Final Independent External Peer Review Report

Greater New Orleans Hurricane and Storm Damage Risk Reduction System (GNOHSDRRS) Lake Pontchartrain and Vicinity (LPV) 111.01-Deep Soil Mixing Design Guidelines

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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)

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of the

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ACRONYMS

A&E	Architecture & Engineering
CIL	Critical Items List
CECW	Corps of Engineer Civil Works
DrChecks [SM]	Design Review and Checking System
GNOHSDRRS	Greater New Orleans Hurricane and Storm Damage Risk Reduction System
HSDRRS	Hurricane and Storm Damage Risk Reduction System
HSDRSDG	Hurricane and Storm Damage Reduction System Design Guidelines
IEPR	Independent External Peer Review
IPET	Interagency Performance Evaluation Task
ITR	Independent Technical Review
LPV	Lake Pontchartrain and Vicinity
MVN	Mississippi Valley New Orleans
NAS	National Academy of Sciences
NAVD88	National Geodetic Vertical Datum of 1988
NOLA	New Orleans Louisiana
NTP	Notice to Proceed
PDT	Project Delivery Team
PRQCP	Peer Review Quality Control Plan
STAS	Short Term Analysis Service
USACE	U.S. Army Corps of Engineers
VE	Value Engineering
WRDA	Water Resources Development Act

Final Report
for the
Independent External Peer Review
of the
Greater New Orleans Hurricane and Storm Damage Risk Reduction System
LPV 111.01- Deep Soil Mixing Design Guidelines

Executive Summary

The U.S. Army Corps of Engineers is currently designing and constructing the Greater New Orleans Hurricane and Storm Damage Risk Reduction System (GNOHSDRRS). One of the vital components of this system is the LPV 111.01 project, which consists of raising the levee along its existing alignment from elevation 19.5 feet to 25–29 feet to provide hurricane risk reduction for the 1% design storm event. In order to implement the LPV 111.01 project, USACE has prepared new guidance, *Draft Design Guide for Levee and Floodwall Stability Using Deep-Mixed Shear Walls* (hereinafter *Draft Design Guide*), for the design and construction of deep-mixed shear walls to stabilize levees and I-walls constructed on soft ground.

An IEPR of the LPV 111.01- Deep Soil Mixing Design Guidelines (hereinafter Deep Soil Mixing Guidelines) was conducted to ensure the reliability of scientific analyses contained within those documents. In addition, the Water Resources Development Act (WRDA) 2007, Section 2035 (Public Law 110-114) requires a safety assurance review by independent experts on the design and construction activities of the GNOHSDRRS projects. Review of the Deep Soil Mixing Design Guidelines is regarded as a critical element to the safety assurance of this project and is performed as required by WRDA. Battelle Memorial Institute (hereinafter Battelle), as a non-profit science and technology organization with experience in establishing and administering expert peer reviews, was engaged to coordinate the IEPR of the Deep Soil Mixing Design Guidelines. The IEPR followed the procedures described in the Department of the Army, USACE, guidance *Peer Review of Decision Documents* (EC 1105-2-410) dated August 22, 2008; CECW-CP Memorandum dated March 30, 2007; *Engineering and Design, Quality Management* (ER 1110-1-12) dated July 21, 2006; and *Engineering and Design,* DrChecks^{SM} (ER 1110-1-8159) dated May 10, 2001.

This final IEPR report provides an overview of the IEPR process, describes the expert reviewers' experience and their selection process, discusses the results of the IEPR, and summarizes the IEPR comments on the subject of the Deep Soil Mixing Design Guidelines.

Battelle initially screened 16 potential expert peer reviewers for their technical expertise, absence of potential conflicts of interests, and their availability. Two expert peer reviewers were selected: a geotechnical engineer and a civil engineer. The IEPR expert reviewers were provided with hard and electronic copies of the *Draft Design Guide* and supporting documentation, along with a charge that solicited their comments on specific sections of the documents that were to be reviewed.

The Deep Soil Mixing Design Guidelines IEPR started on April 3, 2009, with the project kick off teleconference conducted by Battelle. The USACE-approved Charge to the Peer Reviewers was

used as a guide to conducting the review. The IEPR expert reviewers produced 15 individual written comments that were submitted to Battelle on April 15, 2009. Battelle collated the comments in tabular format and submitted this table to the peer reviewers. A quality review teleconference was conducted by Battelle with the goal of discussing all peer reviewer comments, and reaching an agreement to eliminate any redundant comments or consolidate overlapping comments. Thirteen IEPR review comments were identified at the meeting; one of the comments was marked as critical.

On April 20, 2009, Battelle entered the 13 IEPR comments into the USACE Design Review and Checking System (DrChecks^{SM}) for tracking. The USACE Project Delivery Team (PDT) evaluated and responded to all 13 comments in DrChecks^{SM}. The USACE PDT concurred with six comments, non-concurred with six comments, and had one comment listed for check and resolve. The USACE PDT also provided an explanation with each response.

Battelle conducted a second quality review teleconference to discuss the peer reviewers' responses to the USACE PDT responses. During this teleconference, the peer reviewers formulated backcheck responses to the six USACE PDT non-concurring responses. Upon review of the single comment marked for check and resolve, the IEPR peer reviewers concurred with the USACE PDT response and this comment was closed. The peer reviewers also assigned a non-concurrence designation to the six USACE PDT non-concurring comments and formulated responses. Battelle entered the peer reviewers' backcheck responses into DrChecks^{SM} on May 18, 2009.

An IEPR Comment Review Teleconference was conducted on June 11, 2009 for the IEPR expert reviewers and USACE PDT to discuss open comments as a group. Upon completion of the IEPR Teleconference, all but two comments were considered adequately addressed; one of these comments was marked as a critical item. At the close of the teleconference, USACE PDT agreed to rewrite their responses to the two open comments. USACE PDT revised responses were recorded in DrChecks^{SM} on August 26, 2009, in the wording prepared during the IEPR Comment Review Teleconference. The revisions to the two open comments were accepted by the peer reviewers and the comments were closed on August 26, 2009.

1.0 INTRODUCTION

1.1 Background of Program

The U.S. Army Corps of Engineers (USACE) is currently designing and constructing the Greater New Orleans Hurricane and Storm Damage Risk Reduction System (GNOHSDRRS). A vital component of this system is the LPV 111.01 project, which consists of raising the levee along its existing alignment from elevation 19.5 feet to 25–29 feet to provide hurricane risk reduction for the 1% design storm event. Deep soil mixing (DSM) will be a component of the project. USACE had prepared new guidance, *Draft Design Guide for Levee and Floodwall Stability Using Deep-Mixed Shear Walls* (hereinafter *Draft Design Guide*), for the design and construction of deep-mixed shear walls to stabilize levees and I-walls constructed on soft ground.

