Amistad Dam Investigation and Oversight: Karst-Founded Dam on the USA-Mexico Border

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Outline

- Background
- Seepage History
- Recent Investigation
- Database/GIS Construction
- Next Steps
Background
- Seepage History
- Recent Investigation
- Database/GIS Construction
- Next Steps
Location of Dam
Project Description

- Constructed between 1963 and 1969 by the United States and Mexico
- Total length of the dam = 6 miles
- Maximum Height of the Concrete Section = 254 ft
- Maximum Height of Embankments = 122 ft
- 16 Tainter Gates
- Zoned Embankment
- Dam Ownership is shared by US and Mexico
  - United States International Boundary and Water Commission (USIBWC)
  - Comisión Internacional de Limites y Agua (CILA)
Stratigraphic Column

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<th>AGE</th>
<th>LITHOLOGY</th>
<th>FORMATION</th>
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Background

Seepage History

- Recent Investigation
- Database/GIS Construction
- Next Steps
Purpose and Objectives of the Investigation
Geology and Foundation Treatment
Purpose and Objectives of the Investigation
Sinkholes, Springs, and Past Remediation Methods
Foundation Treatment

- Single row grout curtain at base of core
- No foundation filters or widespread surface treatment
- Exposed solution features were cleaned out and filled with concrete
Performance Reviews

- 2005/6 Periodic Inspection prompted report to IBWC Commissioners
- IBWC (Dam Owners) hired USACE as their technical advisors
- Amistad Dam was rated a DSAC 2
- Quantitative Risk Analysis performed
- Dam Safety Modification Study nearly complete
Background
Seepage History

**Recent Investigation**
- Database/GIS Construction
- Next Steps
Investigation Components

- Dye Tracing
- Surface Geophysics
- Exploratory Boreholes
- Downhole Geophysics
- Laboratory testing of Rock and Soil
- Observation Well Installation and Automation
- Detention Basin Construction & Instrumentation

Contracted out to AECOM, Overseen by USACE
Performed in 2015-2016
Subsurface Investigation – US Side
Borings and Wells

► Boring locations and drilling methods selected to:
  • Determine filter compatibility between core and shell materials
  • Investigate phreatic surface level across selected cross sections

► Six Vertical Borings Drilled in Dam Core Zone
  • Sonic drilling method, continuous core sample recovered
  • 35 m (115 ft) target depth
  • Bore holes either tremie backfilled with bentonite cement grout or a PVC open stand-pipe well installed
Subsurface Investigation – US Side Borings and Piezometers (Cont.)

- Four Inclined Borings Drilled in Downstream Shell Zone
  - Sonic drilling method, continuous core sample recovered
  - 124 ft to 141 ft target depth
  - PVC open stand-pipe piezometers installed in each boring
  - Water encountered at the base of the shell in E-CI-1B and W-CI-2
  - Deviation surveys performed on all borings

Sonic Core Samples from Downstream Shell of Dam

Track Sonic Drill Rig
Mexico Side Dye Tracer Study
Mexico Side Dye Trace Study
Mexico Side Surface Geophysical Survey
Surface Geophysical Survey

- Methods
  - Microgravity
  - Electrical Resistivity Imaging (ERI)
  - Multi-Channel Analysis of Surface Waves (MASW)

- Performed Work
  - Upstream toe, downstream toe, and centerline (4,734 m)
  - 4 Upstream area lines (945 m)
  - 4 Downstream area lines (1206 m)
Mexico Side Drilling and Testing
Mexico Side Drilling and Testing

- 7 Geophysics Calibration Borings: 2 upstream, 1 crest, and 4 downstream
  - Confirmed anomalies include: intensely fractured rock close to ground surface, cavities, thicker layer of Del Rio Clay, fault, higher water table, etc.
  - Typically, a cavity was confirmed when there was a large dip in the microgravity and a large area of low resistivity.
Mexico Side Drilling and Testing

- 3 Vertical and 12 Inclined Crest Borings
- 1 Vertical and 4 Inclined Upstream Borings
- 3 Vertical and 22 Inclined Downstream Borings
- 4 Inclined Side Slope Borings
- Sonic Drilling through Soil and Marl
- HQ Coring through Rock
- Downhole geophysics in all borings
Mexico Side Findings

- 36 Cavities Total, between 2 inches and 45 feet long
Mexico Side Findings

- Water Pressure Testing
Mexico Side Findings

Cavity at W-D-14

Cavity in Vertical Boring W-U-4
Mexico Side Findings

W-U-5
Mexico Side Findings
Mexico Side Findings

Fault Under Dam at W-D-11

7-foot Cavity at W-D-14
Some exploratory holes were converted to observation wells and automated.
Background
Seepage History
Current Investigation

Database/GIS Construction

Next Steps
Database Construction

- Historical Information
- 3D Elements
- Database & GIS
- Investigation Data
- Cross-Sections and Profiles
- Aerials and Contour Mapping
3D GIS
3D GIS
3D GIS
3D GIS – Zoomed View
- Background
- Seepage History
- Recent Investigation
- Database/GIS Construction

- Next Steps
Next Steps

- USACE finishes “Dam Safety Modification Study” and Report
- Take chosen repair to 100-percent design
- Construct repair on dam
Special Thanks Go To

- International Boundary and Water Commission
- Comisión de Aqua y Límites
- ConAgua
- US Bureau of Reclamation
Questions?
Upstream Sinkholes

Sinkhole #19, approx. 200m upstream of embankment. (6-16-99, resv. 328.05m.)

Sink #10, 1994

Sink #17, small whirlpool and dye located 3km (3,000 meters) north of dam station 10+800; May 1997, approx. resv. 329.29m. (3km = 1.99mi.)
Subsurface Investigation – US Side Borings and Piezometers (Cont.)

Three Vertical Borings in Downstream Area

- PVC open stand-pipe piezometer installed in each boring
- Sonic drilling method, continuous core sample recovered
- Depth varies from 13 to 22 feet bgs
Subsurface Investigation – US Side
Borings, Test Pits, and Piezometers

- Test Pits
  - Three test pits completed on the downstream side ramp
  - Boulders encountered in all of the test pits.
Subsurface Investigation – US Side
Filter Compatibility – Preliminary Analysis

Figure 5-48e: Eastern Embankment Filter Gradation Curves (El. 1080-1120)
Summary of Investigation Tasks

- **Phase I:**
  - Dye Tracer Testing
  - Surface Geophysics: Gravity, Resistivity, Seismic

- **Phase II:**
  - Drill on US Side and Install Wells
  - US Side Laboratory Testing
  - Use Phase I information to select the proposed boring locations for Mexico side

- **Phase III:**
  - Drill borings on Mexico Side and Install Wells
  - Mexico Side Laboratory Testing
  - Excavate Test Pits at Potential Borrow Area

- **Phase IV:**
  - Plan and Install the automatic data acquisition system (ADAS)
  - Design and Construction of Settling Tanks
  - Create a 3-Dimensional Geologic Model