Use of Inflatable Weir Structures Makes Water Resources Management More Efficient

Stefan Haecker and George Reilly

Built in the 1960s, the city of Cape Coral is located in Southwest Florida and covers a total area of approximately 110 square miles. Like many other coastal communities in the state, Cape Coral is characterized by a flat topography close to seawater elevations. In order to develop the area for residential and commercial use, a canal system was created to drain excess water to the Calosahatchee River and eventually to the Gulf of Mexico.

Faced with the need to provide potable and irrigation water to a projected population of approximately 400,000 people at build-out conditions, the city in 1988 initiated the Water Independence for Cape Coral Master Plan. Until then, irrigation water had been provided from the potable system, private wells, and minimal withdrawal from the city's freshwater canal system.

Realizing that potable water is limited and relatively expensive, that private wells are depleting the Upper Hawthorn Aquifer, and that reclaimed water and canal water are viable sources for irrigation, Cape Coral was one of the first communities in the United States to implement a dual water system, which went into service in 1992.

The secondary water system takes reclaimed water from the city's two water reclamation facilities (WRFs) and distributes it to city customers for irrigation. The average daily demand in the year 2000 for secondary water was approximately 22 MGD, while the WRFs produced only 9 MGD. In order to meet the demand for irrigation water during the dry season, the city supplements reclaimed water with water from its vast freshwater canal system.

In order to balance the two functions of the canal system as a stormwater management system and as a supplemental water reservoir, the city operates a series of 25 weirs, dividing the canal system into 18 canal basin areas. To increase the storage capacity in the canal system during the dry season when the demand for irrigation water from residential and commercial customers is highest, the city installs stop logs seasonally to temporarily raise the control elevation at various weir locations.

Some weirs are box-type concrete culverts installed underneath road overpasses, while others are regular sharp-crested concrete weirs. Although the stop logs have worked well in the past, they also have several disadvantages. The logs can be difficult to install and to remove, depending on the type and location of the weir structure. Handling the logs usually requires several city staff members and the use of a trailer-mounted crane. Most logs also do not provide a tight seal and allow water to leak through the gate.

The city therefore decided to move forward with a program to replace the existing logs with modern adjustable weir structures. In 2002 Cape Coral retained CDM Inc. to design and permit adjustable weir structures for nine of the city's 25 weirs. The objective was not only to make the weir structures adjustable but also to increase the storage capacity in the affected canal basin areas during dry-season conditions, while still fully maintaining the function of the canal system as a stormwater management system. Increasing the storage capacity would assure the availability of supplemental water to meet an increased demand from a growing population.

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Methodology

The first phase of the project included the development of stormwater runoff models for existing and proposed conditions in the project area. The predictions of the model could then be used to determine the maximum water level in the canal system without negatively impacting adjacent properties and structures.

The overall area modeled consisted of 22.4 square miles of distribution area, composed of seven basins divided into 32 subbasins. The water-surface elevations in the canal system were evaluated using recent versions of the RUNOFF (hydrology) and EXTRAN (hydraulics) blocks of the EPA Stormwater Management Model (SWMM), Version 4.4. Topographic data to define hydrologic boundaries, overland flow patterns, and stage-area relationships were extracted from two-foot digital contours provided in ArcInfo® format and supplemented by spot elevations from available survey plans.

The volume of storage in the canal system was calculated using the trapezoidal method. Based on large-scale physical features, the contributing area was then divided into hydrologic units using the Geographic Information System (GIS) software ArcView. Land-use data provided by the Cape Coral GIS Department were used to estimate the directly connected impervious area for individual hydrologic units for use in runoff calculations.

Soils data for the contributing areas were obtained from the Soil Conservation Service (SCS) Soil Survey. The soils in the study area are predominantly sands consisting of Hydrologic Soil Groups C or D, as defined by the SCS. Both groups indicate soil conditions with low infiltration potential.

The Horton soil infiltration method was used to simulate infiltration into the soil.

