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Numerical Model Water Quality for Hidalgo County, Texas; Main Drainage System

Jose Orvyl Gonzalez[1], Grimaldo Carrillo[2], Jungseok Ho[3]

[1,2]Research Assistant, [3]Assistant Professor, Department of Civil Engineering, The University of Texas Rio Grande Valley, 1201 West University Drive, Edinburg, Texas, United States of America

Abstract: **Increasing urbanization, water intake, and human water interaction of drainage canals of the Hidalgo County watershed seals the drainage basin and expands floodplains along the canal-side. Incremental use of drainage systems affects the amounts of nutrients that can cause an exposure to residues of agriculture chemicals, water related parasitic diseases, and fecal diseases. Proper water quality management is crucial for pollutant transport detection, estimation of non-point source discharge, and prediction of pollutant discharge at water endpoints. This research seeks to improve the understanding stormwater quality and quantity that is influenced by the frequency of human-water contacts and associated with treatment disposal of drainage water. This study developed one-dimensional water quality transport numerical analysis model, where a stable hydraulic analysis is moderated by fixed weirs as internal boundary conditions to reflect low flow conditions and are then used to construct a water quality analysis model. It estimates changes in temperature, nutrient transport, and flow effects of North Hidalgo County drainage canals. Model simulation results were compared to monthly measurements, an energy budget, nutrient concentration, and flow regime for each stream reach. Project results characterize energy exchange processes at the stream surface and their effect on nutrient biology and transportation. Understanding the physical processes of the canal systems will provide managers with improved information to sustainably manage these ecological complex systems.**

Keywords**: water quality, numerical model, stormwater drainage, nutrient transport, water flow rate.**

I. INTRODUCTION

The extensive modification of landscapes created by increased human population, land development, and agricultural activities contributes to increased disposal of local excess surface waters that creates various issues with water related disease. The Rio Grande Valley, located in South Texas, United States seals the drainage basin and concretization of expanding floodplains of building along the canal-side expanding the runoff water into the drainage canals **[13]**. Storm drain systems were proposed to be designed to convey the 25-year flow to provide conveyance in accordance with the rules for discharge from existing development, as determined by Hidalgo County Mainflood Drainage Systems (HCMDS) as seen in Figure 1. The canals were also proposed to provide detention storage for runoff from all new development, run-off capacities, and flow mitigation **[15]**. Due to South Texas' dependent use of agriculture, there is reasonable suspicion of high nutrient loadings washing into the canal water in a storm event. The land cover and land use changes affect the precipitation and runoff component as impermeable surfaces prevent soils from naturally regulating the flow of pollutants in the drainage basin; increasing runoff velocity flushes pollutants faster away from their point source **[7]**. In the case of dry seasons and the fact that the land slope of the area is small, low flow is dominant throughout the year, which leaves stagnant waters within the canals raising the possibility that with high nutrient loadings from the surrounding agricultural area, nutrient loading can cause bacterial population to increase within the sections **[1]**

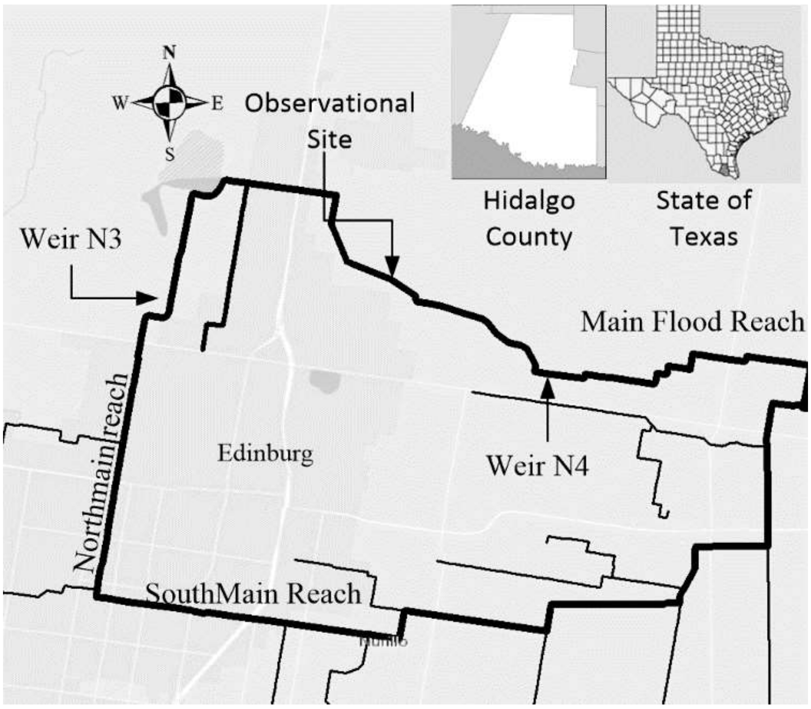

Fig. 1. Modeling Reach of Hidalgo County Drainage System Canal System

Considering that the HCMDS is located in the centerfold of a transitional state from rural to urban, various considerations have to be done about the qualitative status of the water impacted by the population. Heavy qualitative impacts to the Hidalgo County waterways currently cannot be seen, but historical assessments to the previously drainage ditch of the Arroyo Colorado. Berthold (2012) reported that the Arroyo Colorado have found elevated fecal coliform densities, low dissolved oxygen concentrations, and sediment toxicity within the drainage water. The Texas Department of Health had issued in 2011 fish consumption advisories for the Arroyo Colorado above tidal due to elevated toxaphene, 1,1-Dichloro-2,2-bis(p-chlorophenyl) ethylene (DDE) a breakdown product of DDT insecticide, and chlordane concentrations of polychlorinated biphenyl pesticide extenders in the fish tissue; general use of water was not recommended due to the elevated chloride, sulfate, and total dissolved solids concentrations **[3]**.

With the incremental use of waterway systems, qualitative properties within the water could become tainted with various harmful residuals. Bacteria growth within the water can be attributed to the activities of humans and from increment of animal waste in the surrounding areas. A source of waste could come in by sewer overflows or malfunctions, leaking septic tanks, various storm events that flush in animal waste, among other factors **[6]**. For locations situated where high agricultural use of land and growing populations, which create impervious land that flushes pollutants, factors of waste seeping into the water, like those mentioned, are highly probable.

Management practices, nutrient management planning, and managing land in the drainage within the systems are in need of predictive numerical model that help assess the qualitative situation of their drainage canals. With a numeric water quality model, concentrations or levels of a pollutant that, if achieved, provide an way to expect, design, and prevent water ways from depleting both the complex ecosystem of the water and protect those whom are in contact with them. The purpose of this study is to develop predictive numerical models to assist in identifying and evaluating operational and structural measures for improving water quality in the HCMDS.

