Temporary Pump Tests for Water Supply from the C-51 Canal to the Lake Worth Drainage District

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Water Supply Department
South Florida Water Management District

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The Lake Worth Drainage District staff helped with operating the temporary pumps, providing rainfall and pump operations data, conducting field visits and identifying structures and controls within the basins in the study area.

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Executive Summary

This project investigated increasing the use of the C-51 Canal to provide water to the Lake Worth Drainage (LWDD) using temporary pumps. The option of increasing capacity from the C-51 Canal could reduce the need to bring water supply releases from Lake Okeechobee into the Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge) to offset the LWDD withdrawals through the G-94 culvert structures. The Refuge currently supplies water by gravity through the G-94 culvert structures to the LWDD's secondary canals.

To assess the feasibility of the project, the South Florida Water Management District (SFWMD or District) started a test in May 2005. The test consisted of installing two temporary pumps at the LWDD's Control Structure No. 2 pumping station to deliver C-51 canal water through Equalization Canal No. 1 (E-1 Canal) to the LWDD's secondary canal system. The 2005 test started in mid-May and it was interrupted by rains in late May of that year; consequently, enough data were not collected to provide useful analyses of the project.

To extend the duration of the test and to obtain adequate data, the 2006 test stated in November 2006 and lasted through April 2, 2007. Two temporary pumps with a combined capacity of 100 cubic feet per second (cfs) were again installed adjacent to the existing Control No. 2 pumping station.

Water levels at six identified sections along the E-1 and E-2 parallel canals were measured using the SFWMD approved stage-recording equipment. There were three sensors along the E-1 to check the north-south flow at Pioneer, Lake Worth, and Boynton. The three along the E-2 Canal were to check possible water losses from the E-1 to the east basins through the lateral canals or by seepage.

Analysis of pump logs, flow measurements and water level data showed that:

- water levels increased at all E-1 sites when temporary pumps were used, compared to using the existing pump alone; increase in water levels reduced farther away from the pump site.
- without the temporary pumps, water levels at Lake Worth and Boynton basins could not be maintained within the 16.00 feet basin control.
- to extend benefits to south of Boynton Beach, it will be necessary to install one 100-cfs pump at Control Structure No. 2 to maintain elevations in the north basin and another 100-cfs pump at Control Structure No. 11, to deliver water to the south basin within the service area of the G-94B structure, to minimize water withdrawals from the Refuge; control No. 11 also reduces losses to tide.

Losses from E-1 to E-2 and High Stages at Whippoorwill Lakes

Unlike water levels in the E-1 Canal that responded immediately when temporary pumps were operated, increases in water levels along the E-2 Canal were not significant.

Water levels along the E-2 increased directly to pumping from Control No. 4 pumping station, not from the temporary pumps.

Overall, water losses from the E-1 Canal eastward to the E-2 Canal were minimal, provided the regulation stage in the E-1 was maintained of 16 feet.

Verification of Pump Capacities

Temporary pumps were verified as delivering the rated capacity of 100 cfs within 4 percent accuracy; however, the existing pump has lost a significant 40 percent capacity due to aging. With additional capacity from the C-51, regulation stages of 16 feet would be better maintained by the new pumps, rather than using the existing pump alone. At Boynton Beach, water levels fell substantially below the maintenance basin stage after the temporary pumps were stopped.

Manual operation of pumps could lead to undesirably high water levels in the eastern basins due to inadequate control at lateral canals; automated control at Control No. 2 is recommended to alleviate this situation.

2007 Water Shortage

Insufficient rainfall in 2006 caused District-wide water shortage, leading to water restrictions that inevitably affected the continuity of the test. However, unlike the 2005 test, substantial data were collected between November 2006 and March 2007 before pump operations were stopped due to water withdrawal restrictions from the C-51 Canal.

Historically, additional water from the C-51 Canal is most beneficial between April and early June. The 2006 test period did not include this critical dry season period due to water restrictions. Fortunately, the 2005 test included the month of May, as part of the critical period.

A separate water shortage site visit was made in March 2007. Pictures showed the severity of the 2006/2007 drought as water levels fell considerably and most of the canals became dry and hydraulically disconnected from the maintenance basins.

