Pocosin Lakes National Wildlife Refuge

Clayton Blocks Seepage Monitoring

The Nature Conservancy
North Carolina

U.S. FISH & WILDLIFE SERVICE
DEPARTMENT OF THE INTERIOR

KRIS BASS ENGINEERING

Introduction

The Clayton Blocks (CB) is a recently completed (2017) wetland restoration area in Pocosin Lakes National Wildlife Refuge (PLNWR). This area is south of Phelps Lake at the southern extent of Restoration Area 1 (RA1) and drains southwest to the Pungo River. The Clayton Blocks border adjacent private farm lands to the west and south. The border between the refuge and farms is created by a shared drainage canal. A unique wetland restoration design was implemented due to concerns about raised water levels and wetland restoration activities on adjacent farmlands. The design included construction of a new canal within the refuge and use of excavation spoil to create a separation berm between the Refuge and the existing drainage canal (**Figure 1**). Clayton Blocks drainage levels are now controlled by a new water control structure (WCS). The WCS are managed by Refuge staff to promote wetland hydrology and prevent fires. A monitoring study was completed to understand the effect of restoration efforts on water levels in CB and the outer drainage canal. The intent of this study is to determine the gradient of surface water across the constructed berm and to assess the efficacy for this design to prevent seepage and water loss from the Refuge.

Figure 1. Aerial imagery of Clayton Blocks inner and outer canals and berm (left) and an upstream view of a water control structure and monitoring well installed in the Clayton Blocks inner canal at PLNWR (right).

Data Collection

Flow and water level monitoring wells were installed at several WCS in and around the Clayton Blocks Restoration Project in October of 2017 (**Figure 2**). The monitoring design involved water level readings at the interior Clayton Blocks WCS and along the shared border canal. Water levels in the managed wetland restoration areas can be directly compared to the adjacent freely draining outer canal. Monitoring equipment was surveyed with a survey grade GPS unit and staff gages were installed to convert all measurements to referenced elevations. After a short period for equalization, data collection was initiated on January 1, 2018. Data was collected at WCSs C11, C14 and C15 in the outer C canal as well as CB14 and CB15 in the inner CB canal. No flow was recorded over the CB11 WCS during the study period. Stage measurements are recorded every 30 minutes and collected from the refuge quarterly; data is corrected using field measurements of water elevation at the time of download.

