Using Remote Monitoring to Increase the Adaptive Capacity of the Alligator River National Wildlife Refuge Forested Wetlands Water Management Plan

Photo: New (center) and old (left) water control structures at Alligator River National Wildlife Refuge and Dare County Bombing Range adjacent to the 2011 Pains Bay Fire scar (background), credit- C. Pickens.

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Using Remote Monitoring to Increase the Adaptive Capacity of the Alligator River National Wildlife Refuge Forested Wetlands Water Management Plan

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***Abstract*:** This purpose of this study was to increase the ability of land managers to inform, implement, and adaptively manage water control structures as part of a large Water Management Plan at Alligator River National Wildlife Refuge (ARNWR) and Dare County Bombing Range. Remote monitoring loggers, software, and wells supplies were purchased, but deployment was delayed due to several complicating factors. Despite these challenges, non-remote monitoring has taken place and water management implementation has proceeded for all partners to include permitting, ditch maintenance, water control structure purchasing, and installation. Once online, the remote monitoring loggers will replace the non-remote monitoring loggers. Additionally, groundwater monitoring on refuge property was completed to document baseline conditions of forested wetlands at ARNWR prior to water management implementation. Water level and salinity monitoring in ditches demonstrate the effects of influencing factors such as wind events and water control structures on water in the ditch network. Groundwater monitoring reveals the variability in groundwater table within the interior portion of the refuge, but also reflects the similar temporal patterns of rising and falling water levels due to rain and evapotranspiration. Monitoring not only informs future water management but also helps to evaluate previous water management activities.

INTRODUCTION

The Pains Bay Fire, which ignited in May 2011, lasted for four months, and burned over 45,000 acres of the Alligator River National Wildlife Refuge and Dare County Bombing Range, began a cascade of awareness and actions related to water management needs and implementation. The Nature Conservancy coordinated efforts and resources provided by the U.S. Fish and Wildlife Service as well as the U.S. Air Force to establish a water management plan for a 65,000 acre project area across the range and refuge. The goals of the water management plan are to 1) re-establish more natural water patterns of the forested wetland and pocosin habitat of the plan area, 2) increase and improve capacity to move and have access to water for fire management activities, and 3) reduce salt water intrusion into the interior areas of the range and refuge. The water management plan was designed by a hydrologic engineering firm with input from project partners. The plan was finalized in the fall of 2014 and included the installation of six new (6) structures on the range. The Nature Conservancy and refuge staff orchestrated the resources to purchase and install a very large check valve water control structure (four 48-inch culverts with

check valves that prevent saltwater intrusion) in July 2014 to improve the overall effectiveness of the water management plan. Additionally, staff from the Alligator River National Wildlife Refuge reviewed the recommended actions of the water management plan that applied to the refuge and secured all permitting needs in 2015.

Current efforts include The Nature Conservancy and refuge staff working together to purchase and install new water control structures and clear out ditches as recommended by the plan. Additionally, the U.S. Navy Fleet Force Command has become an additional partner and contributed funding to implementing plan actions on the range to include ditch maintenance and installing nine new culverts. On range property, water management activities are generally managed by the North Carolina Forest Service. Therefore, at this point, there are now federal, state, and NGO partners working together to improve water management across the range and refuge. Given the goals of the water management plan and multiple partners, monitoring was identified as an on-going need that could be expanded and improved to evaluate effectiveness of the plan and guide adaptive measures as needed.

The original monitoring objectives were to:

1) Establish remote access water monitoring wells at four (4) locations to support the water management plan;
2) Provide real-time data and notifications to project partners;
3) Manage, analyze, and share water monitoring data to elucidate hydrologic patterns.

STUDY AREA

The project area of the water management plan is represented in Figure #. This area is a mixture of wetland types including fresh marsh, forested wetland, and pocosin. Vegetation patterns are heavily influenced by a legacy of ditching and drainage, as well as fire activity, particularly the Pains Bay Fire scar that still exists in the southeast region of the project area. Water level and salinity sampling was done at four sites highlighted and labeled as shown in Figure #.

