# JOINT REPORT OF THE TECHNICAL ADVISORS OF THE INTERNATIONAL BOUNDARY AND WATER COMMISSION REGARDING THE GEOTECHNICAL, ELECTRICAL, MECHANICAL & STRUCTURAL SAFETY OF AMISTAD DAM

To the Honorable Commissioners
International Boundary and Water Commission (IBWC)
United States and Mexico
El Paso, Texas and Ciudad Juarez, Chihuahua

Sirs:

The undersigned Technical Advisors to the Commission visited Amistad Dam on 23 and 24 April 2007, with the objective of inspecting the dam and reviewing the records relative to the dam's geotechnical, electrical, mechanical, and structural features. Pool elevation on the date of inspection was 338.2 meters.

Our review covered records of the indicated component features of the dam and we were briefed on actions taken to comply with recommendations from prior technical inspections.

Our review did not cover hydrologic issues, hydraulic adequacy, or operating criteria of the dam.

## Conclusions

The project appears in excellent visual condition and appears generally well maintained. IBWC has made good progress in accomplishing recommendations from previous reports. However, based on our observations, review of records, the recent pool rise to near conservation pool, and in consideration of the project experiences with upstream sinkhole formation, we conclude that the dam is potentially unsafe, and that the entire dam foundation is in need of further evaluation and study. Starting in the next funding request cycle, a panel of geotechnical consultants should be convened for this purpose. The electrical and mechanical equipment is capable of operating under normal as well as flooding conditions. The other recommendations which are presented below should be implemented within a reasonable time frame.

## General Recommendations

1. The project should continue to be routinely monitored for conditions that could represent a dam safety problem. Threshold pool elevations should be established that dictate or modify the frequency of inspections. Suggested elevations should at least include the elevation associated with historical sinkhole formation, conservation pool, and 3-meter increments above conservation pool. Inspections and piezometer readings should be daily when approaching previous pool of record. When previous pools of record are exceeded, 24 hour surveillance should be initiated.

2. Continue with actions associated with recommendations from previous joint inspections that are applicable.

3. Both Sections of the IBWC should update their Emergency Action Plans (EAP) in accordance with accepted guidelines. Notification lists should be updated at least annually.

4. Consider low flow hydropower generation in penstocks not currently in use in the U.S. and Mexico.

**Electrical/Mechanical Recommendations**

1. All radial gates should be cleaned and inspected for paint condition and corrosion prior to each five year safety of dams inspection or more often as required.

2. The Little Rock District of the U.S. Army Corps of Engineers performed a reconnaissance level study in October 2006 entitled, "Amistad Dam Project, Del Rio, Texas Irrigation Penstock Gate Study for International Boundary and Water Commission" wherein several recommendations were made. The purpose of this study was to investigate possible solutions for the gate catapulting problems in U.S. Penstock #4. The U.S. penstock #4 has not been operated for 20 years. Therefore the condition of the gate and hoist is unknown. If the original purpose of irrigation remains, then serious consideration should be given to implementing one of the recommendations in the Little Rock study. A decision is needed on the future usage for the U.S. penstock #4.

3. Radial gates were evaluated by Little Rock District October 2004 to determine if gate strut arms were being overstressed due to trunnion pin friction. The study concluded that the gate strut arm stresses varied, but were generally in acceptable ranges. It is recommended that radial gate trunnion pin friction also be evaluated on the Mexico side as was done for the US side. The Little Rock report also observed that radial arm stresses were reduced after exercising. Currently, stoplogs have to be set for each gate to prevent losing the pool when opening and therefore the U.S. and Mexico's current practice is to only operate two gates each year in accordance with the operations and maintenance manual. It is recommended that each gate be lubricated and fully opened once per year. This recommendation should apply to all 16 gates as a standard practice.

4. The ceiling and floor in the U.S. gallery level 5 were observed to be wet with small stalactites and stalagmites indicating a long term leak. The condition was very localized and only appeared at pool elevations above approximately 336 m to 337 m. This section of the ceiling appears to have been used for ventilation or for access for materials delivery and was later plugged. Water seepage in the horizontal construction joints travels along until it hits the vertical joint and then seeps into the gallery. The gallery is generally dry. The seepage quantity is low and does not appear to be a serious problem.

5. Correct grease leaks at the trunnion pins of the radial gates on the U.S. side using procedures similar to those applied on the Mexican side.

6. Install an automatic transfer switch, and speed and voltage regulators in the Mexican emergency generator.

**Geotechnical/Structural Recommendations**

1. Establish uniform criteria for representing the information obtained from measurements based on the International System of Units.

2. Continue to monitor the project instrumentation and report any conditions that may be indicative of dam safety problems. Monitoring should include downstream weirs, piezometers, gallery drains, level surveys of surface reference marks and tiltmeters on the current schedule. In addition, continue to monitor and evaluate the apparently non-responsive gallery piezometers which are located downstream of the dam axis. If these piezometers are determined to be nonfunctional, a decision will need to be made concerning their replacement, repair, or abandonment.

