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February 20, 2006

LTG Carl A. Strock, P.E.
Chief, U.S. Army Corps of Engineers
HQUSACE
441 G Street, N.W.
Washington, DC 20314-1000

Dear General Strock,

SUBJECT: External Review Panel Progress: Report Number 1

The American Society of Civil Engineers (ASCE) presents this progress report, which summarizes review comments by its External Review Panel (ERP) on Report 1 prepared by the Interagency Performance Evaluation Task Force (IPET). The mission of the IPET is to provide credible and objective scientific and engineering answers to fundamental questions about the performance of the hurricane protection system in the New Orleans metropolitan area and to assist in the reconstitution of the hurricane protection system. The role of the ERP—which is composed of 14 experts who possess a range of technical expertise—is to provide an objective, independent technical review of the IPET's activities and findings.

The purpose of this letter is to summarize the findings of ASCE's ERP in its review of the *Performance Evaluation Plan and Interim Status, Report 1 of a Series*, issued by the IPET on January 10, 2006, and referred to herein as Report 1.

The ERP has been engaged in reviewing the IPET's work since early November 2005. The ERP has toured damaged areas of New Orleans, held three meetings (two with the IPET) and several conference calls, reviewed documents, and had dozens of conversations and e-mail exchanges with IPET members. The communication lines between the IPET and the ERP are functioning well, and a good working relationship has been established. The ERP has provided the IPET with dozens of comments, questions, and suggestions on a continuing basis. The IPET has considered all of the ERP's comments and most have been incorporated into the IPET's work plan.

Comments on IPET Report 1

In general, and with the exceptions noted in the individual task descriptions in the appendix, the ERP is satisfied with the work and progress to date. Report 1 met the ERP's expectations as an early progress report.

The information in Report 1 on high-water levels and hydrographs is a good preview of what the ERP anticipates in subsequent reports—that is, detailed, credible, factual information pieced together from various sources to provide a clear picture of what happened. The ERP is especially interested in the effort under way to understand the causes of levee and floodwall failure, such as

occurred on the 17th Street Canal. With respect to the levee and floodwall failure on the 17th Street Canal, the IPET has drilled additional soil borings, conducted field cone penetration tests, performed additional laboratory tests on soil samples, created new cross sections of subsurface conditions, generated new data sheets compiling test data, excavated a test trench through the failure zone, exhumed large block samples of material for testing purposes, initiated a series of computer analyses of failed zones, and begun a program of centrifuge modeling. The ERP anticipates that the IPET will use this information, when finalized, to achieve a comprehensive understanding of the causes of the failures and to provide a benchmark for how other areas should be handled in the future. The final IPET report will also serve as a basis for assessment of system performance, design processes, and institutional or organizational factors that may have played a role in the failures.

Additional comments and suggestions, presented by task, are attached in the appendix.

Findings to date

The IPET presented no specific findings and conclusions in Report 1, which is not surprising in view of the many questions that as yet are unanswered. The ERP agrees with the IPET's approach of first defining the facts with a sufficient level of completeness before drawing conclusions. The response of the hurricane protection system is complex and multifaceted, and many open questions remain to be answered.

Recommendations of the ERP

Several issues critically influenced the performance of the hurricane protection system. The ERP believes that it has a responsibility to comment on these issues at this time and to encourage full assessment, even of the issues that are beyond the scope of the IPET's work. Four critical areas warrant urgent and thorough examination.

1. ***Organizational issues:*** No one person or organization is in charge of the New Orleans hurricane protection system. Local levee districts are responsible for maintaining levees. Local parishes are responsible for operating pump stations (and even for deciding whether they will be operated during a hurricane). Numerous penetrations affecting such infrastructure as rail lines, bridges, and roadways have been made below the tops of levees and floodwalls under various jurisdictions. Construction contracts are awarded piecemeal, sometimes resulting in abrupt discontinuities in the elevations of floodwalls or levees. Even within the U.S. Army Corps of Engineers differing levels of responsibility exist at the district, division, and headquarters levels. The City of New Orleans, the state of Louisiana, and perhaps other entities also are involved in hurricane protection for New Orleans.

   The ERP sees clearly that organizational complexities and the ways in which decisions are made are among the most important factors that influenced the performance of the hurricane protection system. Organizational effectiveness has been and will continue to be questioned, with justification. It is impossible for the ERP to conceive a mechanism through which the levee system can be rebuilt and operated effectively and efficiently with such organizational discontinuity and chaos. The ERP recommends that organizational issues be assessed critically and thoroughly as soon as possible.

