Pollutant Removal Efficiency of Self-Converted Dry Detention Ponds
2015

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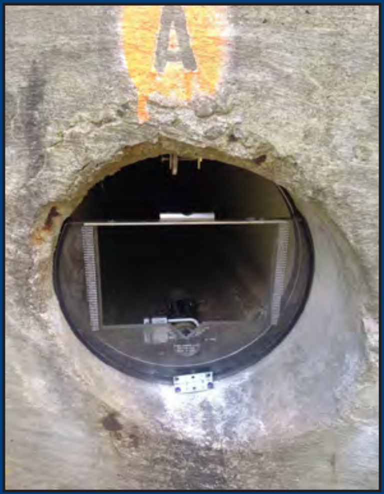

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Baltimore County, Maryland

Baltimore County Executive Kevin Kamenetz and the County Council

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EXECUTIVE SUMMARY

Background

Baltimore County, Maryland conducted a research study on the pollutant removal efficiency of self-converted dry detention ponds in an effort to better understand the removal efficiencies of ponds that have converted over time to include shallow marsh and/or forested wetland systems and to more effectively prioritize restoration activities for pollutant load reductions. A primary goal of this study was to test the hypothesis that self-converted dry detention ponds provide greater removal efficiencies than unconverted dry detention ponds. The County partnered with KCI Technologies, Inc. (KCI) and their project team including Towson University's Urban Environmental Biogeochemistry Laboratory (UEBL) and Chesapeake Environmental Management (CEM) to implement this study. The focus was the evaluation of dry detention ponds that have self-converted to ponds with soils and vegetation species that are characteristic of wetlands, which have not been well studied and may provide enhanced pollutant removal when compared to maintained (i.e., unconverted) dry detention ponds. The results will allow the County to determine the relative removal efficiencies (nutrients and solids) of self-converted dry detention ponds, as well as existing dry detention ponds, within the Piedmont physiographic region of Maryland, with the possibility of extrapolating those results within the County and potentially throughout the broader Chesapeake Bay watershed. Relative removal efficiencies for existing dry detention ponds may provide further evidence for increased credit for these BMPs for various portions of the Chesapeake Bay restoration framework. Results from this study may also help the County demonstrate progress towards addressing the stormwater wasteload allocations for water quality pollutants under its NPDES MS4 permit, and enhance the County's ability to more effectively prioritize restoration activities for pollutant load reductions across the County.

Methods

Three (3) self-converted (study) ponds and three (3) control ponds that met the needs of the study were selected following the guidance of the *Urban Stormwater BMP Performance Monitoring Manual* (USEPA, 2009) to ensure that the sites are optimally suited for the projects goals. Monitoring protocols for the study were implemented to evaluate the effectiveness of each type of facility at reducing pollutants, namely nutrients (total phosphorus and total nitrogen) and suspended solids. A Quality Assurance Project Plan (QAPP) (KCI, 2014) was developed for the study to ensure the data collected are consistent and of the highest quality. The study design consists of water quality monitoring, both storm flow and base flow (when present) sampling of influent and effluent at six facilities located throughout the County over the course of a year. The study began in the summer of 2014 and continued through the fall of 2015. Sampling was generally conducted to provide a range of small and large storm events representing all four seasons, with a total of 8 storm events spread throughout the year at each site. Precipitation samples were also collected in each season to document wet deposition of pollutants directly into the facilities. The study employed automated rain gauges at each facility to collect continuous precipitation data (10-minute intervals), as well as pressure transducer level loggers and flow gauging devices for continuous discharge gauging (5-minute intervals) at all inflow and outflow structures. Discrete water quality samples representing the rise, peak, and falling limb of each storm hydrograph were collected at each inlet/outlet and were laboratory analyzed for Total Suspended Solids (TSS), Total Kjehdahl Nitrogen (TKN), Nitrate/Nitrite Nitrogen, Total Nitrogen (TN), Total Phosphorus (TP), Orthophosphorus, and Total Dissolved Solids (TDS). Precipitation samples were analyzed for nutrients only.

Event Mean Concentration (EMC) values were calculated for each storm event, which were used to compare influent and effluent concentrations and evaluate BMP efficiency. Paired samples were compared using the non-parametric Wilcoxon signed-rank test (Wilcoxon, 1945). Cumulative distributions between influent and effluent EMCs were compared using a two-sample Kolmogorov-Smirnov test. EMCs were also used to evaluate BMP performance using the Effluent Probability Method (Burton and Pitt, 2001), which involves examining the influent and effluent quality on a standard probability plot.

Annual loads for TN, TP, and TSS were calculated using the U.S. Army Corps of Engineers' FLUX32 Load Estimation Software (Walker, 1999). Annual loads were estimated using the Flow-weighted Concentration (Ratio Estimate) method for each sampling parameter. The software uses the mean daily discharges that were calculated from the continuous level loggers, storm event EMCs, and base flow concentrations, where applicable, to calculate annual loading rates for influent and effluent. BMP performance utilizing annual loads was evaluated by determining the percent annual load reduction for each facility. Percent load reduction was determined by calculating the annual output load (effluent load) and dividing it by the combined input load (i.e., inlet loads plus direct rainfall load). Mann-Whitney (two-tailed) tests were performed to compare statistical differences in pollutant load reductions between study and control ponds.

Results

Wilcoxon signed-rank tests identified statistically significant reductions (at 90% confidence) for TN concentrations at one study pond and one control pond, for TP at a one study pond and one control pond, and for TSS at all three study ponds and two control ponds. Kolmogorov-Smirnov test results indicates statistically significant reductions of TN concentrations at one study pond, TP at one study pond, and TSS at two study ponds and one control pond. Estimated load reductions of TN ranged from 1% to 29% for control ponds, and 9% to 36% for study ponds, but no significant difference in pollutant removal rates between pond types for TN. Estimated load reductions for TP ranged from 15% to 42% for control ponds and 24% to 75% for study ponds, with no significant difference in pollutant removal rates between pond types. Removal rates were highest for TSS with percent reductions ranging from 19% to 73% for control ponds and 24% to 82% for study ponds. As with TN and TP, the difference in pollutant reductions between pond types was not statistically significant.

The results of this study suggest that mature (i.e., decades-old) dry detention ponds provide greater removal efficiencies than the crediting currently provides, whether they are considered self-converted or unconverted. Our study population of self-converted dry ponds showed average reductions of 23.3% for TN, 47.9% for TP, and 60.0% for TSS. Similar performance was observed unconverted dry detention ponds, with average reductions of 18.5% for TN, 28.8% for TP, and 53.2% for TSS. Comparison between the study results and the current approved CBP rates suggests that the self-converted group was quite similar to that of the wet pond/wetland category. The control group of un-converted ponds performed much better than the CBP dry detention pond rates and performed overall more closely to the dry extended detention pond rates.

1. INTRODUCTION

1.1 BACKGROUND

Baltimore County is conducting a research study on the pollutant removal efficiency of self-converted dry detention ponds in an effort to better understand the removal efficiencies of shallow marsh and/or forested wetland systems and more effectively prioritize restoration activities for pollutant load reductions. Data generated by this study will allow the County to test the hypothesis that self-converted dry detention ponds provide greater removal efficiencies than unconverted dry detention ponds. The County has retained KCI Technologies, Inc. (KCI) and their project team including Towson University's Urban Environmental Biogeochemistry Laboratory (UEBL) and Chesapeake Environmental Management (CEM) to implement this study. The focus of this study is the evaluation of dry detention ponds that have self-converted to ponds with soils and vegetation species that are characteristic of wetlands, which have not been well studied and may provide enhanced pollutant removal when compared to maintained (i.e., unconverted) dry detention ponds.

Best Management Practice (BMP) technologies are designed to control stormwater in one of three ways: preventing contaminants from coming into contact with stormwater by source control, reducing contaminant loads by physical, chemical, and/or biological treatment of stormwater discharged to surface or ground waters, or controlling the volume or flow rate of stormwater by quantity control. Dry detention pond BMPs were originally designed and installed primarily to provide quantity control with little to no water quality treatment of stormwater. Dry detention ponds are created by excavating a depression or constructing an embankment to temporarily store stormwater runoff and to release it slowly over time (USEPA, 2010; Koch et al., 2014). Dry detention ponds typically retain water for less than 24 hours and are dry between storm events (USEPA, 2010; Koch et al., 2014). The relatively short residence time allows for a limited amount of pollutant settling, microbial processing, or vegetative uptake when compared to dry extended detention structures (stormwater residence time of 24-48 hours) or wet ponds and constructed wetlands (Koch et al., 2014). Extended detention is designed to store runoff from the 1-year event for 24 hour drawdown. Current extended detention designs augment other ponds and wetlands, such as micropool ponds, wet ponds, or shallow wetlands.

This study focuses on facilities designed and constructed as dry detention ponds, therefore dry extended detention facilities were specifically excluded. Wet ponds and wetlands are designed to have a permanent pool that stores the water quality volume. They differ in that wetlands are designed with a shallow basin of 6-8 inches for most of the area promoting wetland vegetation and nutrient uptake. Wet ponds are typically deeper providing sedimentation for pollutant removal, and are designed with an aquatic bench at the perimeter providing for more limited vegetative uptake.

Consideration for urban stormwater management ponds in the Chesapeake Bay restoration framework includes varying crediting for pollutant removal and for impervious surface treatment, depending on the type of facility. The Chesapeake Bay Program's Urban Stormwater Workgroup established an expert panel to study stormwater performance and recommend standard removal rates. The expert panel published the 'Recommendations of the Expert Panel to Define Removal Rates for New State Stormwater Performance Standards' in 2012 with updates in January 2015 (Schueler and Lane, 2012a). The expert panel's approved rates give pollution removal credit for dry detention ponds at rates of 5% (TN), 10% (TP) and 10% (TSS). Rates for dry extended detention, and wet ponds/wetlands were also provided and are presented here in Table 1. The removal rates are consistent with pollutant removal credit in the current version of the Chesapeake Bay Program's Watershed Model (v5.3.2) (USEPA, 2010), and are therefore consistent with the Maryland Assessment Scenario Tool (MAST), which Phase I municipalities rely on for modeling baseline loads, wasteload allocations, and target reductions, using the same pollutant removal efficiencies as the Chesapeake Bay Program's Watershed Model (MDE, 2014b).

The expert panel developed a series of BMP removal rate adjustor curves used to determine removal rate for two different classes of BMPs including those that provide runoff reduction (RR) and more standard approaches termed 'stormwater treatment (ST) practices'. Because dry ponds and dry extended detention ponds have relatively low removal rates they are omitted from the ST category and are not encouraged or promoted under new state stormwater performance standards. Dry facilities are no longer included in Maryland's stormwater design manual. Municipalities would not get restoration credit for installation of dry facilities. Wetland ponds and wetlands fall into the ST category and are given removal rates on the adjustor curve equivalent to 33% (TN), 52% (TP), and 66% (TSS) assuming treatment of 1.0-inch rainfall depth, which is the full water quality volume (WQv).

Table 1 - Chesapeake Bay Program[1] BMP Reduction Efficiency

BMP Type	Reduction Efficiency		
	TN	TP	TSS
Dry Detention Pond	5%	10%	10%
Dry Extended Detention	20%	20%	60%
Wet Ponds/Wetlands	20%	45%	60%

[1] Schueler and Lane, 2012

For impervious treatment, stormwater facilities are credited by determining the proportion of the WQv treated versus that required, or the equivalent runoff depth treated in inches. Dry ponds and dry extended detention ponds by their definition do not provide water quality treatment and are therefore not credited with impervious surface treatment. Municipalities can however demonstrate on a case by case basis facilities that based on their specific design are providing water quality volume treatment and can be credited. Crediting for wet ponds / wetlands is determined by multiplying the inches of runoff treated times the impervious surface in the facility drainage area, such that treatment of the 1.0-inch runoff provides 100% treatment.

Previous studies have indicated that dry detention ponds can provide greater removal efficiencies than are currently credited through the Chesapeake Bay Program's Watershed Model, possibly due to self-conversion of dry ponds to shallow marsh or forested wetlands. A review of stormwater BMP monitoring studies and data by the Center for Watershed Protection found that dry ponds had median pollutant removal rates of 25% for TN, 19% for TP, and 47% for TSS (Winer, 2000). A recent review of available data regarding stormwater management BMPs and pollutant removals found that dry detention ponds had a removal efficiency of 27% for total nitrogen (Koch et al., 2014). Another conclusion of the review was that data used to derive pollution removal efficiencies often relied on a single sample, or only a few samples over time for analysis. The results of these reviews suggest that the pollution removal credits for dry detention ponds used in modeling in Maryland may be too low. An expert panel, convened by the Urban Stormwater Workgroup and Water Quality Goal Implementation Team, recommended enhanced pollutant removal rates for BMPs converted to wet ponds and wetlands (Schueler and Lane, 2012b). While these enhanced removal rates are for BMPs which are retrofitted via construction activities, self-conversion of dry ponds are an existing data gap and may realize similar water quality benefits. This Baltimore County study will help develop a robust data set which can objectively assess pollutant removal efficiencies and begin to fill the data gap for self-converted dry ponds.

1.2 GOALS OF THE STUDY

The results of this study will allow the County to determine the relative removal efficiencies (nutrients and solids) of self-converted dry detention ponds within the Piedmont physiographic region of Maryland, with the possibility of extrapolating those results within the County and potentially throughout the broader Chesapeake Bay watershed. Pollutant removal efficiencies for existing dry detention ponds from this study may provide further evidence for increased credit for these BMPs for various portions of the Chesapeake Bay restoration framework. Pollutant removal efficiencies from this study may help the County demonstrate progress towards addressing the wasteload allocations for primary pollutants under its NPDES MS4 permit. Results of this study will also enhance the County's ability to more effectively prioritize restoration activities for pollutant load reductions across the County.

2. METHODS

2.1 OVERVIEW OF MONITORING ACTIVITIES

Monitoring efforts were developed to compare the pollutant removal efficiencies of two types of stormwater management facilities, standard dry detention and dry detention that have self-converted over time to include wetland systems within the facility footprint. Monitoring protocols for the study were implemented to evaluate the effectiveness of each type of facility at reducing priority pollutants, namely nutrients (total phosphorus and total nitrogen) and suspended solids.

A Quality Assurance Project Plan (QAPP) (KCI, 2014) was developed for the study to ensure the data collected are consistent and of the highest quality. The QAPP includes standard operating procedures (SOPs) for routine field methods, deployment and maintenance or gauging equipment, and laboratory analysis. Additionally, individual site sampling plans were developed for each selected control and study site to ensure the sampling procedures would meet the individual needs of each specific site and to ensure a level of consistency between varying field crews. Sampling methods are briefly described in this methods section. Detail on specific sites can be found in the QAPP Site Specific Sampling Plans (KCI, 2014).

The study consists of water quality monitoring, both storm flow and base flow (when present) sampling of influent and effluent at six facilities located throughout Baltimore County, Maryland over the course of a year. The study began in the summer of 2014 and continued through the fall of 2015. Sampling was generally conducted to provide a range of small and large storm events representing all four seasons, with a total of 8 storm events spread throughout the year. Rain samples were collected in each season to document direct wet deposition of pollutants to the facilities. The study employed automated rain gauges at each facility to collect precipitation data, as well as installed pressure transducer level loggers and flow gauging devices for continuous discharge gauging at all inflow and outflow structures.

Water quality samples representing the rise, peak, and falling limb of each storm hydrograph at each inlet/outlet and for the sampled rainfall were laboratory analyzed for Total Suspended Solids (TSS), Total

Kjehdahl Nitrogen (TKN), Nitrate/Nitrite Nitrogen, Total Nitrogen (TN), Total Phosphorus (TP), Orthophosphorus, and Total Dissolved Solids (TDS). This report will focus on the TN, TP and TSS results.

2.2 SITE SELECTION

2.2.1 Criteria for Selection

Three (3) self-converted (study) ponds and three (3) control ponds that met the needs of the study were selected following the guidance of the *Urban Stormwater BMP Performance Monitoring Manual* (USEPA, 2009) to ensure that the sites are optimally suited for the projects goals. The County's existing BMP database and relevant data files were reviewed to develop a short-list of potential self-converted ponds for inclusion into the study. Field visits were then conducted to verify site conditions and assess sampleability. Sites were selected to meet the two study populations criteria (dry versus self-converted) and also to meet sampleability requirements. Sampleability was largely depending on how well the facility could be instrumented for continuous discharge gauging. These criterion are outline here.

General Inclusion - Criteria for inclusion in either sample population:

- Facility must be a dry detention pond
- Facility must not be a dry extended detention pond
- Attempt will be made to select sites representing a range of land use conditions including impervious cover and drainage area

Control Ponds - Specific criteria used to select control ponds included the following criteria:

- Facility must not contain wetland (based on criteria below)
- Facility must have regularly maintained vegetation

Study Ponds - Specific criteria used to establish self-converted ponds and wetland status included the following criteria:

- Facility must contain wetland soils
- Facility must have evidence of wetland hydrology
- Facility must support wetland vegetation
- Facility must be well-vegetated and must not be actively mowed
- Attempt will be made to select a range of wetland percentages

Sampleability - Specific criteria used to determine if pond could be sampled:

- Inlets and outlets should be accessible for gauging instruments
- Pipe slopes should be low enough to allow for accurate flow gauging
- Pipes should not be backwatered at regular intervals

2.2.2 Wetland Determination

Wetland status was determined through a wetland delineation performed inside the pond footprint at each site. KCI utilized the "Routine Determination" method to identify wetland boundaries within the ponds. Delineations were conducted using the criteria outlined in the *Corps of Engineers Wetlands Delineation Manual* (Environmental Laboratory, 1987) and the *Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Atlantic and Gulf Coastal Plain Region (Version 2.0)*

(Environmental Laboratory, 2010). Areas suspected to be wetland would need to meet the three wetland criteria for vegetation, hydrology, and soils.

At each site, dominant plant species within suspected wetland areas were identified and recorded for each stratum present. The United States Army Corps of Engineers (USACE) *National Wetland Plants List (NWPL) Atlantic and Gulf Coastal Plain Region* (Lichvar and Kartesz, 2009*)* was used to determine the indicator status of the vegetation found within each community. KCI then characterized the plant community as hydrophytic or upland based upon the results of the Dominance Test and the Prevalence Index worksheets within the *Wetland Determination Data Form – Atlantic and Gulf Coastal Plain Region*.

KCI assessed wetland hydrology within the study area based on the presence of one primary or two or more secondary hydrology indicators. Surface water inundation, depth to soil saturation, drift lines, water marks, and sediment deposits are some of the primary indicators listed in the *Wetland Determination Data Form – Atlantic and Gulf Coastal Plain Region*. Secondary indicators include surface soil cracks, a sparsely vegetated concave surface, drainage patterns, and moss trim lines, as well as other less commonly found indicators.

Soil pits were typically excavated to a depth of approximately 18-24 inches, barring refusal, or immediately below the A-horizon. KCI recorded soil texture and the color of the matrix and any concretions or soft masses within a representative soil sample were assigned hue, value, and chroma utilizing the *Munsell Soil Color Charts* (Munsell, 2000). All soil samples were thoroughly investigated for the presence of redoximorphic features and/or hydric soil indicators included in *Field Indicators of Hydric Soils* (USDA-NRCS, 2010) and the *Wetland Determination Data Form – Atlantic and Gulf Coastal Plain Region*. KCI then classified soils as hydric or non-hydric based upon the presence or absence of hydric soil characteristics and indicators.

KCI determined areas to be wetlands once all three wetland parameters (vegetation, hydrology, and soils), as described above, were identified (Environmental Laboratory, 1987 and 2010). When wetlands were identified in the field, the boundaries was captured using GPS with sub-meter accuracy. Area of wetland and percent wetland of pond bottom were calculated to characterize the ponds.

2.2.3 Site Selection Results

A total of six (6) dry detention stormwater pond facilities located throughout Baltimore County were selected to serve as monitoring locations. Sites were located throughout the County, but generally to the north and west of the Baltimore Beltway (I-695); (Figure 1).

Sites within each group (control and self-converted) were selected to be generally representative of the broader population of dry detention ponds located throughout Baltimore County. Both study populations included ponds in commercial, medium density residential, and low density residential settings (Table 2). A range of drainage areas and impervious areas are accounted for and the impervious area generally follows the same pattern as the land use with commercial sites at 60% impervious or greater, medium density residential sites approximately 24% and low density residential ranging from approximately 10 to 12%.

The runoff curve number (CN) is an empirical parameter used in hydrologic studies for predicting direct runoff or infiltration from rainfall excess. A CN value was derived for each pond drainage area to express the overall level of runoff potential for each site. A higher CN indicates greater runoff potential while a lower CN indicates lower runoff potential. The CN values for this study were calculated using hydrologic soil groups and land cover factors. The CN values range from 68.8 to 82.7 for the self-converted sites and from 67.9 to 93.7 for the control sites and follow the same pattern described above in regards to the land use type and impervious surface.

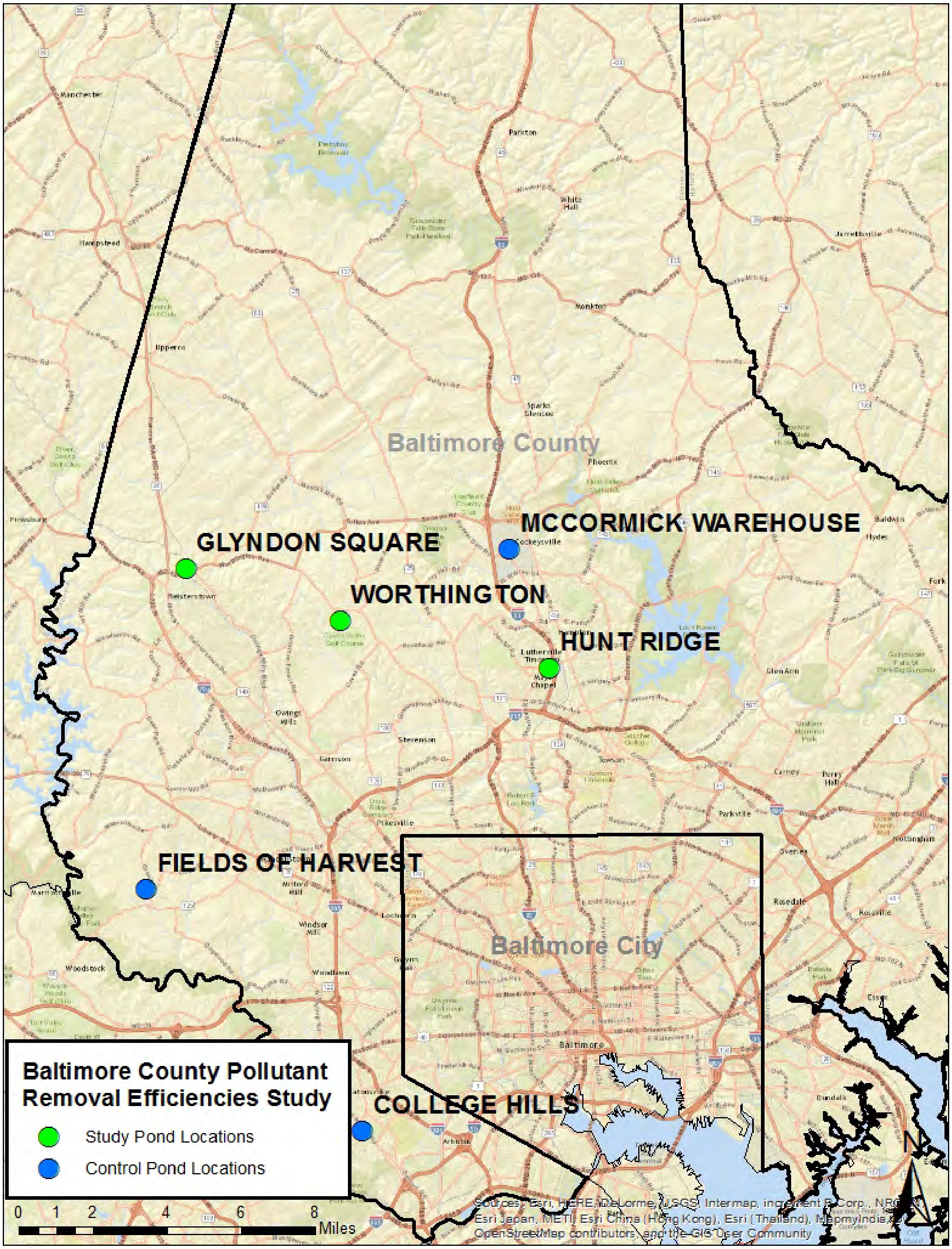
Table 2 - Pond Drainage Area Characteristics

Facility and Code	County Pond #	Predominant Land Use	Drainage Area (ac)	Impervious Area (ac)	Impervious Percent	Runoff Curve Number
Study (Self-Converted) Ponds						
Glyndon Square (GS)	18	Commercial	5.7	3.43	60.0	82.7
Hunt Ridge (HR)	111	Residential (Medium Density)	20.6	4.82	23.4	78.9
Worthington (WO)	64	Residential (Low Density)	63.4	6.81	10.7	68.8
Control Ponds						
McCormick (MC)	1385	Commercial	8.6	6.07	70.9	93.7
College Hills (CH)	415	Residential (Medium Density)	8.0	1.97	24.6	75.9
Fields of Harvest (FH)	495	Residential (Low Density)	7.2	0.91	12.6	67.9

Characteristics of the ponds are included in Table 3. Most importantly the wetland area and percent wetland are presented. The wetland percent is calculated as the percent of the pond bottom. Worthington, at 82% wetland has the largest wetland area and the largest percentage of wetland among the study ponds. Hunt Ridge, the largest facility by overall pond footprint area and pond bottom area includes a much smaller wetland area at 0.02 acres and only 4%. All of the ponds are older than 25 years with most built in the late 1970s and early 1980s.

Table 3 - Pond Facility Characteristics

Facility and Code	County Pond #	Number of Inlets	Pond Year Built	Pond Age (years as of 2015)	Pond Footprint Area (ac)	Pond Bottom Area (ac)	Wetland Area (ac)	Wetland Percent
Study (Self-Converted) Ponds								
Glyndon Square (GS)	18	1	1979	36	0.92	0.37	0.23	62%
Hunt Ridge (HR)	111	2	1981	34	1.19	0.50	0.02	4%
Worthington (WO)	64	1	1979	36	0.98	0.48	0.39	82%
Control Ponds								
McCormick (MC)	1385	2	1977	38	0.32	0.11	0.00	0%
College Hills (CH)	415	1	1988	27	0.25	0.08	0.00	0%
Fields of Harvest (FH)	495	1	1985	30	1.04	0.37	0.00	0%



Sources: Esri, HERE, DeLorme, USGS, Intermap, increment P Corp., NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

Figure 1 - Site Location Map

2.3 SITE CHARACTERISTICS

The following descriptions provide details for each of the study and control ponds selected for investigation with drainage area maps and select photos included for descriptive purposes. Additional site photos are included in Appendix A, including photos of each inlet and outlet pipe sampling location.

2.3.1 Study (Self-Converted) Sites

Figure 2 - Glyndon Square facing south from behind Outlet. Inlet A at top left and Inlet B at top right of photo.

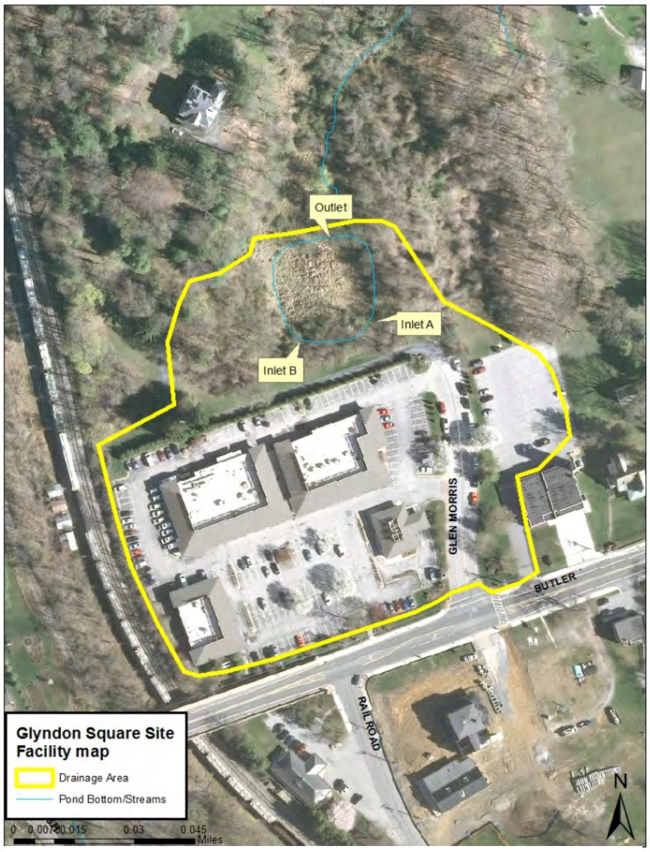


Figure 3 - Glyndon Square Site Facility Map

<u>Glyndon Square (GS)</u>

Glyndon Square is a self-converted pond located behind a commercial shopping center in Glyndon, Maryland. The pond has two inlets, inlet A, which drains Glen Morris Rd along with half of the impervious surface of the shopping center, and inlet B draining the other half of the shopping center (Figure 3). Frequent observations of foul smelling odors and darkly colored waste water were noted at inlet B, the source of which was identified as a commercial dumpster.

Pond slopes consist of a combination of typical deciduous woods with trees and dense understory vegetation and grasses. The wetland portion of the pond bottom has a mixture of wetland grasses and forbs, and cattail species *(Typha spp.)* (Figure 2). Wetland makes up 62% of the pond bottom area.

Inlet A saw episodic base flow throughout the year which was almost always captured and stored by the pond as base flow was not observed with regularity at the outlet. Inflow from both inlets flows through short, 20-30 ft channels into the main pond area. Inflow then moves over and through wetland like soils and vegetation, with no direct confined channel of flow observed throughout the sampling year.

With large amounts of storm flow interacting with wetland soils and vegetation, it was expected that GS would perform well with respect to load reductions of TN, TP and TSS.

Hunt Ridge (HR)

Hunt Ridge is a study pond located just west of I-83 alongside the eastbound lane of West Timonium Lane between Hunters Ridge Rd and Holly Ridge Ct in Timonium, Maryland.

The pond has two inlets, both of which drain residential communities (Figure 5). The pond slopes and bottom consist of a combination of trees, shrubs, and herbaceous plants. Influent from Inlet A followed a relatively direct flow path to the low flow perforated pipe of the outlet; however there was a large debris dam between Inlet A and the outlet which caused water to pool prior to entering the low flow pipe of the outlet. Flow from inlet B first drains into a small cattail wetland area in the southwest corner of the pond prior to making its way to the low flow outlet pipe. The wetland makes up only 4% of the pond bottom area.

Large amounts of sediment and coarse particulate organic matter (CPOM) have accumulated around the low flow outlet pipe causing many holes in the perforated pipe to be covered or partially clogged (Figure 4). With fewer openings available for drainage, there appears to be an increased retention time of the influent prior to being discharged through the outlet.

Figure 4 - Hunt Ridge pond bottom facing west at low flow perforated Outlet pipe.

Figure 5 - Hunt Ridge Site Facility Map

Worthington (WO)

Worthington is a study pond located at the corner of Chellis Ct and Heneson Garth in Owings Mills, MD. The pond has the largest drainage area of the ponds in this project and is located in a low density residential neighborhood (Figure 7).

Pond slopes consist of both typical deciduous woods and grasses while the pond bottom is wetland plant species dominated by common reed (*Phragmites australis*).

Consistent baseflow was observed at both the inlet and outlet of this pond throughout the year, likely due to interception of groundwater. At the base of the inlet there is a deep scour pool (approximately 1 – 2 ft.), which provides some temporary small storage of the influent (Figure 6).

Although there is a large percentage of wetland present in the pond (82%), a direct flow path conveys flow from the pool at the inlet to the outlet. With this direct channel in place, event intensity and overall storm volume likely has an effect on the retention time. Smaller and less intense events may be conveyed completely within the channel, bypassing the adjacent wetland system. It is also possible that during low intensity events, that retention time in the channel is greater as the flow will be moving more slowly from inlet to outlet allowing relatively greater gravitational settling to occur. More intense storms will be conveyed faster from inlet to outlet, resulting in less retention time; however higher intensity and volume events will also access the wetland area which would result in higher levels of retention and treatment. During high intensity storms the time between flushing at the inlet and outlet is 15-20 minutes.

Figure 6 - Worthington pond bottom facing west at Inlet pool and direct channel

Figure 7 - Worthington Facility Site Map

2.3.2 Control Sites

College Hills (CH)

College Hills is a control pond located southwest of the cul-de-sac on Hunter Way in Catonsville, MD. A single inlet drains this residential neighborhood with a high percentage of impervious surface (Figure 9).

The pond bottom and slopes are turf grass which is mowed on a regular basis. A rip rap pilot channel connects the inlet to the outlet in this pond (Figure 8). Prior to the study the pilot channel had become filled with sediment. Excavation of the pilot channel down to the original channel elevation was necessary to gauge the pond inflow without experiencing significant and regular backwatering into the inlet.

Large amounts of road grit are deposited into the pond from the inlet. This was regularly removed by sampling crews during site visits. During sampling of several intense events a sediment source was noted originating from the property immediately to the northeast of the Hunter Way cul de sac and flowing into the inlet at the southeast of the cul de sac.

Very large and intense rainfall events are required for influent to get out of the pilot channel and flood onto the broad grassy area of the pond bottom. Flow travel time between the inlet and outlet is between 5-10 minutes.

Figure 8 - College Hills pond facing northeast from the outlet towards the inlet. Direct flow path during storm event is evident.

Figure 9 - College Hills Site Facility Map

Fields of Harvest (FH)

Fields of Harvest is a control pond located on Harvest Fields Dr. in Woodstock, Maryland. A single inlet drains this low density low impervious residential neighborhood (Figure 11). Adjacent to this pond to the west is an agricultural field and a powerline utility clearing. To the east is a residential property with a well-manicured lawn

The pond bottom and side slopes consist of mowed turf grass with a small amount of herbaceous plants located directly downstream of the inlet (Figure 10).

Fields of Harvest does not have a direct pilot channel from inlet to outlet which allows the influent to contact more soil and vegetation as it travels to the inlet. Influent flow travels toward the southeast corner of the pond, spreading over the whole basin before exiting the pond.

Figure 10 - Fields of Harvest pond overview facing north from the outlet towards the inlet.

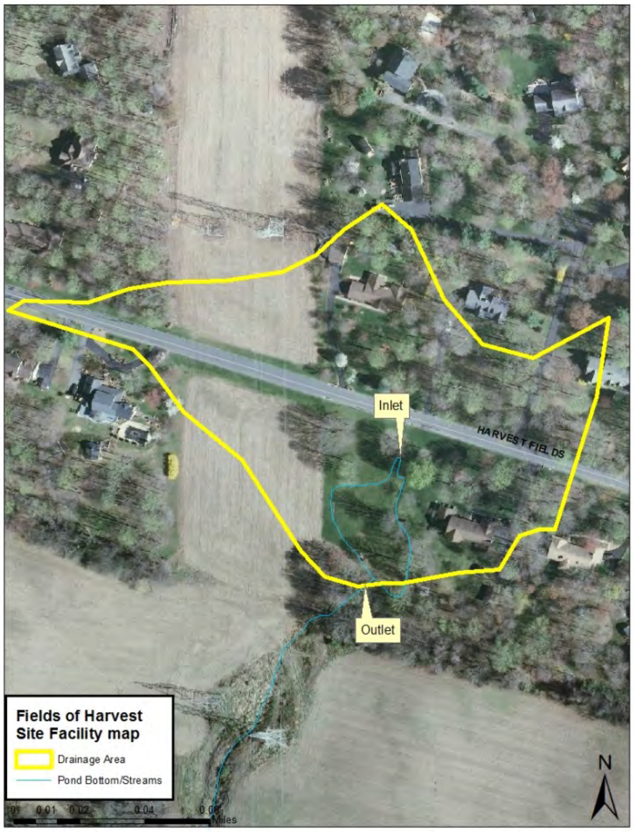


Figure 11 - Fields of Harvest Site Facility Map

McCormick Warehouse (MC)

McCormick Warehouse is a control pond located along the northbound side of McCormick Rd across from McCormick and Company. This pond has two inlets which drain a highly impervious commercial property (Figure 13).

Inlet A drains the northwest portion of the property and makes up about 10 percent of the total influent volume. Inlet B drains the other 90 percent of the property. Inlet B also experiences regular baseflow which is captured completely in the pond as there is no outlet baseflow.

Inlet A influent flows towards a low depressional area in the northwest corner of the pond, which is providing storage. While no elevation survey data was collected, the area is approximately 1.5 feet below the outlet low flow orifice at its lowest elevation and a significant area across the western half of the pond is approximately 0.5 to 1.0 feet below the orifice invert.

Inlet B has a direct channel leading from the inlet to the area at the outlet pipe. The upstream half of the channel closest to the inlet pipe consists of riprap bottom and eroded banks. The bottom portion of the channel consists of tall grasses. Some attenuation just prior to the outlet orifice does occur in the dense grassy area at the orifice.

This pond is maintained regularly, but has multiple plant types on the slopes and bottom, unlike the other control ponds with mainly mowed grass (Figure 12). Side slopes are dominated by grasses and Japanese knotweed (*Polygonum cuspidatum*). The pond bottom is dominated by hummocky grasses including red fescue (*Festuca rubra*), with smaller amounts of yellow nut-sedge (*Cyperus esculentus*) a facultative wet plant.

Figure 12 - McCormick Warehouse pond during storm event. Facing southeast from outlet towards inlet A.

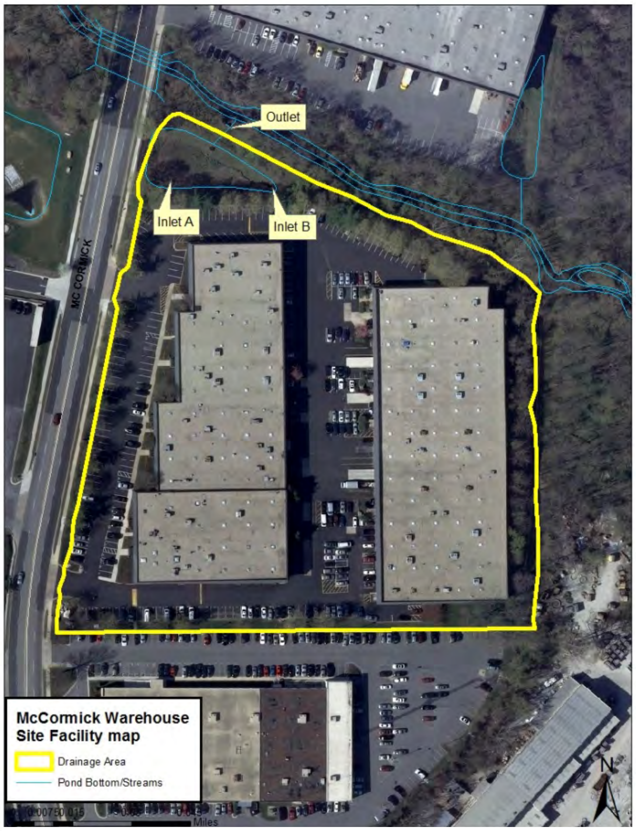


Figure 13 - McCormick Warehouse Site Facility Map

Wetland delineation results in this facility did indicate hydrologic indicators (water stained leaves and saturation) but did not have adequate soils or wetland plants to qualify as wetland.

2.4 EVENT SAMPLING

Water quality sampling was performed during eight (8) storm events spread over the course of approximately one year at each monitoring location. To attempt a storm event, the timing and forecast generally required a minimum of 24 hours of antecedent dry time, with a predicted rainfall of no less than 0.10 inches. It was subsequently found that many of the ponds received influent runoff and outlet flow with less than 0.10 inches of rainfall depending on the intensity of the event.

An attempt was made to sample a range of storm events (both large and small), so as to provide a representative sample of storm events throughout the year. Storm events were generally spread out over each season such that two (2) samples would be collected per season to capture any variability that may occur due to seasonality.

Sampling was generally limited to storm flow; however, some sites had periodic base flow, which required additional base flow sampling prior to storm flow sample collection. Specific procedures for each type of sampling are described below.

2.4.1 Base Flow Sampling

Base flow samples were collected immediately prior to a sampling event whenever base flow was present. Samples were collected after a minimum of 24 hours of dry weather. Sampling entailed collecting a single grab sample from each monitoring station where base flow was observed. Date, time, water level and other site observations were recorded at the time of sample collection.

For each sample, one 2-Liter sample bottle was filled using a sample bottle or plastic scoop. Sample bottles were clean from the laboratory. The scoop device, which was needed during periods of low flow was cleaned between sampling events. During sampling events, it was rinsed once with distilled water and three times with sample water prior to sample collection.

Once collected, samples were immediately preserved on ice and sent to the laboratory for processing and analysis. Chain of Custody (COC) forms were filled out completely and accompanied each sample delivery to the lab. COC forms were filled out following a standard operating procedure (KCI-SOP-WQ-004: Completing Stormwater Grab Sample Chain of Custody Record).

2.4.2 Storm Flow Sampling

Storm flow water quality samples were collected during eight (8) storm events at each of the aforementioned ponds. All storm flow samples were collected manually according to the procedure summarized here. Full sampling protocols are included in site specific 'Sampling Plans' included in the project QAPP (KCI, 2014).

To representatively sample storm flow, a total of three samples were collected from each inlet/outlet location, representing the rising limb, peak, and falling limb of the storm hydrograph. The rising limb sample was typically represented by the first flush. Following the first flush and collection of the rising limb sample, stage measurements were observed from the gauging device and recorded approximately every 5-10 minutes or more frequently depending on the rainfall intensity and discharge variability. The stage was converted to discharge using site specific stage-discharge rating tables and a hydrograph was generated real-time in the field to identify the appropriate time for collecting the peak and falling limb samples. Each grab sample was collected into a single 2-Liter sample bottle. Data recorded with each sample collection included time, stage, cumulative rainfall amount and general observations (e.g., water color, foaming, odor). Once collected, samples were immediately preserved on ice for laboratory analysis. COC forms were filled out following a standard operating procedure (KCI-SOP-WQ-004: Completing Stormwater Grab Sample Chain of Custody Record).

2.5 CONTINUOUS DISCHARGE MONITORING

Continuous discharge was monitored at each site using a combination of flow restriction gauging devices (i.e., weirs, orifices) paired with pressure transducer level data loggers. In-Situ Rugged TROLL® 100/200 data loggers (In-Situ, Inc., Fort Collins, CO) were installed in the inflow and outflow structures at each site and programmed to record measurements at 5-minute intervals providing a continuous record of water depth and temperature throughout the sampling period. In-Situ Rugged BaroTROLL® data loggers were installed to record barometric pressure at 5-minute intervals to allow for pressure compensation of water level data. Loggers were downloaded and maintained regularly following a standard operating procedure (KCI-SOP-TE 002: Use of In-Situ RuggedTroll 100 and BaroTROLL Devices).

All inlet and outlet structures were outfitted with flow restriction devices with known dimensions to develop stage-discharge rating curves for measuring discharge. Most inlet/outlet pipes were outfitted with Thel-Mar volumetric weirs (Thel-Mar LLC., Brevard, NC); however, some were outfitted with custom weir plates or round plate orifices due to unusual or atypical site conditions. Weir plates were generally sized to pass a 2-year storm event and consisted of either a 90° v-notch, 120° v-notch, or compound weir. Stage vs. discharge rating curves were developed at each monitoring station to convert level readings to instantaneous discharge, in cubic feet per second (cfs). Photos of flow gauging devices as well as inlet/outlet structures are included in Appendix A.

2.6 PRECIPITATION

Precipitation was accounted for both in terms of amounts and in terms of pollutant loading to the system. The following describe the two data collection methods. Loading calculations are described in later sections of the report.

2.6.1 Precipitation Monitoring

Precipitation monitoring was performed at each site using automated rainfall gages. Onset RG3 data logging rain gauges (Onset Computer Corp., Bourne, MA) were installed at each site, calibrated, and programmed to record rainfall at 10-minute intervals throughout the duration of the monitoring period. Monitoring followed a standard operating procedure (KCI-SOP-TE-003: Use of Onset HOBO Logging Rain Gauge RG3 Device). Additionally, Tru-Chek® rain gages (Edwards Manufacturing Co., Albert Lea, MN) were used at each site during storm events to measure precipitation and rainfall intensity specific to each storm and for field validation of the automated units.

2.6.2 Precipitation Sampling

To account for pollutant contribution from direct rainfall and wet deposition of aerosol particles, rainfall water quality samples were taken throughout the sampling year at a variety of pond sites. Samples were collected using a rainfall collection tray mounted to the 2-Liter sample bottle. Rainwater was collected throughout the duration of the storm event and each bottle filled was immediately preserved on ice and transported to the laboratory for analysis. COC forms were filled out following a standard operating procedure (KCI-SOP-WQ-004: Completing Stormwater Grab Sample Chain of Custody Record).

2.7 WATER QUALITY LABORATORY ANALYSIS

Stormflow, baseflow, and precipitation samples were analyzed by Towson University's UEBL for the following parameters: Total Suspended Solids (TSS), Total Nitrogen (TN), Total Kjehdahl Nitrogen (TKN) by subtraction, Nitrate/Nitrite Nitrogen, Total Phosphorus (TP), Orthophosphorus, and Total Dissolved Solids (TDS). A small subset of sample analysis for TP was completed by Martel Inc. The analytical techniques including the method quantitation limits are presented in Table 4. Samples were processed in a metal free clean laboratory. QA/QC for all sample batches analyzed included one duplicate (split of a single sample) and one certified reference sample with every 10 samples analyzed. Results from samples run with SRM recoveries outside 85%-105% were discarded and reanalyzed (Appendix H).

Table 4 - Water Quality Analytical Methods

Analyte	Technique	Method Quantitation Limit
Total Suspended Solids (TSS)	SM 2540 D	1 mg/L
Ammonia Nitrogen	Ion Chromatography SM 4110 B.	0.1 mg/L
Nitrate/Nitrite Nitrogen	Ion Chromatography SM 4110 B.	0.1 mg/L
Total Nitrogen	ASTM D5176-08	0.1 mg/L
Total Phosphorus	Digestion followed by ascorbic acid method SM 4500-P B and 4500-P E	0.01 mg/L
Orthophosphorus	Ascorbic acid method SM 4500-P E	0.01 mg/L
Total Dissolved Solids (TDS)	SM 2540 C	1 mg/L

2.8 DATA ANALYSIS

2.8.1 Outlier Screening

In addition to the standard QA/QC procedures described in the QAPP (KCI, 2014), data were screened for outliers as recommended by the *Urban Stormwater BMP Performance Monitoring Manual* (USEPA, 2009). Data were screened for extreme outliers in XLSTAT version 2010.3.07, which are defined as values that exceed (or are less than) 3X the interquartile range for each sample population (Addinsoft, 2010). Values that exceeded this threshold were investigated to make sure that they were not erroneous (e.g., data entry errors, incorrect units) or inaccurate (e.g., exceeded lab performance standards, holding times, etc.). One TSS sample from HR was omitted from the data set due to questionable concentration values, three outlet TSS samples and one TP sample from WO were omitted due to likely contamination from bank erosion upstream of the sampling location, and one entire storm event at CH was omitted due to construction activities that generated atypical runoff into the facility and yielded questionable results.

Several additional extreme outliers were identified but remained in the data set after passing QC checks, as shown in the box plots in Section 3.4. These values were included in all statistical comparisons of storm EMCs; however, they were not included in the loading estimates because they could potentially skew the flow-weighted concentrations and lead to greater variability in the loading estimates. Loads were calculated both with outlier values and without. Flux variance and C.V. values were consistently lower with exclusion of the outliers present, which increases confidence in the result.

2.8.2 Event Mean Concentrations

Event Mean Concentration (EMC) is a statistical parameter used to represent the flow-proportional average concentration of a given parameter during a storm event (EPA, 2002). To calculate EMCs the following methods were used.

After downloading level logger data from each station, the data were compared against field measurements and adjusted accordingly prior to converting to discharge values. Flow volume (cubic feet) was determined for each measurement interval by taking the average discharge (in cfs) between the start of the period and the end of the period and multiplying by the number of seconds in the interval (i.e. 300 seconds in a 5-minute interval). Discharge data were then plotted graphically to produce hydrographs, which were used to partition out storm flow from base flow and to partition storm limbs (rise, peak and falling). Storm flow was separated from baseflow, typically when discharge decreased to a value equal to 1.1 times the baseflow discharge prior to the storm event. However, when this criteria could not be applied due to atypical conditions, the following alternative criteria were utilized:

1. If there was no baseflow prior to storm, the storm flow was cut once discharge returned to near zero flow or 24 hours after precipitation stopped, whichever occurred first.
2. If no additional precipitation occurred and 1.1 x baseflow conditions did not return, the storm flow was cut 24 hours after precipitation stopped.
3. If additional precipitation occurred (i.e., a new storm event) after precipitation stopped and the falling limb sample was collected, the storm flow was cut prior to the new storm event regardless of discharge.