Hidalgo County suffered from a lack of local drainage canals and was in need of multiple and the county recognized that it was in need for construction of extensive drainage systems to collect and dispose local excess surface waters even with the Federal Rio Grande floodway System **[15]**. The low velocity of these overland flows does not have sufficient force to cause substantial erosion, and consequently there are not many natural surface drainage canals developed. With a typical land slope of one foot per 1,500 feet and drain ditch bottom slopes of 1 foot per mile are common **[13]**. The flows in the canals also experience excessive backwater because of restrictive culverts crossing under roadways. Overall, the water remains in the canals for prolonged periods of time due to the extremely low velocity of the flow **[12]**. The drainage canals are trapezoidal shaped, with extends surrounded by thick vegetation if negated. Flow sections monitored were section near concrete weirs that extended throughout the reach of study.

II. MODELING PLAN

Development of a numerical model would build fundamental insights about the effect of a critical hydraulic control on nutrient concentrations, where the critical flow would be a dominant feature to study as the flow of the water of a normal condition would not flush out the concentrations of nutrients to study the effect of nutrient transportation. Under the critical flows, nutrient concentrations would not vary drastically as their effect of sink/advection, advection would stabilize compared to a high velocity mass transportation, and would be influenced by the surrounding area and atmospheric conditions **[9].** The interrelationship between the nutrient concentration, dispersion, water temperature, and time affect both the nutrient transportation and biological make-up of the water, as the relationship between nitrogen, orthophosphate and algae concentrations, as algae can multiply quickly in waterways with an overabundance of nitrogen and orthophosphate **[4]**. Using a one-dimensional river analysis program of Hydraulic Engineering Center River Analysis System (HEC-RAS), developed by the US Department of Defense, Army Corps of Engineers, a numerical model can compute steady and unsteady flow hydraulics, heat budget, water sink/advection, and nutrient dispersion to use as a tool to study the transportation of nutrients within the reach. The model solves the one-dimensional advection-dispersion equation water quality model implementing the principle of mass conservation using a control volume approach with a fully implemented heat energy budget **[10]**. By introducing the nutrient parameters into the system, the model takes into account rate constants for physical and chemical reactions that control the sours and sink in advection dispersion as seen in equation 1:

$$\frac{\partial}{\partial t}(V\phi) = -\frac{\partial}{\partial x}(Q\phi)\Delta x + \frac{\partial}{\partial x}\left(\Gamma A \frac{\partial \phi}{\partial x}\right)\Delta x \pm S \qquad \text{(eq1)}$$

Where V is the volume of the water (m^3), ϕ is water temperature (C) or concentration (kg/m^3), Q is flow (m^3/s), Γ is independently defined dispersion coefficient (m$^{2/}$ s), A is cross-sectional area (m^2), and S is source and sinks (kg/s).

The equation requires that if there is a source of mass at a location, the mass being introduced must be accounted for. All to which the nutrients are subjectable to the flow present at simulated time and heavily influenced by temperature changes within the water that affect their chemical properties. The nutrient computation is designed to conduct aquatic water quality computation with simplified processes and minimum state variables. It simulates carbonaceous biological oxygen demand (CBOD), dissolved oxygen (DO), amplified nitrogen and phosphorus cycles, which resulted in organic nitrogen (OrgN), ammonia (NH4), nitrate (NO2), nitrite (NO3), organic phosphorus (OrgP), and total inorganic phosphorus (PO4), and algae (Alg) and benthic algae biomass as additional state variables as seen on Table 1. The model simulated Hidalgo County's drainage systems critical inflow density distribution, and overall exchange of nutrients stimulated by the heat budget to study, compare, and calculate nutrient dispersion/distribution, spatial and temporal trends in modeled water quality constituents.

TABLE 1. Monitored nutrient parameters used in the model

Nutrient (mg/L)	DO	NO2	NO3	NH4	PO4	TP	OrgP	Alg
Weir N1	7.28	1.65	0.097	0.104	1.5	3.8	2.3	0.84
Weir N2	9.11	1.55	0.109	0.109	1.6	4.2	2.6	1.84
Weir N3	8.01	1.63	0.112	0.146	1.5	4.0	2.5	1.97
Weir N4	8.61	1.70	0.109	0.157	1.8	4.4	2.6	2.72
Weir N5	10.65	1.47	0.093	0.080	1.5	4.2	2.7	1.72
Weir N6	9.95	1.40	0.101	0.062	1.7	4.8	3.1	1.96

A. Modeling flows:

To implement the model's hydraulics, we had to identify sections along the canal that would provide the most amount of flow information. Various weir sections were readily available around the Weir N3 sections of the study as seen in Figure 1, where its location indicated a critical flow after various trips to the site, where flow was low enough that stagnant water upstream was to be identified at times. The sections that were monitored were upper-reach section of reach, Weir N3; lowest section, Weir N4; and section in-between Weir N3-Weir N4 located 4.5 km downstream of Weir N3. The critical flow identification was an imperative feature for the study, as the effect of nutrient transportation created allows our study of nutrient concentrations accumulation. The critical flow would allow the model to indicate the accumulation of mass within the water to account for the minimum of nutrient mass at any given time. Using the critical flow, the model can compute the source/sink concentrations of the nutrients throughout the reach and simulate the interlaced effects of nutrients affected by the meteorological influence in the water's heat and its transportation downstream. Capturing the critical flow was composed of using weir structures along the canal to obtain the flow at each section to simulate critical flow. Model results depend on the underlying input data to produce a computational reach network that accurately represents the riffle and pool characteristics. To capture varying water quality from low flow to high flow conditions, water quality data for modeling require planning and data collection for six months. Model input data must be collected in advance to accurately represent the actual conditions of interest. Complete data sets are required to develop a model, and complete reference data sets for selected flow conditions are necessary to calibrate the base model against know conditions.

A creation of one-dimensional quality numerical model will be made to estimate the quality of storm water based on a critical flow and not based on frequency storm events. In comparative events between a frequency and critical flow when it refers to qualitative study, is the effect of flow on nutrient transportation. Rather than flushing away the nutrients from a specific section in a frequency storm event, modeling would for a critical flow would simulate the transportation of nutrients, water temperature changes, and the biological effect in concentrations of nutrients. The model requires canal flow data, which will be obtain by using weirs as internal boundary conditions, over a period of approximately four to five months **[5]**. In the same manner the data required for the quality part of the model will be collected during that same time period. The model extents will cover the entire extent of the Northmain of two weirs into the Main Flood Canal as seen in Figure 1. The decision of using critical flow comes to the extent of focusing in studying normal conditions and not overflows. In the case of overflows, it may carry a wide range of pollutants including sediment, nutrients, pathogens, trash and debris, petroleum hydrocarbons, and synthetic organics, such as pesticides into other waterways **[6]**. The reference condition could be based on data collected at downstream conditions, as model simulated the conditions, to determine the impact of nutrients by flow, change in temperature, and collective biological factors. Water quality in the Hidalgo County drainage canals has not been extensively monitored, potentially limiting application of a reference condition approach for minimal criteria development.

B. Nutrient transportation:

It is important to factor the evaluation and to quantify extent of nutrient loadings into the water placed in by the surrounding area, as most of the runoff comes from the agricultural and carried off by drainage ditches **[8]**. Quantifying nutrient loadings from drainage ditches is limited to a few measurements that convey the surrounding water. The water quality sampling of the study vary in such nutrients as the nitrogen species; ammonia-nitrogen, nitrite and nitrate-nitrogen, total and dissolved phosphorus, dissolved oxygen, algae, and other water quality parameters.

