DESIGNING FROM INSIDE THE BOX

Spillway Gate Closure System for Broken Bow & Hugo Lakes

Kansas City SAME Industry Day

Presented by: Jeff Anderson, PE, Mead & Hunt
June 26, 2019
Introduction

Spillway Gate Closure System for Broken Bow & Hugo Lakes (Floating Segmental Bulkhead)

• Background
• Description of segmental bulkhead system
• Design constraints
• Design approach
• Solution
Background

**Broken Bow Dam**

- Existing segmental bulkhead built in 1994
- Difficult to assemble and install
- Not eligible for rehab due to corrosion and structural damage
Background

Hugo Dam

- Existing floating bulkhead built in 1974
- Rehabilitated in 1993
- Due for another round of rehabilitation

Existing Hugo Bulkhead
Scope of Design

• Floating segmental bulkhead system (1 system for Hugo and Broken Bow)
• Boat-mounted mechanical skid and all other components needed for operation
• New storage building and equipment container at Broken Bow powerhouse yard
• Civil improvements at Broken Bow launch site
What is a Segmental Bulkhead?

- System of two or more bulkhead segments that, when assembled, constitute a single, larger floating bulkhead
- Bottom segments can be flooded to rotate assembled bulkhead from horizontal to vertical
- Individual segments light enough to move with a medium-sized crane and store on land
Numerous (Often-Competing) Design Constraints

• Different spillway geometries and design heads at each project
• Different desired operating ranges at each project
• 2 feet of freeboard required
• Tulsa District’s 75-ton crane used for deployment/retrieval – limited segment weights
• Limit personnel needed for deployment and assembly
• No divers needed for assembly
• Maintain marine stability of individual segments and all bulkhead assemblies
• Design in accordance with USACE ETL 1110-2-584
• Provide safe access to interior of segments for inspection and maintenance
Design Approach

• Besides basic geometric requirements, primary drivers of design were:
  – Segment weight limitations
  – Structural adequacy
  – Marine stability
• Iterative design process required – automated structural and marine stability design spreadsheets
• Verify results with finite element analysis and commercial marine stability software
Basic Geometry

- Segment length = 51 feet (based on center-to-center pier width at Hugo)
- Segment width = 2.75 feet (to limit segment weights, achieve marine stability of individual segments, and provide ample space for internal inspections)
- Maximum assembled bulkhead heights for Hugo and Broken Bow are 36.5 feet and 21.75 feet, respectively (Hugo controls)
Segment Weight

- Maximum allowable segment weight driven primarily by three factors:
  - Lifting capacity of Tulsa District’s 75-ton truck crane
  - Maximum capacity of Tulsa District’s 50-ton lowboy trailer
  - Buoyancy of the individual bulkhead segments
- Design team set a maximum allowable segment weight of 34,500 pounds
- Heavier segments on bottom of bulkhead assemblies and lighter segments on top

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Marine Stability

- Maintain positive buoyancy and stability of each individual segment
- Maintain marine stability with 2 feet of freeboard for all bulkhead assemblies
- Avoid any gaps in desired operating ranges for each project
- Volume of ballast water required for each segment for draft leveling during assembly
- Stability verified by a Naval Architect using marine stability software
Structural Adequacy

- Designed in accordance with ETL 1110-2-584, “Design of Hydraulic Steel Structures” and AISC’s Steel Construction Manual (15th Edition)
- Enhanced material toughness requirements (ASTM A709, Grade 50 steel)
- Avoid weld details that are susceptible to fatigue and fracture
- Increased non-destructive testing (NDT) requirements
Structural Adequacy

• Segments designed as rectangular box sections – 4 plates welded at corners
• Globally, segments designed as simply-supported beams in weak-axis flexure between piers
• Locally, segment walls design for external hydrostatic pressure to prevent collapse
• Due to complexity of loading, finite element analysis (FEA) used to verify design
Iterative Design Approach

- Initial Segment Design Based on Weight Restrictions
- Check Buoyancy and Stability of Individual Segments
- Check Marine Stability of All Bulkhead Assemblies
- Check for Gaps in Operating Ranges
- Check Structural Adequacy
- Check Segment Weights
- Modify Skin Thickness and/or Internal Bracing
Final Configuration

- 7 segments designated A through G (bottom to top)
- All segments 2.75 feet wide and 51 feet long
- Segment heights vary from 40 to 70 inches
- Skin plate thickness varies from 3/8” to 3/4”
- Segments A through E have internal stiffeners
- Segments A through C have floodable chambers
- Segments B and C have refill valves
Operating Range – Hugo

• All 7 segments required to cover desired operating range at Hugo
• 5 bulkhead assemblies with a maximum height of 36.5 feet
• Segmental bulkhead can be used to achieve closure of spillway bays over 14-foot range (EL. 394.5 to 408.5)
Operating Range – Broken Bow

- 6 segments required to cover desired operating range at Broken Bow (all but segment D)
- 5 bulkhead assemblies with a maximum height of 21.75 feet
- Segmental bulkhead can be used to achieve closure of spillway bays over 6.5-foot range (EL. 594.5 to 601.0)
Current Status

• Tulsa District currently reviewing bids
• Intent is to award contract in 2019
• Bulkhead fabrication, storage building construction, and civil improvements tentatively planned for 2020-2021
THANK YOU!!!