# Annual Monitoring Report for Jordan Marsh Water Quality Treatment Park, City of Sanibel

Submitted by: SCCF Marine Lab, July 2020

For the Natural Resources Department

City of Sanibel

***Background***

This report includes results and analyses used to satisfy specific objectives outlined in the Jordan Marsh Water Quality Treatment Park monitoring work plan submitted by Sanibel Captiva Conservation Foundation (SCCF) Marine Laboratory in 2018. Objectives included evaluation of the performance of the Jordan Marsh Water Quality Treatment Park (Jordan Marsh) and determination of nutrient load reduction achieved by the facility. The overall goal is to provide information to be used to adjust the operation parameters to maximize nutrient removal efficiency and to determine the water quality improvement benefits of the marsh especially as they relate to the Sanibel Slough East Basin Total Maximum Daily Load (TMDL) issued by the Florida Department of Environmental Protection (FDEP) in August 2017.

The City of Sanibel contracted to have the filter marsh constructed on 6.5 acres of City-owned land known as the Jordan Marsh Preserve and a portion of 8.5 acres of SCCF-owned conservation lands known as the Bob Wigley Preserve. These lands are located within the east basin of the Sanibel Slough. Modeling by the design engineers (AIM Engineering 2018) estimated the filter marsh would remove between 360-500 kg (790-1100 lbs.) total nitrogen (TN) each year and 45-80 kg (100-175 lbs.) total phosphorus (TP). The Jordan Marsh was placed into operation in January 2019.

Jordan Marsh treats stormwater runoff from the eastern Sanibel Slough basin, which has a watershed of about 3,700 acres. The Sanibel Slough east basin (WBID 2092F2) is verified impaired by the Florida Department of Environmental Protection for TN and TP and a chlorophyll *a* TMDL target of 21 µg/L (Group 2, Cycle 3, 2014) has been set. To meet the TMDL target, a 54% reduction in TN and a 74% reduction in TP input to the east basin is required. This equates to a required reduction of 1,280 kg (2,816 lbs.) of nitrogen and 350 kg (770 lbs.) of phosphorus annually.

The design-stage estimate of nutrient removal achieved by the Jordan Marsh Water Quality Treatment Park determined by AIM engineering (2018) suggested 27-39% of the TMDL-required nitrogen reduction and 12-23% of the required TP reduction goals could be met for the east basin of Sanibel Slough with this one project. The nutrient concentration reduction in the model simulation varied directly with flow – as flow increased, nutrient concentrations in effluent also increased (Table 1). The best nutrient concentration reduction for modeled flow rates was obtained at a hydraulic loading rate (HLR) of 9.4 cm/day or 324,000 gallons/day (0.5 cfs). However, the simulation found that the most efficient mass removal was at a higher HLR of 38 cm/day (2 cfs) or 1,296,000 gallons/day (gpd) (Table 1).

Table 1. AIM Engineering estimated nutrient removal within Jordan Marsh at various influent flow rates.

| Pumped into Jordan Marsh | % of original concentration | | % of removed | | Concentration in Sanibel Slough | | mass removed (lbs per year) | |
|---|---|---|---|---|---|---|---|---|
| Q (cfs) | TN | TP | TN | TP | TN (mg/l) | TP (mg/l) | TN | TP |
| 2 | 85 | 66 | 15 | 34 | 1.90 | 0.13 | 1,119 | 174 |
| 1.5 | 81 | 57 | 19 | 43 | 1.90 | 0.13 | 1,063 | 165 |
| 1 | 73 | 43 | 27 | 57 | 1.90 | 0.13 | 1,007 | 145 |
| 0.5 | 54 | 19 | 46 | 81 | 1.90 | 0.13 | 858 | 103 |

Table 2. AIM Engineering modeling results for residence time at differing influent flow rates.

| Area (ft2) | Depth (ft) | Volume ft3) | Q (cfs) | Q(ft/day) | Residence time (days) |
|---|---|---|---|---|---|
| 160,000 | 3 | 480,000 | 0.5 | 43,200 | 11 |
| | | | 1 | 86,400 | 6 |
| | | | 1.5 | 129,600 | 4 |
| | | | 2 | 172,800 | 3 |
| | | | 3 | 259,200 | 2 |

***Scope of Work and Methods***

The one-year period of concern for this study is March 2019 through March 2020. Water quality monitoring sites included the influent (near influent pump screen), the effluent (v-notch weir) and 2 representative mid-system monitoring sites (Figure 1). All sites were monitored for nitrogen (TN, TKN, NOx, NH3) and phosphorus (TP and OP), salinity and specific conductivity, CDOM, dissolved oxygen, turbidity, pH and temperature. The influent and effluent sites were sampled simultaneously 9 times over the year (3 wet season, 6 dry season) using an automatic sampler set to obtain a composite of 24 samples collected hourly for 24 hours. Samples were kept on ice during the sampling process. Three of the 9 influent/effluent sampling events occurred within 48 hours of a significant rain event (> 0.3 inches). For the purpose of this study, dry season is designated October 15 through June 15.

The two internal sites were discretely sampled at three different occasions during the study period to determine removal efficiencies within the treatment train. When sampling the internal marsh sites, two samples were taken within close proximity of one another at each of the sites to provide a measure of variability. The calculated removal efficiency is plotted versus position within the marsh to provide information on removal rates relative to location within the treatment train.

The monitoring results were analyzed to determine removal efficiency for nutrients, turbidity, chlorophyll *a* and CDOM. The change in temperature, DO and pH from influent to effluent was also calculated.

The influent flow rate is measured by a clamp-on ultrasonic flow meter; however, for most of the first year of operations, the clamp-on influent flow meter failed to provide accurate and reliable flow readings. After extensive troubleshooting by the City and its contractors, it was determined that one of the sensors had malfunctioned; subsequently, the flow meter was replaced by the manufacturer on October 21, 2020. Without accurate and reliable flow meter data, influent flows for this period were instead calculated using pump run times with known pumping rates. A record of pump run times was available for the period of July 19, 2019 through March 10, 2020. In addition, reasonably accurate pumping rates are known for this period with a mean pumping rate of 1,000 gpm before October 10, 2019 and mean pumping rate of 800 gpm after October 29, 2019. Due to a mechanical issue, the pump was not operational for the period from October 10, 2019 through October 28, 2019.

The effluent flow rate is estimated using the v-notch weir calibrated to a level sensor. However, in monitoring flows at the outfall, staff observed that the “point” of the v-notch of the installed weir was filled with cement creating a flattened surface, not the specified “v”, likely an action taken by the contractor to meet the specified elevation. On June 4, 2019, the additional cement was chipped away to restore a true “v” and allow for the effluent flow rate to be calculated accurately. Before June 4, 2019 the elevation at the bottom of the v-notch was approximately 1.5 ft. NAVD. After the excess concrete was removed, the elevation was 1.4416 ft. NAVD. To provide the most accurate information for this report, the v-notch weir data from July 2019 through June 2020 was used for annual flow estimates even though nutrient concentration data was collected between March 2019 and April 2020.

A water and nutrient mass balance for the system was developed using best estimates for influent flow rates using pump run times and effluent flow estimates from the depth sensor at the v-notch weir. Problems with the influent flow measurement device are now resolved, and mass balance estimates for the future will be more accurate.