Recognizing the importance of this project, an Independent External Peer Review (IEPR) was conducted of the Lake Pontchartrain and Vicinity, Louisiana, (LPV) 111.01- Deep Soil Mixing Design Guidelines Project (hereinafter Deep Soil Mixing Design Guidelines). Independent, objective peer review is regarded as a critical element in ensuring the reliability of scientific analyses.

Battelle Memorial Institute (hereinafter Battelle), as a non-profit science and technology organization with experience in establishing and administering peer reviews, was engaged to coordinate the IEPR of the Deep Soil Mixing Guidelines project. The IEPR followed the procedures described in the Department of the Army, USACE guidance *Peer Review of Decision Documents* (EC 1105-2-410) dated August 22, 2008; CECW-CP Memorandum dated March 30, 2007; *Engineering and Design, Quality Management* (ER 1110-1-12) dated July 21, 2006; and *Engineering and Design, DrChecks*^{SM} (ER 1110-1-8159) dated May 10, 2001.

This final IEPR report provides an overview of the IEPR process, describes the expert reviewer's experience and the selection process, discusses the results of the IEPR teleconferences, and summarizes the IEPR comments on the Deep Soil Mixing Design Guidelines. All IEPR comments were detailed and documented in Design Review and Checking System (DrChecks^{SM}), the USACE's Web-based tool for facilitating the review of complex project documents.

1.2 Project and Documents Reviewed

The IEPR for the Deep Soil Mixing Design Guidelines specifically reviewed the *Draft Design Guide* and supporting documentation. USACE had prepared this new guidance for the design and construction of deep-mixed shear walls to stabilize levees and I-walls constructed on soft ground. The scope of the Deep Soil Mixing Design Guidelines was limited to specialized design considerations and analysis procedures associated with deep-mixed shear walls in areas of low seismicity. The guidance referenced existing documents for soil strength characterization, stability analysis methods, performance criteria, and other relevant procedures.

The IEPR experts reviewed the following documents:

Documents for Review

- Draft Design Guide for Levee and Floodwall Stability Using Deep-Mixed Shear Walls (February 10, 2009 - Main Document)
- Appendix A: Earthen Levee with Deep-Mixing Support beneath the Levee
- Appendix B: I-wall with Deep-Mixing Support on the Flood Side
- Lessons Learned from the Designer

Reference Documents

- Engineer Manual 1110-1-1905, Bearing Capacity of Soils
- Engineer Manual 1110-2-1902, Stability of Earth and Rock-Fill Dams
- Engineer Manual 1110-2-1913, Design and Construction of Levees
- Engineer Manual 1110-2-2502, Retaining and Flood Walls
- Engineer Manual 1110-2-2504, Design of Sheet Pile Walls
- Engineer Technical Letter 1110-2-547, Introduction to Probability and Reliability Methods for Use in Geotechnical Engineering
- Engineer Technical Letter 1110-2-561, Reliability Analysis and Risk Assessment for Seepage and Slope Stability Failure Modes for Embankment Dams
- USACE Hurricane and Storm Damage Risk Reduction System Design Guidelines

Supporting Documents

- Independent Technical Reviews (06 Jan 09 and 06 Feb 09)
- 32 documents referenced as "Other References"

1.3 Purpose of Independent External Peer Review

The purpose of an IEPR, in general, is to strengthen USACE's safety assurance as outlined in Water Resources Development Act (WRDA) 2007, Section 2035 (Type II) for the GNOHSDRRS program in the Greater New Orleans area. Independent, objective external peer review is regarded as a critical element in ensuring the reliability of scientific and engineering analyses.

To help ensure that USACE documents are supported by the best scientific and technical information, a peer review process has been implemented by USACE that utilizes an IEPR to complement the agency technical review, as described in the Department of the Army, USACE, guidance *Peer Review of Decision Documents* (EC 1105-2-410) dated August 22, 2008. In this case, the IEPR of the Deep Soil Mixing Design Guidelines project was conducted and managed using contract support from an independent 501(c)(3) organization, Battelle, to ensure independent objectivity, along with a high degree of flexibility and responsiveness, which was essential for USACE to meet deadlines.

2.0 INDEPENDENT EXTERNAL PEER REVIEW PROCESS

This section describes the methodology followed in selecting external peer reviewers and in planning and conducting the IEPR. The IEPR followed the process described in the Peer Review Quality Control Plan (PRQCP), which Battelle developed specifically for this project, and was

conducted following procedures described in USACE's guidance cited above (Section 1.1) and in accordance with the Office of Management and Budget's *Final Information Quality Bulletin for Peer Review*, released December 16, 2004. In addition, the IEPR followed supplemental guidance on the evaluation of conflicts of interest from the National Academies' *Policy on Committee Composition and Balance and Conflicts of Interest for Committees Used in the Development of Reports*, dated May 12, 2003, was also followed.

2.1 Planning and Schedule

Table 1 defines the schedule followed during the IEPR.

Table 1. IEPR Project Schedule

Task	Action	Date(s)
	Notice to Proceed (NTP)*	12 Mar 09
1	**USACE Kick-Off Meeting and Charge** USACE Kick-Off Meeting* Battelle submits Draft Charge to USACE for review USACE comments on Draft Charge Battelle prepares Final Charge (*delay between NTP and USACE Kickoff Meeting due to USACE program changes)	 26 Mar 09 27 Mar 09 27- 31 Mar 09 01 Apr 09
2	**Peer Reviewer Recruitment** Peer reviewers placed under contract Battelle sends Final Charge and review documents to reviewers Peer reviewers participate in start-of-work teleconference	 31 Mar 09 01 Apr 09 03 Apr 09
3	**Document Review** Peer reviewers conduct document review Quality review teleconference Battelle posts peer reviewers' comments in DrChecks^{SM} USACE PDT Evaluator reviews and responds to comments Peer reviewers review USACE PDT Evaluator responses Battelle posts backcheck recommendations on DrChecks ^{SM} USACE PDT Evaluator responds to comments (second round)	 03- 17Apr 09 18 Apr 09 20 Apr 09 07 May 09 07 -18 May 09 18 May 09 02 June 09
4	**IEPR Comment Review Teleconference**	11 Jun 09
5	**Final Report** Closeout all comments in DrChecks ^{SM} Battelle submits Draft Final Report USACE reviews Draft Final Report Battelle submits Final Report Project Closeout	 26 Aug 09 07 Oct 09 15 Jan 10 29 Jan 10 31 Jan 10

Note: DrChecks^{SM} = Design Review and Checking System

2.2 Identification and Selection of Independent External Peer Reviewers

Battelle identified 16 peer review candidates who had requisite areas of expertise for the Deep Soil Mixing Design Guidelines project. The candidates were identified using referrals, internet searches, and personal contacts. Of the 16 potential candidates, three were contacted and screened for their technical expertise, potential conflicts of interest (COIs), previous performance on similar reviews, and availability to meet the project schedule. Of the three peer review candidates who were contacted, two were selected to review the Deep Soil Mixing Design Guidelines based on their expertise and availability.