Using a monthly input data, small time-step, the model simulates the atmospheric warm/cold surface layer that affects both water temperature. Simulated results will assess the kinetic processes and corresponding time rates of change of the concentration due to biochemical reactions and its dispersion factor. The kinetic process will be determined by the change in water temperature created by the heat budget which includes solar radiation, wind mixing, air temperature, cloud dispersion of solar radiation, humidity and atmospheric pressure.

Using the critical flow that would represent the minimal flow where water won't remain stagnant and enough for inflow and outflow of water to run through different sections of the canal, simulations of water mass transportation were modeled to compare the nutrient mass transport to that of surveyed results to initially obtain a control quality model. The canal flow samples were collected at weir sections to monitor water quality over the canal reach. Field water quality parameters were monitored by using a multiprobe sonde that displays parameters such as temperature, dissolved oxygen, conductivity, pH, turbidity and salinity. While the nutrients were analyzed by a spectrophotometer an instrument which measures the amount of light of a specified wavelength which passes the nutrients of nitrate, nitrite, organic nitrogen and orthophosphate.

Water was tested for various nutrients were collected from every weir section and in between sections of weirs. Data is based on monitoring of the water quality parameters over the period of six months on a monthly basis at various sites in the North Main and Main Floodway sections of the canal. The following are the parameters: temperature, dissolved oxygen, pH, salinity, turbidity, nitrite nitrogen, dissolved nitrate nitrogen, dissolved organic nitrogen, dissolved ammonium nitrogen, dissolved organic phosphorus, dissolved orthophosphate, carbonaceous biological oxygen demand, and algae. The chemicals were analyzed by equipment Spectrophotometer from the water samples. All of these parameters were collected on surveyed dates and used for modeling, with an indication of measured data, where that information will be used to be review the modeled quality transport in the canal and compared to that of real surveyed results. Water samples were collected at three specific points; Upper-reach section of reach, Weir N3; lowest section, Weir N4; and section in-between Weir N3-Weir N4 located 4.5 km downstream of Weir N3, all of which were tested for their respected nutrient as seen on table 1. Each applied nutrient has a biological impact on the water that relate to the quality of the water as well as their nutrient counterparts.

III. MODEL IMPLEMENTATION

Simulated results were to be conducted between two boundary conditions designated to reflect two weirs sections in the Hidalgo Drainage canal located in the North main region designated weir North 3, or Weir N3, for the inflow; upstream section weir section of the reach and its counterpart of the weir North 4, or Weir N4 for the downstream weir section. Qualitative properties that were to be compared with the computations were obtained and measured in approximately 4.5 km downstream Weir N3 between the Weir N3 and Weir N4 sections as well as before the downstream section the weir 4. Modeling information would only correspond to the Weir N3 section of the canal, so when a computation is made, the nutrient's dispersion, chemical consistency, and concentrations would be only influenced by the Weir N3 section and only compared to the downstream sections.

Cross-sectional information for the drainage canals were obtained from a digital elevation model (DEM) was obtained from the United States Geological Survey for automated GIS (Geographic Information System) and the canals delineations were obtained. Drainage canal sections were obtained and identified to obtain the cross-sectional structure that would be the basis for the geometric files of the reach Weir N3 to Weir N4 and its canal slope.

The model geometry consists of longitudinal segments with vertical layers in each segment obtained by the DEM data. Water surface elevations at each individual segment were to represent the overall distribution of water caused by the critical inflow of the upper-most section at a steady-state condition. During each individual normal profile computation, fundamental hydraulic properties of the flow, wetted area, average velocity, the Froude number for each cross-section are computed. Since the goal of the study is to represent the critical distribution of nutrients, flow conditions would be simulated for three low flows representing the dates that correspond to the date when nutrition concentration was obtained. Water surface elevations were also considered as a validation for the flow; observational water depths were measured approximately 4.5 km downstream of Weir N3 between the reach, where they could be compared to the simulated distribution of water surface elevations.

Water surface elevations were considered as a comparison to not only have the accurate amount of flow volume rate within the canal, but use as an indication of using the correct critical flow within the model. Mean velocities of a uniform flow is assumed to be constant, with the energy lines having the same slopes as the hydraulic graded lines of both upstream and downstream. Using the comparative measured and computed elevations were used as an indicator that the critical flow was correct, as the definition of flow is $Q=H\times B\times V$, where H is water height and B is canal width. Since the width was obtained using DEM, an accurate source, the indicators of velocity and water heights were needed for a comparison of flow calculations.

Canal flow was measured to cover mild to wet conditions for approximately 6 months, where flow variations were modeled to each corresponding date. Known water elevations were recorded, modeled and compared to sites that corresponded at midway sections. There were two methods that could be implemented to determine the flow in a canal, either using a flow rate definition of wetted cross-sectional area multiplied by water velocities from hydraulic structures such as weirs, and used for determination of calculating the flow using the weir equation as shown in Equation 2 (Bengston, 2011).

$$Q = C_w B H^n \quad \text{(eq. 2)}$$

where B = weir width, H = notch water height, C_w = 3.33 (average weir), and n = 3/2, suppressed weir (B=L) conditions: (H/P < 0.33 & H/B < 0.33) where L is canal width; B is weir width; and P is wetted perimeter **[2].**

The only type of input place into the model corresponds to section of Weir N3 as the model calculates both hydrological and nutritional computation in a stepwise matter, meaning that each section below the upper most section corresponds its computation based on the input provided by the Weir N3 section **[10]**. Conditions for a critical flow were general in the study area, not over the heavy rains as to keep for a critical flow at a constant use for the modeling. Essentially the true format of measuring the flow would be to implement the water velocity with the flow area, but considering that water velocities varied as the weir is an obstruction in an open canal flow path, velocities would vary before and after weir locations that might impede an accurate measurement.

As per roughness coefficient (*n*) used in the hydraulic model was provided by Texas Department of Transportation for a descriptive Hidalgo County drainage section of trapezoidal channel with short grass, few weeds to be n = 0.022 to 0.033, using the average of 0.0275 for the model **[14].**

Comparative data of the weir equation to that of the essential use of velocity and area brought in considerations for the use in methodology. The results are represented in Figure 2 validates the use of the right format of weir equation with the similarity in flows by both method vary at a standard deviation of 0.119 m^3/s as an average, knowing this we can proceed to use the weir equation format for flow acquisition.

