

May 1, 2006

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

SUBJECT: External Review Panel Progress Report

Dear General Strock:

The purpose of this progress report is to provide technical comments on the U.S. Army Corps of Engineers' (USACE) Interagency Performance Evaluation Task Force (IPET) Report 2, dated March 10, 2006. The External Review Panel (ERP) is, in general, satisfied with the progress made by the IPET, with the methods of data collection and analysis employed, and with the IPET's general conclusions to date. The ERP is satisfied with the level of communication and cooperation offered by the IPET, and we particularly appreciate the efforts that the IPET has made to meet with ERP team members to discuss in detail the findings concerning levee section failures. We are also gratified that the comments of the ERP continue to be considered by the IPET and, in many cases, incorporated into the IPET's work.

This progress report is organized to present the ERP's comments by major topic areas.

Geodetic Vertical and Water Level Datum

Southern Louisiana is known to be a region of significant subsidence and apparent sea level rise. The combination of these two factors makes the availability of well-defined, timely data for both geodetic and water level datums critical to the design, construction, and monitoring of a hurricane protection system (HPS) in the New Orleans area. On the basis of a review of design memoranda and documents for selected HPS projects in New Orleans, the ERP believes that the findings from the geodetic vertical and water level datum task group show a lack of consistency with existing agency guidance documents that address the critical need for carefully monitoring the geodetic and water surface elevation in the New Orleans area.

Specific project reviews show consistent lack of use and documentation of solid geodetic and water elevation datums for project design and implementation. The use of older geodetic elevation data and unsupported assumptions regarding mean sea level elevations have apparently led to significant reductions (0.8 to 1.9 ft) in design protection level expectations for the projects investigated. It is not apparent in IPET Report 2 how the relative changes caused by subsidence and water surface elevation were monitored and used to address reduction over time in levels of hurricane protection.

The report offers a comprehensive set of recommendations to correct the problems identified. The establishment of a network of monitoring stations to provide timely data regarding changes caused by subsidence and sea level elevations is critical in understanding the current level of flood protection. The role proposed for the National Oceanic and Atmospheric Administration and the necessary coordination with other agencies require a lasting commitment. Carrying out these recommendations will require clear accountability and communication between agencies. The ERP recommends detailed guidance regarding documentation and procedures to ensure a reliable and appropriate application of data from these monitoring efforts in the design and implementation of HPS projects. This guidance should be reflected in a new USACE manual on maintaining geodetic and water level datums in areas of high subsidence.

Given the design guidance documents already in place at the time these projects were developed, the ERP sees a clear need for a stronger commitment to consistent use of existing policies and procedures than has been the case in the past.

The Storm

The IPET analysis of the storm represents a combination of results from wind, wave, and surge model simulations that are compared with available field measurements. The simulations used an advanced interpretation of the wind and pressure fields. The significant improvements of the original winds were based on extensive analysis and reanalysis of the available data from various sources.

Results from this regional-scale analysis are in close agreement with the measured and observed values for wave height and period offshore and also near the canal outfalls into Lake Pontchartrain. Although there are problems with the measurements from the buoy in the lake during the passage of Hurricane Katrina, the measured height of 8.4 to 9.4 ft with a period of 6.7 to 7.3 seconds compares well with the computed value of 8.7 ft with a 6.7 second period at the 17th Street Canal. Similar simulations of wave heights and periods from Katrina are presented and compared with design levels used for the HPS. The report also provides a comparison of the simulated water level maxima from Katrina with both the measured values and the design values; for example, at the London Avenue Canal the simulated maximum was 10.9 ft (NAVD 2004.65), while the measured and design levels were respectively 10.7 and 11.8 ft. Along much of the south shore of Lake Pontchartrain the computed, observed, and design levels were within 2 ft. However, Report 2 shows a striking difference between the design and simulated water level maxima for Plaquemines Parish and St. Bernard Parish; here the differences are from 4 to 6 ft.

We understand that for the next iteration the IPET will revise the simulations for the final analysis after incorporating recent topographic survey data and additional grid refinements. We feel the work to define the storm characteristics on a regional scale represents a melding of the best available numerical modeling methodology and field observations and reflects devoted efforts on the part of experienced professionals. The descriptions are clear and comprehensive. Altogether this is a fine piece of work.

