Inter-Agency Agreement to Conduct Scientific Studies Relevant to the Stormwater Treatment Areas

Agreement No. 4600003125

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PREPARED FOR:	South Florida Water Management District, and Everglades Agricultural Area Environmental Protection District
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Introduction

A field-scale periphyton-based stormwater treatment area (PSTA) was constructed from 2004 to 2005 for the purpose of addressing uncertainties associated with large-scale implementation of periphyton-based treatment technology. The PSTA Cell in STA-3/4 is unique among STA treatment cells in that the extant peat was scraped to expose the underlying rock.

A key aspect of the PSTA concept is that either the removal of muck soils to expose underlying limerock substrate, or the addition of limerock to effectively cap the existing muck soils, is thought to be necessary for optimal P removal. This is based on the premise that successful removal of P to ultra-low levels depends on limiting internal P loading sources.

The STA-3/4 PSTA facility has developed an accrued marl sediment layer on top of the bedrock that was exposed during project construction. This new material is different than the underlying limerock surface upon which the PSTA community was first established, and may affect both water column nutrient exchange and macrophyte and periphyton growth. It is important to understand how the accumulation of new sediment over the original substrate can influence outflow TP concentrations and sustainability of P removal performance.

As a starting point in addressing these issues, we defined the extent of new sediment accumulation and quantified its chemical composition. Surficial sediments in the PSTA Cell are low in P, as are the underlying muck soils (where present), when compared to soils in muck-based cells (DBE 2014, Andreotta et al. 2014). An important question that remains despite these recent findings is this. Regardless of the type/condition of substrate employed at PSTA system startup, does the accretion of new material (marl) gradually impair P removal performance over time?

We have compared sediment P stability and release potential from PSTA sediments to other muck-based substrates in use within Everglades STAs (DBE 2014). That earlier work provided evidence that muck soils can provide more P to macrophytes than an exposed LR substrate or sediments from the PSTA Cell (core studies in DBE 2014). We have shown that macrophyte tissue P contents are quite low in the PSTA Cell (219 ± 29 mg/kg), compared to those in other STAs (DBE 2014). Low tissue nutrient contents are likely to limit internal P loading from senescent vegetation. Perhaps the best indicator of the degree to which internal P loading is reduced may be alkaline phosphatase activity, as measured in surface water, periphyton and sediments (DBE 2014). The effects of sediment accrual on enzyme activity will be reviewed in a later report.

The current report focuses on a series of surveys conducted in the PSTA Cell to determine the rate of sediment accretion. Specifically, we examine the following:

- Sediment accretion trends over time
- Spatial variability in PSTA cell sediment depths
- Comparison of sediment accretion upstream and downstream of the numerous vegetated strips within the PSTA cell

The work described in this report is part of a multi-year effort to improve our understanding of P removal mechanisms that operate in PSTA systems. Further analyses of these findings will be presented in future reports.

Field Methodology

The depth of total soil material above bedrock was measured in the PSTA Cell on December 3, 2014, at the onset of the dry season. Similar surveys were conducted during previous events: January 2012, November 2012, July 2013, March 2014, and May 2014. During each survey, depth of total soil material above bedrock was determined in situ using a tape measure and tile probe. The probe was inserted vertically into the sediment to the point of refusal, and the length of the probe from its tip to the water surface was recorded as “depth to bedrock”. Water depth was also recorded and subtracted from the depth to bedrock to determine the total soil depth above bedrock. The measurements were made at 3 stations in each of the 13 compartments of the PSTA Cell as defined by the vegetated strips (Figure 1).

In most regions within the cell, the muck soils were removed during cell construction (2004), or were used to construct internal berms for vegetated strips (Figure 2). These internal berms are oriented perpendicular to the dominant flow direction. In April 2012, emergent vegetation on selected berms was treated with herbicide. The following month, the dead emergent vegetation was compacted into the soil to reduce hydraulic resistance within the cell. It should be noted that the soil material that originally comprised the internal berms may be susceptible to sloughing into the deeper, adjacent treatment areas. The berms have not been included in sediment surveys described in this report. Rather, the current study characterized the sediments from areas between the internal berms within the PSTA Cell.