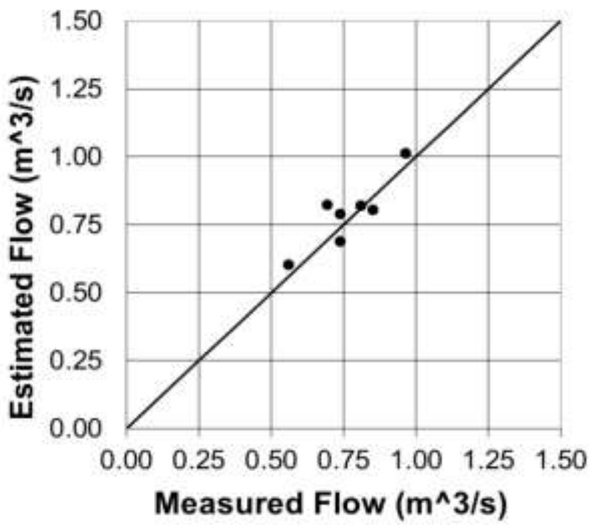

Fig. 2. Comparison of canal flows between estimation and measurement

A. Water quality computational cells:

When the water quality model is created with the initial boundary conditions, water quality cells are initially established as a roughly equally sized lengths exactly between cross section paired stations of the reach. The computational water cells conduct computations in between themselves at various degrees of stepwise time, where the cells' input depends on the output of the previously located upstream cell, to which the computational chain reaction leads up to its original input by the hydraulic boundary condition **[10]**. The variably defined size of the computational cell has an effect on the time step and its computation time, in which case, increment of computational cell merges cross sections under one cell and has an effect of reduction of overall computational time, but reduction of quality computation for the range of cross sections under the cell. While reduction in computational cell specifies more cell per cross section**,** increasing quality computational range, but increasing the time step as there would be more cells to be computed. Once the boundary conditions and water quality cell constituents are dependent on the control of temperature calculation, the model needs to be specified on the range to interpolate results based on the nutrient date information.

B. Meteorological data:

The Hydrologic Engineering Center recommends the use of nearest meteorological station in order to model the water temperature changes over time (USACE, 2010). Weather data for the reach were assembled from a variety of surrounding gauge stations that were obtained online. The information collected provides a general insight about the weather conditions for the model reach for the section of Hidalgo County, where the study section is located. The program requires a set of meteorological data must consist of: atmospheric pressure; air temperature; humidity; solar radiation; wind speed; and cloudiness, to provide the influence of outside sources to the water in net heat flux exchange between the atmosphere and the water. The projected area of heat will be exchange over an interface between the water and the outside atmosphere, the interface is contracted over the surface area of the water or a specific water cell surface area **[10]**

$q_{net} = q_{sw} + q_{atm} - q_b + q_{h-} - q_1$ (Eq. 3)

where: q_{net} = Net heat flux; *qsw* = solar radiation (joules/m^2/sec), q_{atm} = atmospheric longwave radiation (joules/m^2/sec), q_b = back upwelling longwave radiation (joules/m^2/sec), q_h = sensible heat (joules/m^2/sec), q_l = latent heat (joules/m^2/sec) (USACE, 2010)

Atmospheric pressure is a strong function of elevation and varies with local meteorology ((Figure 3). It generally decreases with increasing altitude. The atmospheric pressure is entered as millibars (mb), with a span of three months. Air temperature, shown in Figure 4 and imputed in Celsius, is a measure of the hotness or coldness of the air Humidity, shown in Figure 5, is required input for the water temperature model **[10]**, and was imputed as relative humidity in percentage. Relative humidity is the ratio of moisture in the air to the maximum amount of moisture the air can hold. Solar radiation is the radiation received from the sun and emitted in the spectral wavelengths less than 4 microns. Solar radiation was available from a local weather station. Internal calculations are performed in W/m2. Cloudiness, shown in Figure 6, is the fraction of sky covered with clouds. An increase in cloudiness leads to a decrease in computed solar radiation and an increase in computer down welling longwave radiation. Wind speed, shown in Figure 7, is the measure the wind that is factored in with evaporation of water alongside with pressure. Wind is a necessary parameter for surface flux estimation **[10]**.