***Results***

GIS analysis reveals that the Jordan Marsh consists of approximately 138,424 $ft^2$ (3.2 acres or 12,860 $m^2$) of treatment train area, the area which accommodates flowing water. The flow rate exiting the treatment marsh varied significantly over the study period ranging from 0 gallons per day (gpd) to over 792,449 gpd (0 -3,000 $m^3$/day) with a mean annual flow rate of 285,034 gpd (198 gpm or 1078 $m^3$/day). At a 1,000 gallons per minute (gpm) pumping rate (initial average pump discharge) the pump would run an average of 4.8 hours/day assuming no losses within the system. At an 800 gpm pumping rate (current pump discharge) the pump runs on average 5.9 hours/day. The HLR using the mean effluent flow rate is 8.38 cm/day. During the study period, the average water elevation at the effluent gage was 2.153 feet NAVD. This mean elevation corresponds to an average depth of 1.436 feet in the first stage, 0.996 feet in second stage and 2.676 feet in the third stage. The average depth within these stages was derived from the post-construction elevation survey data plotted on site drawings. The first and third stage areas have “ponds” of deeper water.

In June 2020, the v-notch weir used for effluent flow measurement from Jordan Marsh was measured to be 24 inches wide by 22.99 inches to the bottom of the notch (design drawings show 24 inches wide by 24 inches deep). The calculated angle of the vertex for the v-notch was 55.1 degrees. This differs from the engineering drawings which show it to be a 53-degree vertex. The elevation at the bottom of the v-notch after modification is 1.4416 ft. NAVD and the elevation at the top of the weir box is 3.3576 ft. NAVD (as referenced to the level gage). In June 2020, the level sensor at the discharge weir was reading 0.0287 ft. lower than the actual water level at the v-notch weir. Using this information with the level sensor recorded depth data at the v-notch weir, the flow equation for this v-notch weir is:

$Q = 4.28\ C_e \tan(\theta/2)\ (H + k)^{5/2}$ - When the constants are added to this equation it reduces to:
$Q = 1.2895\ (h+0.004017)^{2.5}$ - Where h is the water height above the bottom of the v-notch.

For the period July 19, 2019 through October 10, 2019 (83 days), the estimated influent flow (pump run times) was 16,418,000 gallons (197,807 gpd) while the estimated effluent flow (v-notch weir) was 16,361,790 gallons (197,130 gpd). Water loss through the system for this period was 0.3%. For the period October 10, 2019 through March 10, 2020 (151 days), the estimated influent flow (pump run times) was 47,284,000 gallons (313,139 gpd) while the estimated effluent flow (v-notch weir) was 37,607,154 gallons (249,054 gpd). Water loss during this period was 20.5% of influent flow. With the available effluent flow rates for the period with no data (March 10, 2020 through June 30, 2020) we can estimate influent flow rate using effluent flow rates and estimating water loss through the system as 20.5% for the dry season period and 0.3% for the wet period. The influent flow from July 1, 2019 through July 19, 2019 (wet period) is estimated to be 9,417,166 gallons (553,950 gpd). The influent flow from March 10, 2020 through May 30, 2020 (dry period) is estimated to be 41,390,796 gallons (510,997 gpd). The influent flow from May 30, 2020 through June 30, 2020 (wet period) is estimated to be 8,404,737 gallons (289,818 gpd**). For the one-year study period, the total estimated influent flow was 123,241,750 gallons (337,650 gpd)**; **the total effluent flow was 104,258,800 gallons (285,035 gpd).** The wet season influent flow was 31,097,100 (259,142 gpd) and the effluent flow was 31,003,800 gallons (258,365 gpd), while the dry season influent flow was 92,144,654 gallons (376,100 gpd) and the effluent flow was 73,255,000 gallons (299,000 gpd). The estimated water loss through the system over the one-year study is 18,983,000 gallons (52,000 gpd) or 15.4%.

A plot of water elevation in the marsh at the effluent weir during a period with no rain (Figure 2) shows the daily fluctuation due to evapotranspiration. During the day, water is lost to atmosphere through the stomata of the plants and marsh water level decreases. At night, water is released from vegetation back into the marsh and the water level increases. This daily fluctuation produces a diel change in water level (at constant pumping rates). As an example, during a period plotted in June, a mean water level elevation change of 2.4 inches was observed from the maximum at about 0900 to the minimum at 2100 (Figure 2). A longer-term downward trend in the water elevation can also be noted in the plotted data (Figure 2). The longer-term trend is related to shallow aquifer level changes and evapotranspiration losses.

The mean influent concentration of TP was 0.102 mg/l based on 9 sampling events while the mean effluent concentration was 0.054 mg/l (47% reduction, Figure 4). Orthophosphate reduction through the system (33%) was less than total phosphorus removal (Table 3). Mean influent/effluent concentrations for TN were 2.99 and 2.41 mg/l respectively for a mean concentration reduction of 20% (Figure 5, Table 3). Inorganic nitrogen concentration reduction (59%) was greater than total nitrogen. Chlorophyll *a* in the influent was reduced from 38.5 to 10.4 ug/l (72% reduction) and turbidity was reduced from 6.4 to 3.5 NTU (45% reduction). Dissolved oxygen was also increased by an average of 3.8 mg/l and temperature increased 0.5 degrees C from influent to effluent (Table 3).

The median effluent concentrations of total phosphorus, chlorophyll *a* and turbidity were found to be significantly less than the influent concentration using the Kruskal Wallis test in Minitab ® (TP, $p = 0.01$; chlorophyll *a*, $p < 0.01$; turbidity, $p = 0.02$), while dissolved oxygen (3.5 vs. 7.3 mg/l, $p < 0.01$), and temperature were significantly greater in the effluent (Table 3). No significant difference could be found between influent and effluent samples for concentrations of total nitrogen, inorganic nitrogen, orthophosphate, CDOM, pH and salinity (Table 3).

Three sampling events at two stations (Figure 1, Table 4) within the marsh revealed varying removal efficiency for different segments of the marsh. In general, the greatest reduction in TN and TP occurred within the first segment of the marsh. The next segment continued to remove TN and TP, however in the third segment of the marsh, there was no removal of phosphorus or nitrogen (Figures 6 and 7, Table 4). The concentrations of inorganic nitrogen and phosphorus were generally near detection limit in the influent so calculation of removal efficiency through the treatment process was not meaningful. Water temperature increased significantly in both the first and second stages while the deeper water of the third stage seemed to allow it to cool again slightly before discharge (Table 4). In general, turbidity was decreased from influent concentrations in stage 1 and 3 (Table 4).

Mean phosphorus and nitrogen concentrations were combined with mean influent and effluent flow rates to estimate loads and load reduction. Over the study period from July 2019 through June 2020, influent and effluent nutrient loads were calculated:

$TN_{in}$ = (2.99 mg/l)(kg/1,000,000mg)(123,241,750gal/yr)(3.78 l/gal) = 1,393 kg/yr

$TN_{out}$ = (2.41mg/l)(kg/1,000,000mg)(104,258,800gal/yr)(3.78 l/gal) = 950 kg/yr

TN removed = 443 kg/yr (977 lbs./yr) = 31.8%

$TP_{in}$ = (0.102mg/l)(kg/1,000,000mg)(123,241,750gal/yr)(3.78 l/gal) = 47.5 kg/yr

$TP_{out}$ = (0.054mg/l)(kg/1,000,000mg)(104,258,800gal/yr)(3.78 l/gal) = 21.3 kg/yr

TP removed = 26.3 kg/yr (58 lbs./yr) = 55.4%

$IN_{in}$ = (0.071mg/l)(kg/1,000,000mg)(123,241,750gal/yr)(3.78 l/gal) = 33.1 kg/yr

$IN_{out}$ = (0.029mg/l)(kg/1,000,000mg)(104,258,800gal/yr)(3.78 l/gal) = 11.4 kg/yr

IN removed = 21.7 kg/yr (47.6 lbs./yr) = 65.6%

$OP_{in}$ = (0.017mg/l)(kg/1,000,000mg)(123,241,750gal/yr)(3.78 l/gal) = 7.9 kg/yr

$OP_{out}$ = (0.012mg/l)(kg/1,000,000mg)(104,258,800gal/yr)(3.78 l/gal) = 4.7 kg/yr

OP removed = 3.2 kg/yr (7.1 lbs./yr) = 40.5%

Analysis of influent flow versus TN and TP concentration showed the greatest TN concentration reduction at approximately 600,000 gpd while the greatest TP concentration reduction occurred at 530,000 gpd (Figures 8 and 9). The greatest TN and TP load reductions occurred above 1,000,000 gpd (Figures 10 and 11).