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BACKGROUND

In order to meet the agricultural and other irrigation water use demands, recharge surficial aquifer systems and prevent encroachment of coastal saline water inland, the Lake Worth Drainage (LWDD) withdraws water from several sources within the South Florida Water Management (SFWMD) regional system. These include the Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge) or Water Conservation Area (WCA-1), Hillsboro Canal, C-15, C-16, and C-51 canals. The C-51 Canal provides water at Control No.2 through the E-1 Canal, Control No. 4 through the E-2 Canal, and further south at Control Structure No. 11 through the E-4 Canal, the interconnected chain of lakes to the C-51 Canal. Withdrawals from various sources are required to maintain water levels in LWDD's secondary canal system. Source options for LWDD are presented in **Table 1** below.

Table 1. LWDD existing source options based on Permit No. 50-000739-W.

Source	Facility Type	Capacity
Groundwater	Surficial	17 million gallons per day
Surface water		
WCA-1	Gravity, G94C	Not specified
WCA-1	G-94B, pumped	72 million gallons per day
WCA-1	G-94C, pumped	72 million gallons per day
C-51	Contro 2	60 million gallons per day
C-51	Control 4	65 million gallons per day
C-15	Canal	65 million gallons per day
C-16	Canal	58 million gallons per day
Hillsboro	Canal	95 million gallons per day

Historically, when WCA-1 is above 14 feet regulation, it contributes about 80 percent to LWDD's source supply. Below 14 feet and during declared water shortages, LWDD benefits from building flexibility into its delivery system including the use of the C-51 Canal as specified in limiting condition # 20 of LWDD's consumptive use permit #50-00739-W:

> The permittee shall submit for approval a compliance report by June 1, 2008, 2013, and 2018. These reports shall include the following: (1) results of calibration of all withdrawal facilities per Limiting Condition No. 17, (2) assessment of feasibility of using reclaimed water as a source of water supply to the LWDD canals, (3) update to the operation plan that addresses other water supply sources or withdrawal facilities made available or reasonable expected to become available over the next five-year period, and (4) an assessment of water conservation actions that could reduce the use of water or otherwise shift the source of supply from WCA-1.

No increase in allocation or source shift is intended as the same Lake Okeechobee water is conveyed through any of the routes illustrated in **Figure 1**.

The key point of this project, therefore, was to test water delivery from Lake Okeechobee to the Lake Worth Drainage (LWDD) using the C-51 Canal route. This test assists, in part, in meeting two of LWDD's clauses in Limiting Condition No. 20 requiring calibration data for existing pump stations at C-51 and demonstrating the feasibility of actions that could reduce using the WCA-1 (Refuge) source.

The C-51 Canal option would bypass the Refuge thus eliminating potential impacts of water supply deliveries on this part of the Everglades. The additional capacity through the existing E-1 Canal facility would also provide flexibility particularly during water shortages.

Currently, water supply from the Refuge is made through the G-94 structures located across the L-40 levee. Under several conditions, LWDD water supply withdrawals from the Refuge must be preceded with deliveries into the Refuge from Lake Okeechobee, which raises issues related to the Everglades water quality and management of the regulation schedule of the Refuge.

Additional water supply from the C-51 Canal at Control No. 2 site could reduce the potential requirement to treat Lake Okeechobee water in Stormwater Treatment Area 1 West (STA-1W) prior to discharge into the Refuge as an offset of LWDD's withdrawals. Furthermore, avoiding passing water through the Everglades is important for the recovery of STA-1W after hurricanes or droughts. In particular, STAs are not designed to treat water supply deliveries.

The SFWMD first met with the LWDD staff on May 9, 2005, to discuss the interim plan to provide additional water supply from the C-51 Canal to the LWDD's E-1 Canal. To formalize this discussion, a two-year agreement was signed between the SFWMD and the LWDD to perform the tests. The SFWMD and LWDD developed an implementation plan and recommended renting two portable pumps to deliver additional 100 cfs capacity. The 2006-2007 test, which started on November 18, 2006, was a continuation of the endeavor started in May 2005. Tests in 2005 started too late and were soon interrupted by the onset of the rainy season on May 27, 2005.

A safe site was chosen for installing the pumps, at the opposite side of the existing LWDD Control No. 2 pumping station (**Figure 2**). This is the north end of the E-1 Canal, near the SE corner of SR 80 (Southern Boulevard) and SR 7. An operational plan for the pumps was also outlined as well as a stage monitoring schedule at selected sections along the E-1 Canal and E-1 canals (**Figure 2**). The Lake Worth has four basins controlled between 8.5 and 16.0 feet NGVD. The westernmost basin controlled at 16.0 feet was most relevant to this study.