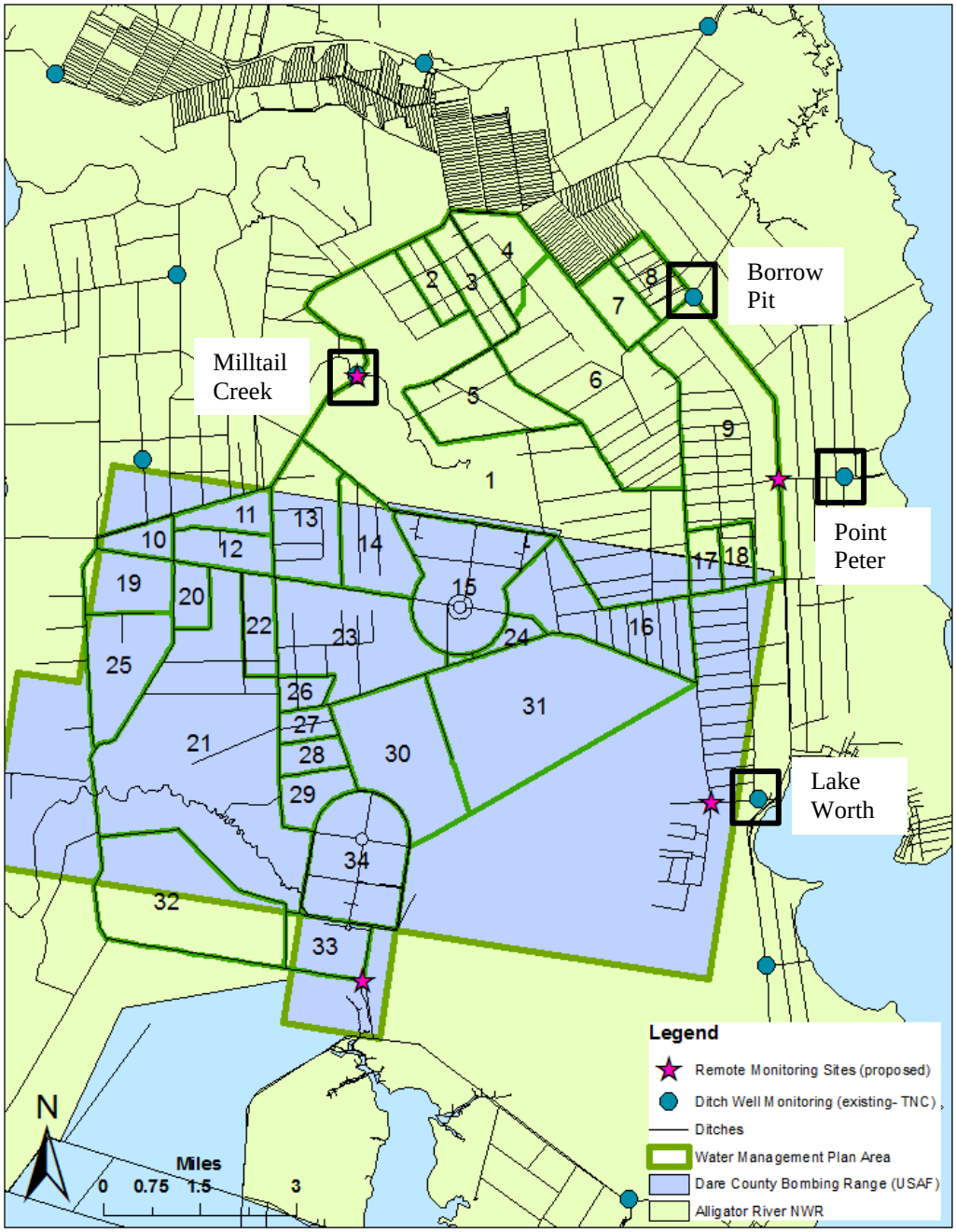

Figure 1. Map of proposed and realized monitored sites for the water management plan, labeled and highlighted with a black box.

Additional groundwater monitoring is occurring at six (6) sites (Figure 2) to document baseline conditions within water management cells on refuge property before water management takes place.

