Annex B

Water Quality Model Validation Discussion

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In Reply Refer to:

MEMORANDUM

DATE 10/18/19

TO: Eric Summa, Jacksonville District, USACE

F**ROM**: Robert Johnson, South Florida Natural Resources Center, EVER/NPS

SUBJECT: Support for Application of the Dynamic Model of Stormwater Treatment Areas for the Central Everglades Planning Project, Post Authorization Change Report

Introduction

This memorandum provides support for the application of the Dynamic Model for Stormwater Treatment Areas (DMSTA) as it is used in the design of stormwater treatment areas (STA) within the Everglades. Towards this effort, we supply an abbreviated history of the development of the tool, key recent applications for the Everglades including the Central Everglades Planning Project (CEPP), Post Authorization Change Report (PACR), and some rationale for STA performance divergence from STA design in the past.

History of DMSTA

The development of DMSTA dates back to 1995 and advanced over a series of improving models with the aim of providing insight for multiple STA design alternatives by engineering professionals without the requirement of site-specific calibration data (Walker and Kadlec 2011). These models, briefly covered here, rely on a simple mass-balance to simulate phosphorus (P) storage and cycling processes along P gradients in STAs and Everglades marshes. These model stages include: Steady-State STA Design Model; DMSTA; and DMSTA2. The models are based on unique combinations for P storage compartments (water column, biota, and soil) and flux among these compartments. The models reflect P storage and net fluxes per unit of marsh with one-dimensional hydraulics to represent sheetflow along marsh or STA gradients. The treatment flow paths within the STAs were divided into treatment cells connected in series or parallel and are designed in Microsoft Excel spreadsheet software.

Steady-State STA Design Model (STADM). In 1995, this model was used to design 40,452 acres of STAs for processing runoff from the 769,742-acre tributary of the Everglades Agriculture Area (EAA) and contributing adjacent areas, prior to delivery to the Everglades Protection Area (EPA; Burns and McDonnell 1994). The treatment phosphorus outflow target for this design was 50 $\mu g\ L^{-1}$.

The STADM considered four P storage compartments: one water column and three P flux compartments (Walker and Kadlec 2011). Flux compartments consisted of inflow, outflow, and net removal. Using these compartments plus input terms to include inflow volumes and loads, flow-path width, and atmospheric deposition, STADM simulated long-term average surface water P gradients. A lower bound on the P concentration was applied for the initial design of STA-3/4. Optimization was based on experience and knowledge acquired through monitoring for the 50-$\mu g\ L^{-1}$ STA phosphorus

target. This information provided a technical basis for expanding the modeling tool and STAs to reach lower P concentrations.

The model assumed the average net P removal rate was proportional to average water column P concentration and the net settling rate (10.2±1.4 m yr^{-1}) was calibrated to peat accretion observed in Water Conservation Area 2A (Area 2A) marsh. Calibrations incorporated inflow, water depth, hydraulics, and vegetation type variability. The result was that STA design assumed similar vegetation and P cycling processes observed in Area 2A.

Dynamic Model for Stormwater Treatment Areas. In 2003, the Dynamic Model for Stormwater Treatment Areas (DMSTA) was completed for designing STAs with the change in the outflow P target from the original 50 $\mu g\ L^{-1}$ to 10 $\mu g\ L^{-1}$. This version of the model was used in initial feasibility study designs for STA designs. Conceptually, this change in targets resulted in the STAs being required to operate within limited ranges for inflow P concentrations and loads (Walker and Kadlec 2011). Further, modifications to handle pulsed basin runoff required more constraints on vegetation types and water depth management. Thus, an additional P storage compartment became necessary to represent labile phosphorus stored in the vegetation and its resulting litter mass. In DMSTA, this P storage compartment regulates P uptake, recycling, and generation of stable P storage in the peat. Associated equations have been calibrated to various emergent and submerged vegetation types based on data from wetlands and treatment areas within south Florida.