2. ***System issues:*** The hurricane protection system of New Orleans evolved over a long period of time. The system is not an integrated, well-thought-out system; rather, it is a joined series of individual pieces conceived and constructed piecemeal. Examples include the following: (1) the canals, which evolved over a period of decades to accommodate the pumping technologies available at the time and the continuing land reclamation northward toward Lake Pontchartrain (even though the logic of having many miles of exposed levee and floodwalls along the canals, as opposed to closing off the mouths of the canals with a gate or short section of levee, is weak at best); (2) the connections between rigid structures and earthen levees, which experienced numerous failures during Katrina; (3) discontinuities and differences in crest elevations of levees and floodwalls; and (4) the pumps, which were designed to remove rainwater and infiltrating groundwater but, when not turned on, are not protected from backflow and exacerbate flooding during a hurricane.

   A logical hurricane protection system for New Orleans would integrate components and the management of components, would be robust and resilient, and would contain a level of redundancy sufficient that, if a levee failed, all would not be lost. A systemwide strategy would also ensure that critical structures—for example, pumping stations, hospitals, places of refuge, and electrical generation and distribution nodes—were protected. The lack of a broader, system-oriented strategy exerted a major deleterious influence on the performance of the system and deserves serious consideration.

3. ***System development:*** It is obvious that the hurricane protection system for New Orleans failed miserably during Katrina. That the system was so clearly overwhelmed and failed so catastrophically demonstrates to the ERP that fundamental flaws were part of how the system was conceived and developed. For example, what was the basis for selecting the standard project hurricane and, hence, the authorized level of protection? What process was in place to review the safety of the design as new knowledge evolved over time? How safe and redundant was the system intended to be upon design? Was adequate funding in place to ensure that satisfactory design standards could be implemented? How were safety margins for design established, and are they appropriate in light of new knowledge and the risks involved? How was the potential for loss of life factored into decision making?

4. ***Overtopping of levees:*** A fundamental flaw in the floodwalls and levees is that they include no means of accommodating overtopping that does not inflict major damage or destruction. Once the levees were overtopped during Katrina, rushing water eroded away many sections of levee and in other cases undermined floodwalls. Most of the 350 miles of levees in New Orleans are unprotected from devastating damage and potentially total destruction if overtopped. No matter how high the levees are built, a possibility always remains of a hurricane causing a surge elevation that is even higher than the one for which the levees were designed.

   One of the lessons of Katrina that is already obvious is that once the levees were overtopped, destruction was catastrophic. In addition to the tragic loss of life, there were at least two other critical results: extensive and catastrophic flooding and an enormous destruction of capital investment. The question is not whether the levees will again be overtopped but when and by how much they will be overtopped. The levees need to be protected from catastrophic failure resulting from overtopping.

The ERP is convinced that there are important lessons to be learned concerning the planning and design processes. As a nation, we must understand these lessons if we are to do better in protecting New Orleans and other American cities from the next major hurricane that strikes.

The ERP looks forward to continuing its work with the IPET and to offering comments when it issues Report 2.

Respectfully submitted,

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- Jurjen Battjes, *Levees/Flood Control*, Delft University, the Netherlands, Retired
- David E. Daniel, P.E., *Geotechnical Engineering*, University of Texas at Dallas
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- George J. Tamaro, P.E., *Soil-Structure Interaction*, Mueser Rutledge Consulting Engineers
- Robert G. Traver, P.E., *Urban Drainage*, Villanova University
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# Appendix

## Task-by-Task Comments on Report 1 and the IPET's Ongoing Work

### Data Collection and Management (Task 1)

Task 1 of the IPET's scope of work is focused on data collection and management. Its objective is to assemble a comprehensive set of data and body of information about the conditions before and after Hurricane Katrina as well as a complete history of construction and maintenance. Task 1 is crucial for successful completion of the nine other IPET tasks. The ERP has not made any specific review comments on task 1; rather, it has focused on the amount and quality of the data required for each of the nine other tasks. The ERP's comments regarding data collection and management have thus been made on a task-by-task basis for tasks 2–10.

### Interior Drainage and Flooding Analysis (Tasks 2 and 3)

1. Progress to date on objectives

The progress to date on the interior drainage and flooding analysis is satisfactory. All comments expressed by the ERP have been discussed with the IPET task 2 and task 3 coleaders and have been resolved, accepted, or incorporated into the work plan. These comments included a fusion of the previously independent task 2 and task 3, a title change, an expansion of the calibration and sensitivity analysis, a review of the impacts of debris, a review of multiple storm tracks and scenarios, and the capturing of lessons learned. The IPET team has selected the hydrologic models (HEC-HMS and HEC-RAS), has begun its analysis, and is making progress.

