean Arnold (504-862-2674) Submitted On: 30-Mar-12
1-1	Backcheck Recommendation **Close Comment** Concur. The Panel disagrees with the PDT Evaluator Response to Recommendation 2 of Final Panel Comment #6 above. Specifically, the Panel disagrees that the CSU WOS achieved 4.0 cfs/ft. The statement in the response "....since the critical armoring areas (> 1.0 cfs/ft) are low wave, low freeboard conditions, the CSU WOS can effectively model flow rates up to 4.0 cfs/ft and this is stated in the Armoring Manual" is contrary to the Panel's conclusion. The Panel concluded that the CSU WOS did not effectively model wave overtopping with estimated average flow rates of 4.0 cfs/ ft. This topic is also addressed in Final Panel Comment 8. Submitted By: Lynn McLeod (781/952-5381) Submitted On: 30-Apr-12
2-0	Evaluation **Check and Resolve** We would like to submit new R&D for the Panel's consideration. This new Wave Overtopping R&D originated with a recent International Coastal Engineering Journal article based on the PhD dissertation of Lander Victor which gives a new representation of the overtopping wave volume distribution which has the following important difference. The original wave volume distribution (as used in the CSU wave overtopping simulator) had a fixed "shape factor" 0f 0.75. The shape factor controls the extreme end of the wave volume distribution, and the extreme end is what determines the largest wave that must be simulated for a specific condition (wave height, period, levee slope, average flow discharge). The Royal Haskoning criticism of the 4.0 cfs/ft wave overtopping simulations was that the CSU simulator could not produce the largest wave volume for the 4.0 simulation. To replicate this flow, more of the larger waves were substituted for smaller waves but these larger waves still had somewhat less than the largest wave volumes required by the 0.75 shape factor distribution. The new research indicates that the 0.75 shape factor is actually only appropriate for low average wave overtopping discharges that have large freeboards. This is vastly different from the 4.0 cfs/ft case that actually occurs in the HSDRRS, which is a low wave, low freeboard condition in those critical reaches which have the highest overtopping flows. The new tests looked at larger overtopping rates generated by larger waves with low freeboard. For these cases (that are actually more representative of the HSDRRS 500-year event) the shape factors increase as a function of both levee slope and decreasing freeboard. A larger shape factor results in a DECREASE in the very largest volumes in the wave volume distribution. So rather than having the same volume distribution for all overtopping rates, the distribution differs for higher overtopping rates caused by lower freeboard. The main difference is that smaller maximum size waves need to be simulated. The implication is this. CSU's simulation of 4.0 cfs/ft, using the largest possible volumes the simulator was capable of, which were slightly less than what was thought they should have been, was not as much of a compromise as originally thought. A comparison was made of the 4.0 cfs/ft wave distribution using the new guidance versus the original CSU wave distribution. The attached plot shows that the new guidance for wave volume distribution (developed for low freeboards and steep slopes) indicates the CSU 4.0 cfs/ft tests were probably simulating a condition slightly greater than 4.0 rather than something less. The new guidance estimates the maximum wave volume needed for this 4.0 cfs/ft condition should be 138 ft3/ft...well within the Simulator's capability of 170 ft3/ft. Submitted By: Dean Arnold (504-862-2674) Submitted On: 11-May-12
2-1	 Backcheck Recommendation **Close Comment** Concur. The Panel agrees that the new paper by Victor supports the PDT and Manual judgment that the WOS did simulate the larger overtopping wave volumes for the low freeboard

	conditions, but the panel does not agree that the tests achieved the 4 cfs/ft overtopping rate. Submitted By: Lynn McLeod (781/952-5381) Submitted On: 07-Jun-12
	Current Comment Status: **Comment Closed**

4385166	Geotechnical	n/a'	Comment 7	n/a

(Document Reference: Medium)

The turf reinforcement testing did not include the characteristics of the embankment subgrade and the wave overtopping that would load the subgrade.

(Attachment: Armoring_II_IEPR_Comment_07_-_Final.pdf)

Submitted By: Lynn McLeod (781/952-5381). Submitted On: 18-Jan-12

1-0	Evaluation **Non-concurred** This comment was reviewed and additional test results where failures occurred on dormant grass was added to section 1.5.2, 5th para., section 3.6.4 and section 3.9.3. The high wave overtopping flow rate (4.0 cfs/ft) for green Bermuda grass without visible grass damage was not expected, so at the request of the non-Federal sponsors, USACE also tested dormant grass to simulate drought conditions. Dormant Bermuda grass, with root volumes comparable to in-situ HSDRRS grass (<3 yrs old), was tested and ultimately failed at 2.0 cfs/ft, after 3 hours, which was less than half of the erosion resistance of healthy green grass. It was then decided to run another test on dormant grass with HPTRM to find out what erosion resistance the HPTRM reinforcement would add. Test results on a sample of dormant Bermuda grass reinforced with a High Performance TRM indicated a much increased erosive resistance capacity having survived flow rates of 4.0 cfs/ft. CSU also tested dormant Bermuda with open weave medium grade TRM and it failed at rates lower than 2.0 cfs/ft. This indicated that TRM did not add any erosion resistance to dormant grass while HPTRM more than doubled the erosion resistance of dormant grass. The failures with dormant grass gave us more insight than the successes with green Bermuda grass. Submitted By: Dean Arnold (504-862-2674) Submitted On: 29-Mar-12
1-1	Backcheck Recommendation **Close Comment** Concur Submitted By: Lynn McLeod (781/952-5381) Submitted On: 30-Apr-12
	Current Comment Status: **Comment Closed**

4385173	Hydraulics	n/a'	Comment 8	n/a

(Document Reference: Medium)

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.

