Rapid design and construction of sheet piling weir protects Florida water control structure

Kathleen Collins, P.E., USA; **Michael DelCharco**, P.E.; Taylor Engineering, Inc., USA; & **Richard J. Hartman**, Hartman Engineering, Clarence, NY USA

Extended drought conditions in the southeastern portion of the United States caused Lake Okeechobee to fall to historically low levels. This resulted in potentially large head to tailwater differences at water control structures operated by the South Florida Water Management District (District). Heavy flows of water, such as those caused by a hurricane, could undermine the existing structures and threaten their stability. The District elected to construct weirs downstream of three water control structures in order to eliminate the threat. An emergency authorization of $25 million was allocated for the protective measures.

Of particular concern was Structure S-65E which had developed a scour hole 200 feet by 200 feet by 10 feet deep downstream of the structure. A soil exploration and design program was instituted with the goal of constructing a protective weir prior to the beginning of hurricane season. The initial concept involved two sheet piling walls across the Kissimmee River in conjunction with four filled circular sheet piling cells and a soil embankment extending to the shores. The soil boring and testing program identified soft soil which would cause the embankments to fail. An alternate system using eight filled circular sheet piling cells was designed and prepared for bid within a two week period. The final design included eight filled circular sheet piling cells, two underwater sheet piling weirs, and two massive tremie concrete installations. The project was bid and awarded, and the contractor completed the project on schedule.

Introduction

Over the last several years, Lake Okeechobee has experienced record low water levels because of an extended drought. One consequence of the low water levels is the reduced functionality of the water control structures discharging into the lake. As designed, hydraulic structures function within a certain range of headwater and tailwater elevations. Low tailwater elevations (on the downstream or lakeside) can reduce a structure's capability to safely discharge high flows. Discharging flows with low tailwater elevation would result in large scour holes, which could possibly undermine the structure. The potential mechanism for erosion is shown schematically in Figure 1.

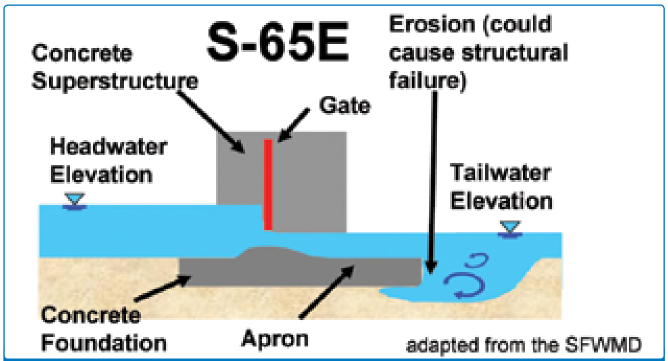

Figure 1. Schematic showing potential for erosion downstream of water control structure.

Figure 2. Photograph of Structure S-65E looking upstream (courtesy SFWMD).

Of particular concern was Structure S-65E which is shown in Figure 2. A scour hole 200 feet long by 200 feet wide and 10 feet deep had developed downstream of the structure.

Failure of a water control structure can have disastrous effects because it could lead to lower tailwater elevations upstream, possibly causing a chain reaction of failures. The worst case could lead to failure of structures as far as 75 miles upstream with resultant catastrophic flooding of residential and agricultural property.

Conceptual design of the preventive measures began in January 2008. Completion of the project was extremely urgent because hurricane season, with its associated heavy rainfall, starts at the beginning of June.

Preliminary design

Because of the urgency of the project, a conceptual design was developed prior to completion of a site specific geotechnical investigation. Two soil borings drilled approximately nine years earlier, and located several thousand feet distant, were used for the conceptual phase of the design. A site specific investigation was conducted simultaneously with development of the conceptual design.

The anticipated preventive measures involved construction of a weir composed of two sheet piling walls approximately 90 feet apart and extending across the river, a distance slightly more than 200 feet. Between the two walls there would be a concrete slab capable of withstanding the energy of water flowing over the upstream sheet piling wall.

At the two ends of the weir, on the two shores of the river, abutments would be constructed of filled circular sheet piling cells. Each abutment would consist of two cells and one connecting arc. Earthen embankments were anticipated for closing the remaining distance between the cellular abutments and the land.

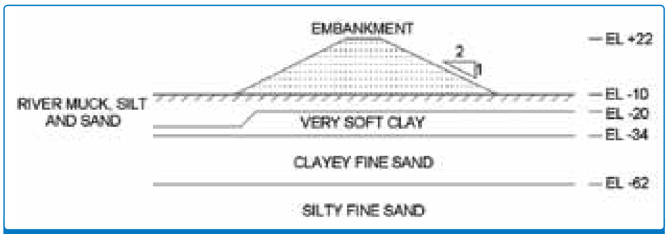

Figure 3. Schematic of embankment and soil strata.