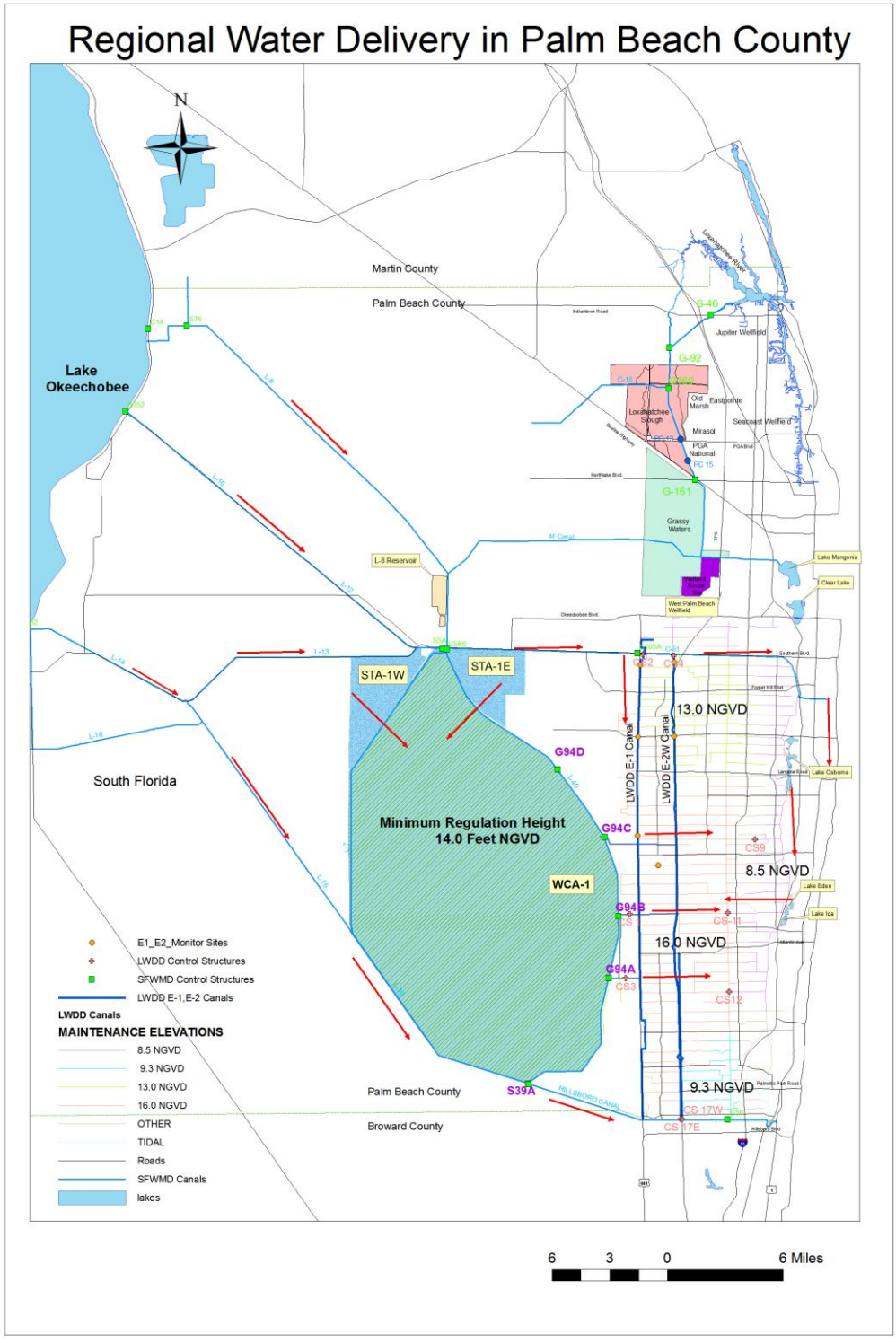

Figure 1. Map showing regional water delivery from Lake Okeechobee to LWDD through the Refuge or C-51 Canal.

Control #2 is recognized as a point of withdrawal in the Consumptive Use Permit held by LWDD. A letter modification of the permit was issued to allow increased use of the C-51 site, without an overall increase in the LWDD allocation of water from the regional water management system.

Figure 2. Project site and stage monitoring locations.