Report 2 also presents the effort to define the local-scale storm characteristics at the 17th Street Canal and the London Avenue Canal breaches by extremely fine scale numerical models and

a physical model. Unfortunately, in neither the IPET Report 1 nor the IPET Report 2 is there a detailed discussion of how this work will assist in answering the final IPET questions about the storm. Moreover, there is no discussion in Report 2 of how other parts of the IPET team will be able to use the information from this work. One of the products of this work that the ERP believes is most useful comes from the application of the Boussinesq wave model to the levee in Saint Bernard Parish along the Mississippi River Gulf Outlet (MRGO) as shown in figure V-63. It suggests velocities as high as 15 ft per second along the back side of the levee as the wave overtops. These results should be considered in the performance of these levees and incorporated into the future protection plans for levees that may be overtopped.

The report notes that the ADCIRC model will be used for simulation of the flow from surge in Lake Pontchartrain into the canal and through the breach at the 17th Street Canal. This may provide additional insight and quantification, but it should be remembered that some basic parameters—for example, the resistance at the bridge and the development of the breach geometry in time—are highly uncertain. Thus, irrespective of the degree of sophistication of the flow model, it is unrealistic to expect that high overall accuracy and reliability can be achieved.

Lastly, the IPET Report 2 provides additional information on the standard project hurricane (SPH) and the probable maximum hurricane (PMH). Clearly the SPH was used for the design conditions as stated in the IPET report. We believe that the rationale for selection of the SPH for design is questionable. The SPH is not equivalent to the 100-year storm or even to the largest storm of record. The original description of the SPH notes that “only a few storms of record over a large region have had more extreme values.” We think that whenever catastrophic damages occur, the next level of protection as provided by the PMH should be required. We are not aware from the report of the level of revision of the SPH, if any, that occurred between the initial Design Memorandum No. 1 in 1968 and the construction that took place for Lake Pontchartrain and the vicinity. Note that it is not stated from which set of possible standard hurricanes the SPH was selected. The text suggests that a choice for a particularly severe hurricane was made, sounding almost apologetic for not having selected a less severe one. It is not clear that the approach taken by the New Orleans District as described on page IV-39 to update the central pressure index (CPI) to better evaluate the SPH is consistent with the approach being taken to understand “The Storm” and to assist in the risk analysis. Both the joint probability method represented by the use of the SPH and the proposed modeling by the district to evaluate how changes in the SPH affect waves and water levels are inconsistent with the tools available to predict these conditions for all probable conditions needed for a proper risk analysis.

Interior Drainage

The ERP is satisfied with the work products to date and the direction of the IPET interior drainage analysis (IDA) team as measured against IPET objectives. Significant progress has been made in developing the HEC-RAS and HMS models of the various polders, and the team is communicating and sharing data with the pump station, hydrodynamics, and risk analysis teams.

The ERP team has specifically addressed the following items from the IPET Report 2 with the IDA team:

1. At our request, the IDA team has conducted HEC-RAS model run comparisons of the Pressman Slot method with UNET, confirming the validity of the installation of this routine within HEC-RAS.
2. It is clear that the historical data available from Katrina and past flooding events will permit only limited calibration and verification. This raises the importance of the sensitivity analysis, the details of which were discussed during the March 9–10 meeting in Vicksburg, Mississippi. The IDA and the ERP agree on the approach.
3. We held discussions and reached agreement regarding the presentation and interpretation of output from the model runs.
4. The question of how the effects of debris will be considered in the analysis is not yet resolved and we expect that it will be incorporated into the sensitivity analysis as reduced pumping capacity.
5. The ERP team believes that lessons learned from these results need to be emphasized in the final report. Topics to watch include levee and canal operations (nonfailure duration, depth of overtopping, and potential need for armoring); ways of maximizing or improving pump operations; and means to channel water to safe areas and to the pumps to prevent damage to residential and industrial areas.
6. During discussions, the IPET team, in coordination with Task Force Guardian (TFG), agreed to model the effect of the lakefront canal closures, to include the operational plan for the coordination of pump station operations, and to evaluate the effect of pooled storm water in the contributing drainage area. Results of this modeling will be forwarded to the risk analysis team.
7. It is possible that, for some areas, models will not be complete by the end of June and work will need to continue beyond that date. The IDA team is giving priority to the modeling work yet to be done.