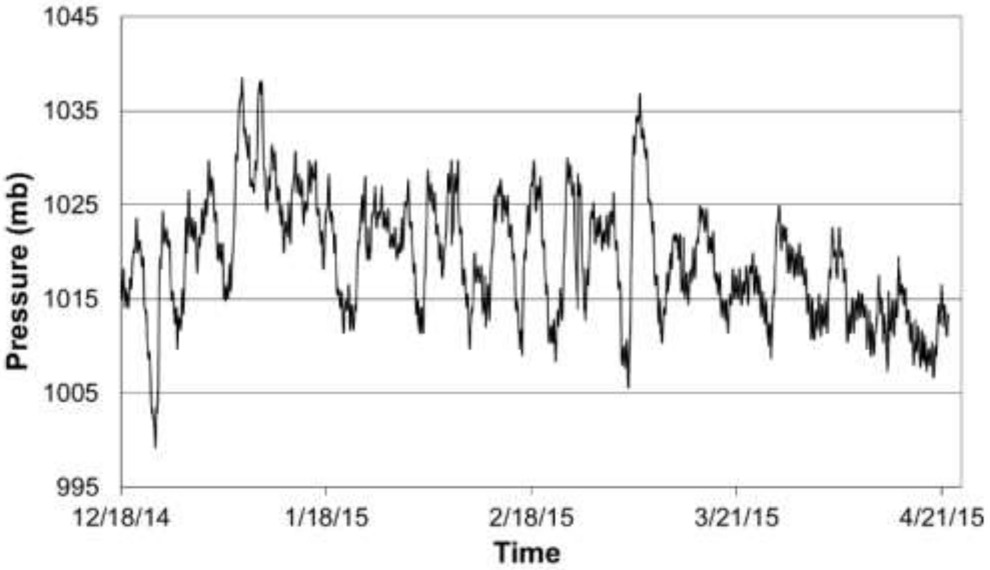

Fig. 3. Time series of daily atmospheric pressure

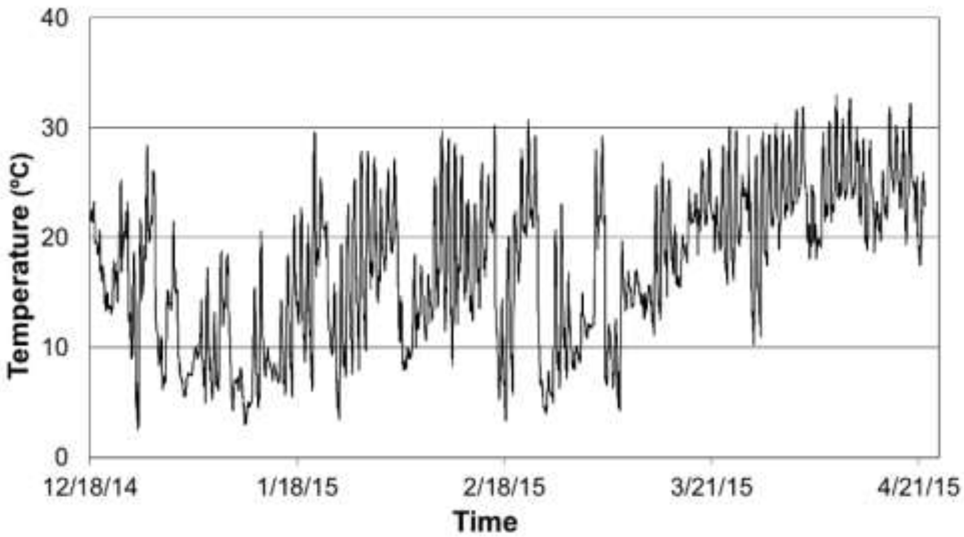

Fig. 4. Time series of daily air temperature

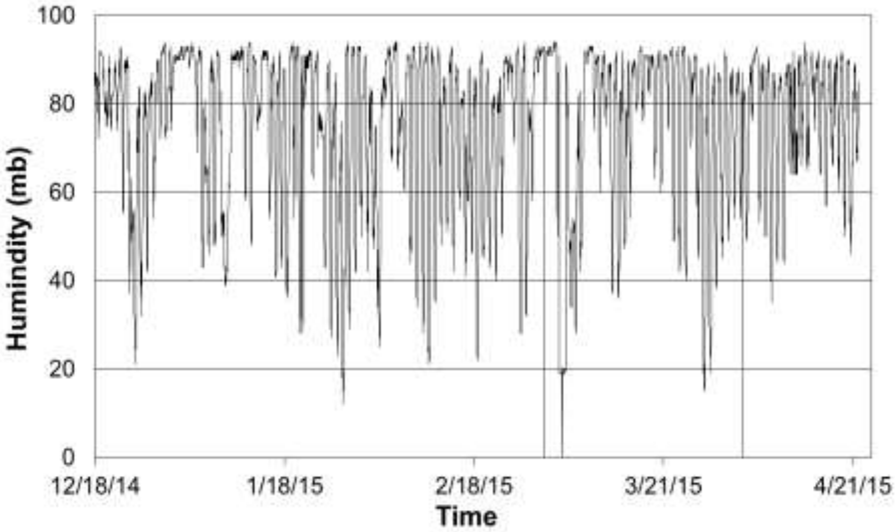

Fig. 5.Time series of daily humidity

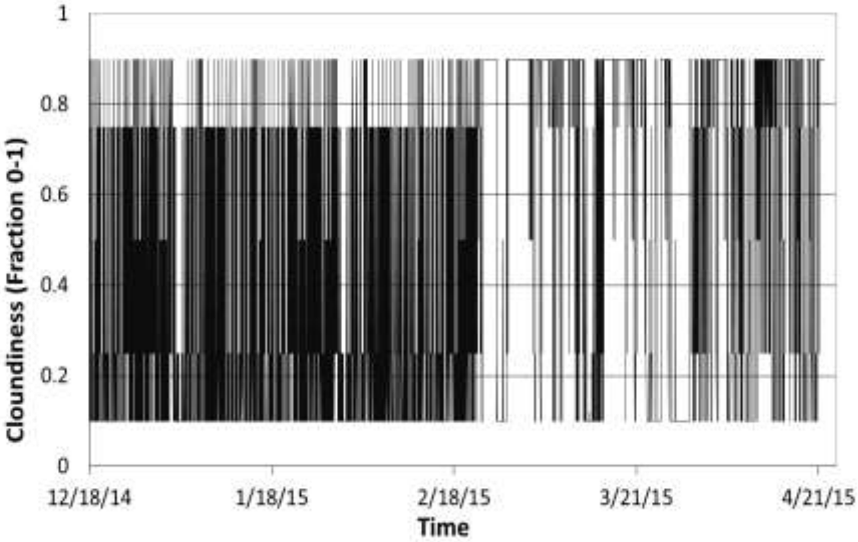

Fig. 6. Time series of daily cloudiness

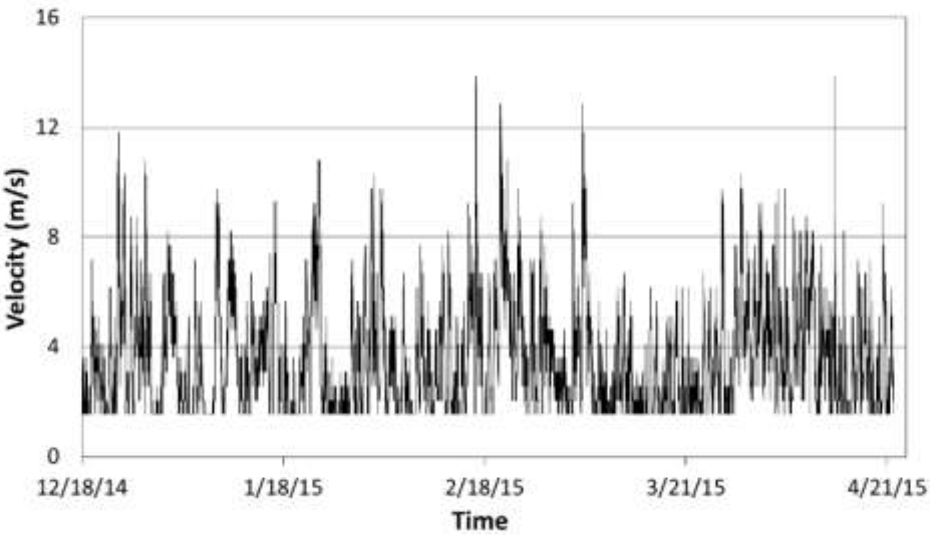

Fig. 7. Time series of daily wind

C. Water temperature data:

The model used a heat budget formulation to quantify heat flux at the air-water interface to model water that controls the water quality in the water. Many water quality kinetic coefficients are temperature dependent. Water temperature computation has been implemented using a full energy budget approach. The source and sink term for temperature; i.e., the change in water temperature with respect to time due to heat exchange at the water surface, was computed as follows:

$$Heat = \frac{q_{nrt} \times A_s}{\rho_w \times C_{pw} \times V} \quad \text{(Eq. 4)}$$

q_{net} = net heat flux at air-water interface w/m^2, ρ_w = density of water (1000 kg/m^3), C_{pw} = specific heat of water (4186 joules/ kg× Kelvin), A_s = surface area of computational cell (m^2), V = volume of wetted cell (m^3)

The heat exchange between the water and the atmosphere would vary on the intensity of heat (w/m^2) over time. The computed exchange of heat is defined by the surface area of the quality cell, and the amount of water within the cell, as the volume within the cell defines the amount of heat absorbed by the water **[10]**. Quantification of changes of temperature over time has been limited to a set of temperatures that only correspond to measured dates. Considering that limited amount of information that was obtained for water temperature changes over time, calculations can be obtained from the atmospheric/flow influences on the water temperature over time.

In this application, it means there is a change in heat content (q_{net}) of the water over some time period, this implies that the temperature of the water (T) is changing over time, this is a result of the input of heat being either greater than (dH/dt > 0) or less than (dH/dt < 0) the losses of heat for this water cell. Calculating the effect of the adsorption of radiation of change of the temperature in the surface water is conducted by

$$\frac{\Delta(V \times \rho_w \times C_{pw} \times T)}{\Delta time} = q_{net} \times Area \quad \text{(Eq. 5)}$$

Although gauges to measure of temperature were not taken at an hourly nor daily rate throughout the monitoring stage of the study period, with the information that was obtained; the manipulation of equation 5 can calculate water temperature change. By using the net heat flux created by the meteorological information, application of size of individual cell lengths, and time rate, temperature can be calculated by using the various meteorological changes over time and the initial measurement of temperature to calculate the change of temperature over time. As seen in Figure 8, the change in temperature was calculated by only using the initial water temperature for the upper stream and lower stream sections and compare to the measurements taken the sites.