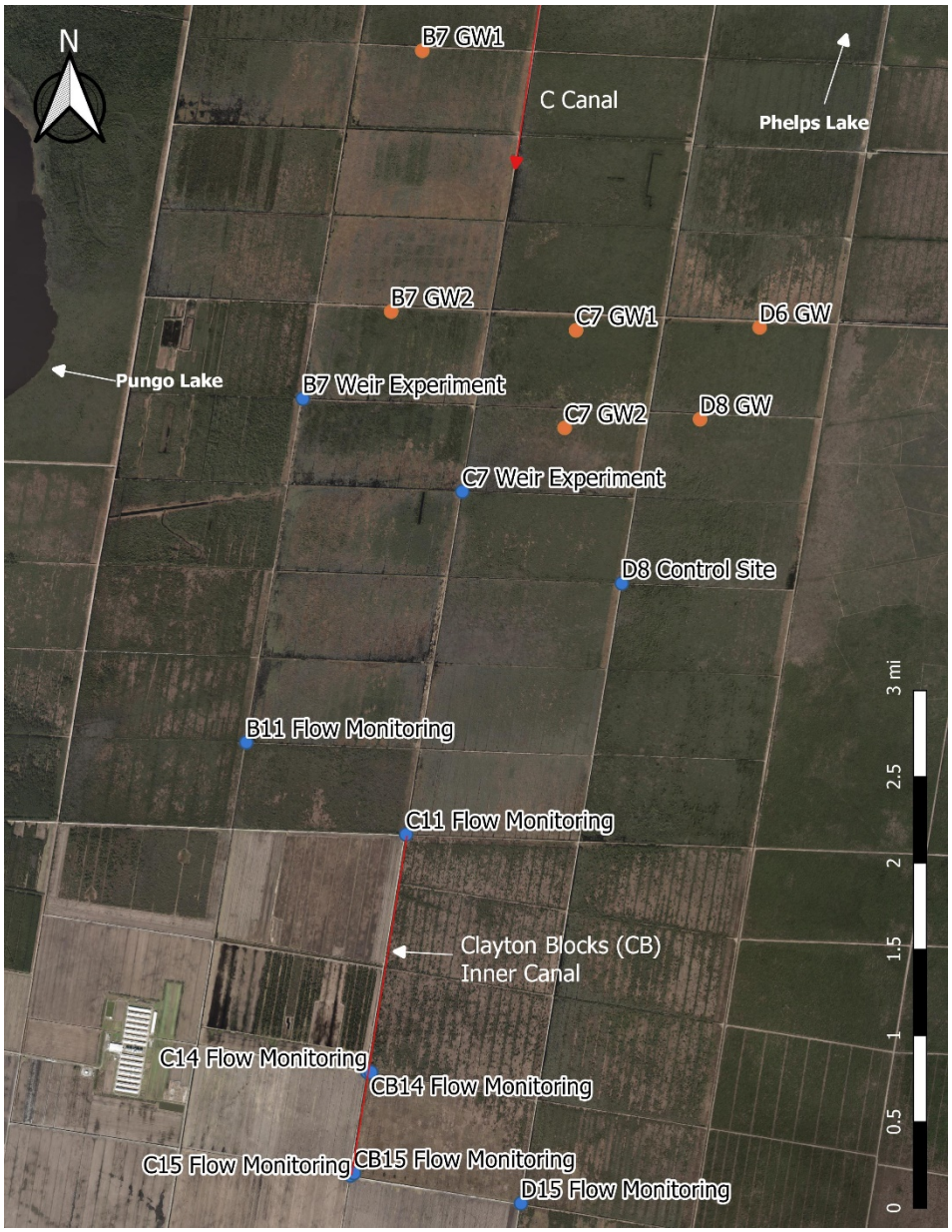

Figure 2. Water table and flow monitoring stations at PLNWR.

Data collection was completed through 2018 with the exception of a period of missing data from April 5 to July 10, 2018. The most recent data collection was January 18, 2019. Several storms of varying intensities were observed during this time, including a period of extremely heavy rainfall in late July and Hurricane Florence in September 2018.

Flow Analysis

The rectangular weir equation is used to calculate the flow rate over the boards at each WCS (**Equation 1**). If a WCS had no boards, a pipe flow equation is used to determine the rate of flow through the open riser (**Equation 2**).

$Q = 3.33\ (b - 0.2\ h)\ h^{3/2}$ (**Equation 1**)

where

Q = flow rate (ft^3/s)

h = head on the weir (ft)

b = width of the weir (ft)

$Q = AV$ (**Equation 2**)

where

Q = flow rate (ft^3/s)

A = area of water inside pipe (ft^2)

V = velocity (ft/s)

Water levels and flow were compared at C15 and CB15 and at C14 and CB14 to check for possible of seepage through the separation berm (**Figures 3 and 4**). The water elevation of the outer C canal is consistently 4-6 feet lower than the inner CB canal (Refuge WCS). Throughout the study period, the water surface elevation at C15 recedes more rapidly than at CB15, indicating that there is not a substantial amount of seepage through the berm. On average, in the 48 hours following a storm event, the water elevation at C15 drops 71% more than the water level at CB15. In the following 48 hours, from 48 to 96 hours after a storm, the water level at C15 drops 65% more than the water level at CB15.

