Ecological Engineering 111 (2018) 69–77

Contents lists available at ScienceDirect

Ecological Engineering

journal homepage: www.elsevier.com/locate/ecoleng

Effects of short-duration hydraulic pulses on the treatment performance of a periphyton-based treatment wetland

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ARTICLE INFO

Keywords:
Hydraulic loading rate
Hydraulic pulses
Hydraulic residence time
Periphyton-based stormwater treatment area (PSTA)
Phosphorus loading rate
Phosphorus reduction
Stormwater treatment area (STA)

ABSTRACT

The effect of high flows on total phosphorus (TP) removal in a 40-ha periphyton-based stormwater treatment area wetland (PSTA Cell) located in Stormwater Treatment Area (STA)-3/4 was evaluated by subjecting the PSTA Cell to three short-duration (3-day) hydraulic (high-inflow) pulses. The intent was to mimic hydraulic conditions that would be experienced during large storm events should the PSTA concept be implemented throughout the complex of treatment wetlands (STAs) operated by the South Florida Water Management District for Everglades restoration. The average inflow rate to the PSTA Cell during the pulses (1.3–2.0 $m^3\ s^{-1}$) was approximately three to four times higher than under normal operation. The hydraulic loading rates (HLRs) during the pulses (28–43 cm d^{-1}) matched the peak 3-day HLRs observed in STA-3/4 during high inflows associated with storm runoff. Correspondingly, the phosphorus loading rates (PLRs) and hydraulic retention times (HRTs) during the pulses (2.3–6.3 mg $m^{-2}\ d^{-1}$ and 1.4–1.8 days, respectively) were substantially higher and lower, respectively, compared to PLRs and HRTs in the PSTA Cell under normal operation. No reduction in TP removal performance was observed in the PSTA Cell during the pulses, and there was no indication that post-pulse outflow TP concentrations increased compared to pre-pulse levels in response to the pulse events. The short-term increase in hydraulic and TP loads during this study did not compromise the treatment efficacy of the PSTA Cell. If implementable in a cost-effective manner in the STAs, the PSTA concept could be part of a treatment strategy that achieves TP effluent limits mandated for these wetlands.

1. Introduction

The Florida Everglades is a vast oligotrophic freshwater wetland that supports a variety of habitat types and dominates the landscape of South Florida (Lodge, 1994). This unique ecosystem is of immense national and international importance (Maltby and Dugan, 1994). Agricultural and urban development has reduced the current size of the Everglades (~960,000 ha) to only 50 percent of its original extent. In addition, portions of the Everglades have experienced eutrophication, primarily due to the inflow of phosphorus (P)-rich runoff from the 283,000-ha Everglades Agricultural Area (EAA) (Davis, 1994; Lodge, 1994). The Everglades stormwater treatment areas (STAs) are five large man-made treatment wetlands that are integral components of State and Federal efforts to protect what remains of the historical Everglades ecosystem (Chimney and Goforth, 2001; Sklar et al., 2005). The STAs are operated by the South Florida Water Management District (District or SFWMD) and currently encompass 23,000 ha of wetted surface area. Each STA is subdivided by internal levees and water control structures into "treatment cells" arranged in "flow-ways" that convey water from inlet to outlet via gravity flow. Because the Everglades is P-limited (Davis, 1994), the primary function of the STAs is to reduce the total P (TP) concentration in surface runoff to levels that protect the downstream Everglades, which has water-column TP concentrations that approach ultra-oligotrophic levels. Accordingly, the STAs have stringent performance requirements mandated by operating permits; STA annual flow-weighted mean (FWM) effluent TP concentrations by 2025 cannot exceed 19 μg L^{-1} in any single year or exceed 13 μg L^{-1} in more than 3 years within a 5-year period (Julian,2017).

The vegetation in pristine areas of the Everglades is dominated by periphyton mats interspersed with sparse macrophytes. Highly productive periphyton communities found in P-limited systems like the Everglades have been linked to increased uptake efficiency and rapid recycling of nutrients due to the close association of autotrophic and heterotrophic microbial components (Wetzel, 1996) capable of reducing water-column TP levels (e.g., Gaiser et al., 2006; Gottlieb et al., 2006). The efficacy of using treatment wetlands managed for sparse emergent macrophytes and abundant periphyton has been investigated by the District and others using a variety of test platforms (Chimney

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https://doi.org/10.1016/j.ecoleng.2017.11.004
Received 27 June 2017; Received in revised form 8 November 2017; Accepted 10 November 2017
Available online 05 December 2017
0925-8574/ Published by Elsevier B.V.