The two reviewers selected for the IEPR were independent engineering consultants. The areas of technical expertise of the selected IEPR reviewers were geotechnical engineering and civil engineering, which corresponded to the technical content of the Deep Soil Mixing Design Guidelines review materials. Battelle evaluated the credentials of the peer reviewers according to the overall scope of the Deep Soil Mixing Design Guidelines, focusing on these key areas of expertise. Participation in previous USACE technical review committees and other technical review panel experience was also considered.

The peer reviewers were screened for the following *potential* exclusion criteria or COIs:

- Financial or litigation association with USACE, "The State" (defined as the State of Louisiana and Local governing entities including Southeast Louisiana Flood Protection Authority), the Design A/E, their engineering teams, subcontractors, or construction contractors
- Current USACE, federal, or state government employee
- Current personal or firm involvement as a cost-share partner on USACE projects
- Participation in developing the HSDRRS project
- Involvement in producing any USACE guidance documents, including, but not limited to the Design Guidelines, the Armoring Backslope Design manual, or the Deep Soil Mixing Design Guidelines
- Any publicly documented statement made by the reviewer or reviewer's firm advocating for or against the subject project
- Paid or unpaid participation in litigation related to the work of the USACE
- Current or future interests in the subject project or future benefits from the project
- Current personal or firm involvement with other USACE projects
- Previous employment by the USACE as a direct employee or contractor (either as an individual or through your firm) within the last 10 years
- Previous direct employment by the USACE, New Orleans District
- A significant portion (i.e., greater than 50%) of personal or firm revenues within the last 3 years came from USACE contracts
- Repeatedly serving as a peer reviewer for Task Force Hope projects

- Other USACE affiliation [Scientist employed by the USACE (except as described in National Academy of Sciences (NAS) criteria, see EC 1105-2-410 section 8d)][1]
- Personal relationships with USACE staff in Mississippi Valley Division Headquarters, Task Force Hope, New Orleans District (Protection Restoration Office), Hurricane Protection Office, or officials from the State of Louisiana and Local governing entities including Southeast Louisiana Flood Protection Authority
- Participation in the Interagency Performance Evaluation Task (IPET) Force, American Society of Civil Engineers External Review of IPET, the Louisiana Coastal Protection and Restoration Study, and/or National Research Council Committee on New Orleans Regional Hurricane Protection Projects
- Other possible perceived COIs for consideration (e.g., former USACE New Orleans employee).

In selecting final peer reviewers from the list of potential peer review candidates, Battelle tried to select experts who were not conflicted by the above COI and who met the criteria and experience factors described in Section 3 of this report. The selection of the final two peer reviewers was based on these considerations (see Section 3 for names and biographical information on the selected IEPR peer reviewers). Battelle established subcontracts with the peer reviewers who had indicated their willingness to participate and confirmed the absence of COIs (through a signed COI form).

2.3 USACE Project Kick off Teleconference

On March 26, 2009 Battelle staff conducted an USACE Kick-off Teleconference meeting on the Deep Soil Mixing Design Guidelines IEPR. During the teleconference, Battelle provided an overview of the IEPR process, reviewed project and reference materials, and discussed overall schedule dates and milestone activities with the USACE PDT and PCX.

2.4 Charge to Peer Reviewers and Peer Reviewer Start of Work Meeting

Based on information received from USACE during the project kick-off teleconference and review of the project documents, Battelle developed a Charge directed to the peer reviewers to guide the IEPR of the Deep Soil Mixing Design Guidelines. The Charge to peer reviewers also included background data for the April 3, 2009 peer reviewer start-of-work teleconference. Prior to this meeting the peer reviewers received the review documents in hard copy and electronic format; USACE reference documents were available in electronic format only.

[1] Note: 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 the OMB memo 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 agency, some may question whether that scientist is sufficiently independent from the agency to be employed as a peer reviewer on agency-sponsored projects."

As part of the Charge, the peer reviewers were asked to determine the following:

1. If the technical approach and scientific rationale presented in the Draft Design Guide are credible and whether the conclusions are valid.
2. If the technical work presented in the Draft Design Guide is technically adequate, properly documented, satisfies established quality requirements, and yields scientifically credible conclusions.

The Charge to the peer reviewers also included instructions on acceptable and non-acceptable comments, comment teleconference protocol, contact information, and the overall project schedule. A complete listing of charge questions provided to the peer reviewers is included in Appendix A of this document.

2.5 Conduct of the Peer Review

The review of the Deep Soil Mixing Design Guidelines was conducted according to the schedule shown in Table 1. Using the Charge to peer reviewers as the basis for their review, the IEPR peer reviewers developed 15 individual comments on the Deep Soil Mixing Design Guidelines. These comments were collated by Battelle and submitted to the peer reviewers for evaluation. Battelle conducted a quality review teleconference with the peer reviewers to remove duplicate comments and resolve contradictory comments, ensuring that all comments were of acceptable quality. By the close of this meeting, 13 peer reviewer comments had been identified. Battelle entered these comments directly into DrChecks [SM].

The USACE PDT evaluated and reviewed the IEPR comments in DrChecks[SM] and provided responses back to the IEPR peer reviewers. There was immediate concurrence and close out for six of the 13 comments. The remaining seven open comments (i.e., six non-concurring comments and one comment marked for "check and resolve") required further discussion by the peer reviewers. One of the seven open comments was flagged as a critical item. The remaining open comments focused on the inclusion of the following items in the Deep Soil Mixing Design Guidelines:

- A step-by-step design procedure, including a flow chart and alternative decision/paths and presentation of factors of safety should be presented in tabular format.
- A summary of deep soil mixing methods and the advantages and disadvantages of each in subsurface conditions similar to those experienced in the GNO project area should be presented in the Deep Soil Mixing Design Guidelines.
- The section on geometric considerations should be expanded to include a discussion of alternate arrangements and their respective geometric equations.
- References to CDIT (2002) and/or other pertinent references as the specific sources for the equations should be included and terminology used in the Deep Soil Mixing Design Guidelines should be revised to be consistent with standard USACE terminology.
- The document should provide clarification of the use of total stress (Chapter V: Strength Values) versus equations for both total stress and effective stress (Chapter VI: External Stability) for calculating soil strength beneath the DSM ground/shear walls should be included, as well as references and examples where deep mixing is applied in unusual geometries, adjacent to structures, for complex conditions, and or with isolated columns.

- Specifications for construction should be expanded and sample specifications developed to include recommended QA/QC roles, responsibilities, and testing.
- Design methodology should be revised such that the spacing of the shear walls is not determined based on a single specific geometry.

Table 2 is an example of an IEPR peer reviewer comment that was entered into DrChecks[SM] by Battelle, evaluated by the USACE PDT, required further discussion by peer reviewers, and was then agreed upon and closed out prior to the IEPR Comment Review Teleconference.

