ESTIMATION OF LONG-TERM POLLUTANT REMOVAL EFFICIENCIES OF WET RETENTION/DETENTION BASINS USING THE WEANES MODEL

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Abstract: A macro spreadsheet model, WEANES (Wet Pond Annual Efficiency Simulation Model), has been developed to predict the long-term or annual removal efficiencies of wet retention/detention basins. The model uses historical, site-specific, multi-year, rainfall data, usually available from a nearby National Oceanic and Atmospheric Administration (NOAA) climatological station to estimate basin efficiencies which are calculated based on annual mass loads. Other required input parameters are: 1) watershed parameters; drainage area, pervious curve number, directly connected impervious area, and time of concentration, 2) pond parameters; control and overflow elevations, pond side slopes, surface areas at control elevation and pond bottom; 3) outlet structure parameters; 4) pollutant event mean concentrations; and 5) pond loss rate which is defined as the net loss due to evaporation, infiltration and water reuse. The model offers default options for parameters such as pollutant event mean concentrations and pond loss rate. The model can serve as a design, planning, and permitting tool for consulting engineers, planners and government regulators.

Key Words: wet retention/detention basins, best management practices, non-point sources

1. INTRODUCTION

One of Best Management Practices (BMPs) being extensively used for treatment of stormwater is wet retention/detention basins. These basins have become popular as BMPs because they not only provide treatment of contaminated stormwater runoff but also provide insurance against flooding and are aesthetically pleasing. Like most BMPs, a problem confronting the planners and engineers designing wet detention basins, to meet targeted pollution reduction goals, is the lack of accurate data regarding the long-term or annual removal efficiency of these ponds

(Pandit and Youn 2002; Pandit et al. 2002 and 2003). A macro spreadsheet model, WEANES (Wet Pond Annual Efficiency Simulation Model), has been developed to predict the long-term or annual removal efficiencies of wet retention/detention basins. The model uses historical, site-specific, multi-year, rainfall data, usually available from a nearby National Oceanic and Atmospheric Administration (NOAA) climatological station to estimate pond efficiencies. The objective of this paper is to show how the model results were calibrated and validated, and to provide examples showing how WEANES can be used for:

1. **Permitting**: The model should have the ability to determine the long-term removal efficiency of an existing or proposed wet retention/detention pond at any location, and
2. **Pond Design and Planning**: The model should be able to identify key design parameters that most affect the long-term removal efficiency of a proposed wet detention pond and should aid in designing a pond that would meet targeted pollution reduction goals.

2. MODELING PROCESSES USED IN WEANES

WEANES determines the long-term efficiencies of wet detention ponds by modeling the following processes:

1. Converting rainfall hyetographs to inflow hydrographs into the wet pond using the Santa Barbara Urban Hydrograph (SBUH) method,
2. Determining the outflow hydrographs from the weir and the orifice by routing the inflow hydrographs through the wet detention pond using the Level Pool Method,
3. Obtaining the average annual inflow and outflow volumes (from the weir and the orifice) from hydrographs, and
4. Determining the pond efficiency based on annual mass inflow and outflow by the following equation:

$$AARE = \left[\frac{(1-n)(AARV)_{or} + (1-m)(AARV)_{w} + (AARV)_{l}}{(AARV)_{i}} \right] \times 100 \qquad (1)$$

where *AARE* is the average annual removal efficiency of a wet detention pond, with respect to any pollutant, $(AARV)_i$ is the average annual runoff volume entering the pond during storm events, $(AARV)_{or}$ and $(AARV)_w$ are the respective average annual runoff volumes leaving the outflow through the orifice and the weir, $(AARV)_l$ is the net average annual loss due to combined effects of evaporation and groundwater seepage, $n = (AAEMC)_{or}/(AAEMC)_i$, and $m = (AAEMC)_w/(AAEMC)_i$, $(AAEMC)_i$ is the average annual event mean concentration of the pollutant in the inflow pipe at

the basin entrance, and $(AAEMC)_{or}$ and $(AAEMC)_{w}$ are the respective average annual event mean concentrations of the pollutant in the water being discharged from the orifice and the weir.

3. MODEL CALIBRATION AND VALIDATION

3.1 Introduction

WEANES was calibrated and validated for a 56-day period between May 6 through June 30, 2002, using measured data from a pond referred to as the Basin 7 Wet Detention Pond which is located in Palm Bay, Florida and receives runoff from a 307,046 m^2 watershed. The information for the watershed, pond, and outfall structure for the pond were provided by the St. Johns River Water Management District (SJRWMD). The following parameters were also continuously measured at the pond from May 6, 2002 to December 31, 2002, by SJRWMD; inflows to the pond, outflows from the pond, and total suspended solid (TSS) concentrations at the inflow and outflow pipes.

3.2 Calibration Procedure

The calibration was conducted in the following two steps:

- **Step 1 - Adjustment of Side Slopes to get desired treatment volume (TV) and permanent pool volume (PPV)**: The model converts irregular shapes, such as that of the Basin 7 Wet Detention Pond, to a prismatoid shape by adjusting side slopes until the TV and PPV values were exactly equal to the values of the actual pond.
- **Step 2 - Adjustment of DCIA value**: The design engineer supplied DCIA value was changed from 24.54% to 19.63% to provide improved comparisons between the measured and model simulated water levels. The maximum difference between model simulated water levels and the measured water levels was 5%, while the average difference between was 1%.

3.3 Validation Procedure

The model was validated by:

1. Comparing measured and model simulated water levels, and
2. Comparing measured and model simulated monthly TSS removal efficiencies.