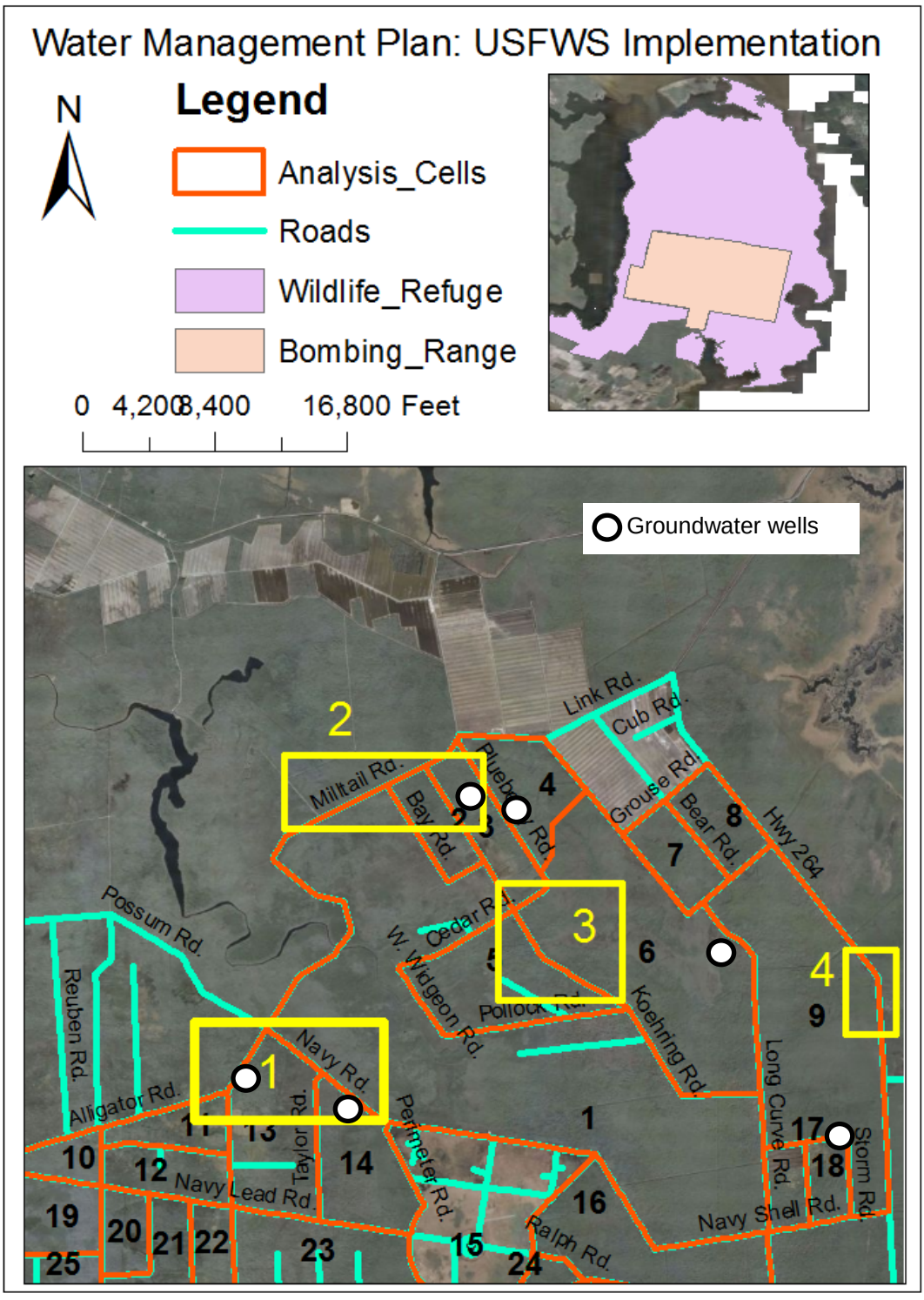

Figure 2. Map of planned USFWS water management actions. Numbered yellow boxes show the areas that will be improved (e.g., water control structures installed) for each phase of work. Black numbers indicate water management cells and white dots show groundwater well locations.

METHODS

The original intent of the project was to establish four remote-accessible water level and salinity loggers. While these loggers were secured, their deployment has been delayed. A substitute approach is being utilized until they are functional.

The Nature Conservancy monitors water level and salinity with non-remote accessible loggers for the Albemarle-Pamlico Climate Change Adaptation Project to assess project effectiveness and environmental trends. These loggers are located in perforated wells within ditches or in the ground (water table is near surface.) Data points are recorded and stored every hour, then downloaded, corrected, and analyzed. Ditch well data are corrected for elevation and groundwater data are corrected to level below surface. Processed data are shared with project partners as needed.

RESULTS

Several challenges arose related to the remote-accessible loggers. Some of those challenges included limited staff capacity of The Nature Conservancy, construction activity at the location of wells, a wildfire, and technical challenges related to equipment itself. Despite these challenges, the loggers will be successful in the near term and we feel confident we will achieve the original goals of the project. Monitoring that took place during the project timeline for the Albemarle-Pamlico Climate Change Adaptation Project and in conjunction with the water management plan are presented here and inform the ongoing implementation of the water management plan.

Overall, water level and salinity of water throughout the ditch network of Alligator River National Wildlife Refuge are impacted predominantly by complex environmental factors including rainfall, wind events/tides, and lunar tides.

Ditch water level and salinity

Water level and salinity for the monitoring site, Borrow Pit (Figure 3) demonstrate that water levels fluctuate daily and vary by nearly 0.5 m (1.6 ft) within the ditch. This particular ditch location is draining an approximately 940 acre area with no hydrologic control. Overland flow is assumed to be moving towards the location of the logger based on elevation, and water from Borrow Pit Road ditch is draining through this location towards the larger HWY 264 ditch. The salinity remains fairly low, likely due to the large area of drainage and connections to large ditches except during some wind events where sustained winds of 15 – 20 mph for at least a day were out of the north (especially the northeast).