Table 2. Example IEPR Peer Reviewer [2] and USACE PDT Evaluator Entries in DrChecks[SM]

Id	Discipline	DocType	Spec	Sheet	Detail
2453686	Geotechnical	n/a	n/a	n/a	n/a
(Document Reference: Chapter IX: Numerical Analysis of Stability **Coordinating Discipline(s)**: Geotechnical and Civil The DSM Design Guide would benefit from references and examples where deep mixing is applied in unusual geometries, adjacent to structures, for complex conditions, and or with isolated columns, for which numerical analyses may be recommended or warranted. The references and examples are necessary to give the designer a basis for assessing the need for alternative / numerical analyses. Submitted On: 20-Apr-09					
1-0	Evaluation **Non-concurred** References for numerical model examples are given in Chapter IX. The Guide is focused only on limit equilibrium methods for evaluating stability. The decision to use a numerical model would have to be a case-by-case decision by the designer and could not be adequately covered within the limited scope of this document. Submitted On: 07-May-09				
1-1	Backcheck Recommendation **Open Comment** The following wording should be added to the document: "As the DSM Design Guide is focused only on equilibrium stability, the decision to use other analyses or numerical models will have to be a on a case-by-case decision by the designer". Submitted On: 18-May-09				
1-0	Evaluation **Concurred** We propose the following language to address this point: "This design guide addresses limit equilibrium analyses of levees supported on deep-mixed shear panels. Numerical analyses are recommended when deep mixing is applied in unusual geometries, adjacent to structures, for complex conditions, and/or with isolated columns. Numerical stability analyses of levees and embankments with deep mixing support are described and illustrated in Han (2005), Navin and Filz (2005, 2006), Filz and Navin (2006), and Adams et al. (2008a,b). Designers considering numerical analyses of deep-mixed ground supporting levees should review these and other relevant publications." Submitted On: 02-Jun-09				
2-1	Backcheck Recommendation **Close Comment** Closed without comment. Submitted On: 03-Jun-09				
	Current Comment Status: **Comment Closed**				

Note: Output modified to remove attribution of comment to any individual peer reviewer.

[2] IEPR Panel Comments were entered into DrChecks by Battelle.

Subsequently, the USACE PDT requested a second round of DrChecks[SM] comment and responses. Battelle then conducted a second quality review teleconference to discuss the peer reviewer's responses to the USACE PDT responses. During this teleconference, the peer reviewers formulated backcheck responses to the six USACE PDT evaluator's non-concurring responses. Battelle entered the peer reviewers' backcheck responses into DrChecks[SM] on May 18, 2009.

2.6 IEPR Comment Review Teleconference

Battelle facilitated an IEPR Comment Review Teleconference between the USACE PDT and the IEPR peer reviewers on June 11, 2009. Members of the State and local stakeholders were also invited. The purpose of the IEPR comment review teleconference provided a forum for a discussion of specific comments that the IEPR peer reviewers considered inadequately addressed regarding the Deep Soil Mixing Design Guidelines.

The majority of the discussion between the IEPR peer reviewers and USACE PDT during the IEPR Conference focused on two comments, one marked as a critical comment. The IEPR Conference presentation was delivered by Battelle, and Battelle facilitated and monitored the discussions. All IEPR peer reviewers, USACE PDT, and the State were present during the discussion session.

Upon completion of the IEPR Teleconference, all but two comments were considered adequately addressed; one of these comments was marked as a critical item. The IEPR peer reviewers were in unanimous agreement that the two remaining comments were vital to the Deep Soil Mixing Design Guidelines. A summary of the revisions recommended by the IEPR peer reviewers follows:

- Specifications for construction should be expanded and sample specifications developed to include recommended QA/QC roles, responsibilities, and testing.
- The spacing of the shear walls should not be determined based on a single specific geometry (flagged as critical).

At the conclusion of the June 11, 2009 teleconference, the USACE PDT agreed to rewrite their responses to the two open comments. USACE PDT rewritten responses were recorded in DrChecks on August 26, 2009. The revisions to the open comments were accepted (i.e., concurred) by the peer reviewers and the comments were closed on August 26, 2009.

2.7 IEPR Final Report

After concluding the IEPR and closing out the final IEPR peer reviewers comments in DrChecks[SM], Battelle prepared a draft final report on the overall IEPR process and the IEPR peer reviewers' findings. Both IEPR peer reviewers reviewed and commented on the report, and the report was subject to an editorial and technical review by Battelle, before being submitted it to USACE.

3.0 EXTERNAL PEER REVIEWER SELECTION

Potential peer review candidates were identified through Battelle's IEPR expert database, trade organizations, engineering societies, targeted internet searches using key words (e.g., terms focusing on technical area and geographic region), search of websites of universities or other compiled expert sites, and through referrals.

Both IEPR peer reviewers met all three of the following minimum requirements:

- Registered professional engineer (or equivalent in home country)
- Masters degree
- 20 years of experience and responsible charge of engineering work.

Peer reviewers in each discipline also were required to have specific technical experience in the areas summarized in Table 3 below.

Table 3. Required Technical Experience for Deep Soil Mixing Design Guidelines IEPR Peer Reviewers

Discipline (# of Reviewers)	Required Experience
Geotechnical Engineer (1)	• Very soft Louisiana-type clay soil foundations • Axial and lateral load testing for piles T-wall and L-wall design • Subsurface investigations in very soft soil • Seepage design • Wave impact/armoring for very soft soils • Slope stability analyses for very soft soils
Civil Engineer (1)	• Designs utilizing very soft soils • Design of levees • Erosion control

Battelle submitted to USACE a draft list of peer reviewers that were screened for availability, technical background, and COI. The final list of IEPR peer reviewers was determined by Battelle (Table 4) based on their specific experience in the areas of expertise specified in the scope of work (Table 5).

