Caloosahatchee River West Basin Storage Reservoir Design and Construction

Shawn Waldeck, Joseph Albers, and Thomas McKernan

The Caloosahatchee River has experienced the consequences of altered flow patterns and degraded water quality as the natural system hydropatterns have been affected by development in southwest Florida. Large influxes of water from Lake Okeechobee discharges and heavy rainfall during the wet season have impacted the health of the Caloosahatchee Estuary. Conversely, reductions in flows in the dry season have resulted in increased salinity regimes affecting the balance of marine life in the estuary.

The South Florida Water Management District (SFWMD) is responsible for implementing projects for the Comprehensive Everglades Restoration Plan (CERP) to help improve water quality and regulate water flows into the Everglades systems and estuarine ecosystems. Located on 10,700 acres of a former citrus grove in Hendry County, the C-43 West Basin Storage Reservoir will store approximately 57 bil gal, or about 170,000 acre ft. The project, expected to be completed in 2022, will include construction of two 5000-acre reservoir storage cells (Cells 1 and 2); three pump stations; a perimeter canal, along with associated water control structures; and required improvements to the State Road 80 Bridge and the Townsend Canal, ultimately connecting to the Caloosahatchee River.

The C-43 West Basin Storage Reservoir Project will reduce the frequency and intensity of harmful freshwater discharges into the Caloosahatchee Estuary, helping to restore historic salinity levels. Once completed, the project will provide immediate environmental restoration benefits by:

- Capturing and storing stormwater runoff from the C-43 Basin and regulatory discharges from Lake Okeechobee, thus reducing excess freshwater flows to the estuary.
- Helping to maintain a desirable salinity balance by controlling peak flows during the wet season and providing essential freshwater flows during the dry season.
- Helping to sustain a healthy estuarine nursery that supports recreational and commercial fisheries.
- Reducing nutrient loading to the Caloosahatchee Estuary, an incidental benefit resulting from the settling of nutrient-rich particulate matter in the reservoir.

The final design of the project was initially completed in 2008 during the Acceler8 Program, which is part of CERP and aims to restore Florida's ecosystem by accelerating the completion of eight restoration projects. The SFWMD is collaborating with the U.S. Army Corps of Engineers (USACE) to update these plans and specifications to current state and federal standards, including dam safety standards. The project will be executed in four construction packages, three of which are already under construction.

Figure 1. Caloosahatchee Estuary *(source: USACE, Ref. 1)*

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Design Features and Construction

- Package 1 – Preloading and Demolition
  - Design completed June 2015
  - Construction completed and preload monitoring is ongoing
  - Construction contract finalized July 2018
  - Contract value: $10 million
- Package 2 – Pump Station S-476 (195 cu ft per second [cfs])
  - Design completed December 2015
  - Construction contract awarded June 2016
  - Construction completion anticipated August 2018
  - Contract value: $11 million
- Package 3 – Pump Station S-470 (1500 cfs)
  - Design completed October 2017
  - Construction contract awarded December 2017
  - Construction completion anticipated March 2021
  - Contract value: $59 million
- Package 4 – 18 mi of Dam/15 sq mi of Reservoir and Water Control Structures
  - Design underway
  - Construction contract awarded 2018
  - Construction completion anticipated 2022
  - Contract value: $400 million (estimated)

This article will provide an overview of the project, and the design, permitting, and construction challenges for the C-43 project in the unique south Florida environment.

Project Background

Everglades Restoration Strategies Plan

The Caloosahatchee River and Estuary (Figures 1 and 2) includes an important estuarine and marine ecosystem that contains aquatic preserves, along with several other federal, state, and local parks and recreation areas. Restoration of a healthy, productive aquatic ecosystem in the river is essential to maintaining the ecological integrity and associated economic activity in these publicly owned and managed areas.

The C-43 project was originally authorized in accordance with the requirements of Section 601(d) of the Water Resources Development Act of 2000 (WRDA2000). In October 2003, SFWMD initiated the Acceler8 Program to move forward with major CERP reservoir projects in parallel with the development of the project implementation report by USACE. The project was shelved in 2008 due to the downturn in the economy in the United States. In 2014 the project was resurrected and implemented as part of the SFMWD restoration strategies program to finalize design and initiate construction on the C-43 Reservoir. Although still considered to be a CERP project, the reservoir is currently being executed through the restoration strategies engineering and construction contracts managed by SFWMD.