(Attachment: Armoring_II_IEPR_Comment_08_-_Final.pdf)

Submitted By: Lynn McLeod (781/952-5381). Submitted On: 18-Jan-12

1-0	Evaluation **Non-concurred** We need to clearly convey that the intent of the Armoring Manual is that the user of the Armoring Manual SHOULD NOT just implement the recommendations in the Armoring Manual but it should be used only as preliminary design guidance, with the final design based on the engineering judgement of the Engineer. The user needs to understand how the recommendations were developed in order to understand the limitations of these same recommendations. These 15 limitations were stated in section 1.3 - Items not covered in the Scope. The following statement was also added to the Introduction on page 2 of Armoring Manual: 'The Armoring Manual is to be used for preliminary armoring design with final design based on the conditions encountered in each individual reach. The Armoring recommendations are based on full scale wave overtopping testing using the world's largest full scale wave

	overtopping simulator, designed by the premier world class subject matter expert on wave overtopping simulation from the Netherlands, Dr. Van der Meer. The simulator had a true average flow rate of 2.0 cfs/ft but, according to Dr. Van der Meer, higher flow rates than 2.0 cfs/ft could be simulated by running the test up to twice as long using only the largest waves. The design conditions modeled were 8 ft waves with 9 second periods of the high wave, high freeboard condition even though the reaches with the highest overtopping rates (> 1.0 cfs/ft) had the low wave, low freeboard condition. The testing was performed at CSU, who has tested nearly all of the commercially available armoring materials. The testing was on HSDRRS clay and Bermuda grass grown in just 5 months at the Corp's Engineering Research and Development Center in Vicksburg, MS and shipped by truck to CSU. The grass tested was compared to real grass on existing levees by Dr. Beasley of LSU by comparing the root weight, length, surface area, average diameter and root volume. His conclusion was that grass quality on real levees could match what was tested at CSU with proper watering, fertilizing and O&M. The recommendations in the Armoring Manual for landside armoring are not based on judgment but on a very thorough comprehensive R&D program that covered pertinent parameters that could occur in the HSDRRS. Even though the Armoring Manual provides guidance up to 4.5 cfs/ft, which exceeds all testing, as explained in the Armoring Manual, if plain green Bermuda survived 4.0 cfs/ft and HPTRM with dormant grass survived 4.0 cfs/ft, then it is reasonable to extrapolate that HPTRM with green Bermuda could conservatively survive 4.5 cfs/ft and probably higher, which is partially based on the % increase illustrated by the Hewlett Curves. The value of 4.5 exceeds the 500-yr overtopping flow rates in any HSDRRS reach, which maxed out at 4.2 cfs/ft in only 2 reaches, with all other reaches below 4.0 cfs/ft. Submitted By: Dean Arnold (504-862-2674) Submitted On: 29-Mar-12
1-1	Backcheck Recommendation **Close Comment** Non-Concur. The work accomplished for this project is extensive, and the participants include world-renowned experts: The effort is commended. However, the IEPR Panel believes that the Manual does not accurately represent that limitations of the testing, and the use of judgment in developing the guidance in the Manual, for the following reasons: 1.The tests are not clearly equivalent to 4.0 cfs/ft, and a maximum of 2.0 cfs/ft seems more accurate: The WOS could produce an average inflow rate of 2.0 cfs/ft and could not reproduce the volumes of water associated with the larger overtopping pulses in the design wave time series. To get around this limitation, the test conditions were modified to have more overtopping pulses. Tests were run longer to allow more overtopping pulses to attempt to compensate for not modeling the larger wave overtopping. A related study (Royal Haskoning) concluded that modified WOS tests were tested up to 1.4 cfs/ft for the larger wave tests, and recommended 1.0 cfs/ft as the "safe" limit. 2.Overtopping tests above 2 cfs /ft are alleged based on unproven theory: The Manual discusses an "equivalent work theory" that relates wave overtopping (which is comprised of pulses) to empirical design curves developed for steady state overtopping. Hughes (2010) page 55): "In reality, there is still a reasonable possibility that the initiation of damage and subsequent protective cover damage are also linked to the severe loading and energetic turbulence that result from the largest overtopping waves." 3.Also, the overtopping flowrates are high relative to the state of practice: • The overtopping rates discussed in the Manual are exceptionally high relative to flood hazard mapping standards (e.g. a FEMA high velocity flood zone criterion is wave overtopping rates in excess of 1.0 cfs/ft), and • The grass and HPTRP performed much better in the CSU WOS tests than expected by practitioners. 4.The tests did not consider overtopping with an impinging trajectory that would impart localized high momentum impact forces, potentially resulting in high shear stress and deformation in the soil. This type of overtopping may occur at flood walls, for example, where wave runup is defected upward and then falls on to the protected side (lee of the flood wall). Submitted By: Lynn McLeod (781/952-5381) Submitted On: 30-Apr-12
2-0	Evaluation **Check and Resolve** New R&D has emerged that we would like to submit for the Panel's consideration. This new Wave Overtopping R&D originated with a recent International Coastal Engineering Journal article based on the PhD dissertation of Lander Victor which gives a new representation of the overtopping wave volume distribution which has the following important difference. The original wave volume distribution (as used in the CSU wave overtopping simulator) had a fixed "shape factor" 0f of 0.75. The shape factor controls the extreme end of the wave volume distribution, and the extreme end is what determines the largest wave that must be simulated for a specific condition (wave height, period, levee slope, average flow discharge). The Royal Haskoning criticism of the 4.0 cfs/ft wave overtopping simulations was that the CSU simulator could not produce the largest wave volume for the 4.0 simulation. To replicate this flow, more of the larger waves were substituted for smaller waves but these larger waves still had somewhat less