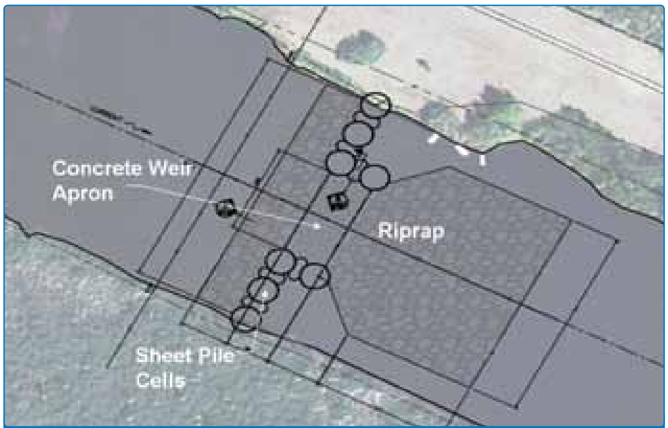

Figure 4. Plan view of the revised design.

Results of the geotechnical investigation

Five new soil borings were drilled and the resulting information indicated that an earthen embankment would not be stable. Figure 3 shows schematically the location of the embankment and the soil strata.

Examination of Figure 3 shows a layer of very soft clay that would be incapable of supporting the embankment. Because of the instability inherent in the system, a type of restraint different from the conceptual design was required.

Revised design

A revised system was designed using four filled circular sheet piling cells on each side of the river. The sheet piling cells extended downward through the very soft clay to Elevation -48, where they were supported by a layer of clayey sand. The revised system is shown schematically in plan in Figure 4.

Use of four circular sheet piling cells to form each abutment provided a method of stabilizing the structure at the ends of the weir. The weir itself is composed of two sheet piling walls

Figure 5. Sheet piling weir and separator wall during construction (courtesy SFWMD).

Figure 6. Water control structure and newly completed weir (courtesy SFWMD).

approximately 90 feet apart. Between the two walls is an eight foot thick concrete slab which was installed as a tremie pour. It was necessary to install the sheet piling walls and the concrete slab in two segments in order to maintain the flow of the river. The two segments of concrete were separated by a third sheet piling wall. Figure 5 shows one of the sheet piling weir walls and the separator wall prior to final driving and cutoff.

The concrete slab, approximately 200 feet by 90 feet by eight feet deep, was placed as two two tremie pours. Each pour involved placing approximately 2,700 cubic yards of concrete and was performed at night in order to facilitate batching and transportation of the concrete. The newly completed weir structure and the water control structure it protects are shown in Figure 6.

Design and construction schedule

Due to concern regarding stability of the water control structure and the immediacy of the hurricane season, design and construction of the weir were put on an accelerated schedule. The accelerated schedule called for design, bidding, and construction to be completed in 6.5 months compared to a typical schedule of two years, a 70 per cent reduction of time. Graphs comparing the accelerated schedule with a typical schedule are shown in Figure 7. As previously described, preliminary design proceeded using existing geotechnical data concurrently with collection of site

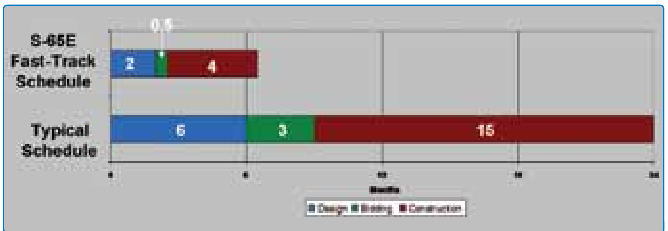

Figure 7. Comparison of accelerated and typical schedules.

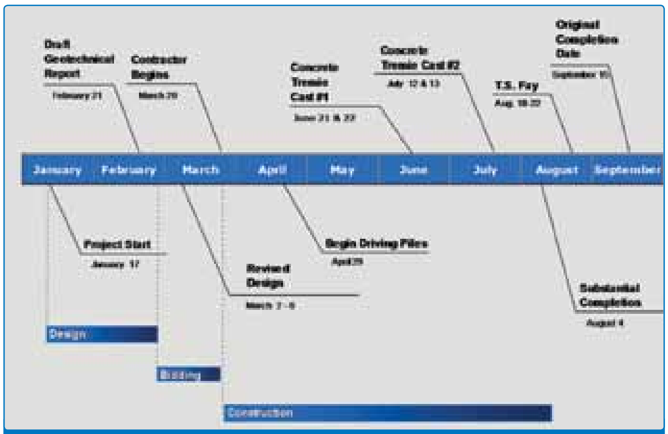

Figure 8. Actual construction schedule.

specific data. When the newly-collected data became available, it was apparent that significant changes were required. An urgent conference call among the District, U.S. Army Corp of Engineers, and the design team resulted in development of the revised concept. Consistent with the fast track requirements, the revised design was performed in four days.