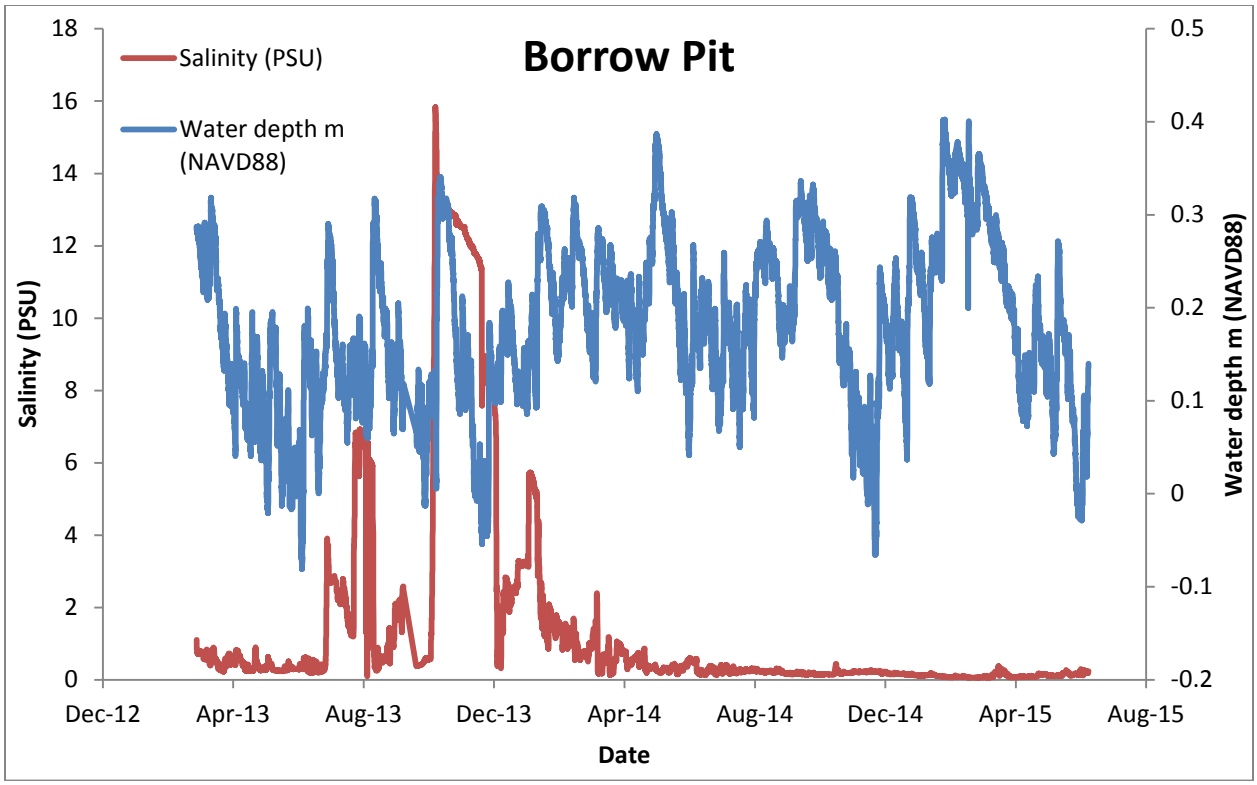

Figure 3. Water level and salinity measured at Borrow Pit from February 2013 – June 2015.

At the monitoring station at Point Peter Road ditch, the logger is located upstream of a water control structure that has set board levels that slow drainage off of the refuge and check valves that limit saltwater intrusion from the Pamlico Sound. This ditch is draining water from refuge lands directly north and south of Point Peter Road, about an 860 acre area southwest of Point Peter Road, as well as the larger HWY 264 ditch from both the north and south directions. Before the water control structure was installed, saltwater from the Pamlico Sound could move into this ditch and reverse flow. Salt water is still able to move through the HWY 264 ditch from the north and south, particularly during strong wind tides. The data collected at this location demonstrate that water levels are fluctuating by as much as 0.48 m (1.6 ft) and the tidal influence is muted here because of the water control structure (Figure 4). Salinity increases briefly at various times, and those times are usually associated with strong wind events that raise water levels over 0.2 m NAVD88. Overall, salinity is about 2 PSU, which is much lower than typical 8 – 14 PSU salinities in the Pamlico Sound where the Point Peter Road ditch connects to the Sound (Figure 4).