As TFG and future USACE projects work to improve flood protection in New Orleans, certain changes will need to be reflected in revised risk models, among them levee heights, probability of failure, and pumping capacity. Though the pump stations were not considered part of the federal HPS before Katrina, their inclusion as part of the IPET scope of work acknowledges that the pump stations are now clearly considered integral to the HPS. Finally, as some tasks will not be completed and are projected to be post-IPET, a coordination plan will be required at the conclusion of the IPET process.

Levees

The IPET Report 2 focuses on an analysis of the failure of the 17th Street Canal floodwall and levee. In addition to determining the cause of failure, the analysis is meant to serve as an example of how the IPET will carry out its analyses of the failures of other levees and floodwalls. It also offers an opportunity for the ERP to review and comment not only on this particular failure but also, more broadly, on the methodology being used by the IPET.

The ERP is pleased with the manner in which the IPET investigation has proceeded to date. The IPET has studied the 17th Street Canal levee failure in a manner consistent with good engineering practice. The assessment procedures used appear to be applicable to the rest of the New Orleans system and will be useful in evaluating causes of failures at the other locations as well as in evaluating levees that were stressed but did not fail.

The report summarizes the following regarding the failure at the 17th Street Canal:

1. The critical layer beneath the levee where failure occurred was lacustrine soft clay, not the peat layer that has been suggested by other investigators.
2. A gap formed at the face of the flood side of the sheetpiling, which deflected as water rose in the canal. As the gap filled with water, full hydrostatic pressure was applied to the sheetpiling. For conditions at the 17th Street Canal, the formation of a water-filled gap reduces the factor of safety for stability by about 25 percent. What remains uncertain are the depth to which the gap opened, the amount of seepage through the sheet piles, and the extent to which the flood-side levee embankment soils followed the sheet piles as they deflected.
3. Though information is limited, the shear strength values of the clay at the failure location were apparently lower than those just north and south where failure did not occur.
4. The General Design Memorandum did not account for design shear strengths in the clay beneath the slope and beyond the toe of the levee lower than those recommended beneath the centerline, did not account for the fact that the strength of the clay increased markedly with depth, and did not account for a water-filled gap on the flood side of the sheet-pile wall.
5. Low design factors of safety (1.3) were used for a critical structure.
6. Overtopping was not a factor at the 17th Street Canal breach.
7. Trees and improvements on the protected side may have been a factor in weakening the levee.

The report indicates that there is sufficient variation in geology and soil profiles along canals, levees, and floodwall areas to warrant caution in extending one type of failure mode to other areas.

When the final IPET report is produced, much attention is likely to be focused on the shear strength data—both the original data used as the basis for design and the data collected by the IPET. A clear presentation of these data, in tables and graphs, will be very helpful for the many readers who, for years to come, are likely to conduct their own independent analyses of the failures.

We understand that the IPET will be performing analyses with noncircular failure surfaces, which should yield slightly lower factors of safety than with circular failure surfaces. We agree that such analyses are necessary. We also believe that the IPET's planned finite-element analyses will provide additional insight into the nature of the failure. The soil-structure interaction analyses are expected

to shed light on the depth to which the gap opened and the extent to which the embankment soils followed the sheet-pile walls in the early stages of failure. When catastrophic failure occurred, the gap was probably full depth and the embankment soil on the flood side was left behind.

The water-filled gap is a critical element in the IPET report. The ERP agrees that evidence for the formation of a gap is very strong. Indeed, following Katrina, numerous extensive gaps were observed along the flood side of many I walls, including areas where the floodwalls were distressed but did not fail completely. The effect on stability of a water-filled gap should be considered at locations where the 17th Street Canal levee and floodwall did not fail to determine if a consistent pattern emerges. In other words, does the combination of properly assessed shear strengths and a water-filled gap yield consistent explanations as to why some sections failed while others did not?