Table 4. Final List of IEPR Peer Reviewers

Discipline/Name	Affiliation	Location	Education	P.E.	Years of Experience
Geotechnical Engineer					
Jesse Coleman	Coleman Consultants	Watauga, TX	BSCE, MSCE	Yes	41
Civil Engineer					
Stephen McCaskie	Hanson Professional Services, Inc.	Maryland Heights, MO	BSCE, MSCE	Yes	30

Table 5. Specific Experience of IEPR Peer Reviewers Requested in the Scope of Work

Expertise	Total	Jesse Coleman	Stephen McCaskie
General Experience			
Planning	**1**		X
Design	**2**	X	X
Construction	**2**	X	X
Geotechnical Engineer		**1**	
Very soft Louisiana-type clay soil foundations	**2**	X	X
Subsurface investigations in very soft soil	**2**	X	X
Seepage design	**2**	X	X
Wave impact/armoring	**2**	X	X
Slope stability analyses for very soft soils	**2**	X	X
Quality control testing	**2**	X	X
Spencer's Method experience and knowledge of the output files of currently used and available computer analysis programs	**2**	X	X
Deep soil mixing	**2**	X	X
Civil Engineer			**1**
Designs utilizing very soft soils	**2**	X	X
Design of levees	**2**	X	X
Erosion control	**2**	X	X
Deep soil mixing	**2**	X	X
Construction Experience			
Constructability of proposed designs	**2**	X	X
Quality control/Quality Assurance (QC/QA) requirements and testing	**2**	X [a]	X [b]
Field experience verifying that projects are being constructed as designed	**2**	X	X
Plans and specifications	**2**	X	X
Worked on at least five multi-million dollar projects (number of projects)	**2**	X (>50)	X (>25)
Worked on multi-million dollar projects with regard to the construction expertise noted in this category (number of projects)	**2**	X (30-40)	X (>12)

[a] QC/QA was associated with earth fill dams, drilled shafts/pile supported structures, deep soil mixing, and large hydraulic concrete structures.
[b] QC/QA was associated with levee/dam/pile supported concrete structures.

A summary of the credentials and IEPR-related qualifications of the two peer reviewers selected for the IEPR is presented below. Resumes of the peer reviewers with more detailed biographical information and technical areas of expertise are presented in Appendix B.

Jesse Coleman, P.E., is a Principal Engineer with Coleman Consultants and has more than 40 years' experience with senior review and project management for design and construction engineering products. He has provided design leadership in the civil, geotechnical, and structural areas for federal government, private, commercial, and industrial clients. He has worked extensively in the areas of dam, levees, flood routing, lined and unlined drainage channels, storm water diversions, stream and channel diversions, retaining walls, deep foundations for the heavy, settlement sensitive equipment associated with repair facilities and aircraft hangers. He also has soft spoil geotechnical design and investigation experience. Mr. Coleman is a member of several professional organizations, including the American Society of Civil Engineers, the American Concrete Institute, and the National Society of Professional Engineers.

Stephen McCaskie, P.E., is a senior civil and geotechnical engineer with Hanson Professional Services. He has 30 years of experience in project management, engineering, and QA/QC of flood protection, water resource, transportation, inland navigation, underground, port and harbor projects. He has planned, conducted, and supervised subsurface explorations, condition surveys/ evaluations/assessments, safety inspections, foundation analysis and design, and construction monitoring and inspection. In addition to handling operations and maintenance, he has worked on specialized foundation analyses, earth dam/levee and embankment design, instrumentation, data collection and analyses, soil-structure interaction, and earthquake engineering.
Mr. McCaskie is a member of the American Society of Civil Engineers, the Society of American Military Engineers, the Earthquake Engineering Research Institute, and several other professional organizations.

4.0 RESULTS – SUMMARY OF IEPR COMMENTS

The IEPR peer reviewers followed the processes described in Sections 2.4 through 2.6 to conduct their reviews, participate in the IEPR Comment Review Teleconference, and finalized remaining comments; Battelle entered these comments into DrChecks[SM]. These processes were in accordance with USACE guidance documents. Listed below are summaries of the general approach the IEPR peer reviewers used for their reviews, conclusions that the peer reviewers reached, and the status of any open issues including critical items.

4.1 Overall Review Approach

With feedback from USACE, Battelle developed the Charge to Peer Reviewers (see Appendix B) and provided it to the IEPR peer reviewers. Once they received the review documents, the IEPR peer reviewers were instructed to use the Charge to Peer Reviewers to focus their review, within their area of expertise, on those items that are critical to the successful design and construction of deep-mixed shear walls to stabilize levees and I-walls constructed on soft ground. The IEPR peer reviewers were advised that they could work both independently or together and that they could contribute to the reviews being conducted by the reviewer in the other discipline, as appropriate based on their expertise (Table 5). The peer reviewers were instructed not to discuss their review involvement or findings with anyone outside of the IEPR.

4.2 Summary of IEPR Comments

The 13 comments made on the Deep Soil Mixing Design Guidelines were placed into one of four categories based on the response provided by the USACE PDT. These categories included:

- For Information – comments made by the reviewers for which the USACE PDT provided additional clarification (2 comments)
- Suggestion for Clarification – small suggestions to improve the document clarity (3 comments)
- Value Added – comments that made an impact or change that would not have happened without the IEPR review (7 comments)
- Open Comments – critical issues on which the IEPR panel and USACE PDT could not come to resolution (i.e., non-concurrence) (0 comments)

The IEPR concluded that the Deep Soil Mixing Design Guidelines did not contain any significant technical errors. Based upon the discussions at the IEPR Comment Review Teleconference and subsequent closeout of DrChecks^{SM} comments, the USACE PDT is in agreement with the IEPR peer reviewers' concerns. It is important to note that, although the IEPR peer reviewers were chosen based on their expertise in a specific discipline, the IEPR peer reviewers have a broad range of experience that crosses disciplines (Table 5). Therefore, the comments made by a particular IEPR peer reviewer may not necessarily be in his specific discipline. All comments were resolved either through DrChecks^{SM} or at the IEPR Comment Review Teleconference.

4.3 Critical Comments and any other Open Issues that Remain to be Resolved

As a result of the IEPR Conference and resolution of all issues included in DrChecks^{SM}, there were no remaining open issues or critical comments at the conclusion of the IEPR of the Draft Design Guide.

5.0 CONCLUSIONS

The selection of the two IEPR peer reviewers using technical experience and potential COI criteria (as defined in the Statement of Work), as well as the IEPR process itself, were conducted in strict compliance with Section 2035 of the WRDA 2007, USACE peer review guidance documents, and the PRQCP. The IEPR process produced 13 comments that were evaluated, backchecked, and closed. The IEPR Comment Review Teleconference provided an effective format to communicate and discuss IEPR comments with the USACE PDT, which helped the IEPR reviewers' understanding of the technical details in the Deep Soil Mixing Design Guidelines. The IEPR comments also helped the USACE PDT identify inconsistencies in the Deep Soil Mixing Design Guidelines so that these issues could be addressed. Overall, the peer reviewers' comments improved the designer's understanding of the Deep Soil Mixing Design Guidelines by providing additional technical references, alternative design examples, and tabular-based data.

APPENDIX A

CHARGE TO PEER REVIEWERS

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FINAL CHARGE TO PEER REVIEWERS

OF THE

HURRICANE AND STORM DAMAGE RISK REDUCTION SYSTEM (HSDRRS)
Independent External Peer Review of the Design Guide for Levee and Floodwall Stability Using Deep-Mixed Shear Walls

by

Battelle
505 King Avenue
Columbus, Ohio 43201

for

U.S. Army Corps of Engineers
Coastal Storm Damage Reduction Center of Expertise
Baltimore District
Mark Chalecki, P.E.
10 South Howard Street
P.O. Box 1715
Baltimore, MD 21203

April 3, 2009

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TCN 09040
Scientific Services Program

The views, opinions, and/or findings contained in this report are those of the author and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other documentation.