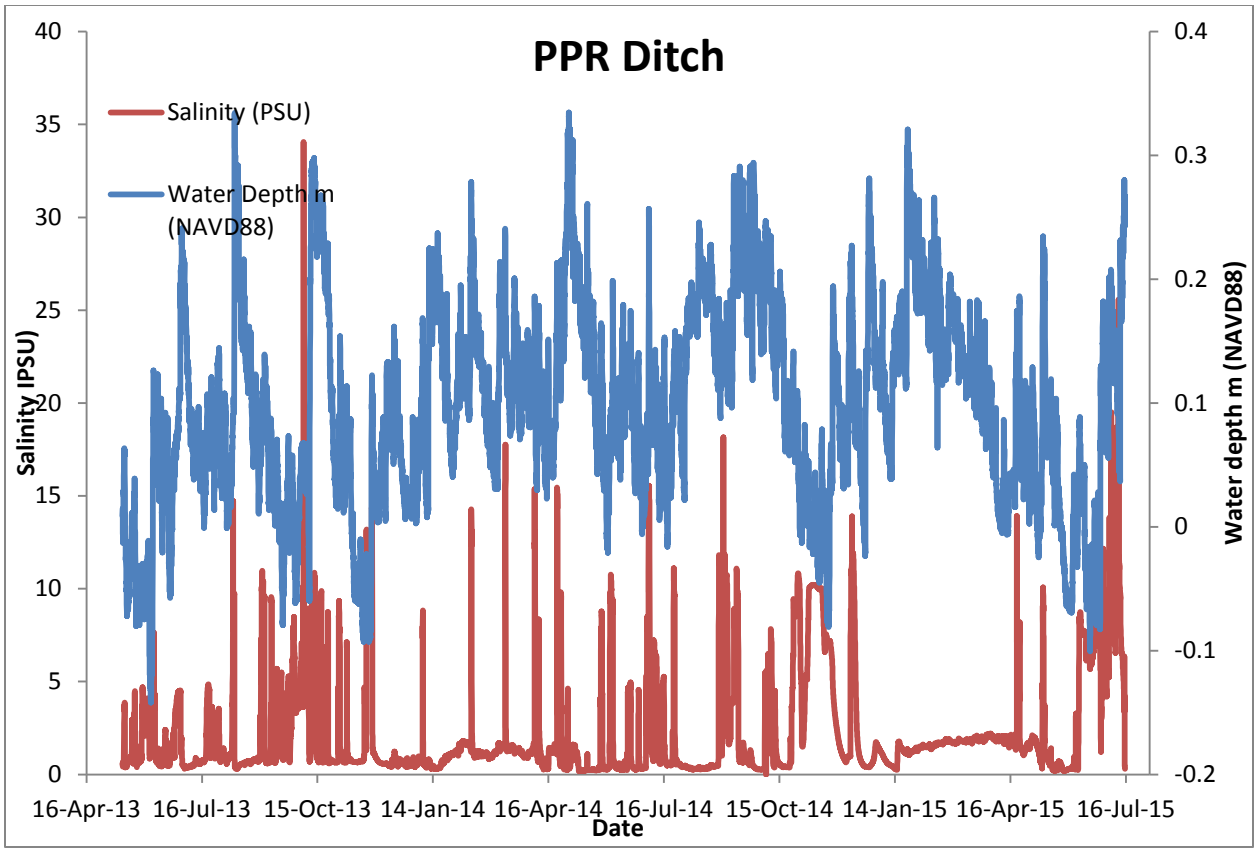

Figure 4. Water level and salinity measured at Point Peter Road ditch from May 2013 – July 2015.

Lake Worth Road ditch monitoring data (Figure 5) are split into before and after conditions at a location where a large water control structure was installed in July 2014. Much like Point Peter Road, water levels still fluctuate by 0.74 m (2.4 ft), but this is a 0.48 m (1.6 ft) improvement on water level fluctuation prior to the structure being installed. The greater fluctuations in water level and salinity were due to daily tides before the structure was installed, but with the new structure, salinity levels are now not driven by daily tides and water levels do not get as low. Salinity is less than 1 PSU currently, which is a great reduction from the 6 PSU average prior to the structure. Tree mortality and stress were also evident adjacent to this ditch. This location is receiving drainage from a large area of the pocosin dome located in the southeast region of the refuge and range, as well as water moving through Long Curve Road ditch.