TEMPORARY PUMP INSTALLATION

Two rented temporary diesel pumps were funded and successfully installed by the SFWMD at Control No. 2. The LWDD was responsible for operating the pumps to meet its demands. Temporary pumps started operating on November 18, 2006. Each temporary pump consisted of a 200 HP, 30-inch axial flow hydraulic submersible unit, capable of delivering 50 cfs at a total dynamic head of 14 feet.

Figure 3 shows the intake and discharge views of the pumps. Pump housing included a noise shield to allow operations at night with reduced noise. The upstream view illustrates how the pumps discharged water to the E-1 Canal.

Figure 3. Temporary pump installation at Control No. 2 site: Left) Intake side; and Right) Discharge end.

FLOW MEASUREMENTS TO CONFIRM CAPACITIES

On March 6, 2007, a contractor managed by the SFWMD's Operations & Hydro Data Management Division of the SCADA & Hydro Data Management Department conducted flow measurements at one cross section on the E-1 Canal using the StreamPro 2.4 MHz Acoustic Doppler (**Figure 4**). The detailed streamgauging results are shown in **Appendix 1**.

Figure 4. Launching of the StreamPro 2.4 MHz Acoustic Doppler

The flow section was located about 500 feet downstream (south) from the Control No. 2 pumping station. Two pump measurements were made at each section: a) existing pump at Control No. 2 pump alone, and b) existing pump in addition to the two new portable pumps. The net flow delivered by the temporary pumps is shown in Column (c). The discharge measurement data are presented in **Table 2**.

Table 2. Results of flow measurements.

Test Mode	Flow measured (cfs)	Flow measured (mgd)
Existing Pump Alone (a)	54	35
Existing and Temporary pumps (b)	150	97
Incremental Flow (c)	96	62

The following observations were made regarding the existing Control No. 2 Pumping Station, working with the temporary pumps:

- Based on independent flow measurements, the existing pump delivered only about 54 cfs, compared to its rated capacity of about 94 cfs. The pump is old and has lost about 40 percent of its capacity.

- When the two temporary pumps were operated, the measured flow increased from 54 cfs to 150 cfs, illustrating that the temporary pumps provided an additional flow of 96 cfs, consistent with their rated capacity of about 100 cfs. Basin elevations were better maintained at 16 feet.

- Without additional capacity from the C-51, the existing pump cannot maintain the basin elevations beyond Pioneer at the desired levels of service.

- Manual operation of pumps could lead to undesirably high water levels in the eastern basins due to inadequate control at lateral canals; automated control at Control No. 2 is recommended to alleviate this situation.

- Replacing and upgrading Control No. 2 will provide additional capacity and flexibility from the C-51 site.

- Additional C-51 Canal capacity at Control No. 2 will provide more benefits for basins north of Boynton Beach than south of it.

WATER LEVEL MEASUREMENT

Figure 5 shows the location of the water level sensors along the E-1 and E-2 Canals. The set of sensors along the E-1 were to measure the southward response of the stages to pumping from the C-51. E-2 sensors were installed to track any losses to the east from the E-1 Canal, either by seepage or through the lateral canals that connect E-1 to the eastern basins.

Water levels at the three identified sections along these canals were measured using a miniTROLL, a data logging probe. It is completely self-contained and features an internal data logger with a pressure/level and a temperature sensor. It collects real-time information for analysis of both short- and long-term water level trends. Six miniTROLLs were installed at locations from just south of the C-51 Canal to Boynton Beach. These were, Pioneer Road (about a mile downstream or south from the Control No. 2 site), Lake Worth Road, and Boynton Beach Boulevard, in order to collect water levels at 15-minute intervals. Recorded data were downloaded weekly. Data for mid-May to early June 2007 were plotted in **Figure 6**.

Monitoring sites were located along the E-1 and E-2 canal sites. The Boynton Beach site was relocated to Lyons Road due to construction activities.

Table 3 below shows the sites and their maintenance basins. Western sites at Pioneer, Lake Worth and Lyons roads are in Elevation 16.00 feet basin. The E-2 South site on Lake Worth Road is also located in Elevation 16.00 feet.

Average daily water levels were plotted (**Figure 6**) for all sites located in Basin 16.00 feet. Water levels at Pioneer responded the most to additional deliveries from the C-51 pumping, followed by the Lake Worth site.

Table 3. Monitoring sites and corresponding maintenance basins.