The EMC for a storm event where discrete samples have been collected (i.e. samples collected during the rise, peak, and falling limb of a storm event), was calculated using the following formula:

$$EMC = \frac{\sum_{i=1}^{n} V_i C_i}{\sum_{i=1}^{n} V_i}$$

where,

V: volume of flow during period i
C: average concentration associated with period i
n: total number of measurements taken during event

2.8.3 Influent and Effluent Annual Load Calculation

Annual loads for total nitrogen, total phosphorus, and total suspended solids were calculated using the U.S. Army Corps of Engineers' FLUX32 Load Estimation Software (Walker, 1999). This program uses continuous flow data and lab analyzed samples to calculate loading mass per unit time (i.e., pollutant flux). Annual loads were estimated using the Flow-weighted Concentration (Ratio Estimate) method for each sampling parameter. This method bases the loading estimate on the flow-weighted average concentration times the mean flow over the averaging period, which amounts to a "ratio estimate" according to classical sampling theory (Cochran, 1977). The model uses the mean daily discharges that were calculated from the continuous level loggers, storm event EMCs, and baseflow concentrations, where applicable, to calculate annual loading rates. The loading estimation algorithm is calculated as follows:

$$W = \frac{Mean(w)Mean(Q)}{Mean\ (q)}$$

Where,

W: estimated mean flux over N days (lbs/year)

w: measured flux during sample i (i.e., concentration in sample X measured flow during sample),

Q = mean flow on day j

q = measured flow during sample i

2.8.4 Precipitation Load Calculation

Loads contributed by wet deposition were added to the FLUX results to derive a total annual load to each facility. Total annual rainfall converted to accumulating volume within the pond was derived by calculating the runoff from the side slopes separately from the pond bottom. It was assumed that because of differences in vegetation in the pond bottom versus the side slopes for some facilities that rainfall on each surface would contribute runoff, or accumulating volume to the pond at a different rate. Rainfall on the pond bottom was considered to be converted to accumulating volume at a rate of 100%. Side slopes used a CN value for the specific pond for the cover type and depending on soils. A fairly conservative approach was used and all were assumed to be C soils. The CN values for McCormick, Fields of Harvest, and College Hills were 'open space (good) grass, CN=0.74; and values for Glyndon Square, Hunt Ridge and Worthington were 'woods/grass combination (good), CN=0.72). The total annual rainfall converted to runoff or accumulating volume was the sum of the product of the side slope area, rainfall, and the CN value plus the pond bottom area and rainfall.

Median rainfall concentrations per pollutant were applied to the total annual rainfall volume to derive the annual pollutant load from rainfall. This is described further in the results section of the report.

2.8.5 BMP Performance Evaluation

BMP performance was assessed using evaluation of both EMCs and annual loads. The methods are described here.

Influent and effluent EMC data were compared at each facility to determine the statistical significance of EMC reductions. Influent EMCs were calculated for sites with multiple inlets by determining the relative proportions of inflow from each inlet as a function of total measured inflow, and proportionally allocating concentrations (based on flow) to achieve a single influent EMC concentration for each event. Having a single influent and effluent EMC then allowed for paired statistical analyses using XLSTAT version 2010.3.07 (Addinsoft, 2010).

EMCs were used to evaluate BMP performance using the Effluent Probability Method (Burton and Pitt, 2001), which involves examining the influent and effluent quality on a standard probability plot. The Effluent Probability Method is a robust and statistically valid method to evaluate the ponds ability to improve effluent water quality, and is the only stand-alone method recommended in the Urban Stormwater BMP Performance Monitoring guidance manual (USEPA, 2002). This method is straightforward and directly provides a clear picture of the ultimate measure of BMP effectiveness, effluent water quality, by first determining if the BMP is providing treatment (i.e., the influent and effluent EMCs are statistically different from one another) and then examining either a cumulative distribution function of influent and effluent or a standard parallel probability plot (USEPA, 2002). Another benefit to this method is that it does not require load calculations, which can skew the comparisons considerably if flow data are problematic or unreliable and a sufficient flow balance cannot be achieved.

BMP performance utilizing annual loads was evaluated by determining the percent annual load reduction for each facility. Percent load reduction was determined by calculating the annual output load (effluent load) and dividing it by the combined input load (i.e., inlet loads plus direct rainfall load), or:

$$Percent\ Load\ Reduction = \frac{output\ load}{sum\ of\ input\ loads}\ X\ 100$$

Before data were compared for statistical significance, each parameter was tested for normality using the Shapiro-Wilk W Test (Shapiro et al., 1968). Since the overwhelming majority of parameters exhibited non-normal distributions, paired samples were compared using the non-parametric Wilcoxon signed-rank test (Wilcoxon, 1945). Cumulative distributions between influent and effluent EMCs were compared using a two-sample Kolmogorov-Smirnov test. This test is used for distribution fitting, and enables the similarity of the distributions to be tested at the same time as their shape and position (Addinsoft, 2010). Mann-Whitney (two-tailed) tests were performed to compare differences in pollutant load reductions between study and control ponds.

3. RESULTS

3.1 BASE FLOW SAMPLING

Base flow samples were collected from facilities where base flow conditions were observed prior to a sampling event. A total of 24 base flow samples were collected in 2014-2015, with at least one base flow sample collected from each facility (Table 85). Base flow was collected from Hunt Ridge, College Hills, and Fields of Harvest only during a single event when snow melt conditions preceded the March storm event. For both College Hills and Fields of Harvest, no base flow was present at the outlet, thus, only a single inlet base flow sample was collected. With the exception of Glyndon Square, the remaining sites (i.e., Worthington & McCormick) had at least five base flow samples collected, although only a single outlet base flow sample was collected from McCormick during snow melt conditions. No outlet base flow was observed at Glyndon Square prior to storm events. It should also be noted that although only a single base flow sample was collected from Glyndon, small amounts of base low were occasionally observed in between sampling events at inlet A. During the 9/9/15 storm at Worthington, stormwater runoff had entered the inlet pipe before a baseflow sample could be collected, therefore, only outlet baseflow was sampled. Base flow samples could not be obtained for two other storm events due to precipitation occurring before samplers arrived at the site.

Table 5 - Results of Base Flow Sampling

Site	Date	TN - In	TN - Out	TP - In	TP - Out	TSS - In	TSS - Out
College Hills	3/9/15	1.49	-	0.17	-	18.4	-
Fields of Harvest	3/9/15	0.83	0.82	0.09	0.06	13.2	3.6
McCormick	2/1/15	2.31	-	0.07	-	164.0	-
McCormick	5/30/15	1.98	-	0.06	-	15.2	-
McCormick	8/11/14	1.24	-	0.05	-	17.2	-
McCormick	10/14/14	0.68	-	0.02	-	1.1	-
McCormick	3/9/15	0.63	0.58	0.09	0.03	48.0	6.4
Glyndon Square	9/24/14	2.16	-	0.09	-	21.6	-
Hunt Ridge	3/3/15	4.56	2.33	0.89	0.05	207.3	21.6
Worthington	3/3/15	3.16	2.79	0.14	0.02	9.6	4.0
Worthington	3/19/15	4.88	2.15	0.01	0.01	0.0	0.3
Worthington	4/13/15	5.08	1.53	0.02	0.02	3.1	1.4
Worthington	6/17/15	4.74	0.59	0.02	0.02	0.6	2.2
Worthington	9/28/15	4.13	2.33	0.19	0.04	17.2	16.2
Worthington	9/9/15	-	0.59	-	0.02	-	6.0

Note: Missing values indicate absence of base flow.

Individual base flow sample concentrations for TN, TP, and TSS are presented for each sampling location in Appendix D. With the exception of Worthington, statistical comparisons of base flow concentrations are not feasible due to small number of base flow events capturing both influent and effluent at each sites. However, general comparisons between influent and effluent base flow can be made for Fields of Harvest and McCormick, although the results should be interpreted with caution since they only represent a single snow melt event. For this single event, both sites show reduced effluent concentrations for all parameters, with the greatest reductions occurring for TSS. What is important to note about McCormick is that of five instances where base flow entered the facility, base flow was only observed leaving the outlet in a single instance. This suggests McCormick has the capacity to infiltrate or otherwise evaporate or evapotranspire small amounts of base flow discharge.

Box plots comparing influent and effluent base flow concentrations at Worthington are presented in Figures 14, 15, and 16, for TN, TP, and TSS respectively. Total nitrogen influent concentrations were notably high, with values ranging from 3.16 mg/L to 5.08 mg/L. However, outlet concentrations were considerably lower, with values ranging from 0.59 mg/L to 2.79 mg/L, which indicates some capacity for nitrogen reductions of base flow. Total phosphorus concentrations ranged from 0.01 mg/L to 0.19 mg/L for the influent and 0.01 mg/L to 0.04 mg/L for the effluent, suggesting some possible reductions of higher concentrations. Influent TSS concentrations ranged from 0.0 mg/L to 17.2 mg/L, while effluent concentrations ranged from 0.03 mg/L to 16.2 mg/L, with a considerable amount of overlap in the interquartile ranges. This suggests no notable differences in TSS concentrations.

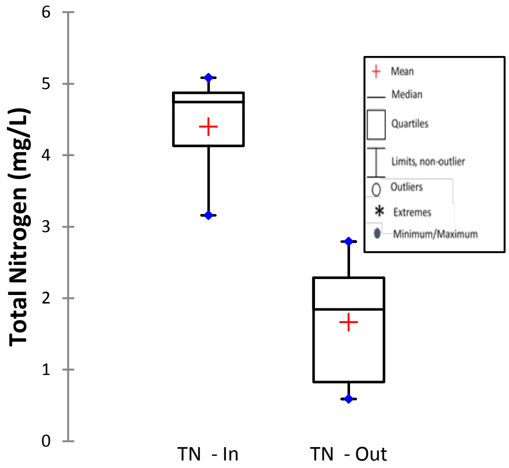


Figure 14 - Box plots of base flow total nitrogen at Worthington. N = 5 for In, N = 6 for Out

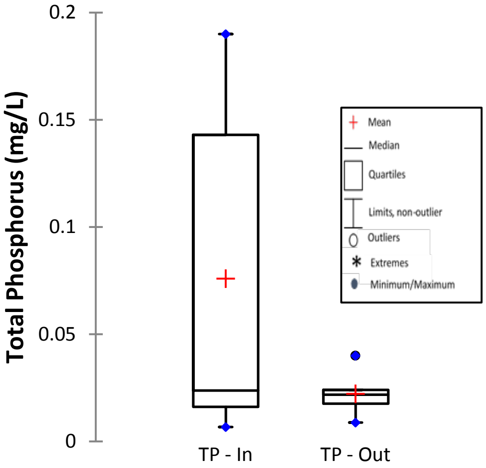


Figure 15 - Box plots of base flow total phosphorus at Worthington. N = 5 for In, N = 6 for Out

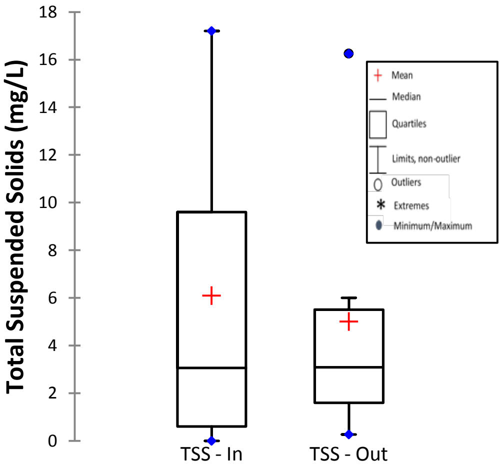


Figure 16 - Box plots of base flow total suspended solids at Worthington. N = 5 for In, N = 6 for Out

Results of the non-parametric Wilcoxon signed-rank test comparing paired samples at Worthington (i.e., influent and effluent concentrations) are presented in Table 6. A statistically significant reduction (at 90% confidence) was observed for TN (p = 0.063, α = 0.1). No other parameters showed statistically significant reductions.

Table 6 - Wilcoxon Signed-Rank test of base flow concentrations at Worthington

	Worthington		
	TN	**TP**	**TSS**
V	15	11	11
Expected value	7.5	7.5	7.5
Variance (V)	13.75	13.75	13.75
p-value (Two-tailed)	**0.063**	0.438	0.438
alpha	0.1	0.1	0.1

Note: Bold values indicate statistical significance

Kolmogorov-Smirnov test results comparing base flow influent and effluent sample distributions are shown in Table 7. Figure 17 shows the cumulative distribution plots for TN, TP, and TSS. For TN, the cumulative distribution plot shows consistently higher inlet concentrations as compared to outlet concentrations. Kolmogorov-Smirnov test results indicates statistically significant TN concentrations for base flow effluent at Worthington (p = 0.004, α = 0.1). No other parameters were shown to be statistically significant, although the cumulative distribution plot for TP shows some potential capacity for reductions of higher concentrations.

Table 7 - Kolomogorov - Smirnov test of base flow concentrations at Worthington

	Worthington		
	TN	**TP**	**TSS**
D	1.00	0.40	0.23
p-value	**0.004**	0.688	0.991
alpha	0.1	0.1	0.1

Note: Bold values indicate statistical significance

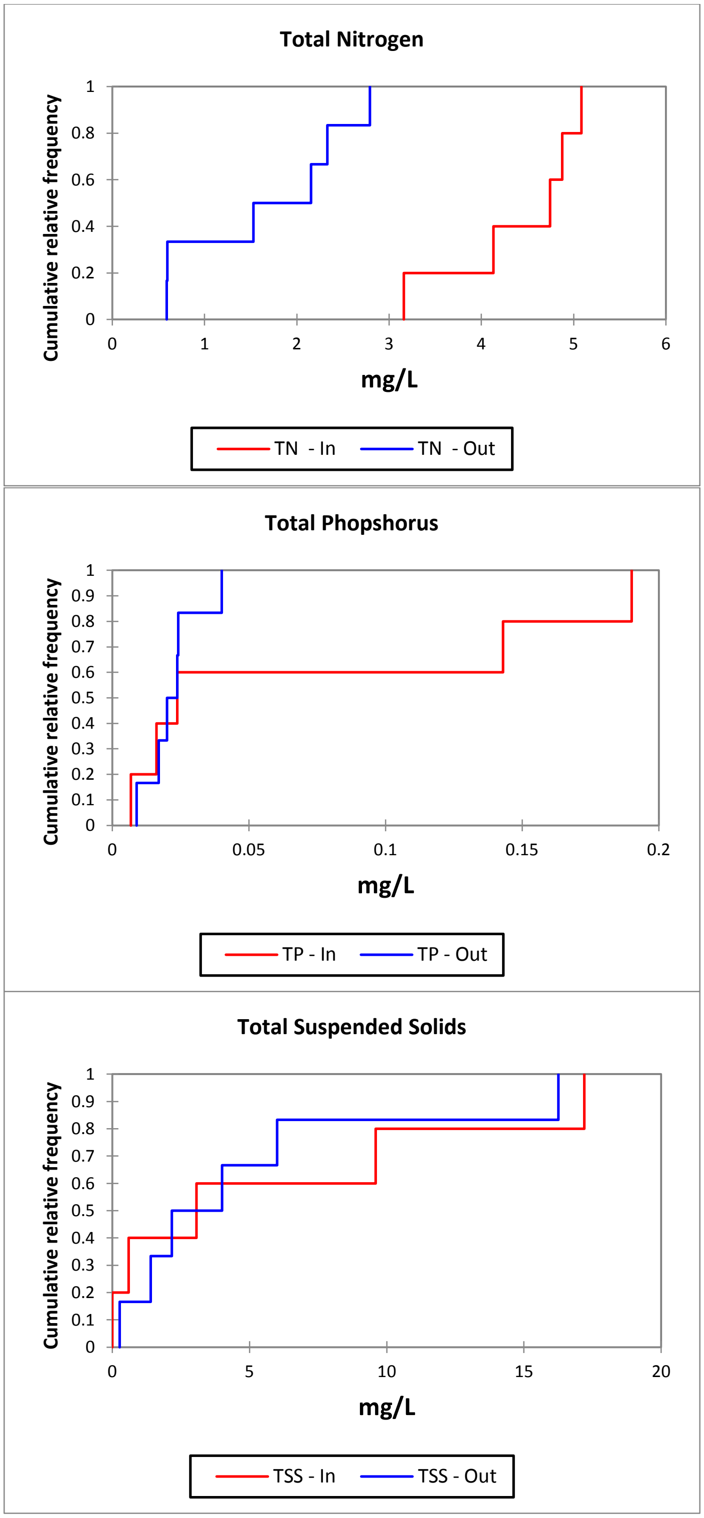


Figure 17 - Cumulative distribution plots for Worthington base flow

3.2 STORM EVENT SAMPLING

A total of 8 (eight) wet weather events were sampled in 2014-2015 at each of the six facilities (Table 8). Storm event precipitation totals ranged from 0.07 to 3.5 inches. Baltimore Washington International Airport (BWI), located in fairly close proximity to all sampling sites, received 52.58 inches in 2014 and 39.49 so far in 2015 (Jan.-Sept.). The average annual rainfall at BWI is 41.88 (average from 1981-2010) (NOAA, 15). Our sampling period covered part of 2014 and 2015 (Table 9), and totals are in the range of the average rainfall at BWI. Since the 2014-15 sampling period occurred during a year of average annual precipitation, the pollutant loads calculated for this period should be considered to be representative of average precipitation conditions. Individual storm hydrographs are included as Appendix B and Storm Event Rainfall Distributions are included as Appendix C.

Table 8 - Storm Event Characteristics for Wet Weather Water Quality Samples

Storm No.	Glyndon		Hunt Ridge		Worthington		McCormick		College Hills		Fields of Harvest	
	Date	Rain (in)	Date	Rain (in)	Date	Rain (in)	Date	Rain (in)	Date	Rain (in)	Date	Rain (in)
1	9/25/14	1.65	8/12/14	2.10	3/4/15	1.00	8/12/14	0.09	9/25/14	0.79	2/2/15	0.44
2	11/6/14	0.84	9/25/14	2.15	3/20/15	0.62	10/4/14	0.25	10/15/14	1.2	3/10/15	0.60
3	1/12/15	0.52	11/6/14	0.69	4/14/15	0.08	10/15/14	0.98	1/18/15	0.17	4/20/15	1.50
4	3/20/15	0.55	3/4/15	0.98	6/18/15	1	2/2/15	0.46	3/10/15	0.52	6/1/15	0.70
5	4/20/15	1.2	3/27/15	1.2	8/20/15	0.8	3/10/15	0.52	4/3/15	0.07	8/20/15	0.66
6	6/18/15	1.1	6/1/15	1.03	9/10/15	1.06	4/14/15	0.075	4/14/15	0.12	9/10/15	0.5
7	8/20/15	0.91	6/18/15	0.77	9/29/15	3.5	5/31/15	0.08	6/1/15	1.1	9/29/15	3.35
8	8/24/15	0.69	8/20/15	0.92	10/9/15	0.34	7/30/15	0.53	9/10/15	1.35	10/9/15	0.35

Table 9 - Rainfall totals in inches during sampling period for each pond

Site	Rain (Inches)	Sampling Period	Number of Days	Rain (in)/day	Rain (in)/365 Days	% Long-term avg (BWI)
Glyndon Square	38.33	8/23/14 - 8/25/15	367	0.104	38.12	91.02
Hunt Ridge	43.63	8/11/14 - 8/21/15	375	0.116	42.47	101.40
Worthington	33.25	2/5/15 - 10/28/15	265	0.125	45.80	109.35
McCormick	47.16	8/6/14 - 8/6/15	365	0.129	47.16	112.61
College Hills*	55.20	8/29/14 - 10/5/15	402	0.137	50.12	119.67
Fields of Harvest	34.91	12/1/14 - 10/28/15	331	0.105	38.50	91.92

*BWI rainfall totals were used for College Hills from 10/21/14 to 1/28/15.

3.3 VOLUME REDUCTION ESTIMATION

Total flow volumes and reductions at each site for the entire sampling period are presented in Table 10. Additionally, individual storm volume reductions at each site are located in Appendix E. Volume reductions were calculated for each pond by subtracting the outlet flow volume from the sum of inlet flow and direct rainfall volumes. With the exception of College Hills, volume reductions were calculated for all sites, ranging from 2% at McCormick to 25% at Worthington. Frequent inlet backwatering at College Hills, caused by an insufficient slope between the inlet and outlet low flow device, resulted in overestimates of inlet flow. Consequently, the outlet flow record was applied to the inlet when generating long-term volumes since confidence was low during unsampled events. Furthermore, no evidence of flow reduction or storage was observed during storm sampling events at College Hills, and the short residence time within this facility supports our use of outlet volumes to estimate inlet volumes.

The Thelmar weirs used in this study have been reported to have a measurement error rate of +/- 5%. During intense rain events, inlets with greater pipe slopes had peak velocities that resulted in runoff flowing through the weirs with increased velocities instead of pooling behind the weir sufficiently to move through the calibrated opening at a steady rate. The volumes and velocities of such flows, coupled with the flashiness of the hydrograph during such events, made efforts to measure flows for calibration purposes unsuccessful. These compounding factors will result in underestimates of flow through the inlet weirs during such events, and subsequently, a comparison of flow volumes was done with a 10% increase at the inlet volumes to account for this error (Table 11). At Worthington, a 10% increase was attributed to the outlet volume rather than the inlet, due to an insufficient amount of pooling at the outlet weir after construction.

Tables 10 and 11 give an indication of the estimated range of volume reduction at all of the facilities. At the study sites, Glyndon, Hunt Ridge, and Worthington, volume reductions ranged from 11-18%, 21-27% and 17-25% respectively. The control sites, McCormick, College Hills, and Fields of Harvest, had volume reductions which ranged from 2-11%, 0-9% and 19-25% respectively.

Table 10 - Volume reduction estimates at each stormwater management facility

Site	Rainfall (in)	Rainfall (cf)	Inlet A (cf)	Inlet B (cf)	Volume In (cf)	Volume Out (cf)	Flow Reduction (cf)	Flow Reduction (%)
Glyndon Square	38.33	106,580	429,597	292,712	828,889	737,533	91,355	11%
Hunt Ridge	43.63	157,870	375,704	321,146	854,721	671,201	183,519	21%
Worthington	33.25	101,386	984,378	-	1,085,764	814,549	271,214	25%
McCormick	47.16	45,434	91,493	607,057	743,984	727,789	16,195	2%
College Hills*	55.2	41,237	261,997	-	261,997	261,997	0	0%
Fields of Harvest	34.91	109,717	359,335	-	469,052	381,227	87,825	19%

* Outlet logger flow at College Hills was used for both inlet and outlet after multiple backwatering issues at the inlet due to an insufficient slope from inlet to outlet

Table 11 - Volume reduction estimates with a 10% increase to inlet volume

Site	Rainfall (in)	Rainfall (cf)	Inlet A (cf)	Inlet B (cf)	Volume In (cf)	Volume Out (cf)	Flow Reduction (cf)	Flow Reduction (%)
Glyndon Square	38.33	106,580	472,556	321,984	901,120	737,533	163,586	18%
Hunt Ridge	43.63	157,870	413,275	353,261	924,406	671,201	253,204	27%
Worthington*	33.25	101,386	984,378	-	1,085,764	896,004	189,760	17%
McCormick	47.16	45,434	100,642	667,763	813,839	727,789	86,050	11%
College Hills	55.2	41,237	288,197	-	288,197	261,997	26,200	9%
Fields of Harvest	34.91	109,717	395,268	-	504,985	381,227	123,758	25%

* 10% applied to Worthington outlet instead of inlet

3.4 EVENT MEAN CONCENTRATIONS

Individual grab sample pollutant concentrations (storm flow and base flow) for TN, TP, and TSS at each sampling location are presented in Appendix D. EMCs for TN, TP, and TSS were calculated for both the influent and effluent at each facility for each of the eight monitored storms and are included in Appendix E. Summary statistics of inlet and outlet EMCs for TN, TP, and TSS are presented in Table 12, 13, and 14, respectively. The percent differences are also presented between mean and median inlet and outlet concentrations, where negative values indicate higher values for output concentrations. Additionally, box plots comparing influent and effluent EMCs for TN, TP, and TSS are presented in Figures 18, 19, and 20, respectively. General influent and effluent EMCs comparisons for each site are discussed below, with statistical testing results presented in Section 3.4.1.

<u>Glyndon Square (Study Site)</u>
At Glyndon, TN EMCs ranged from 0.39 to 5.31 mg/L for the influent and 0.44 to 1.96 mg/L for the effluent, suggesting reductions of high TN flows. Median TN values were 1.06 mg/L for influent and 0.82 mg/L effluent. Concentrations of TP ranged from 0.03 to 2.19 mg/L for the influent and 0.05 to 0.37 mg/L for the effluent, suggesting reductions of high TP flows. Median TP concentrations were only slightly lower for effluent (0.13 mg/L) as compared to influent (0.15 mg/L). TSS EMCs ranged from 9.8 to 206.1 mg/L for the influent and 3.0 to 50.0 mg/L for the effluent. Median TSS values were considerably lower for effluent (12.5 mg/L) as compared to influent (78.9 mg/L), suggesting good reductions across all concentrations for TSS. It is important to note that unusually high TN and TP concentrations were occasionally observed at Inlet B during the first flush (i.e., rising limb of the hydrograph) due to an observed point source input (commercial dumpster) adjacent to the storm drain inlet.

<u>Hunt Ridge (Study Site)</u>
At Hunt Ridge, TN EMCs ranged from 0.90 to 2.45 mg/L for the influent and 0.72 to 1.57 mg/L for the effluent, suggesting reductions of high TN concentrations. Median TN values were much closer with effluent concentrations (1.14 mg/L) slightly less than influent concentrations (1.17 mg/L). Concentrations of TP ranged from 0.06 to 1.53 mg/L for the influent and 0.06 to 0.20 mg/L for the effluent, suggesting reductions of high TP concentrations. Median TP concentrations were notably lower for the effluent (0.12 mg/L) as compared to the influent (0.28 mg/L). TSS EMCs ranged from 14.5 to 218.4 mg/L for the influent and 4.7 to 51.4 mg/L for the effluent, suggesting good TSS reductions across all concentrations. Median TSS values were also lower for effluent (34.0 mg/L) as compared to influent (40.7 mg/L). It should be noted that one TSS influent EMC at Hunt Ridge was deemed non-representative and considered an extreme outlier, therefore, it was omitted from use in statistical calculations.

Table 12 - Summary Statistics of Inlet and Outlet Total Nitrogen EMCs (all values reported in mg/L)

	Control Ponds						Study Ponds					
Statistic	MC In	MC Out	CH In	CH Out	FH In	FH Out	GS In	GS Out	HR In	HR Out	WO In	WO Out
Minimum	0.38	0.12	1.01	0.89	0.36	0.56	0.39	0.44	0.90	0.67	0.77	0.90
Maximum	4.58	3.37	1.69	2.09	2.65	3.64	5.31	1.96	2.45	1.57	4.59	2.15
1st Quartile	0.53	0.49	1.24	0.99	0.65	0.71	0.62	0.51	0.97	0.77	0.88	0.98
3rd Quartile	1.55	1.38	1.41	1.35	1.20	1.86	1.45	1.03	1.48	1.35	2.36	1.80
Median	0.91	0.79	1.32	1.12	0.87	1.14	1.06	0.82	1.17	1.14	1.30	1.47
Median % difference	14%		16%		-26%		26%		2%		-12%	
Mean	1.42	1.12	1.33	1.26	1.09	1.47	1.52	0.89	1.37	1.10	1.96	1.44
Mean % difference	24%		6%		-30%		52%		21%		30%	

Table 13 - Summary Statistics of Inlet and Outlet Total Phosphorus EMCs (all values reported in mg/L)

Statistic	MC In	MC Out	CH In	CH Out	FH In	FH Out	GS In	GS Out	HR In	HR Out	WO In	WO Out
Minimum	0.02	0.01	0.20	0.10	0.06	0.02	0.03	0.05	0.12	0.06	0.05	0.02
Maximum	0.76	0.36	0.82	0.85	0.33	0.84	2.19	0.37	1.53	0.20	0.36	0.34
1st Quartile	0.06	0.02	0.28	0.20	0.11	0.10	0.08	0.08	0.17	0.10	0.11	0.05
3rd Quartile	0.14	0.09	0.47	0.39	0.27	0.26	0.28	0.18	0.52	0.18	0.27	0.24
Median	0.10	0.08	0.33	0.31	0.17	0.17	0.15	0.13	0.28	0.12	0.20	0.17
Median % difference	22%		7%		-1%		12%		77%		15%	
Mean	0.17	0.10	0.41	0.35	0.19	0.25	0.42	0.15	0.46	0.13	0.20	0.16
Mean % difference	57%		16%		-28%		94%		111%		18%	

Table 14 - Summary Statistics of Inlet and Outlet Total Suspended Solids EMCs (all values reported in mg/L)

Statistic	MC In	MC Out	CH In	CH Out	FH In	FH Out	GS In	GS Out	HR In	HR Out	WO In	WO Out
Minimum	6.8	1.7	30.7	42.9	22.6	8.5	9.8	3.0	14.5	4.7	9.6	1.9
Maximum	403.4	68.5	261.8	259.1	393.4	107.2	206.1	50.0	218.4	67.1	95.9	54.1
1st Quartile	15.5	3.5	59.5	66.9	35.9	12.0	18.6	5.8	28.0	12.4	14.1	12.0
3rd Quartile	49.7	17.0	199.0	126.2	86.1	26.5	127.3	21.5	108.6	49.5	62.2	37.0
Median	23.9	10.5	112.6	75.8	66.2	22.1	78.9	12.5	40.7	34.0	48.5	13.6
Median % difference	78%		39%		100%		145%		18%		113%	
Mean	75.5	17.5	131.7	109.1	100.0	29.7	85.3	16.6	78.1	32.5	46.9	23.7
Mean % difference	125%		19%		108%		135%		83%		66%	

Worthington (Study Site)

At Worthington, TN EMCs ranged from 0.77 to 4.59 mg/L for the influent and 0.90 to 2.15 mg/L for the effluent, suggesting reductions of high TN concentrations. However, 1st quartile and median values for effluent TN (0.98 mg/L and 1.47 mg/L, respectively) were higher than those measured for influent (0.88 mg/L and 1.30 mg/L, respectively), suggesting poor performance at lower concentrations. Concentrations of TP ranged from 0.05 to 0.36 mg/L for the influent and 0.02 to 0.34 mg/L for the effluent, while median values were comparable at 0.20 mg/L and 0.17 mg/L, for influent and effluent respectively. These results suggest no difference in influent and effluent TP. TSS EMCs ranged from 9.55 to 95.92 mg/L for the influent and 1.85 to 54.08 mg/L for the effluent, suggesting good reduction of high concentrations. Median effluent concentrations (13.6 mg/L) were also considerably lower than influent concentrations (48.5 mg/L) suggesting good reductions across all concentrations. It should be noted that three TSS effluent samples were considered outliers, and subsequently omitted from statistical analyses. Direct sediment input was observed above the outlet sampling point due to localized bank erosion caused by heavy rains and continued foot traffic of samplers accessing the sampling location via a steep slope.

McCormick Warehouse (Control Site)

At McCormick, TN EMCs ranged from 0.38 to 4.58 mg/L for the influent and 0.12 to 3.37 mg/L for the effluent, suggesting reductions of high TN concentrations. Median TN values were also lower for effluent (0.79 mg/L) as compared to influent (0.91 mg/L). Concentrations of TP ranged from 0.02 to 0.76 mg/L for the influent and 0.01 to 0.36 mg/L for the effluent, suggesting reductions of high TP concentrations. Median TP values were comparable between influent (0.10 mg/L) and effluent (0.08 mg/L), suggesting minimal reductions across lower concentrations. TSS EMCs ranged from 6.8 to 403.4 mg/L for the influent and 1.7 to 68.5 mg/L for the effluent, suggesting good reductions across all concentrations. Median values for effluent (10.5 mg/L) were less than half of those observed for influent (23.9 mg/L). No EMC records were omitted from analysis at this site.

College Hills (Control Site)

At College Hills, TN EMCs ranged from 1.01 to 2.66 mg/L for the influent and 0.89 to 4.02 mg/L for the effluent, suggesting no reductions of high TN concentrations. However, median effluent TN concentrations (1.18 mg/L) were slightly lower than influent concentrations (1.33 mg/L). Concentrations of TP ranged from 0.20 to 0.82 mg/L for the influent (median = 0.32 mg/L) and 0.10 to 0.85 mg/L for the effluent (median = 0.31 mg/L), suggesting no difference in TP concentrations. TSS EMCs ranged from 31 to 262 mg/L for the influent and 43 to 259 mg/L for the effluent, suggesting no reductions of high TSS concentrations. However, median values were lower for effluent (95.6 mg/L) as compared to influent (126.4 mg/L), suggesting some possible reductions of TSS concentrations.

Fields of Harvest (Control Site)

At Fields of Harvest, TN EMCs ranged from 0.36 to 2.65 mg/L for the influent (median = 0.87 mg/L) and 0.56 to 3.64 mg/L for the effluent (median = 1.14 mg/L), suggesting no reductions in TN concentrations. Concentrations of TP ranged from 0.06 to 0.33 mg/L for the influent and 0.02 to 0.84 mg/L for the effluent, with median values equal at 0.17 mg/L, suggesting no reductions in TP concentrations. TSS EMCs ranged from 22.6 to 393.4 mg/L for the influent and 8.5 to 107.2 mg/L for the effluent, suggesting good TSS reductions across all concentrations. Median TSS concentrations were also considerably lower for effluent (22.1 mg/L) as compared to influent (66.2 mg/L).

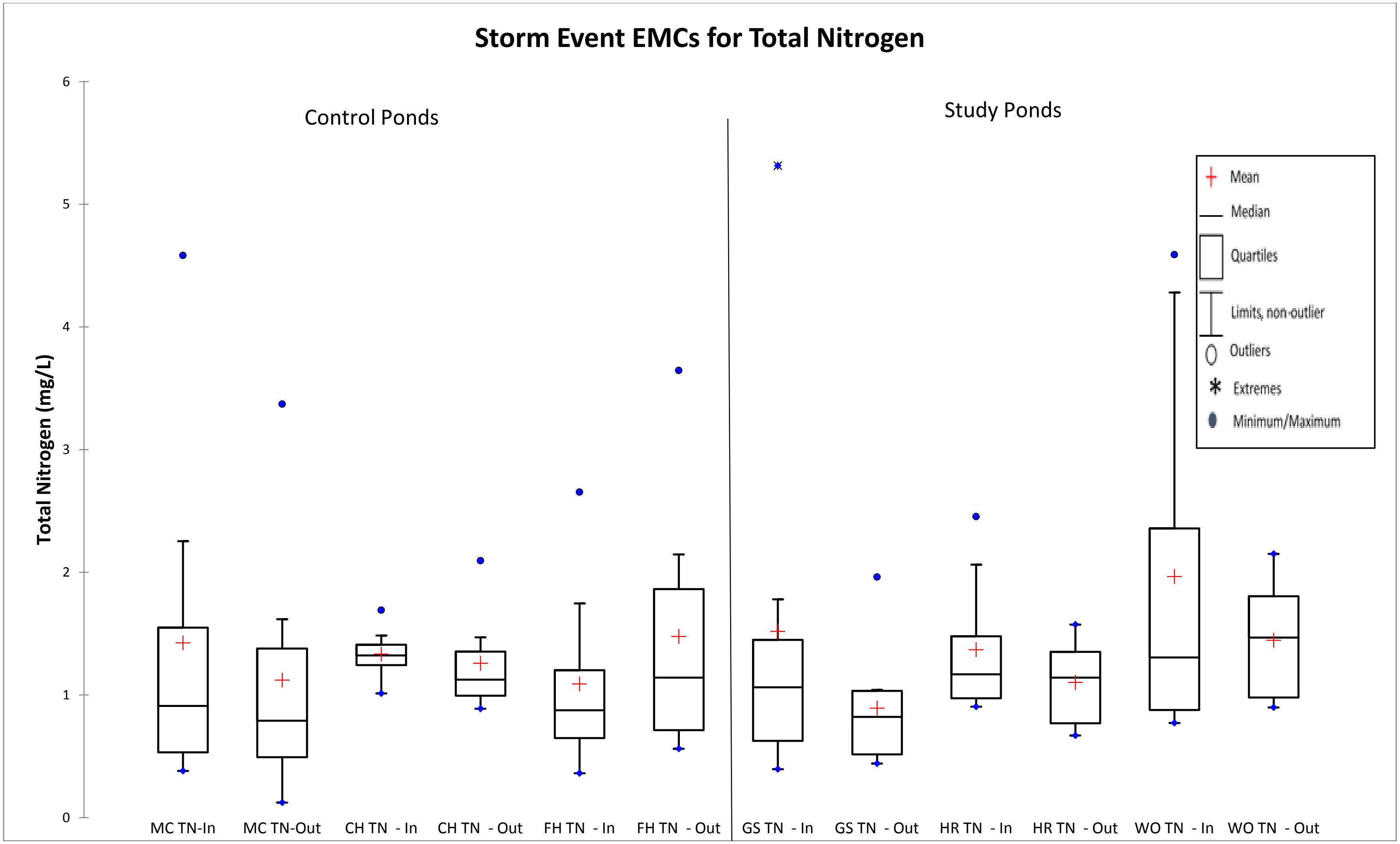


Figure 18 - Box plots of storm event EMCs for total nitrogen

N = 8 for all sites, except CH-In (n=7), CH-out (n=7)

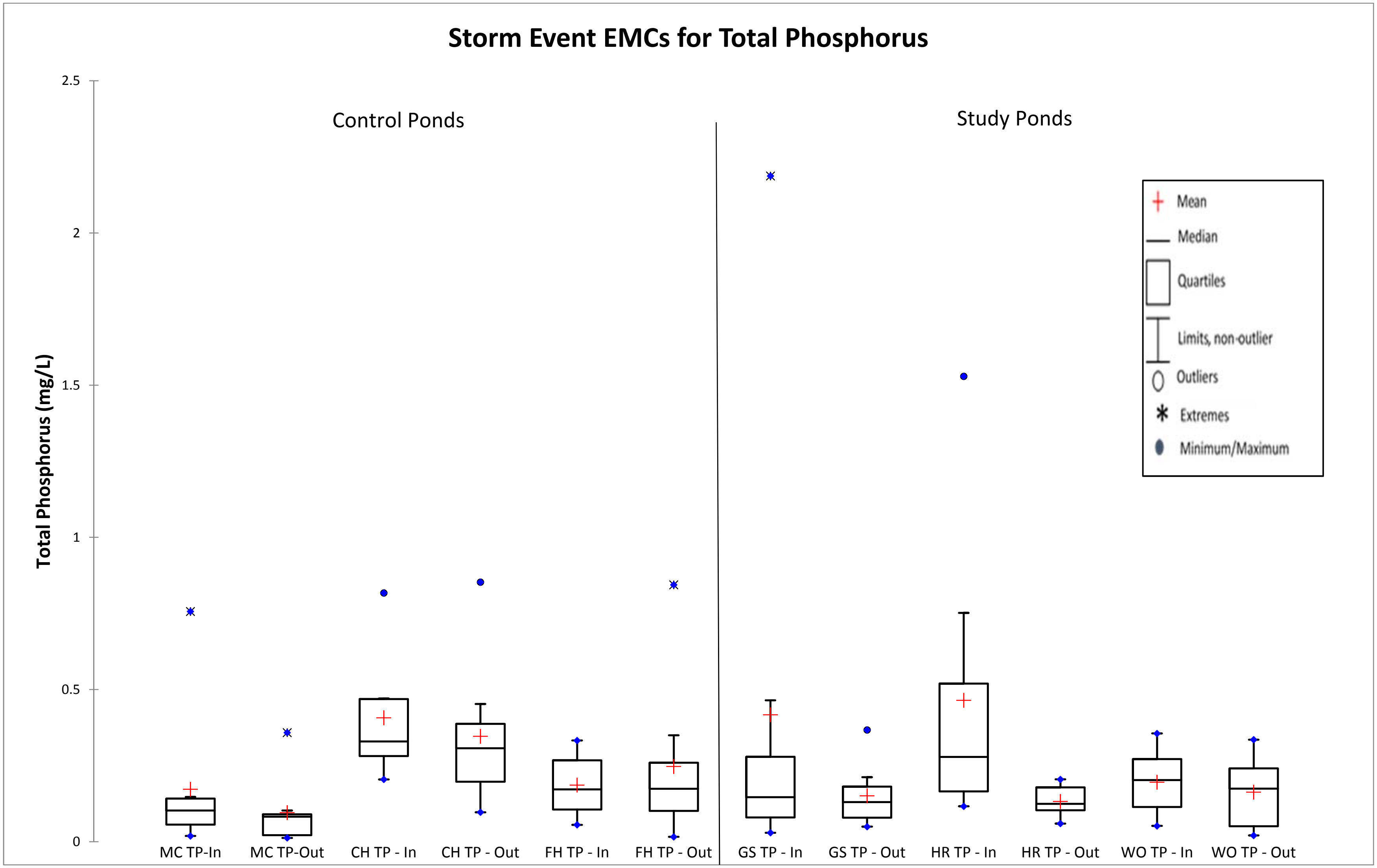


Figure 19 - Box plots of storm event EMCs for total phosphorus

N = 8 for all sites, except CH-In (n=7), CH-out (n=7)

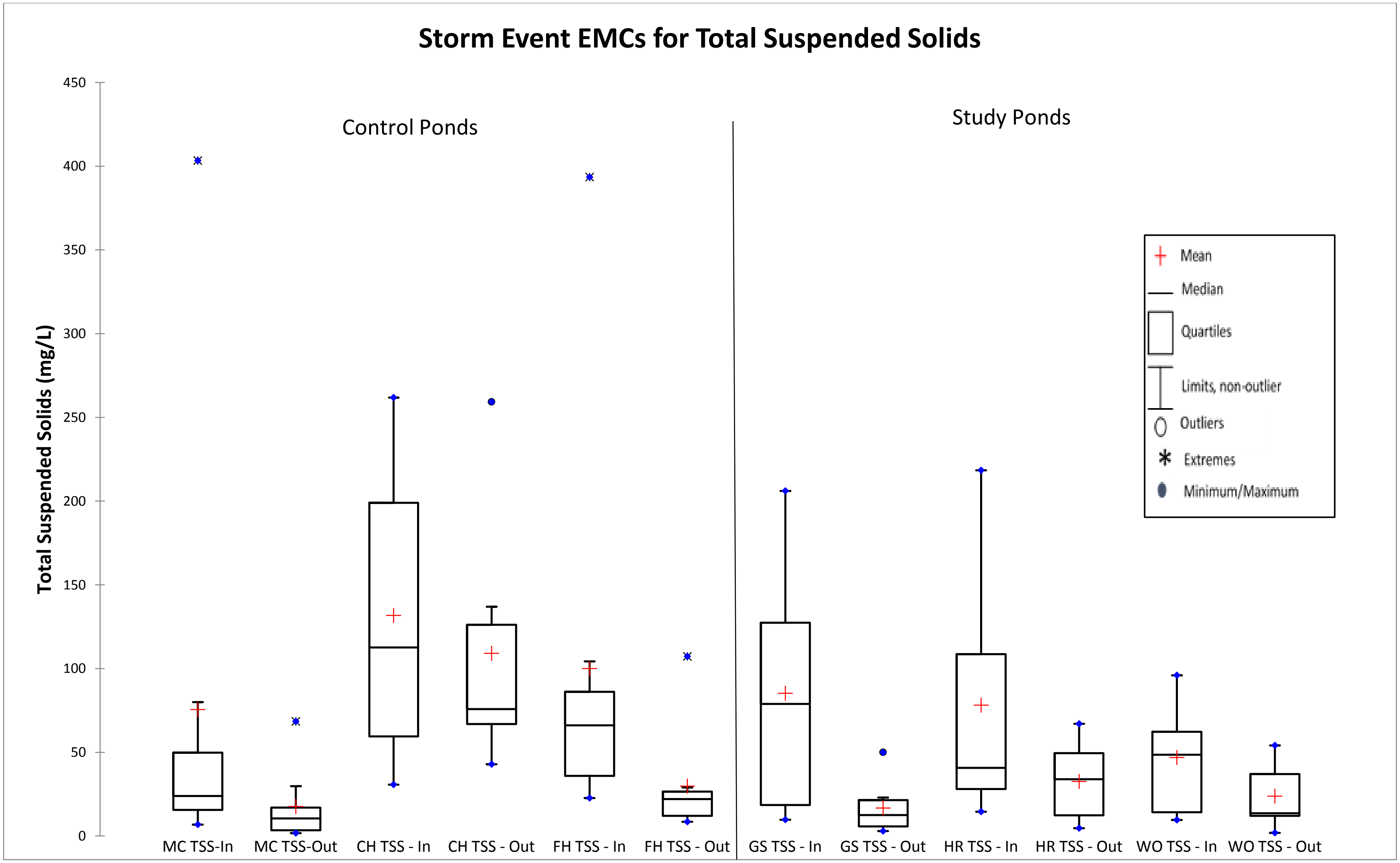


Figure 20 - Box plots of storm event EMCs for total suspended solids

N = 8 for all sites, except HR-In (n = 7), WO-Out (n = 5), CH-In (n=7), CH-out (n=7)

3.4.1 Evaluation of BMP Efficiency

Results of the non-parametric Wilcoxon signed-rank test comparing paired samples (i.e., influent and effluent EMCs) are presented in Table 15 and 16 for study and control ponds, respectively. For the study ponds, statistically significant reductions (at 90% confidence) were observed at Glyndon for TSS (p = 0.008, α = 0.1); at Hunt Ridge for TN (p = 0.055, α = 0.1), TP ((p = 0.008, α = 0.1), and TSS (p = 0.039, α = 0.1); and, at Worthington for TSS (p = 0.054, α = 0.1). Statistically significant reductions were also observed in some control ponds. For instance, McCormick showed statistically significant reductions for TN (p = 0.039, α = 0.1), TP (p = 0.027, α = 0.1), and TSS (p = 0.004, α = 0.1), while Fields of Harvest showed significant reductions for TSS (p = 0.004, α = 0.1). Only one pond, College Hills, did not show a statistically significant reduction in TN, TP and TSS EMC concentrations. It is important to note, however, that prior to the study the pond bottom was partially excavated to remove large quantities of deposited sediments from the pilot channel and adjacent to the inlet to eliminate backwatering and facilitate flow gauging at this sampling location. It is possible that modifications to the pond, which approximated the original design dimensions and function, may have inhibited this pond's ability to reduce influent pollutant concentrations.

Table 15 - Wilcoxon Signed-Rank test of storm flow EMCs for Study Ponds

	Study Ponds								
	Glyndon			Hunt Ridge			Worthington		
	TN	TP	TSS	TN	TP	TSS	TN	TP	TSS
V	22	27	36	39	44	42	76	78	55
Expected value	18	18	18	18	22.5	18	52.5	52.5	33
Variance (V)	51	51	51	71.25	71.25	51	253.75	253.75	126.5
p-value (Two-tailed)	0.641	0.250	**0.008**	**0.055**	**0.008**	**0.039**	0.153	0.119	**0.054**
alpha	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Note: Bold values indicate statistical significance

Table 16 - Wilcoxon Signed-Rank test of storm flow EMCS for Control Ponds.

	Control Ponds								
	McCormick			College Hills			Fields of Harvest		
	TN	TP	TSS	TN	TP	TSS	TN	TP	TSS
V	40	41	45	18	18	16	6	22	45
Expected value	22.5	22.5	22.5	14	14	14	22.5	22.5	22.5
Variance (V)	71.25	71.25	71.25	35	35	35	71.25	71.25	71.25
p-value (Two-tailed)	**0.039**	**0.027**	**0.004**	0. 578	0. 578	0.813	0.055	1.000	**0.004**
alpha	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Note: Bold values indicate statistical significance

BMP efficiency was also evaluated using the Effluent Probability Method, which examines the cumulative distribution function of influent and effluent quality. Kolmogorov-Smirnov test results comparing influent and effluent sample distributions are shown in Table 17 and 18 for study and control ponds, respectively. Figure 21 shows the cumulative distribution plot for TN at all pond sites. For all sites, TN appears to be poorly removed for lower concentrations (<2.0 mg/L), but the removal increases substantially at higher concentrations, especially within the study facilities. Kolmogorov-Smirnov test results indicates statistically significant TN reductions at Worthington (p = 0.059, α = 0.1). Cumulative distribution plots for TP are shown in Figure 22. Among the control ponds, TP distributions are very similar for all but McCormick, which shows some minor reductions across all concentrations, although not statistically significant. With the exception of Glyndon, the study ponds show less overlap in concentrations suggesting improved TP removal. Worthington showed good performance at concentrations below 0.2 mg/L, while Hunt Ridge showed statistically significant differences across all concentrations (p = 0.034, α = 0.1). Cumulative distribution plots for TSS are shown in Figure 23. Both control ponds and study ponds show generally good performance for TSS reduction. Two control ponds show reductions across all concentrations, although only Fields of Harvest was statistically significant (p = 0.034, α = 0.1). In contrast, two of the three study ponds showed statistically significant reductions, Glyndon (p = 0.087, α = 0.1) and Hunt Ridge (p < 0.0001, α = 0.1), with only one pond, Worthington, not showing significant reductions.

