

**JOINT REPORT OF THE TECHNICAL ADVISORS OF THE  
INTERNATIONAL BOUNDARY AND WATER COMMISSION REGARDING THE  
GEOTECHNICAL, ELECTRICAL, MECHANICAL & STRUCTURAL SAFETY OF  
FALCON 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 Falcon Dam on April 25, 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 82.2 meters.

Our review covered records of the component features of the dam and we were briefed on actions taken to comply with recommendations of 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 on the surface to be generally well maintained. Numerous items related to the seepage collection and pressure relief systems need evaluation and repair or replacement.

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.

Based on our observations, review of records, and in consideration of the project experiences with foundation seepage, sulfates in the foundation seepage, and lack of current seepage and stability analyses, we conclude that the dam is conditionally unsafe, and that specific investigations, evaluations, and studies are needed. Starting in the next funding request cycle, these studies and investigations should be initiated.

**General Recommendations**

1. Project personnel and management should continue their vigilance with respect to routine project surveillance, especially considering the long period of low reservoir pools that have been experienced. A false sense of security should not prevail due to the lack of seepage at the present. Non routine project surveillance should be based on threshold pool elevations predetermined and listed in the project's Emergency Action Plan (EAP). These elevations should be established such that they dictate or modify the frequency of inspections. Suggested elevations should at least include the elevation associated with historical seepage appearing along the downstream areas, conservation pool, and 3-meter increments above conservation pool.

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Inspections and piezometer readings should be at least daily when approaching previous pool of record. When previous pools of record are exceeded, 24 hour surveillance should be initiated.

2. Continue to implement actions associated with all applicable recommendations from previous joint inspections.
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. 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. Establish uniform criteria for representing the information obtained from measurements based on the International System of Units.

**Electrical/Mechanical Recommendations**

1. Continue to pursue the possibility of low to medium flow generation capacity in the United States and Mexico.
2. Install Tuff Boom buoy protection, or similar, around the Mexican intake tower.
3. Investigate the integrity of wire rope cables between spillway gates and counterweights on the U.S. side.
4. Replace the control cables on the spillway and roadway cranes as needed (scheduled). Continue efforts to upgrade the electromechanical controls on both cranes at the intake structures and replace with modern electronics (in progress).
5. Finish cleaning and applying anticorrosive treatment to the intakes and valves of the hydroelectric plant on the Mexican side.
6. U.S. federal law and U.S. Federal Highway Administration regulations require that all U.S. public vehicular bridges be periodically inspected. We recommend that the spillway bridge be inspected in accordance with these regulations.

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**Geotechnical/Structural Recommendations**

1. Project personnel should continue to monitor the project instrumentation on the current schedule. An effort should be made to determine the pool elevation at which each seepage area/spring, relief well and collector systems begin to flow. Extent of wet areas should be mapped for various pool elevations.
2. Recommend video inspection and cleaning as necessary of all toe drain collector pipes on both the US and Mexican sides. Either rehabilitate or abandon the relief well system based on the results of the seepage and embankment stability analysis described below.
3. Continue monitoring extensometers, total dissolved solids and sulfates. Solutioning, as removal of residual fines from fractures within foundation rock, appears to be continuing. Review regional geology for possible presence of gypsum.
4. Continue surveying for vertical movement of the crest using procedures and control monuments used to date. Rebound appears to be occurring after an extended drought period, but rebound should be considered normal for dams with reservoir levels that fluctuate like those at Falcon Dam (approximately 20 meters).
  - a. Confirm that the control reference point on the U.S. side is reliable.
  - b. Install a reliable reference point on the embankment wraparound on the Mexican side.
  - c. Embed all of the reference points on the dam into the crest itself.
  - d. Purchase dual-band GPS survey equipment and accessories. This equipment will enable measuring of the settlement and the horizontal displacement in a single session, and could also be used for the topographic measurement of Amistad Dam.
5. Install two extensometers on the Mexico side similar to those located on the U.S. side.
6. Instrumentation data should continue to be presented graphically and should include plots of reservoir pool elevation versus piezometric pressures, and reservoir elevation versus seepage flow or relief well flows, as applicable. Extrapolations should be made when possible to predict pressures and flows for maximum design reservoir pool elevations. Upper limit lines (as opposed to best-fit) should be drawn for correlation and projection to maximum pool levels. This should help to eliminate the effect of time-lag. Upper limit lines may need to be drawn manually, using judgment. These correlations should be useful for performing the stability analyses described below.