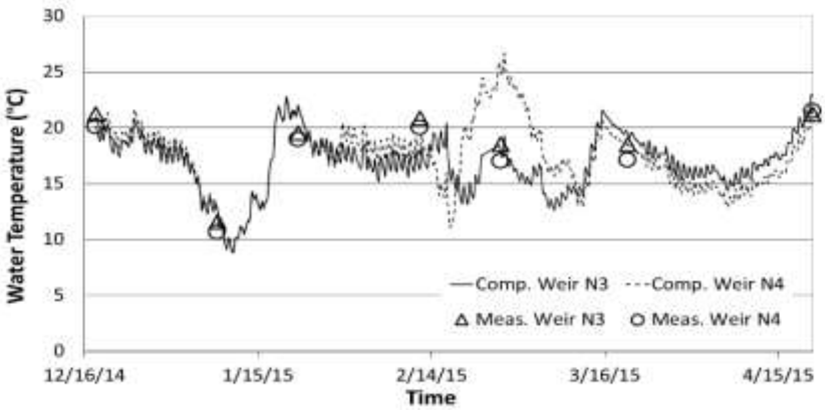

Fig. 8. Time series of computed and measured daily water temperature for North Main at Weir N3 & N4

Considering that an critical flow creates stagnant water at times and rather low flows, variably assigned quality cell surface area can create a regular ratio size between the surface air-water heat intake and the present volume of water to be at a 1:1 ratio; that is, control the intake of heat by adjusting the quality cell surface area to a size small enough that where there is small volume of water, the heat absorption, as indicated by equation 5, would not intake excessive amount of heat over time **[16]**. Using the methodology, temperate fluctuation can be calculated over changing time, by only using the beginning temperature input as calculations and then comparing them to other data used as observation as seen in Figure 8; all but only one date, 02/26/15 had reasonable results.

IV. RESULTS

Different nutrient concentration situations of the canal system, different critical flow possibilities, and at a various range of a meteorological influence in water that were translated into 3 flow condition scenarios. Hydraulic computation was translated into nutrient mass transportation as a crucial element for the study. Output from the nutrition model includes results of time-step calculations such as computation of individual process terms, as well as computed water quality. The plotted model results are hourly averages of model output for each constituent and for each station, and the measured data were collected at corresponding dates for each station and date collected.

A. Hydraulic computations:

Three flow scenarios, corresponding to obtained date, were created and compared by the computed and measured water surface profiles. Figure 9, shows comparisons of computed water surface elevations for three different hydrologic scenarios with the measurements. The results reflect a depiction of water distribution for the section seen in the hydraulic profile graph. The hydraulic components of measured velocities and computed ones were compared to one another for accuracy in that they were representation of critical flow of the canal.

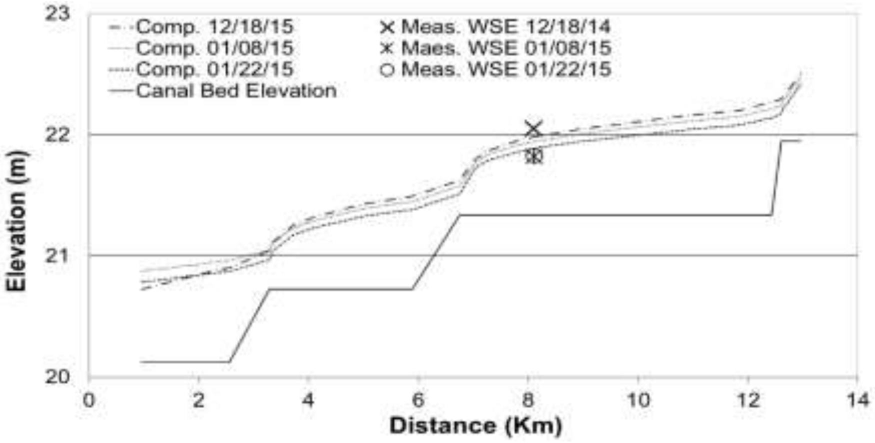

Fig. 9. Computed water surface profiles comparison with measurements

Measurements produced a relatively low water velocity similarity between measured dates as for 12/18/14, 01/08/15, and 01/22/15 measured, respectively, 0.441, 0.415, 0.356 m/s. Results that are simulated by the model will be validated by a quantitative representation by implementing the quantifiable measurement of percent error for evaluation as:

$$PBIAS = \frac{\sum_i (OV_i - MV_i)}{\sum_i OV_i} \times 100 \quad \text{(eq. 6)}$$

where OV_i = observed value at the i time step, MV_i = modeled value at the i time step, and *PBIAS* is percent error.

The hydraulic computations of the three different dates were compared to the velocities of measurements, as seen in table 2, where the *PBIAS* for 12/18/14, 01/08/15, and 01/22/15, 1.36%, 2.44%, and -7.87%, respectively, for Weir N3, and 12/18/14, 01/08/15, and 01/22/15 where 7.15%, 4.7%, and 6.29%, respectively, for Weir N4. The use of the weir equation as flow estimation, that was comparable to that of the measured water velocities. Stronger correlations are presented with the percent error for the modeled hydraulic elevation and measured water elevation was calculated to a small varying degree of error; where a differential water elevation varied from 0.79% to -0.04% error as presented on Table 3. The water elevations computations that it prompts enough accuracy provided that the flow used is an accurate description of real flow conditions that reflect the advection of water based on the comparisons done.

TABLE 2. Comparison of measured and simulated water velocities comparison

Stations	Scenarios	12/18/2014	1/8/2015	1/22/2015
Weir N3	Measurements (m/s)	0.441	0.415	0.356
	Computations (m/s)	0.435	0.405	0.384
	PBIAS (%)	1.36	2.41	-7.87
Weir N4	Measurements (m/s)	0.302	0.403	0.322
	Computations (m/s)	0.280416	0.384048	0.301752
	PBIAS (%)	7.15	4.70	6.29

TABLE 3. Measured and simulated water surface elevation comparison

Stations	Scenarios	12/18/2015	1/8/2015	1/22/2015	2/12/2015	2/26/2015
4.5 km Downstream Weir N. 3	Measurements (m)	22.05	21.82	21.83	21.82	21.86
	Computations (m)	21.88	21.85	21.8	21.83	21.81
	PBIAS (%)	0.79	-0.14	0.14	-0.05	0.23

B. Nutrient model computations:

Nutritional transportation model for the reach was created as a device for a comparison of simulated and measured data for the locations of 4.5 km downstream of Weir N3 and lowest section of the reach Weir N4. For the comparisons of field and model data there were five model state variables were chosen: temperature, dissolved oxygen, algae, nitrate, and phosphate. Time series, and spatial plots of simulated and measured data are shown in Fig. 10 to Fig. 15.