Table 17 - Kolomogorov-Smirnov test of storm EMCs for Study Ponds

	Study Ponds								
	Glyndon			**Hunt Ridge**			**Worthington**		
	TN	**TP**	**TSS**	**TN**	**TP**	**TSS**	**TN**	**TP**	**TSS**
D	0.375	0.250	0.625	0.333	0.667	1.00	0.500	0.286	0.182
p-value	0.660	0.980	**0.087**	0.730	**0.034**	**< 0.0001**	**0.059**	0.635	0.997
alpha	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Note: Bold values indicate statistical significance

Table 18 - Kolomogorov-Smirnov test of storm EMCs for Control Ponds

	Control Ponds								
	McCormick			**College Hills**			**Fields of Harvest**		
	TN	**TP**	**TSS**	**TN**	**TP**	**TSS**	**TN**	**TP**	**TSS**
D	0.222	0.444	0.556	0.429	0.286	0.286	0.333	0.222	0.667
p-value	0.989	0.352	0.126	0.575	0.963	0.963	0.730	0.989	**0.034**
alpha	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Note: Bold values indicate statistical significance

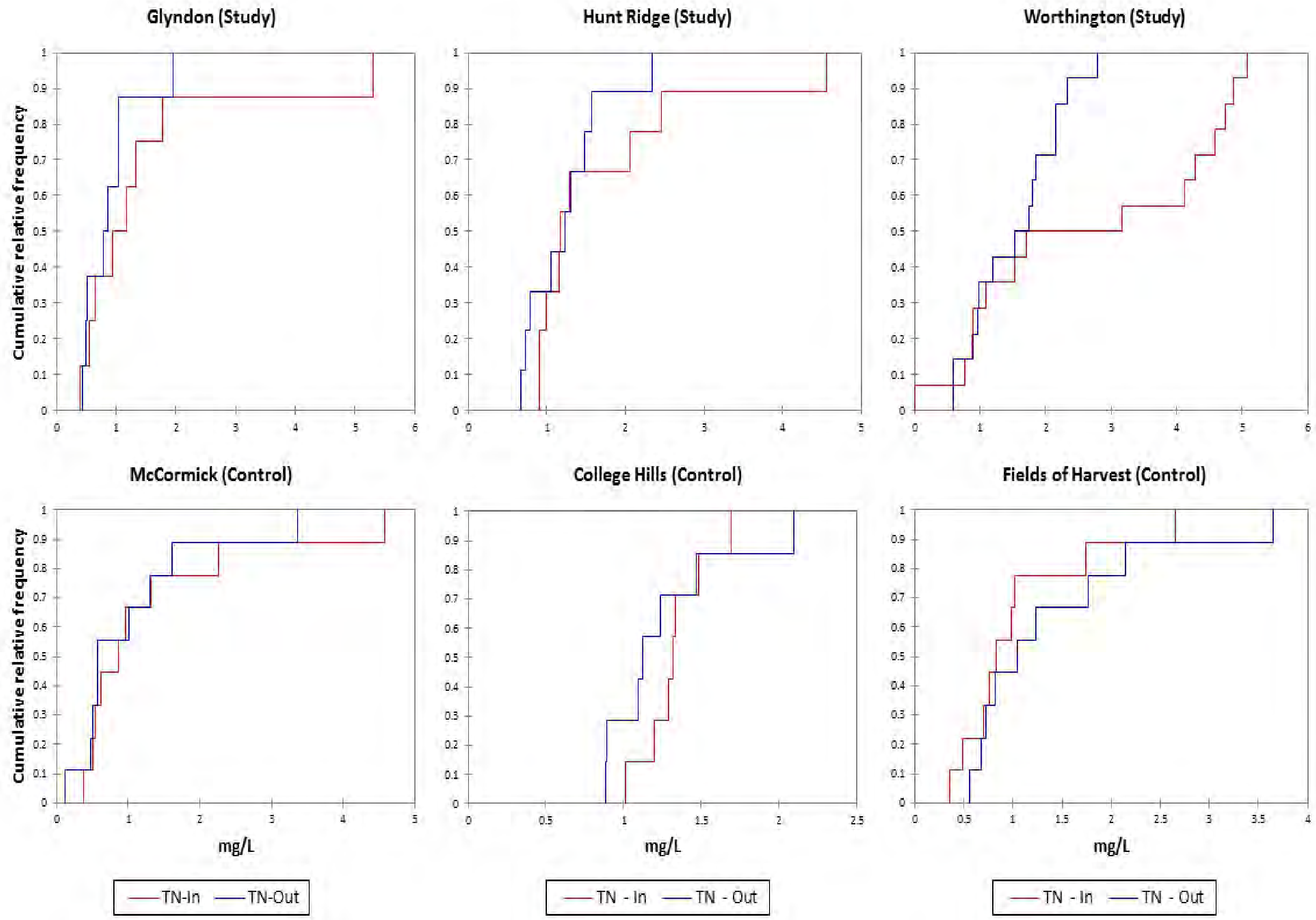


Figure 21 - Cumulative distribution plots for Total Nitrogen

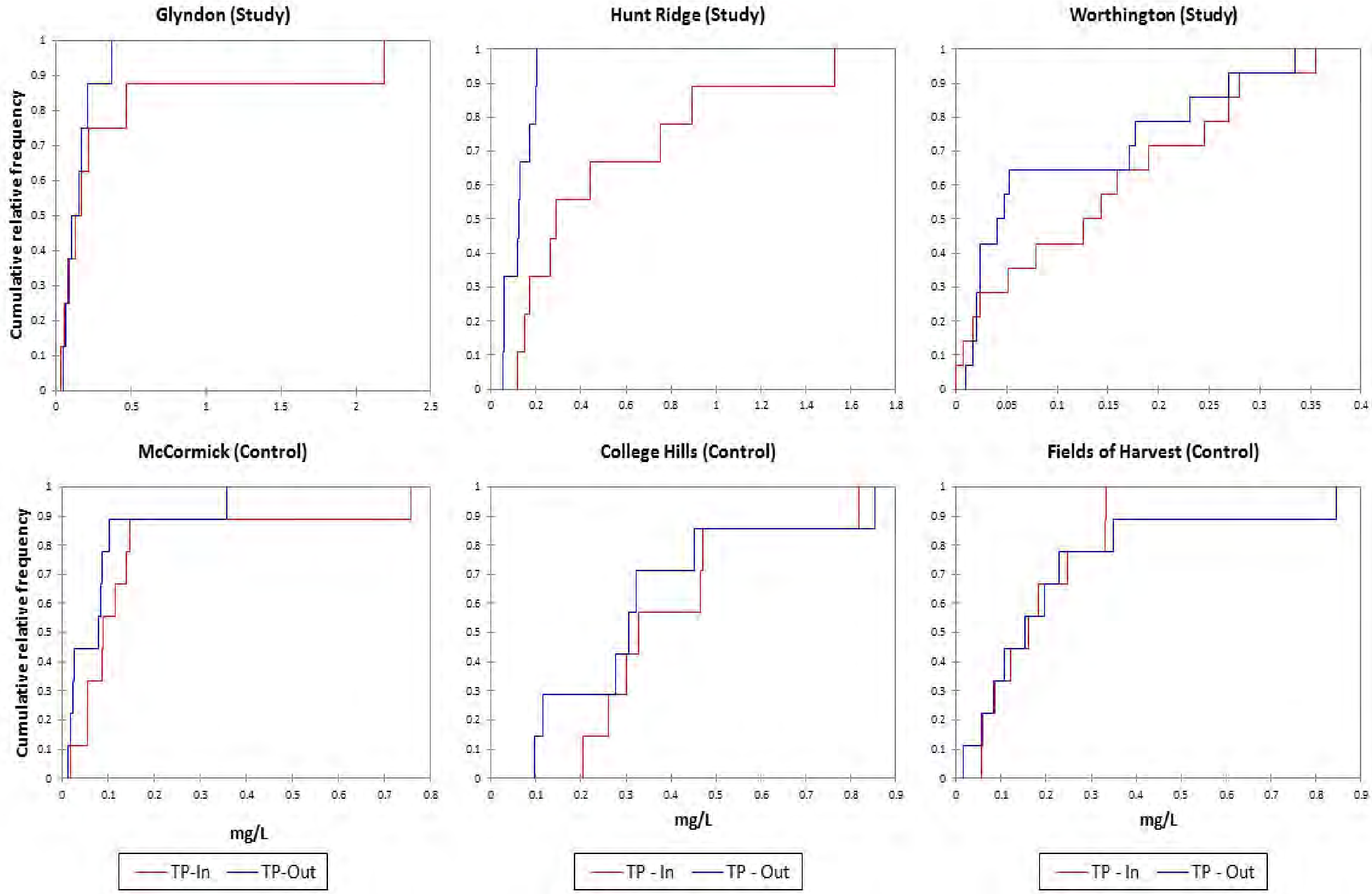


Figure 22 - Cumulative distribution plots for Total Phosphorous

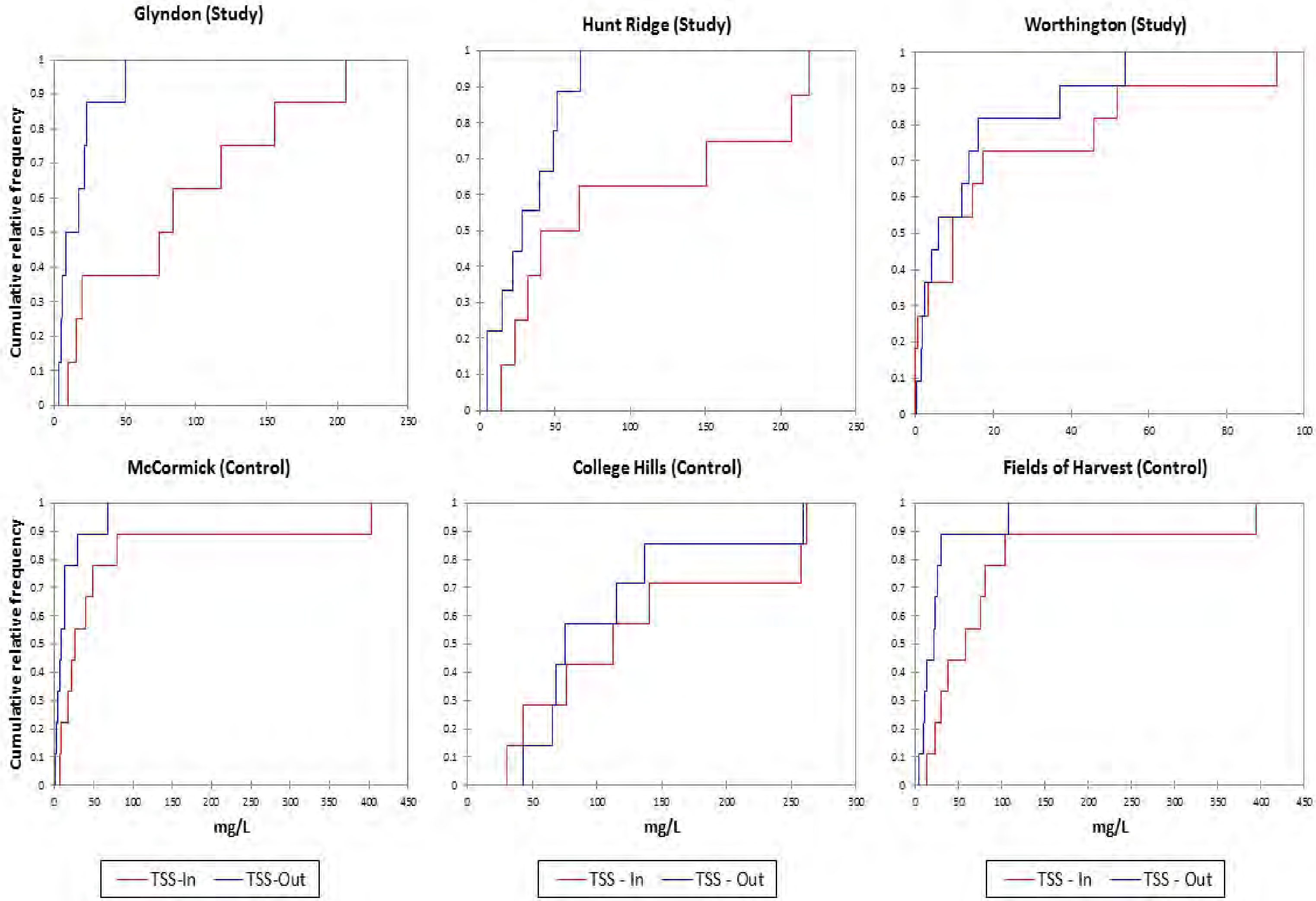


Figure 23 - Cumulative distribution plots for TSS

3.5 POLLUTANT LOADS

Pollutant loads were calculated separately for rainfall, which are presented in Section 3.5.1, and for influent and effluent, which are presented in Section 3.5.2.

3.5.1 Rainfall Loads

A total of eight rainfall samples were collected during four storm events, representing one storm event per season. Rain sample results are summarized in Table 19 and complete results are presented in Appendix F. Some sites had more than one bottle of rain collected, therefore, those sites have pollutant concentrations reported as the average between both bottles. TSS sampling ceased after the first storm since very low concentrations were observed that were near or at the method detection limits for this parameter, and it was determined that the contribution would be negligible compared to influent and effluent inputs. Total nitrogen values ranged from 0.06 mg/L to 0.53 mg/L, with a mean of 0.32 mg/L and a median of 0.34 mg/L. Total phosphorus values ranged from 0.005 mg/L to 0.09 mg/L, with a mean of 0.026 mg/L and a median of 0.005 mg/L. It should be noted that TP values that were reported below the detection limit were assigned a value of ½ the detection limit, or 0.005 mg/L.

Rain pollutant loads (lbs/year) were calculated using the median pollutant concentrations for TN (0.34 mg/L) and TP (0.005 mg/L) for each of the six ponds and are presented in Table 20. Because rainfall loads for each site were calculated using the median pollutant concentrations for TN and TP, ponds that received the greatest amount of direct rainfall (i.e., Hunt Ridge and Fields of Harvest) had the highest rainfall pollutant loads. Total nitrogen loads from rainfall ranged from 0.27 lbs/yr at College Hills, to 3.33 lbs/yr at Hunt Ridge. Four of the six ponds had an estimated rainfall contribution of 2.0 lbs/yr or greater, which indicates a fairly significant contribution for this pollutant. On the other hand, TP loads from rainfall ranged from between 0.01 lbs/yr at College Hills, to 0.05 lbs/yr at Hunt Ridge, suggesting that it is not a substantial source of loading for this pollutant.

Table 19 - Rainfall Sampling Results

Sample ID	Date	Total N (mg/L)	Total P (mg/L)	TSS (mg/L)
WO-Rain Avg	3/6/15	0.25	0.005	1.00
HR-Rain Avg	3/6/15	0.32	0.006	0.55
CH-Rain Avg	6/2/15	0.36	0.010	n/a
FH-Rain Avg	6/2/15	0.53	0.090	n/a
FH-Rain Avg	8/20/15	0.43	0.083	n/a
GS-Rain	8/20/15	0.47	**0.005**	n/a
FH-Rain	9/30/15	0.06	**0.005**	n/a
WO-Rain Avg	9/30/15	0.16	0.005	n/a
median		0.34	0.005	0.00
mean		0.32	0.026	0.19
standard dev		0.16	0.037	0.38

Note: Bold values indicate measurements reported below the detection limit, assigned ½ DL.

Table 20 - Estimated Pollutant Loads from Rainfall for Total Nitrogen and Total Phosphorus

Site	Direct Rainfall Input (in)	Direct Rainfall Input (cf)	Loads	
			TN (lbs/y)	TP (lbs/y)
Glyndon Square (GS)	38.3	106,580	2.25	0.04
Hunt Ridge (HR)	43.6	157,870	3.33	0.05
Worthington (WO)	33.3	101,386	2.14	0.03
McCormick (MC)	34.9	45,434	0.96	0.02
College Hills (CH)	55.2	41,237	0.27	0.01
Fields of Harvest (FH)	34.9	109,717	3.30	0.04

3.5.2 Influent and Effluent Loads

Influent and effluent pollutant loads of TN, TP, and TSS for each inlet and outlet are presented in Table 21, 22, and 23, respectively. Pollutant loads are provided for the overall mass (lbs) for the entire monitoring period and flux (lbs/year), along with the average flow-weighted concentration used for load calculation. Additionally, the variance of the flux estimate and the coefficient of variation (C.V.) are also included to provide a level of confidence around the load estimates. The higher the values, the greater the uncertainty. Average daily discharge time series plots with sample concentration and associated discharge used in annual load calculations are presented in Appendix G.

Table 21 - Inlet and Outlet Pollutant Loads for Total Nitrogen

Site	Pond Type	Mass (lbs)	Flux (lbs/y)	Flux Variance	Flow-Weighted Conc.(mg/L)	C.V.
WO-In	Study	86.1	118.6	157.4	1.65	0.16
WO-Out		80.2	110.1	253.4	1.56	0.21
GS-In A	Study	23.9	23.8	9.9	0.84	0.2
GS-In B		19.7	19.5	9.4	0.99	0.23
GS-Out		29.3	29.1	7.1	0.64	0.14
HR-In A	Study	28.0	27.2	2.2	1.19	0.08
HR-In B		26.2	25.4	4.2	1.30	0.12
HR-Out		43.0	41.9	9.6	1.03	0.11
FH-In	Control	21.8	24.0	32.8	0.93	0.35
FH-Out		18.8	20.7	17.5	0.9	0.3
CH-In	Control	21.7	19.7	0.9	1.32	0.07
CH-Out		22.2	20.1	12.1	1.35	0.26
MC-In A	Control	3.6	3.6	0.4	0.63	0.25
MC-In B		27.9	27.8	19.5	0.73	0.24
MC-Out		22.9	22.9	19.2	0.51	0.28

Table 22 - Inlet and Outlet Pollutant Loads for Total Phosphorus

Site	Pond Type	Mass (lbs)	Flux (lbs/y)	Flux Variance	Flow-Weighted Conc.(mg/L)	C.V.
WO-In	Study	13.8	19.1	13.92	0.27	0.29
WO-Out		7.6	10.5	4.74	0.15	0.31
GS-In A	Study	3.8	3.8	0.25	0.13	0.19
GS-In B		5.9	5.9	0.90	0.30	0.24
GS-Out		7.4	7.4	0.41	0.16	0.13
HR-In A	Study	16.5	16.0	2.03	0.70	0.13
HR-In B		5.7	5.5	0.42	0.28	0.17
HR-Out		5.7	5.6	0.36	0.14	0.16
FH-In	Control	5.2	5.7	1.17	0.22	0.28
FH-Out		3.0	3.3	0.39	0.13	0.28
CH-In	Control	6.1	5.5	0.27	0.37	0.14
CH-Out		5.2	4.7	0.48	0.32	0.22
MC-In A	Control	1.0	1.0	0.03	0.18	0.24
MC-In B		2.7	2.7	0.41	0.07	0.35
MC-Out		2.7	2.7	0.68	0.06	0.46

Table 23 - Inlet and Outlet Pollutant Loads for Total Suspended Solids

Site	Pond Type	Mass (lbs)	Flux (lbs/y)	Flux Variance	Flow-Weighted Conc.(mg/L)	C.V.
WO-In	Study	1856	2558	1348124	35.6	0.67
WO-Out		1419	1949	329244	27.6	0.44
GS-In A	Study	2225	2208	39467	77.8	0.13
GS-In B		1020	1012	46125	51.3	0.31
GS-Out		591	5884	9768	12.9	0.25
HR-In A	Study	1923	1868	19546	81.9	0.11
HR-In B		2976	2891	511886	148.0	0.37
HR-Out		1247	1214	54539	29.7	0.29
FH-In	Control	1285	1418	53059	54.8	0.24
FH-Out		411	452	5280	17.2	0.24
CH-In	Control	1746	1582	54258	106	0.22
CH-Out		1422	1288	38064	86.7	0.22
MC-In A	Control	190	189	2727	33.1	0.41
MC-In B		1573	1565	293606	41.2	0.51
MC-Out		477	476	13695	10.5	0.36

3.5.3 Load Reductions

Estimated load reductions were calculated as the difference between the input loads (i.e., inlet loads and rainfall loads) and output loads for each pond, and then standardized as a percent reduction of input load. Results of the estimated annual load reductions for TN, TP, and TSS are presented in Tables 24, 25, and 26, respectively. Estimated reductions of TN ranged from 1% to 29% for control ponds, with the highest percent reduction observed at McCormick. Estimated reductions of TN at the study ponds ranged from 9% to 36% for study ponds, with the highest percent reduction observed at Glyndon Square. Mann-Whitney (two-tailed) test results indicate no significant difference in pollutant removal rates between pond types for TN ($p = 0.7$, $\alpha = 0.1$, Table 27). Estimated reductions were generally higher for TP with ranges of 15% to 42% for control ponds and 24% to 75% for study ponds. Again, McCormick showed the highest reduction of TP for the control ponds, while Hunt Ridge had the highest removal for the study ponds. There was no statistically significant difference in TP reduction rates between pond types ($p = 0.4$, $\alpha = 0.1$). Removal rates were highest for TSS with percent reductions ranging from 19% to 73% for control ponds and 24% to 82% for study ponds. McCormick showed the highest reduction of TSS for the control ponds and Glyndon Square had the highest for the study ponds. As with TN and TP, the difference in pollutant reductions between pond types was not statistically significant ($p = 0.4$, $\alpha = 0.1$).

Table 24 - Estimated Load Reductions for Total Nitrogen

Site	Type	Influent Flux(lbs/y)	Effluent Flux(lbs/y)	Pounds Removed	Percent Reduction
CH	Control	20.5	20.1	0.4	2%
FH	Control	27.3	20.7	6.6	24%
MC	Control	32.3	22.9	9.5	29%
				Control mean	**18.5%**
GS	Study	45.6	29.1	16.4	36%
HR	Study	55.9	41.9	14.0	25%
WO	Study	120.7	110.1	10.6	9%
				Study mean	**23.3%**

Table 25 - Estimated Load Reductions for Total Phosphorus

Site	Type	Influent Flux(lbs/y)	Effluent Flux(lbs/y)	Pounds Removed	Percent Reduction
CH	Control	5.5	4.7	0.8	15%
FH	Control	5.8	3.3	2.4	42%
MC	Control	3.7	2.7	1.1	29%
				Control mean	**28.8%**
GS	Study	9.7	7.4	2.3	24%
HR	Study	21.6	5.6	16.1	75%
WO	Study	19.1	10.4	8.7	45%
				Study mean	**47.9%**

Table 26 - Estimated Load Reductions for Total Suspended Solids

Site	Type	Influent Flux(lbs/y)	Effluent Flux(lbs/y)	Pounds Removed	Percent Reduction
CH	Control	1582.1	1288.5	293.6	19%
FH	Control	1418.2	452.6	965.7	68%
MC	Control	1754.2	476.4	1277.8	73%
				Control mean	**53.2%**
GS	Study	3220.8	588.4	2632.4	82%
HR	Study	4759.2	1214.2	3545.0	74%
WO	Study	2558.2	1949.1	609.0	24%
				Study mean	**60.0%**

Table 27 - Mann-Whitney Test Results Comparing Control and Study Pond Pollutant Removal Rates

Statistic	TN	TP	TSS
U	3.0	2.0	2.0
Expected value	4.5	4.5	4.5
Variance (U)	5.3	5.3	5.3
p-value (Two-tailed)	0.7	0.4	0.4
alpha	0.1	0.1	0.1

4. DISCUSSION

The primary goal of this study was to test the hypothesis that self-converted dry detention ponds provide greater removal efficiencies than unconverted dry detention ponds. Statistical testing of load removals between groups did not support our hypothesis, but a small sample size (n = 3 ponds) of each limited the power of detecting a statistically significant difference in load reductions. Furthermore, one of the 'Control' ponds performed much better than expected, which resulted in considerable overlap between the sample groups. Although the results from our study do not support the notion that self-converted ponds perform statistically better than unconverted dry ponds in our sample population, they do suggest that some unconverted dry ponds perform as well as, or better than, some self-converted facilities. In effect, this raises many questions regarding the mechanisms behind the pollutant removal within these different types of dry ponds, which could be the focus of future research. It also highlights the difficulties in attempting to group 'mature' detention ponds into generic categories given the many unique characteristics observed at each site with regard to vegetation, micro-topography within the facility, water retention and/or infiltration, and hydrologic functionality.

It is also important to consider how these ponds function in their present state 30 or more years after construction, as opposed to how they were designed to function when newly constructed. For example, of the dozens of ponds visited as part of the site selection process, many showed signs of decades' worth of sediment accumulation within the pond bottom that influenced the hydrology and occasionally resulted in areas of storage and attenuation. A common occurrence was the formation of 'deltas' immediately below the inlet structures where the energy had dissipated and the stormwater dropped sediment and/or organic matter loads. Over time these deposits became vegetated and stabilized often acting as berms, ultimately changing the flow path and rendering the pilot channels less effective at passing small events through with minimal retention time. Many ponds no longer showed evidence of rip-rap pilot channels, which were shown on the design plans, because they had become filled with sediments and subsequently vegetated. Many potential sites had to be excluded because the inlets were submerged and/or backwatered, which would have hindered our ability to accurately gauge discharge into the facilities.

What is not surprising in this study is the demonstrated ability of self-converted dry detention ponds to provide greater removal efficiencies (Avg TN = 23.3%, Avg TP = 47.9%, Avg TSS = 60.0%) than the CBP and MDE crediting currently provides. However, we also observed a broad range of pollutant removal performance across the unconverted dry detention ponds (Avg TN = 18.5%, Avg TP = 28.8%, Avg TSS = 53.2%) that suggests comparable performance but within a broader range than the self-converted facilities. Load reductions tended to be influenced by storage and infiltration of base flow in addition to small amounts of storm flow, therefore, facilities with base flow input generally performed better.

Because we selected an array of ponds with different drainage area characteristics within each class (control vs. study) in an effort to be more representative of the County's larger population of dry detention ponds, it becomes more difficult to determine why some ponds perform much better than others. After studying theses ponds for a year or more and observing how they perform under a broad range of storm events of differing durations and intensities, we feel that it is more appropriate to discuss and evaluate the ponds individually, as opposed to being grouped into one category, and to provide some insight to explain the complexities that were not apparent during our site selection, but nonetheless have influenced our results. We have identified a number of additional factors that may affect the performance of pollutant removal for these facilities, as well as the expected direction of response, which are displayed in Table 28. Each pond was evaluated for the following characteristics:

- Direct Flow Path – Does the facility have at least one inlet with a direct flow path, either as a constructed pilot channel or defined channel, leading from the inlet to the outlet?
- Diffuse Flow – Does the influent spread out over the pond bottom, rather than remain concentrated in a defined flow path?
- Base flow Input – Does the facility have seasonal or year-round base flow inputs?
- Base flow Retained – If base flow is present, is it primarily retained within the facility?
- Mowed Vegetation – Is the vegetation in the facility mowed regularly, or at least annually?
- Herbaceous Vegetation – Does the facility contain herbaceous vegetation?
- Woody Vegetation – Does the facility contain woody vegetation (i.e., shrubs and trees)?
- Detritus Present – Does the facility contain noticeable quantities of detritus (i.e., leaf litter, sticks, seed pods, etc.) in the pond bottom?

Table 28 - Additional Factors that May Affect Facility Pollutant Removal Performance

Site	Pond Characteristics							
	Direct Flow Path	Diffuse Flow	Base flow Input	Base flow Retained	Mowed Vegetation	Herbaceous Vegetation	Woody Vegetation	Detritus Present
GS		↑	—	↑		↑	↑	↑
HR		↑				↑	↑	↑
WO	↓		—			↑	↑	↑
MC	↓		—	↑	↓	↑		
CH	↓				↓			
FH		↑			↓	↑		

↑ indicates an expected increase in pollutant removal performance

↓ indicates an expected decrease in pollutant removal performance

— indicates unknown effect on pollutant removal performance

A discussion of each facility with regard to pollutant removal performance and observed pond characteristics that may affect performance is included below

McCormick Warehouse

Although this pond was categorized as a 'Control' pond due to a lack of wetland soils and dominant wetland vegetation, this site was similar to most of the study ponds with regard to base flow hydrology that was often present, albeit with small volumes of flow. Base flow was typically observed entering the facility but rarely measured leaving the facility, which suggests some storage and infiltration/evapotranspiration of small volumes of water. Furthermore, there is a fairly large portion of the pond that has been observed providing storage due to a depression that does not drain entirely. This reduction in volume leaving the facility ultimately reduces pollutant loads. Lastly, a dense stand of Japanese knotweed was observed growing immediately adjacent to inlet A, which follows a more diffuse flow path to the outlet. Not only are the plants likely utilizing nutrients from the influent and surrounding soils, but they appear to be mowed and removed as part of annual pond maintenance. This could help to remove nutrients permanently from the facility through the harvesting of plant biomass.

The base flow and depression volume storage, along with vegetation harvesting and removal may collectively influence pollutant reduction rates and may explain why this pond performs better than the other control ponds, in addition to some of the 'Study' ponds.

Fields of Harvest

Overall nutrient load reductions were observed at this site primarily due to overall volume reductions. This is despite having occasional effluent concentrations exceeding influent concentrations for TN and TP. This condition was attributed to two factors, first the proximity to crop lands directly to the west of the site which likely contributed dry and wet deposition of pollutants. High pollutant loads were indicated in rainfall at this site. The second factor was well manicured and likely fertilized lawn which partially drains directly into the facility from the east. These factors are not accounted for in the influent from the pipe which would result in higher effluent concentrations. Fields of Harvest does not have a direct pilot channel from inlet to outlet, and sediment accumulation at the inlet location forces more flow out onto the broad basin allowing the influent to contact more soil and vegetation as it travels to the outlet. Influent flow travels toward the southeast corner of the pond, spreading over the whole basin before exiting the pond. Due to the long distance between inlet and outlet and lack of pilot channel (approximately 260 feet), lower intensity and volume events were largely captured prior to reaching the outlet. A total of 10 storm events, ranging from 0.04 to 0.18 inches of rainfall, did not generate any effluent. The majority of these storms occurred in July, with two in August and one in October. This time period is generally the warmest of the year, which will cause the pond bottom to dry out more quickly allowing more infiltration of stormwater during events. The average intensity of these ten storms ranged from 0.01 to 0.72 inches/hour. The total influent of all ten storms was 1,644 cubic feet. Fields of Harvest also has the least amount of imperviousness at 0.91 acres. This signifies that a small portion of the rainfall that falls within the drainage area will become immediate runoff. In all other areas of the drainage area, the soils will need to become saturated before runoff occurs. Rainfall amount, intensity, and duration are driving factors at producing significant runoff at this facility, which was observed in the field and in the level loggers, as many minor rainfall and intensity events that occurred during the summer growing season were entirely captured within the facility.

College Hills

This 'Control' pond showed the lowest percent reductions for all pollutants, which is not surprising given that a riprap pilot channel connects the inlet directly to the outlet in this pond over a distance of approximately 60 feet. Over the past few decades, however, the pilot channel had filled in with sediment and a large sediment berm nearly 2ft high had formed adjacent to the inlet, which impeded inflows and partially submerged the inlet eliminating the free-board needed for flow gauging. As a result, the pilot channel was excavated approximately down to the original design elevations, to restore the condition of the pilot channel to its original state. However, it is possible that pollutant reductions may have been better for this facility if the flow had been allowed to spread out more broadly over a larger portion of the pond bottom, as it is likely to have done before the pilot channel was excavated back to its original form.

Glyndon Square

This self-converted pond, which drains a commercial shopping center with 60% imperviousness, showed the highest percent reduction of TN (36%) and TP (82%) across all sites, but a relatively low percent reduction for TP (24%). Given that 62% of the pond bottom area is comprised of wetland, the pond slopes consist of a combination of typical deciduous woods with trees and dense understory vegetation and grasses, and diffuse flow patterns spread the influent over a broad area of vegetated bottom, the high reductions for TN and TSS are not unexpected. Unusually high TP concentrations were occasionally observed coming from inlet B, where foul smelling, darkly colored waste water was observed leaking into the inlet from a commercial dumpster. It is possible that pulses of high TP have been entering the pond for some time, which may have impeded the ponds ability to utilize phosphorus and show greater removal during our study period.

Hunt Ridge

This self-converted pond, which drains a medium density residential community with 23% imperviousness, showed a moderate percent reduction of TN (25%) and high reductions for TP (75%) and TSS (75%). While only 4% of the pond bottom area is comprised of wetland (0.02 acres), the pond slopes and bottom are densely vegetated with a combination of trees, shrubs, and herbaceous plants. Flow from Inlet A quickly becomes backwatered by a large debris dam blocking the general flow path, which caused water to pool and spread out more widely over the pond bottom prior to entering the low flow pipe of the outlet approximately 130 feet away. Flow from inlet B first drains into a small cattail wetland area in the southwest corner of the pond before reaching the low flow outlet pipe approximately 250 feet away.

Additionally, large amounts of sediment and coarse particulate organic matter (CPOM) have accumulated across the pond bottom and particularly around the low flow outlet pipe causing many holes in the perforated pipe to be covered or partially clogged. With fewer openings available for drainage, there appears to be an increased retention time of the influent prior to being discharged through the outlet. This increased retention time may help reduce TN, TP and TSS by gravitational settling, while partial filtration through CPOM may further reduce pollutants.

Worthington

Worthington is a self-converted wetland pond that drains low-density residential land with 10.7% imperviousness. However, this facility has the largest drainage area in the study at 63.4 acres, which is more than three times the drainage area of the next largest facility and larger than the other facilities combined. Despite having 82% of the pond bottom comprised as wetland, this pond showed the lowest percent reduction of TN (9%) and TSS (24%) of all self-converted ponds. The percent removal of TP fared better than all but one site at 45%. Even though the pond bottom is mostly wetland, a defined channel has developed that conveys storm flows directly to the low flow device at the outlet. There appears to be little interaction with the broader wetland pond bottom during smaller events, which likely affects the pollutant removal performance. On the other hand, effluent concentrations for base flow TN were significantly lower than influent concentrations, suggesting increased performance of base flow removal. It is likely that the wetland conditions are consistently reducing base flow concentrations, but that retention times are not sufficient for improved storm flow performance.

5. CONCLUSIONS

The results of this study suggest that mature (i.e., decades-old) dry detention ponds provide greater removal efficiencies than the crediting currently provides, whether they are considered self-converted or unconverted. Our study population of self-converted dry ponds showed estimated reductions of 9-36% for TN, 24-75% for TP, and 24-82% for TSS. A broad range of pollutant removal performance was also observed in our population of unconverted dry detention ponds, with estimated reductions of 2-29% for TN, 15-42% for TP, and 19-73% for TSS. Comparison between the study results using average rates for each pollutant and the current approved CBP rates is included in Table 29. The control group of unconverted ponds performed much better than the CBP dry detention pond rates and performed overall more closely to the dry extended detention pond rates. Performance of the self-converted group was quite similar to that of the wet pond/wetland category.

Table 29 - BMP Reduction Rate Comparison

BMP Type	**Reduction Efficiency**		
	TN	**TP**	**TSS**
Chesapeake Bay Program Rates (Schueler and Lane, 2012)			
Dry Detention Pond	5%	10%	10%
Dry Extended Detention	20%	20%	60%
Wet Ponds/Wetlands	20%	45%	60%
Study Results			
Dry Detention Ponds (Avg)	18.5%	28.8%	53.2%
Self-Converted Ponds (Avg)	23.3%	47.9%	60.0%

With the broad range in performance for both self-converted and unconverted facilities, it may become a challenge to extrapolate the results to the County's other facilities since the factors driving pollutant removal success involve more than just the presence or absence of wetland soils and vegetation. While there appear to be numerous factors responsible for increasing the potential for pollutant removal, the primary characteristics observed among the best performing facilities are 1) diffuse flow through the facility without a pilot channel; 2) base flow retention, and 3) presence of vegetation (other than turf grass). What is perhaps less clear, is the contribution each of these factors play in the overall reduction of TN, TP, and TSS. Future studies could investigate how much the diffuse flow and vegetation contribute to removal, since these are the only two characteristics that can be modified for retrofit/enhancement purposes. It is possible that relatively inexpensive and disruptive retrofits using flow splitters or plugging pilot channels could direct flow through the facility to results in better interaction with vegetation and soils to promote enhanced treatment. Furthermore, it remains unknown whether attempting to recreate some of these conditions artificially would provide the same levels of performance as those that have developed over decades through natural ecological processes such as sediment deposition, vegetative colonization, and nutrient cycling.

Since conducting this study to evaluate the performance of self-converted and unconverted dry detention ponds, a number of additional questions have been raised that follow-up studies may help to address. Additional water quality parameters were tested for that were outside of the direct focus of this investigation and therefore not reported on here, but can be investigated in the future. Questions to investigate include: Are these types of ponds as effective at removing sodium and chloride, given the pervasiveness of salt use in treating roadways in the winter? What is the performance of these ponds for the removal of the different forms of nitrogen and phosphorus? Does storm intensity and/or duration of storms affect the removal rates, and if so, to what degree? Does influent concentration impact performance or reduction efficiency?

Lastly, it is recommended that the data be presented to MDE and the Chesapeake Bay Program for a review, given that the pollutant removal rates observed in this study far surpassed those currently recommended by MDE and the Chesapeake Bay Program. Accurate crediting is increasingly important in today's regulatory environment, especially with the current Chesapeake Bay TMDL goals for reducing nutrients and sediments throughout the entire watershed.

As conditions of the Pioneer Grant supporting the study, KCI, Towson UEBL and Baltimore County will present the results to the Bay Program's Urban Stormwater Workgroup and will submit the resulting data to the International Stormwater BMP Database.

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Appendix A: Site Photographs

Glyndon: Outlet

Glyndon: Inlet A immediately following weir installation

Glyndon: Inlet B

Glyndon: General pond view

Hunt Ridge: Riser/low flow outlet pipe

Hunt Ridge: Inlet A

Hunt Ridge: Inlet B

Hunt Ridge: Wetland area during storm event

Worthington: Inlet weir

Worthington: Common Reed (*Phragmites australis)* stand

Worthington: Outlet weir

Worthington: Direct channel through pond

McCormick: Inlet A

McCormick: Inlet B

McCormick: General pond view

McCormick: Outfall

College Hills: Inlet prior to pilot channel excavation

College Hills: Outlet

College Hills: Riser

College Hills: Rain Event

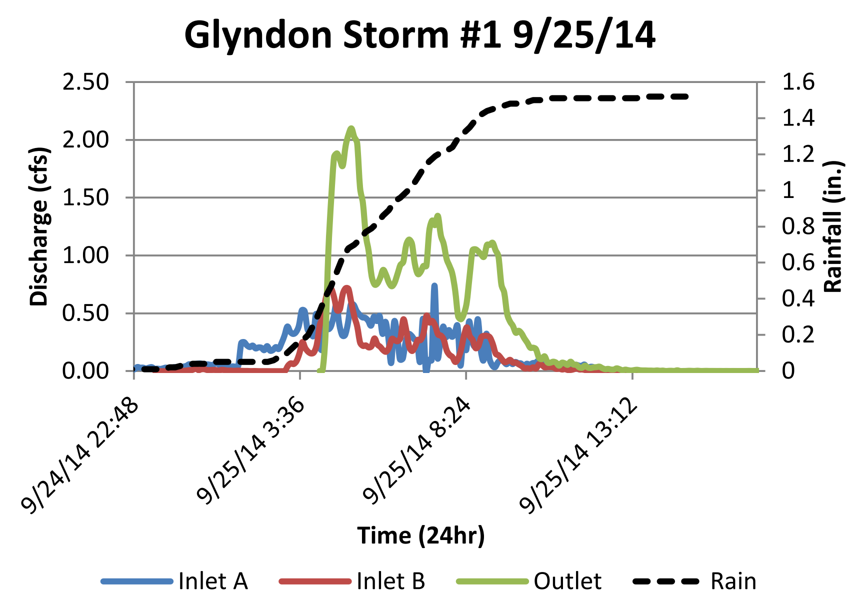
Fields of Harvest: Inlet

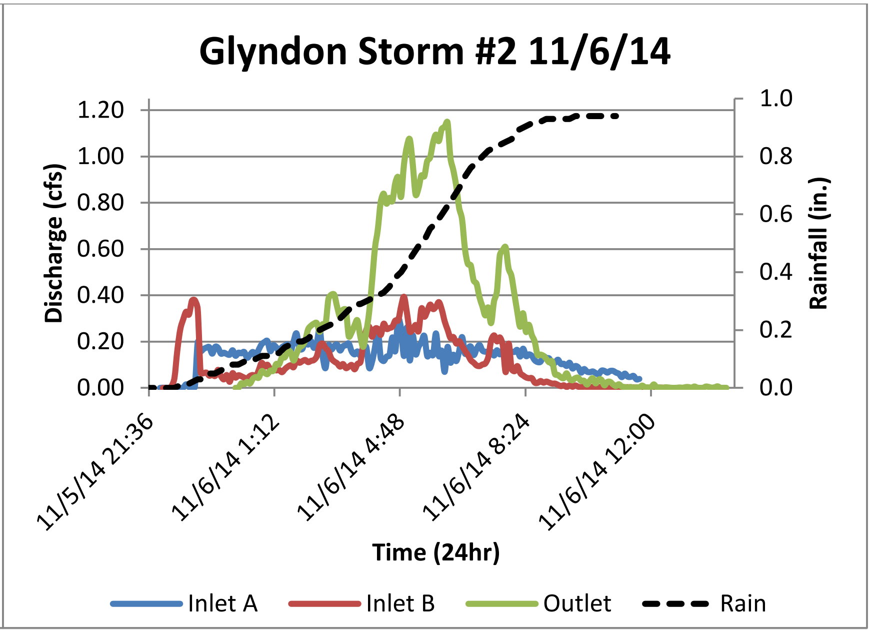
Fields of Harvest : General pond view

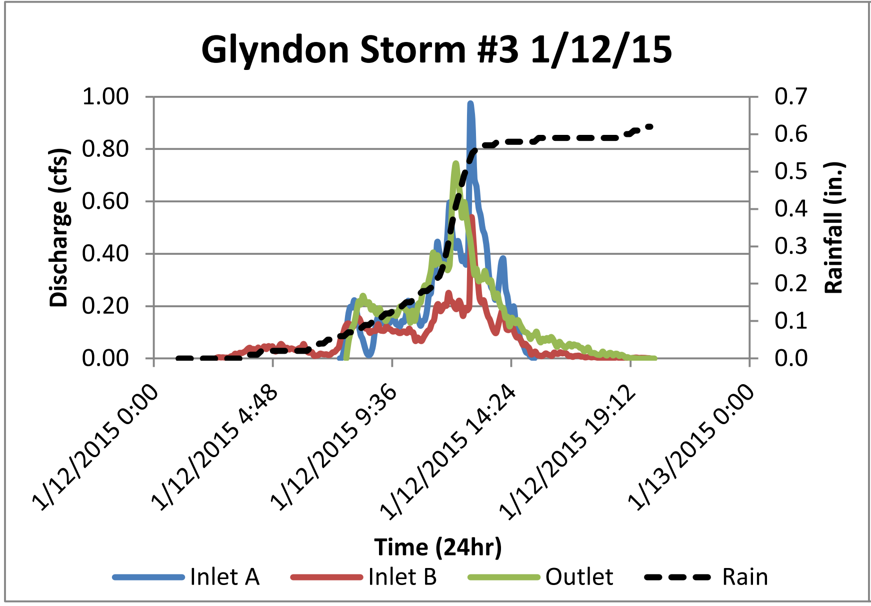
Fields of Harvest: Outlet box structure, low flow orifice obscured by vegetation

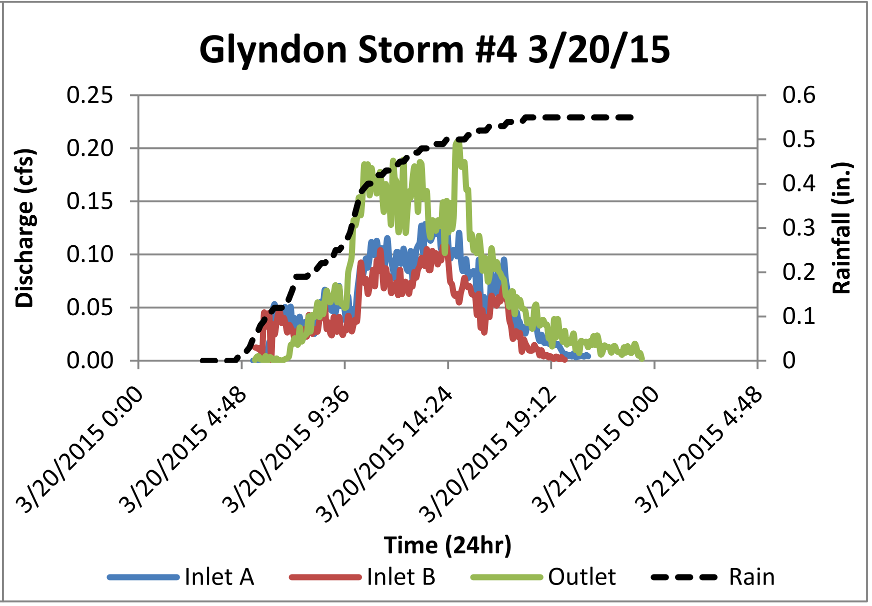
Fields of Harvest : Outlet Pipe

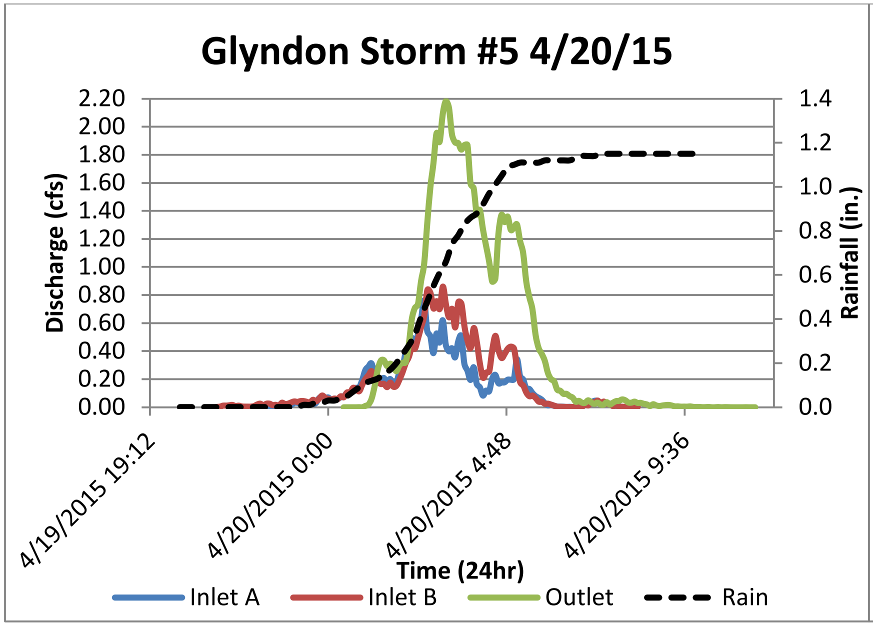
Appendix B: Storm Hydrographs

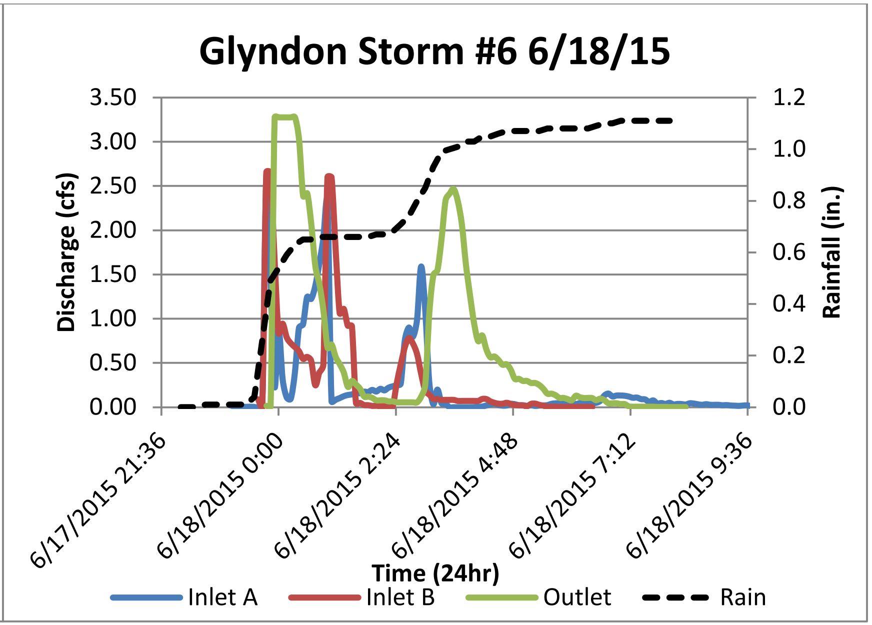

Glyndon Storm #1 9/25/14

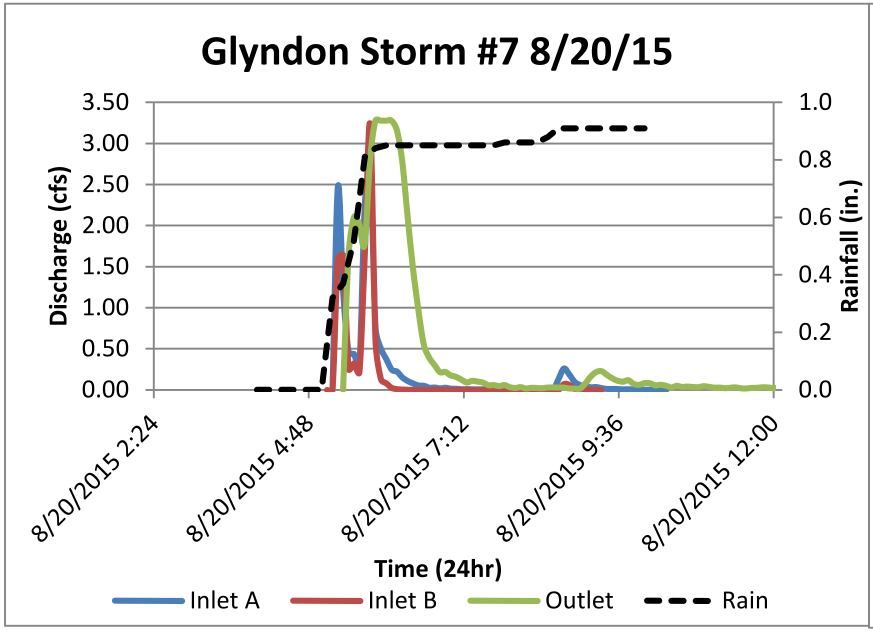

Glyndon Storm #2 11/6/14

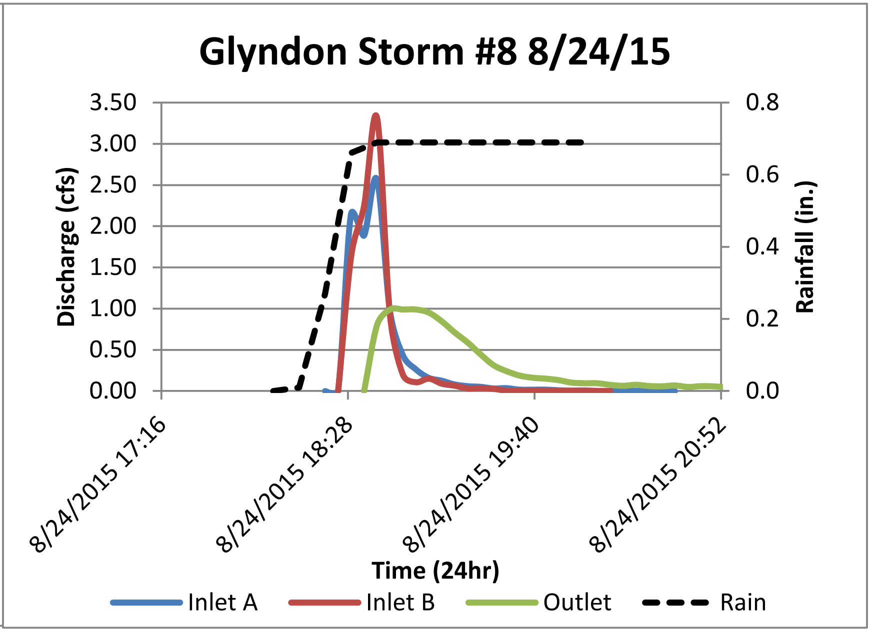

Glyndon Storm #3 1/12/15

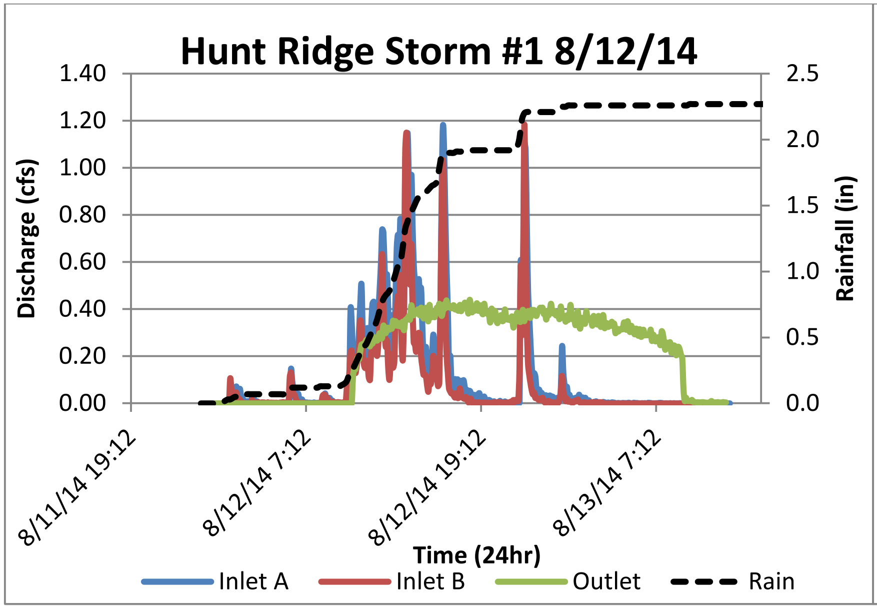

Glyndon Storm #4 3/20/15

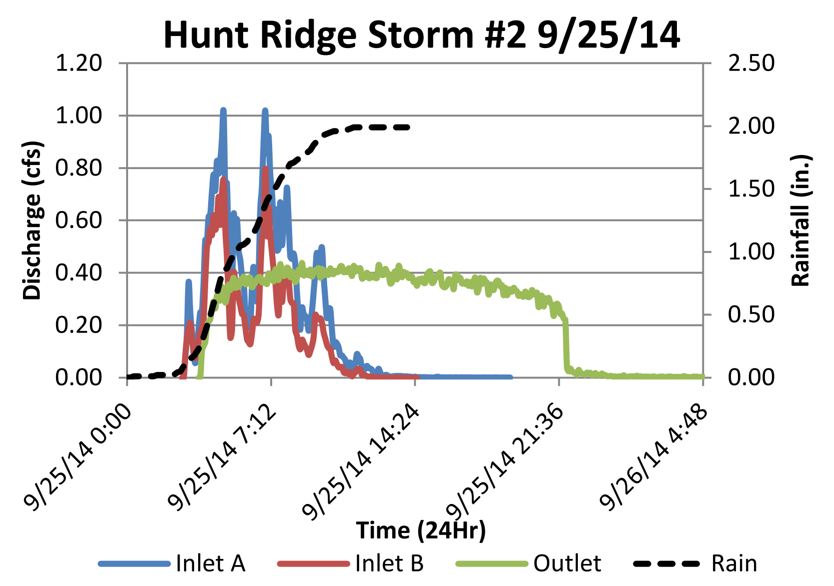

Glyndon Storm #5 4/20/15
Discharge (cfs)
2.20
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Rainfall (in.)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
4/19/2015 19:12
4/20/2015 0:00
4/20/2015 4:48
4/20/2015 9:36
Time (24hr)
Inlet A
Inlet B
Outlet
Rain