Lessons learned from the levee failures after Hurricane Katrina resulted in the project being redesigned to incorporate the updated engineering standards from USACE. The project is being incrementally delivered as each of the contracts are redesigned and moved forward into construction.

The project includes approximately 170,000 acre ft of above ground storage on over 10,700 acres of former citrus groves. The volume in the two-cell reservoir includes normal pool depths, when the reservoir is full, varying from 15 ft at the southeast corner to 25 ft at the northwest corner. Major features of the project include external and internal embankments, canals, three pump stations, water control structures, and environmentally responsible design features. The project provides deepwater habitat within the impoundment cells, including refugia (created by embankment excavation), for fish and other aquatic animals during extremely dry periods. Some water quality benefits may be realized in the estuary, since some of the nutrient-laden runoff and lake water will be stored in the reservoir,

Figure 2. Caloosahatchee Watershed *(source: USACE, Ref. 1)*

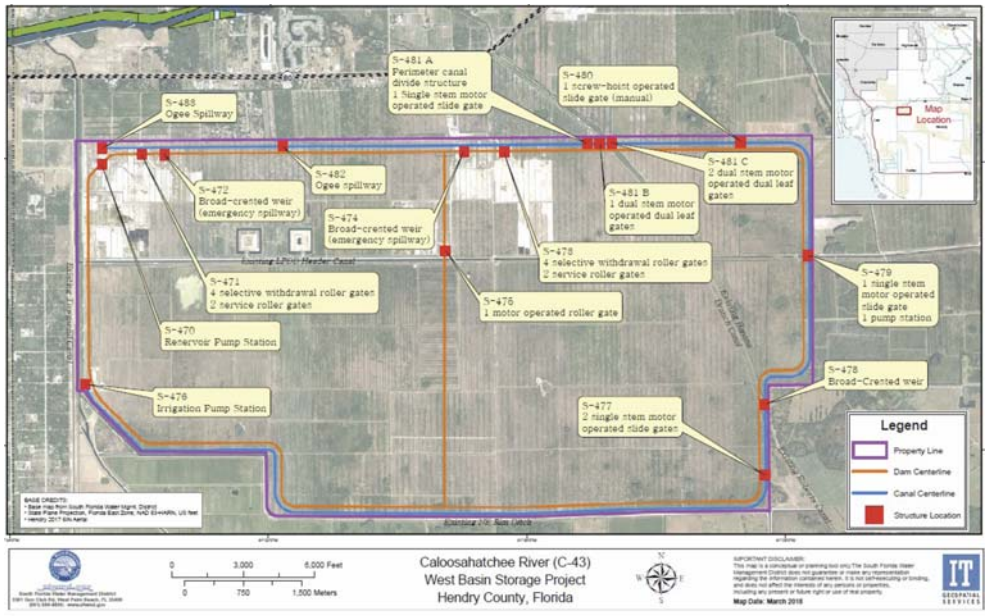

Figure 3. C-43 Reservoir Project Site Plan

allowing for the settling of nutrients within the reservoir cells prior to delivery to the estuary.

C-43 Reservoir Project Site Location and Conditions

The C-43 project site is located in LaBelle in Hendry County, south of SR 80 and along the C-43 Canal, approximately 30 mi east of the City of Fort Myers. The reservoir is about 6 mi long and approximately 3 mi wide, and averages approximately 17 ft in depth. The top of the perimeter dam is at an elevation of more than 54.5 ft North American Vertical Datum (NAVD). The bottom of the reservoir varies in elevation from approximately 16 to 26 ft.

The site geology consists primarily of a thin and variable surface layer of top soils, un-

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derlain by sands and clayey sands, down to a deposit of clays of marine origin. This formation, which comprises the bottom impermeable layer, generally extends from less than 20 ft. The formation is an area of unique geological character in south Florida, and when combined with a soil bentonite cutoff wall, the reservoir will efficiently "hold" water.

Most south Florida water storage facilities experience excessive seepage flows. The clay zone deposit has low hydraulic conductivities and allows effective storage in the above ground impoundment with minimal seepage outflows and losses. This minimizes the need for substantial seepage pumping.

Design and Construction Overview

The design and construction of the C-43 project includes improvements to the existing Townsend Canal and serves as a direct connection from the reservoir to the Caloosahatchee River. An improvement to the level of flood protection and preservation of water supply for the surrounding agriculture is an added requirement of the project. An overall site plan of the project is shown in Figure 3.