It would be helpful if the report figures showed north arrows or the cardinal direction of the views. We understand that a new datum has been established and that all relevant figures will be adjusted to the same datum.

In summary, the ERP generally agrees with the data collection and analysis of the 17th Street Canal failure. A similar approach should yield a detailed understanding of the causes of failure at other levee sections and offer insight into the performance of levees and floodwalls that did not fail. We encourage the IPET to do the following:

1. Present comparative data on design-basis shear strengths and IPET-measured shear strengths in a form that will be convenient for readers to use.
2. Ensure that key mechanisms of failure used to explain the 17th Street Canal failure—that is, lower shear strengths beyond the toe of the levee and a water-filled gap on the flood side of the sheet-pile wall—are consistent in explaining why other sections of levee did not fail.

Pumping Stations

Significant progress has been made since the IPET Report 1. While the data collection is not complete, there appears to be sufficient information for the IPET pumping station team to begin an analysis of each pumping station.

From our review of the data received, there seem to be significant differences in the way each of the four parishes (Plaquemines, St. Bernard, Orleans, and Jefferson) approaches design, construction, maintenance, and tidal surge protection at the stations. There are even significant differences in the approach to pumping stations within each parish. It appears that Jefferson Parish east bank Lake Pontchartrain pumping stations are well designed, well constructed, and properly maintained. There is concern, however, about backflow prevention during tidal surges exceeding invert elevations of the discharge tube high points. This must be addressed either with operational procedures in the short term or with permanent shutoff gates in the long term. The west bank of Jefferson Parish has a mix of new pumping stations that are well designed and properly maintained and older stations that are poorly maintained.

By the May review meeting, all data collection and analyses should be complete.

The interactions between the ERP and the IPET on the work related to pumping stations have greatly improved. The ERP remains concerned, however, about the absence of an overall CPM schedule for the cross movement of data with the interior drainage team. The relationships remain very positive and a cooperative spirit exists.

An evaluation of the pumping stations must be made on the basis of their ability to do the following:

1. Prevent tidal surge from entering the protected side of the basin either via backflow through an inoperable or unoperated pump or via overtopping of the floodwall or levee at the station.
2. Sustain operations during an extended storm event with sufficient fuel storage on-site for diesel-driven pumps and diesel-driven generators.
3. Provide backup generation for electric pumps and ancillary pump station equipment, including vacuum pumps, compressors, station lighting, motor control panels, and communications equipment.
4. Harden the station structure to withstand storm winds in excess of 150 miles per hour.
5. Provide operator protection inside the station structure during severe storms, including remote controls and visual and audible monitors for remote operation during the peak of the storm.
6. Remove debris from the bar screens during the peak of the storm without endangering operators by employing such means as trash rack cleaners and conveyor belts.
7. Elevate and protect all equipment vital to the pump operation, including elevation of the operating floor slab above the expected tidal surge from the SPH.
8. Provide backup systems for such vital infrastructure as the transfer fuel pumps and the water supply used to cool bearings.

There must be consistency in the ability of these pumping stations to pump for extended periods under extreme weather conditions as well as to provide adequate tidal surge protection during a hurricane.

Consideration should be given to shifting responsibility for the external drainage pumping stations (pumping stations that discharge into a tidal waterway) to the two new levee boards for the Pontchartrain and Barataria basins so that consistency of design, construction, operation, and maintenance can be obtained.

Consequence Analysis

The consequence analysis involves four subtasks and various subgroups on the consequence analysis team. The ERP is concerned that a mechanism is needed to ensure that there is consistency in the definitions and approaches used by the various subgroups. One way to do this would be

to hold special meetings for the various subgroup leaders to identify consistent definitions and approaches.

The economic consequences subtask (economic model validation) states that available economic models cannot be used to assess indirect/induced market impacts because of changes in regional economic relationships and says that a simplified economic base model approach is preferable. Subsequent reports should clearly explain why some models were not used and fully describe the parameters of the models that were used.

The preliminary estimates of total damage cataloged in table 1 (cataloged economic costs) should be accompanied by an explanation of how these numbers were derived. For example, the source of these numbers, along with the level of confidence that can be placed in them, should be specified.