***Discussion***

The influent flow meter delivered inconsistent and inaccurate readings (e.g., negative numbers, unreasonably high numbers) much of the time while it was on-line during the first year. Although sound estimates could still be made of influent flow, the estimates are not as accurate as those that would be obtained from a properly functioning and calibrated flow meter.

Evapotranspiration estimated by South Florida Water Management District (SFWMD) for Southwest Florida is about 100mm/month during dry season and 115mm/month for wet season with an annual average of about 108mm/month. Using the treatment system surface area of 12,860 $m^2$ the estimated dry season water loss due to evapotranspiration is 2,901,090 gallons while the estimated wet season evapotranspiration is 1,583,452 gallons and the total annual loss due to evapotranspiration is 4,484,542 gallons. For comparison, the actual water loss through the Jordan Marsh treatment system for the dry season was 18,889,700 gallons while the wet season water loss was 93,300 gallons and the total water loss was 18,983,000 gallons (about 4.2 times the estimated annual evapotranspiration rate).

The mean diel water level change observed in June 2020 at the effluent weir due to evapotranspiration processes was nearly identical to the diel change found in a shallow aquifer well installed at the Jordan Marsh site in 2015 (Figures 2 and 3). The mean diel water level elevation change in the Jordan Marsh in June 2020 was 2.4 inches. In August 2015, the mean water table elevation change at a well previously installed at the Jordan Marsh site was 2.3 inches. The mean time of day of the maximum water table elevation was 0900 for both the marsh effluent and the aquifer while the mean time of minimum elevation was 2000-2100 for both. These findings suggest an intimate relationship between the marsh water level and the underlying shallow aquifer. **Water in the Jordan Marsh essentially "floats" on top of the shallow aquifer** and water level changes (diel and longer term) are mainly due to water level changes in the aquifer below it when pumping rates are fairly steady. In the wet season, the aquifer's water table is near or above the bottom of the excavated marsh's bottom elevation and minimal water loss occurs through the system due to "replenishment" from the aquifer. As shown above, water loss rate in the wet season is below the evapotranspiration rate from the marsh. In the dry season, the water table is most often below the excavated bottom elevation of the marsh and water pumped into the marsh is lost through both infiltration into the soils and evapotranspiration. During the dry season, the water loss rate in the marsh exceeds the evapotranspiration rate (by about 400%).

Using the estimated influent flow rate (which accounts for water loss), the mean annual HLR for Jordan Marsh is 9.9 cm/day. This estimate is more realistic than using the measured effluent flow rate for estimating the hydraulic loading. It also shows that the actual loading is within the original engineering hydraulic loading design specifications for the system (9.4-38 cm/day).

The estimated mean HLR of 9.9 cm/day is in the range found at other operating surface water flow systems. The very large STA 5 operated by SFWMD for nutrient removal in the everglades is operated at an HLR between 0.6 to 2.5 cm/day resulting in a mean TP concentration reduction of 66%. The HLR for a large treatment wetland for Lake Apopka varies from 8.7-11 cm/day. Larger treatment wetlands are typically operated at lower loading rates due to their scale. For comparison, Lee County's 9-acre Ten Mile Canal Filter Marsh was designed to operate at a maximum loading rate of about 200 cm/day or about 5 times the design loading rate for the Jordan Marsh (Karuna-Muni, et al. 2008).

The AIM engineering design report suggested a mean daily flow rate of 1,292,634 gpd would result in greatest load removal. The single pump installed at Jordan Marsh can pump between 750 and 1000 gpm (1,080,000-1,440,000 gpd). To achieve this loading rate, the current pump would need to run most of the day. In our analysis, the greatest TP and TN load removal occurred at a flow rate above 1,000,000 gpd. Given the sampling and measurement error, the values obtained with our analysis are comparable to those design phase modeling results.

Based upon load removal estimates, during this 1-year study period, the marsh achieved engineering modeling estimates for TN reduction and removed enough TN (443 kg) to meet 34.6% of the TMDL reduction goal (Figure 12). Though TP load removal was better than TN (55.4% vs. 31.8%), the total load reduction (26.3 kg) was only 60% of the modeled result and the reduction achieved was about 8% of the TMDL requirement (Figure 12). The TN removal performance was good and the 62% IN removal efficiency shows that the readily available forms of nitrogen in the influent are effectively reduced. However, the lower than modeled effectiveness of phosphorus removal is a concern for the first year of operation. In the Everglades, the large STA 5 was operated at a much lower HLR and TP load removal was 60-70%. The HLR for the Lake Apopka treatment marsh was similar to that of the Jordan Marsh and had similar TP load removal between 35 and 50% annually.

At the current estimated TP load reduction Jordan Marsh removes less than 10% of the load required by the east basin Sanibel Slough TMDL. Relying upon this marsh system to remove more significant amounts of TP annually (relative to the TMDL) may require improvements within the system. Greater and more consistent hydraulic loading along with sufficient sampling to correctly characterize the influent and effluent may result in improved removal efficiency next year. TP removal may also be improved through increased vegetation coverage in the third stage of the treatment train. Decreasing the water depth through additional fill may be necessary to provide the existing vegetation a better chance of recruiting to the third stage. Or, as an alternative, floating vegetation which can exist in deeper water such as *Nymphea spp*., *Lemna spp.* , *Wolffia spp*., *Utricularia spp*., and *Nuphar spp.* could be established instead of emergent plants.

The design depth that AIM engineering used for modeling was 3 feet. At 3 feet of depth many wetland plants are not able to establish themselves. According to the scientific literature, maximum operational water depths are between 1-2 feet (Iowa Wetland Manual, EPA Wetland Manual, Hydrik Wetland Manual) with deeper water pools in upstream treatment train stages used only for settling solids. The 3-foot design depth may not be a practical goal especially with low density of vegetation already a problem in the deeper stage three (2.6 feet mean depth). The mean depths of 0.9 to 1.4 feet in the first two stages have allowed the wetlands plants in those stages to become very well established, resulting in the desired nutrient removal. To allow establishment of a denser vegetation community, the third stage area may need additional fill material. The second stage area has places which most often do not have water flowing due to higher elevation and shallow depths. In these areas the flow "short circuits" through the deeper portion of the second stage and the some of the vegetated treatment area often does not see flow (treatment area is reduced). In the future, relocating sediment from the shallowest portions of the second stage and adding it to areas in the third stage will increase the vegetated treatment surface area of the marsh system.

### ***Conclusions***

The Jordan Marsh Water Quality Treatment Park met many of the design expectations during the first year of operation. P It appears that the marsh will effectively meet nitrogen reduction goals outlined in the original design reports. However, TP load reduction did not meet goals. By improving vegetative cover in the third stage area of the marsh treatment train, TP reduction may improve. A more consistent and increased hydraulic loading rate may also improve load reduction. Mechanical issues with the influent pump and short-term construction activity adjacent to the marsh resulted in periods of very low or no hydraulic loading, producing inconsistent operation and nutrient removal for significant periods of time during the first year of operation. With better influent flow management based upon information found in this report, more effective nutrient removal will likely be possible.