The model simulated water levels are compared to the measured water levels for the 184-day validation period between July 1 through December 31, 2002 in Figure 1. The maximum difference between model simulated water levels and the measured water levels was 8%, while the average difference was 3% during the validation period.

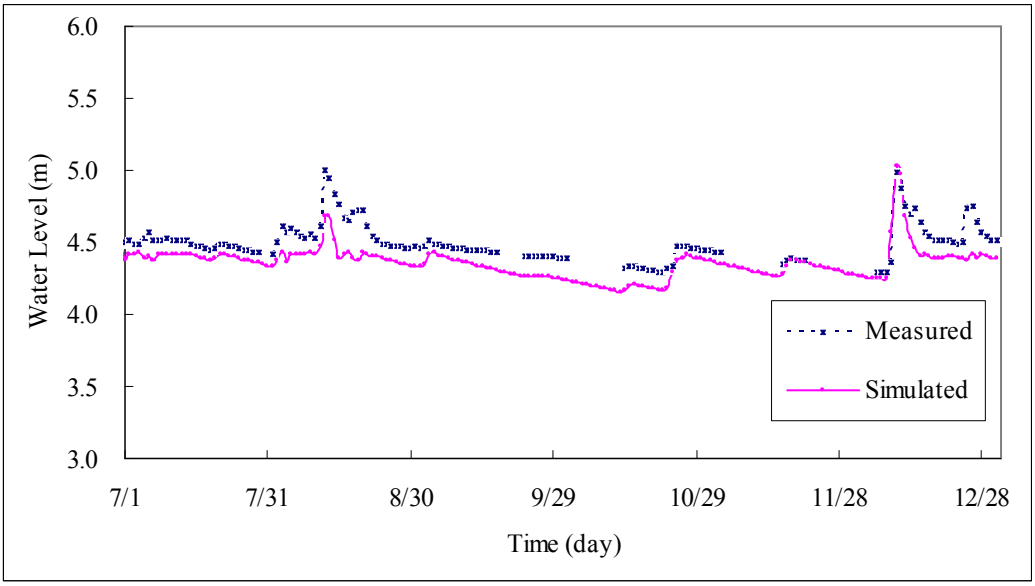

Fig. 1 A Comparison of WEANES Simulated Water Levels with Measured Water Levels for the Basin 7 Wet Detention Pond from July 1, 2002, and December 31, 2002

The model simulated monthly TSS removal efficiencies are compared with the measured monthly TSS removal efficiencies for a 8- month period between May through December 2002 in Figure 2. The largest difference for the model predicted monthly efficiency and the measured monthly efficiency for TSS is 31.8% for the month of September while the lowest difference is

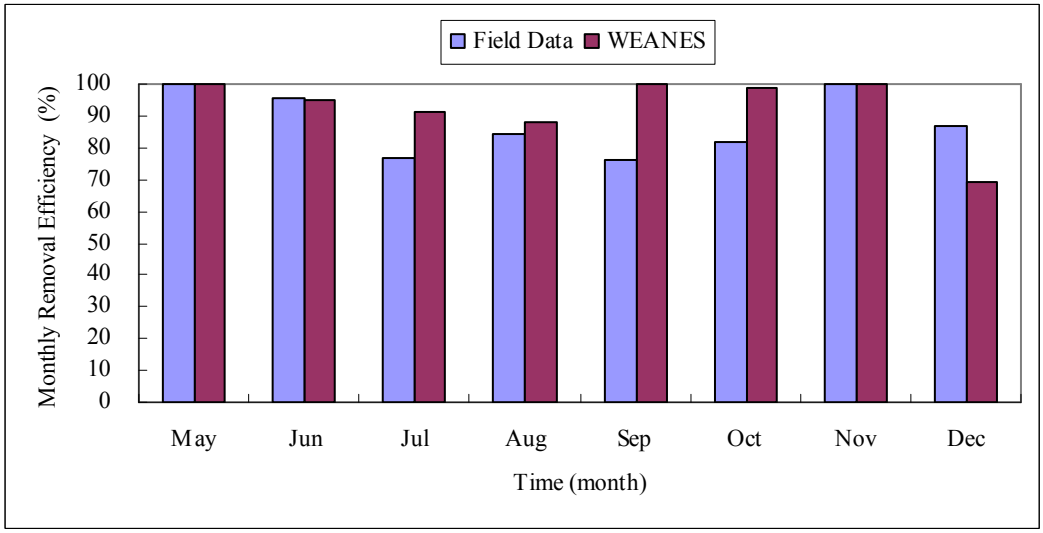

Fig. 2 Comparison of WEANES Simulated TSS Efficiencies with Measured Values for Basin 7 Wet Detention Pond

zero for the month of May when both the model predicted and measured monthly efficiencies are 100%. The model predicted efficiency for the entire 8 month period is within 4.6% of the measured efficiency.

4. CONCLUSION

A macro spreadsheet model, WEANES (Wet Pond Annual Efficiency Simulation Model), has been developed to predict the long-term (multi-year) or average annual removal efficiencies of wet retention/detention basins. The model has the ability to use real, historical, multi-year rainfall data from a National Oceanic and Atmospheric Administration (NOAA) climatological station near the project area to estimate pond removal efficiencies. Moreover, it has been demonstrated that WEANES can also be used to obtain monthly or annual pond removal efficiencies if so desired by the user. As part of the process of calculating long-term pollutant removal efficiencies, WEANES also continuously predicts the water level in the pond, and allows the user to graphically observe the periods when the water levels exceed the control elevation or the overflow elevation. The model can be used for model permitting, and pond design and planning.

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