With respect to the economic costs examined, the text provided leads one to conclude that economic costs will be cataloged for housing units, nonresidential structures, vehicles, business losses, navigation-related topics, and employment and wages in three parishes. It is not clear if this subtask will examine other factors, gather other data, or profile those data for other places. Descriptions of the costs that are measured, together with an explanation of why these variables have been assessed while other costs have not, should be provided. Additionally, the source of these numbers and the level of confidence that can be placed in them should be provided.

The IPET Report 2 provides only limited information on the social, cultural, and historical consequences subtask. As a result, the following comments are based on a review of the work plan for this subtask:

1. Report 2 proposes to evaluate many of the dimensions of emergency preparedness and response. However, the ERP is under the impression that the IPET will not evaluate these issues. Consequently, we do not offer comments on this section. If this subtask does move forward to investigate these topics, we will offer comments.
2. Report 2 contains many lists of factors to be investigated. It is, however, difficult to clearly understand what will be evaluated and why. We recommend that the social, cultural, and historical variables to be investigated be listed in a table under each of those three headings. We also recommend that each of the variables in this table then be crisply defined in another column of the same table. After this understandable list of variables is constructed, three things should be done with it:
 - 2.1 First, a subtask assessment should be performed by sharing this table of variables and their definitions with the other major subtask groups working on consequence analysis for consistency and to avoid duplication of effort.
 - 2.2 Second, the table of variables and their definitions should be shared with those who oversee the entire effort so that the mandate given to the USACE can be compared with what the subgroup on social, cultural, and historical consequences intends to do. This will address our concern as to whether emergency preparedness and response are being addressed by the IPET.

- 2.3 Third, once assembled, this table of variables and their definitions can be readily reviewed for completeness, clarity, and comprehensiveness.
3. The units of analysis against which each of the variables in the table of variables described above will be measured should be specified. If this were done in a matrix, it would make for greater clarity. Care should be taken in defining what exactly is meant by each unit of analysis. Additionally, sharing these intended units of analysis with the other subgroups will help in integrating the various subtasks.
 4. The time frames for the measurement of each of the variables in the table of variables should be specified (immediate, intermediate, long-term) and each of these time frames should be clearly defined.
 5. The list of variables in the table should cite a few key documents in the published literature. The reference documents should be seminal publications in the field—that is, the most significant publications in the field should be used to support the inclusion of the most important variables in the table (to the extent that this is possible).
 6. To benefit the reader, each of the factors referred to above, namely, investigated variables (classified as social, cultural, or historical), definitions, units of analysis, and time frames, should be incorporated into a matrix that provides a bird’s-eye view of the work.

Some effort should be expended to address the causes of the consequences being described—for example, the breach of the levees, the failure to evacuate, and the lack of political action to reconstruct. Perhaps it would be better to simply add some text explaining that there were multiple causes of the consequences being investigated but that this research could not discern the degree to which different causes contributed to the observed consequences. Where possible, however, consequences that can be linked to the levee failures should be described.

The methods to be used in this task should be clearly described. For example, what are the data sources, data collection methods, and data analysis approaches for each of the variables in the table of variables? Additionally, the variables measured and their reliability and validity should be addressed. This information should be linked to the table of variables or matrix addressed above.

Attention should be given to how the social ramifications of the details revealed in this research will be addressed. In other words, how will this subgroup flesh out such aspects as the loss of property of historical importance and the disappearance of a way of life? How will these social ramifications be discerned and how will they be linked to the data that support them?

The events and scenarios to be analyzed in the human health and safety subtask should include a “standardized Katrina case.” This case would include an estimate of lives lost in the actual Katrina event using the same evacuation assumptions that will be used in the scenarios for determining alternative outcomes. Comparisons of lives lost in scenarios for determining alternative outcomes should be made with the standardized Katrina case and not with what was actually observed in Katrina’s aftermath. Only in this way can the implicit and explicit comparisons of lives lost in alternative scenarios with actual Katrina lost lives be standardized.

As part of the human health and safety subtask, the data that will eventually be assembled on fatalities should be cataloged on the basis of significant social and demographic characteristics, for example, race, ethnicity, socioeconomic class, gender, and age. It is not clear if this is planned.