The water level in the treatment marsh varies directly with the shallow aquifer water table elevation. The water in the marsh floats on top of the shallow aquifer and during the wet season, when the water table is above the bottom of the marsh, there is little or no infiltration into the underlying marsh substrate. During the dry season, the water table is below the marsh bottom and water loss is much greater than would be estimated by evapotranspiration alone (due to infiltration).

Table 3. Mean influent and effluent concentrations or values for parameters monitored in this study. The %removal equates to the mean reduction in concentration or value between influent and effluent. Significant differences between influent and effluent values are noted.

| Parameter | Mean Influent Value | Mean Effluent Value | Significant Difference | % Removal |
|---|---|---|---|---|
| TN mg/l | 2.99 | 2.41 | No | 19.5 |
| TP mg/l | 0.102 | 0.054 | Yes | 47.0 |
| OP mg/l | 0.017 | 0.012 | No | 32.9 |
| IN mg/l | 0.071 | 0.029 | No | 59.3 |
| NOx mg/l | 0.008 | 0.007 | No | 18.4 |
| Ammonia mg/l | 0.063 | 0.023 | No | 64.2 |
| OrgN mg/l | 2.92 | 2.38 | No | 18.5 |
| Chlorophyll a ug/l | 38.5 | 10.4 | Yes | 72.9 |
| Turbidity NTU | 6.4 | 3.5 | Yes | 45.1 |
| CDOM QSE | 271.1 | 259.5 | No | 4.3 |
| Temp Change DegC | 24.3 | 24.8 | Yes | 0.5 |
| DO Change mg/l | 3.5 | 7.3 | Yes | 3.8 |
| pH Change | 8.0 | 8.2 | No | 0.2 |

Table 4. Concentration of nutrients through interior of marsh treatment system (3 stages) from 3 sampling events. Most or all TN and TP removal took place in first two stages.

| Concentration | TN mg/l | TP mg/l | Chla ug/l | OP mg/l | Ammonia mg/l | Nox mg/l | IN mg/l | ON mg/l | Temp C | CDOM QSE | Turb NTU | DO mg/l | pH |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Influent | 3.72 | 0.165 | 51.6 | 0.023 | 0.062 | 0.055 | 0.008 | 3.661 | 23.0 | 267.7 | 6.8 | 3.7 | 7.9 |
| 1st Stage | 3.03 | 0.079 | 35.0 | 0.021 | 0.086 | 0.065 | 0.021 | 2.946 | 28.7 | 253.9 | 3.9 | 7.4 | 8.2 |
| 2nd Stage | 2.88 | 0.053 | 14.0 | 0.009 | 0.034 | 0.028 | 0.006 | 2.846 | 29.5 | 248.6 | 5.3 | 10.8 | 8.3 |
| Effluent | 3.02 | 0.053 | 13.4 | 0.013 | 0.039 | 0.033 | 0.006 | 2.982 | 27.0 | 248.4 | 2.8 | 8.8 | 8.1 |
| Removal Efficiency | TN | TP | Chla | OP | Ammonia | NOx | IN | ON | Temp | CDOM | Turb | DO mg/l | pH |
| 1st Stage Mean | 17.3 | 43.5 | 74.1 | 5.1 | -70.6 | -43.8 | -196.7 | 18.0 | 0.1 | -0.2 | 48.5 | 1.2 | -0.2 |
| 2nd Stage Mean | 4.6 | 33.1 | 21.3 | 55.3 | 58.3 | 52.3 | 52.4 | 2.9 | 1.0 | 2.1 | -85.7 | 2.2 | 0.1 |
| 3rd Stage Mean | -5.6 | 1.4 | 9.2 | -53.7 | -3.8 | -1.9 | 0.0 | -5.5 | -0.8 | -0.3 | 43.8 | 14.3 | -0.1 |
| Overall Mean | 17.2 | 64.0 | 71.7 | 37.5 | 35.2 | 40.2 | 18.1 | 16.7 | 1.0 | 1.4 | 57.3 | 5.1 | 0.2 |
| Cumulative % Removed | TN | TP | Chla | OP | Ammonia | NOx | IN | ON | Temp | CDOM | Turb | DO mg/l | pH |
| Influent | | | | | | | | | | | | | |
| 1st Stage Mean | 18.6 | 52.1 | 32.2 | 10.8 | -37.7 | -18.2 | -178.8 | 19.5 | 5.7 | 5.1 | 43.2 | -96.9 | -4.0 |
| 2nd Stage Mean | 22.7 | 67.7 | 72.8 | 63.0 | 44.6 | 48.0 | 20.4 | 22.3 | 6.5 | 7.1 | 23.0 | -188.6 | -5.4 |
| 3rd Stage Mean | 18.9 | 67.8 | 74.1 | 45.7 | 37.9 | 40.4 | 20.4 | 18.6 | 4.0 | 7.2 | 58.5 | -135.2 | -2.9 |

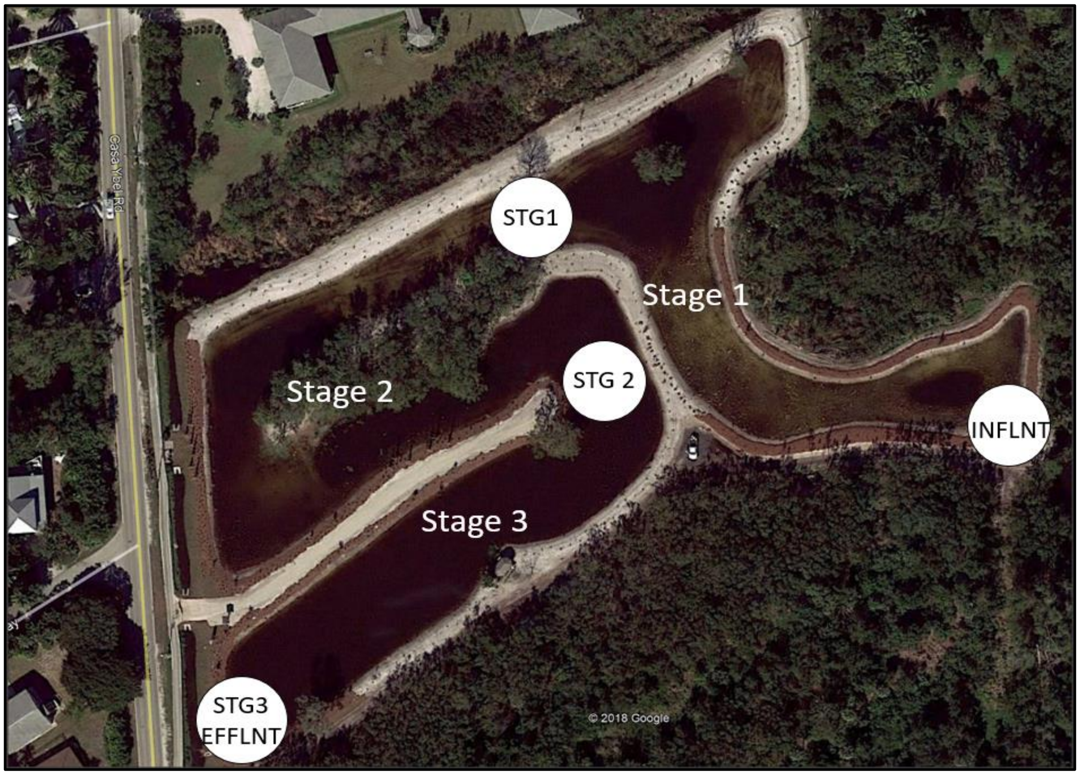

Figure 1. Sampling locations are indicated by the white dots. The 4 sampling locations divide the marsh into 3 stages (labeled).