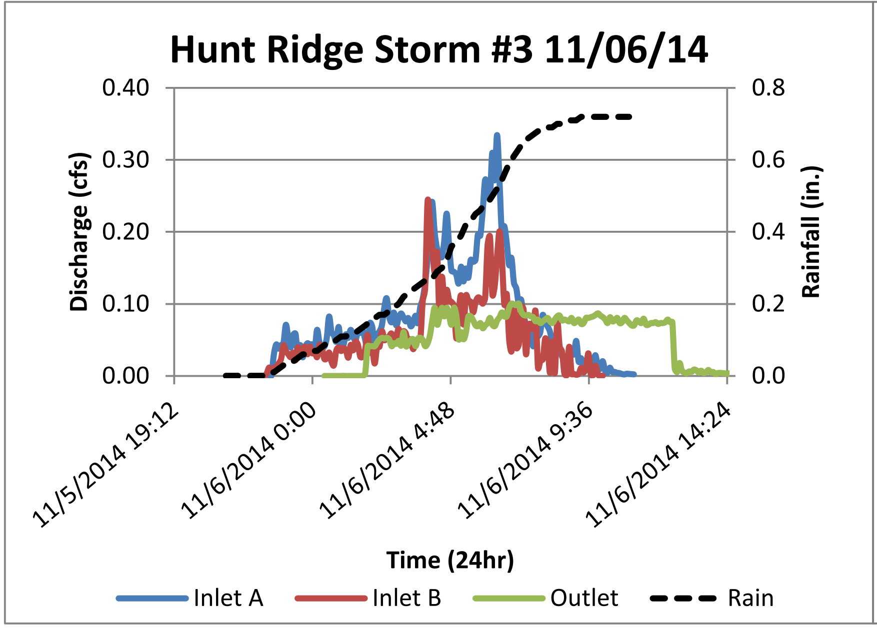

Glyndon Storm #6 6/18/15
Discharge (cfs)
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Rainfall (in.)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
6/17/2015 21:36
6/18/2015 0:00
6/18/2015 2:24
6/18/2015 4:48
6/18/2015 7:12
6/18/2015 9:36
Time (24hr)
Inlet A
Inlet B
Outlet
Rain

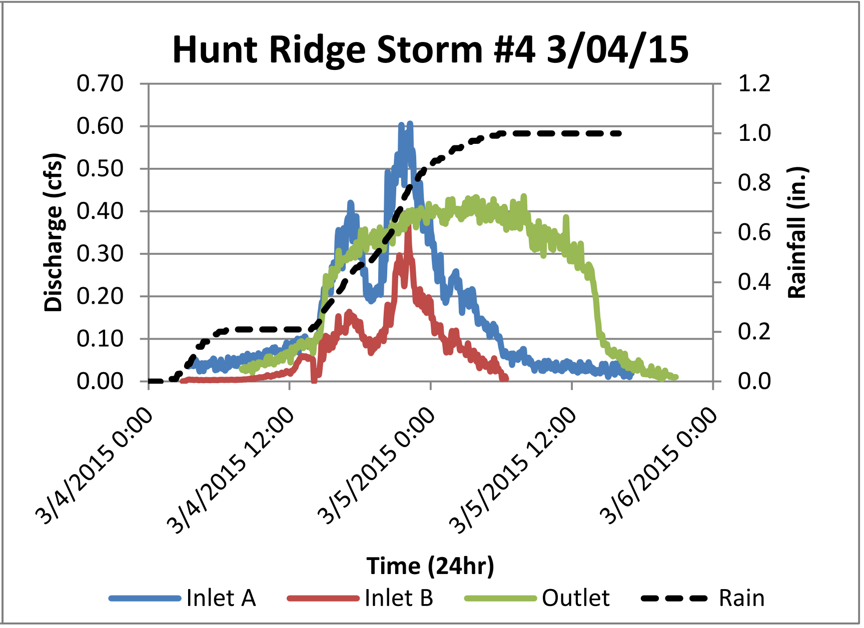

Glyndon Storm #7 8/20/15
Discharge (cfs)
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Rainfall (in.)
1.0
0.8
0.6
0.4
0.2
0.0
8/20/2015 2:24
8/20/2015 4:48
8/20/2015 7:12
8/20/2015 9:36
8/20/2015 12:00
Time (24hr)
Inlet A
Inlet B
Outlet
Rain

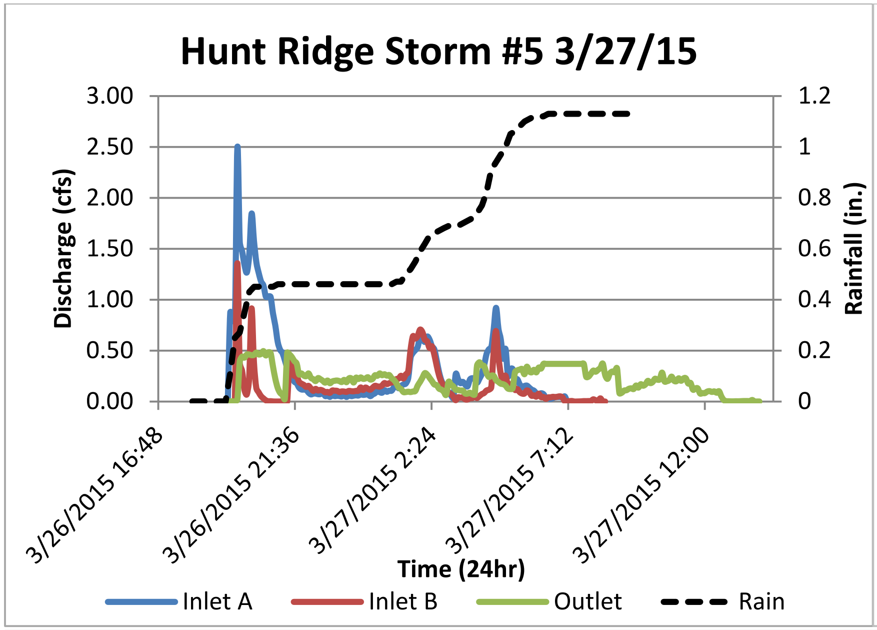

Glyndon Storm #8 8/24/15
Discharge (cfs)
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Rainfall (in.)
0.8
0.6
0.4
0.2
0.0
8/24/2015 17:16
8/24/2015 18:28
8/24/2015 19:40
8/24/2015 20:52
Time (24hr)
Inlet A
Inlet B
Outlet
Rain

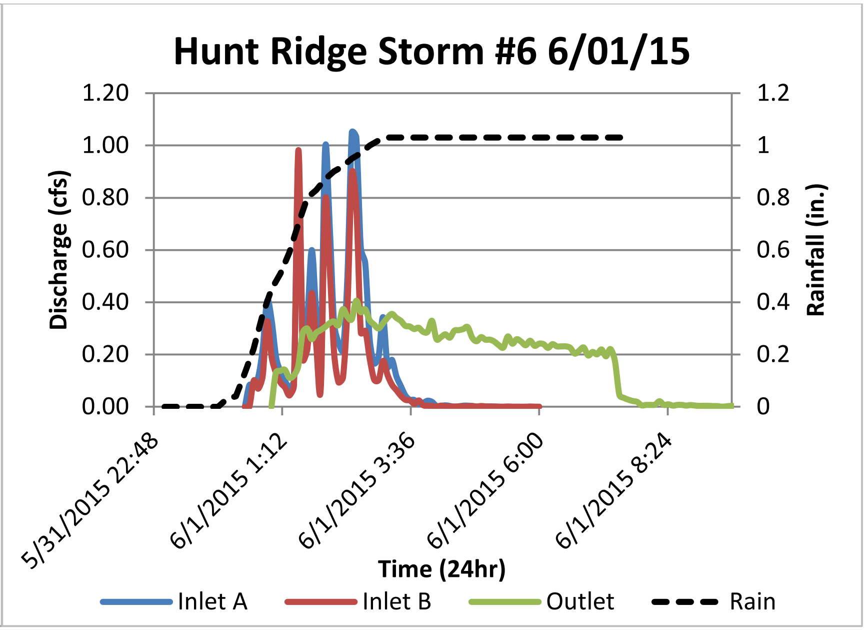

Hunt Ridge Storm #1 8/12/14
Discharge (cfs)
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Rainfall (in)
2.5
2.0
1.5
1.0
0.5
0.0
8/11/14 19:12
8/12/14 7:12
8/12/14 19:12
8/13/14 7:12
Time (24hr)
Inlet A
Inlet B
Outlet
Rain

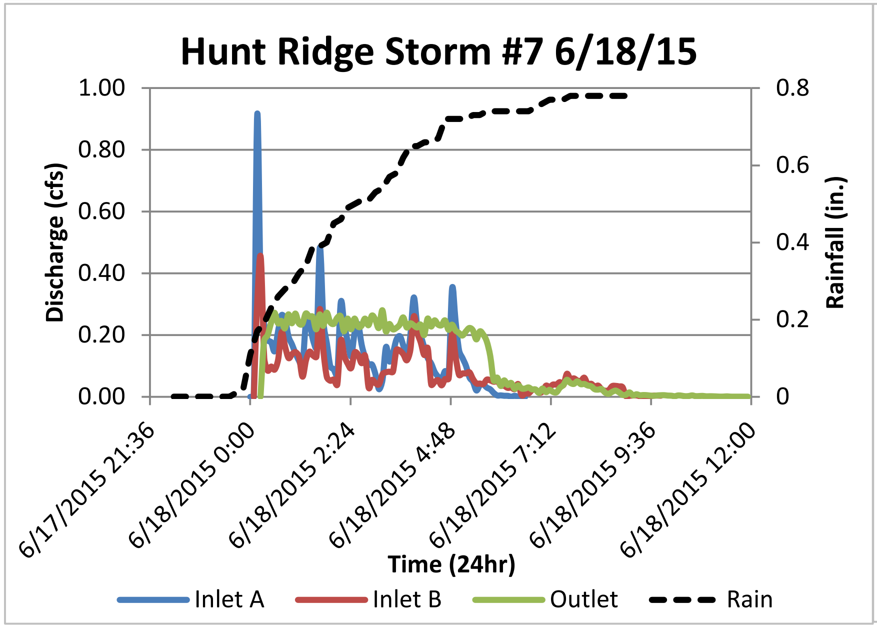

Hunt Ridge Storm #2 9/25/14
Discharge (cfs)
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Rainfall (in.)
2.50
2.00
1.50
1.00
0.50
0.00
9/25/14 0:00
9/25/14 7:12
9/25/14 14:24
9/25/14 21:36
9/26/14 4:48
Time (24Hr)
Inlet A
Inlet B
Outlet
Rain

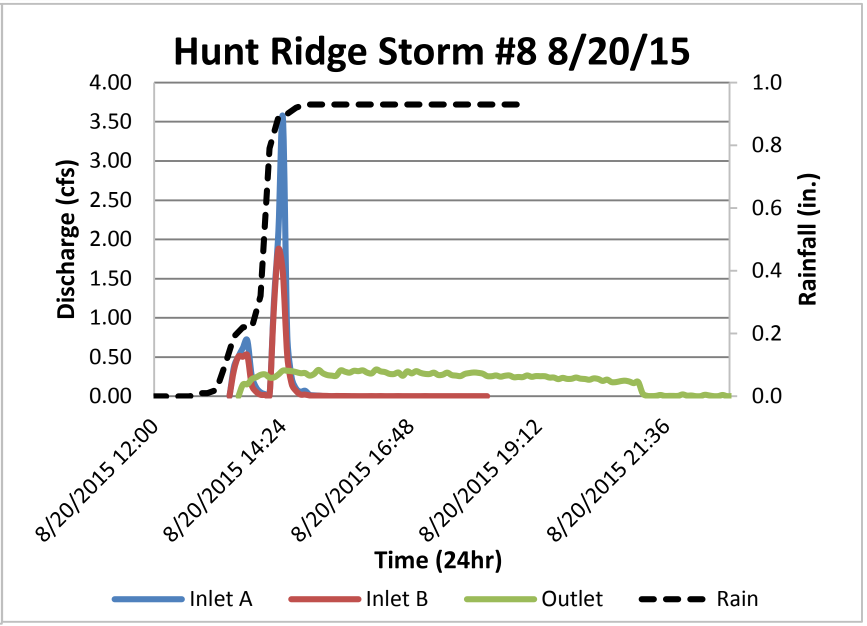

Hunt Ridge Storm #3 11/06/14
Discharge (cfs)
0.40
0.30
0.20
0.10
0.00
Rainfall (in.)
0.8
0.6
0.4
0.2
0.0
11/5/2014 19:12
11/6/2014 0:00
11/6/2014 4:48
11/6/2014 9:36
11/6/2014 14:24
Time (24hr)
Inlet A
Inlet B
Outlet
Rain

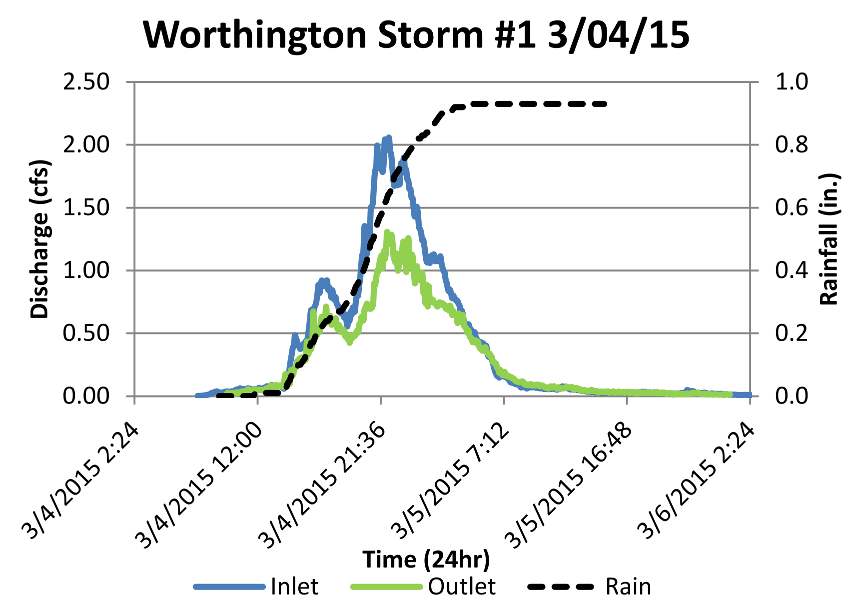

Hunt Ridge Storm #4 3/04/15
Discharge (cfs)
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Rainfall (in.)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
3/4/2015 0:00
3/4/2015 12:00
3/5/2015 0:00
3/5/2015 12:00
3/6/2015 0:00
Time (24hr)
Inlet A
Inlet B
Outlet
Rain

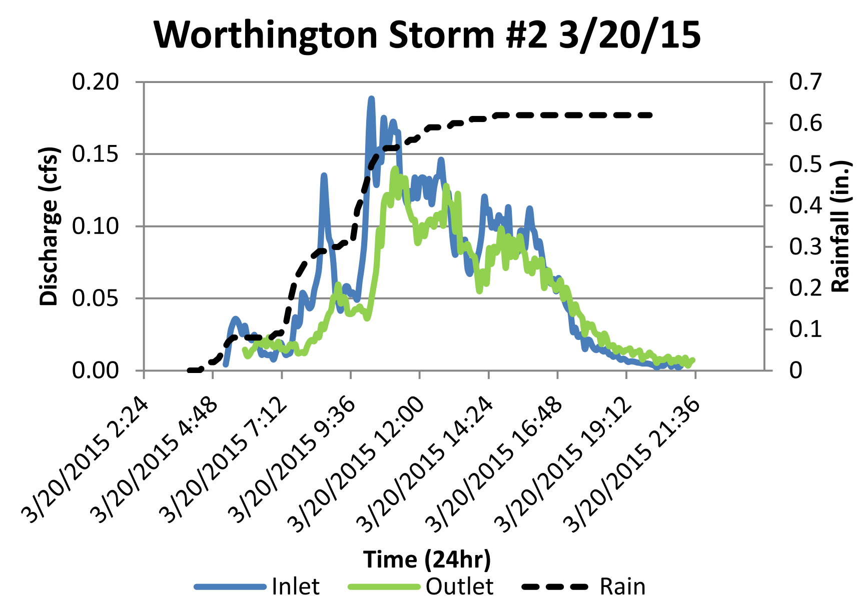

Hunt Ridge Storm #5 3/27/15

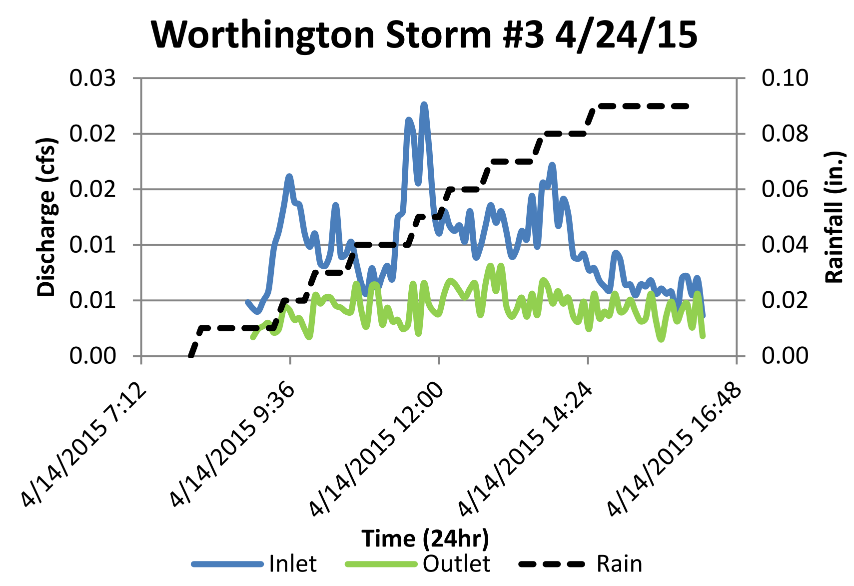

Hunt Ridge Storm #6 6/01/15

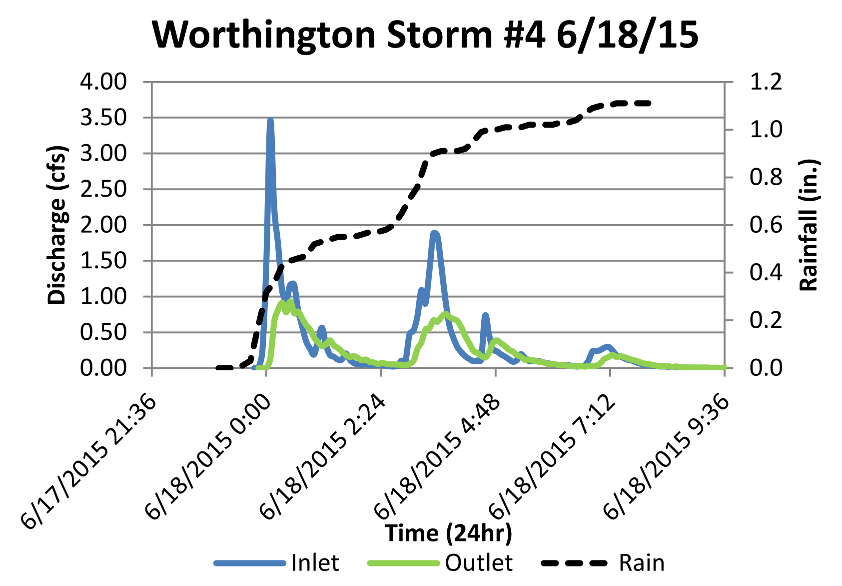

Hunt Ridge Storm #7 6/18/15

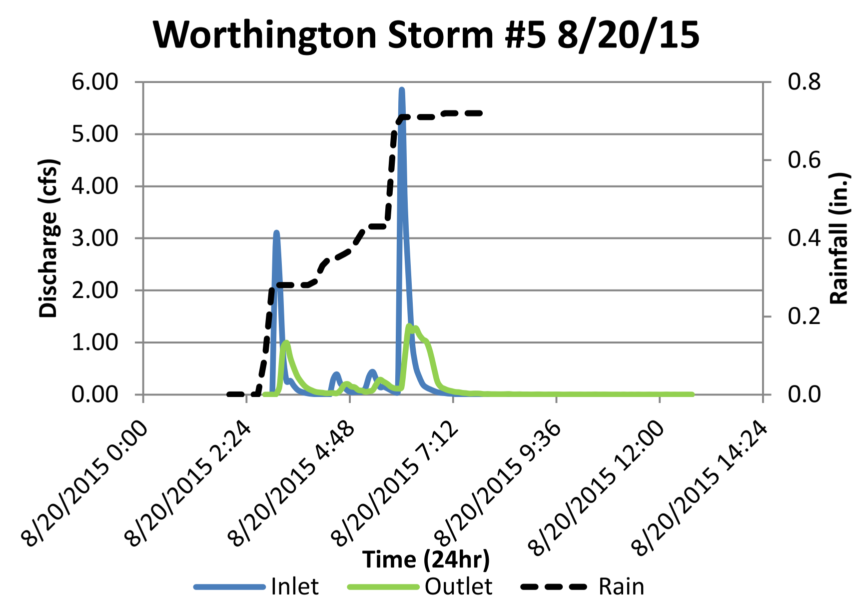

Hunt Ridge Storm #8 8/20/15

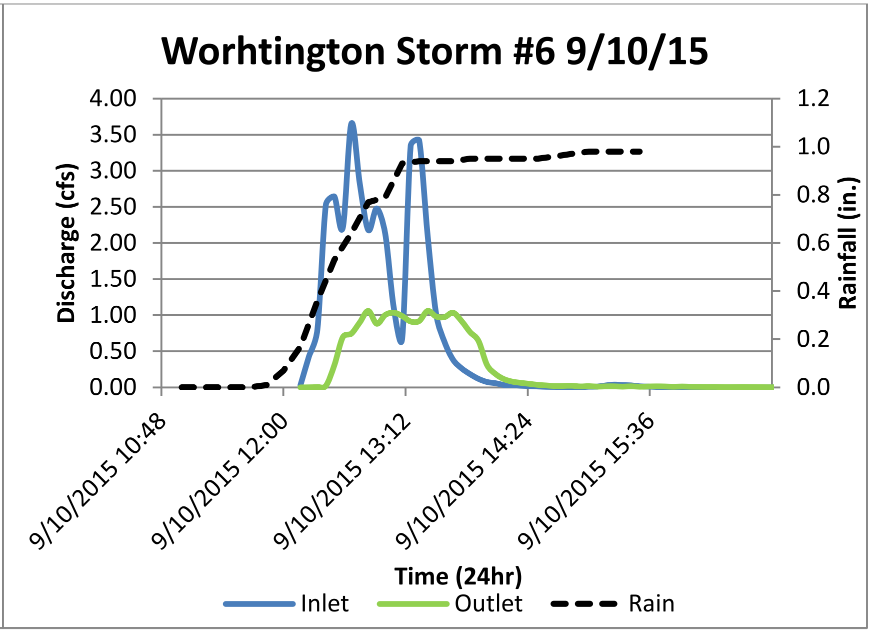

Worthington Storm #1 3/04/15
Discharge (cfs)
2.50
2.00
1.50
1.00
0.50
0.00
Rainfall (in.)
1.0
0.8
0.6
0.4
0.2
0.0
3/4/2015 2:24
3/4/2015 12:00
3/4/2015 21:36
3/5/2015 7:12
3/5/2015 16:48
3/6/2015 2:24
Time (24hr)
Inlet
Outlet
Rain

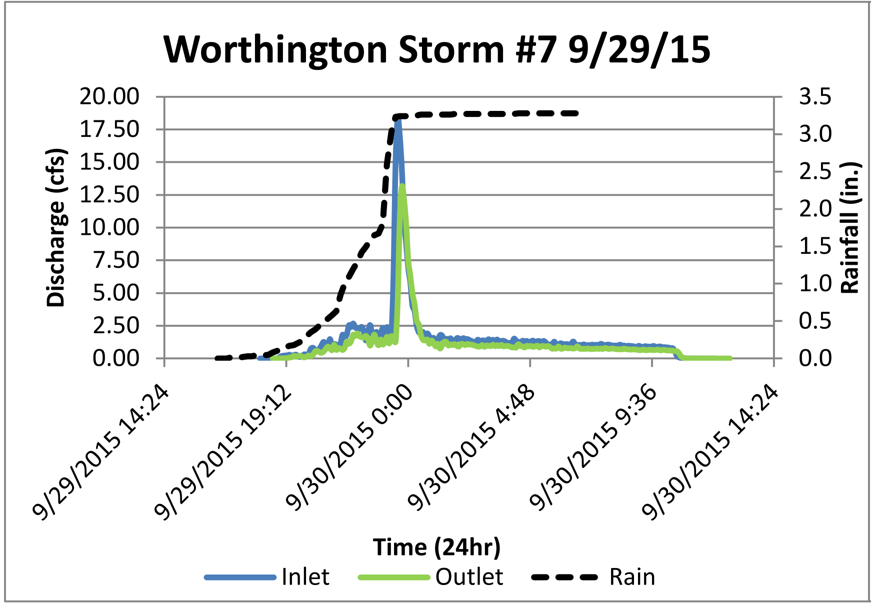

Worthington Storm #2 3/20/15
Discharge (cfs)
0.20
0.15
0.10
0.05
0.00
Rainfall (in.)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
3/20/2015 2:24
3/20/2015 4:48
3/20/2015 7:12
3/20/2015 9:36
3/20/2015 12:00
3/20/2015 14:24
3/20/2015 16:48
3/20/2015 19:12
3/20/2015 21:36
Time (24hr)
Inlet
Outlet
Rain

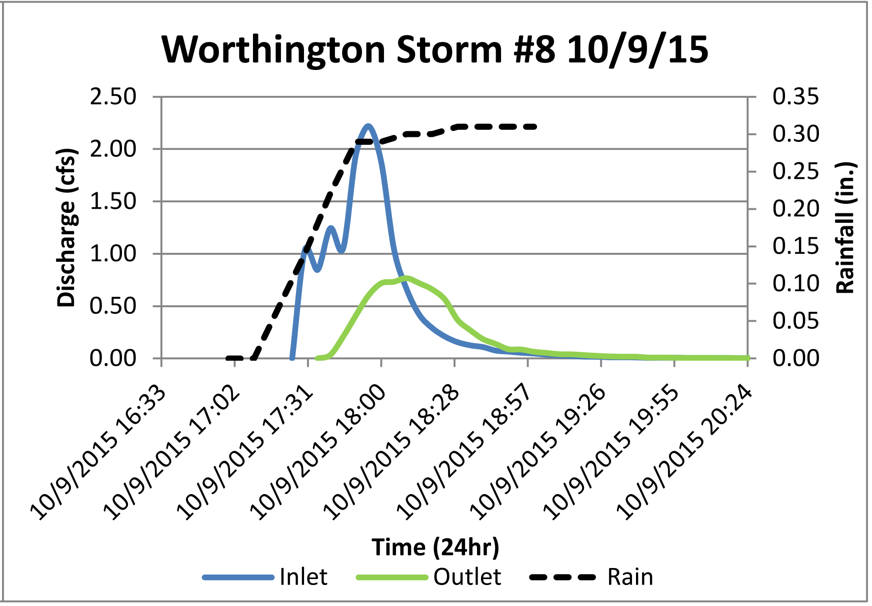

Worthington Storm #3 4/24/15
Discharge (cfs)
0.03
0.02
0.02
0.01
0.01
0.00
Rainfall (in.)
0.10
0.08
0.06
0.04
0.02
0.00
4/14/2015 7:12
4/14/2015 9:36
4/14/2015 12:00
4/14/2015 14:24
4/14/2015 16:48
Time (24hr)
Inlet
Outlet
Rain

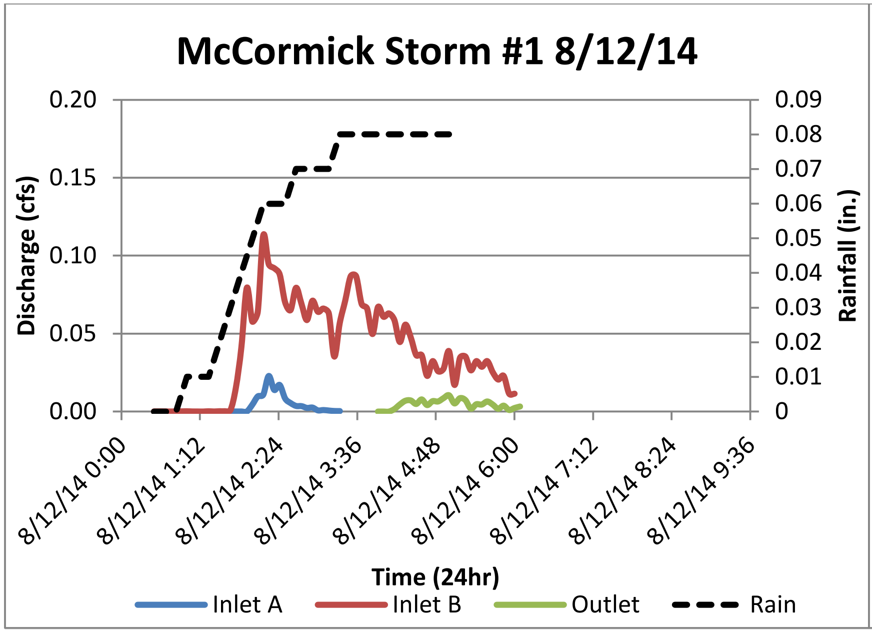

Worthington Storm #4 6/18/15
Discharge (cfs)
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Rainfall (in.)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
6/17/2015 21:36
6/18/2015 0:00
6/18/2015 2:24
6/18/2015 4:48
6/18/2015 7:12
6/18/2015 9:36
Time (24hr)
Inlet
Outlet
Rain

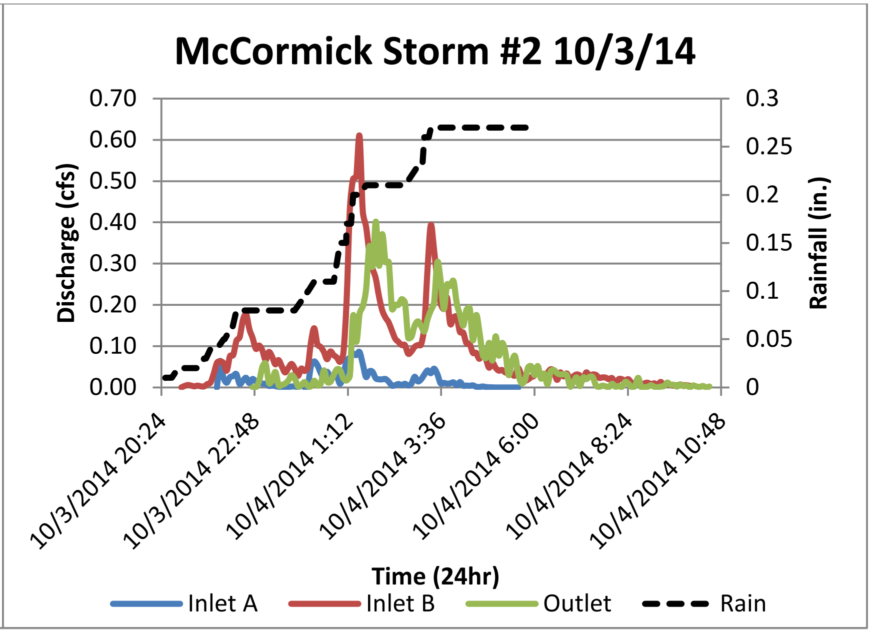

Worthington Storm #5 8/20/15
Discharge (cfs)
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Rainfall (in.)
0.8
0.6
0.4
0.2
0.0
8/20/2015 0:00
8/20/2015 2:24
8/20/2015 4:48
8/20/2015 7:12
8/20/2015 9:36
8/20/2015 12:00
8/20/2015 14:24
Time (24hr)
Inlet
Outlet
Rain

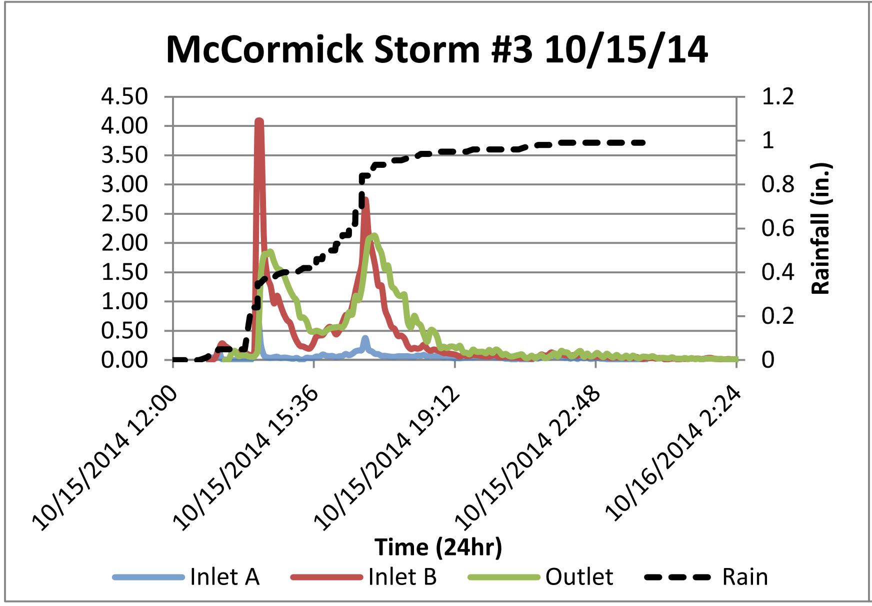

Worhtington Storm #6 9/10/15
Discharge (cfs)
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Rainfall (in.)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
9/10/2015 10:48
9/10/2015 12:00
9/10/2015 13:12
9/10/2015 14:24
9/10/2015 15:36
Time (24hr)
Inlet
Outlet
Rain

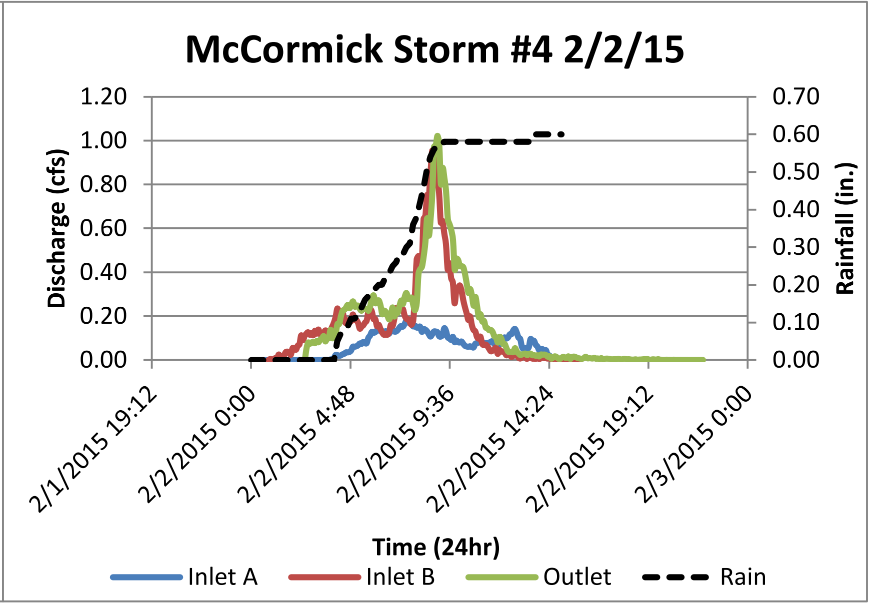

Worthington Storm #7 9/29/15
Discharge (cfs)
20.00
17.50
15.00
12.50
10.00
7.50
5.00
2.50
0.00
Rainfall (in.)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
9/29/2015 14:24
9/29/2015 19:12
9/30/2015 0:00
9/30/2015 4:48
9/30/2015 9:36
9/30/2015 14:24
Time (24hr)
Inlet
Outlet
Rain

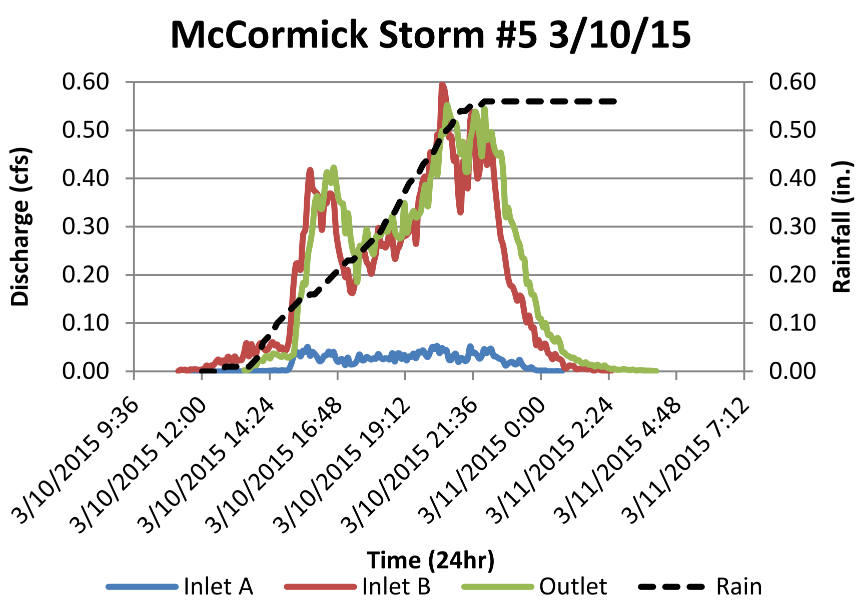

Worthington Storm #8 10/9/15
Discharge (cfs)
2.50
2.00
1.50
1.00
0.50
0.00
Rainfall (in.)
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
10/9/2015 16:33
10/9/2015 17:02
10/9/2015 17:31
10/9/2015 18:00
10/9/2015 18:28
10/9/2015 18:57
10/9/2015 19:26
10/9/2015 19:55
10/9/2015 20:24
Time (24hr)
Inlet
Outlet
Rain

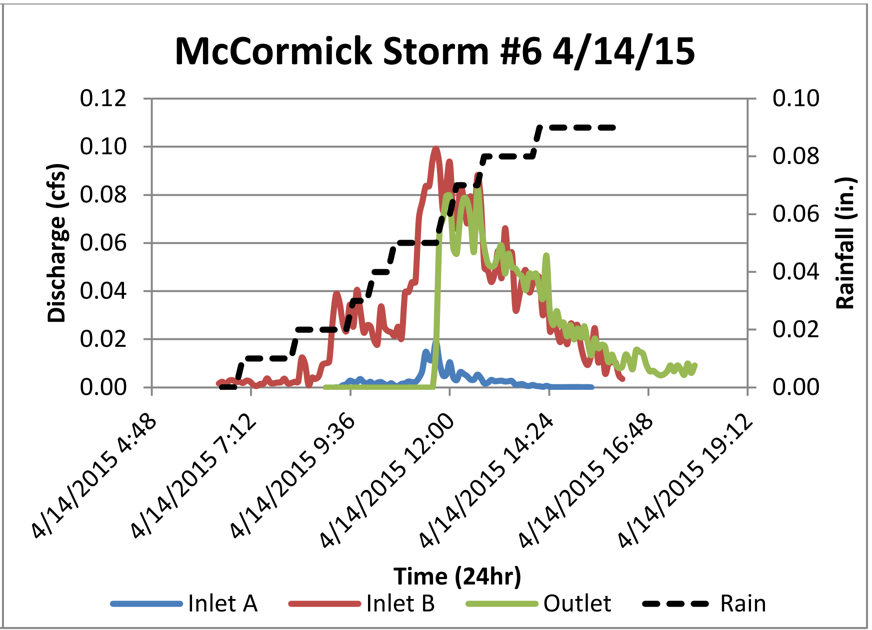

McCormick Storm #1 8/12/14
Discharge (cfs)
0.20
0.15
0.10
0.05
0.00
Rainfall (in.)
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
8/12/14 0:00
8/12/14 1:12
8/12/14 2:24
8/12/14 3:36
8/12/14 4:48
8/12/14 6:00
8/12/14 7:12
8/12/14 8:24
8/12/14 9:36
Time (24hr)
Inlet A
Inlet B
Outlet
Rain

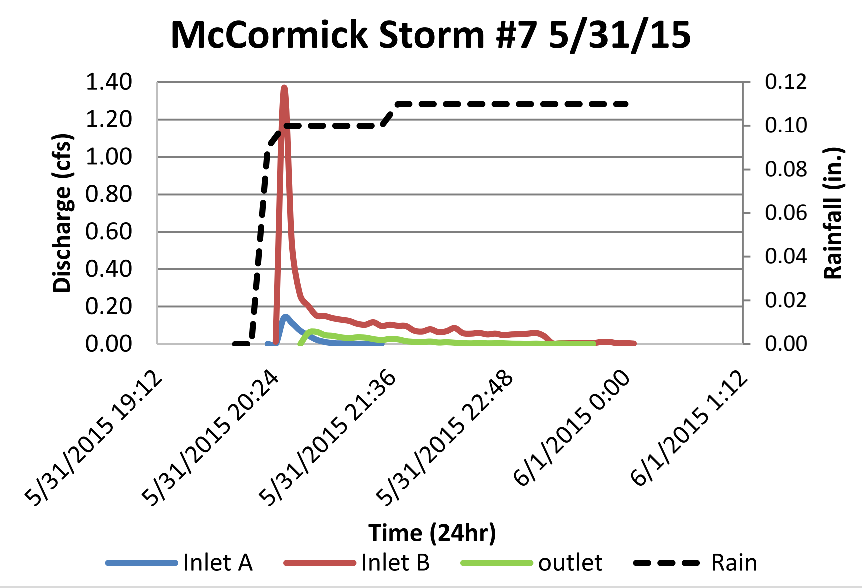

McCormick Storm #2 10/3/14
Discharge (cfs)
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Rainfall (in.)
0.3
0.25
0.2
0.15
0.1
0.05
0
10/3/2014 20:24
10/3/2014 22:48
10/4/2014 1:12
10/4/2014 3:36
10/4/2014 6:00
10/4/2014 8:24
10/4/2014 10:48
Time (24hr)
Inlet A
Inlet B
Outlet
Rain

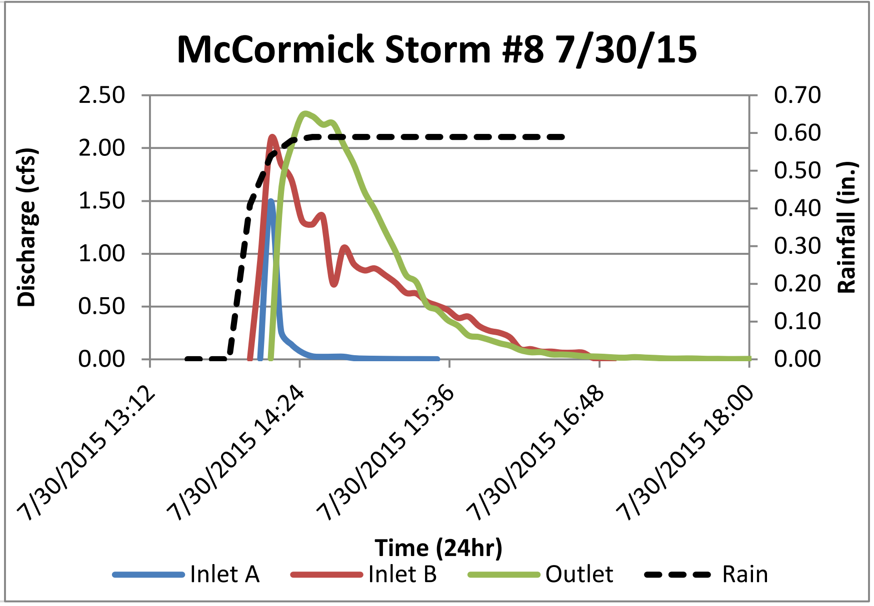

McCormick Storm #3 10/15/14
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Rainfall (in.)
1.2
1
0.8
0.6
0.4
0.2
0
10/15/2014 12:00
10/15/2014 15:36
10/15/2014 19:12
10/15/2014 22:48
10/16/2014 2:24
Time (24hr)
Inlet A
Inlet B
Outlet
Rain