	than the largest wave volumes required by the 0.75 shape factor distribution. The new research indicates that the 0.75 shape factor is actually only appropriate for low average wave overtopping discharges that have large freeboards. This is vastly different from the 4.0 cfs/ft case that actually occurs in the HSDRRS, which is a low wave, low freeboard condition in those critical reaches which have the highest overtopping flows. The new tests looked at larger overtopping rates generated by larger waves with low freeboard. For these cases (that are actually more representative of the HSDRRS 500-year event) the shape factors increase as a function of both levee slope and decreasing freeboard. A larger shape factor results in a DECREASE in the very largest volumes in the wave volume distribution. So rather than having the same volume distribution for all overtopping rates, the distribution differs for higher overtopping rates caused by lower freeboard. The main difference is that smaller maximum size waves need to be simulated. The implication is this. CSU's simulation of 4.0 cfs/ft, using the largest possible volumes the simulator was capable of, which were slightly less than what was thought they should have been, was not as much of a compromise as originally thought. A comparison was made of the 4.0 cfs/ft wave distribution using the new guidance versus the original CSU wave distribution. The attached plot shows that the new guidance for wave volume distribution (developed for low freeboards and steep slopes) indicates the CSU 4.0 cfs/ft tests were probably simulating a condition slightly greater than 4.0 rather than something less. The new guidance estimates the maximum wave volume needed for this 4.0 cfs/ft condition should be 138 ft3/ft...well within the Simulator's capability of 170 ft3/ft. Submitted By: Dean Arnold (504-862-2674) Submitted On: 11-May-12
2-1	Backcheck Recommendation **Close Comment** Non-Concur. The Panel acknowledges that the new report is beneficial toward an improved assessment of the WOS testing. However, the Panel's judgment is that there is a risk that the tests did not emulate the 500-year, 50% non-exceedance condition. Please see the attached file for the full Backcheck response to this comment as it exceeds the character limit in DrChecks. ArmoringIIFinal_Panel_Comment_8_Backcheck_2.pdf Submitted By: Lynn McLeod (781/952-5381) Submitted On: 07-Jun-12 (Attachment: ArmoringIIFinal_Panel_Comment_8_Backcheck_2.pdf)
	Current Comment Status: **Comment Closed**

4385182	Hydraulics	n/a'	Comment 9	n/a

(Document Reference: Medium)

A potential weakness in the conclusions drawn from the CSU modeling may be the wave parameters used as input for the CSU WOS.

(Attachment: Armoring_II_IEPR_Comment_09_-_Final.pdf)

Submitted By: Lynn McLeod (781/952-5381). Submitted On: 18-Jan-12

1-0	Evaluation **Non-concurred** Per the request, the discussion of the appropriate wave breaker parameter was added to the Armoring Manual at the end of section 3.14 in order to document its selection. Submitted By: Dean Arnold (504-862-2674) Submitted On: 29-Mar-12
1-1	Backcheck Recommendation **Close Comment** Concur. The PDT Evaluator Response and proposed modifications clarify the use and applicability of the Armoring Manual and are helpful for the Manual user to know the background and source of wave conditions for their further review and consideration when making final design decisions. Furthermore, the development of the breaker parameter and resulting wave overtopping rates are very critical to the design of these levee facilities and it is the Panel's understanding that the methodology and procedure thereof is outside the scope of the review of the Armoring Manual. Changes in local conditions (such as topography, presence of structures, etc.) and the sensitivity of small changes in the corresponding breaker parameter could have a significant effect on the computed overtopping rates and correspondingly the proper selection of the appropriate armoring material. It will be critical that an adequate level of sharing of information and coordination take place between an armoring design engineer and coastal processes analysis engineer to develop an appropriate level of understanding of local conditions through sensitivity analysis' prior to final selection of the armoring materials.