3. Continue treatment of sinkholes as they appear using the established procedure.

4. The IBWC should continue to encourage the development and testing of evacuation plans by the local jurisdictions responsible for flood prone areas. Joint emergency exercises should be conducted to test the EAP.

5. Monitor the upstream riprap on the embankment wrap-arounds adjacent to the concrete structure on the Mexico side. Add upstream riprap on the U.S. side from about station 72+00 to station 155+00 between about elevation 1110 feet (338 M) and 1125 feet (343 M).

6. Continue to periodically clean and maintain gallery drains on the U.S. and Mexico sides. Video inspection of a few drain holes should be performed to determine extent of calcification. If encrusted, the hole could be reamed to re-establish functionality. Piezometer station #2 on level 5 on the U.S. side in particular should be considered as a starting point.

7. At the downstream seepage weirs, clean the metallic edges, extend the walls to reduce flow turbulence, and replace the vernier scales ensuring they are securely mounted. In addition, replace the brass identification plates which have been damaged.

8. In gallery level 5 on the Mexican side, replace the crack monitor gage with stainless steel device along with necessary armoring to protect it against physical damage.

9. Ambient temperatures should be recorded at each gallery level when tiltmeter readings are recorded. Data should be graphically presented to show correlation between temperature, pool elevation, and cyclic tilt of the structure.

10. A stilling basin inspection should be performed after releases through the spillway exceed 3,000 cubic meters per second.

11. Providing future technical advisors with briefing packages that include summaries and histories of such items as project experiences, repairs, as-built drawings, and instrumentation readings (tabular and graphical) should be continued. The briefing packages should be furnished at least three weeks in advance of scheduled inspection dates. In addition, a historical digest or document (including photographs) should be created that records history of incidents, problems and conditions that have been observed and dealt with at the project.

12. Analyses and associated inundation mapping are underway by the U.S. Section. Downstream data should be shared with the Mexican Section so that data gaps can be filled in. Dam break and inundation mapping should be performed and developed for various discharges up to maximum spillway release bands. Inundation mapping should extend all the way downstream past Falcon Dam, and should be used to disclose impacts on populations at risk in the U.S. and Mexico, and on Falcon dam. Suggested pool elevations for dam break analyses might include the pool level at which sinkholes occurred on the Mexico side, at conservation pool, and PMF with and without breach. Inundation maps should be included in the EAP and should be furnished to and coordinated with local authorities responsible for developing evacuation plans.

13. Drill one NQ size core hole near station 106+10 adjacent to the existing piezometers located near the downstream toe of the dam to a depth of 50 meters. The core hole should be pressure tested at 5-meter intervals. Pressure should be gradually increased in one $kg/cm^2$ increments. The maximum pressure should not exceed $10kg/cm^2$ effective pressure or until hydraulic fracturing of the formation is detected, whichever is less.

14. Grouting in the vicinity of the sinkholes on the Mexico side was accomplished approximately ten years ago. Grouting in Karst formations is considered to be a temporary or interim risk reduction measure. Therefore, an evaluation should be made of the grouting effectiveness during the upcoming funding request cycle. Evaluation should also include consideration of the entire dam foundation and not be limited to just the sinkhole area. To accomplish this, a panel of geotechnical consultants should be established to guide the evaluation. The panel's first task might be to guide the analysis and re-interpretation of the project data by an individual or organization. The panel should consist of at least four experts, two selected by each Section. The analyses should focus on items such as increased seepage with time, the presence of sinkholes, cavities, or sand boils. Seepage analyses such as critical

gradients, flow net construction, and finite elements should be performed as required when sufficient data are available. Additional investigations such as drilling, sampling, field tests (such as test void filling using low pressure), laboratory testing, and/or installing additional monitoring instrumentation may be necessary as determined by the panel.

15. To facilitate understanding the need to engage the geotechnical panel of consultants and to encourage management's support for Joint International funding of the foundation analyses and investigations described above, the inspection team recommends that a risk based action classification that is being developed by the Corps of Engineers is appropriate for application to the IBWC dams. The Corps is assessing its dams and will place each dam into Dam Safety Action Classes (DSAC) based on their individual dam safety risk considered as probability of failure and potential failure consequences. This allows the Corps to focus on the correct dam safety issues and not the 'next on the list' or 'one size fits all' in a time of constrained resources. There are five Dam Safety Action Classes as follows:

DSAC I – URGENT AND COMPELLING (Unsafe)
DSAC II – URGENT (Potentially Unsafe)
DSAC III – HIGH PRIORITY (Conditionally Unsafe)
DSAC IV – PRIORITY (Marginally Safe)
DSAC V – NORMAL (Safe)

Based on engineering judgment, Amistad Dam fits into DSAC-II as potentially unsafe. Urgent actions are needed based on the high risk in terms of the combination of potential loss of life and economic damages. This conclusion is based on experiences with similar dams with Karst foundations where cyclic pools seem to induce or cause additional sinkholes to occur. The panel of geotechnical consultants should further evaluate the DSAC.

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