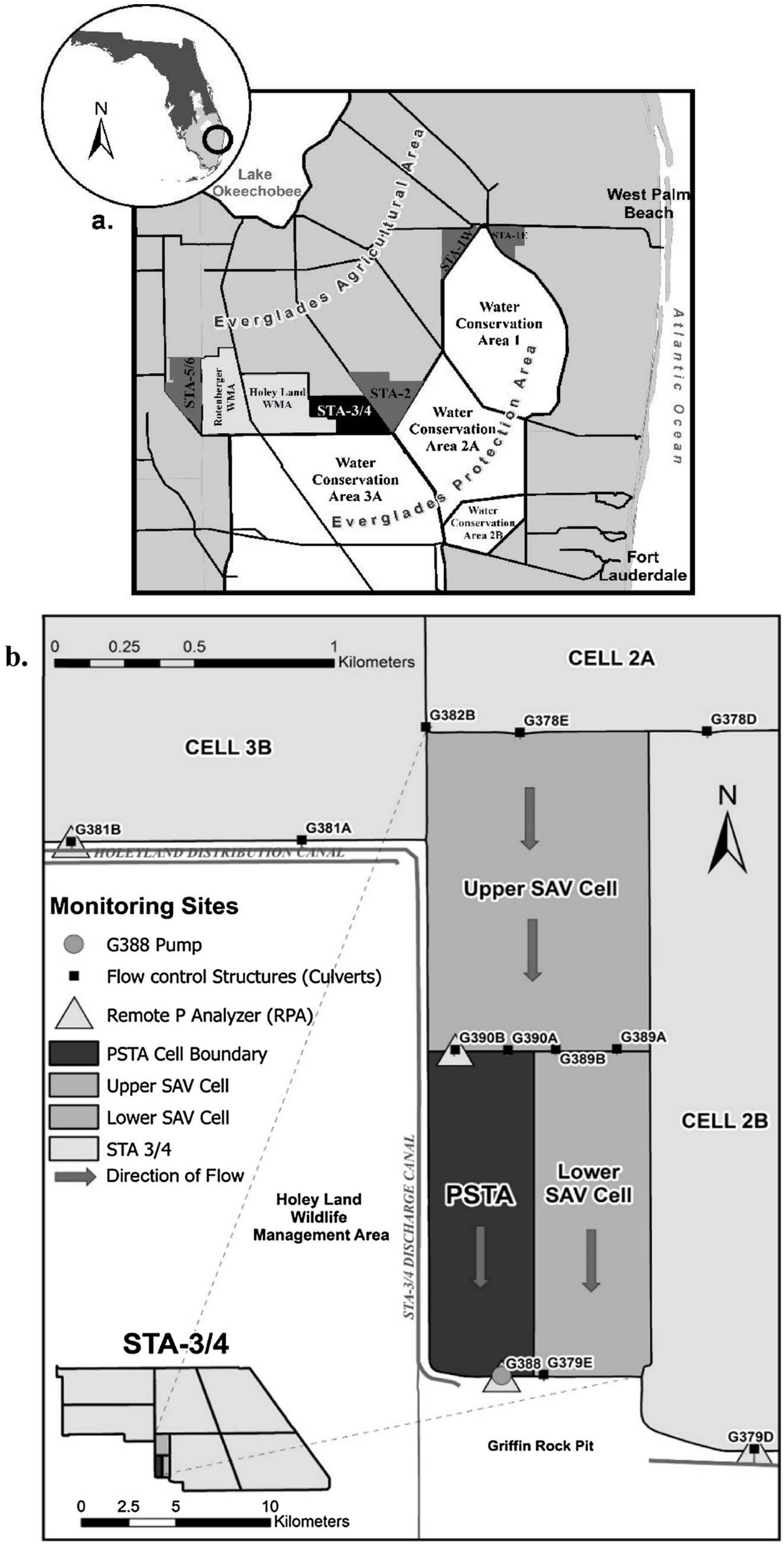

Fig. 1. Location of (a) STA-3/4 in Palm Beach County, FL and (b) the PSTA Project showing the inflow (G-390A and B) and outflow (G-388) water control structures in the PSTA Cell.

et al., 2000; Bays et al., 2001; Kadlec and Walker, 2003; DeBusk et al., 2004; Goforth et al., 2005; Gu and Dreschel, 2008; ANAMAR/WSI, 2011). Several test platforms also supported dense beds of submerged aquatic vegetation (SAV); the District refers to this wetland type (i.e., abundant periphyton with or without SAV and sparse emergent macrophytes with the native soil removed or covered with limestone) as a “periphyton-based stormwater treatment area” (PSTA). PSTA cells are suited for treating water with relatively low inflow TP concentrations