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7. The effort to create accurate color-coded as-built drawings which depict locations of instrumentation, seepage areas, seepage collector systems, and weirs should be continued.
8. 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.
9. Analyses and associated inundation mapping are underway by the U.S. Section. This should be a Joint International effort. 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 be used to disclose impacts on populations and infrastructure at risk in the U.S. and Mexico. Suggested pool elevations for dam break analyses might include conservation pool (sunny day conditions), at some pool intermediate between conservation pool and PMF, 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.
10. The stability of the entire Falcon Dam should be evaluated. This evaluation should begin with a comprehensive seepage analysis. Accomplishing this would require extensive effort to locate and archive all of the as-built drawings, shop drawings, and design analyses. Hard copies should be digitized. Once all archived materials are recovered, a comprehensive assessment consisting of a review of existing data, stability and seepage analysis, structural analysis, and review of the hydrologic criteria should be performed. Furthermore, the possibility of induced seismic loading due to hydro fracturing associated with oil and gas exploration near the dam should be evaluated.
- a. The seepage analysis should focus on items such as increased seepage with time, the presence of sinkholes, cavities, or sand boils, and will utilize information records in the evaluation. Seepage analyses such as critical gradients, flow-net construction, and finite elements should be performed when sufficient data are available. The seepage control integrity of filters, drains, blankets, and transition zone materials should also be analyzed including a review of the design criteria for the filters.
- b. The slope stability analyses should be performed using force equilibrium numerical methods for steady seepage case for both upstream and downstream slopes and sudden drawdown for the upstream slope.
- c. An abbreviated stability analysis of the concrete portion of Falcon Dam should also be performed using current numerical methods. Parametric studies should be initiated to develop final input properties.

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d. Install a digital seismic station with remote satellite access that has a low threshold of response to vibrations downstream of the curtain and the crest, in a section where seepage has occurred on the United States side. If seismic activity is detected near the dam, follow up with the installation of two other stations.

e. Review the operation and maintenance programs for the dam during ordinary and extraordinary flood conditions; verify that they are suitable under current dam and reservoir conditions, taking into account the results from the most recent silt survey relative to conditions in previous studies and the design criteria.

11. Subsequent to performing the stability evaluations and the inundation mapping, these should be used to perform a Failure Mode Analysis and risk assessment for Falcon Dam.

12. To facilitate understanding the need to conduct the investigations and studies described above, and to encourage management's support for Joint International funding, 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)

Assignment of a DSAC to Falcon Dam at this point has to be based on engineering judgment because the level of risk is not known; i.e., the project has a very high population and infrastructure at risk in both the U.S. and Mexico, but the probabilities of unsatisfactory performance (failure) is not known.

The project has a history of seepage; it has sulfates in the foundation seepage; embankment drainage systems that need evaluation, repair, and/or replacement; and stability of the embankment and spillway have not been evaluated using current analytical methods. The undersigned recommend that Falcon Dam fits into DSAC-III as conditionally unsafe.

When the investigations and studies recommended above are completed, the IBWC will then be in a position to utilize the results to perform risk evaluation and risk assessment of the project. The risk evaluation will be necessary to confirm or change the DSAC appropriate for the dam.

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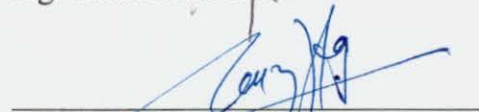
  
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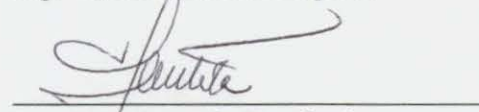
  
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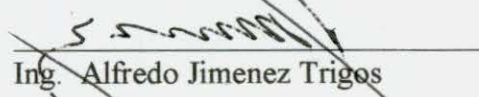
  
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