2. Expected progress toward Report 2

As stated in Report 1, the Report 2 goals for the priority 1 areas are to have 75 percent completion of the HEC-RAS and HEC-HMS models using non-Katrina events for calibration and to have early results from the Katrina event. For the priority 2 events, the team expects 25 percent completion of the modeling. It also expects to have drafts of the output presentation format.

The calibration and verification for these hydrologic models are dependent on the available drainage system data (breach, precipitation, pumping, et cetera). This task is expected to continue past the June 1 date. A challenge for the team is to accomplish the initial verification using an independent storm event not only to provide confidence in the model results to meet the goals of the IPET team, but also to deliver a model that can be used in future phases of the project. The results section of Report 2 should include a discussion of the calibration and verification effort to whatever extent calibration and verification were achieved.

Report 2 should also consider the following:

- Discuss the methodology employed by HEC-RAS in a closed conduit application.

- Define "pump station performance scenarios" and discuss which scenarios were considered and the logic behind the decisions to evaluate those scenarios.

- Further consider the quantification of the contribution of the pumping stations and drainage system in the dewatering of flooded areas. (Report 1 does not state that Report 2 will make this quantification; however, such quantification is described in the list of objectives.)

- Review the significant dewatering that occurred as a result of water flowing back through the breaches in the levee into Lake Pontchartrain, bearing in mind that the hydraulic conditions governing this reverse condition may change.

- Reiterate the list of objectives and describe how those objectives were addressed.

3. ERP-IPET interaction

The ERP is in regular contact with the IPET team through e-mail correspondence and bimonthly telephone conference calls. The ERP has been provided with sample copies of the data files pertaining to 17th Street for review. To date, all recommendations have been accepted in one form or another.

4. Study recommendations

a. Debris: The assumption that debris was not a problem needs to be verified. If in fact it was a problem, a work-around is required.

b. Breaches: The modelers need to focus on the "breaches" and "low spots" of the levee system that turned into weirs during the storm. Currently, the Corps of Engineers' Task Force Guardian is correcting some of these areas. The breaches need to be modeled as weirs both to verify the Katrina performance and to assess the performance for areas where no levee failures occurred. A low spot example is at the London Avenue Canal pump station. Note that the overflows at this location would have been more severe if the breach had not formed.

c. Historical review: It may be prudent to consider the historical performance of the drainage system (for example, the performance and possible failure of the St. Bernard levee in 1969 during Hurricane Camille).

5. Lessons learned

Overtopping analysis: During the model runs, areas that overtop can be identified. The depth of overtopping and the length of time the area is overtopped can be used to determine which areas need to be analyzed or strengthened.

Collection systems: Areas that may need supplemental collection to transport flow to the pumping station should be identified. Debris may be a consideration.

## Storm Surge and Wave Analysis (Task 4)

1. Progress to date on objectives

This task is moving forward in answering the following important question (see IPET objectives, page 6 of Report 1):

> *What were the storm surges and waves used as a basis of design, and how do these compare to the storm surges and waves generated by Katrina?*

The progress to date on the storm surge and wave analysis is satisfactory. It is much closer to completion than other tasks, as it should be, since the data it is producing will be used in several other tasks. An extensive report has been produced describing in detail the aims and methods used as well as the key results obtained so far.

The IPET team for task 4 has provided a time series of winds, water levels, and wave conditions for Katrina at all points of interest for the 70 percent solution. Moreover, the advanced circulation (ADCIRC) model has been modified to include effects of land-water transitions on winds blowing from land onto the water. Some attention to high-water marks shows that the surge elevations are very close even without the additional refinement in the grid and wind fields. Nevertheless some of the observed high-water marks in the southwestern part of Lake Pontchartrain are lower than the model results.

Although breaching is not included in this analysis, overtopping of the levees is. This information may be reported to the coleaders for tasks 2 and 3, but the members of those groups have stated that they will use the exterior water level only as input to their own models. Comparison of the storm surge and wind and wave data has proceeded. The simulated offshore Gulf of Mexico waves appear to compare quite well with those measured The waves in Lake Pontchartrain appear similar to the measured data—although the wave heights are underestimated in the buildup phase of the storm—but the performance of the wave gauge during the storm calls into question the accuracy of the field data. However, these are the only wave data that were measured during the storm in Lake Pontchartrain.