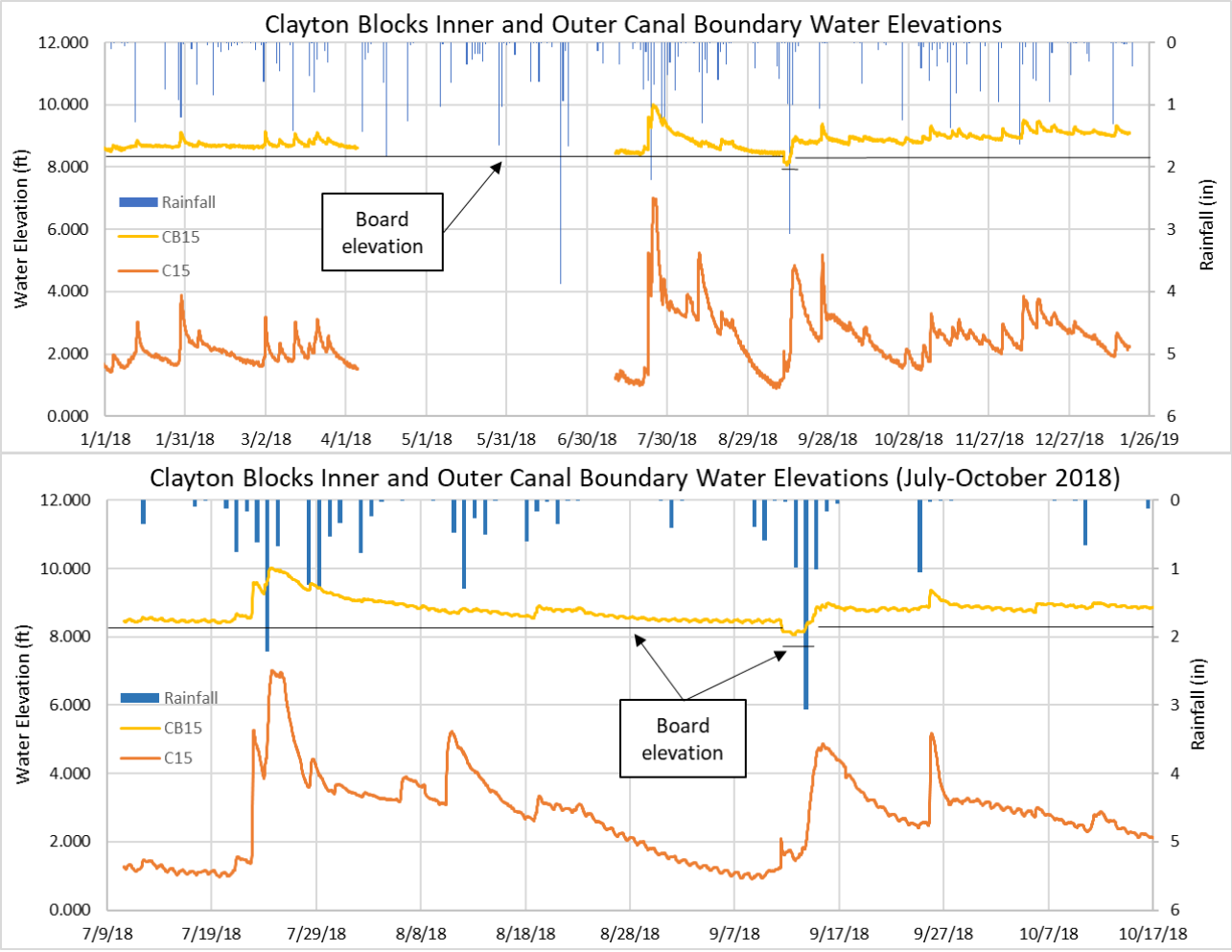

Figure 3. Water elevations at Clayton Blocks inner (CB15) and outer (C15) canal boundary water control structures for the study duration (top) and a period of heavy rainfall (bottom) at PLNWR.