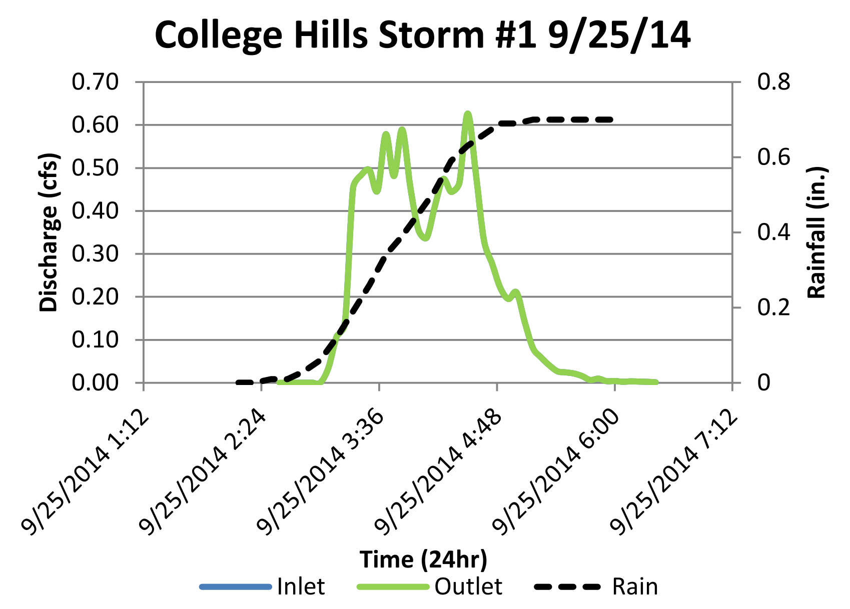

McCormick Storm #4 2/2/15
Discharge (cfs)
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Rainfall (in.)
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
2/1/2015 19:12
2/2/2015 0:00
2/2/2015 4:48
2/2/2015 9:36
2/2/2015 14:24
2/2/2015 19:12
2/3/2015 0:00
Time (24hr)
Inlet A
Inlet B
Outlet
Rain


McCormick Storm #5 3/10/15
Discharge (cfs)
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Rainfall (in.)
0.60
0.50
0.40
0.30
0.20
0.10
0.00
3/10/2015 9:36
3/10/2015 12:00
3/10/2015 14:24
3/10/2015 16:48
3/10/2015 19:12
3/10/2015 21:36
3/11/2015 0:00
3/11/2015 2:24
3/11/2015 4:48
3/11/2015 7:12
Time (24hr)
Inlet A
Inlet B
Outlet
Rain

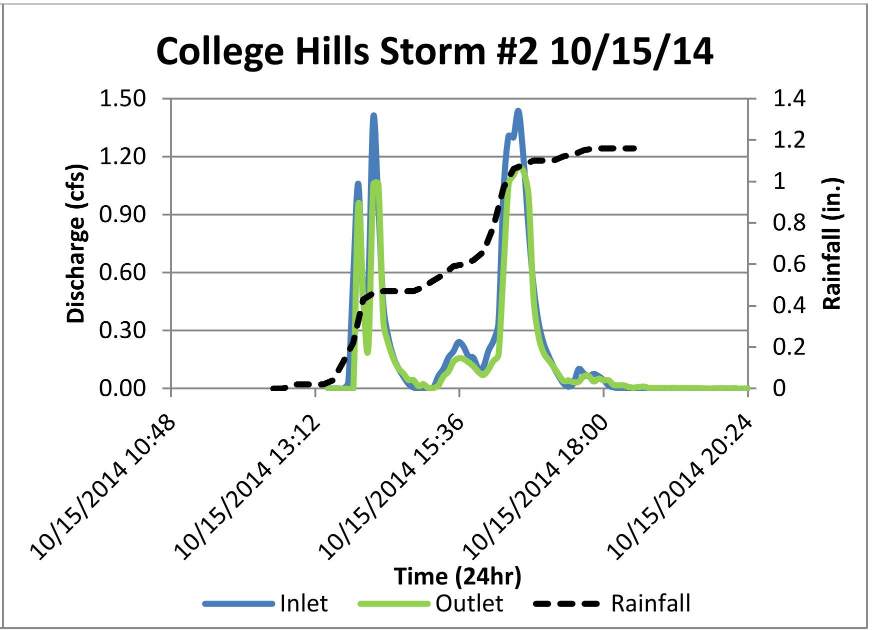

McCormick Storm #6 4/14/15
Discharge (cfs)
0.12
0.10
0.08
0.06
0.04
0.02
0.00
Rainfall (in.)
0.10
0.08
0.06
0.04
0.02
0.00
4/14/2015 4:48
4/14/2015 7:12
4/14/2015 9:36
4/14/2015 12:00
4/14/2015 14:24
4/14/2015 16:48
4/14/2015 19:12
Time (24hr)
Inlet A
Inlet B
Outlet
Rain


McCormick Storm #7 5/31/15
Discharge (cfs)
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Rainfall (in.)
0.12
0.10
0.08
0.06
0.04
0.02
0.00
5/31/2015 19:12
5/31/2015 20:24
5/31/2015 21:36
5/31/2015 22:48
6/1/2015 0:00
6/1/2015 1:12
Time (24hr)
Inlet A
Inlet B
outlet
Rain

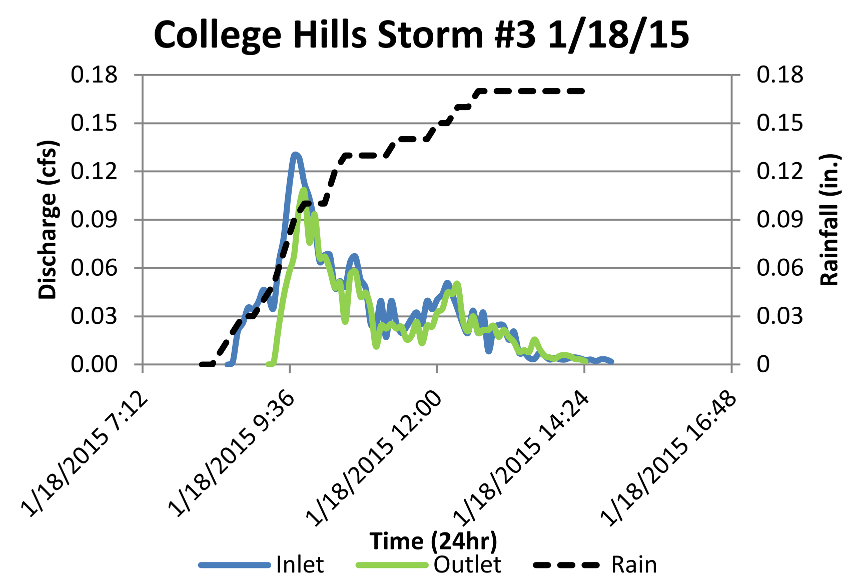

McCormick Storm #8 7/30/15
Discharge (cfs)
2.50
2.00
1.50
1.00
0.50
0.00
Rainfall (in.)
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
7/30/2015 13:12
7/30/2015 14:24
7/30/2015 15:36
7/30/2015 16:48
7/30/2015 18:00
Time (24hr)
Inlet A
Inlet B
Outlet
Rain



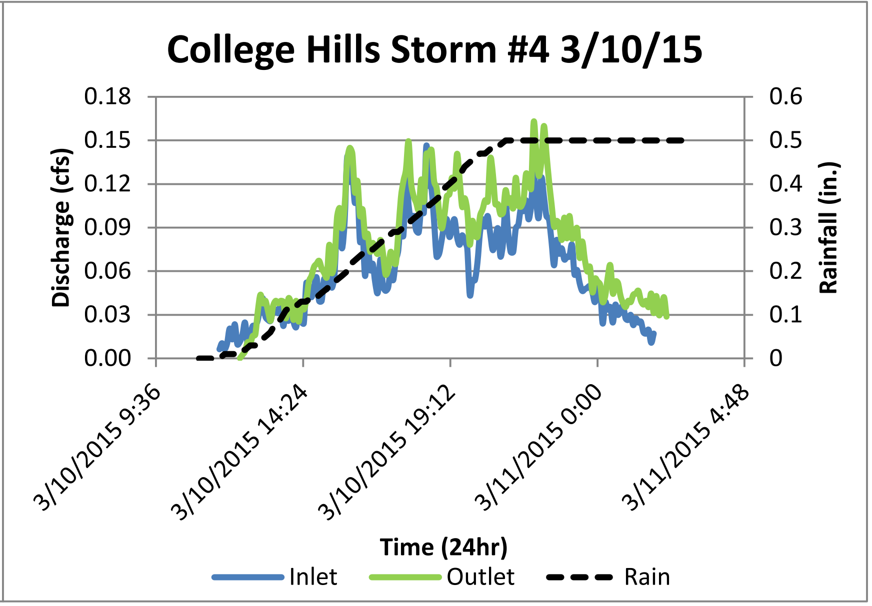
College Hills Storm #1 9/25/14



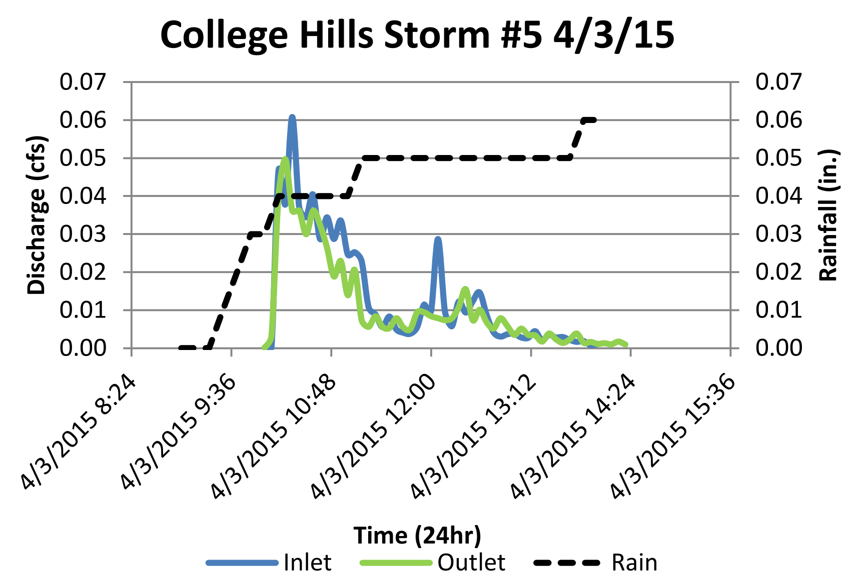
College Hills Storm #2 10/15/14

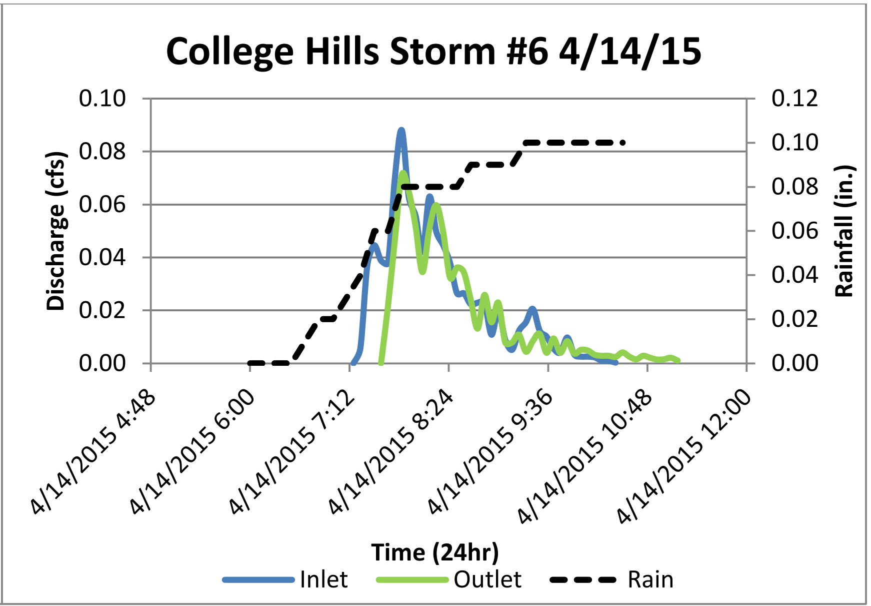


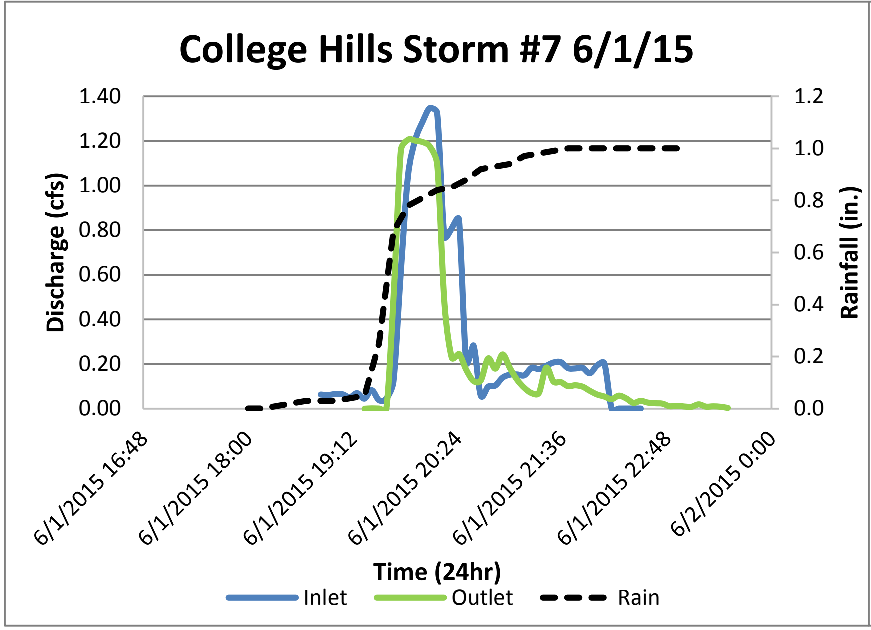
College Hills Storm #3 1/18/15

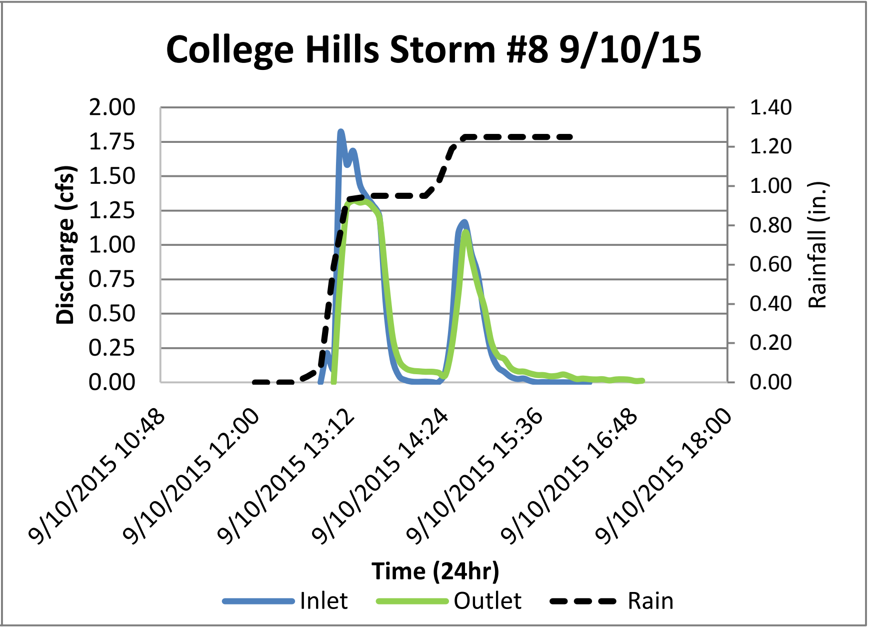


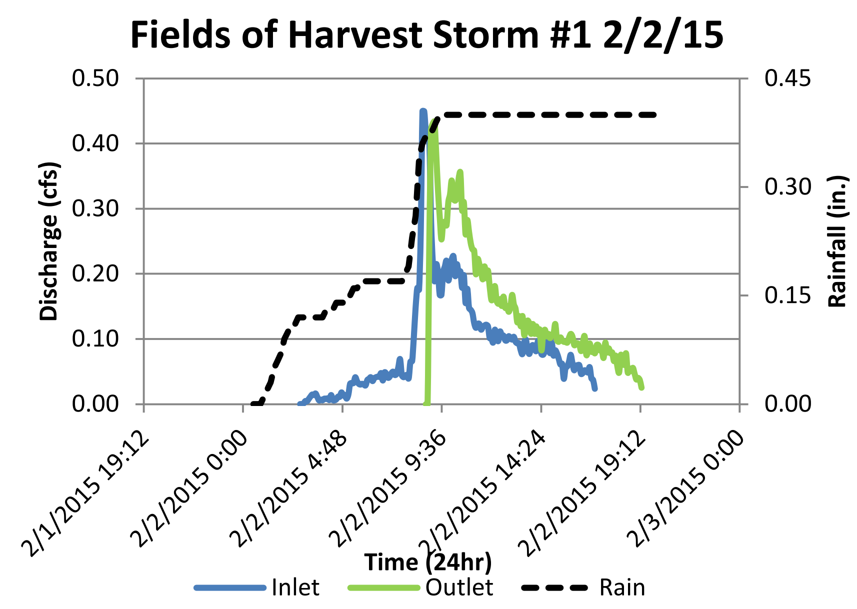
College Hills Storm #4 3/10/15


College Hills Storm #5 4/3/15

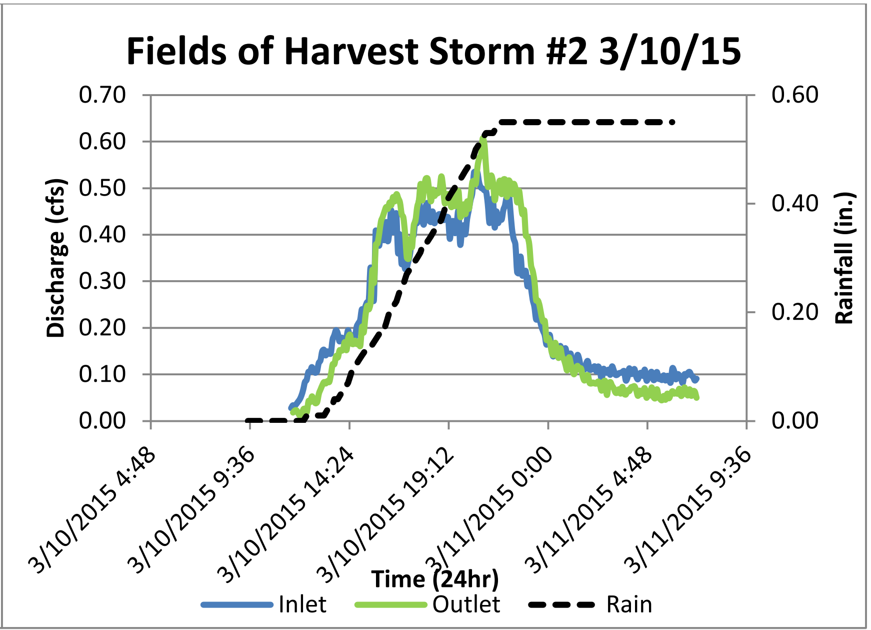

College Hills Storm #6 4/14/15


College Hills Storm #7 6/1/15

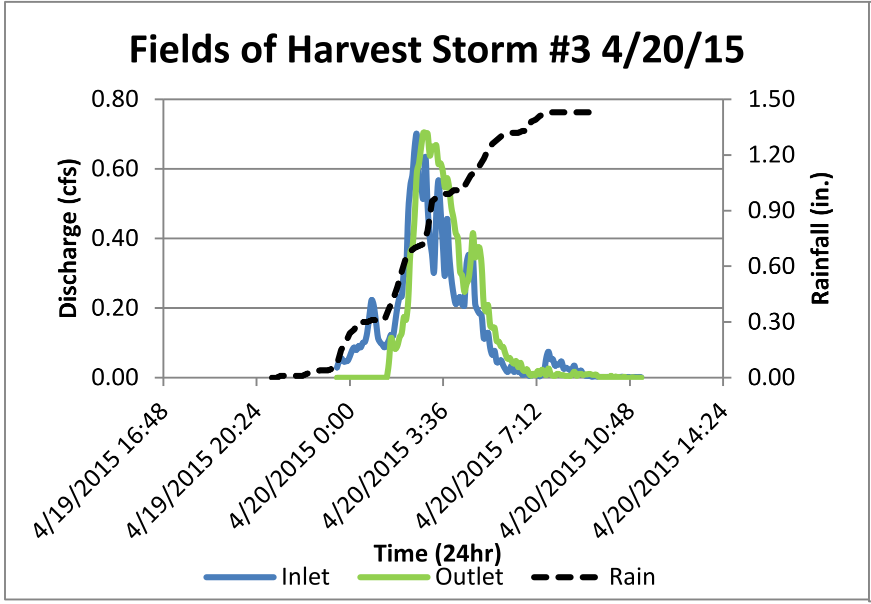

College Hills Storm #8 9/10/15



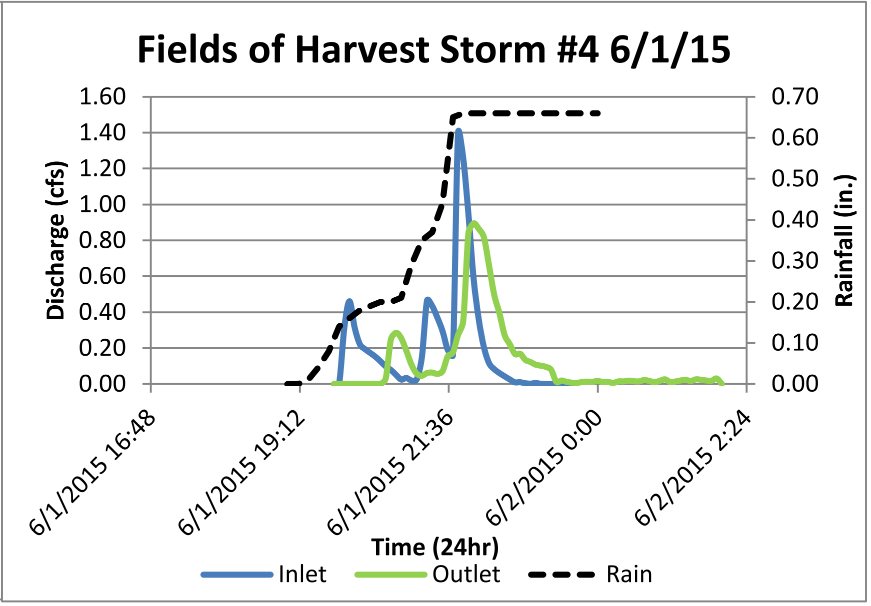
Fields of Harvest Storm #1 2/2/15



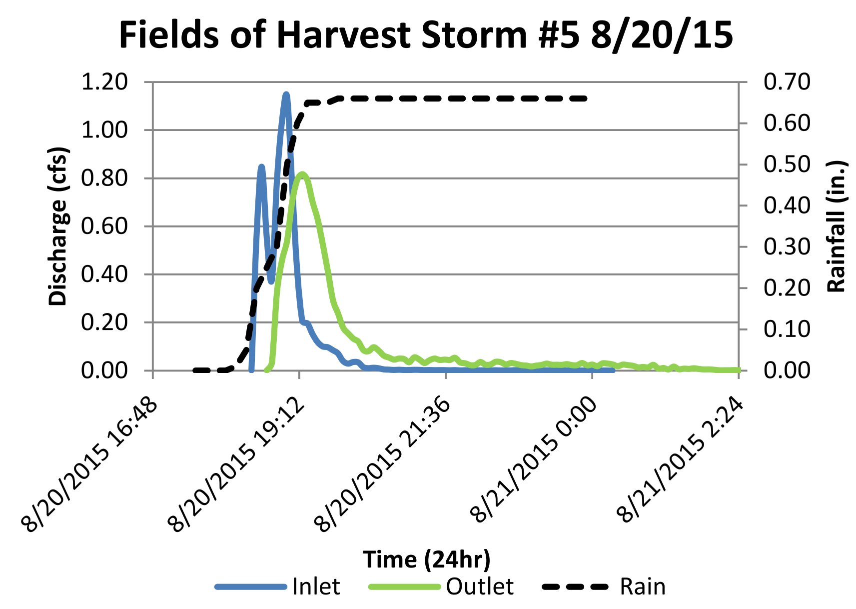
Fields of Harvest Storm #2 3/10/15

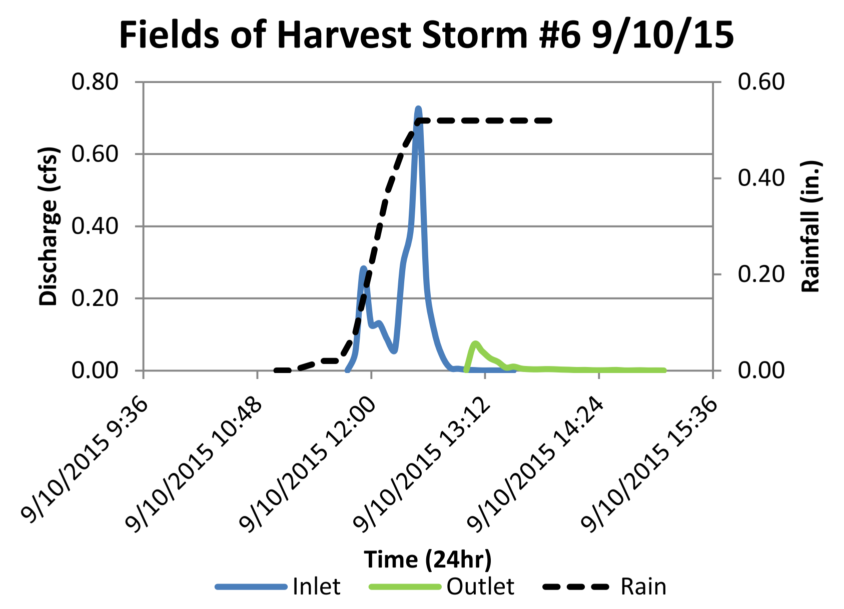


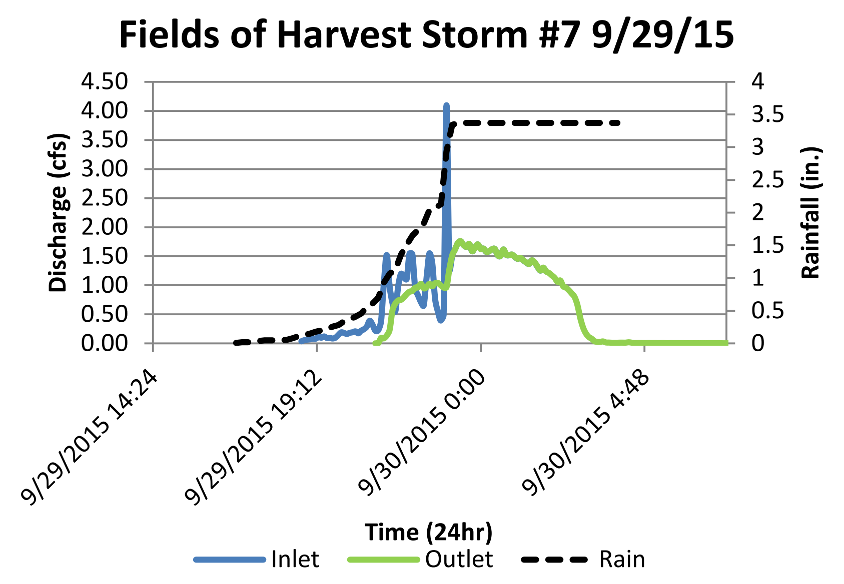
Fields of Harvest Storm #3 4/20/15

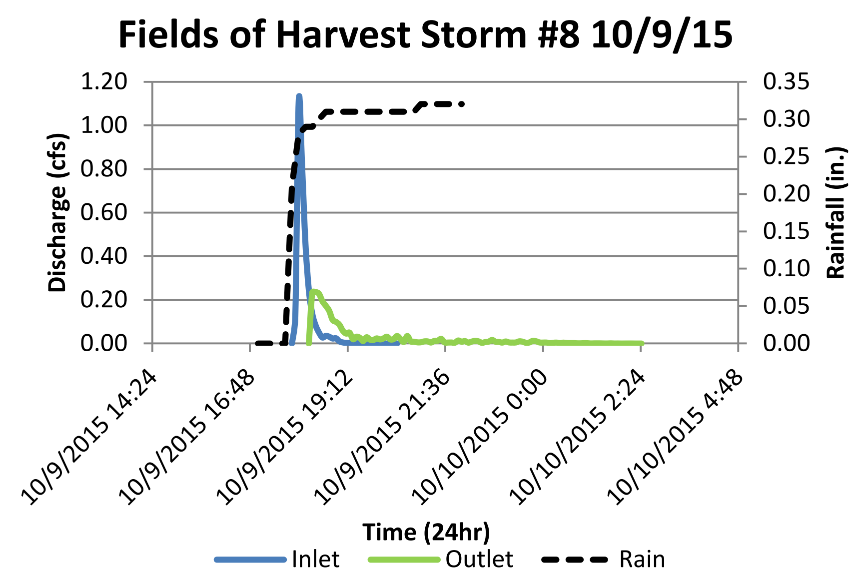


Fields of Harvest Storm #4 6/1/15

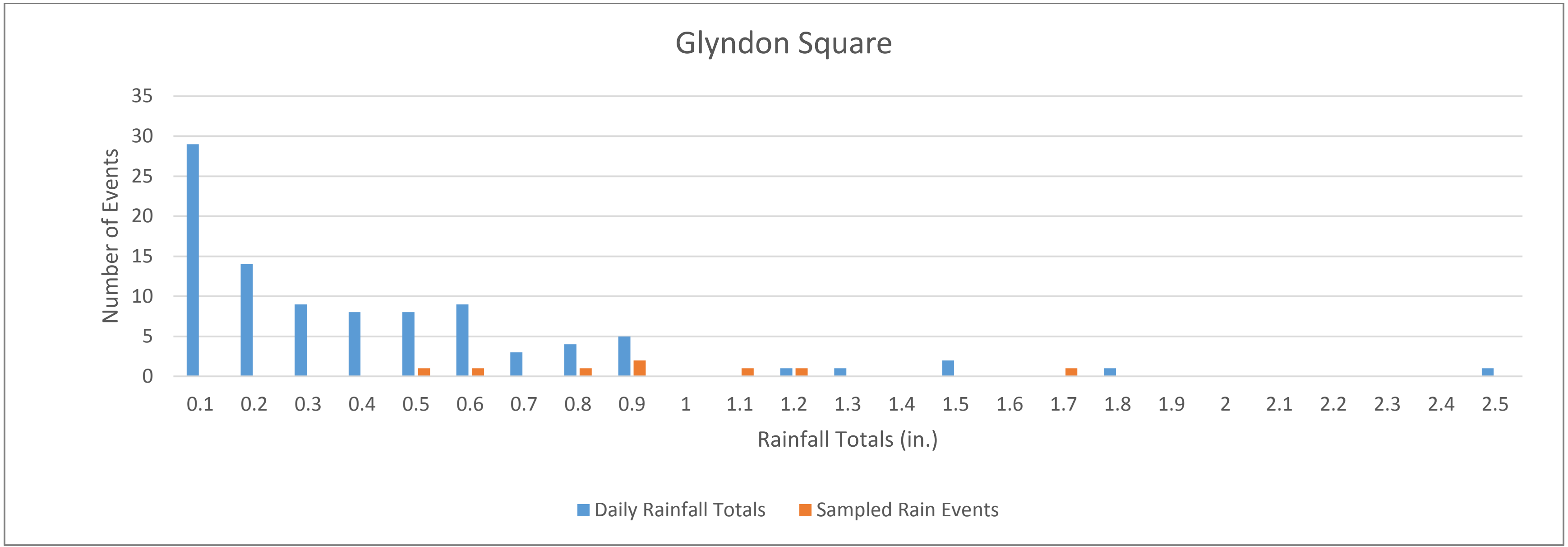

Fields of Harvest Storm #5 8/20/15

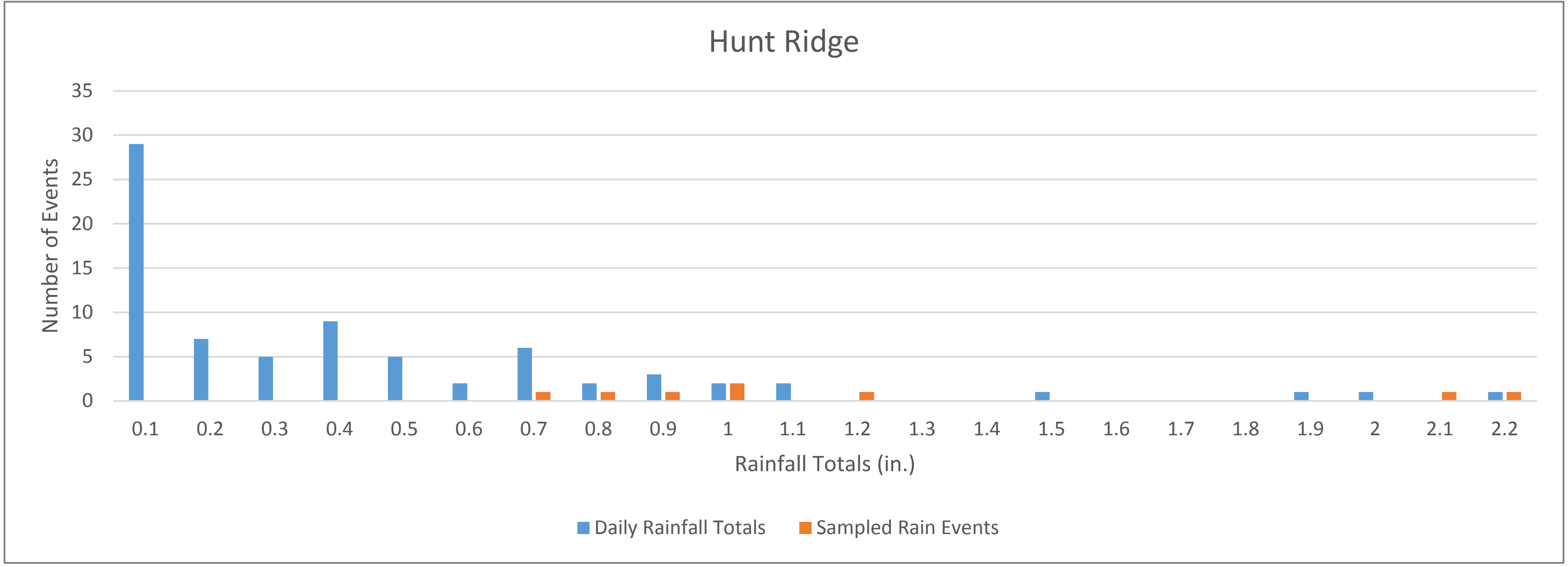

Fields of Harvest Storm #6 9/10/15

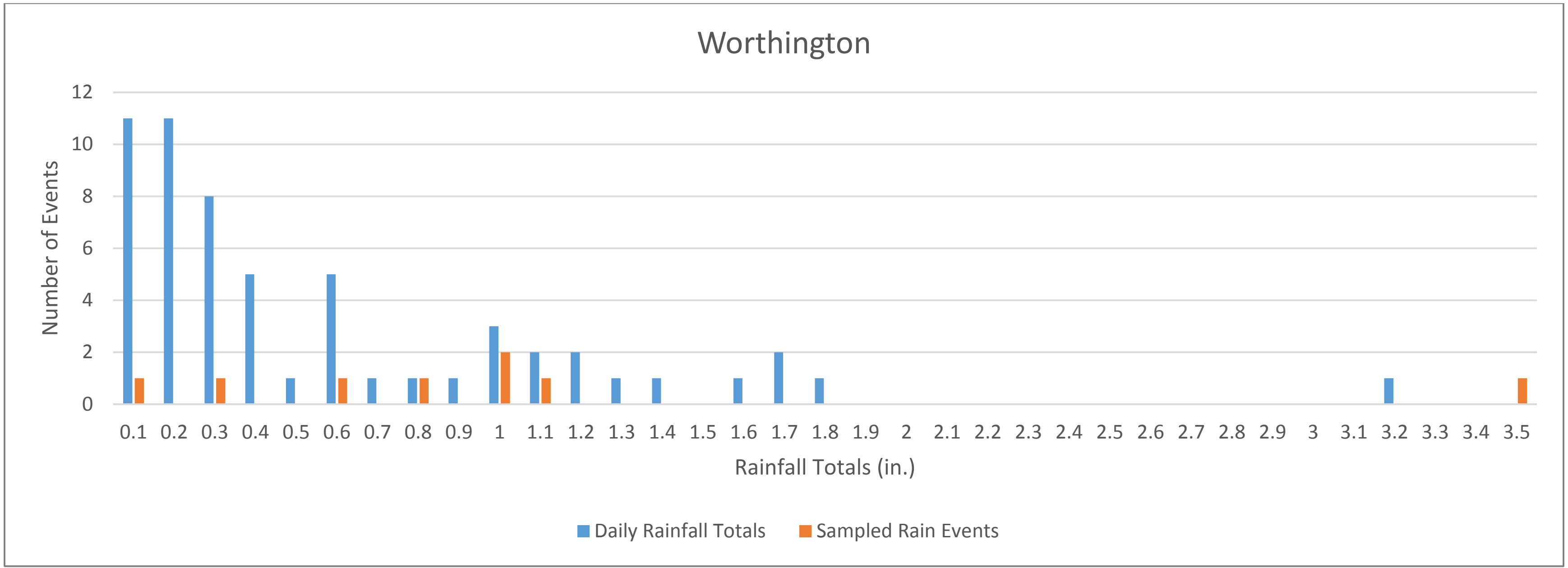

Fields of Harvest Storm #7 9/29/15

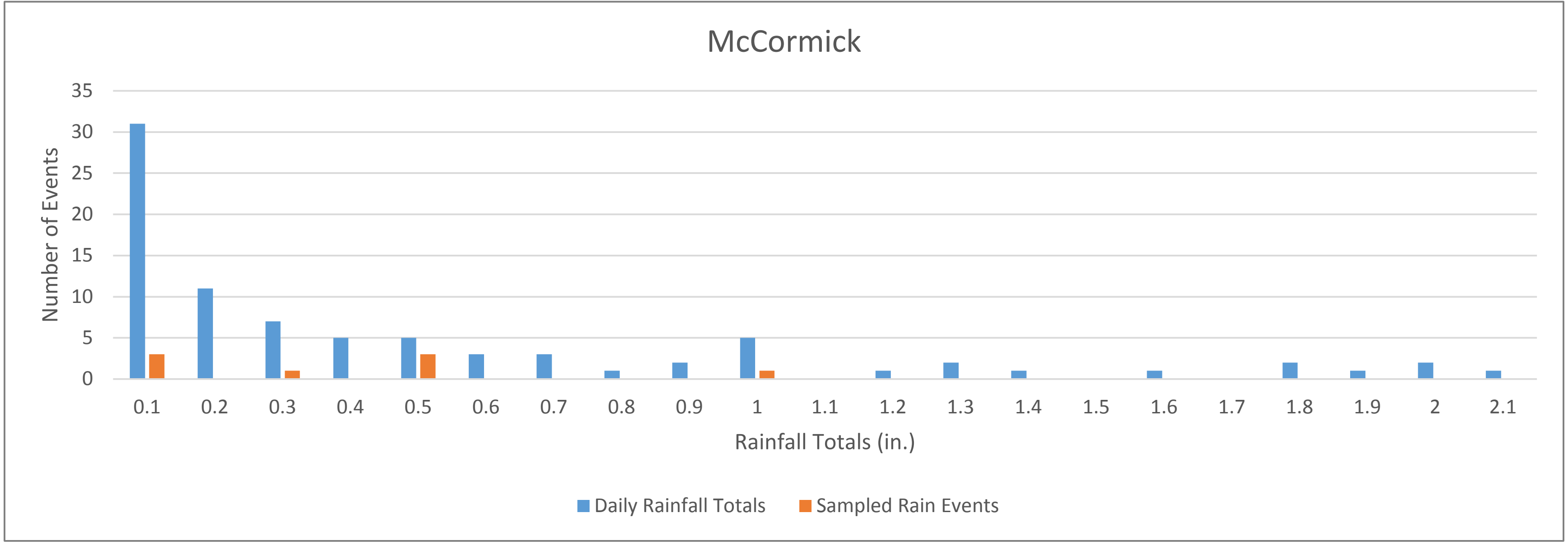

Fields of Harvest Storm #8 10/9/15

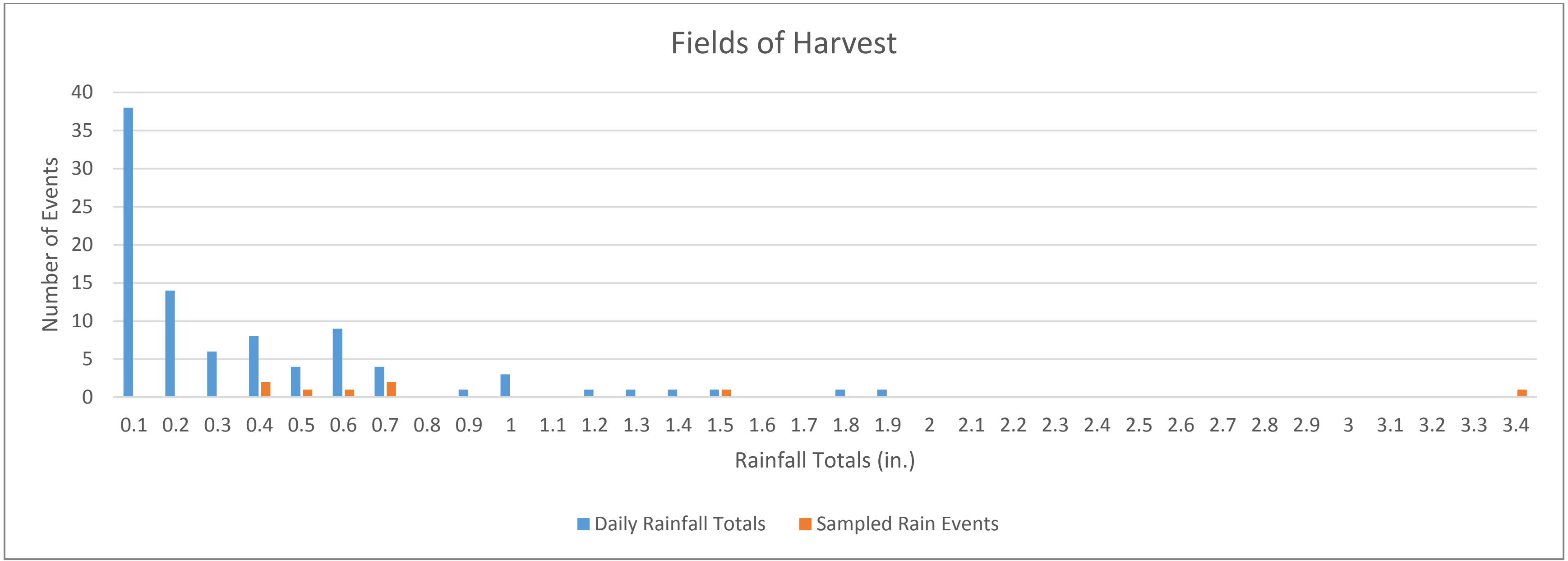
Appendix C: Storm Event Rainfall Distribution

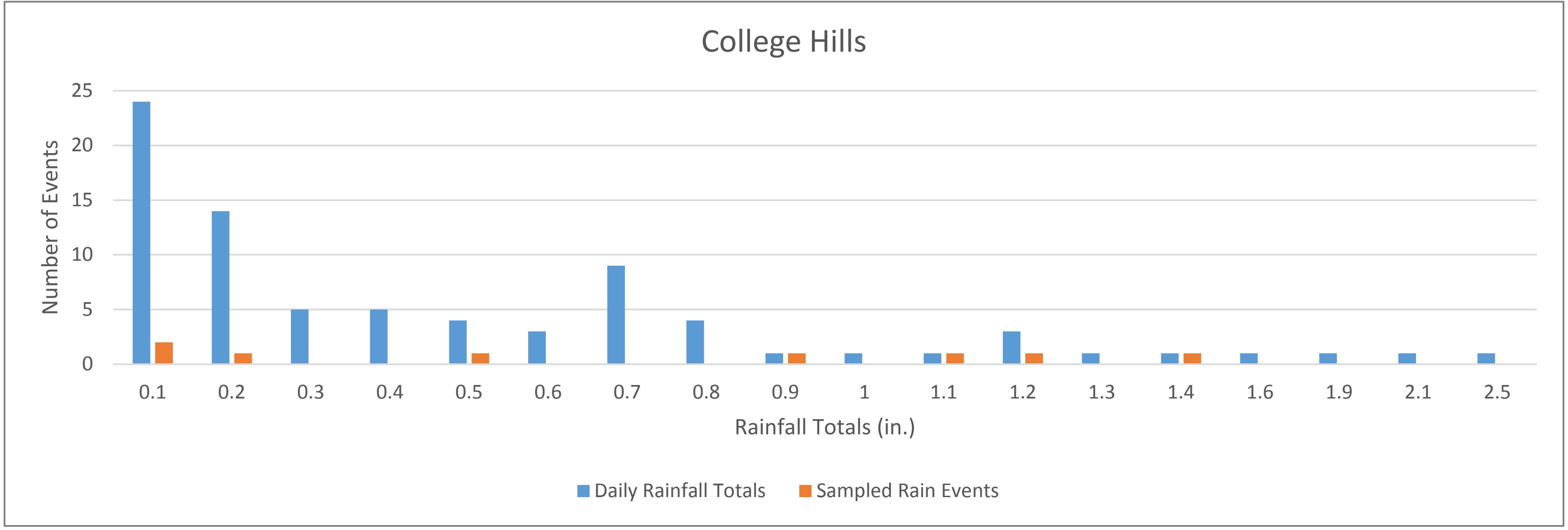

Glyndon Square
Number of Events
35
30
25
20
15
10
5
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2
2.1
2.2
2.3
2.4
2.5
Rainfall Totals (in.)
Daily Rainfall Totals
Sampled Rain Events


Hunt Ridge
Number of Events
35
30
25
20
15
10
5
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2
2.1
2.2
Rainfall Totals (in.)
Daily Rainfall Totals
Sampled Rain Events


Worthington
Number of Events
0
2
4
6
8
10
12
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.9 2 2.1 2.2 2.3 2.4 2.5 2.6 2.7 2.8 2.9 3 3.1 3.2 3.3 3.4 3.5
Rainfall Totals (in.)
Daily Rainfall Totals
Sampled Rain Events


McCormick
Number of Events
0
5
10
15
20
25
30
35
0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.9 2 2.1
Rainfall Totals (in.)
Daily Rainfall Totals
Sampled Rain Events





Note: Periodically, sampled rain events occurred over two days and do not match the daily rainfall totals.