2. Expected progress toward Report 2

By the time Report 2 is released, results of additional analyses of high-water marks and hydrographs should be available, as well as a comparison of surge and wave results with values used in the design. The ADCIRC grid and the wave grids will be extended to cover the Mississippi coastal region, use a higher spatial resolution, and incorporate data corrections and the lidar elevations of levees. The wind adjustments to the H*Wind model will be complete and these will be incorporated into the wave model and ADCIRC. Tide and riverine flow will be incorporated into the storm surge work during the next phase of storm surge modeling for the specific Katrina time period. Moreover, the storm surge and STWAVE models will be linked via the wave radiation stress. In consultation with the task 10 coleaders, a set of historical and hypothetical storms should be selected and generated for simulation so that statistics on surge elevations and waves can be

obtained in the context of a risk analysis.

3. ERP-IPET interaction

The ERP is in contact with the IPET team through e-mail correspondence and telephone conference calls. The IPET team provided the ERP with sample copies of the data files via file transfer protocol so that the ERP could review them before Report 1 was released.

The IPET team has reviewed and responded to the comments presented by the ERP and has modified the scope to incorporate most of them. The IPET has agreed to consider the application of SWAN in more detail to determine if the STWAVE model will provide adequate results in Lake Pontchartrain during a rapidly changing wind field.

4. Study recommendations

The ERP suggests that the IPET consider the following as it moves toward Report 2:

- Evaluate very carefully the incorporation of whitecap-induced momentum flux in addition to a conventional air-sea drag formulation in which the flux may already be embedded.

- Evaluate the impact of temporally and spatially variable wind fields in the lake to investigate the acceptability of STWAVE versus SWAN wave model results.

- Add original high-water lines to all contour plots for ease of viewing when looking at inundation maps on which the location of the original shoreline is not apparent.

- Communicate regularly with the tasks 2 and 3 coleaders to determine what information they will use to support their internal hydrologic and hydraulic studies.

5. Lessons learned

Most of the lessons learned will be apparent in June and beyond. Some, however, are already clear:

- The ADCIRC needs better winds than the PBL model for simulation of real storms.

- It is important to validate the surge model and the wave model with more wave instrumentation for future storms. This is true in Lake Pontchartrain as well as along the coast.

## Hydrodynamic Forces and Overtopping Analysis (Task 5a)

1. Progress to date on objectives

Overall, the achievement to date in this task is still very much in a preliminary, preparatory stage. Simple analytical models have been formulated for wave penetration and transmission, for wave forces on walls, and for run-up and overtopping; results have not yet been reported.

Detailed numerical models (Boussinesq, Navier-Stokes) are applied to assess wave action against levees with or without floodwalls. These models have a very high temporal and spatial resolution. The ERP is of the opinion that these levels of detail are higher than is commensurate with the use that can be made of the results. The IPET team is aware that this detail may be more than is necessary and will further evaluate the needs after the first phase of modeling is complete.

The ADCIRC model was refined to provide a high degree of resolution in the canals where the floodwalls failed. It is being compared with high-water marks but those results are not yet available. Similarly, STWAVE is being employed to evaluate wave transmission and generation within the canals, and a physical scale model is in preparation. No results from these activities are available yet. The members of the IPET task 5a team collected some additional data for specific high-water marks to use in these tasks. They also commissioned a multibeam bathymetric survey at the entrances to the 17th Street and London Avenue canals as well as some surveys within the canals. Delays of the surveys inside the canals have affected completion of the physical model. Construction of the physical model is scheduled to be complete in mid-February.

The potential impact force on a wall from a loose barge has been assessed, with good results. This analysis was performed to determine the potential impact force from a free-floating barge.

The ERP commented that the nappe trajectory over the walls and the discharge coefficient may be much different than illustrated in Report 1, owing to the absence of an air source under the nappe.

2. Progress expected by Report 2

By Report 2, the physical model will be constructed and some tests will be completed. A demonstration will be given at the next IPET-ERP meeting. The results of the effort should be at the 60 percent completion point. No results are available for the numerical modeling using the STWAVE for the Industrial Canal and the 17th Street and London Avenue canals. The grid has been shown, but the model is still undergoing sensitivity testing. Results are expected by Report 2. Results of wave forces using the Boussinesq model should be at the 60 percent completion point by Report 2. The analysis for potential impact forces from a loose barge should be well beyond the 60 percent stage for Report 2.

Report 2 is to include information about the needs of other tasks in relation to task 5a.

3. ERP-IPET interaction

Communications between the ERP and the IPET have been cordial and informative. It has been agreed that interim reports on specific topics will be distributed for review between now and preparation of Report 2. The ERP members who are available to attend the IPET-ERP meeting in March in Vicksburg, Mississippi, will meet the day before the meeting to review the progress being made on the physical model and to discuss the numerical modeling.