DMSTA also advances STADM's simple sheetflow hydraulics within the STA. Hydraulics in DMSTA incorporate internal simulation with multiple treatment cells in series or parallel with seepage, bypass constraints based on water depth or pump capacity, and outlet hydrologic controls. Treatment objectives are simulated through optimizing cell sizes, configurations, depths, flows, and specific vegetation communities. These controls are then used to generate the most cost-effective designs. Additionally, the model can be stacked with other modeled areas to generate regional network simulation for STAs and reservoirs, driven by 35-year daily flow time-series output from South Florida Water Management District's regional hydrologic models.

Calibration for this version of the model was done using phosphorus data from ~70 treatment cells and wetlands with sizes up to 2,500 acres. Much of the data was generated using experimental tanks and small-scale test cells with differing vegetation types and varying water depths for up to three years. However, a full-scale test facility, the Everglades Nutrient Removal Project, and the Boney Marsh treatment wetland were used as the primary dataset for calibration. Calibration covered periphyton, emergent and submerged vegetation. Validation was performed against the smaller experiment platforms.

DMSTA-2. In 2005, DMSTA was advanced again based on data collected in the operating STAs with full-scale treatment cells and wetlands with dynamic inflows and water depths. This second version of DMSTA (DMSTA-2) included calibrations for emergent, submerged, periphyton, mixed vegetation wetland types and open-water reservoirs. Unlike the vegetation types, the open-water reservoirs were calibrated based on data from shallow lakes in Florida. This addition of reservoirs was necessary to evaluate regional plans that included storage reservoirs along with the STAs in plan designs. In this version of the model, calibrated vegetation types were applicable under specific depth ranges, velocities, and concentrations.

Validation results for data extending through 2009, show quality simulation of observed data (**Figure 1**). Simulated long-term P flow-weighted outflow concentrations for the STAs show predicted concentrations were generally between 4 and 11% (relative percent difference) of the observed concentrations. Simulation of STA1E had the poorest performance with a 54% (relative percent difference). Predicted loads performed well, capturing the peaks and valleys of the observed loads data for the validation period (April 2005 through September 2009).

DMSTA-2 application

DMSTA-2 has been applied for several feasibility and design studies for additional flows and P loads using STAs coupled with storage reservoirs north and south of Lake Okeechobee. More specifically and more recently, the model has been used to design STA expansion for the Environmental Protection Agency's required Amended Determination (AD), the Florida state's Restoration Strategies (RS) program, Central Everglades Planning Project (CEPP), Western Everglades Restoration Project (WERP), and the Post Authorization Change Report for CEPP. Each of these projects was a multiagency planning effort aimed at improving hydrology and water quality delivered to the Everglades Protection Area. Below we discuss the application of DMSTA-2 for several of these projects.

Environmental Protection Agency's Amended Determination. The United States Environmental Protection Agency (USEPA) was directed by the United States District Court, Southern District of Florida through the 2010 Order to correct deficiencies in the USEPA's December 2009 Determination and to carry out their mandatory duties under the Clean Water Act of achieving water quality standards for the Everglades Protection Area (USEPA 2010a). This 2010 Order directed the USEPA to issue an Amended Determination (AD). The AD was supposed to direct Florida State on key measures to remedy water quality issues through the establishment of scientifically sound Water Quality Based Effluent Limits (WQBEL) in the shortest time possible. DMSTA-2 was used to design STA expansions aimed at achieving the WQBELs for the five STAs (USEPA 2010b). Overall, to meet the goals of the AD, about 42,000 acres of additional land for STAs was needed across the system to protect the Everglades Protection Area. The effective treatment area for this land was 37,600 acres, the rest was for levees, berms, and canals. The treatment features generated by DMSTA-2 modeling included STAs and a new feature termed flow-equalization basins (FEBs). These FEBs required less internal management, but provide unique benefits to treatment when coupled with STAs to include: P removal, reducing short-term pulse flows to the STAs, and providing limited water when the regional system is dry and the STAs need water.

This set of remedies was delivered to the judge for this case, who allowed the state of Florida to propose an alternative suite of features that were predicted to achieve the WQBEL developed by the USEPA. This project is presently term Restoration Strategies (RS) and DMSTA-2 was used for STA design/expansion.