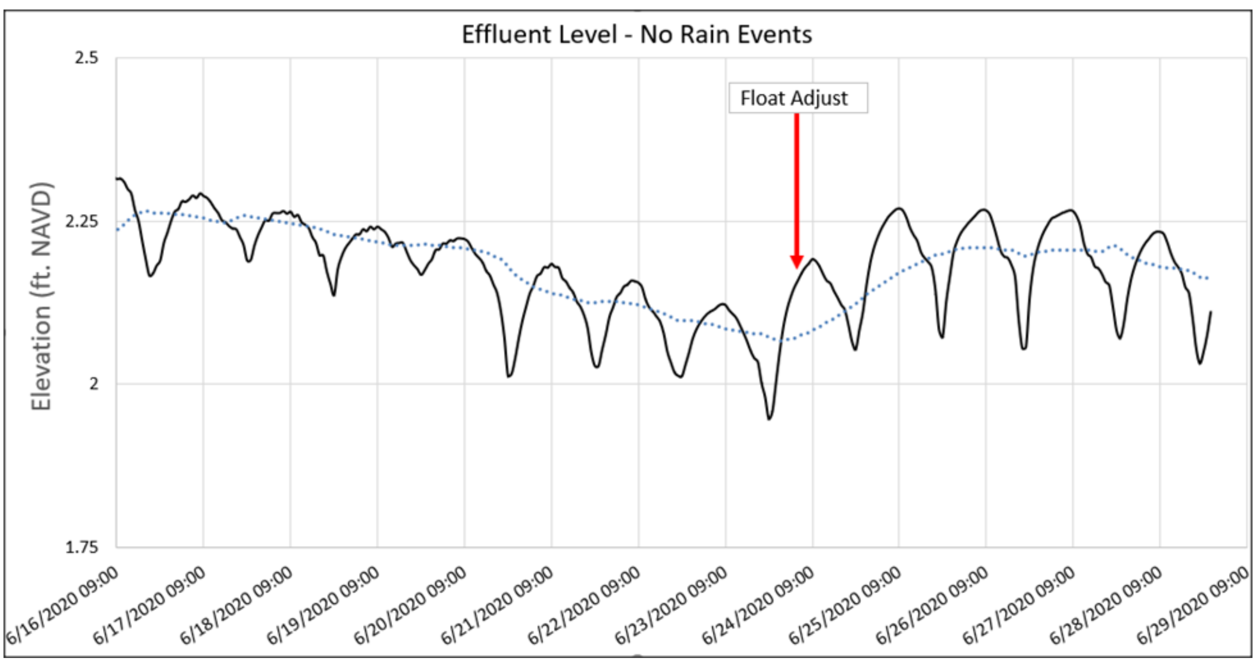

Figure 2. Water level fluctuation at the Jordan Marsh effluent weir during a wet season period with no rain and one change in the influent pumping rate. The effects of daily evapotranspiration and infiltration are seen in a diel cycle of maximum water level around 0900 and minimum water level around 2000.

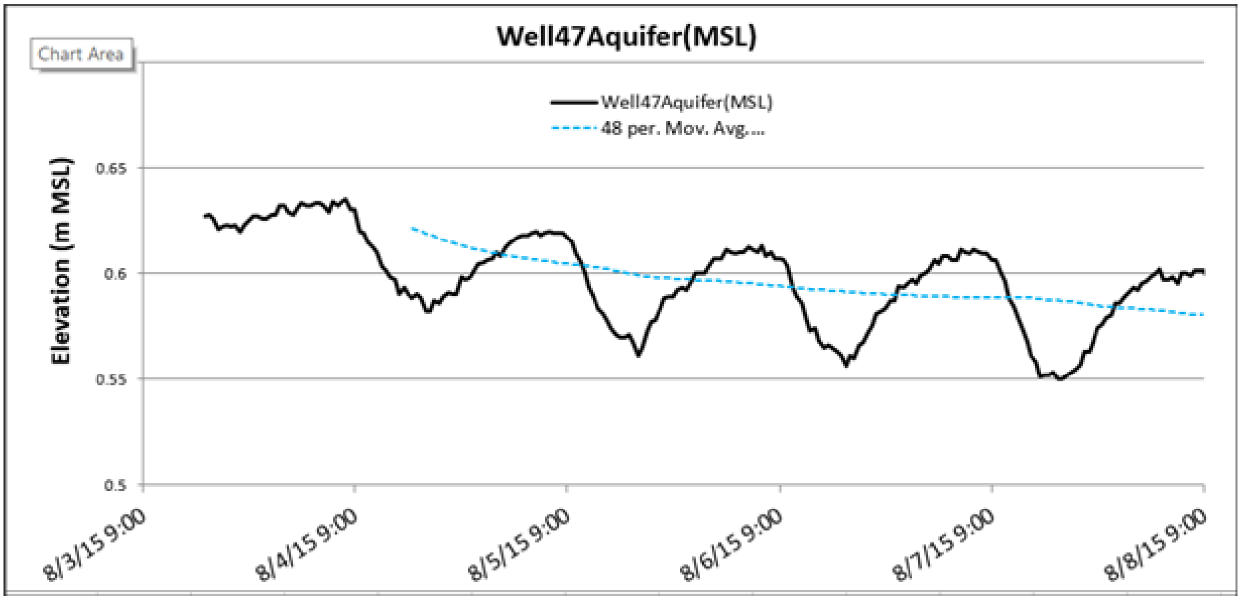


Figure 3. Water level at a shallow aquifer well installed adjacent to the Jordan Marsh site in August 2015. The diel water table level variation due to regional evapotranspiration can be seen with daily maximum at 0900 and minimum at 2000. The longer-term trend line shows gradual water table depression due to a period of no rain.

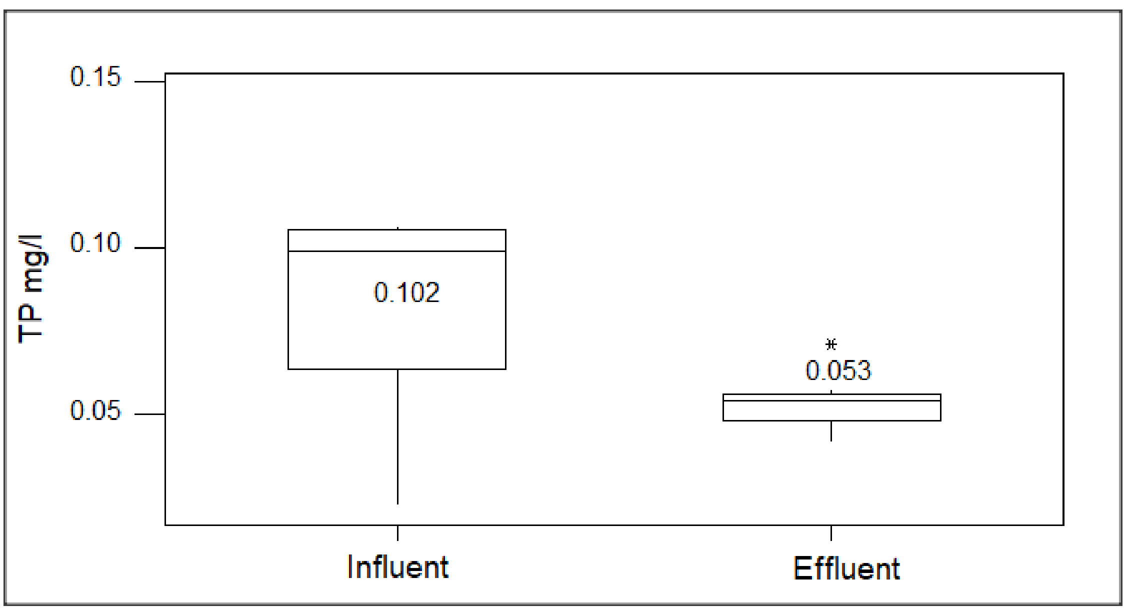


Figure 4. Mean influent and effluent TP concentration boxplot showing median concentration line and 25th and 75th percentile values. Mean effluent TP concentration was significantly less than the influent concentration.