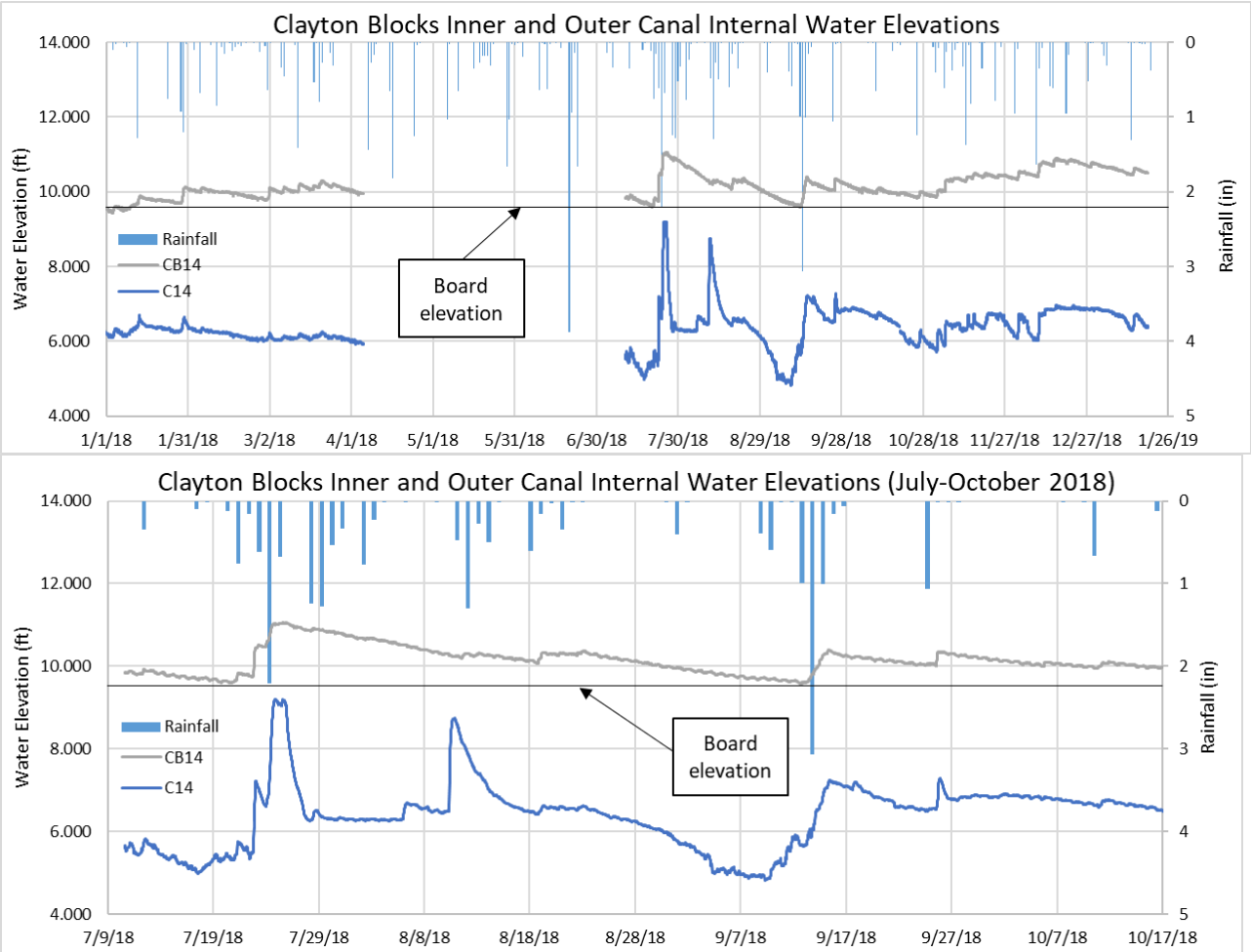

Figure 4. Water elevations at Clayton Blocks inner (CB14) and outer (C14) canal internal water control structures for the study duration (top) and a period of heavy rainfall (bottom) at PLNWR.

On August 10, an increase in water elevation was observed at the C14 and C15 WCS but not at CB14 or CB15. This is likely caused by the clearing of debris at the C11 WCS, resulting in lower water levels at C11 and a temporary increase in water level downstream at C14 and C15. The CB canal, which does not receive water from upstream of C11, was unaffected (**Figure 5**).