4. Study recommendations

The ERP suggests that the IPET evaluate the importance of the depth of investigation in the scope of this task as derived from what is required to answer the five questions posed by the IPET in Report 1 as it moves toward the second report. More specifically:

- Coordinate with task 2 and task 3 coleaders to determine their needs with respect to water levels along levees and floodwalls and wave overtopping of those structures.

- Coordinate with task 7 coleaders to determine their needs with respect to water levels along and wave forces against levees and floodwalls.

- Use as much pre-Katrina bathymetric data for the analyses as possible, since post-Katrina surveys are not fully representative.

5. Lessons learned

Lessons to be learned will be apparent in June and beyond.

## Geodetic Vertical and Water Level Datum Assessment (Task 6)

1. Progress to date on objectives

Work activities reported to the ERP are progressing to reach milestone targets. Current field survey data are necessary to support work of other task groups. The establishment of a common datum for historical survey data and the definition of mean sea level are critical to the understanding of elevation issues that are part of the IPET charge.

2. Expected progress toward Report 2

All of the new field data collection is expected be completed prior to Report 2. The review of historical datums and relationships between various datums over the years in the southern Louisiana area are also projected to be completed. Establishment of the ties between NAVD88 (2004.65) and the NOAA Tidal Benchmarks will enable NAVD88 (2004.65) links to historical tide stations and local mean sea level to be completed.

Report 2 will include an evaluation of the relationship between design elevation and current elevation as related to the local mean sea level for several construction projects from the 1980s and 1990s including :

a. Parallel protection (levees, floodwalls, and flood-proofed bridges) along the 17th Street, Orleans Avenue, and London Avenue outfall canals

b. IHNC (breach site)

c. Mississippi River-Gulf Outlet (MR-GO): Bayou Bienvienue and Bayou Dupre

Providing information on the changes over time of the elevations of benchmarks used in the design and construction of flood control and hurricane protection projects in the study area will be necessary in the evaluation of effects of subsidence.

3. ERP-IPET interaction

The ERP is in contact with the IPET team via e-mail correspondence and has received the revised task outline for Report 2.

4. Study recommendations

The ERP had no recommendations on the task implementation strategy. The ERP's concerns focus primarily on the need for a clear understanding of how the effects of subsidence in the New Orleans area may have played a role in the level of protection afforded by projects constructed over the past several decades and the need to capture the elevation data from all task areas in a consistent datum (NAVD88 [2004.65]). As part of the task 6 Report 2, a methodology for conversion of the previous vertical datum to NAVD88 (2004.65) will be described.

5. Lessons learned

The establishment of a consistent datum for the region will allow for long-term monitoring of flood/hurricane protection elevations relative to the local water surface elevation datum and to better understand the effects of subsidence in the area on the relative level of protection.

## Floodwall and Levee Performance Analysis (Task 7)

The objectives and scope of this task are set forth on page 110 of the IPET's Report 1:

*This task . . . has the responsibility to determine how the flood protection structures performed in the face of the forces to which they were subjected by Hurricane Katrina, and to compare this performance with the design intent, the actual as-built condition, and observed performance as depicted in Figure 61. This task also includes understanding why certain structures failed catastrophically and others did not.*

The approach is stated on page 113:

*The approach for the evaluation of the levees and floodwalls making up the New Orleans area (including Saint Bernard and Plaquemines [p]arishes) hurricane and flood protection system will involve conducting a comprehensive assessment of background information on the geology of the area and the corresponding geological conditions along the system, the history of the construction, design criteria and approach, actual design documents and the as-built drawings for the system, and inspection and maintenance records. The entire levee system will be examined to identify areas or reaches that have performed satisfactorily and those that have suffered damage.*

The ERP concurs with both the statement of objectives and the approach for attaining them. The ERP emphasizes that these assessments and the conclusions drawn from them must provide not only the factual information needed to understand the causes of the failures at specific locations on the canals and levees, but also the information needed to understand similarities and differences between these locations and the sections that did not fail. Only with comparisons of this type will it be possible to assess the safety of the overall system and develop a meaningful answer to the IPET's question 5 (see "The Questions Synthesized" presented by Ed Link at the IPET-ERP meeting in Reston, Virginia, January 9–10, 2006):

*Following the immediate repairs, what will be the quantifiable risk to New Orleans and vicinity from future hurricanes and tropical storms?*

1. Progress to date on objectives

The work plan for task 7 was approved by the ERP at the January IPET-ERP meeting in Reston. A plan for compiling the information needed for evaluation of performance has been developed. The status, schedule, and target dates for completion of the subtasks within the work plan are given on pages 118–120 of Report 1.

