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Simulating water table response to proposed changes in surface water management in the C-111 agricultural basin of south Florida

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ABSTRACT

As part of an effort to restore the hydrology of Everglades National Park (ENP), incremental raises in canal stage are proposed along a major canal draining south Florida called C-111, which separates ENP from agricultural lands. The study purpose was to use monitoring and modeling to investigate the effect of the proposed incremental raises in canal stage on water table elevation in agricultural lands. The objectives were to: (1) develop a MODFLOW based model for simulating groundwater flow within the study area, (2) apply the developed model to determine if the proposed changes in canal stage result in significant changes in water table elevation, root zone saturation or groundwater flooding and (3) assess aquifer response to large rainfall events. Results indicate the developed model was able to reproduce measured water table elevation with an average Nash–Sutcliffe >0.9 and Root Mean Square Error <0.05 m. The model predicted that incremental raises in canal stage resulted in significant differences ($p < 0.05$) in water table elevation. Increases in canal stage of 9 and 12 cm resulted in occasional root zone saturation of low elevation sites. The model was able to mimic the rise and fall of the water table pre and post Tropical Storm Isaac of August 2012. The model also predicted that lowering canal stage at least 48 h prior to large storm (>2 year return period storm), reduced water table intrusion into the root zone. We conclude that the impact of operational changes in canal stage management on root zone saturation and groundwater flooding depended on micro-topography within the field and depth of storm events. The findings of this study can be used in fine tuning canal stage operations to minimize root zone saturation and groundwater flooding of agricultural fields while maximizing environmental benefits through increased water flow in the natural wetland areas. This study also highlights the benefit of detailed field scale simulations.

1. Introduction

The C-111 canal constructed in 1966 is the southernmost canal of the central and south Florida canal system and serves a 259 square-kilometer basin. The primary function of the C-111 canal system is to provide flood protection and drainage for agricultural areas along the eastern boundary of Everglades National Park (ENP). Taylor Slough is a natural drainage feature of the Everglades that empties its fresh water into Florida Bay (Fig. 1). Past dredging of the C-111 canal redirected water flow, causing water to flow east from ENP into C-111 (Fig. 1). This resulted in reduced flows in Taylor Slough which impacted water quality, fisheries and ecology of Florida Bay (U.S. Army Corps of Engineers, and South Florida Water Management District, 2000). The re-direction of water flows to the east results in approximately 6.4 million cubic meters of water a day to be removed from the Taylor Slough system (US Army Corps of Engineers, 2009).

To address some of the unintended consequences of the canal system, hydrological modifications are occurring in south Florida as part of the Comprehensive Everglades Restoration Plan (CERP), which has the overall goal of restoring the natural ecosystem that was negatively impacted by an extensive canal network originally constructed to allow for development and provide flood protection (U.S. Geological and Survey, 1999). One of the 68 components of the CERP is the C-111 spreader canal project (U.S. Army Corps of Engineers, and South Florida Water Management District, 2000). Through operational adjustments and structural modifications, the goal of the C-111 spreader canal project is to restore the