Site	Maintenance Basin
Pioneer Road	16.00 feet
Lake Worth Road – E1	16.00 feet
Lake Worth Road – E2 South	16.00 feet
Lake Worth Road – E1	16.00 feet
Benoist Farm/Pioneer – E2	13.00 feet
Lake Worth Road – E2 North	13.00 feet

Levels at Boynton Beach also responded, but when only the existing pump was operating, water levels fell well below maintenance levels. The Boynton Beach sensor was not located on the E-1 Canal, but to the east of it, near to Lyons Road; this may be responsible for lower levels observed at Boynton Beach.

Water levels increased substantially at all E-1 sites when temporary pumps were used, compared to using the existing pump alone. Without the temporary pumps, water levels at Lake Worth and Boynton basins could not be maintained within the 16.00 feet basin control.

Figure 6 shows the average daily water levels plotted for all sites located in Basin 13.00 feet. Water levels at both Benoist Farms and Lake Worth at E2-N sites did not respond appreciably to pumping from the C-51 pumps at Control No. 2. Rather, water levels along the E-2 increased directly with pumping from Control No. 4 pumping station, which pump on March 26 and 27.

Higher than expected stages east of E-1 can be avoided by reducing pumping as necessary to keep stages within maintenance levels.

PUMPING AND RAINFALL

During the test period, pumping was coordinated with predicted rainfall events. Included in **Figures 5** and **6** are plots of rainfall and pump logs during the test period. Complete logs of monthly rainfall and pumping are presented in **Appendix 2**. Control No. 4 pump logs are not included. Between November 2006 and April 2007, rainfall was sparse. One noticeable event was December 14-15, 2006, with about 2 inches of rain. The pumps were turned off accordingly.

Basins within the LWDD responded quickly to rainfall. Therefore, the E-1 Canal water level was lowered to about 13.5 feet in anticipation of forecasted rain while the E-2 Canal was lowered to about 12.5 feet.