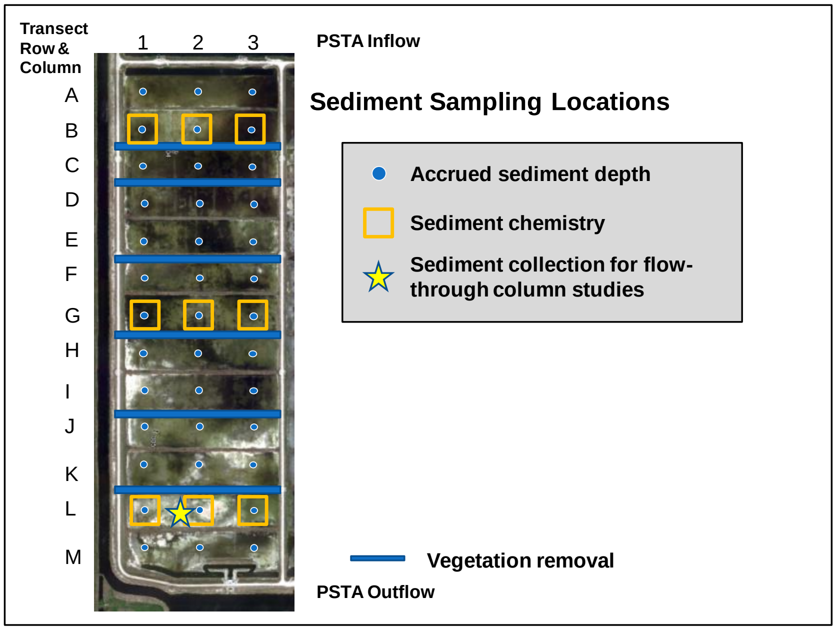

Figure 1. Internal locations within the STA-3/4 PSTA Cell where sediments were assessed for accrual depth, chemistry and P flux studies. For reference, the internal berms where emergent vegetation was removed in 2012 are also shown.

Figure 2. Photo of substrate preparation during PSTA cell construction. Organic soils were scraped from limerock, then removed or formed into berms that extend perpendicular to the dominant (north-to-south) flow direction.

On three occasions (November 2012, May 2014, and December 2014), intact cores were retrieved at each station to discriminate the depth of accrued sediment material from underlying muck. Thickness of the underlying residual muck (where present) was determined as the difference between total soil depth above bedrock, as described above, and the accrued soil depth observed in the intact core. This approach was taken because it was found that the entire muck depth was not always captured in the bottom of the intact cores. An additional survey of the accrued sediment depth was performed on May 31, 2012, but included only stations along the B, G, and L transects that were also sampled for chemical characterization. Samples were again retained in May 2014, and the chemical composition of the sediments was determined.

Data Analyses

Sediment Accretion Trends over Time

The accrued sediment depth was examined several ways. First, a cell-wide average accretion depth was calculated for each survey date using data from all 39 stations. The accrued depth values for each date were tested for normality using Shapiro-Wilks test at alpha = 0.05. Data were square-root transformed to achieve a normal distribution prior to ANOVA using Statistica software (StatSoft, Inc., recently acquired by Dell Software).

Longitudinal Profiles in Sediment Accretion

We used data from three transects in the inflow region (ABC), three in the middle of the cell (FGH), and outflow region (KLM), to test for significant differences between these regions of the PSTA Cell. Data within each of these regions were normally distributed, and evaluated using a single-factor ANOVA (region). Evidence of strong longitudinal gradients in accretion depth would support the hypothesis that accretion rates are highest in the inflow region of the cell, and perhaps also that vegetated strips provide stability, impairing longitudinal movement of flocculent sediments within the wetland.