Major features include:

- Preloading and Demolition – Construction Package 1
- S476 Pump Station (195 cfs bypass water supply) – Construction Package 2
- S470 Pump Station (1,500 cfs reservoir inflow) – Construction Package 3
- C-43 Reservoir (170,000 acre ft above ground storage) – Construction Package 4

Project Design and Construction

Preloading and Demolition: Construction Package 1

The first step in the construction of the reservoir included demolition of existing agricultural infrastructure (including underground irrigation piping and wells) and installation of seven preload mounds. While the clay layer extending throughout the site is beneficial to the completed reservoir, it presents challenges for construction. The results of the laboratory analyses revealed that the clay layer was susceptible to significant settlement when loaded with embankment and structures. Settlements were predicted to be between 20 and 30 in. at various locations throughout the site.

To minimize the excess predicted settlement, the geotechnical engineer designed earthen preload mounds at specific structure locations (photos 1 and 2) around the site; these areas included softer embankment reaches and major water control structures. The mounds were constructed of onsite soil sands and were constructed to a height of 56 ft, totaling more than 2 mil cu yds of material. The onsite sands will eventually be reused as aggregate for the future soil cement embankment protection on the dam in Construction Package 4.

Instrumentation was included on each preload mound to measure settlement and pore pressures in the clay layer below. These devices included vibrating wire piezometers, inclinometers, and settlement plates. The data were collected weekly and monthly as the mounds were constructed until the movement and pore pressure in the mounds had dissipated. Settlements are expected to occur within a year of the preload construction. Figure 4 represents the settlement plate data recorded at the S470 pump station. As can be seen, the settlement of the mound responds to the application of the fill. As the mound is topped out, the settlement readings indicate that the bulk of the settlement occurs within approximately three to four months, with a total settlement of approximately 16 in.

Corresponding pore pressure measurements show similar results, indicating that, over the same relative period, the pore pressures in the clay layer below dissipate as the mound settles. A representation of pore pressure measurements for the preload mound at an embankment preload area is shown in Figure 5. This particular mound was constructed in two phases to allow the mound to achieve initial consolidation. After a slight delay, the remainder of the embankment fill was placed. The pore pressure response can be seen to dissipate after application of the load and reduces to near zero change in four to six months.

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Photo 1. Preload Mound at S471