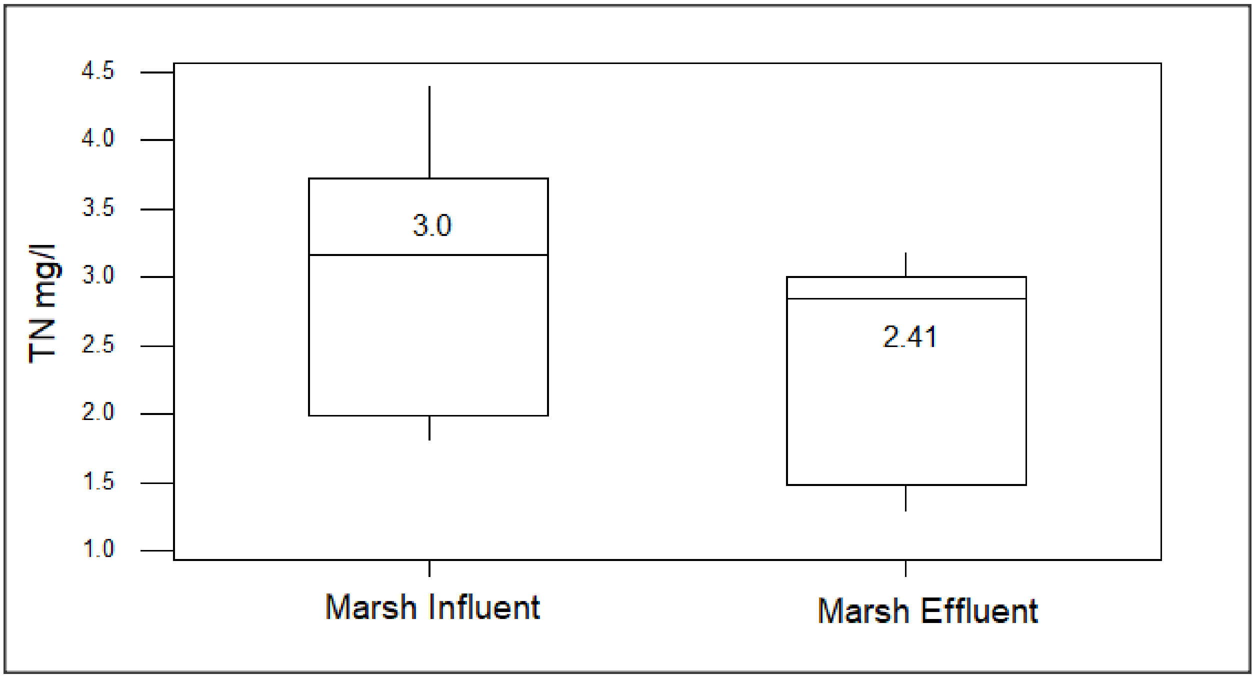


Figure 5. Mean influent and effluent TN concentration boxplot showing median concentration line and 25th and 75th percentile values. No significant difference could be found between mean influent and effluent TP concentration.

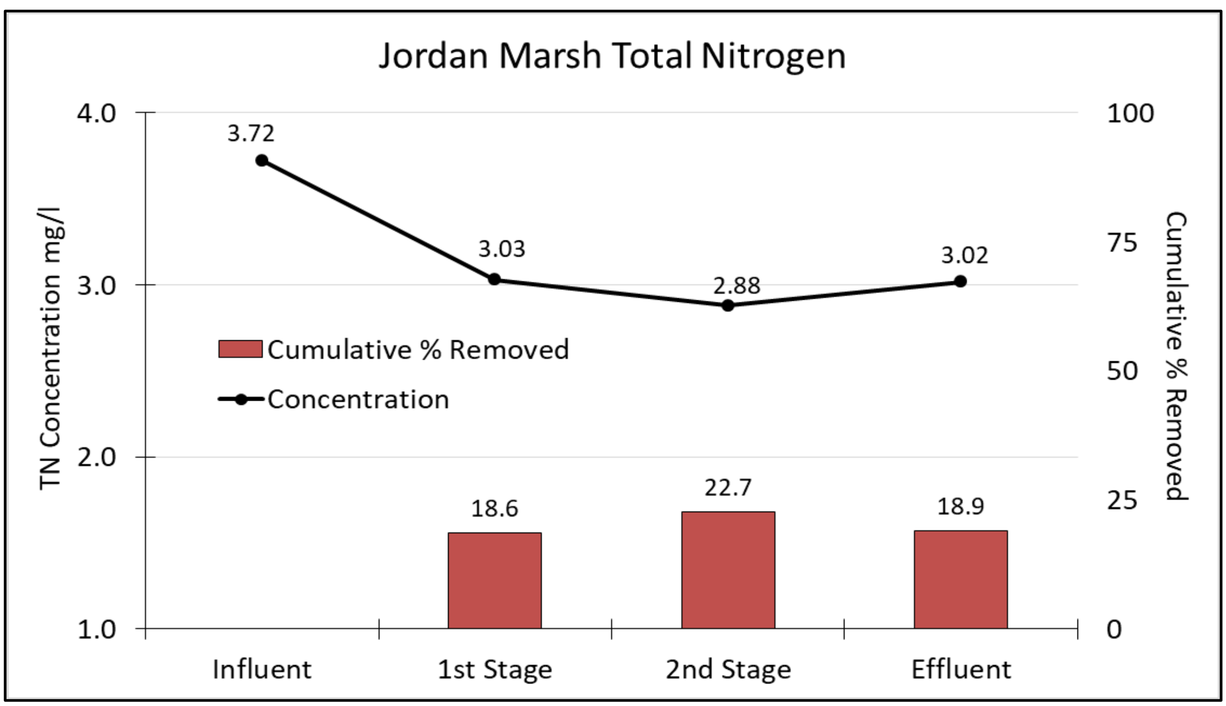


Figure 6. Mean total nitrogen at progressive stages within Jordan Marsh with the accompanying cumulative percentage of nitrogen removed.