	Submitted By: Lynn McLeod (781/952-5381) Submitted On: 30-Apr-12
	Current Comment Status: **Comment Closed**

4385187	Hydraulics	n/a'	Comment 10	n/a

(Document Reference: Medium)

The Armoring Guidance Manual does not consider an "importance factor" or "localized condition variable factor" when determining sufficient armoring for a location.

(Attachment: Armoring_II_IEPR_Comment_10_-_Final.pdf)

Submitted By: Lynn McLeod (781/952-5381). Submitted On: 18-Jan-12

1-0	Evaluation **Non-concurred** Congress authorized and funded, under the Fourth and Sixth Supplemental Appropriations Act (2006&2008), the armoring of critical elements of the HSDRRS. The 'critical elements of the HSDRRS' were defined by IPET and the ASCE External Review Panel, as those elements that suffered severe erosion during Hurricane Katrina and include the transitions, pipeline crossings, utility crossings, and the landside of floodwalls and levees. The landside of levees was defined as a critical element versus the floodside of levees evident in the following IPET quotes: '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. There was no evidence of systemic breaching caused by erosion on face or water sides of the levees exposed to surge and wave action.' Such armoring reduces the risk of breaching and contributes to the resiliency of the HSDRRS, when subjected to storm surge events greater than a 100-year event (<1% chance in any given year). Armoring is prevent severe erosion that could cause a levee breach and is not to prevent overtopping and flooding of adjacent facilities. Preventing levee breaches expedites the recovery process if a storm surge exceeds the design event. Submitted By: Dean Arnold (504-862-2674) Submitted On: 13-Mar-12
1-1	Backcheck Recommendation **Close Comment** Concur. It is still not clear if USACE understood the Panel's concern regarding the large overtopping rates in relation to impacts on adjacent facilities. The Panel's concern pertained less to the direct effects to the armoring and more to the indirect effects to the adjacent infrastructure due to the higher hydrodynamic loads and larger volume of water that would need to be handled by the protected infrastructure. Assuming the levee armoring system adequately performs (no breach) during the design storm, the hydrodynamic forces associated with the larger overtopping would be significantly higher and could result in impacts to the structures and facilities (if they are not designed to accommodate those larger loads) that are being protected by the levee thereby negating the purpose of the levee. The "localized condition variable factor" that the Panel has suggested would (1) ensure areas adjacent to critical infrastructure, such as pumping stations, power stations, emergency services, etc., could handle high overtopping rates (4.5 cfs/ft), and (2) consider additional design factors to ensure they remain operational and don't suffer catastrophic damage due to the higher forces. This could result in new facilities needing to meet higher loading criteria or could require the retrofit of existing facilities to meet these new loading conditions. Submitted By: Lynn McLeod (781/952-5381) Submitted On: 30-Apr-12
	Current Comment Status: **Comment Closed**

4385193	Geotechnical	n/a'	Comment 11	n/a

(Document Reference: Low)

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.

(Attachment: Armoring_II_IEPR_Comment_11_-_Final.pdf)

Submitted By: Lynn McLeod (781/952-5381). Submitted On: 18-Jan-12

1-0	Evaluation **Non-concurred** Clay that can be used in levee construction is either a CH or CL per the Unified Soil Classification System. The clay types used are those which are available in borrow pits and is selected for geotechnical engineering considerations. The clay's textural class and mineralogy vary per available borrow pit and are not taken into account for agronomy considerations or for armoring purposes. The clay type varies per borrow pit but Commerce and Sharkey soils are probably the 2 most common. However, soil series are based on only the upper 5 or 6 feet. It is the geotechnical engineering soil properties that determine what is suitable for levee construction. Submitted By: Dean Arnold (504-862-2674) Submitted On: 13-Mar-12
1-1	Backcheck Recommendation **Close Comment** Concur. In addition to the PDT Final Evaluator Response, the Panel suggests a similar explanation of the use of the word 'clay' be explained in the Manual and specific abbreviations of clay types such as CH or CL also be defined in the Manual. Submitted By: Lynn McLeod (781/952-5381) Submitted On: 30-Apr-12
	Current Comment Status: **Comment Closed**

4385200	Other	n/a'	Comment 12	n/a

(Document Reference: Low)

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.

(Attachment: Armoring_II_IEPR_Comment_12_-_Final.pdf)

Submitted By: Lynn McLeod (781/952-5381). Submitted On: 18-Jan-12

1-0	Evaluation **Non-concurred** The Bermuda and Bahia grass, meant for the Greater New Orleans HSDRRS, was grown in Vicksburg, Ms and only tested in Colorado. The grass species tested were the predominate HSDRRS armoring species and were the species that should have been tested. Use of cool-season grasses would not have provided any useful information since hurricanes season ends in December each year. The cost of sodding is not prohibitively expensive and is included in the budget for Armoring but seeding will be evaluated as an option, in two Pilot Projects of 5000 LF each. Submitted By: Dean Arnold (504-862-2674) Submitted On: 29-Mar-12
1-1	Backcheck Recommendation **Close Comment** Concur Submitted By: Lynn McLeod (781/952-5381) Submitted On: 30-Apr-12
	Current Comment Status: **Comment Closed**

4385204	Other	n/a'	Comment 13	n/a

(Document Reference: Low)

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.