Appendix D: Storm Event Water Quality Data

					cf	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Storm	Limb	Date	Collection	Site	Flow Volume	Nitrate - N	Nitrite - N	Ammonia	TKN	Total Nitrogen	Ortho-P	Total Phosphorus	TSS	TDS
1	Base	9/24/2014	20:55	GS-IA		1.42	ND	ND	0.74	2.16	0.01	0.09	21.60	185.20
1	Rise	9/25/2014	0:17	GS-IA	1358	0.63	ND	0.08	1.62	2.24	0.05	0.13	9.00	49.40
1	Peak	9/25/2014	4:50	GS-IA	7150	0.00	ND	0.02	0.12	0.13	0.01	0.02	24.40	23.40
1	Fall	9/25/2014	10:50	GS-IA	719	0.05	ND	ND	0.29	0.34	0.01	0.03	4.80	37.00
1	**EMC**	**9/25/2014**		**GS-IA**	**9227**	**0.10**	**0.00**	**0.03**	**0.36**	**0.46**	**0.02**	**0.04**	**20.61**	**28.29**
1		9/25/2014	0:25	GS-IB	106	1.09	0.09	ND	37.33	38.51	0.78	3.08	39.17	500.00
1	Peak	9/25/2014	4:30	GS-IB	5488	0.04	ND	0.12	0.25	0.30	0.04	0.04	20.80	28.90
1	Fall	9/25/2014	9:40	GS-IB	1511	0.05	ND	0.14	0.38	0.43	0.04	0.06	8.20	36.81
1	**EMC**	**9/25/2014**		**GS-IB**	**7105**	**0.06**	**0.00**	**0.12**	**0.83**	**0.90**	**0.05**	**0.09**	**18.39**	**37.61**
1	Rise	9/25/2014	4:25	GS-O	247	0.13	ND	ND	0.63	0.76	0.12	0.32	21.20	85.37
1	Peak	9/25/2014	4:45	GS-O	21161	0.23	ND	ND	0.56	0.79	0.17	0.38	3.23	60.98
1	Fall	9/25/2014	10:30	GS-O	689	0.04	ND	ND	0.41	0.45	0.06	0.14	2.00	58.48
1	**EMC**	**9/25/2014**		**GS-O**	**22097**	**0.23**	**0.00**	**0.00**	**0.56**	**0.78**	**0.17**	**0.37**	**3.39**	**61.17**
2	Base	11/6/2014	23:00	GS-IA		0.65	0.08	0.20	0.21	0.93	0.05	0.09	7.80	32.90
2	Rise	11/6/2014	23:06	GS-IA	1073	0.50	0.08	0.16	0.30	0.88	0.05	0.08	6.80	38.60
2	Peak	11/6/2014	4:00	GS-IA	4004	0.36	0.07	0.16	0.00	0.43	0.01	0.03	6.80	38.60
2	Fall	11/6/2014	8:30	GS-IA	1617	0.63	0.08	0.27	0.13	0.84	0.01	0.03	3.80	29.80
2	**EMC**	**11/6/2014**		**GS-IA**	**6694**	**0.45**	**0.07**	**0.19**	**0.08**	**0.60**	**0.02**	**0.03**	**6.08**	**36.47**
2	Rise	11/6/2014	23:02	GS-IB	102	0.05	0.09	0.32	0.57	1.18	0.13	0.22	5.80	46.40
2	Peak	11/6/2014	4:50	GS-IB	5148	0.27	0.06	0.18	0.05	0.38	0.02	0.02	15.20	5.40
2	Fall	11/6/2014	8:30	GS-IB	851	0.63	0.05	0.33	0.28	0.95	0.03	0.03	6.30	29.60
2	**EMC**	**11/6/2014**		**GS-IB**	**6101**	**0.32**	**0.06**	**0.20**	**0.09**	**0.48**	**0.02**	**0.02**	**13.80**	**9.46**
2	Rise	11/6/2014	0:15	GS-O	2429	0.55	0.07	ND	0.31	0.93	0.09	0.14	10.80	119.30
2	Peak	11/6/2014	6:00	GS-O	11593	0.34	0.06	0.15	0.03	0.43	0.03	0.03	4.80	27.90
2	Fall	11/6/2014	9:35	GS-O	735	0.32	ND	0.02	0.25	0.58	0.08	0.08	6.90	59.00
2	**EMC**	**11/6/2014**		**GS-O**	**14757**	**0.37**	**0.06**	**0.12**	**0.09**	**0.52**	**0.04**	**0.05**	**5.89**	**44.49**
3	Rise	1/12/2015	2:53	GS-IA	1504	ND	ND	ND	2.43	2.43	0.08	0.25	169.51	21435.01
3	Peak	1/12/2015	11:40	GS-IA	5200	0.10	ND	ND	0.17	0.28	0.02	0.24	225.20	417.17
3	Fall	1/12/2015	14:55	GS-IA	235	0.26	ND	ND	0.38	0.64	0.03	0.07	13.91	670.01
3	**EMC**	**1/12/2015**		**GS-IA**	**6939**	**0.09**	**0.00**	**0.00**	**0.67**	**0.76**	**0.03**	**0.23**	**205.97**	**4981.26**
3	Rise	1/12/2015	2:40	GS-IB	1790	1.02	ND	ND	1.43	2.46	0.08	0.16	36.00	4653.97
3	Peak	1/12/2015	11:50	GS-IB	2487	0.10	ND	ND	0.30	0.40	0.04	0.22	118.00	721.29
3	Fall	1/12/2015	14:30	GS-IB	321	0.25	ND	ND	0.46	0.71	0.09	0.16	14.44	772.58
3	**EMC**	**1/12/2015**		**GS-IB**	**4598**	**0.47**	**0.00**	**0.00**	**0.75**	**1.22**	**0.06**	**0.19**	**78.85**	**2255.86**
3	Rise	1/12/2015	8:30	GS-O	1702	0.30	0.22	ND	1.39	1.92	0.14	0.19	42.40	12224.58
3	Peak	1/12/2015	12:00	GS-O	4879	0.15	0.21	ND	0.39	0.74	0.08	0.14	60.40	3498.15
3	Fall	1/12/2015	15:40	GS-O	968	0.31	ND	ND	0.63	0.94	0.09	0.16	14.80	1500.03
3	**EMC**	**1/12/2015**		**GS-O**	**7549**	**0.20**	**0.18**	**0.00**	**0.65**	**1.03**	**0.10**	**0.15**	**50.49**	**5209.40**
4	Rise	3/20/2015	5:20	GS-IA	659	2.38	ND	ND	0.89	3.27	0.05	0.13	59.60	1062.98
4	Peak	3/20/2015	12:45	GS-IA	2148	1.78	ND	ND	ND	1.78	0.02	0.02	38.40	1016.75
4	Fall	3/20/2015	16:30	GS-IA	476	1.78	ND	ND	ND	1.78	0.02	0.03	22.40	446.79
4	**EMC**	**3/20/2015**		**GS-IA**	**3283**	**1.90**	**0.00**	**0.00**	**0.18**	**2.08**	**0.02**	**0.04**	**40.34**	**943.39**
4	Rise	3/20/2015	5:25	GS-IB	395	2.38	ND	ND	ND	2.38	0.09	0.19	46.35	1030.48
4	Peak	3/20/2015	9:10	GS-IB	1675	ND	ND	ND	1.05	1.05	0.07	0.29	307.63	37544.24
4	Fall	3/20/2015	16:30	GS-IB	415	1.77	ND	ND	ND	1.77	0.05	0.07	36.80	792.81
4	**EMC**	**3/20/2015**		**GS-IB**	**2485**	**0.67**	**0.00**	**0.00**	**0.71**	**1.38**	**0.07**	**0.24**	**220.87**	**25602.68**
4	Base	3/20/2015	17:10	GS-O		**ND**	ND	ND	0.48	0.48	0.01	0.04	7.60	3245.31
4	Rise	3/20/2015	7:30	GS-O	412	0.62	ND	ND	0.70	1.32	0.02	0.07	12.80	2652.96
4	Peak	3/20/2015	12:00	GS-O	3786	2.06	ND	ND	ND	2.06	0.03	0.07	23.60	8150.32
4	Fall	3/20/2015	19:45	GS-O	486	1.72	ND	ND	ND	1.72	0.02	0.06	6.80	2819.11
4	**EMC**	**3/20/2015**		**GS-O**	**4684**	**1.90**	**0.00**	**0.00**	**0.06**	**1.96**	**0.03**	**0.07**	**20.91**	**7113.62**

					cf	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Storm	Limb	Date	Collection	Site	Flow Volume	Nitrate - N	Nitrite - N	Ammonia	TKN	Total Nitrogen	Ortho-P	Total Phosphorus	TSS	TDS
5	Rise	4/19/2015	23:05	GS-IA	1334	0.80	0.15	0.39	7.06	8.00	0.47	0.73	20.40	284.97
5	Peak	4/20/2015	3:00	GS-IA	3996	0.12	ND	ND	0.08	0.20	0.01	0.03	99.20	11.41
5	Fall	4/20/2015	7:45	GS-IA	316	0.68	ND	ND	0.29	0.97	0.03	0.03	15.60	68.11
5	**EMC**	**4/20/2015**		**GS-IA**	**5646**	**0.31**	**0.04**	**0.09**	**1.74**	**2.09**	**0.12**	**0.19**	**75.90**	**79.22**
5	Rise	4/19/2015	23:45	GS-IB	1315	0.54	0.16	ND	1.36	2.06	0.10	0.43	61.82	290.75
5	Peak	4/20/2015	3:00	GS-IB	5814	0.08	ND	ND	0.06	0.14	0.02	0.08	78.40	7.14
5	Fall	4/20/2015	7:45	GS-IB	317	0.32	ND	ND	0.22	0.54	0.04	0.10	11.20	90.94
5	**EMC**	**4/20/2015**		**GS-IB**	**7446**	**0.17**	**0.03**	**0.00**	**0.30**	**0.49**	**0.03**	**0.15**	**72.61**	**60.80**
5	Rise	4/20/2015	8:30	GS-O	1624	0.30	ND	ND	0.51	0.81	0.02	0.07	6.40	1924.07
5	Peak	4/20/2015	12:00	GS-O	16570	0.12	ND	ND	0.27	0.40	0.06	0.11	25.60	69.34
5	Fall	4/20/2015	15:40	GS-O	623	0.21	ND	ND	0.58	0.79	0.03	0.12	7.60	290.75
5	**EMC**	**4/20/2015**		**GS-O**	**18817**	**0.14**	**0.00**	**0.00**	**0.30**	**0.44**	**0.05**	**0.11**	**23.35**	**236.74**
6	Rise	6/18/2015	23:40	GS-IA	23	0.87	0.09	0.51	3.27	4.23	0.03	0.16	9.20	133.05
6	Peak	6/18/2015	23:55	GS-IA	8118	0.12	0.06	0.25	0.22	0.40	0.03	0.11	12.40	0.86
6	Fall	6/18/2015	5:20	GS-IA	1121	0.31	0.06	0.10	0.61	0.98	0.03	0.05	2.01	55.11
6	**EMC**	**6/18/2015**		**GS-IA**	**9262**	**0.15**	**0.06**	**0.23**	**0.27**	**0.48**	**0.03**	**0.11**	**11.13**	**7.75**
6	Rise	6/18/2015	23:40	GS-IB	96	0.89	0.10	0.75	1.14	2.13	0.07	0.25	64.80	65.37
6	Peak	6/18/2015	23:55	GS-IB	6488	0.12	0.06	0.25	0.11	0.29	0.02	0.07	20.00	ND
6	Fall	6/18/2015	5:25	GS-IB	1614	0.31	0.07	0.09	0.13	0.51	0.04	0.07	2.40	46.22
6	**EMC**	**6/18/2015**		**GS-IB**	**8198**	**0.17**	**0.06**	**0.23**	**0.13**	**0.36**	**0.02**	**0.07**	**17.06**	**9.87**
6	Rise	6/18/2015	23:51	GS-O	2	0.06	ND	ND	1.05	1.11	0.02	0.15	33.33	617.27
6	Peak	6/18/2015	0:10	GS-O	17313	0.17	0.06	0.16	0.25	0.48	0.04	0.08	5.47	12.56
6	Fall	6/18/2015	6:45	GS-O	1616	0.07	ND	ND	0.61	0.68	0.03	0.09	2.53	150.61
6	**EMC**	**6/18/2015**		**GS-O**	**18931**	**0.16**	**0.06**	**0.15**	**0.28**	**0.50**	**0.04**	**0.08**	**5.22**	**24.42**
7	Rise	8/20/2015	5:11	GS-IA	371	0.21	ND	ND	1.10	1.31	0.00	0.46	275.49	104.09
7	Peak	8/20/2015	5:45	GS-IA	2863	0.20	ND	0.07	0.27	0.47	0.00	0.08	53.60	16.82
7	Fall	8/20/2015	6:25	GS-IA	783	0.44	0.06	0.07	0.45	0.95	0.00	0.11	7.00	43.62
7	**EMC**	**8/20/2015**		**GS-IA**	**4017**	**0.25**	**0.01**	**0.06**	**0.38**	**0.64**	**0.00**	**0.12**	**65.01**	**30.11**
7	Rise	8/20/2015	5:11	GS-IB	240	ND	0.04	ND	139.56	139.60	0.00	60.00	4660.00	1403.95
7	Peak	8/20/2015	5:40	GS-IB	2625	0.14	0.04	0.02	0.16	0.34	0.00	0.14	22.40	3.60
7	Fall	8/20/2015	6:25	GS-IB	103	0.22	ND	0.05	1.19	1.41	0.00	0.24	6.43	59.80
7	**EMC**	**8/20/2015**		**GS-IB**	**2968**	**0.13**	**0.04**	**0.02**	**11.47**	**11.64**	**0.00**	**4.98**	**396.85**	**118.79**
7	Rise	8/20/2015	5:20	GS-O	244	0.34	ND	ND	1.10	1.44	0.00	0.35	33.60	119.47
7	Peak	8/20/2015	5:50	GS-O	10322	0.31	ND	0.06	0.48	0.79	0.00	0.17	8.60	40.73
7	Fall	8/20/2015	7:50	GS-O	1247	0.20	ND	ND	1.08	1.28	0.00	0.14	1.80	224.29
7	**EMC**	**8/20/2015**		**GS-O**	**11813**	**0.30**	**0.00**	**0.05**	**0.56**	**0.86**	**0.00**	**0.17**	**8.40**	**61.73**
8	Rise	8/24/2015	18:25	GS-IA	324	0.57	0.07	0.47	0.88	1.51	0.05	0.33	193.60	58.65
8	Peak	8/24/2015	18:35	GS-IA	2121	0.22	0.06	0.26	0.30	0.58	0.02	0.15	92.40	9.02
8	Fall	8/24/2015	19:11	GS-IA	226	0.37	0.05	0.06	0.47	0.89	0.03	0.07	12.00	34.81
8	**EMC**	**8/24/2015**		**GS-IA**	**2671**	**0.27**	**0.06**	**0.27**	**0.38**	**0.72**	**0.02**	**0.17**	**97.87**	**17.22**
8	Rise	8/24/2015	18:23	GS-IB	246	ND	ND	2.57	14.50	14.50	2.44	6.70	431.25	298.70
8	Peak	8/24/2015	18:40	GS-IB	2218	0.22	0.05	0.25	0.35	0.63	0.03	0.15	33.60	6.71
8	Fall	8/24/2015	19:25	GS-IB	184	0.47	0.05	ND	0.71	1.23	0.18	0.26	5.71	55.69
8	**EMC**	**8/24/2015**		**GS-IB**	**2648**	**0.22**	**0.05**	**0.45**	**1.69**	**1.96**	**0.26**	**0.77**	**68.60**	**37.24**
8	Rise	8/24/2015	18:35	GS-O	381	0.27	ND	ND	1.00	1.27	0.06	0.51	131.60	91.59
8	Peak	8/24/2015	18:45	GS-O	6660	ND	ND	ND	1.03	1.03	0.06	0.20	11.20	27.95
8	Fall	8/24/2015	19:50	GS-O	340	0.27	0.05	ND	0.59	0.90	0.09	0.11	2.53	80.54
8	**EMC**	**8/24/2015**		**GS-O**	**7381**	**0.03**	**0.00**	**0.00**	**1.01**	**1.04**	**0.07**	**0.21**	**17.02**	**33.66**

ND= Non Detect

					cf	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Storm	Limb	Date	Collection	Site	Flow Volume	Nitrate - N	Nitrite - N	Ammonia	TKN	Total Nitrogen	Ortho-P	Total Phosphorus	TSS	TDS
1	Rise	8/12/2014	2:14	HR-IA	2931	1.57	0.26	0.24	2.17	4.23	0.58	0.98	23.50	220.00
1	Peak	8/12/2014	14:00	HR-IA	9485	0.26	ND	ND	0.17	0.43	0.07	0.07	74.00	35.00
1	Fall	8/12/2014	17:15	HR-IA	1888	0.49	ND	ND	0.68	1.17	0.10	0.19	2.90	90.00
1	**EMC**	**8/12/2014**		**HR-IA**	**14304**	**0.56**	**0.05**	**0.05**	**0.65**	**1.31**	**0.18**	**0.27**	**54.27**	**80.17**
1	Rise	8/12/2014	2:20	HR-IB	2112	1.19	0.19	ND	1.24	2.62	0.23	0.62	9.60	220.00
1	Peak	8/12/2014	14:00	HR-IB	6581	0.27	ND	ND	0.09	0.36	0.05	0.23	118.80	20.00
1	Fall	8/12/2014	17:01	HR-IB	810	0.62	ND	ND	0.65	1.27	0.13	0.27	4.80	80.00
1	**EMC**	**8/12/2014**		**HR-IB**	**9503**	**0.50**	**0.04**	**0.00**	**0.39**	**0.94**	**0.10**	**0.32**	**84.81**	**69.56**
1	Rise	8/12/2014	10:25	HR-O	3599	0.80	ND	ND	0.58	1.38	0.07	0.17	134.00	60.00
1	Peak	8/12/2014	15:34	HR-O	5645	0.34	ND	ND	0.20	0.54	0.07	0.14	19.30	30.00
1	Fall	8/12/2014	18:30	HR-O	18684	0.43	ND	ND	0.31	0.74	0.07	0.18	10.80	45.00
1	**EMC**	**8/12/2014**		**HR-O**	**27928**	**0.46**	**0.00**	**0.00**	**0.33**	**0.78**	**0.07**	**0.17**	**28.39**	**43.90**
2	Rise	9/25/2014	2:52	HR-IA	368	0.16	0.06	0.39	3.34	3.55	1.54	1.75	36.59	408.51
2	Peak	9/25/2014	4:50	HR-IA	11435	0.20	ND	0.07	0.45	0.65	0.10	0.19	43.20	30.98
2	Fall	9/25/2014	10:35	HR-IA	869	0.54	ND	ND	0.93	1.47	0.12	0.14	8.29	102.36
2	**EMC**	**9/25/2014**		**HR-IA**	**12672**	**0.22**	**0.00**	**0.07**	**0.57**	**0.79**	**0.14**	**0.23**	**40.61**	**46.84**
2	Rise	9/25/2014	3:00	HR-IB	304.0	0.39	0.04	0.49	2.02	2.45	0.68	1.29	27.00	207.63
2	Peak	9/25/2014	4:50	HR-IB	7516	0.67	ND	0.04	0.54	1.21	0.11	0.29	19.89	39.61
2	Fall	9/25/2014	10:40	HR-IB	329	1.46	ND	ND	1.01	2.47	0.11	0.14	4.32	120.13
2	**EMC**	**9/25/2014**		**HR-IB**	**8149**	**0.69**	**0.00**	**0.05**	**0.62**	**1.31**	**0.13**	**0.32**	**19.52**	**49.13**
2	Rise	9/25/2014	3:45	HR-O	201	1.56	ND	ND	0.76	2.32	0.20	0.46	8.55	122.90
2	Peak	9/25/2014	9:45	HR-O	18966	0.52	ND	ND	0.63	1.15	0.13	0.20	4.50	61.69
2	Fall	9/25/2014	18:10	HR-O	4669	0.65	ND	ND	0.91	1.55	0.10	0.22	5.20	93.22
2	**EMC**	**9/25/2014**		**HR-O**	**23836**	**0.55**	**0.00**	**0.00**	**0.69**	**1.23**	**0.12**	**0.20**	**4.67**	**68.38**
3	Rise	11/6/2014	22:52	HR-IA	1118	ND	ND	ND	7.98	7.98	1.74	2.50	17.70	310.30
3	Peak	11/6/2014	5:55	HR-IA	2321	0.76	0.08	0.28	0.05	0.89	0.10	0.19	21.20	46.40
3	Fall	11/6/2014	8:35	HR-IA	413	0.56	0.79	0.01	0.16	0.80	0.09	0.18	6.40	108.20
3	**EMC**	**11/6/2014**		**HR-IA**	**3852**	**0.52**	**0.13**	**0.17**	**2.36**	**2.94**	**0.57**	**0.86**	**18.60**	**129.62**
3	Rise	11/6/2014	22:50	HR-IB	725	0.54	0.16	0.29	1.95	2.65	1.45	1.45	9.30	195.10
3	Peak	11/6/2014	5:50	HR-IB	1350	1.12	ND	0.23	0.00	1.12	0.14	0.21	8.50	47.80
3	Fall	11/6/2014	7:45	HR-IB	372	1.91	ND	0.13	0.00	1.91	0.16	0.28	4.40	90.20
3	**EMC**	**11/6/2014**		**HR-IB**	**2447**	**1.07**	**0.05**	**0.23**	**0.58**	**1.69**	**0.53**	**0.59**	**8.11**	**97.89**
3	Rise	11/6/2014	1:56	HR-O	1004*	1.30	0.35	0.11	0.69	2.34	0.11	0.11	67.50	254.60
3	Peak	11/6/2014	4:10	HR-O	3264*	0.75	0.10	0.03	0.11	0.96	0.18	0.11	56.90	91.20
3	Fall	11/6/2014	9:00	HR-O	1129*	1.57	0.08	ND	1.95	2.65	0.09	0.15	9.20	188.20
3	**EMC**	**11/6/2014**		**HR-O**	**5397***	**1.03**	**0.14**	**0.04**	**0.60**	**1.57**	**0.15**	**0.12**	**48.89**	**141.88**
	Base	3/3/2015	11:30	HR-IA		0.54	ND	ND	3.84	4.38	0.05	0.15	20.00	8524.11
4	Rise	3/4/2015	13:50	HR-IA	2486	0.70	ND	ND	2.51	3.21	0.13	0.21	11.60	895.22
4	Peak	3/4/2015	21:25	HR-IA	14126	0.36	ND	0.12	0.74	1.10	0.04	0.13	18.00	187.47
4	Fall	3/5/2015	3:05	HR-IA	3357	0.27	ND	ND	0.65	0.93	0.04	0.08	5.20	304.16
4	**EMC**	**3/4/2015**		**HR-IA**	**19970**	**0.39**	**0.00**	**0.08**	**0.94**	**1.33**	**0.05**	**0.13**	**15.05**	**295.21**
	Base	3/3/2015	12:05	HR-IB		0.40	ND	ND	4.24	4.64	0.25	1.21	287.50	9607.09
4	Rise	3/4/2015	14:50	HR-IB	1053	0.35	ND	ND	1.45	1.80	0.09	1.30	733.78	1238.42
4	Peak	3/4/2015	22:27	HR-IB	5576	0.36	ND	0.12	0.71	1.07	0.06	0.11	7.20	126.00
4	Fall	3/5/2015	2:47	HR-IB	832	0.32	ND	0.03	0.58	0.90	0.06	0.04	2.80	201.20
4	**EMC**	**3/4/2015**		**HR-IB**	**7462**	**0.36**	**0.00**	**0.09**	**0.80**	**1.15**	**0.07**	**0.27**	**109.26**	**291.39**
	Base	3/3/2015	11:55	HR-O		0.79	ND	ND	1.54	2.33	0.01	0.05	21.60	7959.74
4	Rise	3/4/2015	2:13	HR-O	1765	0.58	ND	ND	1.99	2.57	0.09	0.14	6.40	1667.79
4	Peak	3/4/2015	3:29	HR-O	22797	0.33	ND	ND	0.60	0.93	0.05	0.05	4.00	259.92
4	Fall	3/5/2015	8:20	HR-O	7608	0.38	ND	ND	0.67	1.06	0.05	0.07	6.40	323.22
4	**EMC**	**3/4/2015**		**HR-O**	**32170**	**0.35**	**0.00**	**0.00**	**0.70**	**1.05**	**0.05**	**0.06**	**4.70**	**352.15**

					cf	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Storm	Limb	Date	Collection	Site	Flow Volume	Nitrate - N	Nitrite - N	Ammonia	TKN	Total Nitrogen	Ortho-P	Total Phosphorus	TSS	TDS
5	Rise	3/27/2015	19:30	HR-IA	636	0.23	ND	0.09	0.60	0.82	0.02	0.48	4156.25	148.80
5	Peak	3/27/2015	19:35	HR-IA	12275	0.24	ND	0.04	0.58	0.82	0.02	2.68	4828.57	178.32
5	Fall	3/27/2015	7:00	HR-IA	2473	0.53	ND	ND	0.48	1.00	0.03	0.12	13.20	272.89
5	**EMC**	**3/27/2015**		**HR-IA**	**15384**	**0.28**	**0.00**	**0.04**	**0.56**	**0.85**	**0.02**	**2.18**	**4026.55**	**192.30**
5	Rise	3/27/2015	19:30	HR-IB	58	0.26	ND	0.17	0.56	0.82	0.03	0.15	2152.00	69.87
5	Peak	3/27/2015	20:00	HR-IB	5210	0.15	ND	0.09	0.53	0.68	0.03	0.24	464.00	45.08
5	Fall	3/27/2015	7:00	HR-IB	2264	1.08	ND	ND	0.75	1.82	0.03	0.12	10.40	535.24
5	**EMC**	**3/27/2015**		**HR-IB**	**7533**	**0.43**	**0.00**	**0.06**	**0.59**	**1.02**	**0.03**	**0.20**	**340.68**	**192.62**
5	Rise	3/27/2015	19:35	HR-O	0	0.28	ND	ND	0.50	0.78	0.03	0.25	3512.00	304.92
5	Peak	3/27/2015	6:30	HR-O	12347	0.30	ND	ND	0.39	0.69	0.03	0.13	54.35	113.87
5	Fall	3/27/2015	11:20	HR-O	2039	0.48	ND	ND	0.46	0.94	0.02	0.11	25.20	172.98
5	**EMC**	**3/27/2015**		**HR-O**	**14386**	**0.32**	**0.00**	**0.00**	**0.40**	**0.72**	**0.03**	**0.13**	**50.22**	**122.25**
6	Rise	6/1/2015	0:34	HR-IA	0	0.79	0.12	0.66	6.54	7.45	0.41	1.48	156.98	422.37
6	Peak	6/1/2015	1:29	HR-IA	2982	0.31	0.05	0.32	0.70	1.07	0.09	0.60	233.87	30.13
6	Fall	6/1/2015	3:27	HR-IA	197	0.44	0.06	0.16	0.98	1.49	0.18	0.36	6.40	67.96
6	**EMC**	**6/1/2015**		**HR-IA**	**3179**	**0.32**	**0.05**	**0.31**	**0.72**	**1.09**	**0.10**	**0.58**	**219.79**	**88.78**
6	Rise	6/1/2015	0:33	HR-IB	0	0.23	0.14	0.69	8.39	8.76	0.20	1.27	98.46	600.83
6	Peak	6/1/2015	1:30	HR-IB	1981	0.27	0.05	0.12	0.74	1.06	0.06	0.69	283.13	41.04
6	Fall	6/1/2015	3:25	HR-IB	272	0.50	0.06	0.02	0.77	1.33	0.04	0.19	7.20	94.88
6	**EMC**	**6/1/2015**		**HR-IB**	**2253**	**0.30**	**0.05**	**0.11**	**0.74**	**1.09**	**0.06**	**0.63**	**249.81**	**122.77**
6	Rise	6/1/2015	1:02	HR-O	0	0.93	0.05	0.18	1.74	2.72	0.24	0.69	85.33	169.17
6	Peak	6/1/2015	2:39	HR-O	5083	0.33	0.06	0.23	0.79	1.18	0.10	0.08	31.20	43.33
6	Fall	6/1/2015	8:20	HR-O	113	0.25	ND	ND	3.74	3.99	0.12	0.61	15.20	838.02
6	**EMC**	**6/1/2015**		**HR-O**	**5196**	**0.33**	**0.05**	**0.23**	**0.86**	**1.24**	**0.10**	**0.09**	**30.85**	**78.08**
7	Rise	6/18/2015	0:05	HR-IA	1	2.96	0.17	3.59	40.47	43.60	1.21	1.61	82.73	298.06
7	Peak	6/18/2015	0:10	HR-IA	1526	0.43	0.06	0.53	0.92	1.41	0.06	0.17	40.40	36.92
7	Fall	6/18/2015	5:00	HR-IA	1904	0.43	0.07	0.19	0.64	1.01	0.07	0.11	9.60	77.57
7	**EMC**	**6/18/2015**		**HR-IA**	**3431**	**0.43**	**0.07**	**0.35**	**0.77**	**1.20**	**0.07**	**0.14**	**23.32**	**59.56**
7	Rise	6/18/2015	0:05	HR-IB	1	0.48	0.35	ND	16.03	16.86	0.69	1.60	192.50	ND
7	Peak	6/18/2015	0:10	HR-IB	942	0.52	0.08	0.45	0.50	1.10	0.11	0.34	65.38	67.05
7	Fall	6/18/2015	4:58	HR-IB	1814	0.71	0.06	0.18	0.38	1.15	0.03	0.07	2.80	63.08
7	**EMC**	**6/18/2015**		**HR-IB**	**2758**	**0.64**	**0.07**	**0.28**	**0.43**	**1.14**	**0.06**	**0.16**	**24.26**	**64.41**
7	Rise	6/18/2015	0:17	HR-O	0	1.32	0.08	0.42	1.19	2.58	0.09	0.42	137.86	86.72
7	Peak	6/18/2015	2:52	HR-O	4314	0.23	0.06	0.04	0.91	1.20	0.06	0.12	3.73	123.94
7	Fall	6/18/2015	5:46	HR-O	496	0.30	ND	ND	1.41	1.71	0.08	0.33	76.40	208.06
7	**EMC**	**6/18/2015**		**HR-O**	**4809**	**0.23**	**0.06**	**0.04**	**0.97**	**1.26**	**0.06**	**0.14**	**11.22**	**131.23**
8	Rise	8/20/2015	13:24	HR-IA	0	0.37	0.10	ND	1.60	2.07		1355.00	228.21	145.37
8	Peak	8/20/2015	14:19	HR-IA	2332	0.14	0.04	0.02	0.19	0.38		143.00	60.00	27.46
8	Fall	8/20/2015	15:03	HR-IA	118	0.49	0.06	ND	0.37	0.92		176.00	38.80	40.66
8	**EMC**	**8/20/2015**		**HR-IA**	**2451**	**0.16**	**0.04**	**0.02**	**0.20**	**0.40**	**0.00**	**144.59**	**58.98**	**56.99**
8	Rise	8/20/2015	13:24	HR-IB	0	0.65	0.08	ND	0.75	1.48		995.00	4.60	181.37
8	Peak	8/20/2015	14:22	HR-IB	1557	0.38	ND	0.03	0.33	0.71		223.00	320.91	18.85
8	Fall	8/20/2015	14:45	HR-IB	67	1.39	0.05	0.07	0.64	2.07		285.00	6.00	68.80
8	**EMC**	**8/20/2015**		**HR-IB**	**1624**	**0.42**	**0.00**	**0.04**	**0.34**	**0.77**	**0.00**	**225.57**	**307.83**	**65.80**
8	Rise	8/20/2015	13:34	HR-O	68	1.04	ND	ND	1.75	2.79		650.00	495.00	265.26
8	Peak	8/20/2015	14:50	HR-O	4949	0.22	0.05	0.04	0.26	0.53		212.00	88.00	14.12
8	Fall	8/20/2015	18:35	HR-O	2198	0.54	0.04	ND	0.34	0.92		150.00	6.80	39.89
8	**EMC**	**8/20/2015**		**HR-O**	**7215**	**0.33**	**0.04**	**0.03**	**0.30**	**0.67**	**0.00**	**197.23**	**67.09**	**24.33**

*Indicates estimated flow volumes due to logger failure

ND= Non Detect

					cf	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Storm	**Limb**	**Date**	**Collection**	**Site**	**Flow Volume**	**Nitrate - N**	**Nitrite - N**	**Ammonia**	**TKN**	**Total Nitrogen**	**Ortho-P**	**Total Phosphorus**	**TSS**	**TDS**
1	Base	3/3/15	12:35	WO-I		2.02	0.00	0.00	1.14	3.16	0.07	0.14	9.60	1585.00
1	Rise	3/4/15	13:55	WO-I	1242	0.55	ND	ND	1.45	2.01	0.05	0.14	45.20	2052.00
1	Peak	3/4/15	22:45	WO-I	56250	0.32	ND	ND	0.50	0.83	0.03	0.05	14.40	192.00
1	Fall	3/5/15	7:30	WO-I	3389	0.55	ND	ND	0.53	1.09	0.05	0.07	6.40	272.00
1	**EMC**	3/4/15		WO-I	**60880**	**0.34**	**0.00**	**0.00**	**0.53**	**0.87**	0.04	0.05	**14.58**	**234.39**
1	Base	3/3/15	12:45	WO-O		2.38	0.00	0.00	0.41	2.79	0.01	0.02	4.00	800.00
1	Rise	3/4/15	14:15	WO-O	2173	0.98	ND	ND	0.91	1.89	0.02	0.04	17.20	1923.62
1	Peak	3/4/15	23:00	WO-O	36724	0.36	ND	ND	0.52	0.88	0.03	0.05	12.60	192.00
1	Fall	3/5/15	7:37	WO-O	4145	0.63	ND	ND	0.47	1.11	0.03	0.06	4.20	249.00
1	**EMC**	3/4/15		WO-O	**43042**	**0.42**	**0.00**	**0.00**	**0.53**	**0.95**	0.03	0.05	**12.02**	**284.90**
2	Base	3/19/15	16:45	WO-I		4.88	0.00	0.00	0.00	4.88	0.00	0.01	0.00	209.84
2	Rise	3/20/15	6:00	WO-I	294	1.69	ND	ND	0.25	1.95	0.02	0.05	14.80	348.83
2	Peak	3/20/15	10:15	WO-I	3155	0.03	ND	ND	1.39	1.42	0.03	0.08	51.20	6635.89
2	Fall	3/20/15	20:06	WO-I	188	2.42	ND	ND	0.10	2.52	0.02	0.03	3.60	843.46
2	**EMC**	**3/20/15**		**WO-I**	**3637**	**0.29**	**0.00**	**0.00**	**1.23**	**1.52**	**0.02**	**0.08**	**45.80**	**5828.25**
2	Base	3/19/15	16:50	WO-O		2.15	0.00	0.00	0.00	2.15	0.00	0.01	0.27	206.14
2	Rise	3/20/15	6:15	WO-O	440	2.74	ND	ND	ND	2.74	0.00	0.01	4.40	212.49
2	Peak	3/20/15	10:45	WO-O	2199	1.46	ND	ND	0.19	1.65	0.01	0.06	16.80	3211.48
2	Fall	3/20/15	20:10	WO-O	272	1.36	ND	ND	0.08	1.44	0.01	0.03	2.40	709.76
2	**EMC**	**3/20/15**		**WO-O**	**2911**	**1.64**	**0.00**	**0.00**	**0.15**	**1.79**	**0.01**	**0.05**	**13.58**	**2524.38**
3	BASE	4/13/15	5:29	WO-I		5.08	0.00	0.00	0.00	5.08	0.00	0.02	3.07	199.27
3	Rise	4/14/15	9:42	WO-I	73	4.65	ND	ND	ND	4.65	0.01	0.08	6.00	253.71
3	Peak	4/14/15	11:40	WO-I	134	3.04	0.15	ND	0.86	4.05	0.04	0.17	14.00	307.08
3	Fall	4/14/15	15:15	WO-I	45	4.18	ND	ND	0.18	4.36	0.02	0.07	2.00	276.96
3	**EMC**	**4/14/15**		**WO-I**	**252**	**3.71**	**0.08**	**0.00**	**0.49**	**4.28**	**0.03**	**0.13**	**9.55**	**286.26**
3	BASE	4/13/15	5:33	WO-O		0.68	0.00	0.00	0.84	1.53	0.00	0.02	1.40	185.53
3	Rise	4/14/15	10:21	WO-O	34	0.68	ND	ND	1.07	1.74	0.00	0.02	2.20	186.06
3	Peak	4/14/15	12:15	WO-O	41	0.98	ND	ND	0.81	1.79	0.00	0.02	1.00	189.23
3	Fall	4/14/15	15:20	WO-O	31	0.61	ND	ND	1.07	1.68	0.00	0.02	2.60	203.50
3	**EMC**	**4/14/15**		**WO-O**	**106**	**0.77**	**0.00**	**0.00**	**0.97**	**1.74**	**0.00**	**0.02**	**1.85**	**192.41**
4	BASE	6/17/15	23:25	WO-I		4.40	0.06	0.00	0.28	4.74	0.01	0.02	0.60	207.73
4	Rise	6/17/15	23:56	WO-I	280	0.70	0.08	0.47	1.96	2.74	0.02	0.21	57.78	123.65
4	Peak	6/18/15	0:07	WO-I	9686	0.35	0.06	0.15	0.37	0.78	0.01	0.31	59.33	68.85
4	Fall	6/18/15	6:20	WO-I	1516	0.71	0.06	ND	0.42	1.19	0.03	0.07	3.70	191.35
4	**EMC**	**6/18/15**		**WO-I**	**11482**	**0.41**	**0.06**	**0.13**	**0.41**	**0.88**	**0.01**	**0.28**	**51.95**	**86.36**
4	BASE	6/17/15	23:25	WO-O		0.48	0.06	0.06	0.06	0.59	0.00	0.02	2.17	181.84
4	Rise	6/18/15	0:00	WO-O	141	0.47	0.07	0.22	0.62	1.16	0.01	0.30	152.40	94.10
4	Peak	6/18/15	0:30	WO-O	6743	0.37	0.06	0.14	0.58	1.01	0.03	0.19	38.80	85.55
4	Fall	6/18/15	6:30	WO-O	900	0.28	0.06	ND	0.42	0.76	0.01	0.06	5.60	151.29
4	**EMC**	**6/18/15**		**WO-O**	**7784**	**0.36**	**0.06**	**0.12**	**0.56**	**0.99**	**0.03**	**0.18**	**37.02**	**93.31**

					cf	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Storm	**Limb**	**Date**	**Collection**	**Site**	**Flow Volume**	**Nitrate - N**	**Nitrite - N**	**Ammonia**	**TKN**	**Total Nitrogen**	**Ortho-P**	**Total Phosphorus**	**TSS**	**TDS**
5	Rise	8/20/15	5:50	WO-I	3028	0.42	0.05	0.07	0.67	1.14	0.00	0.22	5.80	116.94
5	Peak	8/20/15	5:55	WO-I	4128	0.12	0.05	ND	0.31	0.48	0.00	0.11	86.00	67.58
5	Fall	8/20/15	8:30	WO-I	130	0.56	ND	ND	0.76	1.32	0.00	0.17	4.80	132.95
5	**EMC**	**8/20/15**		**WO-I**	**7286**	**0.25**	**0.05**	**0.03**	**0.47**	**0.77**	**0.00**	**0.16**	**51.22**	**89.26**
5	Rise	8/20/15	6:05	WO-O	2238	0.59	ND	ND	0.54	1.13	0.00	0.34	289.09	92.63
5	Peak	8/20/15	6:20	WO-O	2721	0.32	ND	ND	0.40	0.72	0.00	0.16	86.80	75.25
5	Fall	8/20/15	8:50	WO-O	235	0.36	ND	ND	0.44	0.80	0.00	0.06	4.00	151.50
5	**EMC**	**8/20/15**		**WO-O**	**5194**	**0.44**	**0.00**	**0.00**	**0.46**	**0.90**	**0.00**	**0.23**	**170.21**	**86.19**
6	Rise	9/10/15	12:09	WO-I	73	2.86	ND	0.31	1.41	4.28	0.10	0.21	50.00	189.23
6	Peak	9/10/15	13:22	WO-I	10346	0.50	ND	0.14	0.56	1.06	0.08	0.25	95.65	73.24
6	Fall	9/10/15	16:01	WO-I	275	0.59	ND	ND	0.79	1.39	0.05	0.09	8.00	124.71
6	**EMC**	**9/10/15**		**WO-I**	**10694**	**0.52**	**0.00**	**0.13**	**0.57**	**1.09**	**0.08**	**0.25**	**93.09**	**75.35**
6	Base	9/9/15	10:30	WO-O		0.26	0.00	0.00	0.33	0.59	0.00	0.02	6.00	180.20
6	Rise	9/10/15	12:18	WO-O	55	0.33	ND	0.08	0.41	0.74	0.00	0.06	31.72	174.97
6	Peak	9/10/15	12:58	WO-O	4749	0.63	0.03	0.11	0.54	1.19	0.07	0.18	56.80	78.63
6	Fall	9/10/15	16:08	WO-O	307	0.69	0.03	ND	0.56	1.28	0.02	0.06	16.00	163.87
6	**EMC**	**9/10/15**		**WO-O**	**5110**	**0.63**	**0.03**	**0.11**	**0.54**	**1.19**	**0.07**	**0.17**	**54.08**	**84.78**
7	BASE	9/28/15		WO-I		1.55	0.23	0.25	2.34	4.13	0.13	0.19	17.20	538.54
7	Rise	9/29/15	19:00	WO-I	5192	0.27	ND	0.07	5.07	5.33	0.10	0.16	36.00	841.88
7	Peak	9/29/15	0:40	WO-I	57017	0.92	ND	0.03	0.58	1.50	0.18	0.49	14.00	92.47
7	Fall	9/29/15	1:54	WO-I	35748	0.88	ND	0.03	0.65	1.53	0.17	0.17	7.60	112.66
7	**EMC**	**9/29/15**		**WO-I**	**97957**	**0.87**	**0.00**	**0.04**	**0.85**	**1.72**	**0.17**	**0.36**	**12.83**	**139.56**
7	BASE	9/28/15	18:50	WO-O		0.14	0.28	0.00	1.90	2.33	0.00	0.04	16.25	501.02
7	Rise	9/29/15	19:25	WO-O	13099	1.60	1.27	0.28	4.47	7.34	0.03	0.23	98.57	47.30
7	Peak	9/29/15	23:40	WO-O	30297	0.29	0.06	0.04	0.18	0.53	0.06	0.33	193.15	60.98
7	Fall	9/30/15	1:50	WO-O	26441	0.38	0.07	0.04	0.18	0.62	0.08	0.22	84.12	62.56
7	**EMC**	**9/29/15**		**WO-O**	**69837**	**0.57**	**0.29**	**0.08**	**0.98**	**1.84**	**0.06**	**0.27**	**134.13**	**59.01**
8	Rise	10/9/15	17:29	WO-I	1096	0.48	0.20	1.89	12.60	13.28	0.11	0.38	186.40	113.03
8	Peak	10/9/15	17:47	WO-I	2724	0.50	0.20	0.30	0.67	1.36	0.08	0.23	65.05	83.12
8	Fall	10/9/15	18:32	WO-I	288	0.95	0.20	0.39	0.90	2.06	0.11	0.21	43.53	113.14
8	**EMC**	**10/9/15**		**WO-I**	**4108**	**0.52**	**0.20**	**0.73**	**3.87**	**4.59**	**0.09**	**0.27**	**95.92**	**93.20**
8	Rise	10/9/15	17:35	WO-O	41	0.38	ND	ND	0.23	0.62	0.01	0.07	46.40	163.87
8	Peak	10/9/15	17:50	WO-O	1850	0.58	0.19	0.16	1.43	2.20	0.04	0.36	146.32	104.05
8	Fall	10/9/15	18:58	WO-O	190	1.02	0.20	0.21	0.74	1.95	0.06	0.15	38.94	120.53
8	**EMC**	**10/9/15**		**WO-O**	**2081**	**0.62**	**0.19**	**0.16**	**1.34**	**2.15**	**0.04**	**0.34**	**134.54**	**106.73**

ND = Non Detect

					cf	(0) mg/L	(0) mg/L	(0) mg/L	(0) mg/L	(0) mg/L	(0) mg/L	(0) mg/L	(0) mg/L	(0) mg/L
Storm	Limb	Date	Collection	Site	Flow Volume*	Nitrate - N	Nitrite - N	Ammonia	TKN	Total Nitrog	Ortho-P	Total Phosp	TSS	TDS
1	Rise	8/12/2014	2:00	MC-IA	6	0.17	ND	ND	1.50	1.67	0.08	0.28	39.00	250.00
1	Peak	8/12/2014	2:16	MC-IA	19	0.18	ND	ND	0.93	1.10	0.06	0.17	9.20	180.00
1	Fall	8/12/2014	2:36	MC-IA	7	0.34	ND	ND	0.71	1.05	0.03	0.09	4.40	160.00
1	**EMC**	**8/12/2014**		**MC-IA**	**32**	**0.21**	**0.00**	**0.00**	**0.98**	**1.20**	**0.06**	**0.17**	**13.74**	**188.75**
1	Base	8/11/2014	22:15	MC-IB		0.43	ND	ND	0.81	1.24	0.01	0.05	17.20	1770.00
1	Rise	8/12/2014	1:46	MC-IB	30	1.29	ND	ND	3.50	4.79	0.10	0.31	40.00	770.00
1	Peak	8/12/2014	3:32	MC-IB	639	0.46	ND	ND	0.74	1.20	0.01	0.04	8.60	60.00
1	Fall	8/12/2014	5:10	MC-IB	138	0.28	ND	ND	0.85	1.13	0.00	0.03	0.70	85.00
1	**EMC**	**8/12/2014**		**MC-IB**	**807**	**0.46**	**0.00**	**0.00**	**0.86**	**1.32**	**0.01**	**0.05**	**8.42**	**90.67**
1	Rise	8/12/2014	4:11	MC-O	9	0.72	ND	ND	0.95	1.67	0.02	0.10	2.80	120.00
1	Peak	8/12/2014	4:56	MC-O	23	0.49	ND	ND	0.76	1.26	0.01	0.08	1.50	100.00
1	Fall	8/12/2014	6:02	MC-O	12	0.38	ND	ND	0.71	1.09	0.01	0.08	1.20	110.00
1	**EMC**	**8/12/2014**		**MC-O**	**44**	**0.51**	**0.00**	**0.00**	**0.79**	**1.30**	**0.01**	**0.08**	**1.68**	**106.82**
2	Rise	10/3/2014	22:13	MC-IA	212	0.66	0.07	0.08	0.83	1.56	0.04	0.08	16.80	131.40
2	Peak	10/4/2014	1:15	MC-IA	284	0.30	0.06	0.22	0.42	0.77	0.01	0.02	20.00	90.46
2	Fall	10/4/2014	3:50	MC-IA	28	0.59	0.07	0.41	0.06	0.72	0.01	0.01	1.60	100.08
2	**EMC**	**10/4/2014**		**MC-IA**	**524**	**0.46**	**0.06**	**0.17**	**0.57**	**1.09**	**0.02**	**0.04**	**17.72**	**107.54**
2	Rise	10/3/2014	21:57	MC-IB	973	1.21	0.08	0.21	0.94	2.23	0.04	0.17	6.80	126.50
2	Peak	10/4/2014	1:26	MC-IB	2591	0.27	0.06	0.19	0.26	0.59	0.02	0.03	6.00	66.49
2	Fall	10/4/2014	4:25	MC-IB	599	0.16	0.05	ND	0.16	0.38	0.00	0.01	0.90	66.03
2	**EMC**	**10/4/2014**		**MC-IB**	**4163**	**0.47**	**0.06**	**0.17**	**0.41**	**0.94**	**0.02**	**0.06**	**5.45**	**80.45**
2	Rise	10/3/2014	22:52	MC-O	242	0.70	ND	ND	0.67	1.38	0.04	0.04	18.40	140.85
2	Peak	10/4/2014	1:45	MC-O	2476	0.25	ND	0.01	0.28	0.52	0.02	0.01	2.61	72.85
2	Fall	10/4/2014	5:00	MC-O	492	0.19	ND	ND	0.22	0.41	0.02	0.03	1.60	85.85
2	**EMC**	**10/4/2014**		**MC-O**	**3210**	**0.27**	**0.00**	**0.01**	**0.30**	**0.57**	**0.02**	**0.02**	**3.64**	**79.97**
3	Rise	10/15/2014	13:07	MC-IA	111	0.27	ND	ND	1.17	1.44	0.05	0.33	55.00	156.30
3	Peak	10/15/2014	14:10	MC-IA	1508	0.12	0.05	0.04	0.03	0.20	0.02	0.51	81.60	62.41
3	Fall	10/15/2014	18:45	MC-IA	718	0.11	0.05	ND	0.07	0.23	0.01	0.01	3.00	88.83
3	**EMC**	**10/15/2014**		**MC-IA**	**2337**	**0.13**	**0.05**	**0.03**	**0.10**	**0.27**	**0.02**	**0.35**	**56.19**	**74.99**
3	Base	10/15/2014	10:55	MC-IB		0.12	ND	ND	0.56	0.68	0.01	0.02	1.07	180.79
3	Rise	10/15/2014	13:00	MC-IB	563	0.44	ND	0.04	3.52	3.96	0.04	0.22	65.60	138.11
3	Peak	10/15/2014	14:10	MC-IB	14282	0.16	0.05	0.05	0.09	0.29	0.02	0.12	94.00	65.44
3	Fall	10/15/2014	18:50	MC-IB	1744	0.10	ND	ND	0.01	0.12	0.01	0.01	1.10	60.14
3	**EMC**	**10/15/2014**		**MC-IB**	**16589**	**0.16**	**0.04**	**0.04**	**0.19**	**0.40**	**0.01**	**0.11**	**83.27**	**67.35**
3	Rise	10/15/2014	13:30	MC-O	231	0.28	ND	ND	1.54	1.82	0.03	0.24	16.40	146.74
3	Peak	10/15/2014	17:10	MC-O	17623	0.05	ND	ND	0.04	0.09	0.01	0.02	2.40	52.65
3	Fall	10/15/2014	19:15	MC-O	1883	0.10	ND	ND	0.08	0.18	0.02	0.04	6.80	75.24
3	**EMC**	**10/15/2014**		**MC-O**	**19737**	**0.06**	**0.00**	**0.00**	**0.06**	**0.12**	**0.01**	**0.02**	**2.98**	**55.91**
4	Rise	2/2/2015	2:45	MC-IA	1229	0.37	ND	ND	1.23	1.60	0.07	0.16	40.00	4029.64
4	Peak	2/2/2015	8:40	MC-IA	1338	0.24	ND	ND	0.32	0.56	0.05	0.15	68.00	1411.26
4	Fall	2/2/2015	9:20	MC-IA	1007	0.14	ND	ND	0.47	0.61	0.06	0.08	23.20	1434.58
4	**EMC**	**2/2/2015**		**MC-IA**	**3574**	**0.26**	**0.00**	**0.00**	**0.67**	**0.93**	**0.06**	**0.13**	**45.75**	**2318.22**
4	Base	2/1/2015	23:00	MC-IB		ND	ND	ND	2.31	2.31	0.06	0.07	164.00	30598.33
4	Rise	2/2/2015	1:10	MC-IB	3355	0.17	ND	ND	1.08	1.25	0.06	0.10	35.60	5405.89
4	Peak	2/2/2015	8:47	MC-IB	4879	0.29	ND	ND	0.31	0.61	0.02	0.06	43.20	475.29
4	Fall	2/2/2015	10:25	MC-IB	776	0.24	ND	ND	0.24	0.48	0.01	0.02	7.40	224.53
4	**EMC**	**2/2/2015**		**MC-IB**	**9010**	**0.24**	**0.00**	**0.00**	**0.59**	**0.84**	**0.03**	**0.07**	**37.29**	**2289.67**
4	Rise	2/2/2015	2:35	MC-O	3774	0.56	ND	ND	1.19	1.75	0.04	0.14	48.00	5872.42
4	Peak	2/2/2015	9:04	MC-O	6223	0.26	ND	ND	0.33	0.59	0.02	0.04	21.20	882.92
4	Fall	2/2/2015	11:30	MC-O	718	0.22	ND	ND	0.55	0.76	0.05	0.07	8.40	2029.40
4	**EMC**	**2/2/2015**		**MC-O**	**10715**	**0.36**	**0.00**	**0.00**	**0.65**	**1.01**	**0.03**	**0.08**	**29.78**	**2717.13**