Spatial Variability in the PSTA Cell

Spatial maps of the accrued sediment depth were constructed using Arc GISv9 Spatial Analyst (Environmental Systems Research Institute, Redlands, CA). A previous survey (January 2012) using this approach was provided in Chapter 5 of the 2013 South Florida Environment Report (Ivanhoff et al., 2013).

Sediment Depths Upstream and Downstream of Vegetated Berms

The vegetated berms that divide the PSTA Cell into 13 compartments were constructed out of muck soils that originally existed within the cell's footprint (Figure 2). During initial establishment of the PSTA Cell, these berms were designed to provide a shallow environment favored by emergent vegetation, and *Eleocharis* spp. was planted into the muck soils. In recent years, herbicide has been applied periodically to restrict emergent macrophyte growth within the PSTA Cell to the shallow area defined by vegetated berms. A 2013 survey indicated the average elevation on the berms was approximately 1 foot higher than the elevation between berms, where our sediment accretion measurements were performed. In 2012, the vegetation on several of these berms was eliminated to improve hydraulic conveyance of water during several planned high-flow events (Figure 3).

Average depth of accrued sediment in compartments immediately downstream of the berms where vegetation was removed (Transects C, F, H, J, and L) was compared to the average depth in compartments downstream of intact, vegetated berms (Transects B, E, G, I, K, and M). If vegetation on the berms was responsible for stabilizing sediments and restricting sediment transport with flow, one might expect to see lower accrued depths downstream of vegetated berms, as the flocculent sedimentary material would instead be retained upstream of the berm vegetation.

Figure 3. Aerial view of the PSTA Cell outflow region in 2012, shortly after herbicide of selected vegetated berms (brown vegetation).

Factors that Contribute to Variability in Total Soil Depth Measurements

During the most recent survey (December 4, 2014), three measurements of the total soil depth were recorded at each station, to compare local (<5 m spacing) variability to spatial variation in sediment depths across transects throughout the cell and temporal variations across multiple survey dates.

Results

Sediment Accretion Trends over Time

Accrued sediment depths measured along 13 transects within the PSTA Cell in December 2014 ranged from 3 to 19 cm, with a cell-wide average of 8.8 ± 0.6 cm. Standard error around the mean of three stations along each transect ranged from 0.9 to 4.6 cm. Total soil depth, including the accrued layer and underlying residual muck soil, ranged from 3 to 45 cm. This agrees well with the previous survey (May 2014) when 7 to 49 cm of total soil depth was observed.

Accretion depth measured repeatedly along three transects in the PSTA Cell showed no consistent pattern over time between May 2012 and December 2014 (Figure 4). Using data from all 39 stations, no change in cell-wide accrued depth was observed among the November 2012, May 2014 or December 2014 surveys.