(Attachment: Armoring_II_IEPR_Comment_13_-_Final.pdf)

Submitted By: Lynn McLeod (781/952-5381). Submitted On: 18-Jan-12

1-0	Evaluation **Non-concurred** Was in agreement with the committee, until additional sampling was conducted and the 'Grass/HPTRM Demonstration Test Report' was recently completed. The timing of the original sampling in the fall of 2010 did occur later in the season when Bermuda grass root growth would be higher. The purpose of the original sampling was to gain a preliminary understanding

	of rooting of existing grass on levees. In the second sampling in 2011, 80 core samples were collected and categorized as Bermuda grass established in just two categories, less than 2 years or older than 10 years. As one would expect, the results indicated grass rooting was highest for more mature levees. Because these findings should not come as a surprise to those in the agronomic sciences, it is better to focus on management practices that would help accelerate rooting of newly established grass given that higher rooting allows for greater wave overtopping resistance regardless of HPTRM installation. Four trials were focused on this objective and results indicate management practices can have a significant effect on Bermuda grass rooting. Further demonstration of nitrogen and mowing effects may be warranted as well as valuable. The costs as compared to benefits should be calculated and presented to the USACE and Levee Boards responsible for levee vegetation maintenance. Submitted By: Dean Arnold (504-862-2674) Submitted On: 30-Mar-12
1-1	Backcheck Recommendation **Close Comment** Concur. Given the additional sampling that has been performed, along with the recent completion of the Grass/HPTRM Demonstration Test Report, this issue has been resolved. Submitted By: Lynn McLeod (781/952-5381) Submitted On: 30-Apr-12
	Current Comment Status: **Comment Closed**

4385207	Other	n/a'	Comment 14	n/a

(Document Reference: Low)

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.

(Attachment: Armoring_II_IEPR_Comment_14_-_Final.pdf)

Submitted By: Lynn McLeod (781/952-5381). Submitted On: 18-Jan-12

1-0	Evaluation **Concurred** In order to clarify the primary focus of the Armoring Manual, the first sentence of the fourth paragraph of section 1.1, was replaced with the following two sentences: 'Even though the two Supplements only authorized landside levee and floodwall armoring for breach risk reduction for extreme events, after the Armoring Program was placed under TFH in the spring of 2009, the program scope was expanded to include the investigation of possible breach causing erosion on flood side slopes for up to 0.2 % annual chance exceedance storm surges. The Armoring Program, however, is not applicable for non-breach causing erosion and for progressive or on-going erosion caused by routine hydrodynamic loading conditions (e.g. vessel waves), whose erosion prevention will be designed in the same historical manner.' Section 1.3 'Items not covered in the Scope' was supplemented as follows: vi. Application for extreme events less frequent than 0.2% and application for routine wave conditions such as vessel wakes, locally generated wind waves, tidal currents, and non-breach causing wave conditions for up to a 0.2% annual chance exceedance storm surges; Submitted By: Dean Arnold (504-862-2674) Submitted On: 30-Mar-12
1-1	Backcheck Recommendation **Close Comment** Concur Submitted By: Lynn McLeod (781/952-5381) Submitted On: 30-Apr-12
	Current Comment Status: **Comment Closed**

4385211	Geotechnical	n/a'	Comment 15	n/a

(Document Reference: Low)

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.

(Attachment: Armoring_II_IEPR_Comment_15_-_Final.pdf)