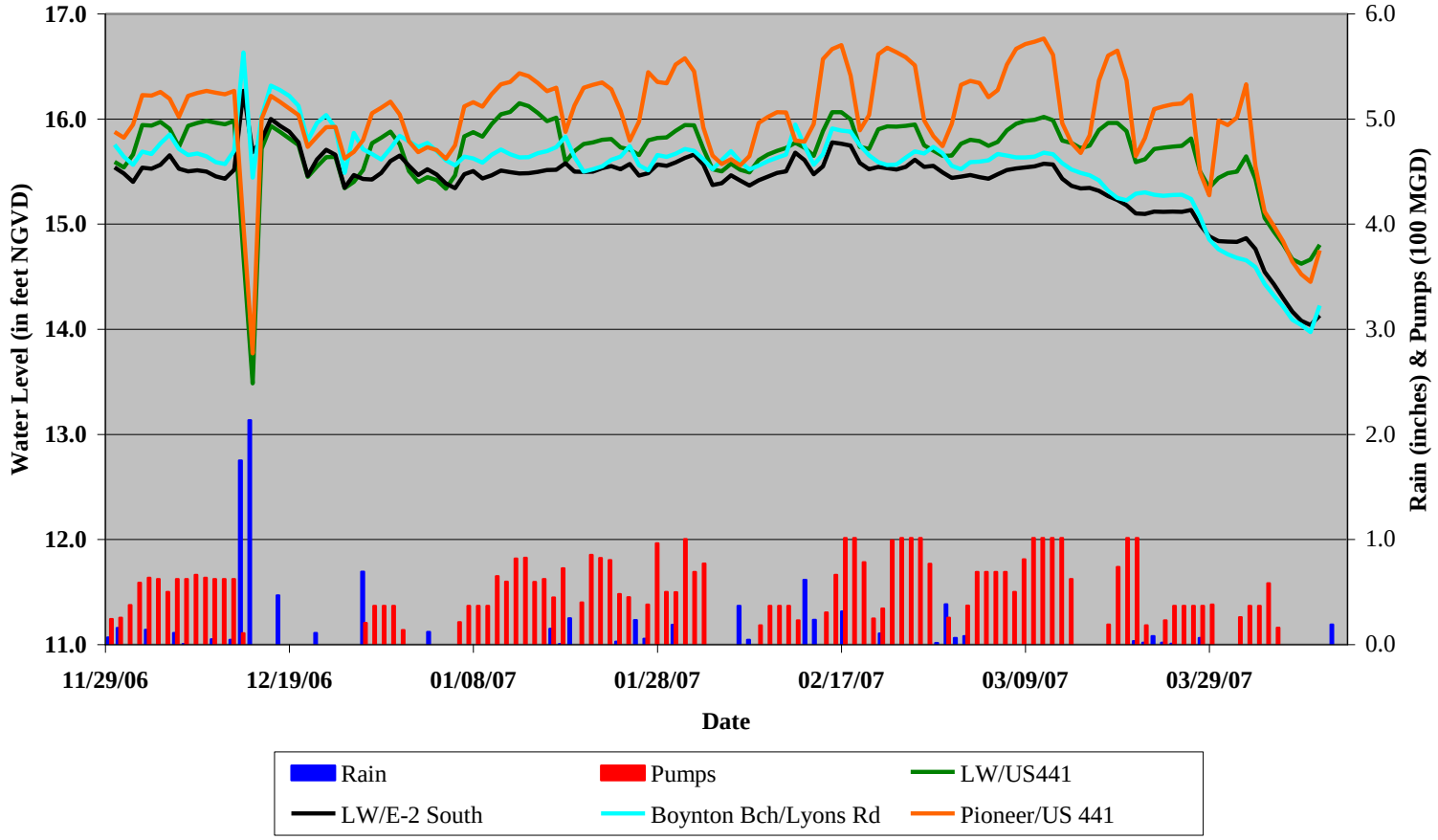

Figure 5. Water levels for Basin 16.00 feet, pump logs and rainfall from November 2006 through April 2007.