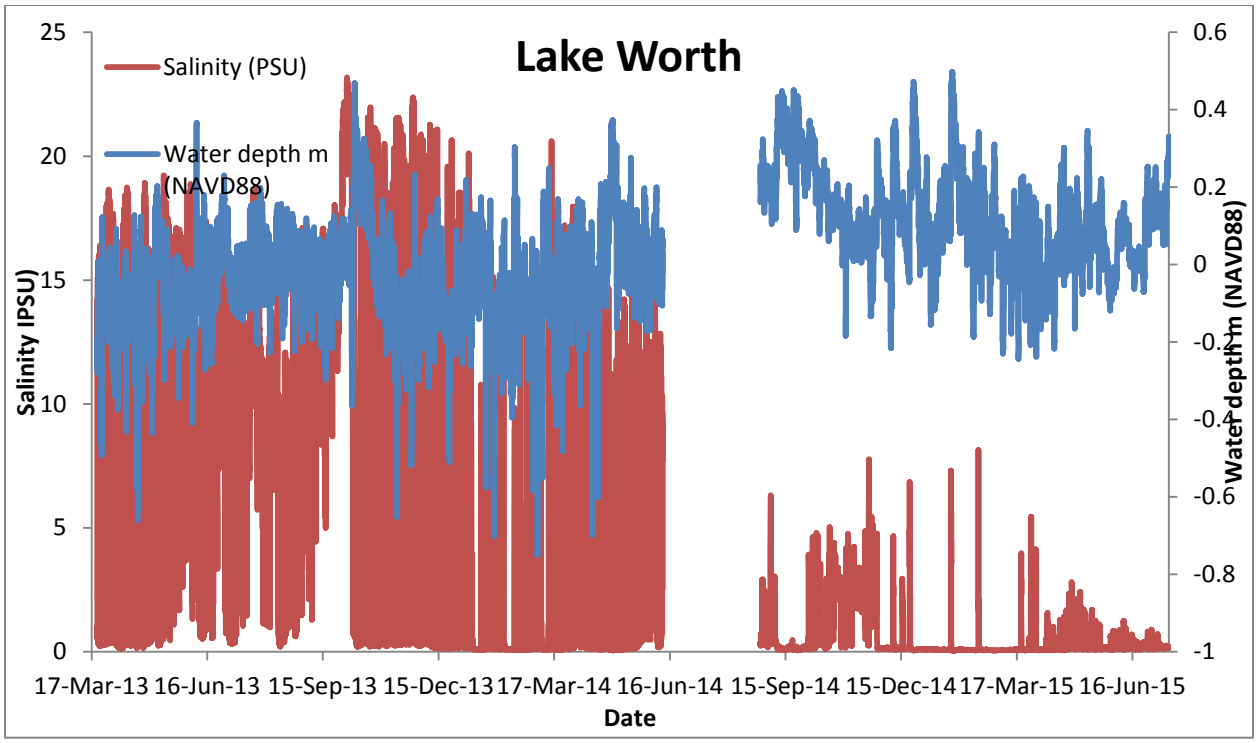

Figure 5. Water level and salinity measured at Lake Worth Road ditch from March 2013 – July 2015

The Milltail Creek monitoring site is draining an area of approximately 6,300 acres of forested wetlands that are relatively less disturbed than most areas of the refuge and range, as well as the Milltail Creek Road ditch from both directions. Data from this location indicate that water level fluctuates by 0.59 m (1.9 ft) and salinity pulses are rare in this freshwater creek (average salinity is 0.1 PSU) (Figure 6). Water levels certainly increase with large rainfall events due to the large area of drainage and surface run-off, but wind still plays a role in water levels. Salinity stays low, but pulses of salinity may come from the Alligator River and move upstream under certain conditions (Figure 6).