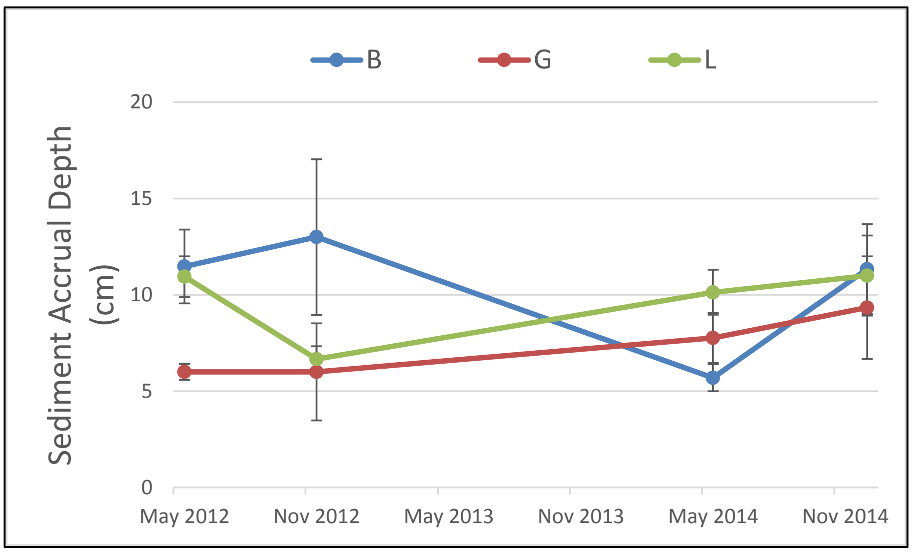

Figure 4. Temporal change in the sediment accretion depth along inflow-region (B), mid-cell (G) and outflow-region transects (L) in the PSTA Cell, across 4 survey dates between May 2012 and December 2014. Error bars denote ± SE around the mean value for three stations per transect on each date.

Longitudinal Profiles in Sediment Accretion

Average sediment depths were not significantly different longitudinally (inflow, mid-, and outflow regions) in the PSTA cell during December 2014 (Figure 5).

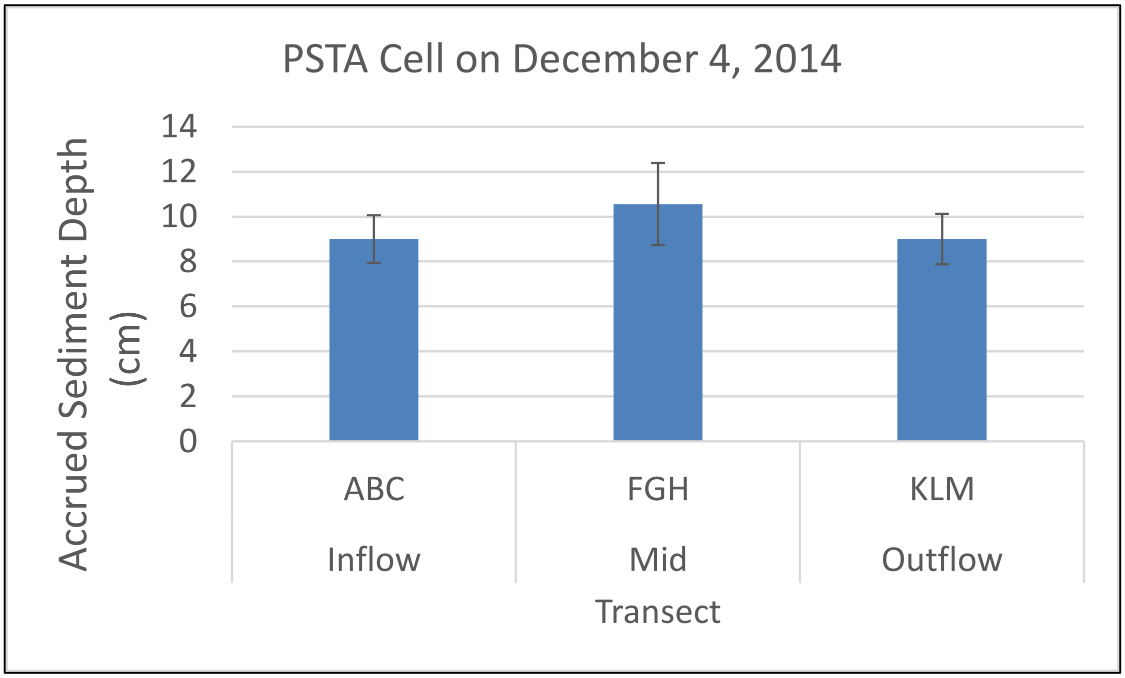

Figure 5. Average depth of newly-accrued sediment in the PSTA Cell on December 4, 2014, as determined by triplicate measurements at each of 3 stations along each of three transects within each region. The error bars denote standard error around average values for the nine stations in each region.

Spatial Variability in the PSTA Cell

The interpolated maps of accrual depth highlight isolated locations with deeper accumulation of sediment material (Figure 6). These areas of deeper material were found throughout the wetland, and were not consistent across the three events. It remains unclear whether movement of bulk sediments may be contributing to these temporal differences in sediment depths.

