1- PROJECT NAME: Kentucky Lock Addition – Downstream Float-In Cofferdam

Project Status: A 600’ long by 110’ wide lock and dam are existing. Design of a new 1200’ long by 110’ wide lock addition is complete and the project is currently waiting funding before continuing with construction. The new design includes use of an innovative float-in downstream cofferdam that will be incorporated into the completed lock wall. The upstream cellular cofferdam has been constructed, but no lock construction has begun.

Project Owner: Tennessee Valley Authority (TVA)
Organization in charge of operation: U.S. Army Corps of Engineers, Nashville District
Construction Company(s): Not selected yet
Design Company(s): Not selected yet

Period of Construction (if available): To be determined
Year Placed in Operation: To be determined
Estimate Cost of Entire Project: $630M (US) estimated for total lock project.

Location:
Country: United States
City/Region:
Relevant river, canal, lake: At mile 22.4 on the Tennessee River and 67.4 river miles above the mouth of the Ohio River at Cairo, IL.

Contact Address(es) (organization(s) that can provide additional information – if different from project Owner):
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References:
2- PROJECT DESCRIPTION AND OVERVIEW (1 page)

- The U.S. Congress under the Tennessee Valley Authority (TVA) Act of 1933 authorized the TVA to construct a series of dams on the lower Tennessee River. The initial appropriation by Congress for the original Kentucky Project was given on May 28, 1937. The TVA Board of Directors authorized the project on December 20, 1937. The Kentucky project includes Kentucky Dam and Kentucky Lock.

- The Kentucky Lock Project is located on the Tennessee River at river mile 22.4 and is 67.4 river miles above the mouth of the Ohio River at Cairo, IL. It is the first of a series of navigation locks and dams up the Tennessee River. The navigation lock is located on the right bank or east side of the river. The upper pool of the dam extends upstream for a distance of 184 miles to the Pickwick Landing Locks and Dam at river miles 206.7.

- Construction of the Kentucky project commenced on July 1, 1938 and the lock was opened to navigation September 12, 1944. The main features of the dam consists of a 5,860-foot long west embankment retained at the spillway terminus by a concrete retaining wall; a 1,176-foot long 24-gate spillway; a 478-foot long five-unit powerhouse and service bay; a 732-foot embankment between the service bay and lock; a 110-foot wide navigation lock; and a 200-foot long east embankment. The total length of the project, from abutment to abutment, is approximately 8,422 feet.

BIRDS EYE VIEW(s) of the entire project

Figure 1. Aerial View of Kentucky Lock.

- The USACE Nashville District has identified the Kentucky Lock as a cause of major delays for the shipping industry on the Tennessee and Cumberland Rivers. The existing lock is 600 ft long; requiring the standard 1,200 ft tows and barges to be broken for locking. Plans initially prepared by the TVA (owners of the lock and dam) and further developed by the USACE Nashville District (operators of the lock) in a feasibility level study recommended the addition of a 1,200 ft lock landward of the existing lock to avert navigation delays.

- The Kentucky Locks Addition Project was authorized by the U.S. Congress in 1982. The U.S. Army Corps of Engineers (USACE), Nashville District, is managing the project. Several of the lock design studies have been completed by Nashville District with assistance from various engineering consulting firms including a study of the downstream cofferdam completed by a joint venture design team of Bergmann Associates and Ben C. Gerwick, for the Phase 1 Design Documentation Report (DDR).

- The studies evaluated several different design concepts for the downstream cofferdam. The TVA and COE reviewed all the recommendations and decided which option to design. The current option was a combination of two options, 1) the float-in option from the VE study (Reference 1 and 2; the conventional cellular cofferdam closure from downstream cofferdam DM (Reference 2). The option
chosen for the downstream cofferdam was to use the float-in wall with cellular sheet pile cells to tie in to the existing right bank. The float-in wall will be used for the temporary cofferdam in order to build the new land chamber, and will be incorporated into the design of the new middle wall to eliminate it’s subsequent removal. The float-in wall will be connected to the right bank by means of sheet pile cells and a tied Z-pile wall. These features are filled with granular fill and will be removed upon completion of the new land chamber.