State of Florida's Restoration Strategies (RS). In the Consent Order (OGC File No. 12-1148) between the state of Florida Department of Environmental Protection and South Florida Water Management District (District), the court ordered the District to implement a suite of water quality remedies to address issues raised in the 2010 Order against the USEPA. This included establishing dates to meet compliance with the WQBEL developed in the USEPA's Amended Determination and designing treatment features to meet the associated numeric water quality criteria.

DMSTA-2 was used to design the RS water quality treatment features. The result was the requirement for STA expansion by 6,500 acres, plus the addition of a deep FEB (reservoir like) and shallow FEBs to process 45,000, 54,000 and, 11,000 acre-ft of EAA runoff per year, prior to delivery to the STAs. Though the District was responsible for design of these features, they consulted heavily with the originators of DMSTA-2. The resulting features were reviewed at a multiagency scale and all parties agreed to the modeling results, which included safety factors to address remaining uncertainties expressed for the modeling results.

CEPP Post Authorization Change Report (PACR). The District, the local sponsor for the authorized CEPP plan, prepared the PACR to increase the amount of water storage and treatment in the CEPP plan (SFWMD 2018). This includes the incorporation of new water in the Project Partnership Agreement and improvements in water conveyance for several major canals moving water north to south through the Everglades. The major aim here is to reduce harmful discharges from Lake Okeechobee to the northern estuaries (Caloosahatchee to the west and St. Lucie to the west). The reduction of these discharges results in the necessity to move water south through the Everglades. To accomplish this, the PACR promotes a deep surface reservoir and associated treatment. The modeling for this effort was performed by the District, and the District sought input on the water quality modeling from the Department of Interior (DOI) and their consultants, experts on STAs design and the designers of DMSTA-2.

Results from the application of DMSTA-2 required the construction of an STA to treat water runoff from the reservoir prior to delivery to the Everglades Protection Area. Several alternative STA configurations were evaluated for differing levels of water storage and delivery. The tentatively selected plan resulted in a 240,000 ac-ft reservoir with a 6,500-acre STA. A number of concerns were raised by DOI and associated consultants (e.g., settling rates used for the reservoir, amount of untreated bypass not being incorporated into compliance estimations for the WQBEL, lack of safety factors to address uncertainties associated with STA design, etc.). These concerns for the most part were alleviated with further modeling leading to the finalized selected plan.

<u>DMSTA Testing Against Recent STA-34 Performance Data</u>

Figure 2 compares observed and predicted water depths, outflow volumes, loads, and concentrations for STA-34 in Water Years 2008-2018. Results are shown for 30-day, 360-day, and cumulative average time scales. These simulations utilize the same model parameters that were used in the Restoration Strategies and PACR design simulations. Agreement is good for all parameters on a cumulative average time scale, which was used as a design basis. As expected, deviations between observed and predicted values are greater on 30-day and 360-day time scales.

The model tends to significantly over-predict outflow loads and concentrations in 2017-2018. While the reasons for the improved performance are unclear, the results indicate that the existing model calibrations provide a conservative basis for designing PACR projects in the Central Basin. Because of similar soils, it is possible that the future EAA STA designed to treat new lake releases under the PACR will have P removal performance similar to that of STA34. This provides some assurance the WQBEL will be achievable if the future flows and loads to the PACR projects are similar to those assumed in the design simulations.

There is considerable uncertainty in future flows and loads due to climatologic variations and trends, as well as other factors. These can be addressed via adaptive management in the future, as guided by operational experience, future monitoring data, and STA research (Restoration Strategies Science Plan). The high storage volume provided by the PACR reservoir will significantly increase operational flexibility for managing the inflow volumes, inflow loads, and vegetation in the STAs. This operational flexibility, as well as future knowledge gained under the Science Plan, will provide performance benefits that are not directly considered in the DMSTA simulations.

Conclusion

In general, DOI fully supports the use of DMSTA-2 in designing the STA associated with the PACR. We do not look at DMSTA-2 as a problem with designing STAs. Instead, given the years of multiagency application of DMSTA-2 to design multiple region scale treatment features (STAs and FEBs), the most recent performance validations on well performing STA flowways, and the fact that vegetation type calibration continue to hold, we fully support the use of DMSTA-2 in planning and designing STAs for the CEPP PACR. Further, recent model validation shows that where DMSTA-2 predictions do not match observed conditions, the predictions are conservative, creating an improved safety factor to better protect the Everglades ecosystem.