Photo 2. Preload Mound at S473

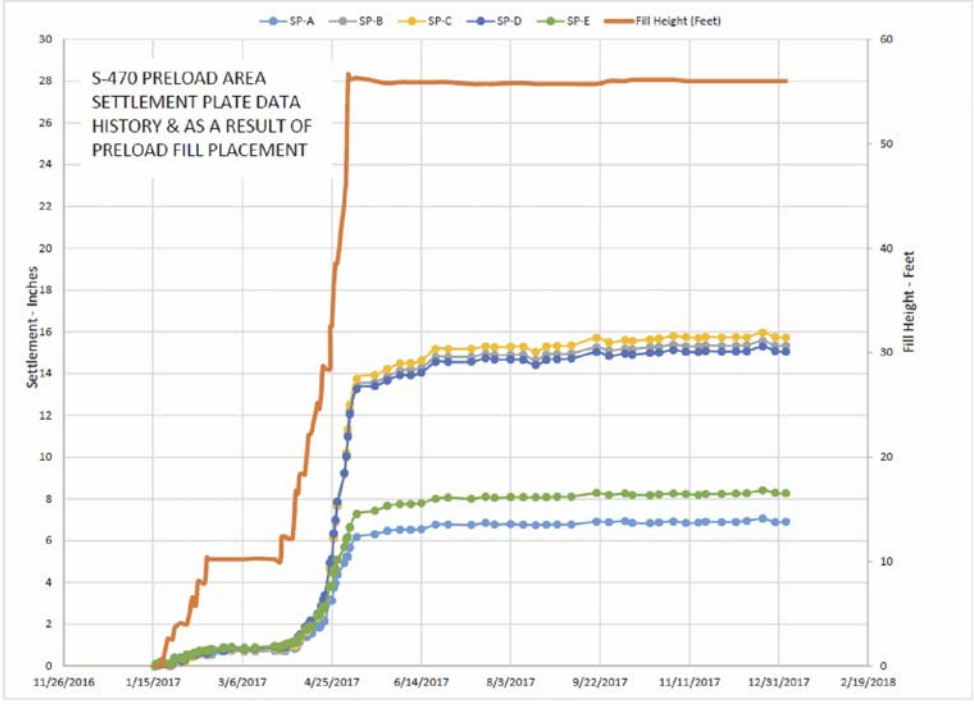

Figure 4. S470 Preload Mound Settlement

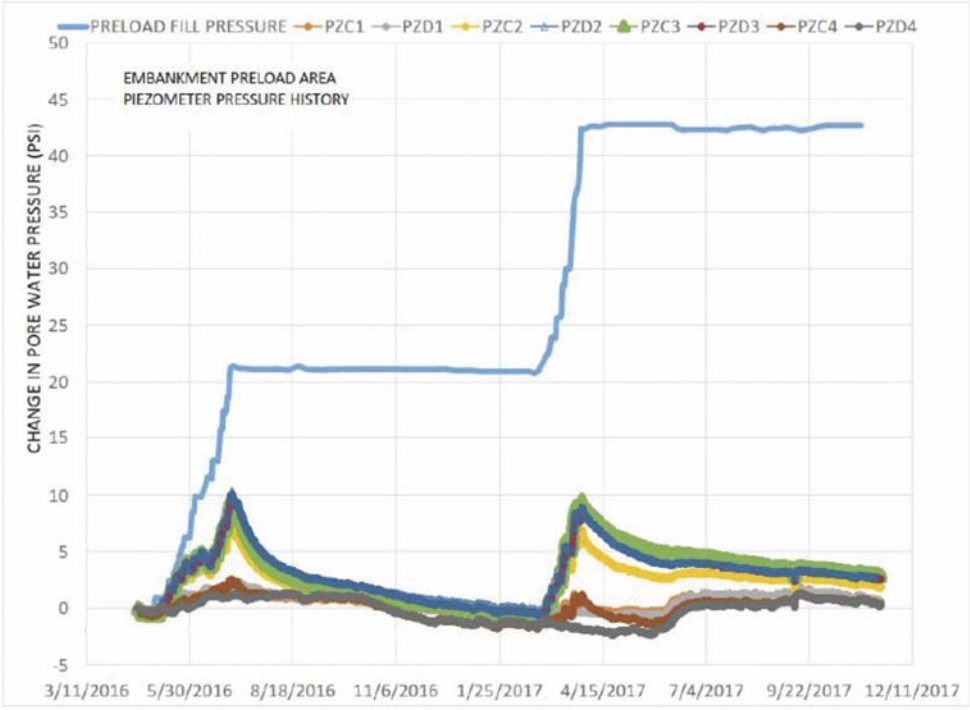

Figure 5. Two-Stage Embankment Preload Mound Pore Pressure Readings

Photo 3. S472 Pump Can

Photo 4. S476 Cofferdam

Photo 5. S476 Pump Can Installation

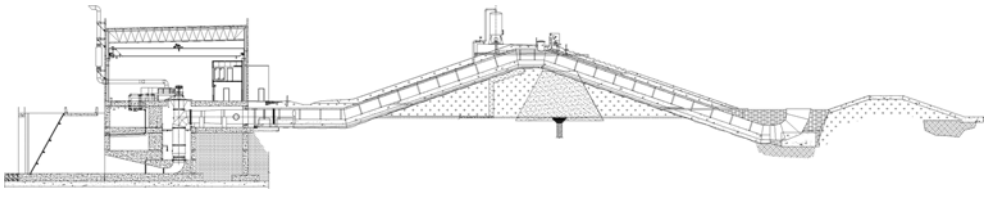

Figure 6. S470 Cross Section and Discharge to Reservoir

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S476 Pump Station (195 cfs bypass water supply): Construction Package 2

Adjacent agricultural activities continue to rely on water supplies from irrigation canals running through the C-43 site. The main header canal running east-west through the site conveys water from the Townsend Canal to the agricultural lands to the east and these water supply deliveries must be maintained. A new perimeter water supply canal will be constructed in Package 4. The S476 pump station replaces the existing water supply pump station and delivers water to the farms through the new perimeter canal system.

A key to the project's success will be the ability to dewater control structures and reservoir excavations that allow maximum flexibility, adapt to variations in anticipated seepage and weather conditions, and allow for flexibility in construction sequencing. Effectively and efficiently constructing the project requires executing a series of comprehensive reservoir dewatering steps. Photo 4 shows the cofferdam system utilized for S476 construction. During construction of the preload mounds and excavation of the S476 pump station foundations, the lessons learned were captured and applied to the design and construction of subsequent engineering packages for the remainder of the reservoir and water control structures.