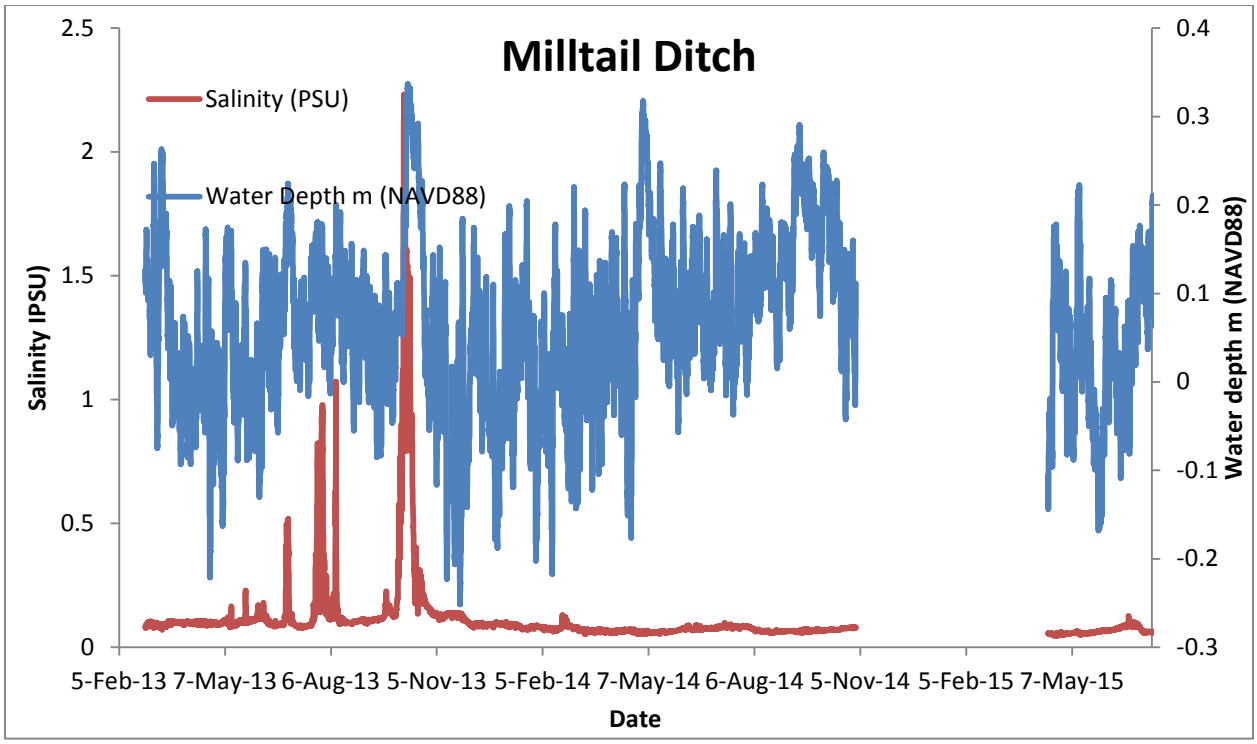

Figure 6. Water level and salinity measured at Milltail Road bridge from March 2013 – July 2015

Groundwater level in water management units

Preliminary data collection at groundwater wells are demonstrating the variation in water patterns that exist in water management cells prior to water management implementation on the refuge (Figure 7). Overall, groundwater level increases with rainfall events, and decreases with drainage and evapotranspiration at the same times at all sites, though at different ranges. Importantly, these data reflect locations and scenarios where water levels are getting further below the refuge goal keeping water levels within approximately 1 ft (0.3 m) of the surface. As this data set is built out, further interpretation will be possible, but some observations can be made. For example, the driest of all the monitoring sites is in water management Cell 18, with water levels nearly a meter below the surface of the ground (Figure 7, orange line). Cell 18 lies to the east of the project area, and is also likely the most fire-vulnerable due to its proximity to an area known for frequent fires. If this pattern continues, we may need to adjust a water control structure to hold water level higher during the drier times of year. Another interesting pattern is that Cells 13 and 14 (Figure 7, purple and light blue lines, respectively), which are directly next to each other, have very different drainage regimes. Water level in Cell 13 varied by 0.67 m during the spring and summer of 2015, while water level in Cell 14 only varied by 0.28 m. This could be due to a number of factors including natural creek flow, water pumping from the range, and soil differences, where Cell 13 may have greater mineral/clay content than Cell 14. Cell 3 (Figure 7, dark blue line) is an area that is known to have beaver activity, which may explain why water levels are higher here than other locations.