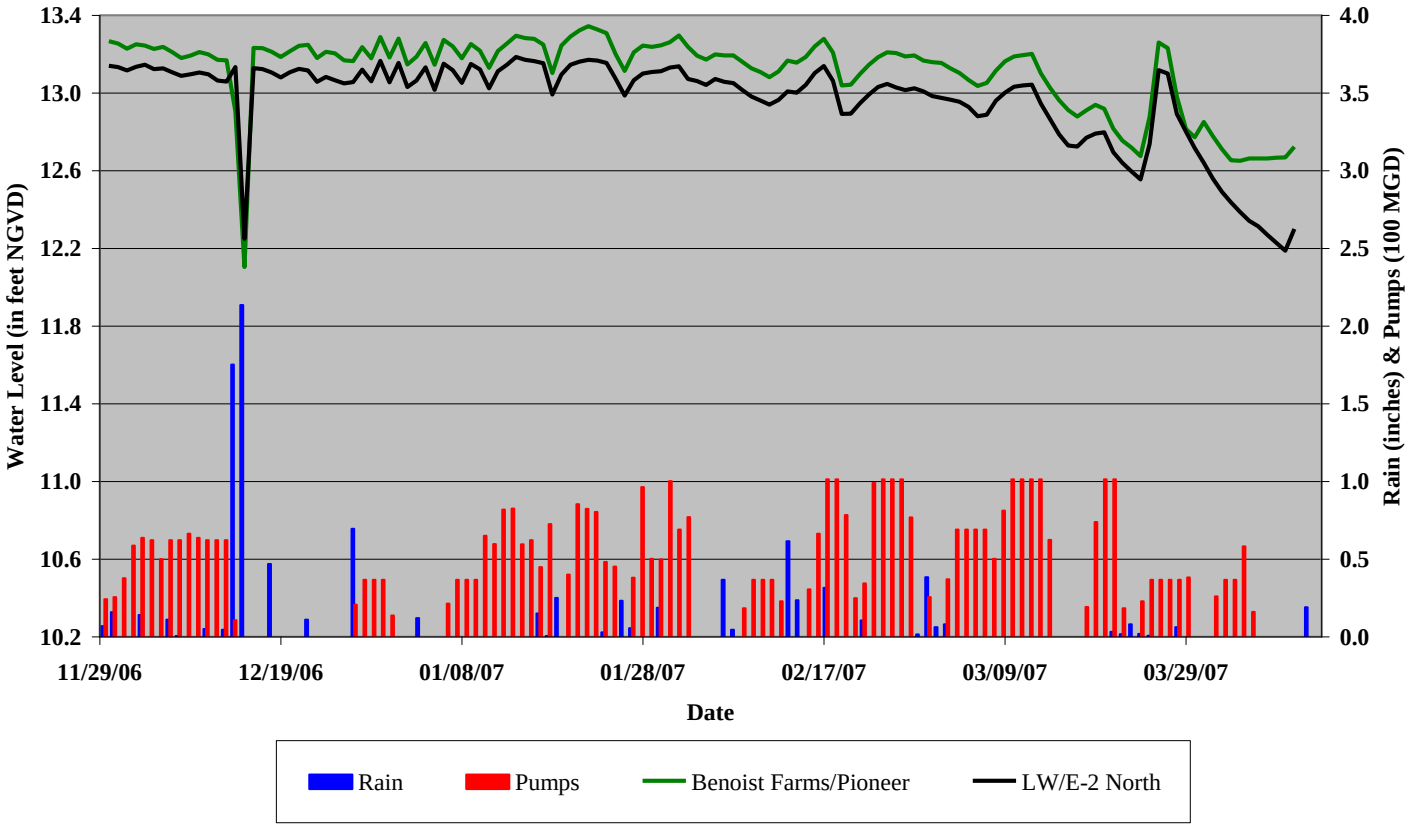

Figure 6. Water levels for Basin 13.00 feet, pump logs and rainfall from November 2006 through April 2007.

WATER SHORTAGE

Appendix 3 is a separate water shortage site visit showing pictures taken in March 2007. Pictures showed the severity of the 2006/2007 drought as water levels fell considerably and most of the canals became dry and hydraulically disconnected from the maintenance basins. Water levels were below the recording levels of staff gauges.

In some cases, one could not distinguish between maintenance basins 16 and 13 feet. The L-12 Canal that runs south of Lake Worth Road was completely dried up. The LWDD used this chance to remove shoal from dried up canals.

BENEFITS

During the test period, the temporary pumps delivered about 3 million gallons of water to recharge basins in the LWDD. The pump test enabled the verification of the following:

- capacities of the existing and temporary pumps
- additional capacity from the C-51 provides flexibility
- basin maintenance levels are better achieved with additional capacity
- need to automate pump operations to avoid undesirably high stages
- collection of essential data stipulated in the LWDD's permit

SUMMARY

It was observed that the exiting pump lacks the capacity to supply more than 60 cfs from the C-51 site. Considering conveyance losses and withdrawals between Lake Worth and Boynton Beach areas, the existing pump cannot maintain the level of service without Lake Worth getting water from additional facilities.

The existing pump, if replaced or supplemented with additional pumps and operated regularly, will provide the LWDD the needed flexibility, possibly reducing or eliminating the need to discharge Lake Okeechobee water into the Refuge to support withdrawals by the LWDD via the G-94 structures. The G-94 structures can remain in service under most circumstances when Lake Okeechobee water is not an issue.

Pumps ran successfully, recharging the maintenance basins to their desired stages. However, operations of the pumps must be coordinated to avoid high

stages. It is recommended to replace manual pump operations with automated operations on telemetry. Undesirably high stages could cause more losses to the east through seepage or overflow at control weirs.

The E-1 Canal must be improved to obtain substantial benefits beyond Boynton Beach. The maintenance basin controlled at 16.00 feet is the most extensive of the four basins and gravity flow alone will not move the water far south enough. Alternatively, a new pump should be installed at control No. 11 to deliver water to the southern maintenance basins, aligned between Lake Ida and the G94B Structure at the Refuge.

RECOMMENDATIONS

After several meetings between the District and LWDD in January and February 2008, both agreed on the following:

The project's main objective is to provide flexibility of increasing the use of the C-51 Canal to deliver water to the LWDD to meet its dry season demands and to reduce the need to bring water supply releases from Lake Okeechobee into Water Conservation Area No. 1 to offset the LWDD's withdrawals from it.

Replace Control No. 2 Pump Station with a new 100-cfs pump

Install a new pump at Control No. 11 to supply water to the Southern basins, located west of Military Trail on the L-30 Canal.

Execute an agreement on partnering and cost-sharing to install pumps at the LWDD's Control Structure No. 2 and Control Structure No. 11 to retain water that would otherwise be lost to tide.

The LWDD to obtain a permit modification to include the installation of Control No. 11, which will deliver additional 100 cfs of water which would have been lost to tide, but without increasing the LWDD's permit allocation.

Both control structures will become part of the LWDD's facilities that will withdraw water in accordance with the LWDD's permit and the structures will be operated and maintained by the LWDD while the District will only be responsible for the cost share of pump installation alone.