Submitted By: Lynn McLeod (781/952-5381). Submitted On: 18-Jan-12

1-0	Evaluation **Non-concurred** Literature from the the following sources: 1.Rock Manual (CIRIA/CUR 2007). 2.Coastal engineering literature related to wave overtopping 3.American River Common Features Project Levees (Sacramento District, USACE). 4.Hamilton Wetland Restoration Project (San Francisco District). 5.Design of Small Dams Manual (3rd Edition, 1987). 6.FEMA levee guidance. 7.U.S.D.A. Agricultural Research Service (ARS) 8.Other dam-related literature from the following suggested sources: Association of State Dam Safety Officials, National Inventory of Dams Program, and National Performance of Dams Programs, have been examined to determine whether useful design information could be utilized and included in the Armoring Manual. It was determined that most of the dam-related research focuses on steady overflow, and this situation is not included in the Armoring Manual because levee crest elevations have been set to prevent steady overflow at the 500-year occurrence probability. Riprap is recommended to prevent wave impacts on the flood side of dams, but this is mostly for portions of the dam slope that are routinely attacked by waves, which is not the case for our levees. Previous research conducted as part of the armoring research program indicated that HSDRRS grass and soil could withstand significant wave impacts over the relatively short duration of typical storm surges without affecting the levee crown integrity. Coastal engineering literature was previously examined and incorporated as appropriate into the Armoring Manual recommendations. Engineering methods developed for rock armor stability on the landward-sides of breakwaters and jetties is not appropriate for HSDRRS levees for two reasons: (1) breakwaters and jetties consist of multiple stone armor layers that result in highly permeable structures that have more stability than stones placed over impermeable clay; and (2) stone armoring or riprap has vegetation maintenance problems, stability issues, and is prohibitively expense. Consequently, stone armoring was not considered to be a viable HSDRRS armoring alternative. It is concluded that the Armoring Manual contains all relevant and available state-of-knowledge guidance; but it is also acknowledged that improvements could be made when additional research becomes available for our particular conditions, which is unlikely. Submitted By: Dean Arnold (504-862-2674) Submitted On: 30-Mar-12
1-1	Backcheck Recommendation **Close Comment** Concur Submitted By: Lynn McLeod (781/952-5381) Submitted On: 30-Apr-12
	Current Comment Status: **Comment Closed**

4385213	Operations	n/a'	Comment 16	n/a

(Document Reference: Low)

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.

(Attachment: Armoring_II_IEPR_Comment_16_-_Final.pdf)

Submitted By: Lynn McLeod (781/952-5381). Submitted On: 18-Jan-12

1-0	Evaluation **Concurred** Emphasis on levee maintenance related to grass management will be given greater attention in the manual now that the 'Grass/HPTRM Demonstration Test Report' has been recently completed. Based on the tests at CSU, grasses can provide an economical and effective erosion resistance to natural rainfall as well as wave overtopping. Recent testing has shown nitrogen fertilization is key in developing dense, higher rooting vegetation. Currently, the specification for unreinforced turf establishment addresses many of the suggestions of the panel with the exception of animal control. However, the present plan to armor all of the levee reaches with HPTRM and the use of HPTRM to armor the critical levee cross section has been shown to be very resistant to hog penetration as reported in the recently completed Grass/HPTRM Demonstration Test Report. Therefore, the incorporation of specific items (e.g. fertilization and mowing) to maintain a quality grass cover will be added to the maintenance section. This type of information should and will be made available to the Levee Boards (e.g. O&M manuals and seminars) as well as incorporated into the levee inspection reports for levee management improvements. Submitted By: Dean Arnold (504-862-2674) Submitted On: 30-Mar-12

1-1	Backcheck Recommendation **Close Comment** Concur Submitted By: Lynn McLeod (781/952-5381) Submitted On: 30-Apr-12
	Current Comment Status: **Comment Closed**

APPENDIX C

Final Charge to the Independent External Peer Review Panel on the HSDRRS Armoring Research Summary and Armoring Guidance Manual

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Charge Questions and Guidance to the Peer Reviewers
for the
Independent External Peer Review of the Hurricane and Storm Damage Risk Reduction System Armoring Research Summary and Armoring Guidance Manual

BACKGROUND

The U.S. Army Corps of Engineers is currently designing and constructing the Greater New Orleans Hurricane and Storm Damage Risk Reduction System (HSDRRS). One of the vital components of this system is the Armoring Research Summary and Armoring Guidance Manual (ARSAG), which is a compilation and explanation of armoring R&D performed for this program and is intended to provide guidance to armoring designers such that an economical, yet flexible, solution to provide protected side wave overtopping erosion can be implemented for greater than the 100-yr and up to the 500-yr storm surge.

The term "State" refers to both the State of Louisiana and Local governing entities including Southeast Louisiana Flood Protection Authorities and any Levee District under their supervision.

OBJECTIVES

The objective of this work is to conduct an independent external peer review (IEPR) of the HSDRRS Armoring Research Summary and Armoring Guidance (hereinafter: Armoring Manual IEPR) in accordance with the Department of the Army, USACE, Water Resources Policies and Authorities' *Civil Works Review Policy* (EC 1165-2-209) dated January 31, 2010.

Peer review is one of the important procedures used to ensure that the quality of published information meets the standards of the scientific and technical community. Peer review typically evaluates the clarity of hypotheses, validity of the research design, quality of data collection procedures, robustness of the methods employed, appropriateness of the methods for the hypotheses being tested, extent to which the conclusions follow from the analysis, and strengths and limitations of the overall product.

The purpose of the IEPR is to assess the "adequacy and acceptability of the economic, engineering, and environmental methods, models, and analyses used" (EC 1165-2-209; p. D-4) for the Armoring Manual documents. The IEPR will be limited to technical review and will not involve policy review. The IEPR will be conducted by subject matter experts (i.e., IEPR panel members) with extensive experience in hydraulic engineering, civil/geotechnical engineering, and agronomist/soil scientist/turf expert issues relevant to the project. They will also have experience applying their subject matter expertise to coastal storm damage reduction.