**Down Stream Cofferdam**

- The downstream cofferdam provides the downstream closure in which the new middle wall and new land wall will be constructed.

- The downstream cofferdam is composed of the following main features:
  1. Tied Z-pile wall, connecting to landside.
  2. Conventional Cellular Sheet Pile Cells, including a Gated Flooding Facility.
  3. Two Float-In Segments (Shown in yellow and orange in Figure 2 below).

- The cellular portion is approximately 335 ft long measured along the centerline of the cells. It extends from the downstream end of the float-in segment No. 2 at station 15+19.38B, curves to the right bank, connects to a tied Z-pile wall and then intersects the right bank. The tops of the sheet pile portions are at El. 343.5. The cells and tied Z-pile wall are filled with granular fill material and are founded on rock.

**Figure 2. Plan view of lower end of new 1200’ lock and downstream cofferdam.**

**Float-In Cofferdam**

- The float-in segmental cofferdam extends from the connection with the existing lower guide wall monolith L-25 to the connection with Cell #1 of the cellular portion of the cofferdam. The float-in portion is constructed in two segments. Segment No.1 is the upstream most segment that connects to
monolith L25. Segment No.2 connects to the downstream edge of Segment No.1 and upstream edge of Cell #1.

- The Nashville District of the U.S. Army Corps of Engineers has selected an innovative float-in cofferdam method for construction of the new addition to the Kentucky Lock. The selection was based on a 1999 value engineering study performed by Ben C. Gerwick, Inc. and Bergmann Associates. The original design called for conventional sheet pile circular cells. As an alternate, Ben C. Gerwick, Inc. proposed replacing sixteen of the cells with two float-in prefabricated concrete cofferdams. The proposed cofferdams are very similar to large concrete caissons used in the construction of deep bridge foundations. The foundations for the western crossing of the San Francisco Bay Bridge were successfully built using this method of construction.

- The segments are designed as open bottomed reinforced concrete shells with internal walls that divide each segment into 24 compartments. Airtight lids will be fitted to the top of the compartments and compressed air will be pumped in to provide flotation.

- The float-in cofferdam consists of two float-in segments, one 261 feet long and the other 221-feet long. Both cofferdams will be 46.5-feet wide and 35-feet high. A float-in height of 35-feet has been selected in order to keep the center of gravity down and to maintain the necessary minimum transverse stability during launch and positioning of the floating segments. After set-down, the joint between the two cofferdam segments will be filled with grout. The cofferdams will be connected to the downstream end of the existing guide wall with a precast closure panel, steel transition nose and concrete infill.

Figure 3. Floating cofferdam on mooring lines.

- The float-in cofferdam will be a reinforced concrete shell structure with an open top and bottom. Removable steel lids will be installed on each of the segment compartments to allow the compartments to be filled with air thus providing flotation buoyancy. These lids are stiffened steel cylindrical shells secured to the top of the compartments with high strength pretensioned bars. During periods of low tail water, all water can be forced out of the segment to minimize segment draft. Two 10 ft wide by 40 ft long by 7 ft deep stabilizing pontoons are attached to the sides of the segments to maintain a minimum 4.0 ft transverse metacentric height (GM). (See section on Stability of Float-in Cofferdam Segments on page 7 for a description of GM.)

- The ballast system shown consists of four independent compressed air piping systems per segment. Each system provides compressed air to the compartments in one quarter of the float-in segment. The ballast system will be designed to level and trim the segments as well as to adjust segment draft.

- Twelve inch thick walls will divide each floating segment into 24 compartments 20-ft by 20-ft 9-in in plan. These walls provide the necessary stiffness for the cofferdam walls and divide the segment into manageable construction units for concrete placement and dewatering.
The segments will be pre-fabricated off-site on the deck of a barge. While the segments are being fabricated, the set-down site for the cofferdams will be pre-excavated and any weathered or loose rock will be removed. Following site preparation and cofferdam fabrication, the cofferdam segments will be launched from the fabrication barge by using the existing Kentucky Lock as a dry dock and by sinking the barge in the lock. Tugs will then remove the barge and floating cofferdam from the lock, and the cofferdam will be positioned over the set-down site.