The total cost of the project is estimated to be $602,470, excluding inkind services and operations and maintenance costs. LWDD is responsible for additional costs exceeding the District's contribution of $300,000.

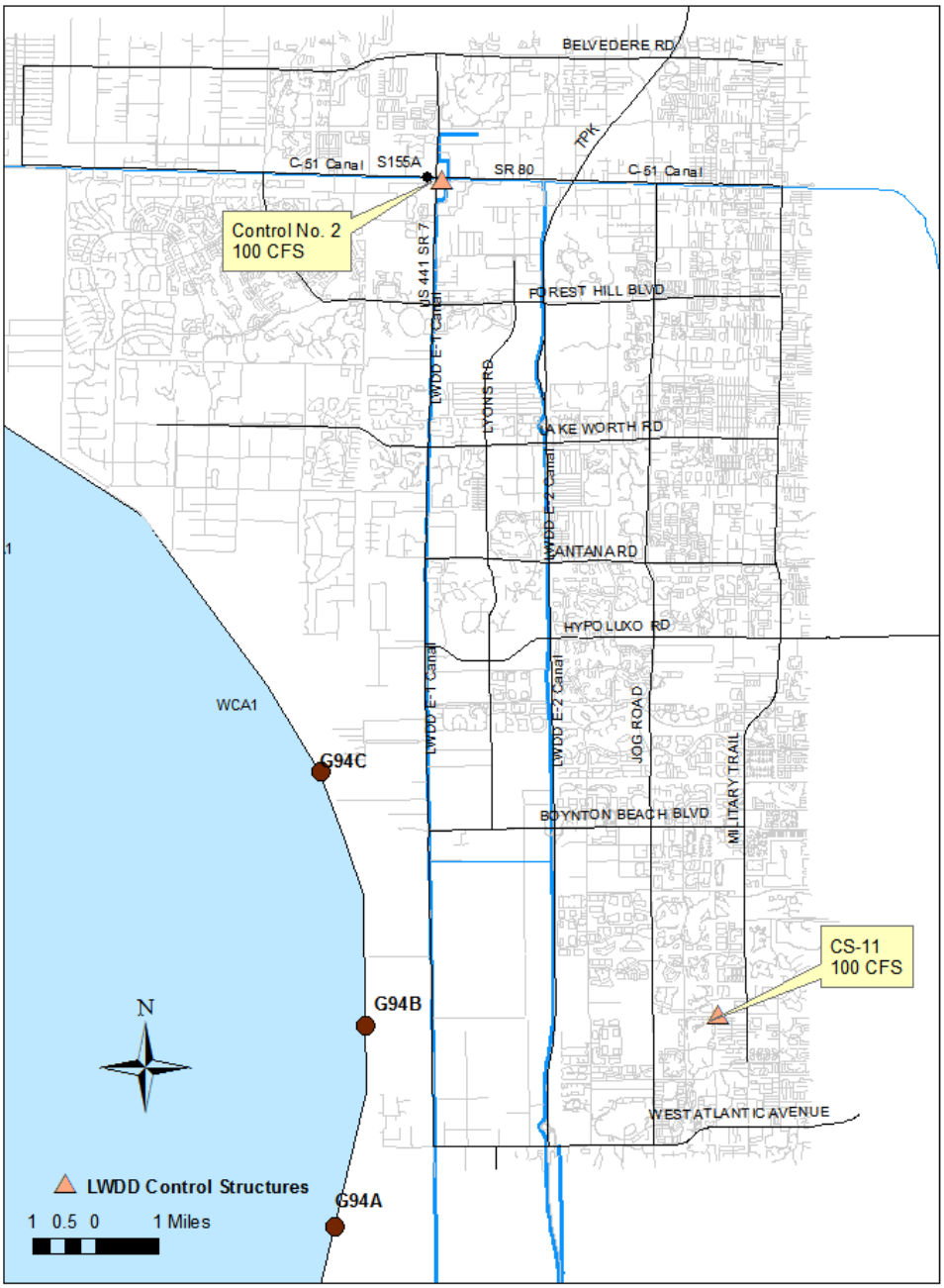

Figure 7. Locations of recommended pump installations showing Control No. 2 and Control 11.

APPENDICES

Appendix 1: Streamgauging Results

Appendix 2: Monthly Logs of Rainfall and pump operations

Appendix 3: LWDD Drought Site Report