Overall progress appears to be consistent with this schedule.

2. Expected progress toward Report 2

The work schedule is ambitious given the vast amount to be done. Nonetheless, we are optimistic that the IPET team in charge of task 7 will be able to meet the challenge. The next meeting (March 9–10) will be the last opportunity for full interaction between the IPET and ERP teams

while there is still time for the ERP's input to influence the work to be completed, so it is critical that by then sufficient results be available to provide assurance that the overall objectives of the work will be achieved by June 1.

We note that the geotechnical structure performance analysis, which originally was to be task 5b and comprised physical modeling and geotechnical centrifuge testing of floodwalls and levees, is now coordinated with and forms part of task 7. The ERP endorses this reorganization within the IPET as logical and appropriate and looks forward to reviewing the progress and findings from this work.

3. ERP-IPET interaction

The IPET task 7 coleaders and the ERP members most concerned with task 7 have interacted and continue to interact on a regular basis in person, by phone, and by e-mail. This has proved essential in reaching concurrence with respect to issues of scope and responsibility and to the specifics of the data collection and work plans.

An especially difficult issue has been the extent to which the IPET should take on the task of assessing the levee and floodwall designs and design processes. In the opinion of the ERP the IPET is responsible for providing such factual information as soil profiles, soil properties (and how they were determined), strength profiles, design methods, factors of safety, et cetera, and to make a comprehensive assessment thereof in accordance with the approach as described on page 113 in the IPET's Report 1. The ERP expects the IPET to document the design and even to compare such specific information as design shear strength with measured shear strength so that anyone reading the IPET's report will have a clear picture of the magnitude of any differences. It is not the IPET's task to judge the reasonableness of the profiles, properties, and methods that were used. The reader should form his or her own judgment. Nevertheless, providing the factual information necessary for the reader to form such judgments is viewed as essential if lessons are to be learned.

4. Study recommendations

The ERP requests that the task 7 coleaders complete the collection of information and data and the planned analyses for one location, as well as the design memorandum applicable for that location, and make them available for review at the earliest practicable date. This will give the ERP an opportunity to assure itself that adequate information will be available for the inevitable judgmental evaluations of the design, design process, construction, inspection, and institutional issues that appear to have played such a major role in the failure of the flood protection system and will be so important in assessments of safety in the future. The ERP hopes that this can be done well before the next scheduled meeting between the IPET and the ERP (March 9–10) because by then the time remaining for completion of task 7 will be too short to permit changes in the work plan that might be beneficial to overall attainment of the objectives.

Report 2 should establish a standardized datum against which all elevations and data are referenced.

5. Lessons learned

The IPET has not yet drawn conclusions at this level of work achievement. Conclusions should become available as the work progresses to the next phases. The recommendations made in the main text of this report concerning the overtopping of levees reflect a lesson learned within the scope of task 7.

## Pumping Stations (Task 8)

1. Progress to date on objectives

The ERP is concerned that the gathering of the large amount of data needed to evaluate the performance of the pumping stations was begun very late. The consultant responsible for gathering the data was apparently given authorization to proceed only on December 16, 2005. The Sewerage and Water Board of New Orleans may have limited its cooperation because of its concerns about security against terrorism. This issue must be resolved as soon as possible.

The 80 pumping stations in the study area each have multiple pumps, some of which have the same design, manufacturer, and capacity while others are very different. Data requirements include numerous items, some of which are not readily available. Priorities must be established for data gathering so that the most critical areas can be evaluated.

The data collected for task 8 provide necessary input for the evaluations required in task 2, which deals with interior drainage and flood modeling. The data required for this modeling will include the total inflow from all sources, rainfall, and backflow from pumps, as well as the pumping ability to remove inflows from all sources.

No overall CPM scheduling shows critical paths of task completions for the June 1 deadline to be met, and thus no specific date by which all pumping station information will be required to satisfy the overall project schedule.

From the ERP's perspective, the data collection appears to be very much behind schedule.

2. Expected progress toward Report 2

By the March 9–10 meeting, all data collection should be complete and the analyses described in Report 1 begun.

3. ERP-IPET interaction

The ERP-IPET interaction for task 8 has been minimal to date but will increase as data are collected and shared with the ERP. The IPET and ERP leaders have had numerous discussions about task 8 and now agree on its mission. The relationships are very positive and a cooperative spirit exists.

4. Study recommendations

Sufficient work has not been completed to make recommendations at this time.