The bidding process was also affected by the surprises in the site specific geotechnical information. The contractors initially were bidding on the preliminary design which used four filled circular sheet piling cells and two connecting arcs. Redesign changed the number of circular sheet piling cells from four to eight, and the number of connecting arcs from two to six. Consequently, the contractors bidding the project were required to incorporate major changes into their bid.

After the contract was awarded, it was imperative that sheet piling material be available very quickly. The preliminary design used approximately 800 tons of flat web sheet piling whereas the revised design used approximately 1,800 tons, an increase of 1,000 tons. The sheet piling supplier accommodated the changes and adopted a 'just-in-time' delivery strategy.

The contractor worked diligently and exceeded the schedule requirements. Construction work began March 20, 2008, with a scheduled completion date of September 15, 2008. However, substantial completion was accomplished on August 4, 2008, six weeks before the scheduled completion date. The actual schedule for the project is shown in Figure 8.

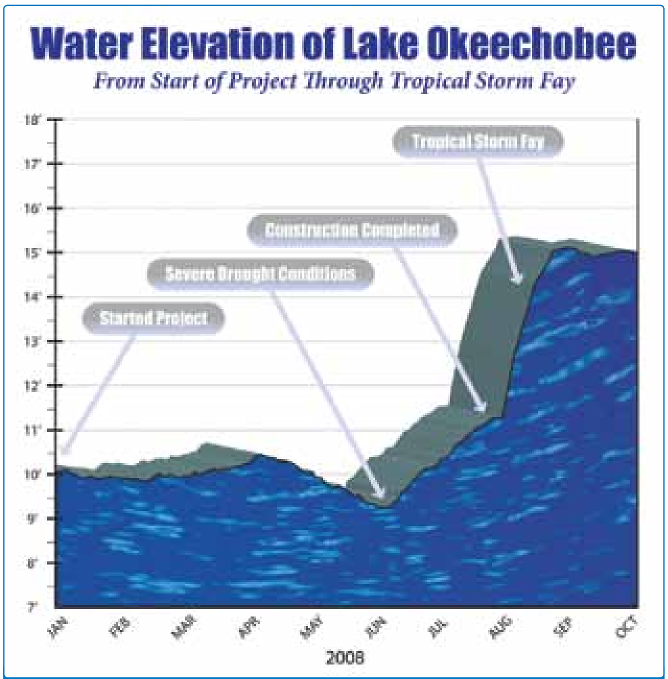

Figure 9. Water elevation of Lake Okeechobee.

Tropical storm fay

The efforts of the owner, design team, suppliers, and contractor were rewarded when Tropical Storm Fay occurred and dropped record rainfall on the Lake Okeechobee basin. The storm occurred from August 18 to August 22, 2008; this was after substantial completion on August 4 and prior to the scheduled completion date of September 15.

Lake Okeechobee experienced the greatest rise in water surface in its 60 year history. A graph showing the lake level from the start of the project through the storm is shown in Figure 9.

The record rainfall forced the owner to release near maximum capacity flows. This is exactly the situation the South Florida Water Management District recognized as a potentially disastrous situation and the reason for adopting the accelerated schedule. The District's foresight and the performance of the structure prevented catastrophic flooding of many homes, communities, and agricultural areas.

ABOUT THE COMPANIES

Hartman Engineering has provided excavation protection design and consultant services since 1968 and has designed hundreds of excavation protection systems. They also perform investigations, write reports, and advise clients in cofferdam failure situations. In addition to work in the United States, projects have been designed in Puerto Rico, Panama, Egypt, and the Marshall Islands.

Taylor Engineering specializes in Coastal Engineering, Hydrology and Hydraulics, Waterfront Engineering, and Environmental Services with offices in Jacksonville, West Palm Beach, Tampa, and Baton Rouge, LA.

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Hartman Engineering
Tel: +1 716 759 2800
Web: www.hartmanengineering.com

Taylor Engineering
Tel: +1 904 731 7040
Web: www.taylorengineering.com