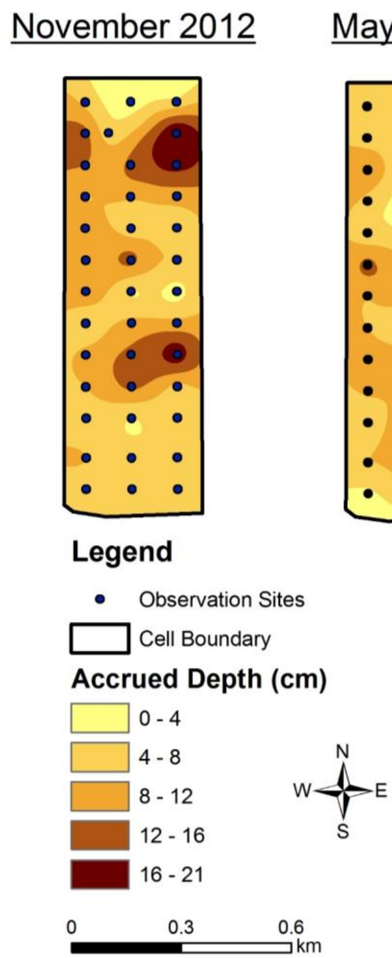

Figure 6. Spatial variation in the depth of the accrued sediment layer in the STA-3/4 PSTA Cell, based on field surveys on three dates of 13 internal transects, each with three stations, where the accrued depth was measured.

Sediment Depths Upstream and Downstream of Vegetated Berms

Across all three dates, a slightly higher mean accrued sediment depth was observed for compartments downstream of the berms where vegetation was removed, compared with those downstream of vegetated berms (Figure 7). Differences between the two categories were small relative to the standard error across sites in each category. However, the difference between categories was consistent across all three events. These results are consistent with the vegetated berms providing stability to the accrued sediment material.

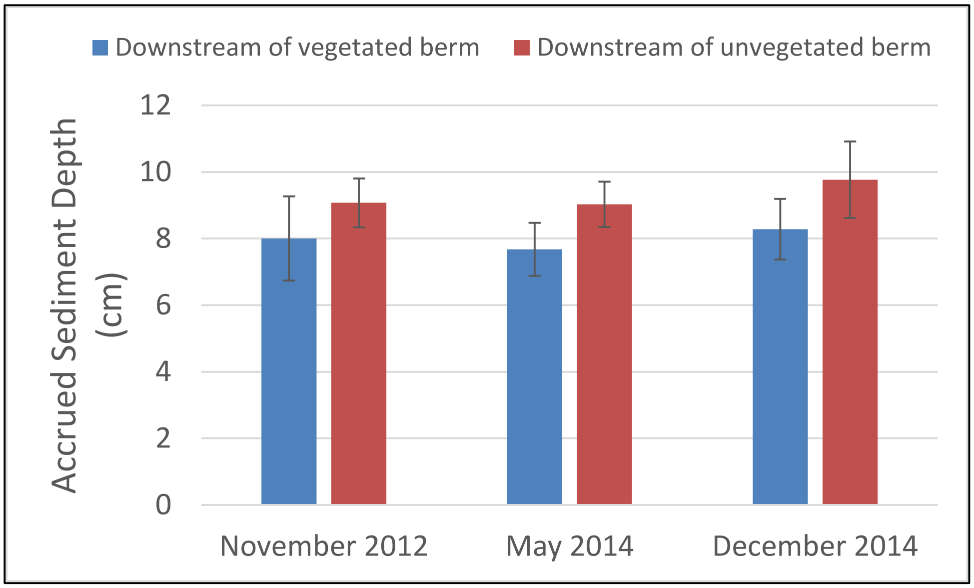

Figure 7. Comparison of accrued sediment depths (mean ± S.E.) for transects downstream of vegetated and unvegetated berms.