5. Lessons learned

Not applicable at this time.

## Consequence Analysis (Task 9)

1. Progress to date on objectives

The work involved in performing task 9 is still being specified and staffed. Existing conceptualizations of the four subtasks are moving in the right direction, but since actual work has not yet begun it is premature to offer detailed, substantive comments on this issue at this time.

The three consequence subquestions listed on page 7 of Report 1 include (subquestion 1) estimating local consequences related to the performance of "individual components" of the flood protection system. It is not clear how task 9 coleaders will perform this aspect of the work—that is, how they will link subsets of forensic Katrina consequences to individual subcomponents of the flood protection system.

The first sentence in the statement of objectives on page 137 of Report 1 reads as follows: "The overall objective of this task is to examine comprehensively the consequences of Hurricane Katrina." This statement should be clarified by distinguishing between consequences actually measured and those that will be estimated or projected through modeling.

2. Expected progress toward Report 2

In some ways, one could view the work involved in task 9 as beginning after the January 9–10 meeting in Reston. Many subcontractors have only recently been added to the team. It is expected that the time remaining before Report 2 will produce additional subtask conceptualization and data assembly so that task 9 can be completed in a timely fashion.

3. ERP-IPET interaction

The ERP-IPET interaction for task 9 that has occurred to date has been productive; however, it has been limited. It is probably important to increase information sharing and interaction between the ERP and the task 9 subtask researchers in the future.

4. Study recommendations

- Eliminate overstatements: For example, the first sentence on task 9 (see page 136) in the report

speaks of a "full assessment of all consequences." Such adjectives as "full" and "all" overstate what can realistically be accomplished within the time available. The text in Report 2 on task consequences might instead simply provide text on what is being examined.

- Add details of subtasks: The slides pertaining to task 9 that were presented at the January 9–10 meeting contained more information about this work than is contained in Report 1. For example, the one-cell matrices for each of the subtasks in the slides provided additional clarifying information. This additional information and much more of the same kind should be included in Report 2. Moreover, since additional choices regarding variables to be examined, measures, approaches, methods, and so on are made within each of the four subtasks, this additional information also should be included in Report 2.

- Include the standardized Katrina case: The matrix of analysis on page 142 of Report 1 should be revised to include the additional baseline case discussed at the January 9–10 meeting. That case was for standardized Katrina consequences based on the same warning and evacuation assumptions as are used in determining probabilities of alternative future scenarios

- Be specific in describing subtasks: Although more is said about the economic subtask than about the others, greater specificity is needed regarding each of the four subtasks (economic; human health and safety; environmental; and social, cultural, and historical) in terms of, for example, what is being measured and how it is being measured. The one-cell matrices in the Reston slides mentioned above could provide a format for including that greater specificity.

- Make the models used transparent: The models that will be used to estimate consequences should be named and described in Report 2. Text should be added to discuss why these models were selected, and each model's "merits" and "shortcomings" should be considered and discussed so that these issues become transparent. (Some of the results of task 9, and subsequently of task 10, will only be as sound as the models used, and readers of the report should be adequately informed of this.)

- Discuss consequences not measured: A section should be added to each subtask that discusses subtask consequences that were not or could not be measured and why. Text should be added that clearly distinguishes between forensic Katrina consequences and alternative future probability scenarios.

- Quantify wherever possible: The segment of this work dealing with Katrina's forensic consequences is vitally important. However, it may not be as significant in determining the future of New Orleans and its citizens as the modeled consequence estimates that feed into task 10. Consequently, the more quantitatively informed the estimates of alternative futures, the better informed the decisions regarding the city's future that draw on the results of task 10.

- Address unique Katrina consequences: Existing theories and models regarding consequences are probably not based on disasters that share some of the unique characteristics of Katrina. For example, evacuees are away longer following Katrina than is typical, and the reconstruction of homes has been delayed longer than in other natural disasters in recent decades. Such characteristics (and others that are relevant) should be considered to ensure that they have no impact on

any of the models used.

- Explain the choice of databases: Some of the databases that will be used in carrying out task 9 are listed in the framework of analysis section on page 137 of Report 1. Text should be added in Report 2 explaining why these databases, and not others, were selected. For example, it might be that the databases included are the most current or the most comprehensive on the topic. If this is the case, it should be stated. Finally, if the consequences examined are limited by the availability of databases, this should be explained, together with the extent of the limitation.

- Explain how variation in databases is managed: The first sentence in the first paragraph on page 138 of Report 1 reads as follows: "The smallest geographical reporting unit of these data is [the] census block, while other data are available down to the census block, census track or zip code levels." It will be important to provide an explanation (perhaps in Report 2) of how this variation in databases is managed to generate consequence measures and estimates.