The Panel will be "charged" with responding to specific technical questions as well as providing a broad technical evaluation of the overall project. Per EC 1165-2-209, Appendix D, review panels should identify, explain, and comment upon assumptions that underlie all the analyses, as well as evaluate the soundness of models, surveys, investigations, and methods. Review panels should be able to evaluate whether the interpretations of analysis and the conclusions based on analysis are reasonable. Reviews should focus on assumptions, data, methods, and models. The panel members may offer their opinions as to whether there are sufficient analyses upon which to base a recommendation.

DOCUMENTS PROVIDED

The following is a list of documents, supporting information, and reference materials that will be provided for the review.

Documents for Review

The following documents are to be reviewed by designated discipline:

Title	No. of Pages	Required Disciplines
Armoring Manual – December 2011	107	All Disciplines
Texas A&M Transition Armoring Appendix	75[a]	All Disciplines
CSU-Wave Overtopping of Proposed Levee Armoring Materials Appendix	303	All Disciplines
LSU Grass Root Analysis Report Appendix	21	All Disciplines
Methodology to Determine Need for Protected Side Slope Armoring Report Appendix	32[a]	All Disciplines

[a] estimated page counts

Supporting Information

- Armoring Quality Management Plan - 6 pages
- Floodside Wave Erosion White Paper - 107 pages
- Case History in Soil and Rock Erosion (Briaud) - 24 pages
- Risk Assessment Report Appendix – 47 pages
- Supporting document for LSU Appendix (available around 12/15)

Documents for Reference

- USACE guidance Civil Works Review Policy (EC 1165-2-209) dated January 31, 2010

SCHEDULE

This schedule is based on the December 7, 2011 receipt of the final review documents. The schedule will be revised upon receipt of final review documents.

Task	Action	Due Date
Conduct Peer Review	Battelle sends review documents to Panel	12/12/2011
	Battelle convenes kickoff meeting with Panel	12/13/2011
	USACE/Battelle convenes Orientation Briefing with Panel	12/13/2011
	Battelle convenes mid-review teleconference for Panel to ask clarifying questions of USACE	12/20/2011
	Panel members complete their individual reviews	12/28/2011
	Battelle provides Panel merged individual comments and talking points for Panel Review Teleconference	12/30/2011
	Battelle convenes Panel Review Teleconference	1/5/2012
	Final Panel Comments finalized	1/17/2012
Comment/ Response Process	Battelle convenes teleconference with Panel to review the Comment Response Process (if necessary)	1/19/2012
	USACE provides draft Evaluator Responses to Battelle	1/31/2012
	Battelle provides the Panel the draft Evaluator Responses	2/2/2012
	Panel members provide Battelle with draft comments on draft Evaluator Responses (i.e., draft BackCheck Responses)	2/7/2012
	Battelle convenes teleconference with Panel to discuss draft BackCheck Responses	2/8/2012
	Battelle convenes teleconference with Panel and USACE to discuss Final Panel Comments and draft responses	2/9/2012
	USACE inputs final Evaluator Responses in DrChecks	2/24/2012
	Battelle provides Evaluator Responses to Panel	2/29/2012
	Panel members provide Battelle with final BackCheck Responses	3/5/2012
	Battelle inputs the Panel's BackCheck Responses in DrChecks	3/9/2012
	*Battelle submits pdf printout of DrChecks project file	3/12/2012
Prepare Final Panel Comments and Final IEPR Report	Battelle provides Final IEPR Report to Panel for review	3/13/2012
	Panel provides comments on Final IEPR Report	3/15/2012
	*Battelle submits Final IEPR Report to USACE	3/21/2012

CHARGE FOR PEER REVIEW

Members of this IEPR Panel are asked to determine whether the technical approach and scientific rationale presented in the Armoring Manual documents are credible and whether the conclusions are valid. The Panel is asked to determine whether the technical work is adequate, competently performed, properly documented, satisfies established quality requirements, and yields scientifically credible conclusions. The Panel is being asked to provide feedback on the engineering and agronomy. The panel members are not being asked whether they would have conducted the work in a similar manner.

Specific questions for the Panel (by report section or Appendix) are included in the general charge guidance, which is provided below.

General Charge Guidance

Please answer the scientific and technical questions listed below and conduct a broad overview of the Armoring Research Summary documents. Please focus your review on the review materials assigned to your discipline/area of expertise and technical knowledge. Even though there are some sections with no questions associated with them, that does not mean that you cannot comment on them. Please feel free to make any relevant and appropriate comment on any of the sections and appendices you were asked to review. Note that the Panel will be asked to provide an overall statement related to the adequacy of the guidance manual.

1. Your response to the charge questions should not be limited to a "yes" or "no." Please provide complete answers to fully explain your response.
2. Identify, explain, and comment upon assumptions that underlie all the analyses, and evaluate the soundness of models, surveys, investigations, and methods.
3. Evaluate whether the interpretations of the analysis and the conclusions based on the analysis are reasonable.
4. Please focus the review on assumptions, data, methods, and models.