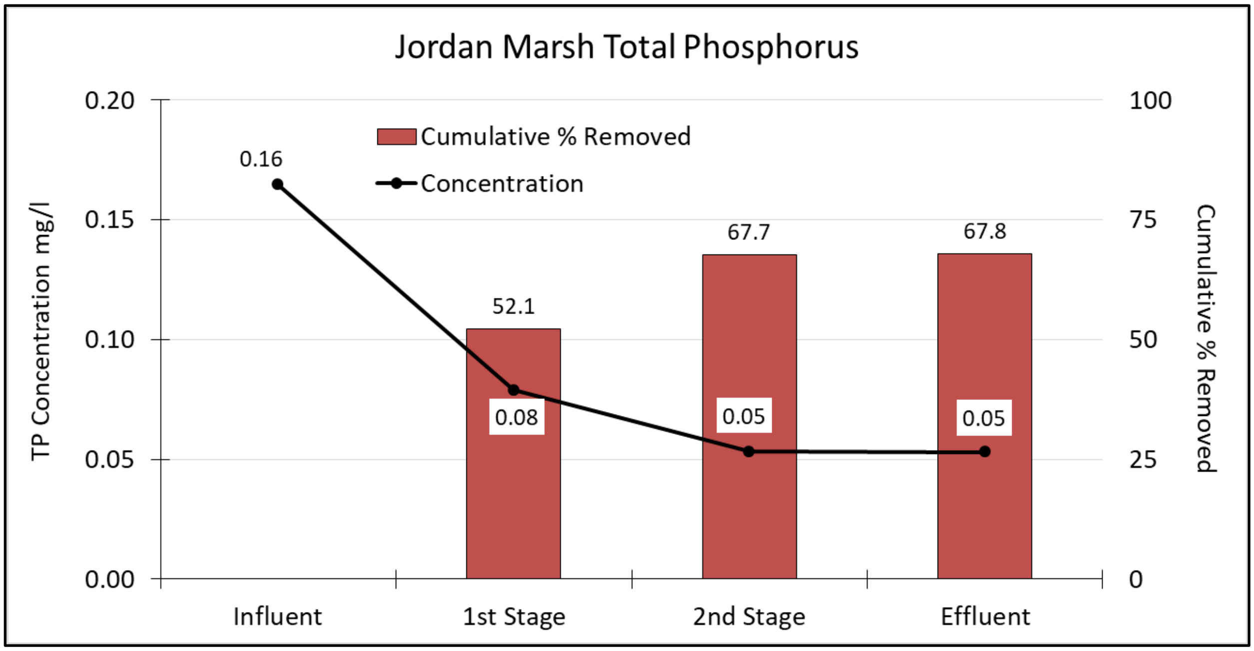


Figure 7. Mean total phosphorus at progressive stages within Jordan Marsh with the accompanying cumulative percentage of phosphorus removed.

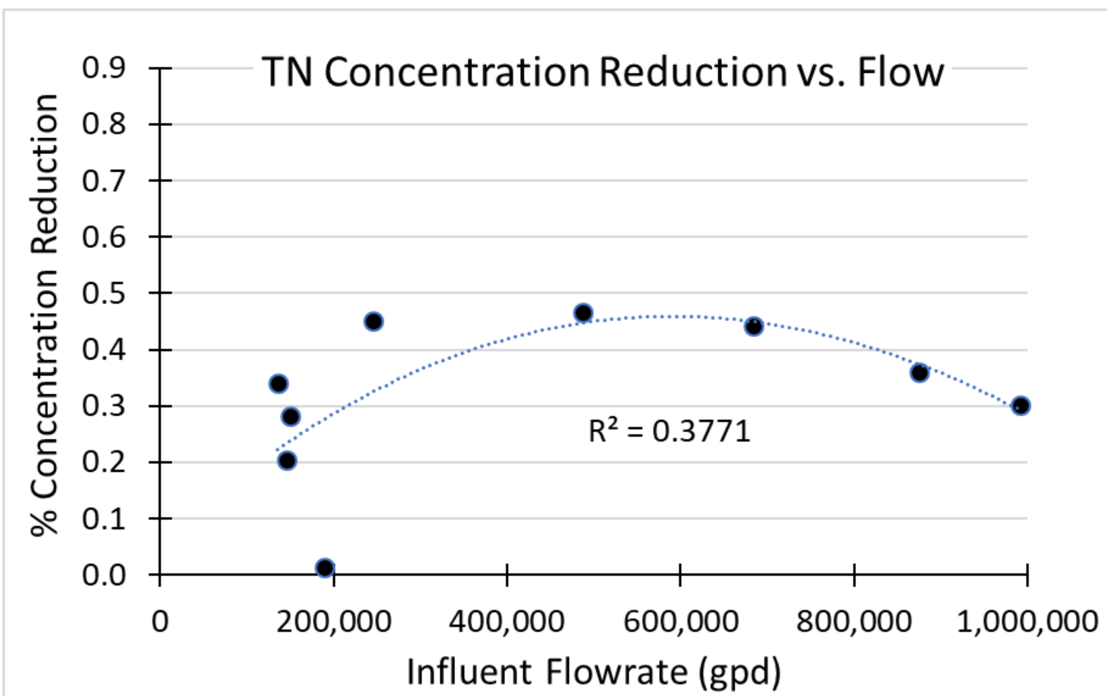


Figure 8. TN concentration reduction vs. influent flowrate during 1st year sampling events. Greatest TN concentration reduction occurred between 500,000 and 600,000 gpd.

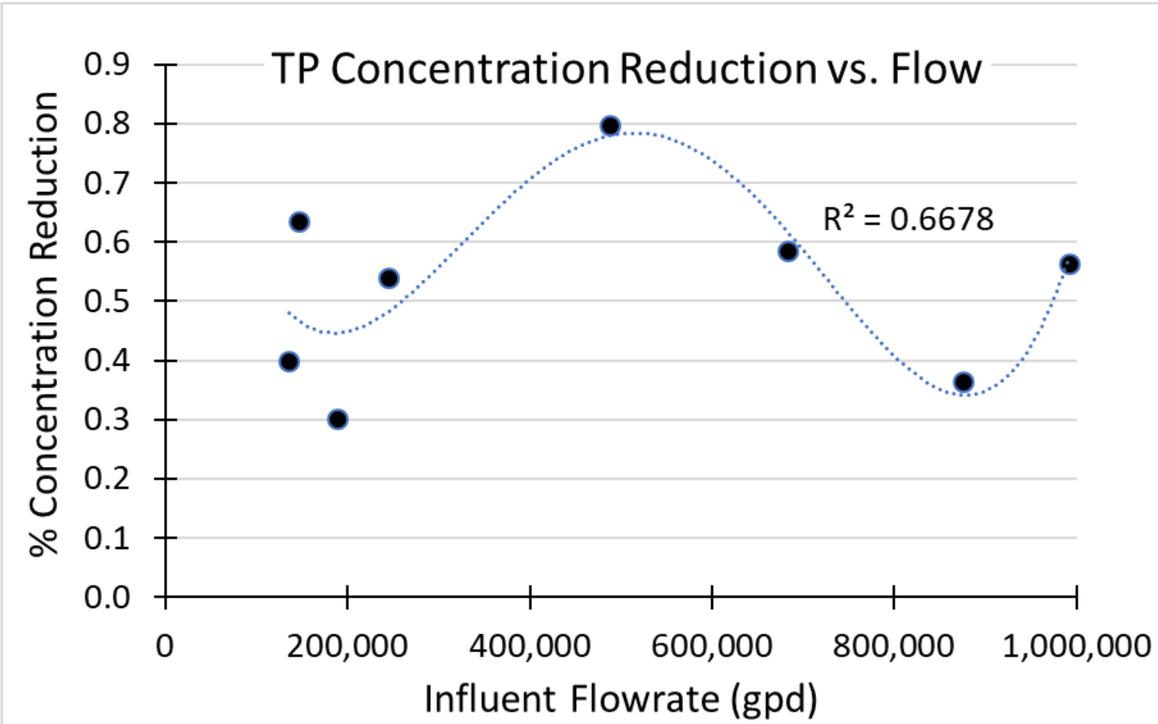


Figure 9. TP concentration reduction vs. influent flowrate during 1st year sampling events. Greatest TP concentration reduction occurred near 500,000 gpd.