For additional information please contact Dr. Donatto Surratt, donatto_surratt@nps.gov, 561-735-6003.

References

Burns and McDonnell, 1994. Everglades protection project conceptual design. Prepared for the South Florida Water Management District. Available at: https://www.sfwmd.gov/sites/default/files/documents/epp%20conceptual%20design.pdf; Last accessed: October 1, 2019

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United State Environmental Protection Agency (USEPA), 2010a. 2010 Amended determination to restore water quality to the Everglades. Available at: https://www.epa.gov/everglades/2010-amended-determination-restore-water-quality-everglades; Last accessed: October 2, 2019

United State Environmental Protection Agency (USEPA), 2010b. Attachment B – Summary of remedies for meeting WQBEL at STA discharges into the Everglades Protection Area. Available at: https://www.epa.gov/sites/production/files/2014-01/documents/attachmentbforad.pdf; Last accessed: October 2, 2019

Walker WW, Kadlec RH, 2011. Modeling phosphorus dynamics in Everglades wetlands and stormwater treatment areas. Critical Reviews in Environmental Science and Technology, v41, p430-446

U.S. Exhibit 2323

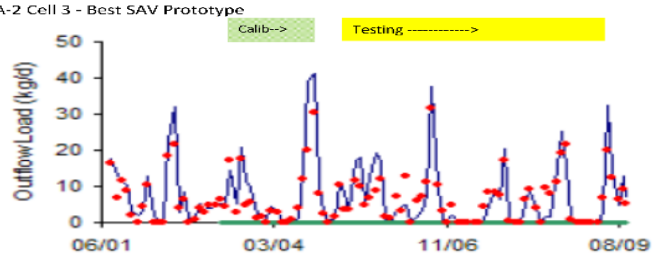
Updated DMSTA Simulations of STA-2 and STA-34

Figures Extracted from DMSTA Website: wwwalker.net/dmstax/track/index.htm
Model = Blue Lines, Data = Red Symbols, 30-day average loads kg/day
Original DMSTA Calibrations based upon data thru March 2005
Simulations Extended thru September 2009 with no change in calibration
Good agreement between observed & predicted Long-term FWMs
Dynamics demonstrate that over-simplified steady-state conc vs. load correlations such as those used by Dr. Goforth are invalid

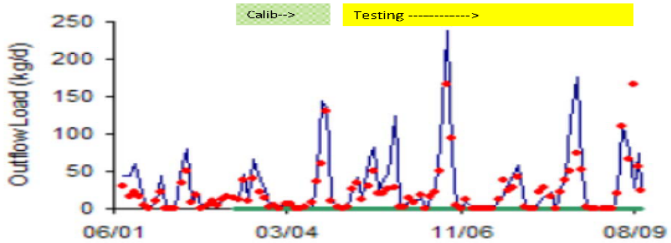
Observed and Predicted Long-Term FWM Outflow Concentrations for Each STA

LTFWM ppb	STA2 C3	STA 2	STA 34	STA 1W	STA 1E	STA 5	STA 6
Observed	18	21	18	67	33	105	23
Predicted	20	20	19	60	19	89	24
Updated Thru	9/09	9/09	9/09	10/07	10/07	10/07	10/07

STA-2 Cell 3 - Best SAV Prototype



STA-2 - Combined Cell 1,2,3 Outflows



STA-34 Combined Outflow

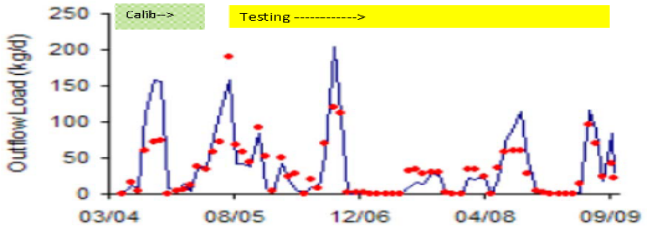


Figure 1. U.S. Exhibit 2323 from Dr. Walker's 2011 expert witness testimony for hearings held by the Special Master in the Moreno Court (U. S. District Court). The hearings were about remedy and STA design.