S470 Pump Station (1500 cfs inflow): Construction Package 3

The primary feature of this project is to construct the reservoir pumping station (S470) with a nominal capacity of 1,500 cfs, including four nominal 375 cfs (each) vertical line shaft electric driven pumps. Other features of the work include a microwave tower and control building, structure removal at the confluence of the Townsend Canal and C-43, and SR-80 bridge armoring. The work includes dewatering, site work, grading, paving, drainage, and associated electrical and communications systems.

The electric pumps are 2,500 horsepower each, requiring upgrades to the existing Florida Power & Light Co. (FPL) distribution system to the pump station facility. The medium voltage pump motors will be powered with 4160-volt service from the new FPL distribution line.

The S470 pumping station will discharge into the reservoir when completed. Several features have been included in this project so that the pumping station may be functionally tested and commissioned; however, the permanent discharge feature will be over the dam piping, which discharges into the reservoir in Package 4 (Figure 6).

Extensive physical modeling of the pump station was conducted at Clemson Engineering Hydraulic Laboratory. The physical model consisted of a scale model of the pump forebay, including screens, formed suction intake (FSI), and pump inlet. The model was used to optimize the design and minimize free surface vortices and preswirl, as well as adverse hydraulic conditions. The results were included in the pump station design. The results of the model indicated refinements to the FSI and intake were required to improve flow hydraulics. These improvements included the addition of straightening vanes and vortex breakers added above the intakes to reduce preswirl. (Photos 6 and 7).

The confluence of the perimeter canal discharge, the large inflows into the pump station, and the intake canal and connection to the Townsend canal were carefully analyzed. Figure 7 represents the model boundaries and cross sections for the open flow channel configuration.

Computational fluid dynamic modeling confirmed intake channel performance during pumping and discharge back out of the reservoir (Figures 8 and 9).

A 320-ft microwave tower and communication facility is also included in this contract. The tower is designed for remote communications and control from the SFWMD operations headquarters. The dam associated with the reservoir is a high-hazard facility requiring extensive reservoir monitoring for dam safety. Monitoring data collected upon the completion of Package 4 (reservoir construction) will be transmitted to both the SFWMD control room and the USACE GOES system.

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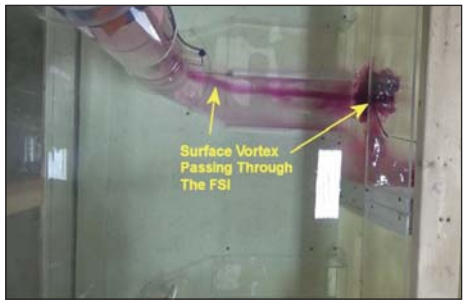