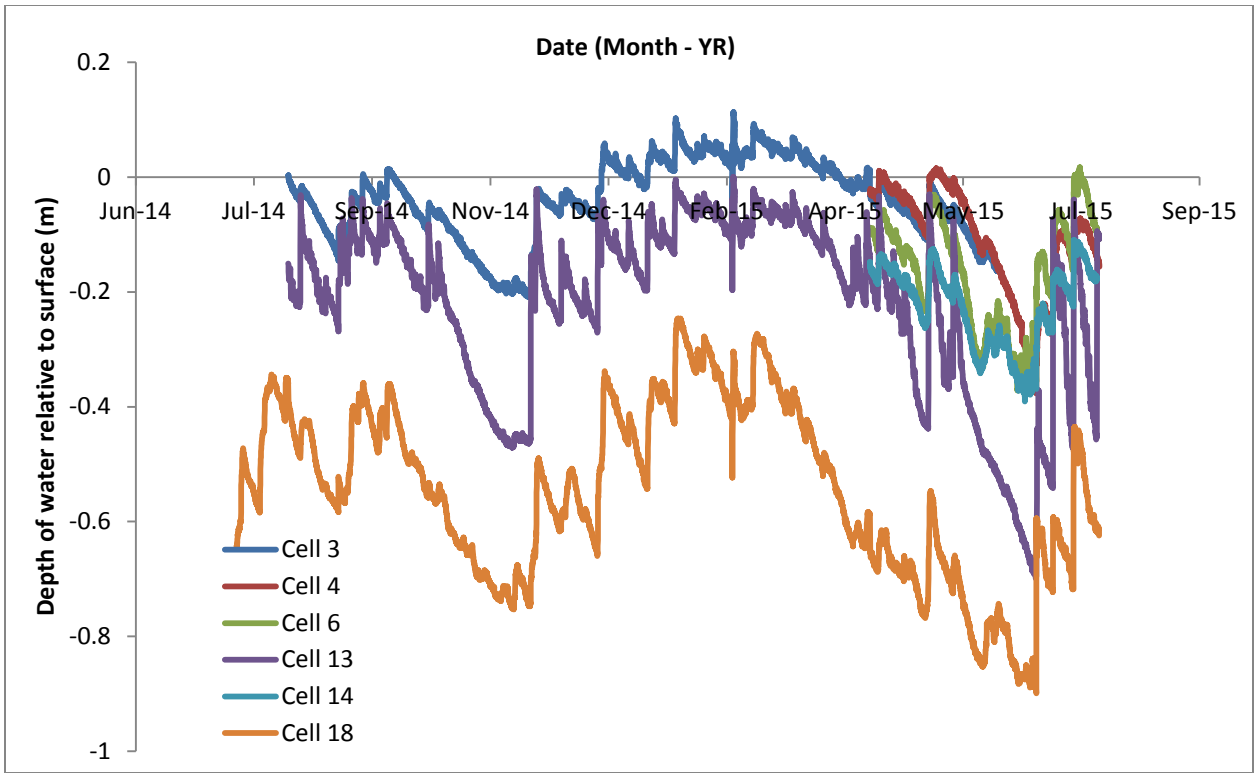

Figure 7. Preliminary groundwater data from refuge-owned water management cells 3, 13, and 18 from July 2014 – July 2015, and cells 4, 6, and 14 from April 2015 – July 2015.

DISCUSSION

Water level and salinity patterns in ditches and groundwater of Alligator River National Wildlife Refuge are highly variable and reflect the influence of factors ranging from wind events, rainfall, drainage, water control structures, evapotranspiration, and uncontrolled connections to saltwater sources. With an average elevation of about 2 ft above sea level, water movement in ditches is bidirectional, which helps to explain how salinity can spike behind a check valve structure or how large increases in water level can occur without rainfall. Water management actions can help to reduce the variability in water level and salinity fluctuations, thus improving the daily conditions that the forested wetlands experience. Furthermore, reducing salinity levels on the interior portion of the refuge and range will help keep a freshwater head to reduce saltwater intrusion.

Borrow Pit data reveal the vulnerability of the large ditches to wide ranges in salinity variation, as well as water level trends that lack strong seasonal patterns. Water management actions may result in even more variation at this location because less fresh water will be draining into this major ditch, as it will be captured to saturate the soils that typically drain this direction. Less fresh water draining into this ditch may allow salinities to vary widely with less fresh water with which to mix within the ditch.

Point Peter Road and Lake Worth Road data provide evidence of water control structure effects on water level and salinity. In particular, the variation in water level and salinity vary greatly

before water control, then are reduced after control. The structures do not completely prevent short-term increases in salinity or drops in water level, but they reduce daily variance and change average conditions. The water control structures that have been and will be installed at the refuge and range will have similar impacts on water level, particularly groundwater level. Noting that there are some fluctuations that still occur, it is important to understand that this landscape will likely never be completely controlled, but strategic structure placement can produce the water patterns that build resiliency into the landscape. At least one more structure is planned for installation at Long Curve and Lake Worth Rds, which will further increase water capacity for keeping peat soils seasonally saturated and managing fire events.

Data from Milltail Creek provide a general description of more natural water patterns that we would expect from a forested wetland because the logger is located at a location in large area (> 6,000 acres) of more naturally-draining forested wetlands compared to other densely-ditched areas of the refuge and range. Namely, salinity levels are very low on average and water level increases with surface flow. However, Milltail Road ditch is still a factor contributing to water level and may be making fluctuations greater than they would be if only influenced by the creek. With more water management, these data may reflect some changes implemented in the northwest area of the water management plan occurring this summer (2016).

The preliminary groundwater data that are collected within water management cells will be important to assess water management actions. We expect water levels to drop slower with more water control, and hope to keep water levels within approximately 1 ft (0.3 m) of the surface. Water levels above the surface may indicate complicating factors like beavers blocking water control structures.

When water management activities were first planned, the actions were ordered in importance and implementation by a historic understanding of fire vulnerability across the range and refuge. That resulted in actions being prioritized from the east to the west, with the expectation that dry conditions would continue to make fire-vulnerable areas even more vulnerable. However, precipitation was above normal by 12 – 20 inches in 2014 and 2015, causing water levels to be very high. Therefore, the order of structure installment was changed to improve the capacity to move water out of areas where it could not drain well, namely from west to east. This was an unexpected change, though an important lesson to learn early in the process. The higher than normal rainfall was also likely an important factor in keeping Whipping Creek Fire (March – April 2016) from becoming a groundfire. Without the excess rain, however, it will become imperative to use water control structures to keep soils saturated and prevent catastrophic groundfire and saltwater intrusion. In conclusion, monitoring data demonstrate the high variance in water level and salinity experienced throughout this relatively flat landscape, as well as how water control structures can improve water conditions. Future monitoring will be improved through greater understanding of groundwater tables within management cells and functioning remote-accessible water gages.

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DATA APPENDIX

See attached excel files for water data.