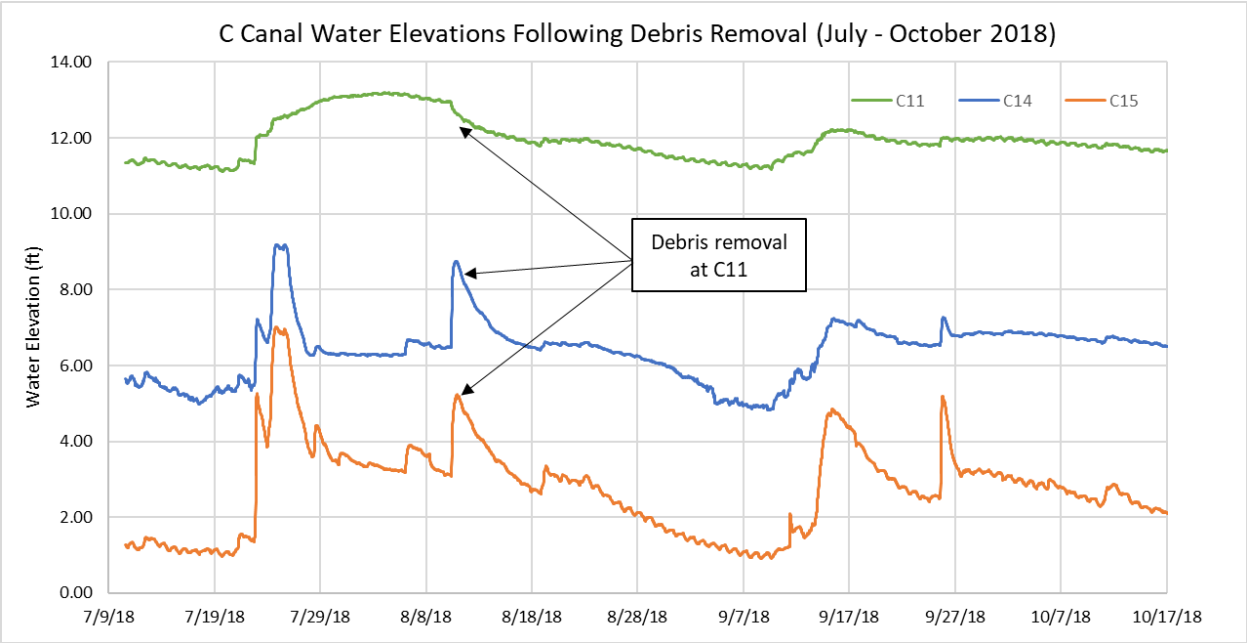

Figure 5. Outer C Canal debris removal and resulting downstream water level changes at PLNWR.

Throughout the study period, the board configuration in the CB15 riser was altered once during September in preparation for Hurricane Florence. During this time, one row of boards was removed from the riser, lowering the drainage level by roughly half a foot. During this study, the water level at CB15 never dropped below the height of the boards, although this did occur at other WCS, including the control D8. Water levels at CB15 remained fairly constant, increasing during storm events but returning afterwards to a constant elevation of 8.4 to 8.5 feet, just above the boards in the riser (**Figures 3 and 4**).

Drawdown time was also compared between C15 and CB15 after storm events and during periods of little to no rain. Following a storm, water at C15 drains much more quickly than water at CB15. On average, water at C15 drained 2.9 times faster than water at CB15. If water were seeping through the berm from CB15 to C15, the ratio of drainage from CB15:C15 would be much smaller (**Figure 6**).

Figure 6. Post-storm 0.1 ft drawdown times at Clayton Blocks inner and outer canal boundary water control structures at PLNWR.

Rain (in)	C15 (Outer) WL	Drawdown Time (hours)	CB15 (Inner) WL	Drawdown Time (hours)	CB15:C15 Ratio
1.28	3.022	5	8.859	17.5	3.5
2.16	3.888	3.5	9.121	10.5	3
0.68	2.740	7.5	8.825	31.5	4.2
	Weir Modification				
0.7	3.182	3	9.139	4.5	1.5
0.8	2.349	5	8.881	19.5	3.9
1.46	3.034	5	9.078	8.5	1.7
1.62	3.108	5	9.11	11	2.2
0.46	2.573	6.5	8.938	21.5	3.3
	Missing Data 4/5/18-7/10/18				
4.55	7.008	7	10.015	18	2.6
5.23	4.860	6.5	8.983	18	2.8
1.08	5.185	3	9.377	8	2.7
				Average Ratio	2.85

During drier periods, water elevations at C15 declined more than at CB15. Water levels at C15 dropped an average of 24% during periods of little to no rain, while levels at CB15 dropped an average of only 1% (**Figures 7 and 8**). The WCS at C15 has two risers to control flow downstream of the Refuge, each with three bays. As of January 2019, one riser contains boards in all three bays that reach nearly to the top of the structure. The second has boards in two of the three bays but no boards in the last bay. This uncontrolled flow through the last bay of this riser likely accounts for some of the decrease in C15 water elevation during times of little to no rainfall.