5. Lessons learned

It is premature to discuss the lessons learned from the work performed in carrying out task 9.

## Risk Assessment (Task 10)

1. Progress to date on objectives

The objectives of task 10 have expanded considerably from what was stated in the initial IPET document outlining the scope of the task, moving from a fairly well defined risk and reliability assessment toward a much broader, risk-based decision-making methodology. As explained to the ERP in Reston, much of this has to do with the emerging requirements of the follow-on South Louisiana Hurricane Protection and Restoration Study (SLHPRS), a comprehensive, risk-based evaluation of hurricane protection, coastal restoration, and flood control throughout the region. The objectives of task 10 have correspondingly become twofold: to meet the immediate needs of the IPET study as of June 1 and to lay the groundwork for the two-year SLHPRS effort to come.

Progress to date on task 10 reflects the dual nature of the challenge in creating a risk model sufficiently versatile to meet future needs but at the same time sufficiently focused to address immediate concerns. This will break new ground for the Corps of Engineers. Whereas its risk-based methods have previously been used internally and almost exclusively for economic planning, they must now serve wider audiences beyond the Corps with diverse requirements for risk information. It is of the utmost importance to the Corps and all of the various stakeholders that both the methods and the processes developed in task 10 be suitable for meeting the full range of these needs.

The ERP believes that the IPET leadership and those with responsibility for task 10 are cognizant of this challenge. Report 1 proposes probabilistic inundation mapping as a vehicle for conveying risk information to displaced individuals and families who face immediate decisions concerning relocation and reconstruction. The ERP endorses and encourages this effort. For the SLHPRS and

related purposes, Report 1 proposes to investigate risk evaluation processes that go beyond economic cost-benefit criteria. This too is a positive development. While more remains to be done, Report 1 goes far in establishing a framework for the remaining work.

2. Expected progress toward Report 2

From the standpoint of risk methodology, task 10 is substantially dependent on the progress of other tasks. Looking ahead to Report 2, the ERP anticipates seeing demonstrable progress and initial results on stage-frequency relationships from probabilistic hurricane and storm surge modeling. Despite the extensive effort involved, this lies at the core of the risk model and is central to the success of task 10. The ERP also expects to see how specific failure modes are represented in the risk model, including the results of systematic failure mode identification. Trial runs of the risk model for Report 2 will require fragility curves for characterizing structure performance, and the ERP anticipates that this will be preceded by training of assessors for probability elicitation.

3. ERP-IPET interaction

The ERP and IPET leaders for task 10 have engaged in a series of communications concerning comments and responses as follow-up to the IPET document describing the scope of work. This communication, along with the face-to-face discussions in Reston, has enhanced the ERP's understanding of the direction of task 10 studies. Certain fundamental matters have not been addressed in a way that ERP considers satisfactory. The ERP looks forward to learning how the IPET proceeds.

4. Study recommendations

It is apparent from the emerging direction of task 10 that it will have at least three separate decision-making applications, each with a separate audience:

1. Personal decisions by displaced individuals and families about whether to return and rebuild;

2. Community decisions regarding the nature and extent of local restoration;

3. Planning decisions at the federal level regarding levels, types, and methods of future hurricane protection.

These different purposes and audiences will require that the risk model be applied using distinctly different sets of assumptions and in distinctly different ways, even if the model itself is substantially the same. In short, the risk assessment process is different, especially when it comes to public involvement. With this in mind, the ERP puts forward the following recommendations:

- Divide risk model application into separate but parallel tracks, each tailored to the needs and purposes of different end users.

- Take concrete steps to ensure that task 10 activities are open and transparent by engaging end users in risk model development and establishing liaison with these groups.

- Seek the advice and participation of risk communication specialists familiar with the experiences—both positive and negative—of such agencies as the U.S. Environmental Protection Agency and the Food and Drug Administration regarding public participation in the risk assessment process.

5. Lessons learned

On multiple occasions, statements by top Corps officials have assured the public that the levee system will be adequately safe, and its risks sufficiently low for displaced residents to return to the city by June 1. These statements have seriously compromised task 10 efforts by introducing a motivational bias that predetermines the outcome of its risk determinations. This undermines the credibility of task 10 and ultimately of the Corps itself. The lesson to be learned is that task 10 will not produce technically sound risk estimates unless there is full support and cooperation from the Corps at the highest levels for unbiased outcomes free of any appearance of manipulation or predetermined conclusions.