					cf	(0) mg/L	(0) mg/L	(0) mg/L	(0) mg/L	(0) mg/L	(0) mg/L	(0) mg/L	(0) mg/L	(0) mg/L
Storm	Limb	Date	Collection T	Site	Flow Volume*	Nitrate - N	Nitrite - N	Ammonia	TKN	Total Nitrog	Ortho-P	Total Phosp	TSS	TDS
5	Rise	3/10/2015	15:15	MC-IA	213	0.13	ND	ND	1.57	1.70	0.03	0.05	201.56	1883.61
5	Peak	3/10/2015	21:40	MC-IA	682	0.11	ND	ND	0.35	0.46	0.04	0.09	14.80	688.14
5	Fall	3/11/2015	0:24	MC-IA	44	0.37	ND	ND	0.83	1.20	0.04	0.09	11.60	2105.22
5	**EMC**	**3/10/2015**		**MC-IA**	**939**	**0.13**	**0.00**	**0.00**	**0.65**	**0.78**	**0.04**	**0.08**	**57.01**	**1025.72**
5	Base	3/10/2015	11:40	MC-IB		0.09	ND	ND	0.53	0.63	0.01	0.09	48.00	2781.68
5	Rise	3/10/2015	15:17	MC-IB	460	0.08	ND	ND	2.34	2.42	0.03	0.04	158.33	10339.41
5	Peak	3/10/2015	21:44	MC-IB	9723	0.18	ND	ND	0.25	0.43	0.01	0.01	7.60	122.71
5	Fall	3/11/2015	0:34	MC-IB	130	0.11	ND	ND	0.34	0.45	0.01	0.01	4.00	302.67
5	**EMC**	**3/10/2015**		**MC-IB**	**10313**	**0.17**	**0.00**	**0.00**	**0.35**	**0.52**	**0.01**	**0.01**	**14.28**	**580.68**
5	Base	3/10/2015	11:30	MC-O		0.17	ND	ND	0.41	0.58	0.01	0.03	6.40	1052.61
5	Rise	3/10/2015	15:31	MC-O	248	0.14	ND	ND	1.18	1.32	0.01	0.13	103.92	2542.58
5	Peak	3/10/2015	21:10	MC-O	10557	0.11	ND	ND	0.33	0.44	0.01	0.01	10.40	282.26
5	Fall	3/11/2015	1:50	MC-O	402	0.11	ND	ND	0.57	0.69	0.02	0.04	6.40	742.96
5	**EMC**	**3/10/2015**		**MC-O**	**11207**	**0.12**	**0.00**	**0.00**	**0.35**	**0.47**	**0.01**	**0.01**	**12.33**	**348.81**
6	Rise	4/14/2015	11:23	MC-IA	17	0.47	0.21	ND	1.15	1.82	0.02	0.25	48.00	542.93
6	Peak	4/14/2015	11:34	MC-IA	25	0.44	0.21	ND	1.12	1.77	0.02	0.18	32.80	439.13
6	Fall	4/14/2015	12:55	MC-IA	20	0.46	0.18	ND	1.14	1.77	0.01	0.16	21.20	505.03
6	**EMC**	**4/14/2015**		**MC-IA**	**62**	**0.45**	**0.20**	**0.00**	**1.13**	**1.78**	**0.02**	**0.19**	**33.21**	**489.35**
6	Rise	4/14/2015	11:38	MC-IB	238	1.60	0.18	ND	1.50	3.29	0.04	0.34	56.40	875.92
6	Peak	4/14/2015	13:10	MC-IB	473	0.94	0.19	0.29	0.84	1.97	0.02	0.12	26.40	132.39
6	Fall	4/14/2015	0:34	MC-IB	365	1.00	0.19	0.30	0.84	2.03	0.01	0.05	6.00	116.94
6	**EMC**	**4/14/2015**		**MC-IB**	**1076**	**1.10**	**0.19**	**0.23**	**0.99**	**2.28**	**0.02**	**0.14**	**26.12**	**291.80**
6	Rise	4/14/2015	11:41	MC-O	15	0.93	ND	ND	0.80	1.74	0.01	0.25	166.40	486.37
6	Peak	4/14/2015	12:00	MC-O	549	0.97	0.17	ND	0.51	1.65	0.01	0.09	11.60	295.67
6	Fall	4/14/2015	14:42	MC-O	180	0.90	0.16	ND	0.45	1.52	0.01	0.05	3.60	206.45
6	**EMC**	**4/14/2015**		**MC-O**	**744**	**0.95**	**0.16**	**0.00**	**0.51**	**1.62**	**0.01**	**0.09**	**12.75**	**277.87**
7	Rise	5/31/2015	20:25	MC-IA	1	1.47	ND	ND	3.85	5.32	0.29	1.33	573.20	544.68
7	Peak	5/31/2015	20:27	MC-IA	86	1.08	ND	ND	3.83	4.91	0.21	1.10	564.00	815.27
7	Fall	5/31/2015	20:46	MC-IA	38	0.72	0.07	0.36	3.37	4.15	0.41	0.73	23.60	216.37
7	**EMC**	**5/31/2015**		**MC-IA**	**125**	**0.98**	**0.02**	**0.11**	**3.69**	**4.68**	**0.27**	**0.99**	**400.27**	**631.57**
7	Base	5/31/2015	20:20	MC-IB		1.30	ND	ND	0.68	1.98	0.01	0.06	15.20	42.73
7	Rise	5/31/2015	20:25	MC-IB	3	1.39	ND	ND	1.30	2.69	0.18	0.84	408.40	42.32
7	Peak	5/31/2015	20:29	MC-IB	820	1.06	0.05	0.31	3.01	4.13	0.09	1.18	703.60	251.94
7	Fall	5/31/2015	21:07	MC-IB	616	1.02	0.07	1.67	4.09	5.18	0.04	0.14	4.00	107.26
7	**EMC**	**5/31/2015**		**MC-IB**	**1439**	**1.05**	**0.06**	**0.89**	**3.47**	**4.57**	**0.07**	**0.74**	**403.63**	**189.57**
7	Rise	5/31/2015	20:29	MC-O	9	1.19	ND	0.15	2.51	3.71	0.12	0.53	260.80	300.92
7	Peak	5/31/2015	20:47	MC-O	101	1.19	0.05	0.18	2.18	3.42	0.10	0.44	88.40	259.52
7	Fall	5/31/2015	21:30	MC-O	63	0.94	0.09	0.16	2.22	3.25	0.03	0.20	8.40	263.60
7	**EMC**	**5/31/2015**		**MC-O**	**173**	**1.10**	**0.06**	**0.17**	**2.21**	**3.37**	**0.08**	**0.36**	**68.47**	**263.17**
8	Rise	7/30/2015	14:07	MC-IA	1	0.34	ND	0.19	0.59	0.93	0.02	0.37	120.40	78.56
8	Peak	7/30/2015	14:13	MC-IA	551	0.18	0.02	0.14	0.25	0.45	0.01	0.16	15.00	56.46
8	Fall	7/30/2015	15:05	MC-IA	77	0.24	0.02	ND	0.40	0.66	0.01	0.16	4.80	103.58
8	**EMC**	**7/30/2015**		**MC-IA**	**629**	**0.19**	**0.02**	**0.13**	**0.27**	**0.48**	**0.01**	**0.16**	**13.85**	**62.28**
8	Rise	7/30/2015	14:05	MC-IB	142	0.60	ND	0.21	0.88	1.48	0.03	0.54	168.00	134.08
8	Peak	7/30/2015	14:11	MC-IB	5668	0.21	ND	0.19	0.29	0.50	0.01	0.11	20.40	53.38
8	Fall	7/30/2015	16:11	MC-IB	648	0.01	0.02	ND	0.33	0.36	0.00	0.05	4.00	67.02
8	**EMC**	**7/30/2015**		**MC-IB**	**6458**	**0.20**	**0.00**	**0.17**	**0.30**	**0.51**	**0.01**	**0.11**	**21.99**	**56.52**
8	Rise	7/30/2015	14:09	MC-O	241	0.48	ND	0.13	0.88	1.36	0.02	0.82	158.80	114.02
8	Peak	7/30/2015	14:22	MC-O	6833	0.19	0.04	0.11	0.25	0.47	0.01	0.08	4.27	54.66
8	Fall	7/30/2015	16:50	MC-O	858	0.14	ND	ND	0.32	0.46	0.01	0.10	1.40	107.84
8	**EMC**	**7/30/2015**		**MC-O**	**7932**	**0.19**	**0.03**	**0.10**	**0.27**	**0.50**	**0.01**	**0.10**	**8.65**	**62.21**

ND = Non Detect

					cf	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Storm	Limb	Date	Collection	Site	Flow Volume	Nitrate - N	Nitrite - N	Ammonia	TKN	Total Nitrogen	Ortho-P	Total Phosphorus	TSS	TDS
1	Rise	9/25/14	3:05	CH-IA	293	1.68	0.08	0.17	2.10	3.86	0.32	0.81	29.50	220.93
1	Peak	9/25/14	4:34	CH-IA	2345	0.06	ND	0.07	0.61	0.66	0.07	0.20	32.80	50.00
1	Fall	9/25/14	5:30	CH-IA	225	0.21	ND	0.11	0.71	0.92	0.09	0.17	10.00	60.24
1	**EMC**	**9/25/14**		**CH-IA**	**2863**	**0.24**	**0.01**	**0.08**	**0.77**	**1.01**	**0.09**	**0.26**	**30.67**	**68.30**
1	Rise	9/25/14	3:20	CH-O	293	0.97	0.04	0.78	3.83	4.85	0.41	0.77	59.33	123.46
1	Peak	9/25/14	4:30	CH-O	2345	0.11	ND	0.07	0.55	0.66	0.08	0.22	44.40	49.38
1	Fall	9/25/14	5:35	CH-O	225	0.44	ND	0.06	0.67	1.10	0.12	0.20	5.60	74.07
1	**EMC**	**9/25/14**		**CH-O**	**2863**	**0.22**	**0.00**	**0.14**	**0.90**	**1.12**	**0.12**	**0.28**	**42.88**	**58.90**
2	Rise	10/15/14	13:42	CH-IA	568	0.17	0.20	ND	6.09	6.46	0.02	0.46	30.00	178.67
2	Peak	10/15/14	16:25	CH-IA	4150	0.16	0.05	0.06	0.37	0.58	0.05	0.50	88.40	39.60
2	Fall	10/15/14	17:15	CH-IA	515	0.89	0.05	0.01	0.77	1.71	0.07	0.18	28.40	93.37
2	**EMC**	**10/15/14**		**CH-IA**	**5233**	**0.23**	**0.07**	**0.05**	**1.03**	**1.33**	**0.05**	**0.47**	**76.16**	**59.99**
2	Rise	10/15/14	13:52	CH-O	455	0.44	0.05	0.21	1.99	2.48	0.12	0.25	188.33	111.28
2	Peak	10/15/14	16:30	CH-O	3408	0.19	0.05	0.05	0.38	0.62	0.06	0.09	67.20	41.37
2	Fall	10/15/14	17:15	CH-O	374	0.63	0.05	ND	0.75	1.43	0.07	0.19	17.20	89.71
2	**EMC**	**10/15/14**		**CH-O**	**4237**	**0.26**	**0.05**	**0.06**	**0.59**	**0.89**	**0.07**	**0.12**	**75.79**	**53.15**
3	Rise	1/18/15	8:40	CH-IA	79	ND	ND	ND	3.89	3.89	0.09	0.72	135.33	2744.97
3	Peak	1/18/15	9:35	CH-IA	610	0.55	ND	ND	0.95	1.50	0.09	0.30	36.00	605.16
3	Fall	1/18/15	12:45	CH-IA	87	0.34	ND	ND	0.71	1.05	0.09	0.18	7.60	395.58
3	**EMC**	**1/18/15**		**CH-IA**	**776**	**0.47**	**0.00**	**0.00**	**1.22**	**1.69**	**0.09**	**0.33**	**42.93**	**799.51**
3	Rise	1/18/15	9:20	CH-O	29	ND	ND	ND	4.00	4.00	0.13	0.20	191.07	2714.42
3	Peak	1/18/15	9:50	CH-O	454	0.51	0.51	ND	0.86	1.36	0.09	0.36	71.88	596.61
3	Fall	1/18/15	13:00	CH-O	85	0.45	0.45	ND	0.73	1.18	0.09	0.18	8.40	542.84
3	**EMC**	**1/18/15**		**CH-O**	**568**	**0.47**	**0.47**	**0.00**	**1.00**	**1.47**	**0.09**	**0.32**	**68.46**	**696.69**
4	Base	3/10/15	10:00	CH-IA	0.002	0.24	ND	ND	1.25	1.49	0.06	0.17	18.40	3276.60
4	Rise	3/10/15	14:15	CH-IA	441	0.07	ND	ND	0.93	1.00	0.02	0.12	40.36	1076.87
4	Peak	3/10/15	15:45	CH-IA	2469	0.20	ND	ND	1.06	1.27	0.03	0.24	334.00	993.16
4	Fall	3/11/15	0:30	CH-IA	340	0.18	ND	ND	0.78	0.96	0.04	0.03	24.80	511.68
4	**EMC**	**3/10/15**		**CH-IA**	**3250**	**0.18**	**0.00**	**0.00**	**1.01**	**1.20**	**0.03**	**0.20**	**261.81**	**954.15**
4	Rise	3/10/15	14:20	CH-O	452	0.10	ND	ND	1.13	1.23	0.11	0.18	47.33	1031.66
4	Peak	3/10/15	16:00	CH-O	2772	0.42	ND	ND	0.66	1.08	0.03	0.03	390.62	624.72
4	Fall	3/11/15	0:30	CH-O	1184	0.45	ND	ND	0.62	1.07	0.10	0.21	32.14	480.52
4	**EMC**	**3/10/15**		**CH-O**	**4408**	**0.39**	**0.00**	**0.00**	**0.70**	**1.09**	**0.06**	**0.10**	**259.13**	**627.71**

					cf	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Storm	Limb	Date	Collection	Site	Flow Volume	Nitrate - N	Nitrite - N	Ammonia	TKN	Total Nitrogen	Ortho-P	Total Phosphorus	TSS	TDS
5	Rise	4/3/15	10:00	CH-IA	20	0.29	ND	ND	1.31	1.60	0.06	0.08	86.32	1142.25
5	Peak	4/3/15	10:10	CH-IA	99	1.01	0.06	ND	2.18	3.25	0.08	0.06	228.42	656.49
5	Fall	4/3/15	11:00	CH-IA	84	0.84	ND	ND	1.36	2.20	0.06	0.10	65.93	601.50
5	**EMC**	**4/3/15**		**CH-IA**	**203**	**0.87**	**0.03**	**0.00**	**1.76**	**2.66**	**0.07**	**0.08**	**147.18**	**681.59**
5	Rise	4/3/15	10:05	CH-O	7	0.28	ND	ND	2.59	2.86	0.23	0.49	125.00	1816.21
5	Peak	4/3/15	10:15	CH-O	95	1.22	ND	ND	4.25	5.48	0.09	0.62	236.23	865.46
5	Fall	4/3/15	11:10	CH-O	71	0.85	ND	ND	1.33	2.18	0.09	0.21	60.98	715.15
5	**EMC**	**4/3/15**		**CH-O**	**173**	**1.03**	**0.00**	**0.00**	**2.99**	**4.02**	**0.10**	**0.44**	**159.81**	**842.24**
6	Rise	4/14/15	7:15	CH-IA	44	1.09	0.20	ND	0.49	1.78	0.23	1.14	434.00	660.16
6	Peak	4/14/15	7:45	CH-IA	164	0.57	0.18	ND	0.55	1.31	0.15	0.97	312.00	313.10
6	Fall	4/14/15	8:50	CH-IA	77	0.31	0.16	ND	0.49	0.96	0.08	0.32	41.38	262.99
6	**EMC**	**4/14/15**		**CH-IA**	**285**	**0.58**	**0.18**	**0.00**	**0.52**	**1.29**	**0.14**	**0.82**	**257.72**	**353.14**
6	Rise	4/14/15	7:40	CH-O	13	0.60	ND	ND	1.38	1.98	0.16	1.34	180.00	1123.31
6	Peak	4/14/15	7:50	CH-O	148	0.72	0.19	ND	0.36	1.27	0.15	1.04	175.44	420.64
6	Fall	4/14/15	9:00	CH-O	72	0.36	0.16	ND	0.53	1.04	0.09	0.37	50.00	267.88
6	**EMC**	**4/14/15**		**CH-O**	**233**	**0.60**	**0.17**	**0.00**	**0.47**	**1.24**	**0.13**	**0.85**	**136.93**	**412.64**
7	Rise	6/1/15	18:50	CH-IA	313	0.99	0.09	ND	2.39	3.47	0.20	0.68	126.14	273.38
7	Peak	6/1/15	19:55	CH-IA	2713	0.37	ND	0.03	0.49	0.86	0.06	0.55	148.57	57.63
7	Fall	6/1/15	22:30	CH-IA	991	1.15	0.05	ND	0.71	1.91	0.08	0.18	10.00	193.34
7	**EMC**	**6/1/15**		**CH-IA**	**4017**	**0.61**	**0.02**	**0.02**	**0.69**	**1.32**	**0.07**	**0.47**	**112.64**	**107.92**
7	Rise	6/1/15	19:19	CH-O	78	0.91	0.10	ND	2.38	3.39	0.14	0.59	120.00	288.66
7	Peak	6/1/15	19:49	CH-O	2495	0.14	ND	0.04	0.31	0.45	0.05	0.32	147.60	44.18
7	Fall	6/1/15	22:40	CH-O	853	0.45	0.05	ND	1.43	1.93	0.08	0.25	20.83	249.55
7	**EMC**	**6/1/15**		**CH-O**	**3426**	**0.24**	**0.01**	**0.03**	**0.64**	**0.89**	**0.06**	**0.31**	**115.41**	**100.88**
8	Rise	9/10/15	12:50	CH-IA	80	2.57	1.06	0.35	8.42	12.05	1.47	2.40	304.00	295.38
8	Peak	9/10/15	13:05	CH-IA	4868	0.25	ND	0.32	1.03	1.28	0.15	0.27	139.20	41.44
8	Fall	9/10/15	15:20	CH-IA	126	1.66	ND	ND	0.88	2.54	0.11	0.17	75.00	139.93
8	**EMC**	**9/10/15**		**CH-IA**	**5074**	**0.32**	**0.02**	**0.31**	**1.14**	**1.48**	**0.17**	**0.30**	**140.20**	**47.89**
8	Rise	9/10/15	13:00	CH-O	113	3.46	0.12	ND	20.05	23.62	10.61	10.00	165.56	305.15
8	Peak	9/10/15	13:09	CH-O	4228	0.25	0.03	0.31	1.07	1.35	0.17	0.22	63.20	41.07
8	Fall	9/10/15	15:30	CH-O	413	1.90	0.32	0.25	1.58	3.80	0.23	0.22	59.57	161.56
8	**EMC**	**9/10/15**		**CH-O**	**4754**	**0.47**	**0.06**	**0.30**	**1.57**	**2.09**	**0.43**	**0.45**	**65.32**	**57.81**

ND = Non-Detect

					cf	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Storm	Limb	Date	Collection	Site	Flow Volume	Nitrate - N	Nitrite - N	Ammonia	TKN	Total Nitrogen	Ortho-P	Total Phosphorus	TSS	TDS
1	Rise	2/2/2015	2:58	FH-I	701	0.22	ND	ND	2.08	2.31	0.11	0.56	200.00	4370.00
1	Peak	2/2/2015	8:40	FH-I	2262	0.31	ND	ND	0.48	0.79	0.04	0.14	95.83	268.89
1	Fall	2/2/2015	12:45	FH-I	1819	0.33	ND	ND	0.72	0.72	0.04	0.09	14.17	72.00
1	**EMC**	**2/2/2015**		**FH-I**	**4782**	**0.30**	**0.00**	**0.00**	**0.81**	**0.98**	**0.05**	**0.18**	**80.04**	**795.18**
1	Rise	2/2/2015	8:55	FH-O	37	0.90	ND	ND	0.62	1.52	0.00	0.04	46.11	1581.00
1	Peak	2/2/2015	9:05	FH-O	3046	0.43	ND	ND	0.85	1.28	0.09	0.21	46.86	664.65
1	Fall	2/2/2015	12:45	FH-O	2779	0.27	ND	ND	0.50	0.78	0.04	0.09	9.20	177.00
1	**EMC**	**2/2/2015**		**FH-O**	**5862**	**0.36**	**0.00**	**0.00**	**0.68**	**1.04**	**0.06**	**0.15**	**29.00**	**439.25**
2	**Base**	3/10/2015	9:15	FH-I		0.21	ND	ND	0.62	0.83	0.03	0.09	13.20	468.55
2	Rise	3/10/2015	15:15	FH-I	2226	0.19	ND	ND	0.62	0.81	0.02	0.04	44.38	247.57
2	Peak	3/10/2015	20:30	FH-I	10881	0.12	ND	ND	0.58	0.70	0.02	0.08	23.20	38.74
2	Fall	3/10/2015	22:45	FH-I	4062	0.16	ND	ND	0.48	0.64	0.02	0.02	9.20	38.69
2	**EMC**	**3/10/2015**		**FH-I**	**17169**	**0.14**	**0.00**	**0.00**	**0.56**	**0.70**	**0.02**	**0.06**	**22.63**	**65.80**
2	Base	3/10/2015	9:05	FH-O		0.11	ND	ND	0.71	0.82	0.01	0.06	3.60	384.65
2	Rise	3/10/2015	15:15	FH-O	1737	0.13	ND	ND	0.58	0.71	0.01	0.05	9.20	246.65
2	Peak	3/10/2015	20:45	FH-O	13197	0.32	ND	ND	0.43	0.74	0.02	0.01	11.60	53.96
2	Fall	3/10/2015	23:30	FH-O	2564	0.26	ND	ND	0.40	0.66	0.02	0.03	6.80	55.38
2	**EMC**	**3/10/2015**		**FH-O**	**17498**	**0.29**	**0.00**	**0.00**	**0.44**	**0.73**	**0.02**	**0.02**	**10.66**	**73.30**
3	Rise	4/19/2015	23:30	FH-I	1197	1.14	0.18	0.27	2.21	3.53	0.15	0.38	83.11	159.55
3	Peak	4/20/2015	2:30	FH-I	3900	0.09	ND	0.10	0.23	0.32	0.01	0.09	122.41	9.20
3	Fall	4/20/2015	5:00	FH-I	708	0.20	ND	ND	0.42	0.63	0.03	0.17	39.73	27.32
3	**EMC**	**4/20/2015**		**FH-I**	**5805**	**0.32**	**0.04**	**0.12**	**0.66**	**1.02**	**0.04**	**0.16**	**104.22**	**42.41**
3	Rise	4/20/2015	0:35	FH-O	532	0.52	ND	ND	1.82	2.34	0.09	0.34	30.63	78.53
3	Peak	4/20/2015	3:05	FH-O	4672	0.11	ND	ND	0.39	0.49	0.03	0.06	27.32	16.09
3	Fall	4/20/2015	5:05	FH-O	823	0.13	ND	ND	0.49	0.62	0.02	0.05	13.20	23.75
3	**EMC**	**4/20/2015**		**FH-O**	**6027**	**0.15**	**0.00**	**0.00**	**0.53**	**0.67**	**0.03**	**0.08**	**25.69**	**22.65**
4	Rise	6/1/2015	19:45	FH-I	1288	0.67	0.05	0.42	2.65	3.37	0.06	0.33	59.41	102.24
4	Peak	6/1/2015	21:45	FH-I	1470	0.09	ND	ND	0.28	0.37	0.01	0.34	91.25	8.28
4	Fall	6/1/2015	22:30	FH-I	94	0.12	ND	ND	0.85	0.96	0.01	0.19	40.00	32.28
4	**EMC**	**6/1/2015**		**FH-I**	**2852**	**0.35**	**0.02**	**0.19**	**1.37**	**1.75**	**0.03**	**0.33**	**75.18**	**51.50**
4	Rise	6/1/2015	20:45	FH-O	511	0.22	ND	ND	5.27	5.49	0.35	0.93	10.77	209.98
4	Peak	6/1/2015	22:00	FH-O	1876	0.09	ND	ND	1.32	1.41	0.06	0.22	11.11	44.88
4	Fall	6/1/2015	22:30	FH-O	413	0.07	ND	ND	1.28	1.35	0.06	0.23	20.91	36.49
4	**EMC**	**6/1/2015**		**FH-O**	**2800**	**0.11**	**0.00**	**0.00**	**2.04**	**2.15**	**0.12**	**0.35**	**12.49**	**73.78**

					cf	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Storm	Limb	Date	Collection	Site	Flow Volume	Nitrate - N	Nitrite - N	Ammonia	TKN	Total Nitrogen	Ortho-P	Total Phosphorus	TSS	TDS
5	Rise	8/20/2015	18:35	FH-I	645	0.25	0.06	ND	0.88	1.18	0.00	0.07	12.32	42.09
5	Peak	8/20/2015	18:55	FH-I	1483	0.03	0.04	ND	0.12	0.19	0.00	0.05	39.60	7.51
5	Fall	8/20/2015	19:35	FH-I	193	0.07	ND	ND	0.33	0.40	0.00	0.06	9.14	15.04
5	**EMC**	**8/20/2015**		**FH-I**	**2321**	**0.09**	**0.04**	**0.00**	**0.35**	**0.48**	**0.00**	**0.06**	**29.49**	**17.74**
5	Rise	8/20/2015	18:45	FH-O	177	0.17	ND	0.10	3.57	3.73	0.00	0.38	17.20	68.04
5	Peak	8/20/2015	19:10	FH-O	1967	0.17	ND	0.01	0.93	1.10	0.00	0.19	7.20	23.57
5	Fall	8/20/2015	19:55	FH-O	839	0.15	ND	ND	0.88	1.03	0.00	0.16	9.60	25.63
5	**EMC**	**8/20/2015**		**FH-O**	**2983**	**0.16**	**0.00**	**0.01**	**1.07**	**1.24**	**0.00**	**0.20**	**8.47**	**26.78**
6	Rise	9/10/2015	11:45	FH-I	213	2.37	ND	1.36	4.76	7.14	0.39	0.65	115.03	99.53
6	Peak	9/10/2015	12:30	FH-I	519	0.31	0.03	0.36	0.57	0.91	0.05	0.09	35.20	12.20
6	Fall	9/10/2015	12:45	FH-I	32	0.42	ND	0.34	0.69	1.11	0.07	0.10	28.80	18.02
6	**EMC**	**9/10/2015**		**FH-I**	**764**	**0.89**	**0.02**	**0.64**	**1.74**	**2.65**	**0.15**	**0.25**	**57.19**	**36.79**
6	Rise	9/10/2015	13:00	FH-O	12	1.99	0.04	0.50	2.38	4.41	1.00	1.30	92.31	67.07
6	Peak	9/10/2015	13:15	FH-O	41	1.44	ND	0.35	2.03	3.47	0.77	0.74	8.00	52.49
6	Fall	9/10/2015	13:30	FH-O	19	1.47	0.04	0.35	2.04	3.55	0.70	0.78	9.20	52.81
6	**EMC**	**9/10/2015**		**FH-O**	**72**	**1.54**	**0.02**	**0.37**	**2.09**	**3.64**	**0.79**	**0.84**	**22.37**	**55.01**
7	Rise	9/29/2015	18:50	FH-I	435	0.45	0.07	0.53	1.39	1.91	0.09	0.17	34.00	40.34
7	Peak	9/29/2015	23:05	FH-I	24281	0.14	ND	0.07	0.19	0.33	0.04	0.33	408.11	7.37
7	Fall	9/29/2015	23:50	FH-I	524	0.39	0.07	ND	0.25	0.71	0.07	0.46	10.40	25.90
7	**EMC**	**9/29/2015**		**FH-I**	**25240**	**0.15**	**0.00**	**0.08**	**0.21**	**0.36**	**0.04**	**0.33**	**393.41**	**8.32**
7	Rise	9/29/2015	21:00	FH-O	435	0.95	0.07	0.12	1.66	2.69	0.70	0.85	12.00	45.16
7	Peak	9/29/2015	23:10	FH-O	24281	0.18	ND	0.07	0.34	0.52	0.08	0.09	109.60	9.35
7	Fall	9/30/2015	2:55	FH-O	524	0.18	ND	0.09	0.43	0.60	0.14	0.28	76.28	15.27
7	**EMC**	**9/29/2015**		**FH-O**	**25240**	**0.20**	**0.00**	**0.07**	**0.36**	**0.56**	**0.09**	**0.11**	**107.23**	**10.09**
8	Rise	10/9/2015	18:30	FH-I	896	0.35	0.19	0.09	0.22	0.76	0.07	0.12	37.71	27.14
8	Peak	10/9/2015	18:32	FH-I	21	0.39	ND	0.06	0.50	0.90	0.07	0.13	34.48	34.61
8	Fall	10/9/2015	18:45	FH-I	37	0.36	0.19	0.08	0.15	0.70	0.07	0.13	47.65	26.64
8	**EMC**	**10/9/2015**		**FH-I**	**953**	**0.35**	**0.19**	**0.09**	**0.22**	**0.76**	**0.07**	**0.12**	**38.02**	**27.29**
8	Rise	10/9/2015	18:33	FH-O	175	0.76	0.20	0.14	0.58	1.54	0.21	0.23	15.20	33.24
8	Peak	10/9/2015	18:35	FH-O	285	0.76	0.20	0.15	0.63	1.59	0.19	0.22	16.80	33.33
8	Fall	10/9/2015	19:35	FH-O	261	1.02	0.21	0.08	0.90	2.12	0.15	0.24	31.69	41.72
8	**EMC**	**10/9/2015**		**FH-O**	**721**	**0.85**	**0.20**	**0.12**	**0.72**	**1.77**	**0.18**	**0.23**	**21.81**	**36.35**

ND = Non Detect

Appendix E: EMC and Volume Summary Table

Site	Date	Rainfall	Direct Rainfall Input (cf)	Combined Inlet and Rainfall Volume (cf)	Outlet Volume (cf)	Volume Difference (cf)*		Total Nitrogen EMC (mg/L)		Total Phosphorus EMC (mg/L)		TSS EMC (mg/L)		Weather/ Unusual Conditions
								In	Out	In	Out	In	Out	
Control Ponds														
MC	8/12/14	0.09	87	926	44	882		1.31	1.30	0.06	0.08	8.62	1.68	
MC	10/4/14	0.25	241	4928	3210	1718		0.96	0.57	0.06	0.02	6.82	3.64	
MC	10/15/14	0.98	944	20374	19737	637		0.38	0.12	0.14	0.02	79.93	2.98	
MC	2/2/15	0.46	443	13027	10715	2312		0.86	1.01	0.09	0.08	39.69	29.78	snow
MC	3/10/15	0.52	501	11753	11207	546		0.54	0.47	0.02	0.01	17.84	12.33	snow
MC	4/14/15	0.075	72	1211	744	466		2.25	1.62	0.15	0.09	26.51	12.75	
MC	5/31/15	0.08	77	1642	173	1468		4.58	3.37	0.76	0.36	403.36	68.47	
MC	7/30/15	0.53	511	7597	7932	-335		0.50	0.50	0.12	0.10	21.27	8.65	
CH	9/25/14	0.79	590	3453	2863	590		1.01	1.12	0.26	0.28	30.67	42.88	
CH	10/15/14	1.2	896	6129	4237	1892		1.33	0.89	0.47	0.12	76.16	75.79	
CH	1/18/15	0.17	127	903	568	335		1.69	1.47	0.33	0.32	42.93	68.46	snow
CH	3/10/15	0.52	388	3638	4408	-770		1.20	1.09	0.20	0.10	261.81	259.13	snow
CH	4/3/15	0.07	52	255	173	82		2.66	4.02	0.08	0.44	147.18	159.81	**see note
CH	4/14/15	0.12	90	375	233	142		1.29	1.24	0.82	0.85	257.72	136.93	
CH	6/1/15	1.10	822	4839	3426	1413		1.32	0.89	0.47	0.31	112.64	115.41	
CH	9/10/15	1.35	1009	6083	4754	1329		1.48	2.09	0.30	0.45	140.20	65.32	
FH	2/2/15	0.44	1383	6165	5862	303		0.98	1.04	0.18	0.15	80.04	29.00	snow
FH	3/10/15	0.60	1886	19055	17498	1557		0.70	0.73	0.06	0.02	22.63	10.66	snow
FH	4/20/15	1.50	4714	10519	6027	4493		1.02	0.67	0.16	0.08	75.18	25.69	
FH	6/1/15	0.70	2200	5052	2800	2252		1.75	2.15	0.33	0.35	75.18	12.49	
FH	8/20/15	0.66	2074	4395	2983	1412		0.48	1.24	0.06	0.20	29.49	8.47	
FH	9/10/15	0.50	1571	2336	72	2264		2.65	3.64	0.25	0.84	57.19	22.37	
FH	9/29/15	3.35	10529	35768	25240	10528		0.36	0.56	0.33	0.11	393.41	107.23	
FH	10/9/15	0.39	1226	2179	721	1458		0.76	1.77	0.12	0.23	38.02	21.81	
Study Ponds														
GS	9/25/14	1.65	4588	20920	22097	-1177		0.65	0.78	0.06	0.37	19.64	3.39	
GS	11/6/14	0.84	2336	15131	14757	374		0.54	0.52	0.03	0.05	9.76	5.89	
GS	1/12/15	0.52	1446	12983	7549	5434		0.94	1.03	0.22	0.15	155.31	50.49	snow
GS	3/20/15	0.55	1529	7297	4684	2613		1.78	1.96	0.13	0.07	118.12	20.91	snow
GS	4/20/15	1.20	3337	16429	18817	-2388		1.18	0.44	0.17	0.11	74.03	23.35	
GS	6/18/15	1.10	3059	21803	20893	910		0.39	0.50	0.09	0.08	15.28	5.25	
GS	8/20/15	0.91	2530	9515	11813	-2297		5.31	0.86	2.19	0.17	206.01	8.40	
GS	8/24/15	0.92	2558	7877	7381	496		1.34	1.04	0.46	0.21	83.30	17.02	
HR	8/12/14	2.10	7599	31406	27928	3478		1.16	0.78	0.29	0.17	66.46	28.39	
HR	9/25/14	2.15	7780	28601	23837	4764		0.99	1.23	0.27	0.20	32.36	4.67	
HR	11/6/14	0.65	2352	8651	5397	3254		2.45	1.57	0.75	0.12	14.52	48.89	
HR	3/4/15	0.98	3546	30978	32170	-1193		1.28	1.05	0.17	0.06	40.68	4.70	snow
HR	3/27/15	1.20	4342	27259	14386	12873		0.90	0.72	1.53	0.13	2815.01	50.22	
HR	6/1/15	1.03	3727	10050	6193	3857		2.06	1.48	0.71	0.19	218.35	39.62	
HR	6/18/15	0.77	2786	8975	2839	6136		1.17	1.30	0.15	0.15	23.74	15.03	
HR	8/20/15	0.92	3329	8836	7215	1621		0.88	0.67	0.44	0.20	150.77	67.09	
WO	3/4/15	1.00	3049	63930	43042	20888		0.87	0.95	51.88	52.08	14.58	12.02	snow
WO	3/20/15	0.62	1891	5528	2911	2617		1.52	1.79	79.27	47.20	45.80	13.58	snow
WO	4/14/15	0.08	244	496	106	390		4.28	1.74	125.26	20.51	9.55	1.85	
WO	6/18/15	1.00	3049	14531	7784	6747		0.88	0.99	279.74	177.43	51.95	37.02	
WO	8/20/15	0.80	2439	9725	5194	4531		0.77	0.90	159.45	231.11	51.22	231.11	***see note
WO	9/10/15	1.06	3232	13926	5110	8816		1.09	1.19	245.61	171.51	93.09	54.08	
WO	9/29/15	3.50	10672	108629	69837	38792		1.72	1.84	355.73	269.60	12.83	134.13	***see note
WO	10/9/15	0.34	1037	5145	2081	3064		4.59	2.15	268.62	335.10	95.92	134.54	***see note

* Volume difference calculated by subtracting Combined Inlet and Rainfall Volume by Outlet Volume.

** Unrepresentative storm due to construction in drainage area .

*** TSS measurements were suspect due to erosion upstream of sampling area.

Appendix F: Rainfall Concentrations

Sample ID	**Date**	**Merged ID**	**Nitrate (NO_3) (mg/L)**	**Nitrite (NO_2) (mg/L)**	**Ammonia (NH_4^+) (mg/L)**	**TKN by subtraction**	**Total N (mg/L)**	**Ortho-P (µg/L)**	**Total P (µg/L)**	**TSS (mg/L)**	**TDS (mg/L)**
WO-Rain 1	3/6/15		0.15	*0.10*	0.04	0.19	0.34	5.88	*5.00*	0.90	40.00
WO-Rain 2	3/6/15		0.14	*0.10*	*0.10*	0.03	0.16	3.96	*5.00*	1.10	16.00
		WO-Rain Avg	**0.14**	**0.10**	**0.07**	**0.11**	**0.25**	**4.92**	**5.00**	**1.00**	**28.00**
HR-Rain 1	3/6/15		0.17	*0.10*	0.10	0.02	0.19	3.86	4.75	0.10	38.00
HR-Rain 2	3/6/15		0.17	*0.10*	0.19	0.27	0.44	6.19	7.24	1.00	0.00
		HR-Rain Avg	**0.17**	**0.10**	**0.15**	**0.15**	**0.32**	**5.02**	**5.99**	**0.55**	**19.00**
CH-Rain 1	6/2/15		0.15	*0.10*	0.15	0.24	0.39	6.08	15.10	-	-
CH-Rain 2	6/2/15		0.16	*0.10*	0.10	0.17	0.32	2.27	*5.00*	-	-
		CH-Rain Avg	**0.15**	**0.10**	**0.12**	**0.20**	**0.36**	**4.17**	**10.05**	-	-
FH-Rain 1	6/2/15		0.16	*0.10*	0.11	0.44	0.60	80.40	116.66	-	-
FH-Rain 2	6/2/15		0.06	*0.10*	0.00	0.40	0.46	59.30	63.16	-	-
		FH-Rain Avg	**0.11**	**0.10**	**0.05**	**0.42**	**0.53**	**69.85**	**89.91**	-	-
FH-Rain	8/20/15		0.07	*0.10*	0.13	0.17	0.24	-	21.00	-	-
FH-Rain2	8/20/15		0.11	*0.10*	0.24	0.52	0.63	-	144.00	-	-
		FH-Rain Avg	**0.09**	**0.10**	**0.18**	**0.34**	**0.43**	**-**	**82.50**	-	-
GS-Rain	8/20/15		**0.11**	***0.10***	**0.29**	**0.32**	**0.47**	**-**	***5.00***	-	-
FH-Rain	9/30/15		**0.10**	***0.10***	**0.08**	**0.06**	**0.06**	**2.48**	***5.00***	-	-
WO-Rain	9/30/15		0.08	0.07	0.23	0.09	0.24	1.90	***5.00***	-	-
WO-Rain 2	9/30/15		0.07	*0.10*	0.10	BDL	0.07	2.25	***5.00***	-	-
		WO-Rain Avg	**0.08**	**0.08**	**0.16**	**0.09**	**0.16**	**2.07**	**5.00**	-	-
Combined Samples		median	0.11	0.10	0.13	0.18	0.34	4.55	5.50	0.78	23.50
Combined Samples		mean	0.12	0.10	0.14	0.21	0.32	14.75	26.06	0.78	23.50
Combined Samples		mean (FH only)	0.10	0.14	0.12	0.38	0.48	34.93	86.20	0.00	0.00
Combined Samples		standard dev	0.03	0.01	0.08	0.13	0.16	27.02	37.22	0.32	6.36

Indicates values measured BDL

(-) Indicates tests not run

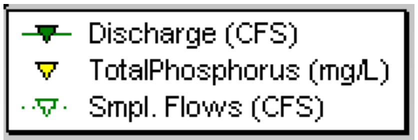
Combined samples median were used in annual rainfall load calculations

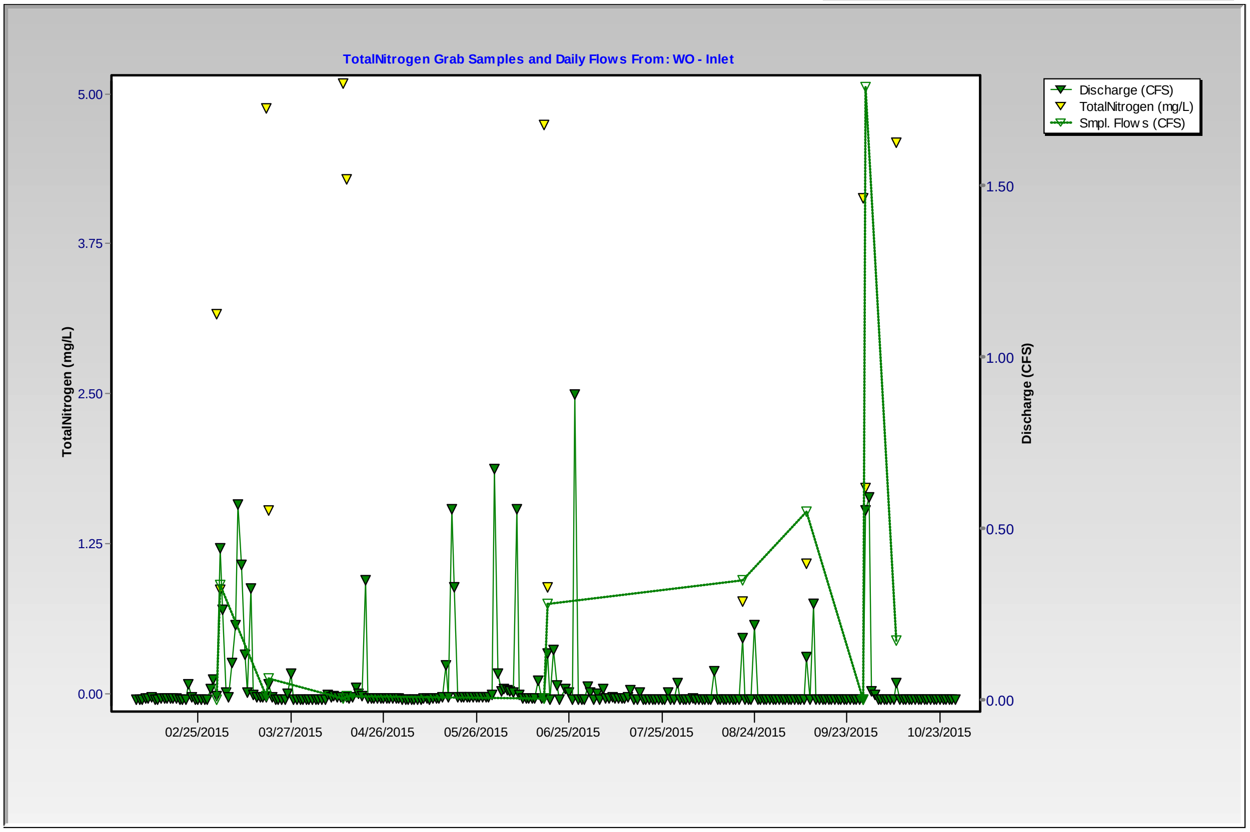
Combined samples mean (FH only) were used in annual rainfall load calculations exclusively at Fields of Harvest

Appendix G: FLUX32 Average Daily Discharge

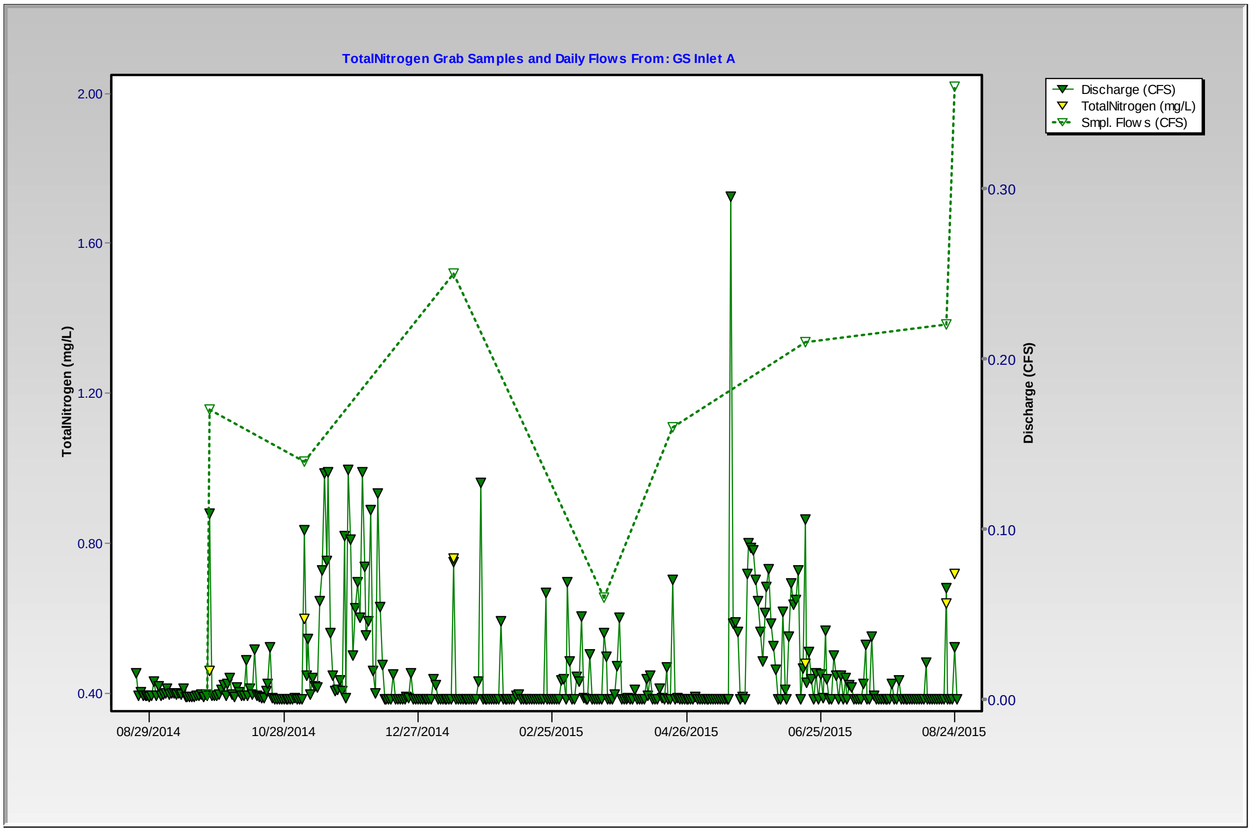
Appendix G includes a FLUX32 pollutant load estimation model output file that provides a visual representation of the major model inputs. Plots are provided for each pond, each pollutant, with a chart for the inflow and outflow. The following example is used to describe the chart elements.

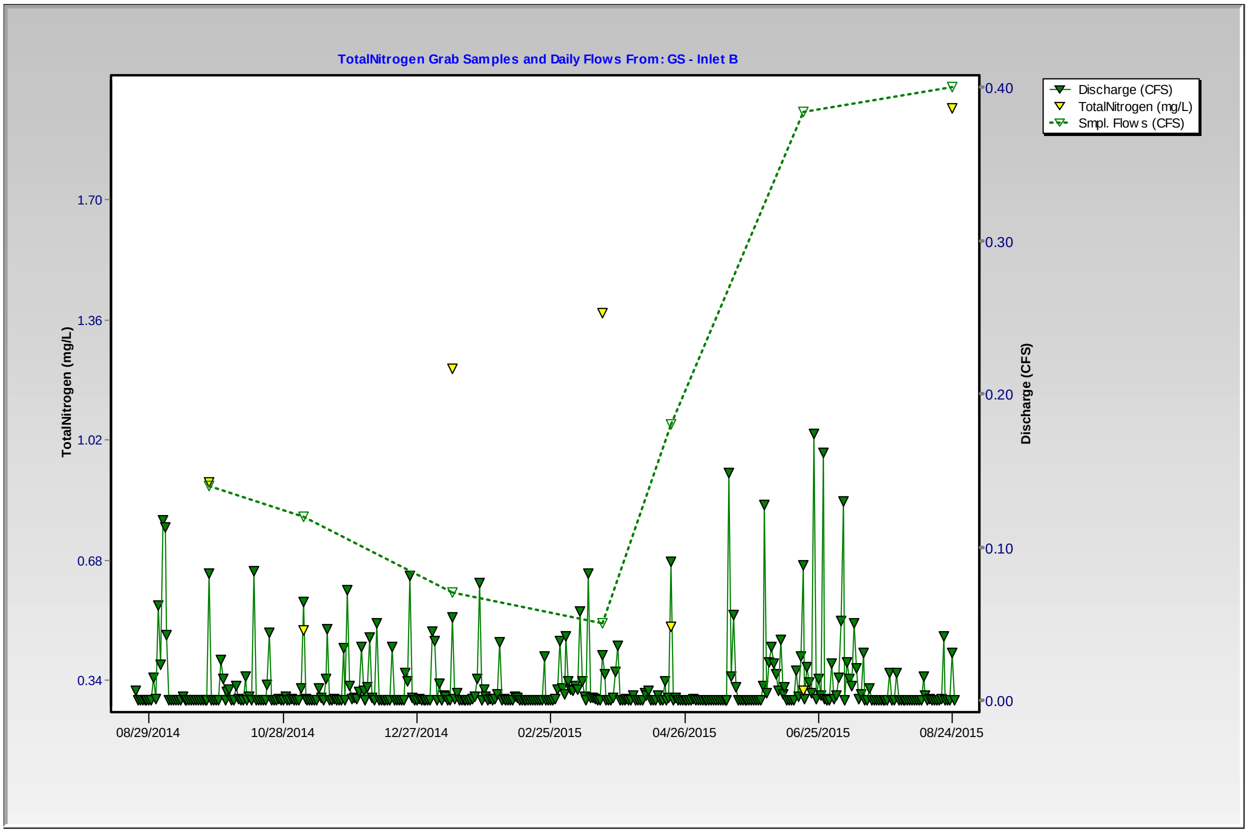
- Discharge in cubic feet per second (cfs) on the right axis is the mean daily discharge time series record for the period of study, generally approximately 1 year. The mean daily discharge record is represented by the green filled icons connected by the solid green line.
- Sample concentrations are represented by the yellow icons. Concentrations are reported in mg/l and represent the EMC for each sampled event.
- Sample flows indicate the mean discharge at the time of sampling reported as cfs. They are represented as hollow green icons connected by green dashed line. Sample flows are most often higher than the mean daily discharge since most ponds had little to no baseflow.