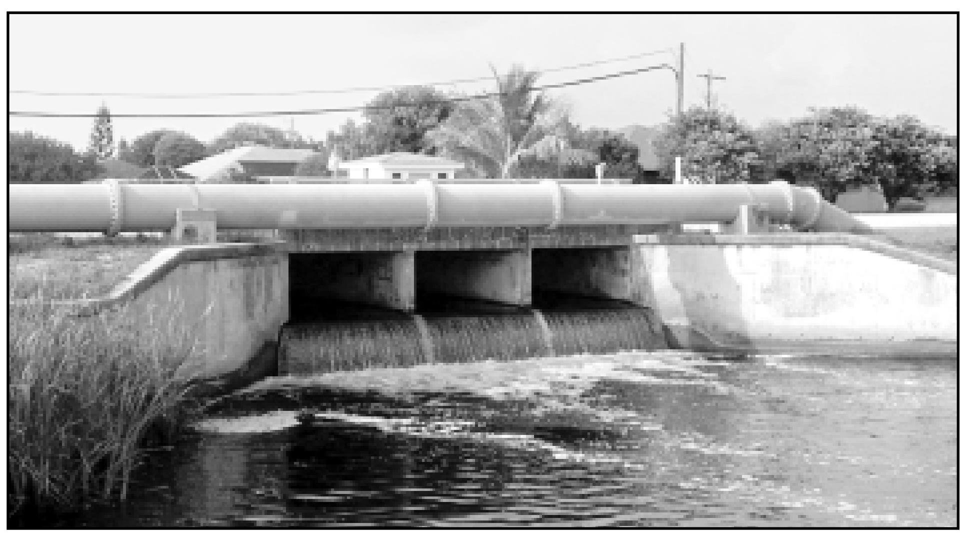

Figure 1: Typical Cape Coral Weir Structure

Once these infiltration parameters were established for each hydrologic soil group, area-weighted parameter values were computed based on the percentage of each group within a basin.

Once the hydrologic parameters for the contributing area were established, the hydraulic model for the primary stormwater management system was developed. An inventory of the system was created based on previous inventories, final construction drawings, and field verification of weir structures. Based on this information, the hydraulic model of the canal system was created as a network of 48 nodes.

Available rainfall data for the time of Tropical Storm Harvey (September 18-21, 1991) was used to verify the accuracy of the model. Since rainfall data could be obtained only as daily total amounts, the rainfall was distributed using a 24-hour SCS Type II Modified Rainfall Distribution to simulate the 15-minute rainfall intensity.

Peak daily stages for three different locations in the canal system could be obtained from the United States Geologic Survey. The model was calibrated by refining land-use parameters of the contributing areas using recent aerial photography. A sensitivity analysis of the boundary conditions showed no significant impact on the predicted peak stages in the canals.

The surface-water elevations in the canal system were evaluated for the Mean Annual, five-year/24-hour, 10-year/72-hour, 25-year/72-hour, and 100-year/72-hour frequency storms using the South Florida Water Management District rainfall distributions. Canal stages in each basin were evaluated for existing conditions and for an increase in weir elevations in 0.5-foot increments to a maximum increase of 1.5 feet above the existing control elevation.

In order to evaluate the feasibility of increasing the control elevation at a particular basin, the following level of service (LOS) criteria were established for the operated system:

1. There must be no flooding of homes during the 100-year/72-hour storm event under any conditions.
2. The control elevation must be adjustable so that permanent flooding of boat docks, seawalls, or yards does not occur.
3. There must be no excessive ponding on septic tanks while the weirs are in the upright position.
4. Roadway ponding must be equal to or less than existing conditions while the weirs are in the lowered position.

The elevation of boat docks was assumed at 18 inches above the control elevation at each basin. Information on road crown elevations was obtained from original construction drawings. Finished floor and septic-tank elevations were obtained from the city's building department and were field verified at critical locations by ground survey.

The LOS criteria were established based on the presumption that none of the proposed enhancements to the canal outfall structures would permanently impact the hydraulic capacity of the canal system. The adjustable weirs will be operated in accordance with the city's protocols, which dictate that the weirs will be raised during the dry season, October through May, when the demand for supplemental water requires larger amounts of storage capacity and stormwater runoff is limited. The weirs will remain in the lower position throughout the wet season when conveyance and storage of stormwater runoff becomes the primary function of the canal system.

Results

In order to minimize the effects of flooding on upgradient streets and properties during rainfall events, CDM recommended the installation of fully automated weir structures at critical locations. Elevations of weirs in the system would be seasonally adjusted and increased or

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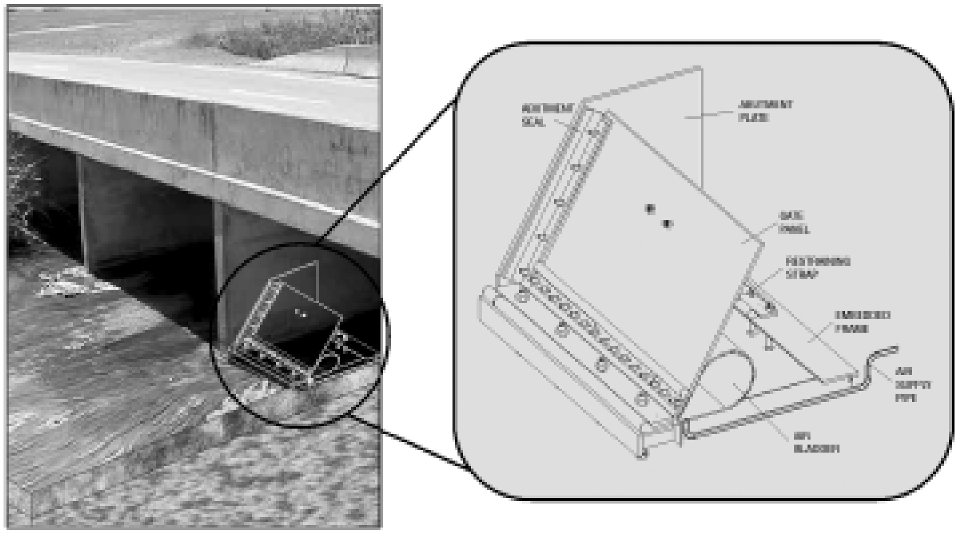

Figure 2: Conceptual Weir Installation

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decreased based on the amount of flow in the system. The flow over each weir would be measured as a function of the canal stage.