Photo 6. Surface Vortex Formation

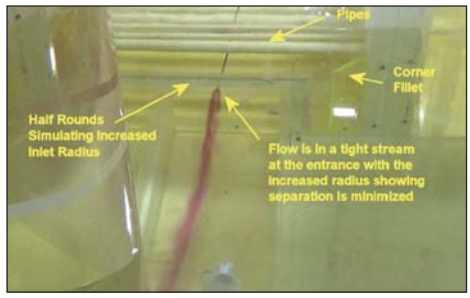

Photo 7. Intake Refinements

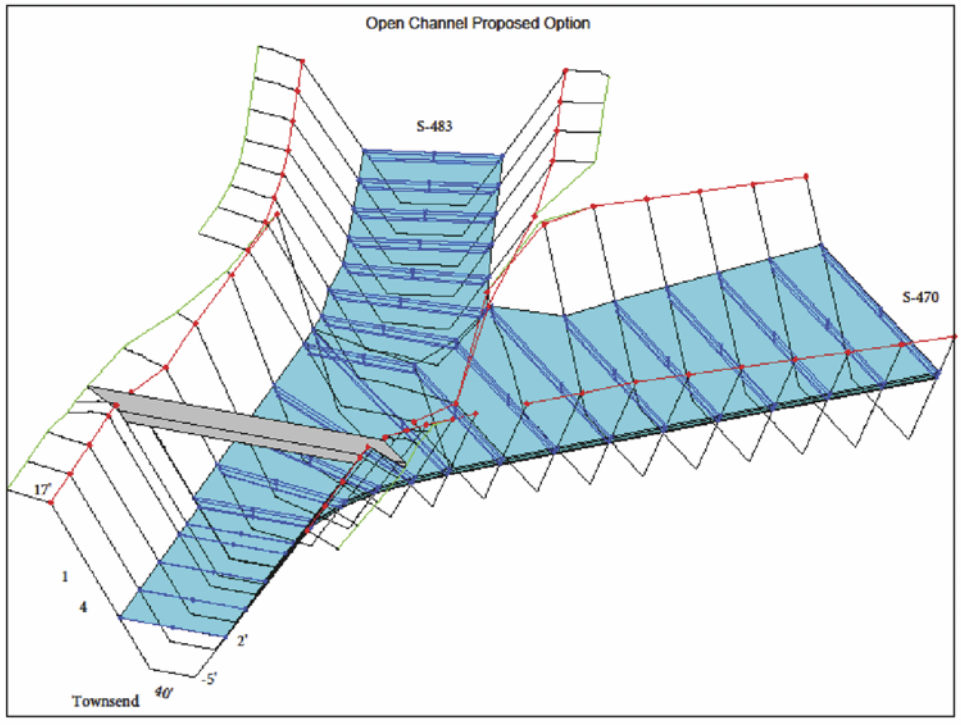

Figure 7. S470 Intake Hydraulic Model Configuration

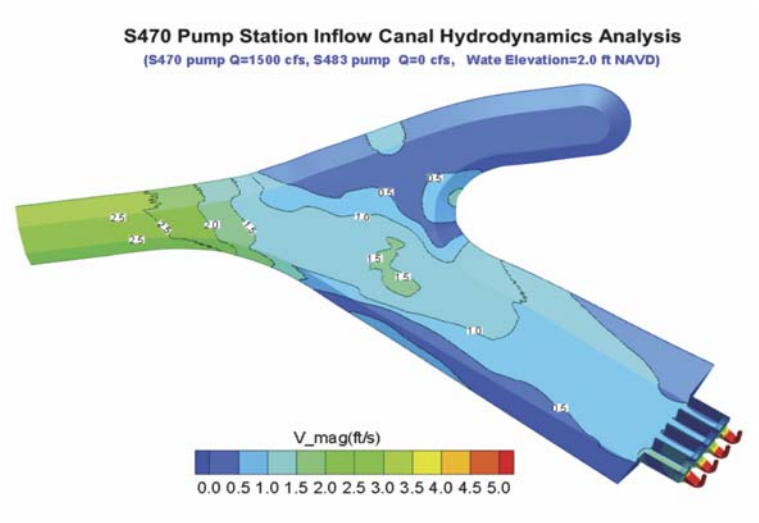

Figure 8. Intake Velocity Results

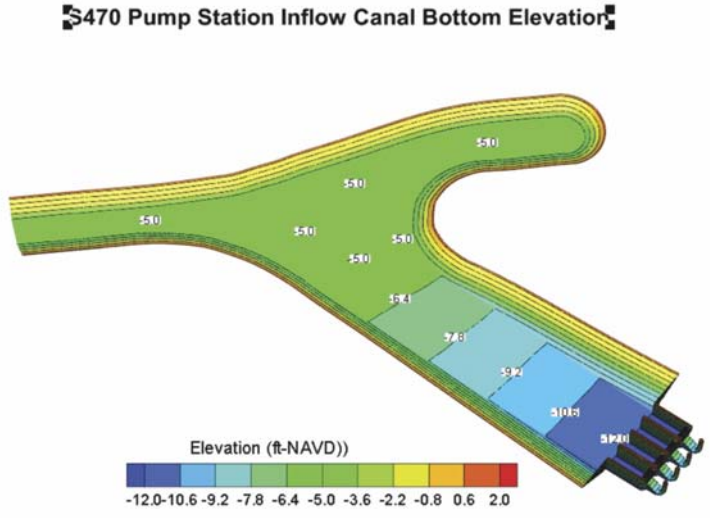

Figure 9. Channel Elevation Model

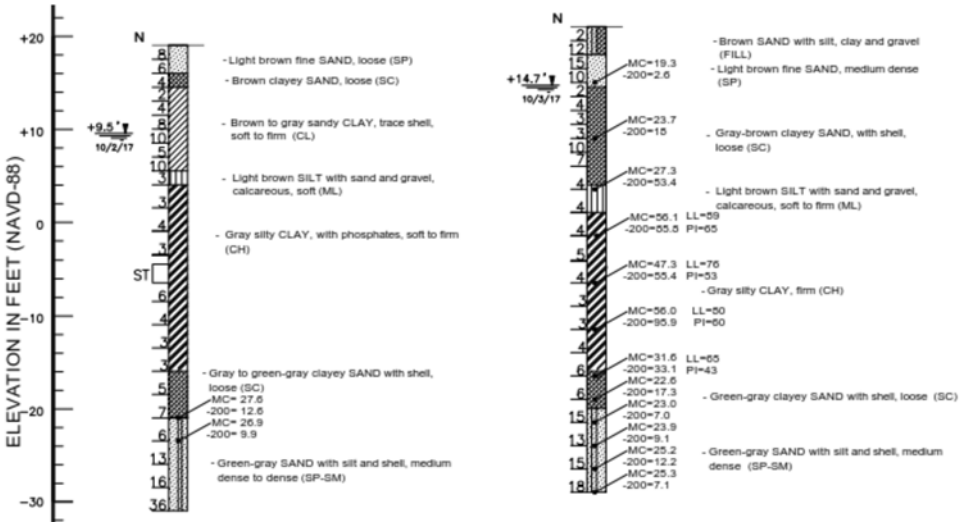

Figure 10. General Soil Profile Beneath the C43 Reservoir

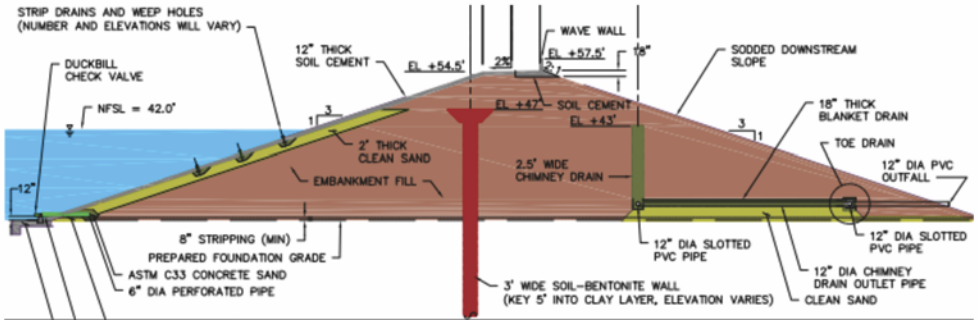

Figure 11. Typical Cross Section of the Dam at C-43 Reservoir

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C-43 Reservoir (170,000 acre-ft reservoir): Construction Package 4

Designed to contain an average depth of approximately 17 ft, the reservoir is expected to store more than 170,000 acre ft of water. The water will be captured during wet season releases and released during dry season demand. Specifics of the reservoir include:

1. It's a large, rectangular, contiguous piece of land and close to the Caloosahatchee River (C-43 Canal).
2. A connection to the Caloosahatchee exists through the Townsend Canal under SR 80 and to the C-43 Canal (within approximately 1 mi).
3. Townsend Canal, with some improvements, has the required conveyance capacity to operate the reservoir.
4. It's in the approximate middle of the Caloosahatchee River Drainage Basin.
5. The geologic formation beneath the reservoir footprint contains a clay (relatively impermeable) layer within 20 ft of the surface and runs relatively consistently across the entire site (see general soil profile in Figure 10).
6. The dam is classified as a high-hazard above ground impoundment and is surrounded by sparse development to date. Impacts to the local community were minimized during the design of this project.

During the Acceler8 phases of design, a pilot test cell program was conducted to evaluate the constructability of various embankment features to confirm efficient, safe, and cost-effective storage. The results of the test cell program demonstrated that the reservoir embankments, combined with a seepage cutoff wall embedded into the clay layer below, resulted in very little