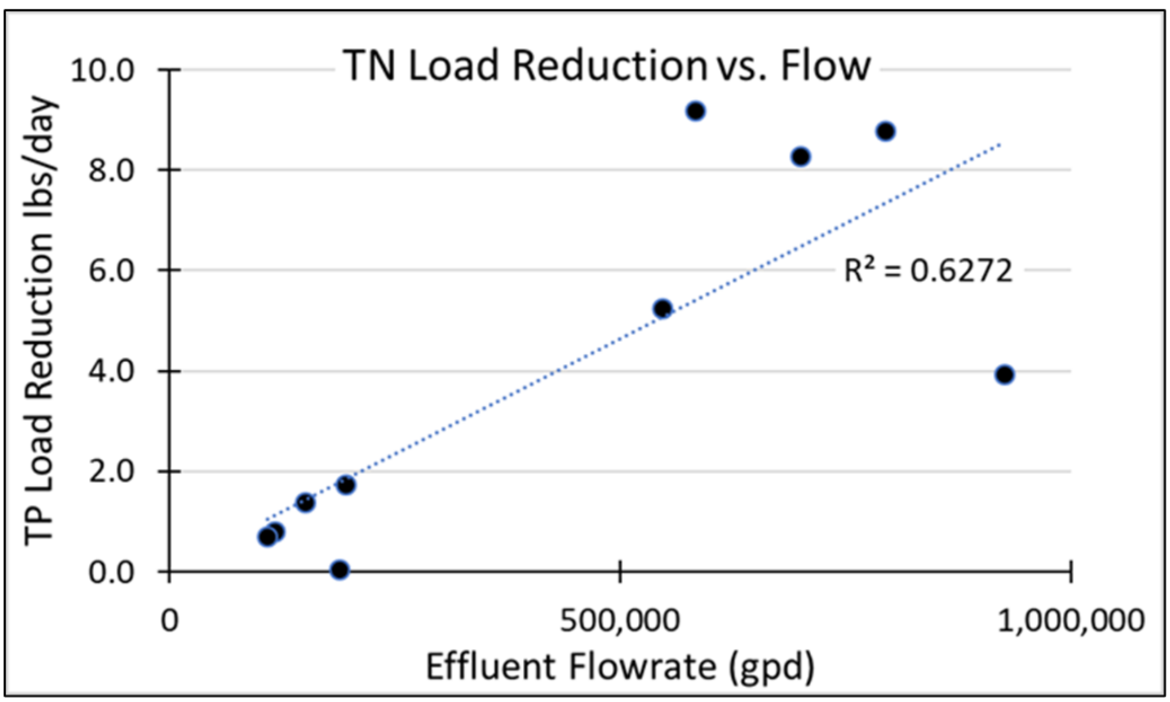


Figure 10. TN load reduction vs. influent flowrate during 1st year sampling events. Greatest TN concentration reduction occurred beyond 1,000,000 gpd.

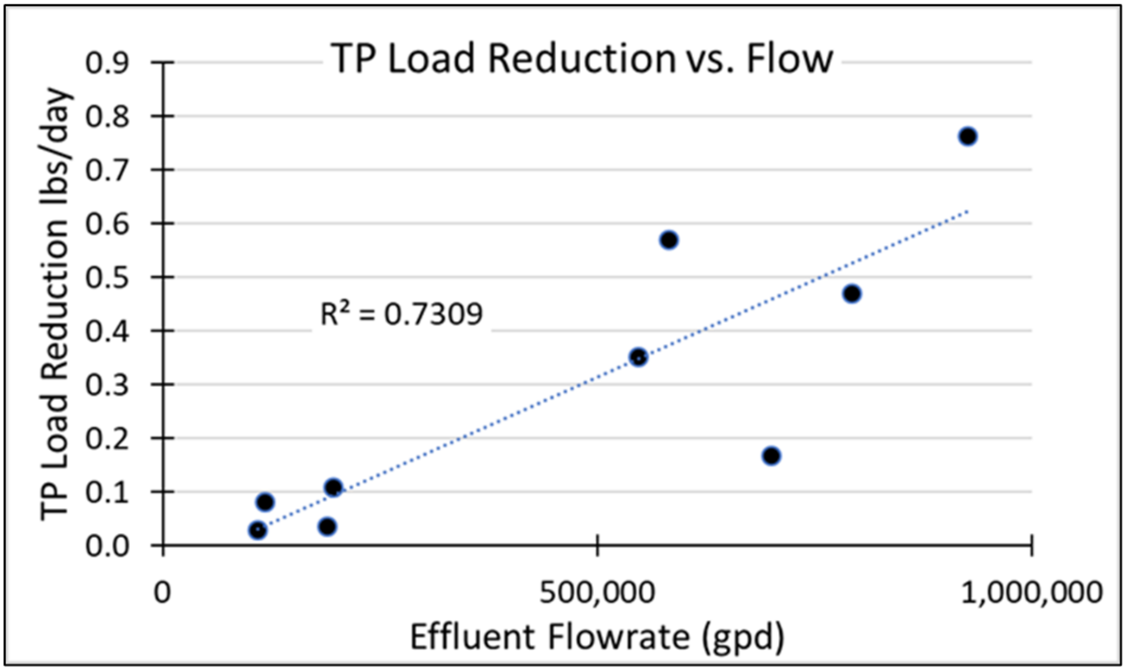


Figure 11. TP load reduction vs. influent flowrate during 1st year sampling events. Greatest TP load reduction occurred above 1,000,000 gpd.

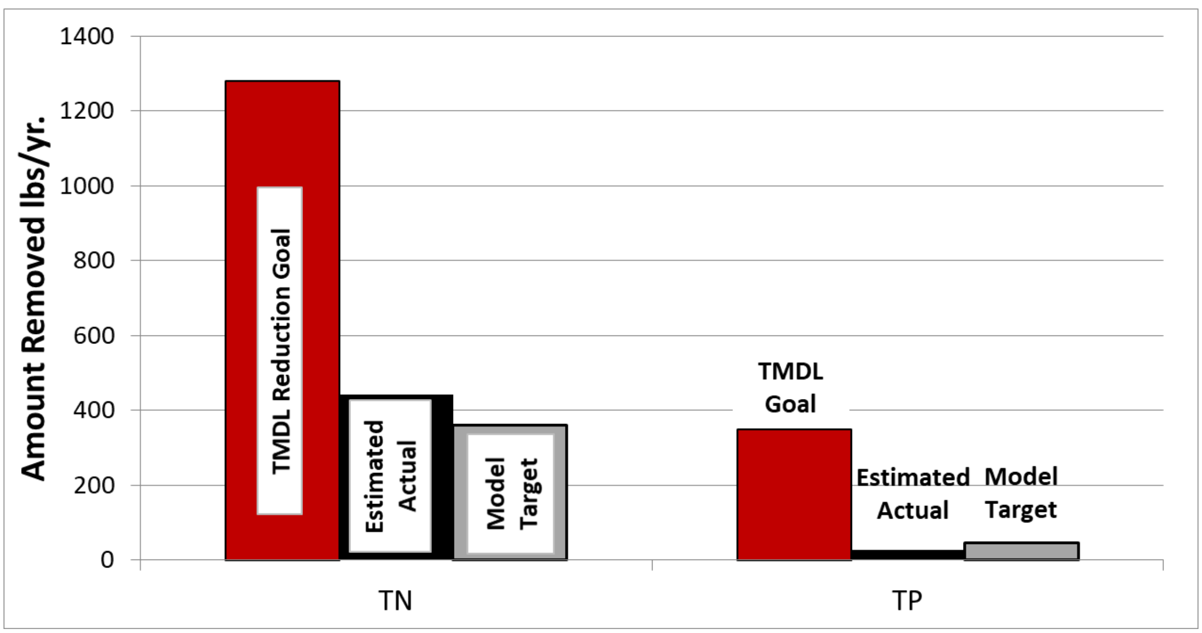


Figure 12. Actual TN and TP load reduction vs. original engineering design estimates of reduction and the load reductions required by the east basin Sanibel Slough TMDL.