Figure 7. Drawdown times during dry periods at Clayton Blocks inner and outer canal boundary water control structures at PLNWR.

Dry Period	Time (days)	Water Level C15	% Drop C15	Water Level CB15	% Drop CB15
1/18/2018 4:30		1.9680		8.699	
1/25/2018 18:00	7.56	1.6840	14.4%	8.647	0.6%
2/7/2018 12:30		2.2710		8.689	
2/28/2018 9:00	20.85	1.6460	27.5%	8.671	0.2%
7/13/2018 12:30		1.3310		8.519	
7/20/2018 3:30	6.63	1.0920	18.0%	8.455	0.8%
8/26/2018 10:30		2.3020		8.606	
9/10/2018 20:00	15.40	1.1620	49.5%	8.448	1.8%
9/29/18 10:00		3.2260		8.892	
10/5/2018 4:00	5.75	2.9080	9.9%	8.789	1.2%
Average			23.9%		0.9%

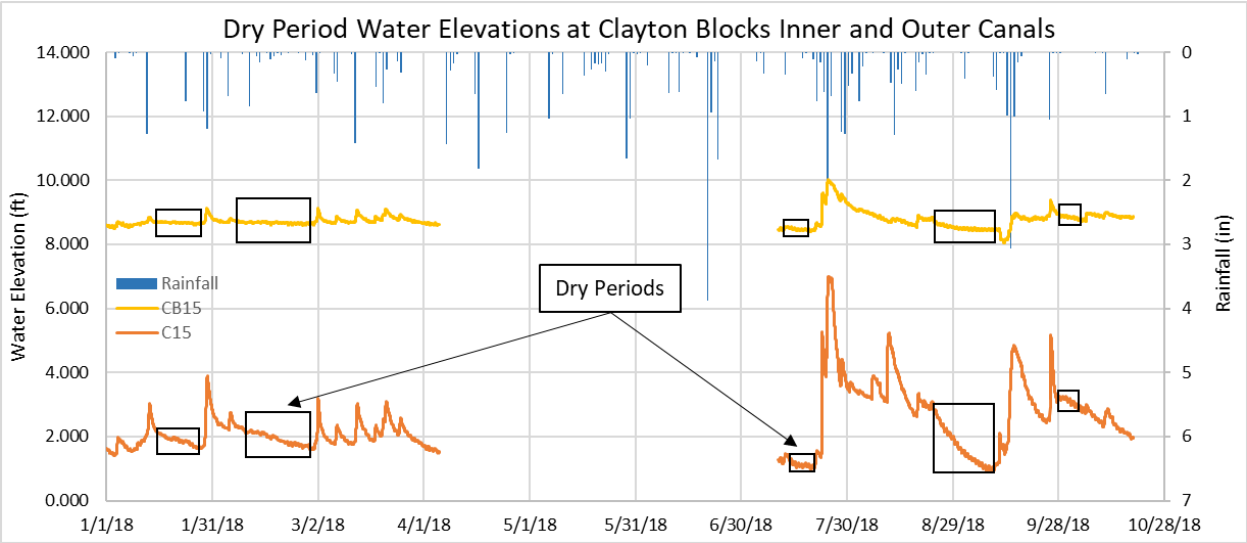

Figure 8. Water elevations during dry periods of little to no rainfall at Clayton Blocks inner and outer canal boundary water control structures at PLNWR.

Water elevation was compared between the CB15 and D15 WCS during dry periods from July to October 2018. Dates from January to April were not included because of the board configuration changes and resulting water level changes caused by the De-Hoog Road project. Both the CB15 and D15 WCS are located at the boundary between refuge and private farmland, and both structures use boards to control upstream water level. During these three dry periods, water elevation declined by an average of 2.6% at D15 and 1.2% at CB15 (**Figures 9 and 10**). Both structures exhibit only a small decline in water level, especially compared to C15. The similar drawdown rates between CB15 and D15 indicate that there is little to no seepage through the separation berm between the C and CB canals.