A conventional mooring system will be used to initially position the cofferdam horizontally. Four spud piles will be driven to lock the cofferdam into horizontal position and provide vertical support during vertical positioning. After confirming correct elevation, inflatable grout bags, pre-attached to the bottom edge of the float-in cofferdam, will be filled with grout to seal the perimeter of the cofferdam. Following inspection of the bottom interior, the cofferdam will be locked to the rock surface by placing a 10-ft deep tremie concrete seal in each of the 24 compartments. After allowing the seal to cure, each of the compartments will be dewatered one at a time and will be filled with structural concrete placed in-the-dry. After infill of the precast shell, the height of the cofferdam will be extended by 30 feet with cast-in-place concrete, the main lock site will be dewatered and the lock wall will be cast against the inside face of the cofferdam.

This cofferdam method offers significant advantages over conventional methods:
1. Less disruption to navigation through the existing lock during construction.
2. Shorter construction time for the cofferdam by allowing the foundation preparation to be performed concurrent with cofferdam pre-fabrication.
3. Lower cost of construction by transferring most of the work from mid channel to dock side.
4. Wider navigation clearance during construction of the cofferdam and new lock.

The illustration in Figure 4 below shows a plan view of a float-in segment. Compressed air is used to control the draft and attitude of the 3500-ton floating structure.

Casting Site for Float-In Cofferdam Segments

The cofferdam segments will be cast in a dry dock or on the deck of a barge. If flat deck barges are used, they must be able to accommodate a 261-foot concrete segment. Barges 260ft by 72ft by 16ft are readily available along the Mississippi River. If a dry dock is used, it would need to be relatively close to Kentucky Lock, and the water depth from the dry dock to the lock would need to be a minimum of 12 feet. The fabrication of only two cofferdam segments would not justify the cost of developing a new dry dock site for this project alone. The most likely option is to cast the segments on the deck of a flat deck cargo barge and launch the segments in the existing Kentucky Lock.

The precast panels will most likely be fabricated at an off-site precast facility. The panel size (14'-0" by 35’ max) and weight (40 tons max) will necessitate that the precast plant be located on the river and delivery of the panels by barge.
Launch of Float-In Cofferdam Segments

- The float-in cofferdam segments are designed as bottomless and topless boxes with interior walls for stiffening. In order to provide the necessary buoyancy for flotation, the interior compartments of each cofferdam will be fitted with airtight lids and the compartments will be pressurized to about 4.3 psi.

- If the segments are cast on the deck of a barge, sinking the barge out from under the segment will launch the segments. The barge could be sunk in open water, however, this method will require water depth of at least 32-feet and preparation of the bottom for landing of the barge. This method also requires special consideration of the barge stability, as the barge will be submerged.

Figure 5. Longitudinal section of float-in cofferdam Segment 2.

- The recommended method for launching the cofferdam segments is to use the existing Kentucky Lock. While the barge with the cofferdam segments is being positioned in the lock, the water level in the lock will be lowered to the tail water elevation. The barge will then be ballasted until it grounds on the lock floor. Additional ballast is to be added to the barge to maintain negative buoyancy during the entire launching process. The amount of negative buoyancy will depend on the barge and on the condition of the lock bottom. A minimum of 5% negative buoyancy is recommended. After the barge is grounded and ballasted the water level in the lock will be raised until the cofferdam floats free of the barge. The segment will be positioned in the lock (downstream of the barge) and the water level lowered to match the tail water level, the barge will be re-floated by pumping water from the barge. The total time required for this operation is less then 24 hours.