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HURRICANE STORM DAMAGE RISK REDUCTION SYSTEM (HSDRRS)
of the
Independent External Peer Review of the Design Guide for Levee and Floodwall Stability Using Deep-Mixed Shear Walls

1.0 BACKGROUND

The Greater New Orleans HSDRRS Design Guide for Levee and Floodwall Stability Using Deep-Mixed Shear Walls ("Design Guide") is intended to provide guidance for design of deep-mixed shear walls to stabilize levees and I-walls constructed on soft ground in areas not subject to high levels of earthquake shaking. The scope of this guide is limited to the specialized design considerations and analysis procedures for deep-mixed shear walls to stabilize levees and I-walls in areas of low seismicity. Where appropriate, reference is made to existing documents for soil strength characterization, stability analysis methods, performance criteria, and other relevant procedures.

The importance of this document requires an objective independent peer review as a critical element in ensuring the reliability of the scientific analyses included within the document. In addition, Public Law (110-114) Water Resources Development Act (WRDA) 2007, Section 2035, requires a safety assurance review by independent experts on the design and construction activities of all HSDRRS projects. Review of the Design Guide, which will be applied to the design and construction of HSDRRS levee stabilization and I-wall construction projects, is critical to the safety assurance of each project.

The project will be conducted in partnership with the State of Louisiana. The term "State" refers to both the State of Louisiana and Local governing entities including the Southeast Louisiana Flood Protection Authority – East and West.

2.0 DOCUMENTS PROVIDED

The following documents were provided by the USACE for review and comment:

- Guide for Levee and Floodwall Stability Using Deep-Mixed Shear Walls, 10 February 2009 (Main Document)
- Appendix A: Earthen Levee with Deep-Soil Mix Support Beneath the Levee
- Appendix B: I-Wall with Deep-Mixing Support on Flood Side
- Lessons Learned by the Designer

The following reference to USACE regulations shall be followed in conducting the IEPR. This document is available at http://www.usace.army.mil/publications/eng-regs.

- ER 1110-1-12, Engineering and Design, Quality Management, 21 July 2006.

The following are USACE references to the Design Guide. The Engineering Regulation (ER) documents are available at: http://www.usace.army.mil/publications/eng-regs.

- Engineer Manual 1110-1-1905, Bearing Capacity of Soils;
- Engineer Manual 1110-2-1902, Stability of Earth and Rock-Fill Dams;
- Engineering Manual 1110-2-2505;
- Engineer Manual 1110-2-1913, Design and Construction of Levees;
- Engineer Manual 1110-2-2502, Retaining and Flood Walls;
- Engineer Manual 1110-2-2504, Design of Sheet Pile Walls;
- Engineer Technical Letter 1110-2-547, Introduction to Probability and Reliability;
- Methods for Use in Geotechnical Engineering;
- Engineer Technical Letter 1110-2-561, Reliability Analysis and Risk Assessment for Seepage and Slope Stability Failure Modes for Embankment Dams; and,
- USACE Hurricane and Storm Damage Risk Reduction System Design Guidelines.

3.0 PEER REVIEW PANEL

The peer review panel consists of one (1) Geotechnical Engineer and one (1) Civil Engineer.

Task	Action	Currently Suggested Dates
	Notice to Proceed (NTP)*	12 Mar 09
1	**USACE Kick-Off Meeting and Charge** USACE Kick Off Meeting* Draft Charge submitted to USACE for review USACE comments on Draft Charge Battelle prepares Final Charge (*delay between NTP and USACE Kickoff Meeting due to USACE program changes)	 26 Mar 09 27 Mar 09 27- 31 Mar 09 01 Apr 09
2	**Peer Reviewer Recruitment** IEPR peer reviewer under contract Final Charge and Review Documents to Panel IEPR peer reviewer Kick Off Conference	 31 Mar 09 01 Apr 09 03 Apr 09
3	**Document Review** Peer reviewers conducts review Battelle enters IEPR comments into DrChecks USACE Evaluator comment review and response Battelle Enters Panel Backcheck to Evaluator Reponses	 03- 17 Apr 09 20 Apr 09 27 Apr 09 04 May 09
4	**Document Review Teleconference**	11 Jun 09
5	**Final Report** Closeout all comments in DrChecks Submittal of Closeout Report (Final Report) Project Closeout	 26 Aug 09 TBD TBD

4.0 CHARGE FOR PEER REVIEW

Members of this peer review are asked to determine whether the technical approach and scientific rationale presented in the Design Guide are credible and whether the conclusions are valid. The reviewers are asked to determine whether the technical work is technically adequate, properly documented, satisfies established quality requirements, and yields scientifically credible conclusions.

Once all expert peer reviewers are on contract, Battelle will host a start of work meeting, currently slated for April 3, 2009. The review documents will be forwarded to the peer reviewers prior to this meeting in hard copy and electronic format; USACE reference documents will be available in electronic format only. Battelle will collate comments provided by the individual peer reviewer, ensuring that they are complete and responsive to the charge, and then enter the comments into DrChecks. After USACE provides their evaluator comments, Battelle will enter BackCheck comments to closeout each original comment.

The peer reviewers will participate in a review teleconference to discuss any unresolved issues with the USACE. The "State" will also be invited to participate in this teleconference. It is expected that most of the comments will be closed out prior to the teleconference. The review teleconference will allow discussion between the expert panel and the USACE evaluators. Following the peer review teleconference, USACE will have one week to close out their evaluator comments. The peer reviewers will then have an additional week to provide final responses and Battelle will closeout the comments.

General charge guidance for the peer reviewers is provided below:

4.1 General Charge Guidance

- Please answer the scientific and technical questions listed below and conduct a broad overview of the Design Guide.
- Identify, explain, and comment on assumptions that underlie engineering or scientific analyses.
- Evaluate the soundness of examples presented in Appendix A and Appendix B as applicable and relevant to your area of expertise.
- Evaluate whether the interpretations of analysis and conclusions are reasonable.
- Please focus the review on scientific information, including factual inputs, data, the use and soundness of models, analyses, assumptions, and other scientific and engineering matters that inform decision makers.
- Preparation of review comments should contain the specific reference to the Design Guide document.
- Please **do not** make recommendations on whether you would have presented the work in a similar manner.
- Please contact the Battelle Project Manager or the Deputy Project Manager (Lauren Baker-Hart, bakerhartl@battelle.org) for requests of additional information.
- If desired, IEPR peer reviewers can contact each other during the review process.
- In case of media contact, notify the Battelle Project Manager immediately.

- Your name will appear as one of the expert peer reviewers. Your comments will be included in the Final Report.

Independent External Peer Review of the Design Guide
For
Levee and Floodwall Stability Using Deep-Mixed Shear Walls
FINAL CHARGE

1. Based on your expertise, please comment on the recommended procedure for design of deep-mixed shear walls. Is there sufficient detail for real-life application?