Factors that Contribute to Variability in Total Soil Depth Measurements

The limerock below the accrued sediment layer is an uneven surface that contains cavities filled with remnant muck and/or newly-accrued marl sediments. This presents a challenge when quantifying the total soil depth across a large area. Variation in total soil depth was sufficiently high to caution against inferring total soil thickness from a small number of measurements. Nevertheless, local variation was typically less than the variation observed over time for a given transect, or between stations along a given transect (Figure 8). The standard errors around triplicate measurements of total soil depth taken on December 3, 2104 were <4 cm, and often < 2 cm. By contrast, variation between stations along transects was greater, with standard errors as high as 8 cm observed along the C transect. Variation over time was greatest along the E transect (Figure 8). Thus, it appears an increased density of measurements may not improve the accuracy of our cell-wide total soil depth estimates. Rather, the array of 39 measurements taken along 13 transects appears to sufficiently captured the variation in sediment depths within the cell.

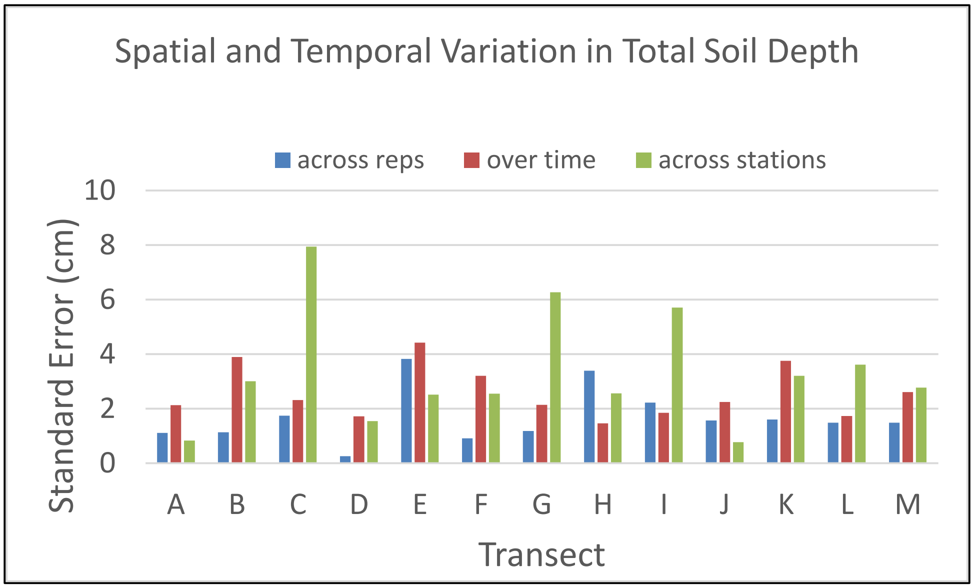

Figure 8. Standard error in replicate measurements of total soil depth, as determined across replicate measurements (within 5 m of one another) performed on the same day (December 4, 2014), over time (variation in transect average values across six dates) or across stations (variation in temporally-averaged values for 3 stations along each transect).

Summary

The PSTA Cell contained an average of approximately 9 cm of accrued sediment in December 2014, with values ranging from 3 to 19 cm. There is no indication that accrued sediment depth has increased since measurements were initiated in 2012. Despite consistent observations of slightly higher mean accrued sediment depth at locations downstream of unvegetated vs. vegetated berms, the differences were small relative to the spatial variation in measured values. Thus, for some berms the effects of removing vegetation were not reflected in the accrued sediment data.

Further analyses will be conducted using these data sets, including a comparison of accrued depths in the PSTA Cell to that in other STA flow ways (i.e., STA 2 Cell 3), and a comparison of sediment chemical constituents with removal of major ions from the surface water. Additional data is required to more fully describe the existing muck soils associated with internal berms, and address whether that material is substantially different than the accrued sediments found between berms. These comparisons will facilitate a mass P balance for the cell, and contribute to our assessment of the sustainability of the P removal performance of the PSTA Cell as sediments accrue along the flow path. These efforts are ongoing, and additional findings will be provided in a future report.

References

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