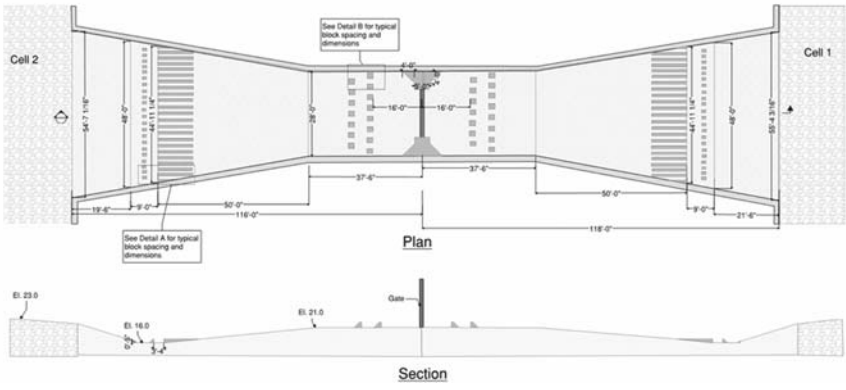

Figure 12. Plan and Section of S475

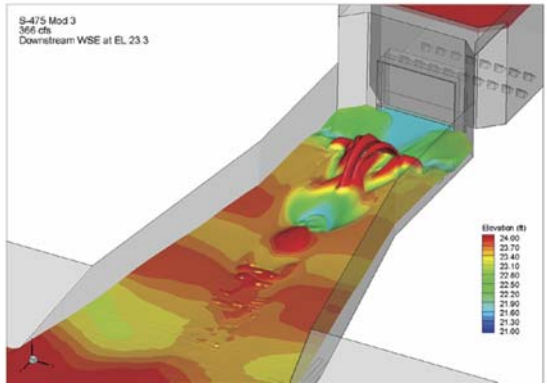

Figure 13. Computational Fluid Dynamic Modeling Results at S475 Discharge

seepage losses from the system. In addition, the test cell program resulted in the selection of a constructible soil cement upstream slope protection for the impoundment dam (the dam typical section is shown in Figure 11).

As noted, the majority of the embankment materials will be excavated and reused onsite. The soil cement drainage, chimney, and blanket drains will be constructed of imported materials produced at a nearby aggregate pit determined to be suitable for the project. The soil bentonite cutoff wall extends from El. 47 (within the top one-third of the dam embankment) and 5 ft into the clay layer below the reservoir. The soil cement is proposed to be 12 in. thick and will be batched onsite utilizing existing surficial sandy materials determined to be sufficient for design. This will result in a reduction of imported materials and fuel usage during construction of the project.

The C-43 Reservoir is surrounded by a perimeter canal, tow roads, and maintenance roads. There are over a dozen water control structures in the perimeter canal and in the dam itself to regulate discharges and manage water supply and stormwater from the adjacent properites. These structures include gated culverts, gated spillways, uncontrolled emergency spillways and wiers, ogee weir discharge structures, bridges, and others.

The S475, shown Figure 12, is a gated spillway that connects Cells 1 and 2 of the reservoir. The spillway allows independent storage in the the two separate cells, but is sized to allow transfer of flow from one cell to another, as well as allow partial reservoir operation during periods of maintenance. Computational fluid dynamic modeling was conducted to evaluate the efficiency of operation and was refined to minimize scour impacts as water is discharged into either cell of the reservoir (Figure 13).

Energy dissipation was accomplished by the design of a stilling basin with baffle blocks and end sills, along with riprap to mitigate the affects of erosion on the reservoir bottom and allow discharge from a full reservoir cell on one side of the separator dam to an empty reservoir cell on the other side.

Permitting and Threatened and Endangered Species

The C-43 project was permitted under the dual-track Acceler8 efforts in the late 2000s. The project received a USACE 404 permit, as well as a Florida Department of Environmental Protection 1502 permit for construction. The permits have been successfully extended due to the delay in previous funding and construction efforts.

Photos 8 and 9. Species Encountered During Project

During the early phases of construction, the project teams encountered a variety of species onsite and provided protection. Some of these are identified as threatened and endangered, including the Florida Panther, Manatee, Eastern Indigo Snake, Gopher Tortoise, Caracara, and others (Photos 8 and 9).

Summary and Conclusions

The C-43 project helps restore America's Everglades. Sustainable project features include capture of stormwater flows and storing them for use in dry season flows to the Caloosahatchee Estuary. No new lands were impacted by the construction of the reservoir. The project converts a 10,700-acre retired citrus grove to an above ground storage reservoir. The unique geology at this particular site consists of clay near the ground surface, minimizing the loss through seepage outflows. An all-electric pumping system reduces hydrocarbon footprint use over a wide range of potential operating scenarios.

Acknowledgments

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- U.S. Army Corps of Engineers (federal partner)
- JTech JV, Joint Venture Jacobs Engineering Inc. and Tetra Tech (site management lead)
- Carollo Engineers and Stanley Consultants (design lead).
- Terracon Inc. (geotechnical engineering lead)
- Clemson Engineering Hydraulics Inc. (project hydraulics testing/modeling)

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