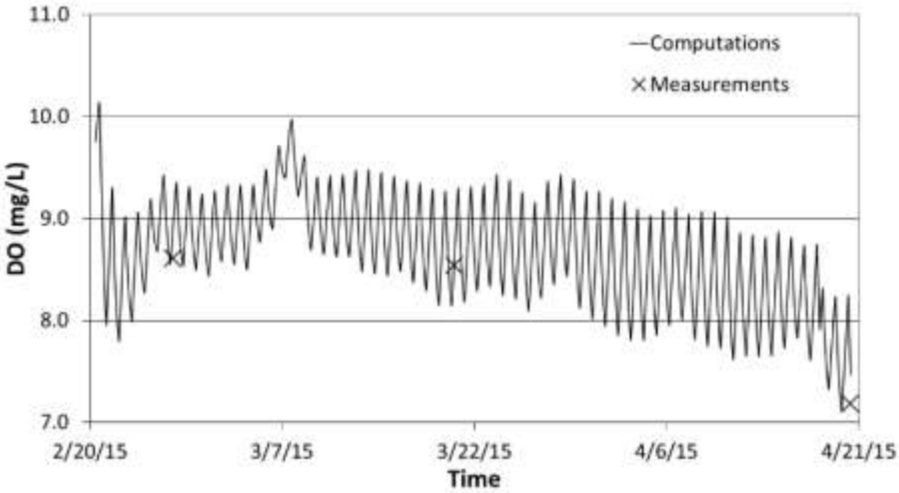

Fig. 10.Time series for computed and measured DO concentration at Weir N4

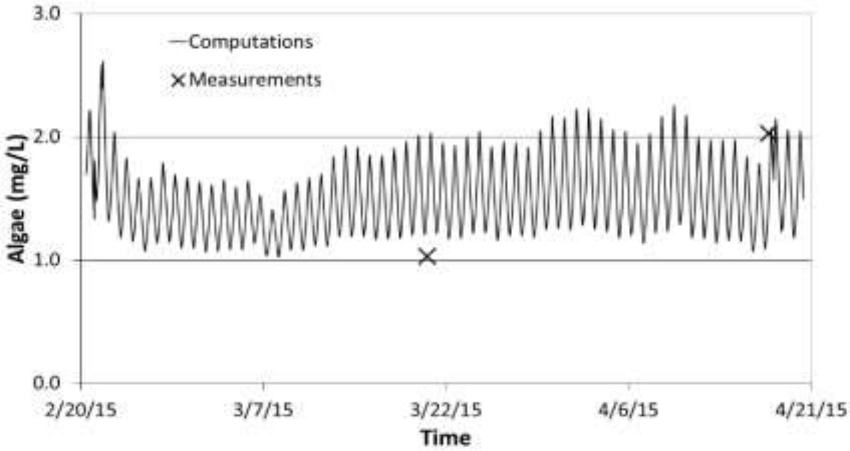

Fig. 11. Time series for computed and measured algae concentration at Weir N4

Figures 10 and 11 represent a steady state critical flow simulation of the nutrients of DO and algae, respectively, for the downstream section of weir N4. The use of a single steady state critical flow nutrient scenario models the baseline condition of flow compares the measured data of nutrient obtained at a critical flow at different dates. The comparison between the measurement and computational ranges to the steady state flow to the obtained data dates can be applied towards the three computed surveyed dates within a time frame of 2 to 3 hours from measured grab water sample, from where the computational concentration change in within the time frame ranges within the measured concentration. As seen in Fig. 12, results like on 03/20/15 where the observed downstream DO concentration is of 8.46 mg/L and the range of computations is between 8.65 to 8.7 mg/L. Results for 04/21/15 showcases the observational data for section middle observation and the downstream Weir N4 as the DO concentration of 7.32 mg/L and 7.19 mg/L, respectively. All while the computed results range the changes of DO for April to range from 7.2 to 7.5 mg/L for the ranged date. The 02/26/15 measured data of DO was of 8.61 mg/L, while the computed output was that of 8.57 to 8.63 mg/L. As seen in Fig. 13, the observational data of phosphate for 04/21/15, the measured site and Weir N4 had a concentration of 1.6 mg/L and 1.85 mg/L, respectively, while the range of change varied from 1.5 to 1.89 mg/L. The March measured data of phosphorous was of 3.13 mg/L for middle observation site and 3.53 for section Weir N4 while the computed output was that of 3.35 to 3.65 mg/L.

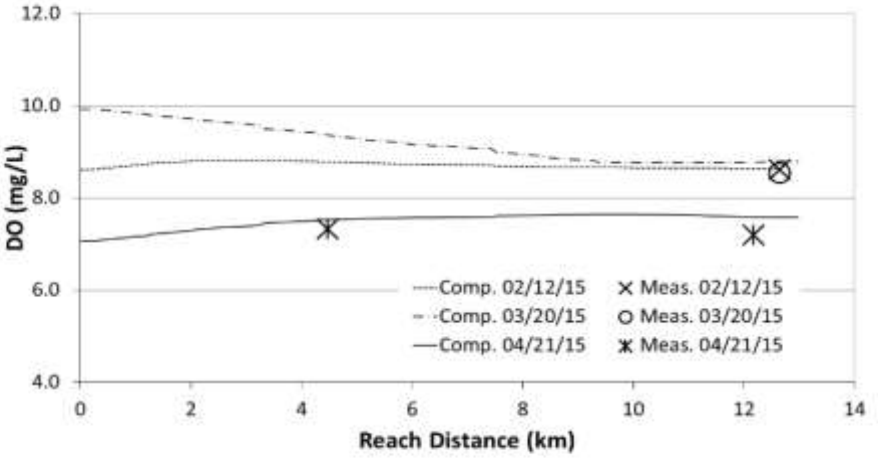

Fig. 12. Comparison of computed and measured DO concentration in reach

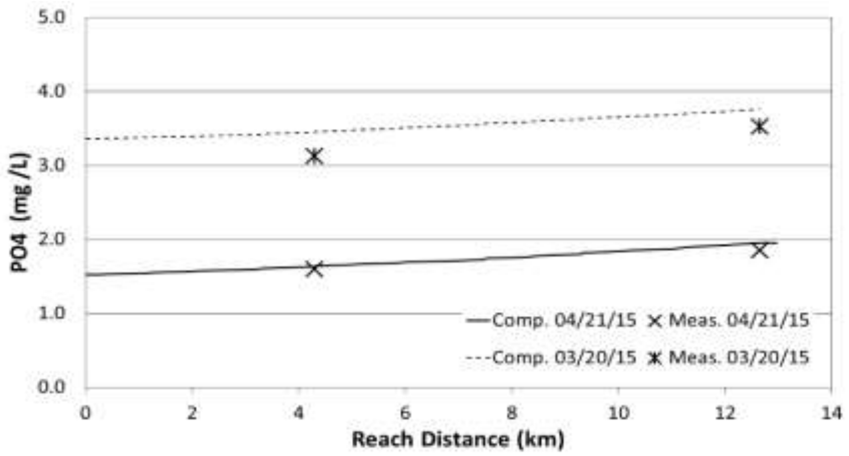

Fig. 13. Comparison of computed and measured PO4 concentration in reach

For stated Fig. 14; algae output Range 1.4 to 1.62 mg/L observed data measurement is 2.03 mg/L for April, 2015; while March 2015 algae output Range 0.8 to 1.05 mg/L observed data measurement is 0.78 mg/L. For Figure 15, the observational data of nitrate for April 21, the measured site and Weir N4 had a concentration of 1.55 mg/L and 1.63 mg/L, respectively, while the range of change varied from 1.57 to 1.64 mg/L. The March measured data of nitrate was of 5.71 mg/L for section Weir N4 while the computed output was that of 6.1- 6.32 mg/L. Strong correlation for the concentration amount of observational data and modeled results are presented for two scenarios of 03/20/15 and 04/21/15 in Table 4, where the percent error for the scenarios had a variation between 2% to 7%.