2. Based on your expertise, is the provided technical information appropriate and sufficient to support the use of the Design Guide as a stand-alone document? Why or why not?

3. Please comment on the overall analysis presented in the Design Guide. Is there any information missing that should be included in order to complete the analysis?

4. Based on your expert opinion, is there any information included in the Design Guide that is not useful or relevant?

5. Do the stated limitations of the document (i.e., seismic stability, erosion/piping, and settlement/lateral deformation considerations) substantially affect the designer's ability to fully evaluate the design method?

6. Please comment on the validity and the completeness of the documented recommendations provided in the Design Guide.

7. Evaluate the typical procedure presented in Appendix A: Earthen Levee with Deep-Mixing Support beneath the Levee and comment on the design guidance provided.

8. Review and comment on completeness of the guidance provided in Appendix B: I-Wall with Deep-Mixing Support on Flood Side.

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APPENDIX B

PEER REVIEW MEMBER RESUMES

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Jesse Eugene Coleman, Jr., P.E.
Geotechnical Engineer

Experience
40+ years

Expertise
Design management
Earth dams, dikes, levies
Pavement evaluation
Transportation projects
Geotechnical investigations
Construction materials testing

Education
M. S., Civil Engineering, University of Texas at Arlington 1974
B.S., Civil Engineering, Lamar University 1968

Registration
Professional Engineer:
Texas, #39721

Professional Affiliations
American Concrete Institute
American Society of Civil Engineers
American Society of Civil Engineers Geo-Institute
National Society of Professional Engineers
Texas Society of Professional Engineers

Specialized Training
MACTEC
Contract Review Seminar
Project Manager Leadership
Quality Assurance Training
Par Leadership and Teamwork
VASS Executive Sales

USACOE
PCASE Workshop
Construction Contract Change Orders

NAVFAC
Design Contract Management
Equal Opportunity Employment
Management by Objectives
Fundamentals of Supervision
Value Engineering Workshop
Effective Writing for Senior Managers
Budget and Resource Management
Fire Protection Design Workshop
Supervisor Course, Navy EEO Course
Supervisor Course, Peak Performance Training
PERT/CPM

Summary of Experience

Mr. Coleman, Principal Engineer with Coleman Consultants in Watauga, TX, provides senior review and project management for design and construction engineering projects. He has extensive background in planning, performing, and managing design construction, and has significant design leadership experience in the civil, geotechnical, and structural sectors for the federal government and for private, commercial, and industrial clients.

As an engineering manager, he developed major project experience in the design of various infrastructure projects including multi-story enlisted man housing; a coal fired co-generation plant for the U.S. Naval Facility at Bremerton, WA; numerous designs of airfield pavement, parking, and streets, water and wastewater utilities, aircraft hangars; and design of earthfill dams. He has managed consulting and in-house designers for a variety of industrial clients in the Dallas/Ft. Worth area, as well as Naval Facilities Engineering Command (NAVFAC) projects in California, Nevada, Washington, Arizona, Oregon, Diego Garcia, Guam, the Philippines, and Thailand.

Relevant Projects

- **Design Management**
  Mr. Coleman has served as the Design Division Manager for numerous projects for NAVFAC both in the U.S. and overseas. These projects have involved design for recommended additions and alterations to existing facilities as well as for construction of new MILCON facilities. Mr. Coleman has served as the project manager for project design, solicitation, and construction of various types of military facilities. He is experienced in developing repair recommendations for existing facilities, as well as evaluation and design recommendations for new facilities. He has extensive experience in the area of dams, levees, flood routing, lined and unlined drainage channels, storm water diversions, stream and channel diversions, retaining walls, deep foundations for the heavy, settlement-sensitive equipment associated with repair facilities and aircraft hangars.
- **Earch Dams, Dikes, and Levees**
  Mr. Coleman has directed design, geotechnical explorations, construction inspections, and performance monitoring for numerous dams, dikes, and levees in California, Georgia, and Washington. He has directed and provided technical review and design for explorations for new dams as well as studies of existing dams, and these have required geophysical surveys, hydrology, seismology, static and dynamic laboratory testing, and special field sampling and testing techniques. Mr. Coleman served as senior geotechnical engineer during design and construction of six dams and as senior engineer manager for the dynamic stability assessment and dambreak analysis.
- **Geotechnical Investigations**
  Mr. Coleman has managed and performed numerous geotechnical explorations related to commercial and public developments, dams and levees, storm water diversions, channel and stream diversions, various industrial facilities, bridges and highways, and waste treatment and disposal facilities. Many of these projects have required coordination with outside consultants performing a wide variety of tasks.

Specification Writing for Construction Contracts

ASCE
Guidelines for the Evaluation and Repair of Residential Foundations (ASCE)

AIA
Risk Management in the New Millennium

USALMC
Management of Defense Acquisition Contracts

- **Construction Materials Testing**
  Mr. Coleman has extensive experience in the construction field. He has monitored the installation of various foundation systems, which have included concrete-lined flood control channels, dam and levee construction, sheet piles, spread footings, driven piles, auger cast piles, and drilled shafts. He currently manages construction materials testing activities involving soils, concrete, and steel on large construction projects in Texas.
- **Transportation Projects**
  Mr. Coleman has directed and performed geotechnical and design field explorations for rail and highway bridges and embankments for the Dallas Area Rapid Transit (DART). Specific experience has involved foundation design recommendations for deep foundations and stabilization of foundation soils for abutment fills associated with a proposed expressway bridge, design recommendations for bridge relocations, design of the NC1B Tunnel Portal, and geotechnical design of the Mockingbird Station. Mr. Coleman has participated in and provided senior technical review for port facility construction projects along the coasts of California, Australia, and the Philippines. Specific experience has involved sheet pile retaining walls, foundation design and construction recommendations for large diameter storage tanks, wharves, piers and mooring dolphins, quay walls, and rail lines associated with port construction. Specific site stabilization techniques consisting of dynamic compaction, deep subsurface drainage with wick drains, vibroflotation, and surcharging have been studied in relation to port facility and other coastal construction in the DFW area, California, Australia, and the Philippines.
- **Pavement Evaluation**
  Mr. Coleman has managed and provided senior technical review on numerous pavement evaluation projects involving both new pavements and repair of existing distressed pavements for airport paving. He has investigated many pavement failures ranging from residential streets to heavy vehicle traffic areas and has recommended the use of lime-soil, soil-cement, soil-aggregate, and fabric.
- **Expert Testimony**
  Mr. Coleman has provided expert testimony in both arbitration hearings and jury trials involving geotechnical design, slope instability, groundwater control, sheet pile retaining walls, deep foundation construction and concrete sampling and testing. His testimony has primarily been concerned with the geotechnical, geologic, design, construction, and quality control testing aspects of the cases considered. Mr. Coleman has performed numerous investigations of building and pavement failures for insurance companies and their legal representatives on cases that were settled prior to trial.