Risk Management

The ERP believes that the approach toward risk analysis is well thought out and that the IPET team is well qualified. We expect that the results will be defensible, although the amount of work that remains to be done is so large that we question whether it will be possible to complete the ambitious work plan by June 2006.

Our major concern is that the team for this task is relying entirely on the development of a very large and complicated model to obtain answers. We are not sure that this complicated model will be the most appropriate one for all of the decisions that need to be made. For example, many key decisions—such as the design conditions and factors of safety that should be used in repairing levee breaches—should be made now, before the model is complete. In addition, such a complicated and cumbersome model may not be practical in making small but important decisions in the future—decisions that will need to consider risk or that will impact risk.

Furthermore, we are not sure that the IPET team will be able to complete the development of the model, populate the model, produce and analyze results in a meaningful way, and present the results by June 2006. Therefore, we recommend that the development of the complicated model be complemented with high-level, simplified analyses of some type. This approach has been used by most of the other IPET teams; they started with simple models to obtain answers and are gradually refining their answers with more complicated analyses. The simplified analyses can help to guide the development of and check the results from the more complicated model.

More detailed comments are provided below:

1. An attempt should be made to include all consequences in the risk analyses. Specifically, we question the exclusion of indirect costs (for example, business interruption) “because of difficulties in data collection and because of time limitations.” The direct costs from Katrina are less than \$20 billion (table VII-7 in the IPET Report 2) while the total costs are between \$100 billion and \$200 billion.
2. Hurricane Katrina provides an incredible wealth of information on the performance of the HPS. We believe that formal analyses (probabilistic updating) with this information would be very helpful in calibrating the risk model and furthering the overall IPET effort. The risk team could play a very useful role in developing an updated assessment of the walls and levees and the loading conditions that were applied to them. This type of analysis could pay rich dividends by incorporating information about sections that did not fail as well as information about those that did.
3. The risk analysis for the pre-Katrina HPS should include the effects of systemic errors in design, such as not accounting for lower undrained shear strengths at the toe of levees in analyzing stability, in addition to natural variations in properties and loading conditions.

4. Failure modes related to seepage and piping should be included in the analysis of wall sections. The effects of failures in the pumping system on these failure modes should be considered.
5. Given the complexity of the risk model and the large number of input parameters, it will be important in the final report to clearly document and justify all the input values and any assumptions made about their interrelationships.
6. What will be deemed an acceptable risk and on what basis? It would be appropriate and ideal if the IPET were an active party in helping to answer these questions.
7. It would be helpful to point out to readers that this effort is the first attempt to conduct a comprehensive risk assessment for an entire levee system on this scale. One question for the USACE is, why was the risk not formally assessed prior to Katrina?

ASCE and the ERP members greatly appreciate the opportunity to be of service to you on this project. If you have specific questions, please feel free to call.

Respectfully submitted,

- Christine F. Andersen, P.E., *Public Works, City of Long Beach, California*
- Jurjen Battjes, *Levees/Flood Control, Delft University, the Netherlands, Retired*
- David E. Daniel, P.E., *Geotechnical Engineering, University of Texas at Dallas*
- Billy L. Edge, P.E., *Coastal Engineering, Texas A&M University*
- William H. Espey, Jr., P.E., *Hydrology, Espey Consultants*
- Robert B. Gilbert, P.E., *Risk Management, University of Texas*
- Thomas L. Jackson, P.E., *Pumping Systems, DMJM Harris, Retired*
- David N. Kennedy, P.E., *Public Works, California Department of Water Resources, Retired*
- Dennis S. Mileti, *Consequence Analysis, University of Colorado*
- James K. Mitchell, P.E., *Geotechnical Engineering, Virginia Polytechnic Institute and State University*
- Peter G. Nicholson, P.E., *Geotechnical Engineering, University of Hawaii*
- Clifford A. Pugh, P.E., *Hydraulics, U.S. Bureau of Reclamation*
- George J. Tamaro, P.E., *Soil-Structure Interaction, Mueser Rutledge Consulting Engineers*
- Robert G. Traver, P.E., *Urban Drainage, Villanova University*