Figure 9. Drawdown times during dry periods at Clayton Blocks inner canal boundary and D canal boundary water control structures at PLNWR.

Dry Period	Time (days)	Water Level D15	% Drop D15	Water Level CB15	% Drop CB15
7/13/18 12:30		10.254		8.519	
7/20/18 3:30	6.63	9.99	2.6%	8.455	0.8%
8/26/18 10:30		10.6		8.606	
9/10/18 20:00	15.40	10.169	4.1%	8.448	1.8%
9/29/18 10:00		10.564		8.892	
10/5/18 4:00	5.75	10.441	1.2%	8.789	1.2%
Average			2.6%		1.2%

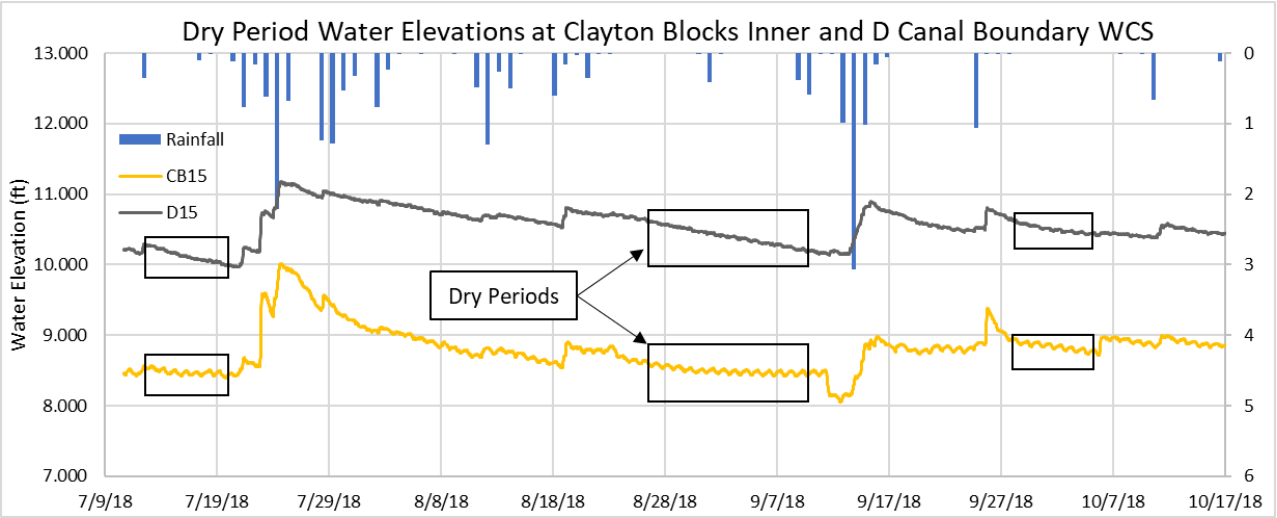

Figure 10. Water elevations during dry periods of little to no rainfall at Clayton Blocks inner canal boundary and D canal boundary water control structures at PLNWR.

During periods of little to no rainfall, water does not flow over the WCS at CB15, although water loss and reductions in water surface elevation continue to occur. This is likely attributed to two main factors: water leaking between the boards in the WCS and evapotranspiration. The boards used to control the water level in the risers are not completely sealed, therefore small amounts of water constantly leak between the boards. Evapotranspiration will also contribute to water losses. These factors were not quantified during the current study; however, it is likely they are contributing to the decline of water levels during periods of no flow.

Results

These results confirm the performance of the separation berm for preventing seepage flow that might impact adjacent private lands. The data documents consistent differences in water elevations and patterns that support this conclusions. Water elevations in the CB canals remain constant following a return to normal water levels after a storm, indicating the effectiveness of the surrounding berms. Drawdown rates during dry periods are similar between D15 and CB15, and are much lower than those at C15. This maintenance of water levels further illustrates berm effectiveness. Finally, comparison of drawdown rates in the Clayton Blocks and a control site at the Refuge show that drawdown rates are consistent and primarily related to water control structure leaks or evapotranspiration.