30-Day Averages 360-Day Averages Cumulative Averages

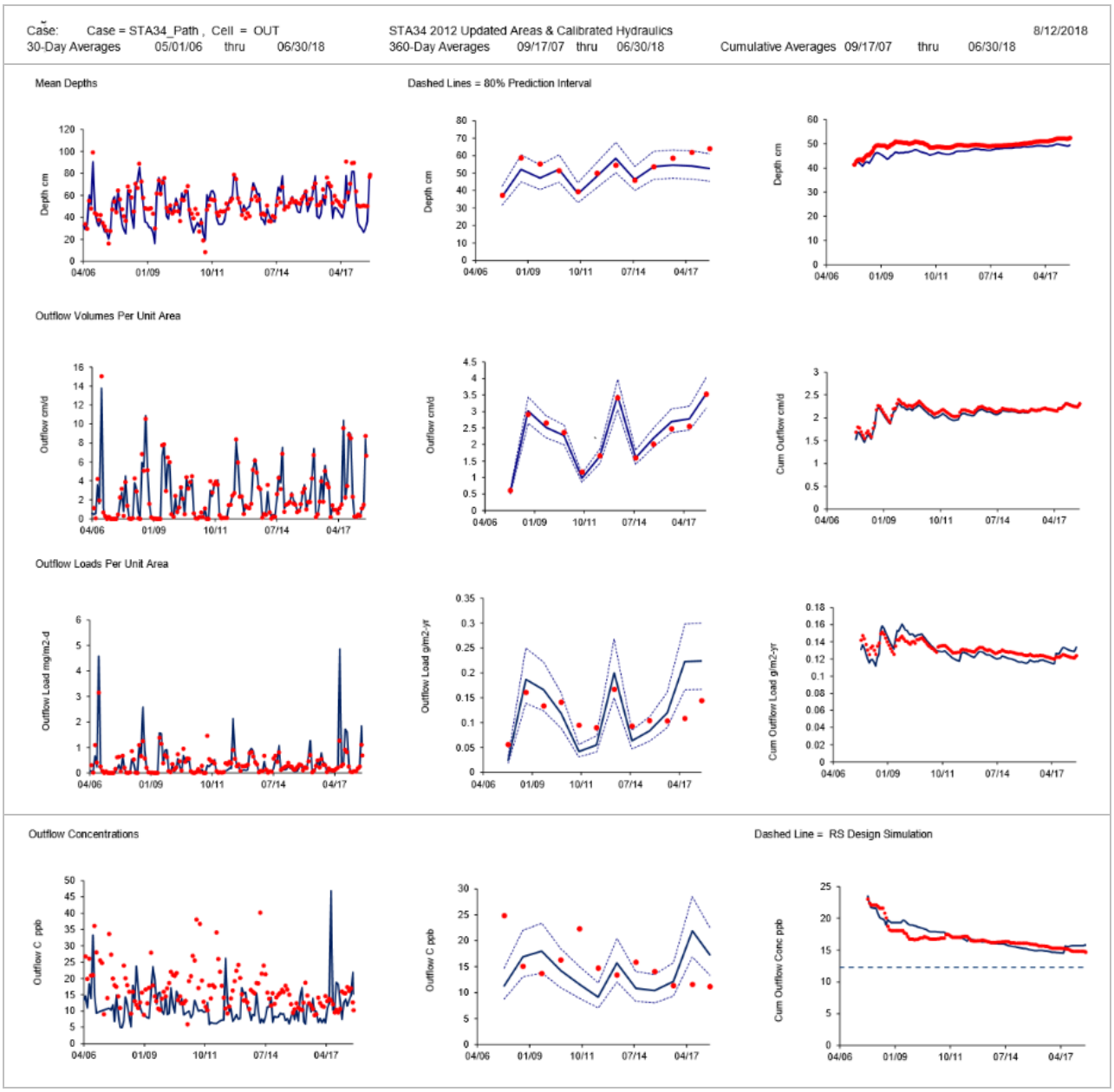


Figure 2. DMSTA Simulations of STA-34 Observed Performance Data, 2008-2018, Red Symbols = Observed, Blue Lines = Prediction Intervals.