- This method offers the advantages of launching close to the set-down site and minimizing any transport risks. This method also allows equalization of pressure within the barge and provides adequate stability without taking any special precautions. If the bottom of the lock is uneven, landing pads can be pre-installed on the lock floor.
Stability of the Float-In Cofferdam Segments

- The specified minimum stability during launch, transport, outfitting and immersion of the cofferdam segment is a transverse metacentric height (GM) of 4.0 feet. GM is the vertical distance between the center of gravity of the floating structure (including all equipment, attachments and ballast) and the metacenter. The metacenter is the point about which the buoyancy of the structure rotates, as the structure is inclined from the horizontal. The higher the GM, the more stable the floating structure. As the GM for the structure approaches zero, the structure becomes easier to tip, until at zero GM, it is at balanced equilibrium. The structure is unstable when GM is negative.

- Two factors, which significantly increase stability, are the width of the structure (GM increases by the square of the floating structures width) and a low center of gravity (GM increases proportionally with lowering of center of gravity).

- In order to minimize the draft, no water plug is considered in the bottom of the pressurized air compartments. Under this situation, the transverse GM is equal to -0.51 ft and the segment will be theoretically unstable. To resolve this problem, two stabilizing pontoons, 10-ft by 40-ft by 7-ft deep, attached to the longitudinal sides of the cofferdam segment will be required. With these pontoons, the transverse GM is increased to 5.08 ft exceeding the minimum requirement of GM = 4.0 ft.

Positioning and Set-Down of Float-In Cofferdam Segment

- The alignment and positioning control system for the two float-in dam segments consists of the following five elements:
  - A five point mooring system attached to preset anchors.
  - A fully reversible ballasting system for lowering the segments.
  - Three 5-foot diameter pre-installed landing pads per segment.
  - Pre-installed positioning bracket attached to the top of float-in segment and a pre-installed horn guide positioned on top of the existing downstream guide wall (or on top of Segment 1 when Segment 2 is positioned).
- A land based conventional survey system with targets on the floating segments.

- This system is designed to position each of the two segments to within a vertical tolerance of +/- 1/4 inch and a horizontal tolerance of +/- 2 inches (in transverse direction). The relative horizontal position between the two segments can be limited to 1/4 inch by using mooring lines pull the segment tight to the pre-set fixed guide.

- The float-in cofferdam segments should be positioned with five mooring lines. Currents at the time of positioning and set-down can be significantly reduced or even eliminated by closing of the locks. The total time required for positioning and set-down should be less than 24 hours.

- The winches for positioning should be located on top of the float-in segment to facilitate coordination of the lines. Controls for all winch lines should be centralized on one control panel.

- Once the segment has been positioned horizontally, the segment will be landed onto the landing pad at upstream end first. At this moment, the downstream end will be trimmed about six inches higher than the upstream end. The prescribed amount of negative buoyancy will be maintained by adjusting the water level in the compartments. The two upstream mooring lines will be used to pull the segment tight to the fixed positioning guide to reach an accurate alignment at upstream end. Finally, the two downstream mooring lines will be used to align the downstream end of the segment and then the downstream end will be lowered onto the remaining two landing pads. Once this position has been reached the negative buoyancy will be increased to 20%.

- The set-down grout bags under the bottom edge of the cofferdam will be inflated and the grout will be allowed to cure until it achieves a minimum strength of approximately 3,000 psi. The full segment weight will then be transferred onto the grouted set down bags as the compartment air is released.

- Filling the perimeter grout bags will seal the gap between the bottom of the segment and the top of rock. When the grout has reached sufficient strength the tremie process can begin.

Figure 7. Float-in cofferdam segment and new lock wall.
Cofferdam Infill

- After sealing of the cofferdam perimeter to the rock, the bottom of each compartment will be inspected and cleaned as necessary. After inspection and cleaning, the cofferdam will be filled with approximately 12 ft of tremie concrete. After the concrete has attained a minimum compressive strength of 1,000 psi, individual compartments can be pumped dry, four compartments at a time and filled with concrete placed in the dry. The height of each lift will be determined by thermal considerations. Location of vertical contraction joints has yet to be finalized. Design of the Lower Lock Monoliths, which is currently ongoing, is addressing this subject. Results of this effort will be incorporated into the design of the cofferdam prior to completion of plans and specifications.