Stephen L. McCaskie, P.E.
Civil Engineer

Experience
30 years

Education
M.S., Civil Engineering (Geotechnical Engineering), Carnegie-Mellon University, 1980
B.S., Civil Engineering (Geotechnical/Structural Engineering), University of Miami, 1977
Graduate Certificate, Earthquake Engineering, Washington University, 2004

Registrations
Professional Engineer
Missouri
California
Illinois
Florida
Kansas

Geotechnical Engineer
California

Professional Affiliations
American Society of Civil Engineers
Earthquake Engineering Research Institute
Society of American Military Engineers
American Council of Engineering Companies - Missouri
Missouri Society of Professional Engineers
United States Society on Dams
Association of State Dam Safety Officials
International Society for Soil Mechanics and Foundation Engineering

Tau Beta Pi (National Engineering Honor Society)

Summary of Experience
A senior geotechnical engineer with Hanson Professional Services, Springfield, IL, Mr. McCaskie primarily serves the government market. He has experience in project management, engineering and QA/QC of flood protection, water resource, transportation, inland navigation, underground, port and harbor projects; planning, conducting, and supervising subsurface explorations, condition surveys/evaluations/assessments, safety inspections, foundation analysis and design, construction monitoring and inspection; operations and maintenance; specialized foundation analyses, earth dam/levee and embankment design, instrumentation, data collection and analyses, soil-structure interaction, and earthquake engineering.

Relevant Projects
- **USACE, St. Paul District, Design Documentation Report for Roads Acting as Dams, Devils Lake, ND.** Project Manager, completing the Design Documentation Report for 12 mi of roads adjacent to Devils Lake, currently impounding water due to the flooding of Devils Lake: design of dam alignments and features; slope stability and seepage analyses; embankment design to minimize future construction costs, constructability and sequencing, riprap sizing; and develop standards for utility and infrastructure features crossing the embankments.
- **USACE, Rock Island District, Lockport Pool Stage IB Approach Dike, Chicago Sanitary and Ship Canal (CSSC), Will County, IL.** Project Manager, responsible for test section evaluation, instrumentation plan, and construction monitoring; planning, development, design and implementation of test plan and instrumentation program including: observation wells, seepage weirs, reference points, survey monuments, inclinometers, and data loggers to monitor and evaluate seepage cutoff barrier (cement/bentonite) construction for the 4,300 ft long west approach dike on the CSSC.
- **USACE, Rock Island District, Lockport Concrete Canal Wall, Chicago Sanitary and Ship Canal (CSSC), Will County, IL.** Project Manager. exploration and evaluation of existing canal wall. Geotechnical engineer. Roller Compacted Concrete (RCC) replacement canal wall and replacement guidewall, slope stability analyses, RCC wall stability, construction methods and sequences, existing wall demolition, thermal study, preliminary designs, and Design Documentation Report (DDR) for the 2.2 mile long east canal wall on the CSSC.
- **USACE, St. Louis District, Monarch-Chesterfield Levee-Walnut Grove Floodwall, St. Louis County, MO.** Geotechnical engineer, provided engineering services for a realignment of an urban flood protection system involving 1,200 ft of pile supported, reinforced concrete floodwall, to provide 500-year level of protection for 4,700 acres of commercial/industrial development, including I-64 and the Spirit of St. Louis Airport, from the Missouri River and its tributaries.
- **USACE Blue River Federal Complex, Kansas City, MO.** Geotechnical engineer, provided data review, analyses and design of a 2,800-ft-long floodwall and stop log gaps/rolling gates for the Blue River Federal Complex.
- **USACE, St. Paul District, Lock and Dam #4, Alma, WI.** Geotechnical engineer for geotechnical evaluations, foundations analysis and designs, and construction consultation for rehabilitation of lock chamber monoliths, guidewalls, and support buildings, for the 50-year-old Lock and Dam #4 on the Mississippi River.

- **Monarch-Chesterfield Levee District, St. Louis County, MO.** As District Engineer (1993-2007), providing engineering services for an urban flood protection system involving 12 mi of earthen levee, closure structures, floodwalls, relief wells, and pump stations to protect 4,700 acres of commercial/industrial development, including I-64 and the Spirit of St. Louis Airport, from the Missouri River. Services include operations, maintenance, inspection, flood monitoring, analyses, design, permitting, and construction of post-1993 improvements and 500-year levee improvements, wetlands mitigation and recreational use, and coordination with all Federal, State and local jurisdictions.
- **Riverport Levee District, St. Louis County, MO.** District Engineer (2004-2007), providing engineering services for an urban flood protection system involving an earth levee, relief wells and pump station to protect 410 acres of commercial development from the 500-year Missouri River flood. Services include engineering evaluations, flood protection and interior drainage system operation, maintenance, inspection, and monitoring.
- **Lakeside 370 Levee District, St. Charles County, MO.** District Engineer (2005-2007), providing engineering services for an urban flood protection system, involving an earth levee, relief wells and pump station to protect 1,400 acres of commercial development from the 500-year Mississippi River flood. Services include engineering evaluations, analyses, flood protection and interior drainage system, operation, maintenance, inspection, and monitoring.
- **Missouri Bottoms Levee District, St. Louis County, MO.** Project manager. Provided preliminary planning, geotechnical explorations, analyses, design, and permitting for upgrade/improvements to the existing levee protecting over 3,000 acres from a 500-year Missouri River flood. Protection will include 10 miles of earth levee, closure structures, and floodwalls.
- **City of Chesterfield Engineering Services, Chesterfield, MO.** Project Manager, responsible for engineering services for recertification of the Monarch-Chesterfield Flood Protection System, including 12 miles of earthen levee, breached during the 1993 flood, protecting approximately 4,700 acres of commercial/industrial development including condition surveys and safety inspections, geotechnical explorations, embankment/ floodwall/closure structure stability, embankment scour/erosion protection, interior drainage, and operations and maintenance plans in response to a request from FEMA.
- **Monarch-Chesterfield Levee District, St. Louis County, MO.** Project Manager, provided explorations, analyses, design and development of construction documents, permitting, and construction monitoring and inspection, for repairs and improvements for recertification of the Monarch-Chesterfield Levee to a 100-yr level of protection.
- **City of Chesterfield Monarch-Chesterfield Levee System Upgrade, Chesterfield, MO.** Project Manager, provided permitting studies and preliminary engineering designs for upgrade of the Monarch-Chesterfield Levee System to a 500-year level of protection.
- **USACE, Clarksville, MO, Olmsted, IL, St. Louis District, Louisiana, Mississippi.** Geotechnical engineer, provided a broad range of geotechnical evaluations for USACE projects on the Mississippi River, the Ohio River, the Red River (LA), and Pelucia Creek (MS).