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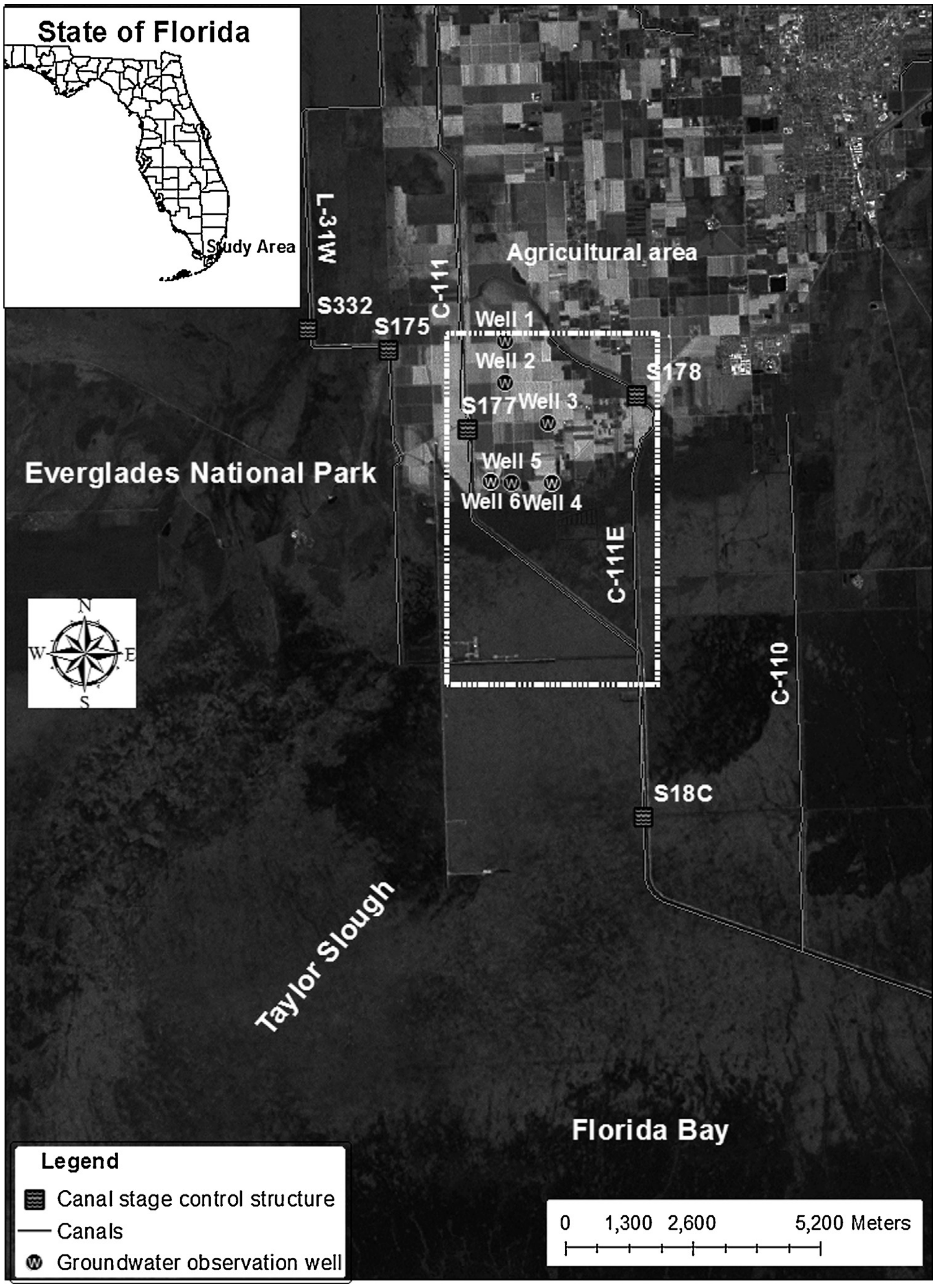

Fig. 1. Study area showing groundwater monitoring sites, agricultural lands adjacent to Everglades National Park (ENP), and canal network within the C-111 basin of south Miami-Dade County, Florida and the modeled area is enclosed in the red box.

quantity, timing and distribution of water delivered to Florida Bay via Taylor Slough to levels as near as possible to pre-drainage conditions, while maintaining flood protection for nearby agricultural lands. In addition, there is a goal to restore hydroperiods that support pre-drainage vegetation patterns in ENP. To achieve the objectives, operational adjustments are proposed that include incrementally raising the canal stage by 3.0 cm per year up to a maximum of 12.0 cm at structure S-18 C which is a gated spillway (Fig. 1).

It is anticipated that raising the C-111 canal stage will affect water table levels in the adjacent agricultural fields (Fig. 1). Earlier research has indicated substantial interaction between the highly permeable Biscayne aquifer and surface water in south Florida canals (Graham et al., 1997; Genereux and Slater, 1999; Lal et al., 2001; Ritter and Muñoz-Carpena, 2006). The hydraulic connection between the Biscayne aquifer and the C-111 canal causes the shallow water table system to fluctuate with respect to changes in canal stage. An increase in water table elevation, due to a rise in canal stage could result in prolonged root zone saturation or temporary groundwater flooding (groundwater flooding occurs in low-lying areas when the water table rises above the land surface, USGS, 2000) which could affect agricultural production in agricultural areas adjacent to ENP. Prolonged saturation of the root zone or short-term groundwater flooding could impact yield potential through impaired root growth caused by anoxia, reduced stomatal conductance and net CO_2 assimilation (Schaffer, 1998). It is