TABLE 4. Model performance statistics for selected water quality parameters

Scenario	Nutrient (mg/L)	DO	NO3	PO4	Alg.
3/20/2015	Measurements	8.4	5.71	3.313	0.78
	Computations	8.65	6.24	3.35	0.8
	PBIAS (%)	-2.98	-9.4	-1.12	-2.56
4/21/2015	Measurements	7.32	1.63	1.6	2.03
	Computations	7.2	1.64	1.5	1.93
	PBIAS (%)	1.64	0.61	6.25	4.93

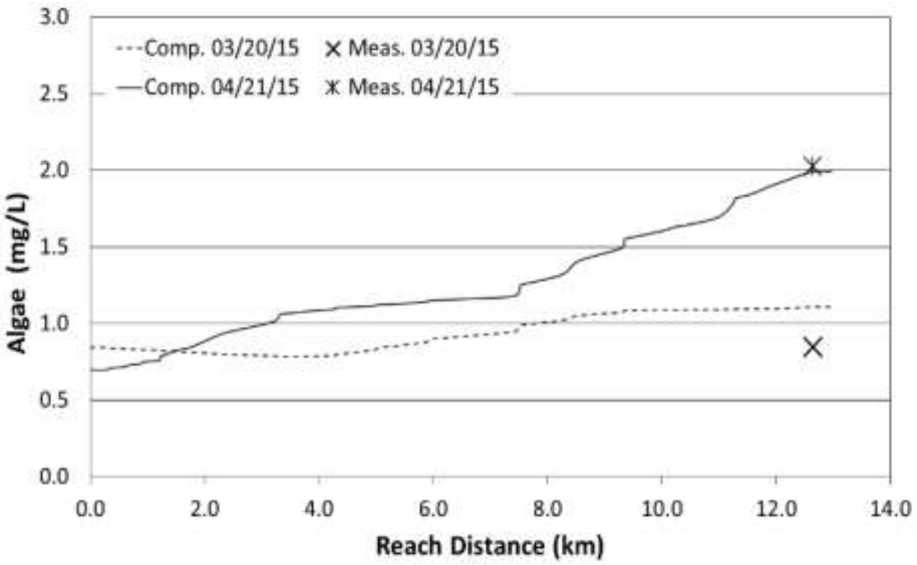

Fig. 14. Comparison of computed and measured algae concentration in reach

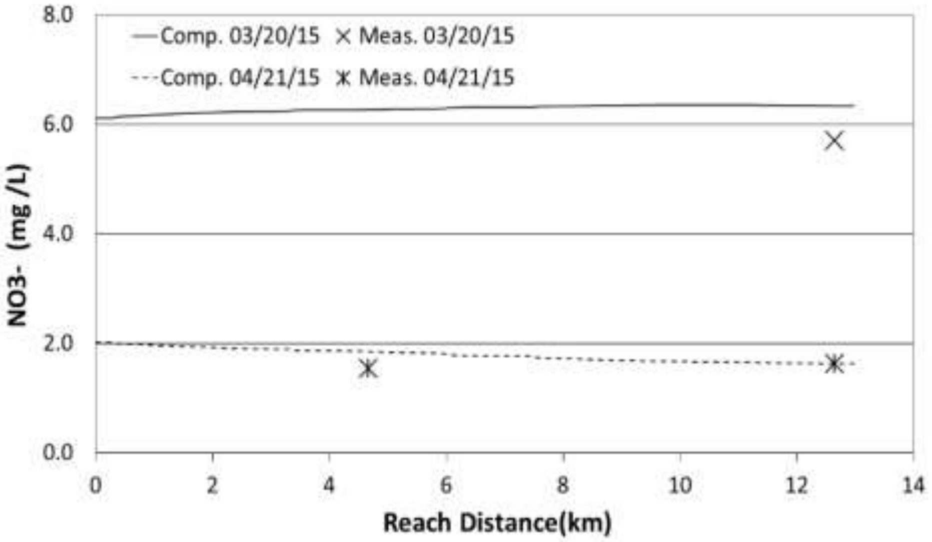

Fig. 15. Comparison of computed and measured NO3 concentration in reach

The overall computations of the model appear to track the nutrient transportation and predict the biological changes created by the environments and concentration along the reach were modeled accurate level. Considering the *PBIAS*, most of the results fell within a range of 10% of error, to which could it be attributed on a number of factors. It seems as if the computations were only successfully matched to the measured dates where the flow corresponded to the specific date of the measurements. To elaborate this fact; the steady state flow assumes the flow of water will remain constant over the simulated time state of the advection-dispersion model. Preliminary testing we were able to simulate a comparison between computed result and those of measured data, in which our model simulates a theoretical comparison to that of flow effects on quality on the canal. The limit falls in the fact that the nutrient transport model was simulated at a dynamic state, while the steady state flow simulations hold the transportation at a limited frame of time. As the transportation of the nutrients concentrations depends highly on the mass velocity and accumulation over the simulated sections, a critical steady-state flow affects the nutrient transportation. The steady state flow correspondence to nutrient grab date yielded a decent comparison to measured data; application of the same quantity amount of nutrient concentration to a similar, but different critical flow measurement, yielded similar results to the original flow. A critical flow that applied to the steady state model, along with a monitored nutrient data obtained at a critical flow, the measured flow date could be irrelevant to the computations. Since as the critical flow used in the model is similar to other flows, nutrient transportation could be meaningful by only using the critical flow to estimate the concentration accumulation throughout the reach.

V. CONCLUSION

The implementation of the one-dimensional qualitative nutrient simulation model was created to estimated DO, simplified orthophosphate cycles, and algae biomass with a comparison of field measurements. This study appears as the critical flow of the section are similar over time allowing the study of nutrient transportation to be studied as an effect of accumulation over sections of the water that could help manage the use of tributary flows out, or into, of the water to soften the effect of nutrient loadings into the water. The critical hydraulic computation was correlated to correspond to specific date of nutrient grab samples to reflect that of regular mass and flow transportation. An advantage of modeling at a critical flow rate would be to correspond a nutrient grab sample to minimal accumulation of concentration over a distance within the reach. Management application can locate those sections of abnormal concentrations and address them than the otherwise option for high flow modeling that would transport nutrients farther downstream at a faster rate. The model is able to predict observed water quality concentration within the canal. Observation of vigorous amount of grab samples and, preferably, daily temperature readings in order to close the gap in accurate results represented in our concerns. The water quality transport models can assist manage sections of reaches where nutrient loadings are of environmental concern, where their accumulation at critical flows can cause damage for a specified ecosystem.

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