Please **do not** make recommendations on whether a particular alternative should be implemented, or whether you would have conducted the work in a similar manner. Also, please **do not** comment on or make recommendations on policy issues and decision-making. Comments should be provided based on your professional judgment, **not** the legality of the document.

1. If desired, panel members can contact one another. However, panel members **should not** contact anyone who is or was involved in the project, prepared the subject documents, or was part of the USACE Independent Technical Review.
2. Please contact the Battelle Project Manager (Lynn McLeod, mcleod@battelle.org) or Program Manager (Karen Johnson-Young (johnson-youngk@battelle.org) for requests or additional information.
3. In case of media contact, notify the Battelle Program Manager, Karen Johnson-Young (johnson-youngk@battelle.org) immediately.

4. Your name will appear as one of the panel members in the peer review. Your comments will be included in the Final IEPR Report, but will remain anonymous.

Please submit your comments in electronic form to Lynn McLeod, mcleod@battelle.org, no later than December 28, 2011, 10 pm ET.

Independent External Peer Review
of the
Hurricane and Storm Damage Risk Reduction System Armoring Research Summary and Armoring Guidance Manual

Charge Questions and Relevant Sections As Supplied By USACE

Floodside Armoring Methodology - The ARSAG uses the ERDC Flood-side Wave Erosion of Earthen Levees publication and a (St. Bernard) T-Wall Analysis to recommend a number of deterministic methodologies derived from grass and soil conditions from non-HSDRRS levees with which to assess the likelihood and magnitude of erosion on the flood side slopes. Please address the following with sufficient explanation:

1. Comment on the application of the methodologies used.

2. Do the assumptions used in the application of these methodologies maintain a realistic approach? If not, explain.

3. Are the conclusions drawn with regards to armoring recommendations for the less than or equal to the 1.0 % and 0.2% return period accurate? If not, explain.

4. Is the conclusion that erosion depths calculated will not threaten the crown of a levee or the global stability of a T-wall structure accurate? If not, explain.

Colorado State University Wave Overtopping Simulator (CSU-WOS) - Using the CSU-WOS testing as the basis, the ARSAG recommends a safe maximum wave overtopping flow of 1.0cfs for bermudagrass, and a maximum of approximately 4.0 + cfs for High Performance TRM (with bermudagrass). The ARSAG also discuses a methodology for the design of ACB, but recommends the continued use of slope paving for transitions. Please address the following with sufficient explanation:

5. Comment on the stated allowable wave overtopping flow rates for grass and High Performance TRM's. Explain whether the CSU-WOS testing program justify them.

6. Is the use of time averaged wave overtopping discharge rates as an appropriate indicator of erosion potential accurate? If not, explain.

7. Are the assumptions / conclusions made regarding the residual capacity of High Performance TRM's above the stated capacities accurate? If not, explain.

8. Comment on the conclusion that properly watered, mowed, and fertilized sodded grass can quickly attain a quality similar to CSU tested grass and adequate maintenance is required to maintain that quality in the future.

9. Are the armoring material capacities appropriate when using 50% non-exceedance values in resiliency design for the extreme 500-yr storm surge case? If not, explain.

10. Comment on the conclusions regarding the need to harden the levee crest when the overtopping flow rate exceeds 1.0 cfs/ft.

11. Are the assumptions made regarding the identification of weak zones on the levee surface; and the potential for weak zones (structured clay) to develop accurate? If not, explain.

LSU Grass Report and the FOS Armoring Methodology Report - The LSU Root Volume Analysis and the FOS (Armoring Methodology) Report's compare the relative variations in root volume of the grass tested at CSU to the grass of real levees of ages ranging from 1 year to 10 years. The FOS report uses the one dormant grass test (in lieu of many green grass tests) to recommend an allowable wave overtopping flow of 1.0 cfs/ft (essentially a factor of safety) for grass based on similar root volume (assumed but not test verified) between the one CSU test and the quality of the grass in real levees less than 3 years old. Please address the following with sufficient explanation:

12. Comment on whether the Subject Matter Expert (SME) approach which used root volume (assumed but not test verified) as an indicator of the variation in erosion resistance, is appropriate.

13. Comment on whether the residual uncertainty associated with the various data points collected, and verifying that the level of analysis (and conclusions drawn) is the appropriate level of professional judgment and scientific analysis required, allows the user to arrive at an appropriate allowable overtopping discharge value.

Armoring Installation and Maintenance Requirements - The ARSAG recommends a number of measures that should be taken during construction and during operation to ensure that the safe discharge capacities remain appropriate during the design life of the armoring. Please address the following with sufficient explanation:

14. Are these measures practical, achievable, and do they satisfy the criteria used to interpret the CSU-WOS testing results?

Transition Armoring - The ARSAG recommends design of armoring systems for transitions, including the footprint design. Please address the following:

15. Comment on whether these conclusions and assumptions reached are appropriate (in unsteady flow conditions) with the level of data provided by the Texas A&M physical modeling program.