Such a system could significantly increase the effectiveness of the canals as a stormwater management system while still maintaining its dual function as a reservoir for supplemental water. An automated system would increase the protection against potential nuisance flooding of docks and seawalls at properties located within the canal boundaries by minimizing fluctuations in canal stages during dry-season extreme events. Remotely controlled weir structures would allow the operators to manage the available supplemental water resources from a central location and react quickly to rainfall events.

As a first step toward such an automated system, the city decided to proceed with the design and installation of manually adjustable weirs that can be upgraded to fully automated operation in the future.

Implementation

Three objectives were identified for the design of the adjustable weir structures:

1.) ***Flexibility***—The design must allow operators to quickly adjust the weir elevations in the event of an expected rainfall event. The design must also allow for future expansion of the weirs to fully remote and/or automatic operation.

2.) ***Simplicity***—The design of the weir structures should be as simple as possible to minimize costs for installation and for operation and maintenance.

3.) ***Safety and Reliability***—The design of the weirs should provide for a safe, reliable operation.

In order to achieve these goals, the design was based on the use of inflatable weir structures. Such weirs consist of a rubber bladder system that is used to lower or raise an aluminum or steel plate mounted on top. The bladder will be inflated and deflated using a trailer-mounted compressor. The fill and purge line connections will be mounted on a panel located at an accessible location near each weir. A pressure gauge at each bladder will allow the operator to field calibrate the elevation of each weir based on the air pressure in the bladder.

In order to minimize construction costs, all proposed weirs have the same vertical elevation of two feet. The maximum elevation of each weir during normal operation can then be adjusted in the field based on the established protocols. This design will also allow stopping the flow over a weir for short periods of time during maintenance activities.

Existing concrete weir structures in Cape Coral are typically of two types. Often box culverts underneath roads are used to control the stage in upstream canals. At other locations, regular sharp-crested weirs are used to maintain certain minimum water elevations in the canals. At box culvert weirs, the proposed adjustable weir structures will be embedded in the concrete floor. At standalone weir structures, the new adjustable weirs will be mounted on a pile-supported foundation attached to the downstream side of the concrete weir. This design will assure that the control elevations of the existing weirs are not increased.

The proposed inflatable weirs can be easily retrofitted for automatic or remote operation. Integrated 24” x 36” x 48” panels are available from the manufacturer and provide housing for a compressor and for any associated electrical and instrumentation equipment. Each weir can be tied into a Supervisory Control and Data Acquisition remote operating system or can be controlled by level control switches in the upstream canal.

Project Status

The objectives of this project were: 1) to study the potential for increasing the storage capacity in parts of the canal system and 2) to design a system of adjustable weir structures as a replacement for the currently used stop logs. A stormwater model was established for the affected canal system and a system of adjustable inflatable weirs was designed that would enable city operators to raise or lower weir elevations by using a trailer-mounted compressor. While the first phase of the program includes manually adjustable weir structures, the system can be expanded in the future to a fully automated or remote operation.

The proposed improvements are currently being permitted by the South Florida Water Management District and will allow Cape Coral to manage its available water resources in a more efficient manner then before.

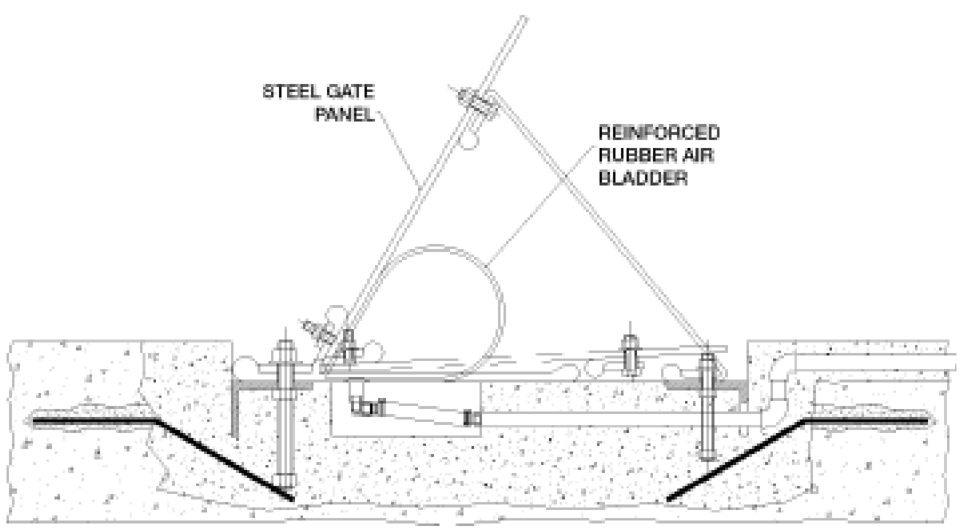

Figure 3: Inflatable Weir Structure – Typical Cross Section