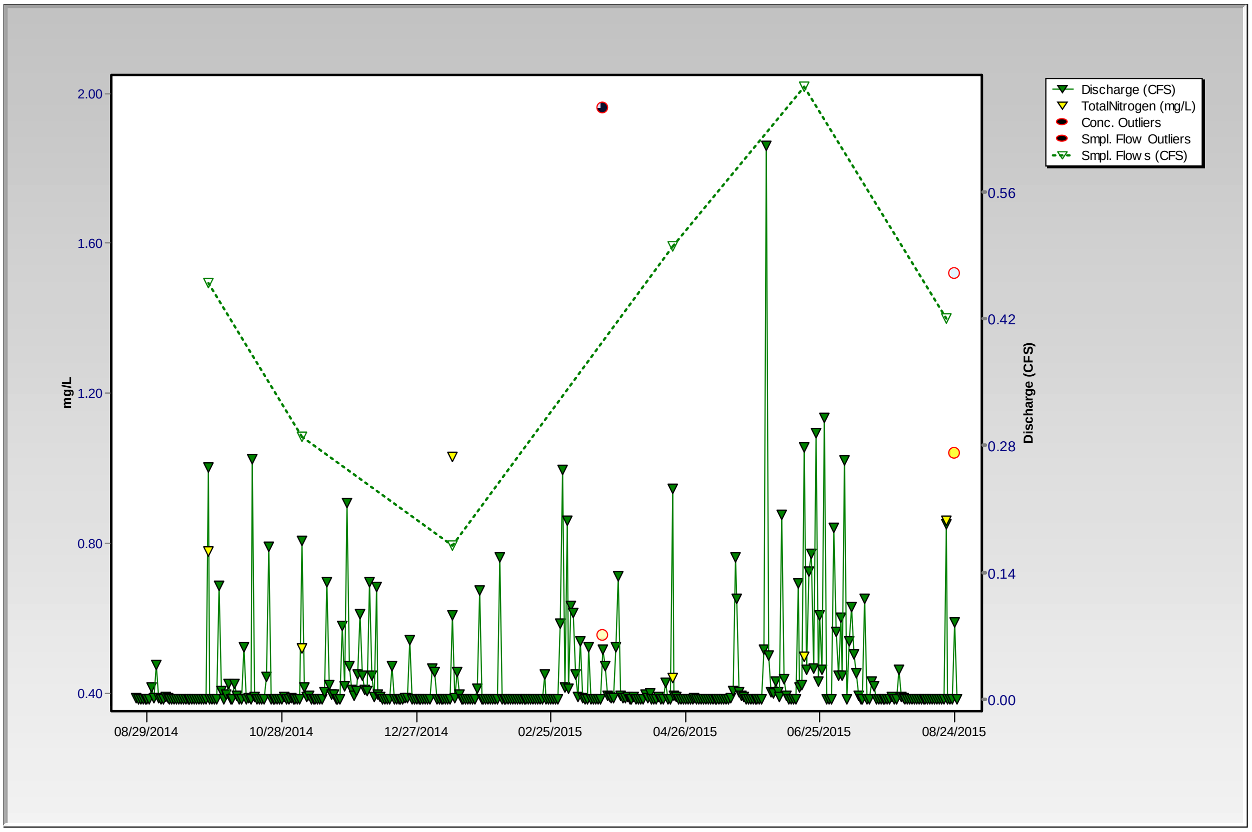


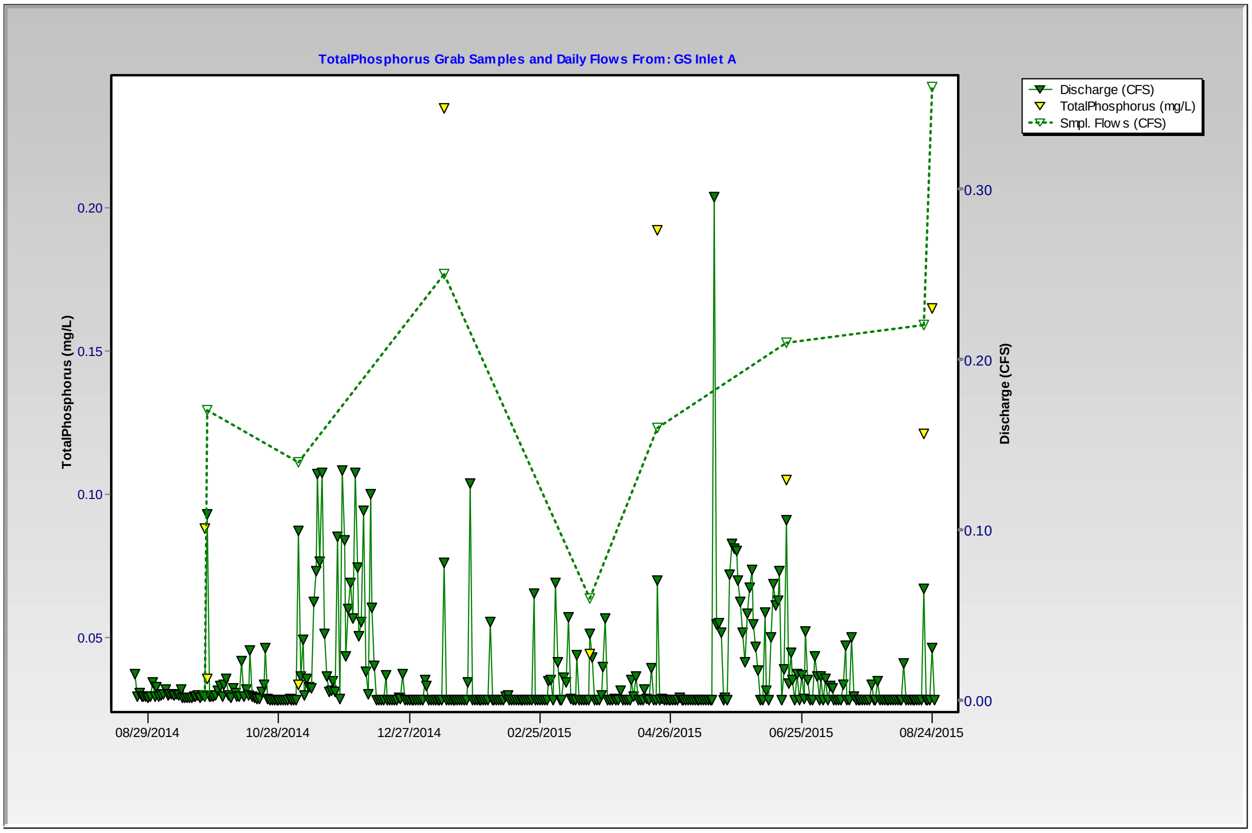
Glyndon Square – FLUX32 Average Daily Discharge





Glyndon Square – FLUX32 Average Daily Discharge





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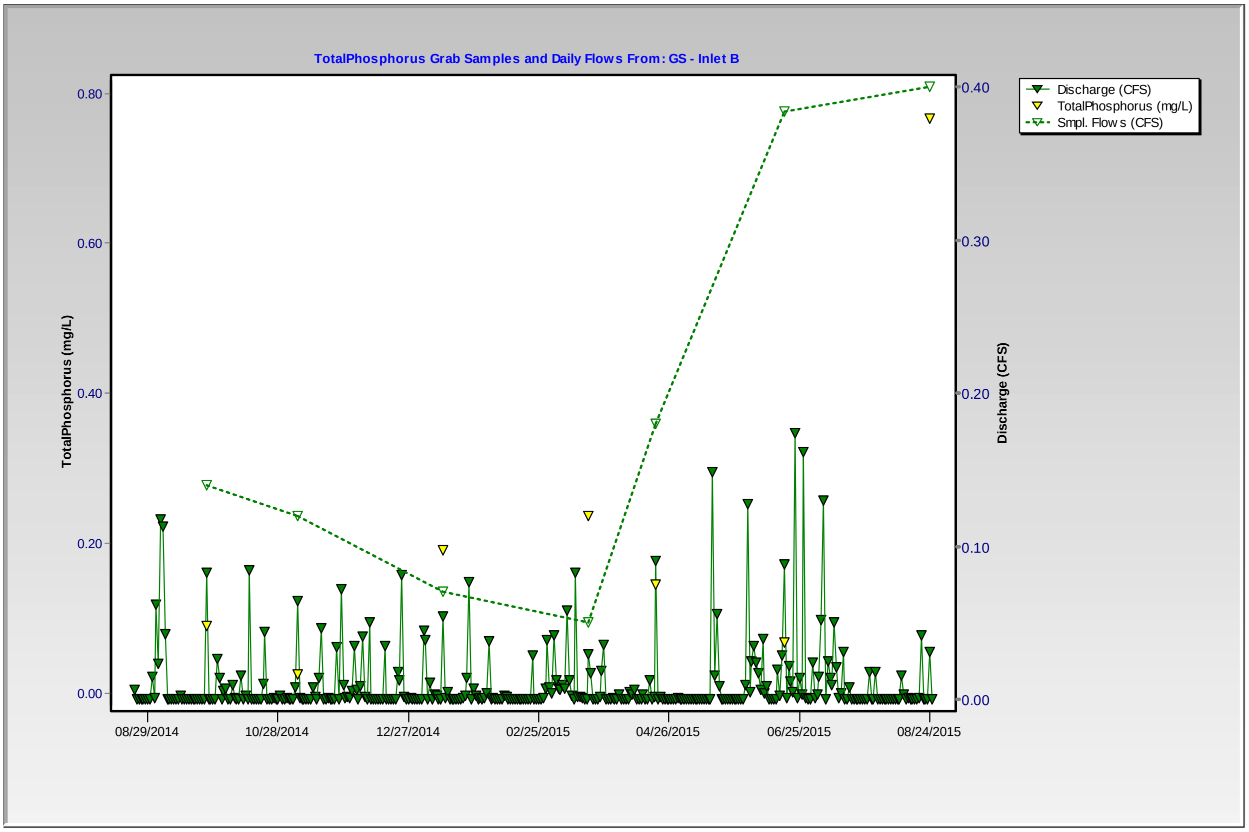

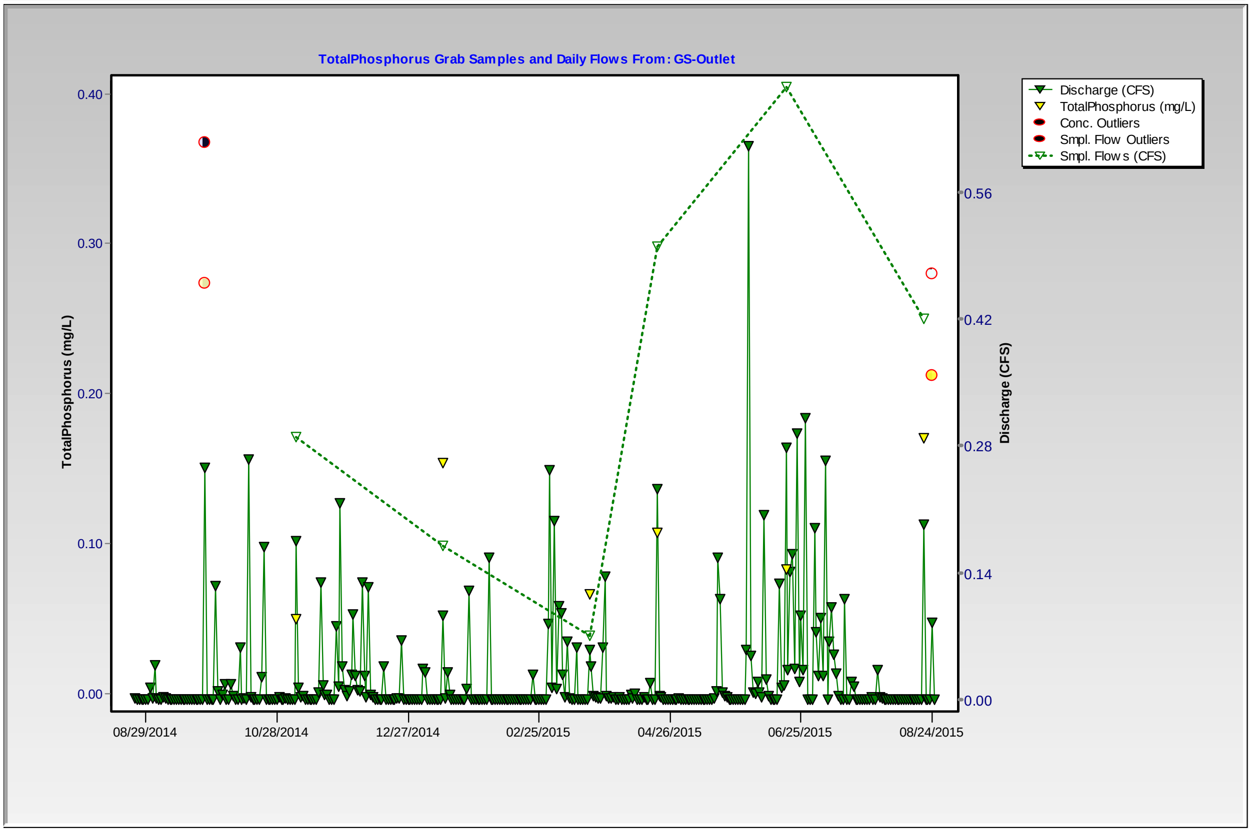

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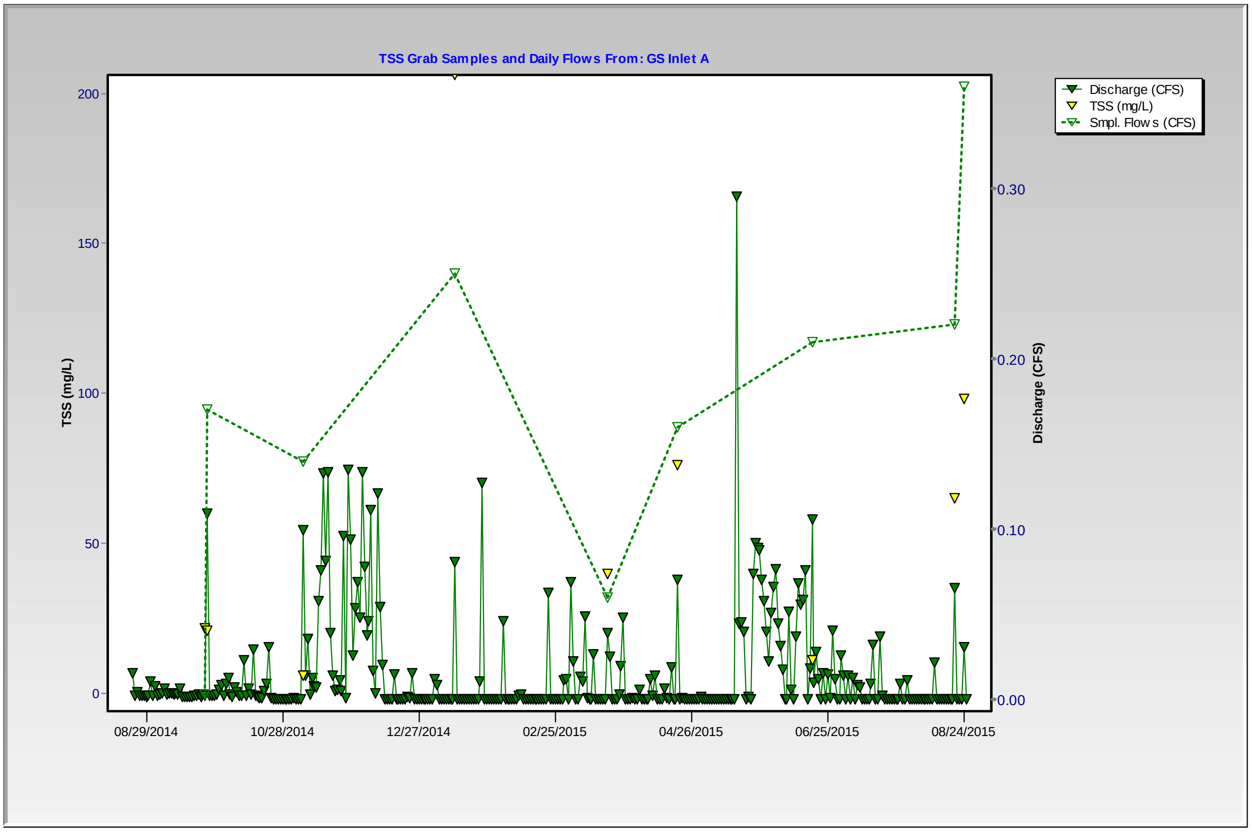
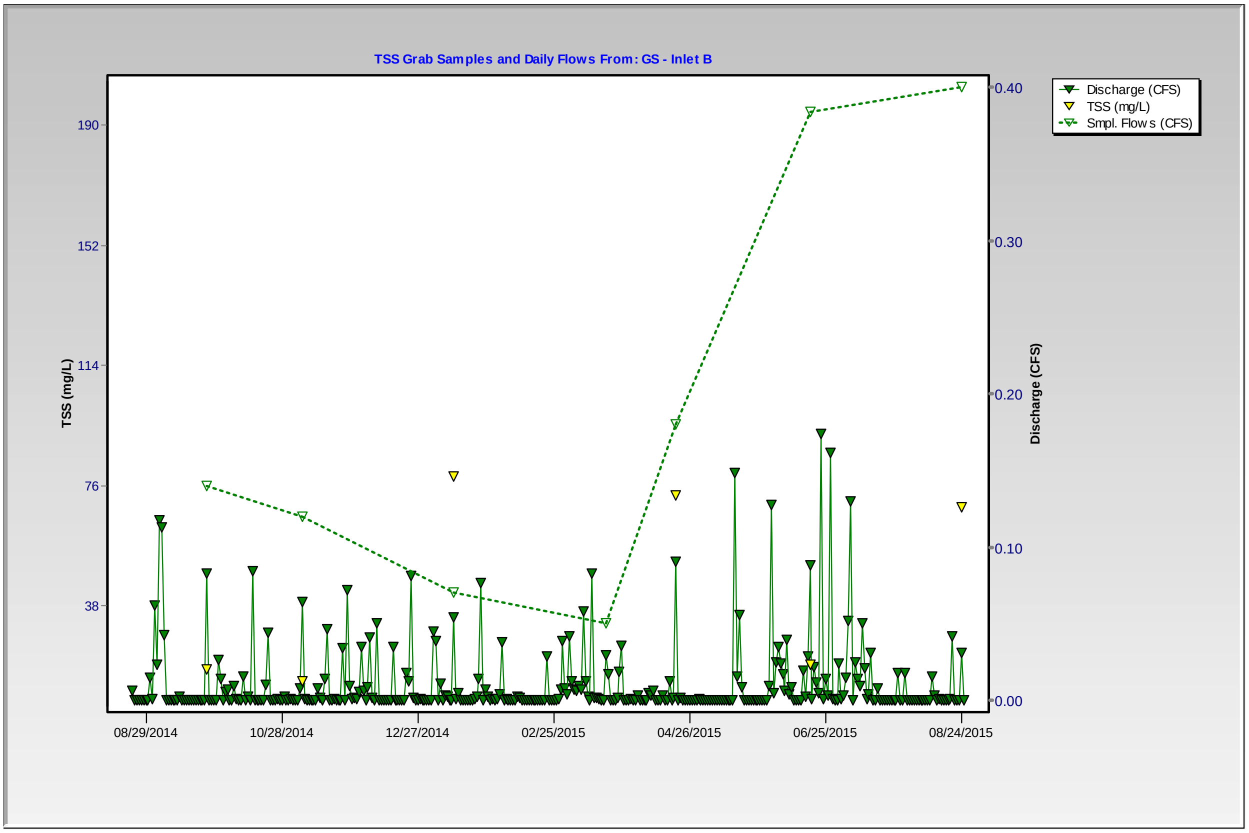
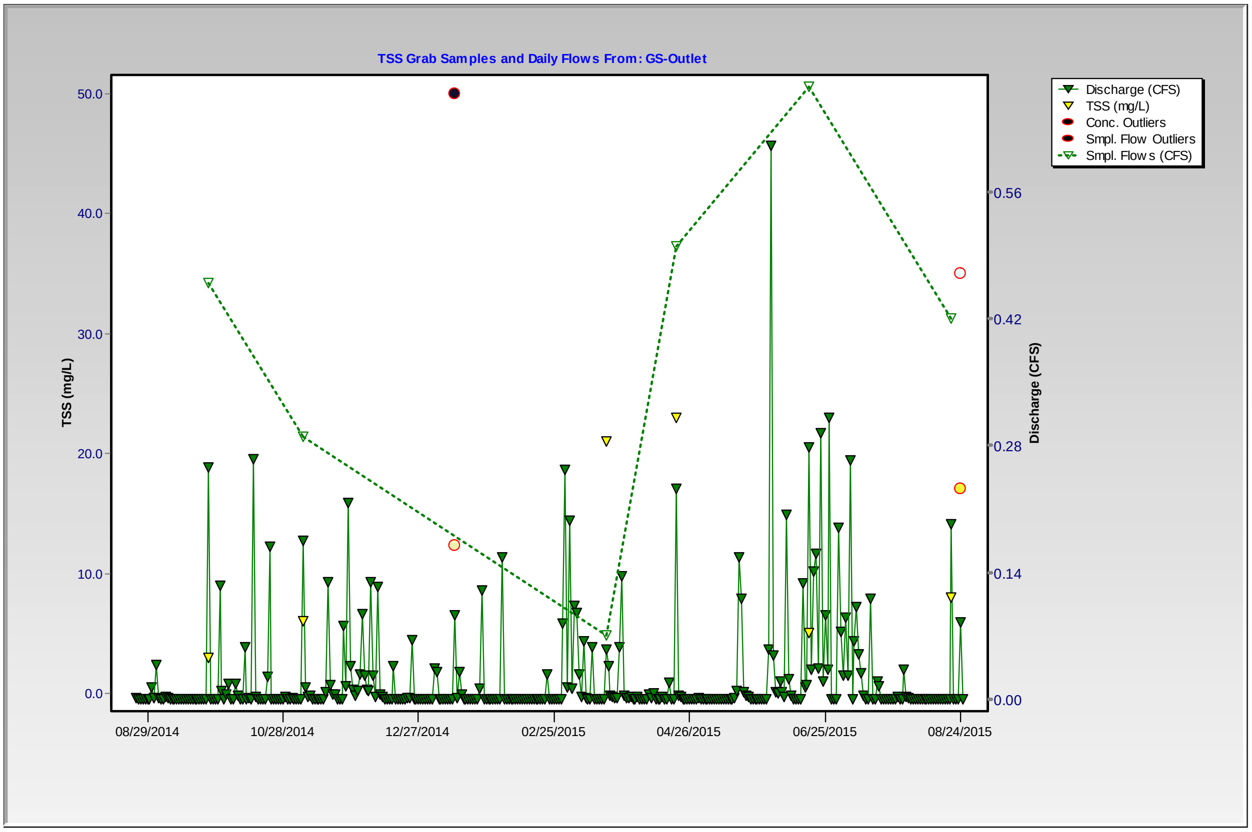
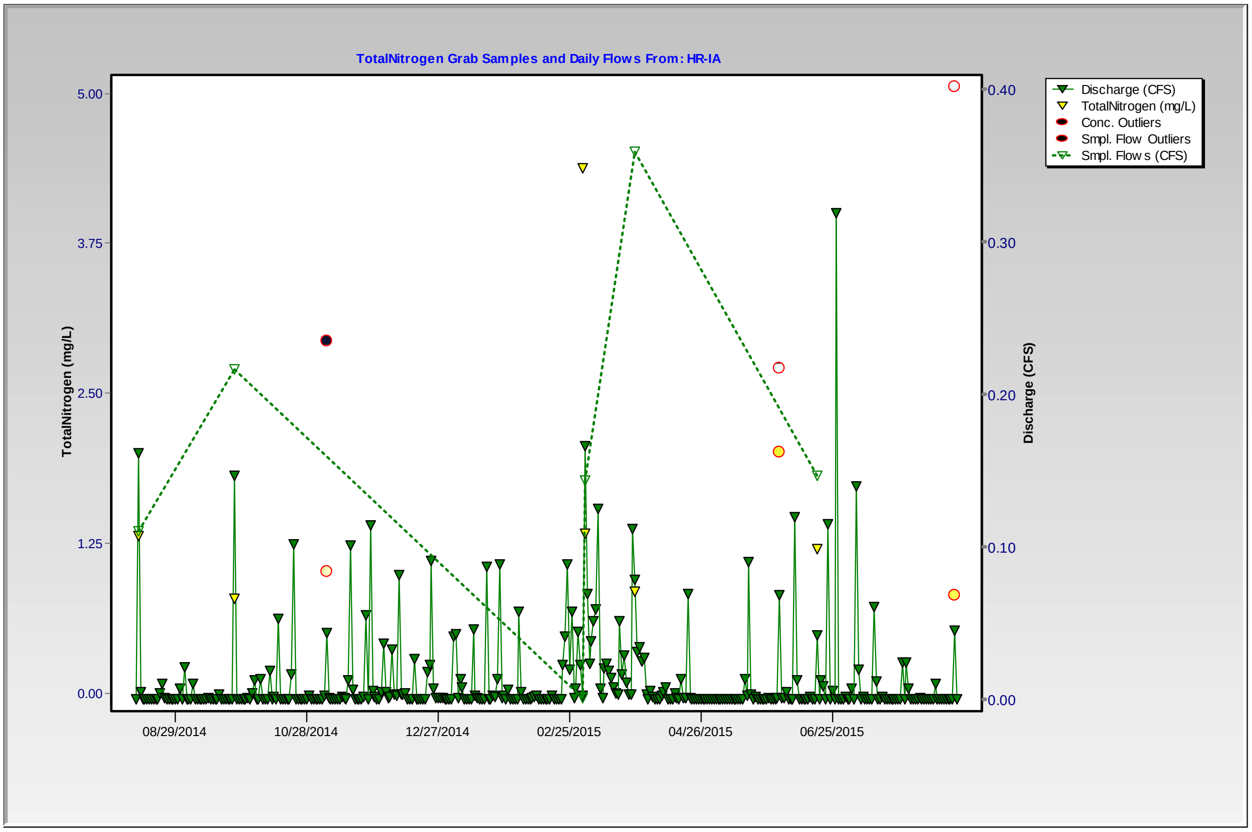


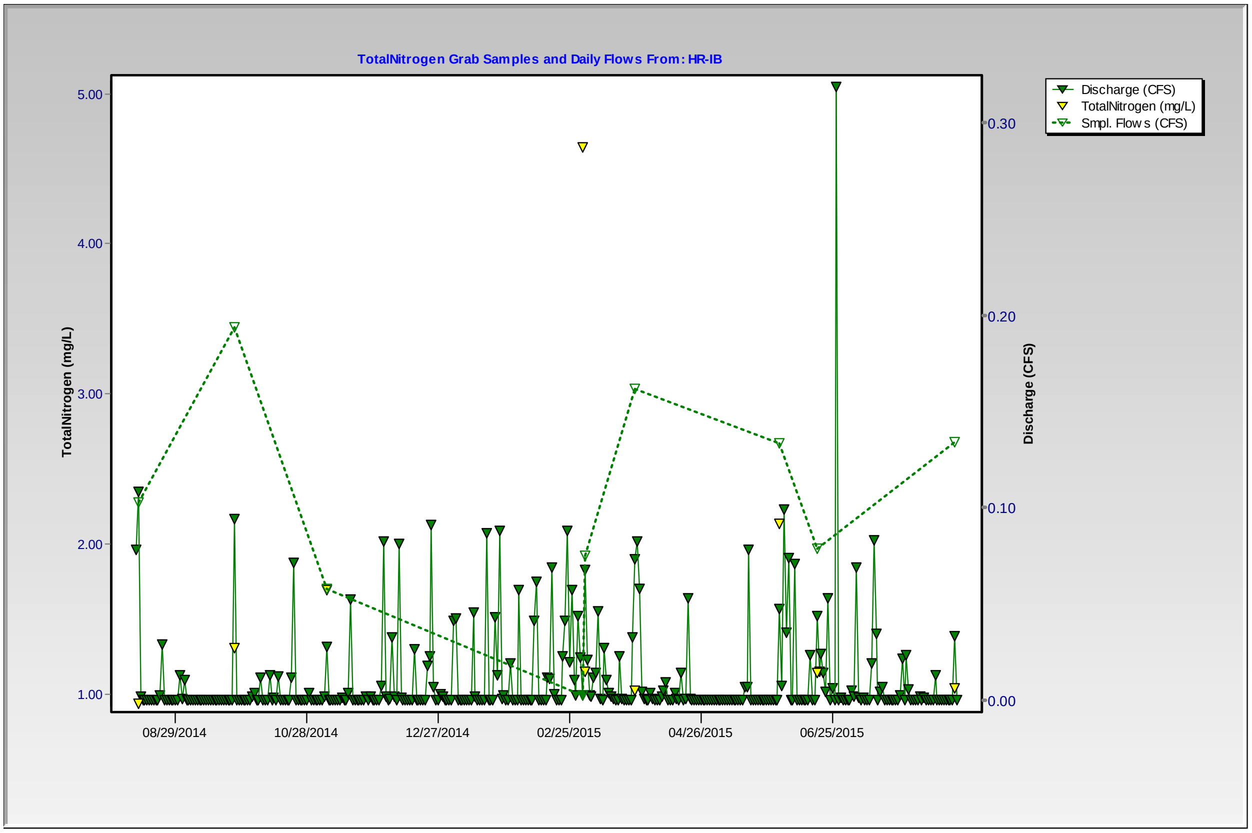


Glyndon Square – FLUX32 Average Daily Discharge



Hunt Ridge – FLUX32 Average Daily Discharge





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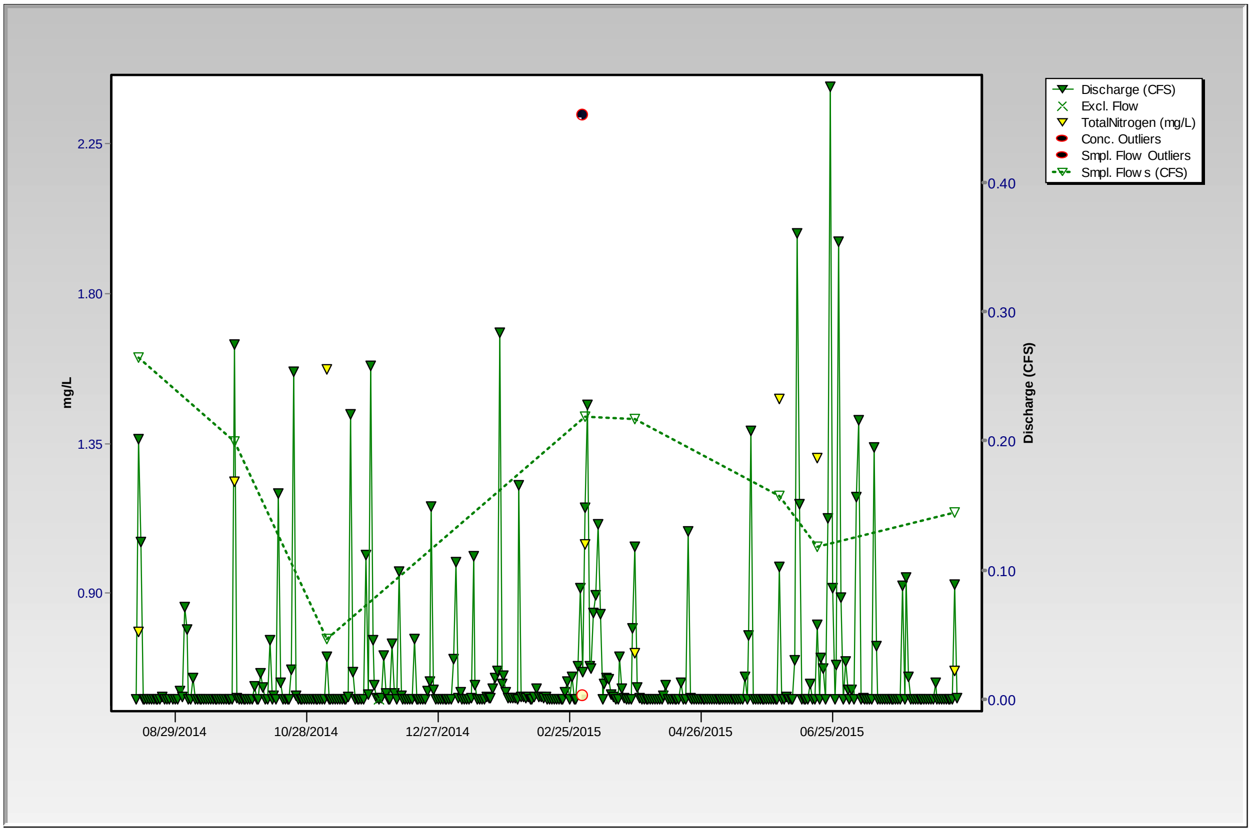

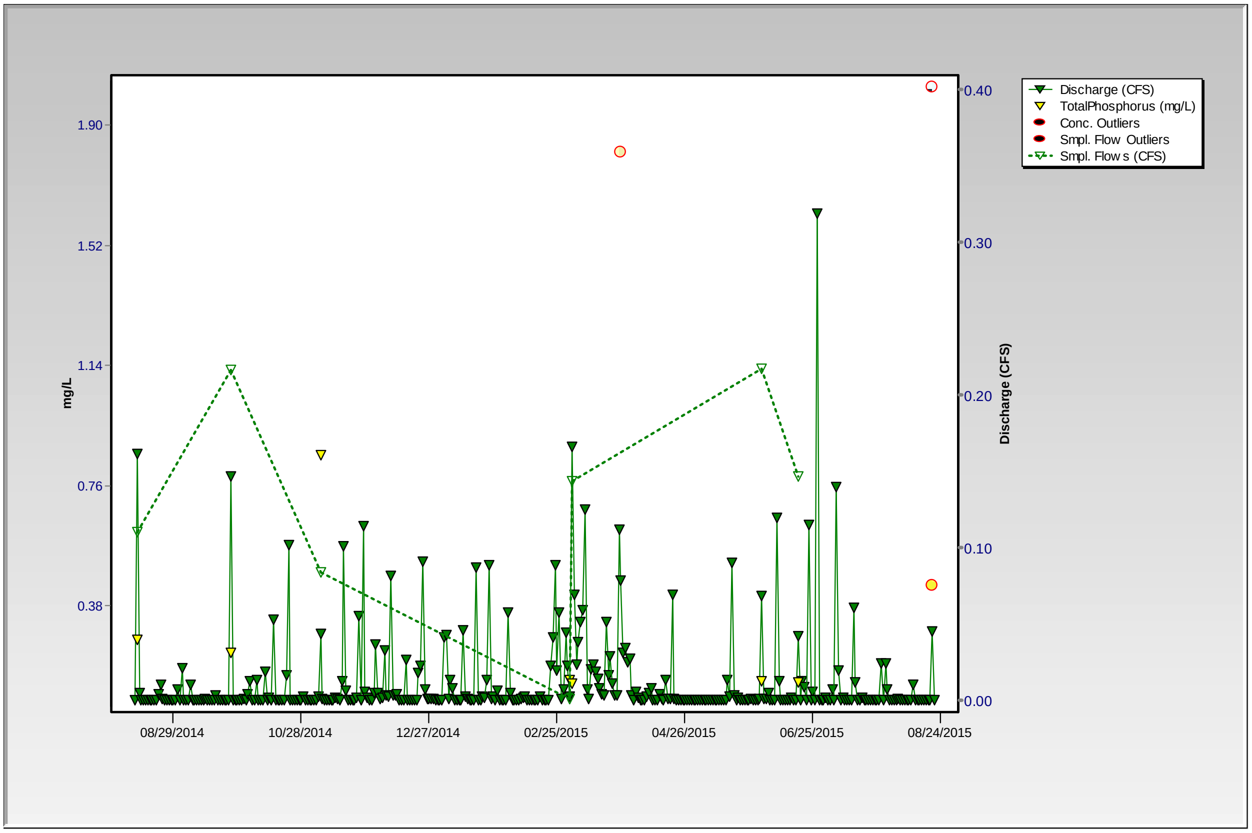

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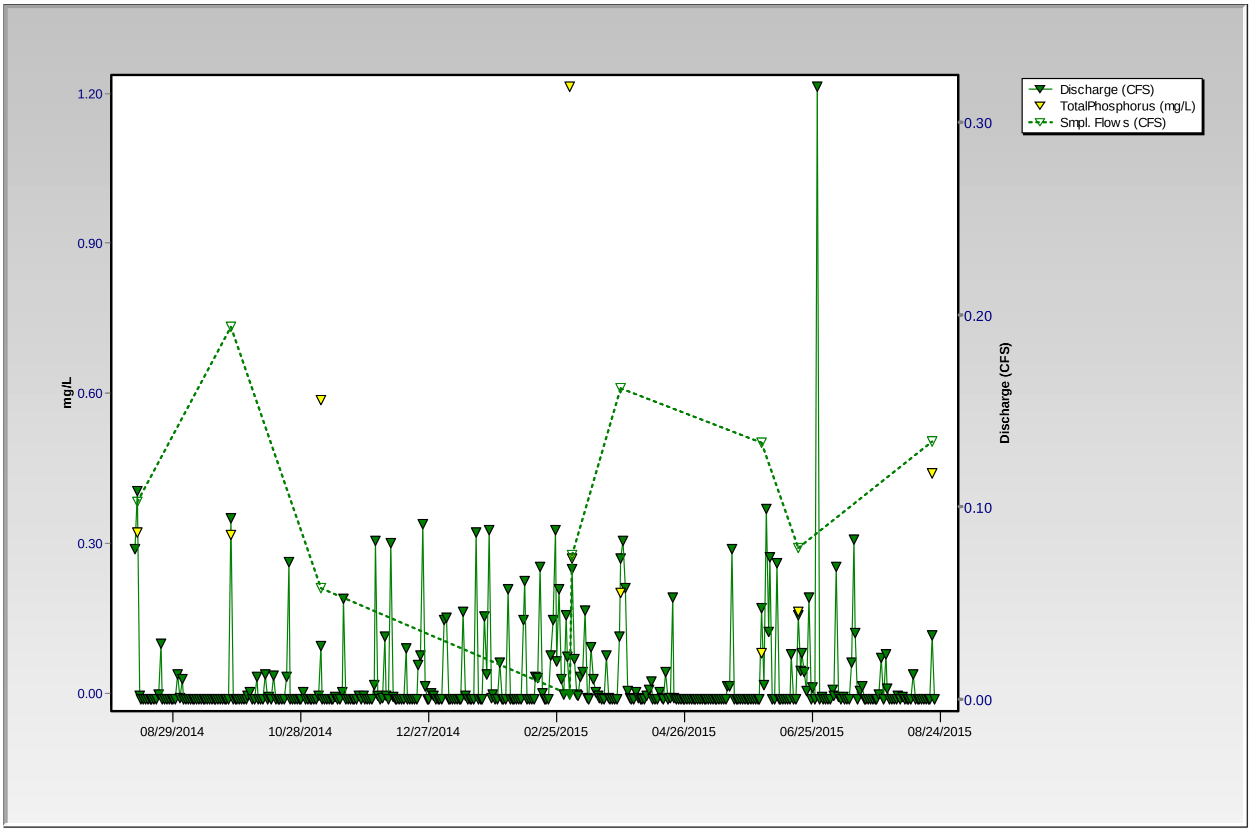

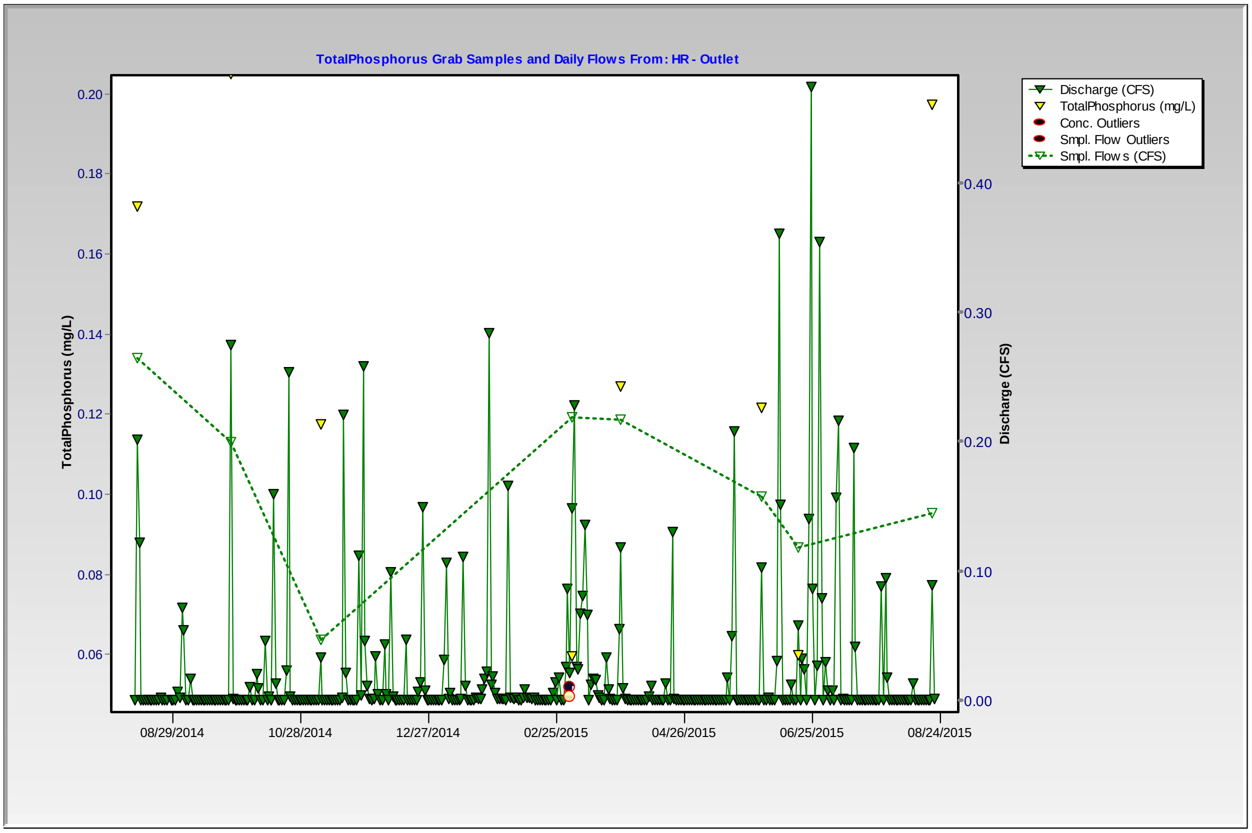

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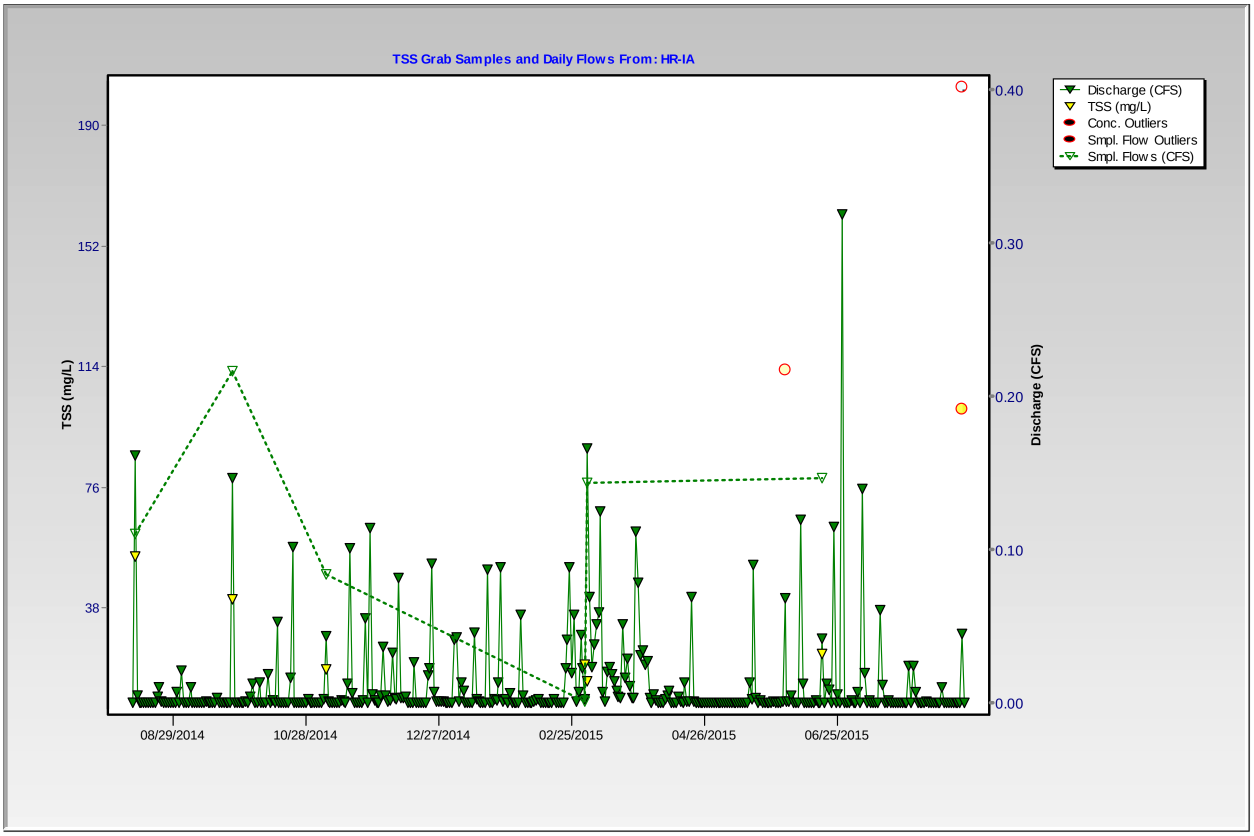

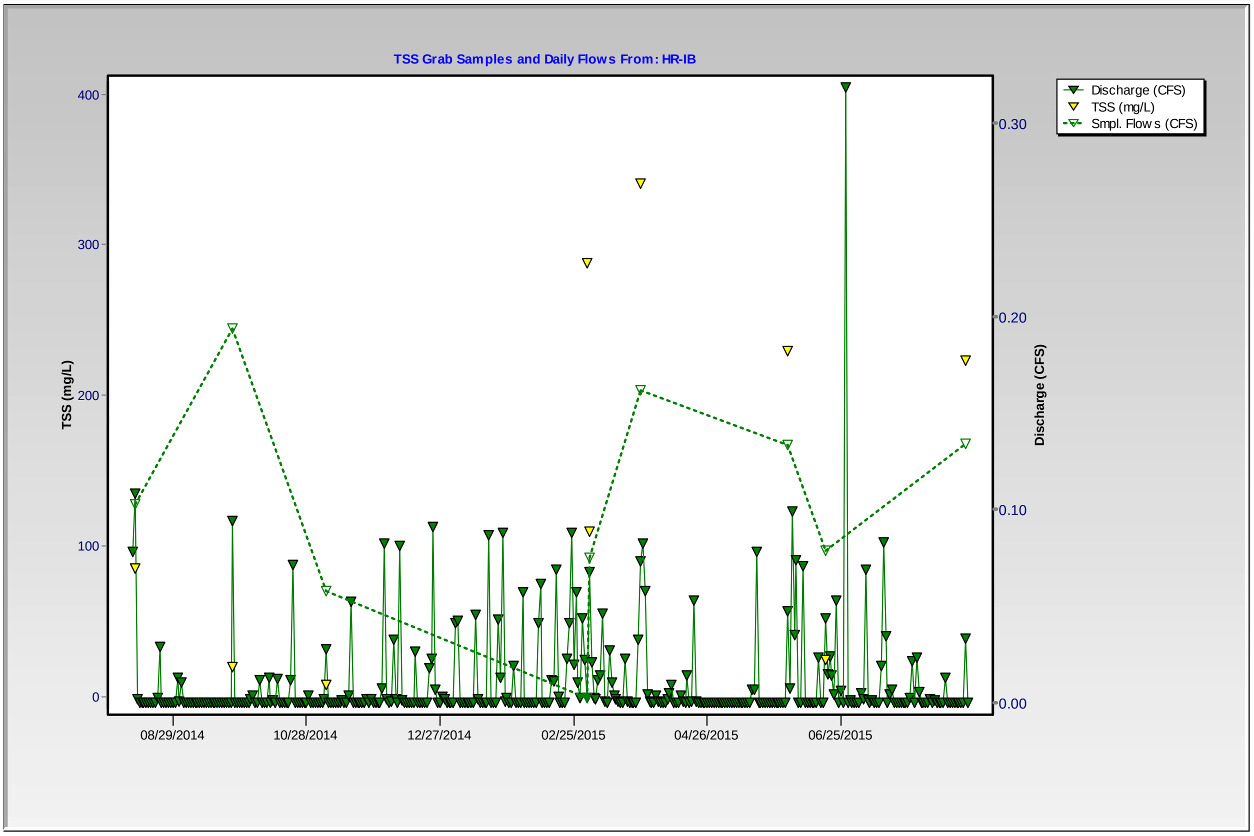

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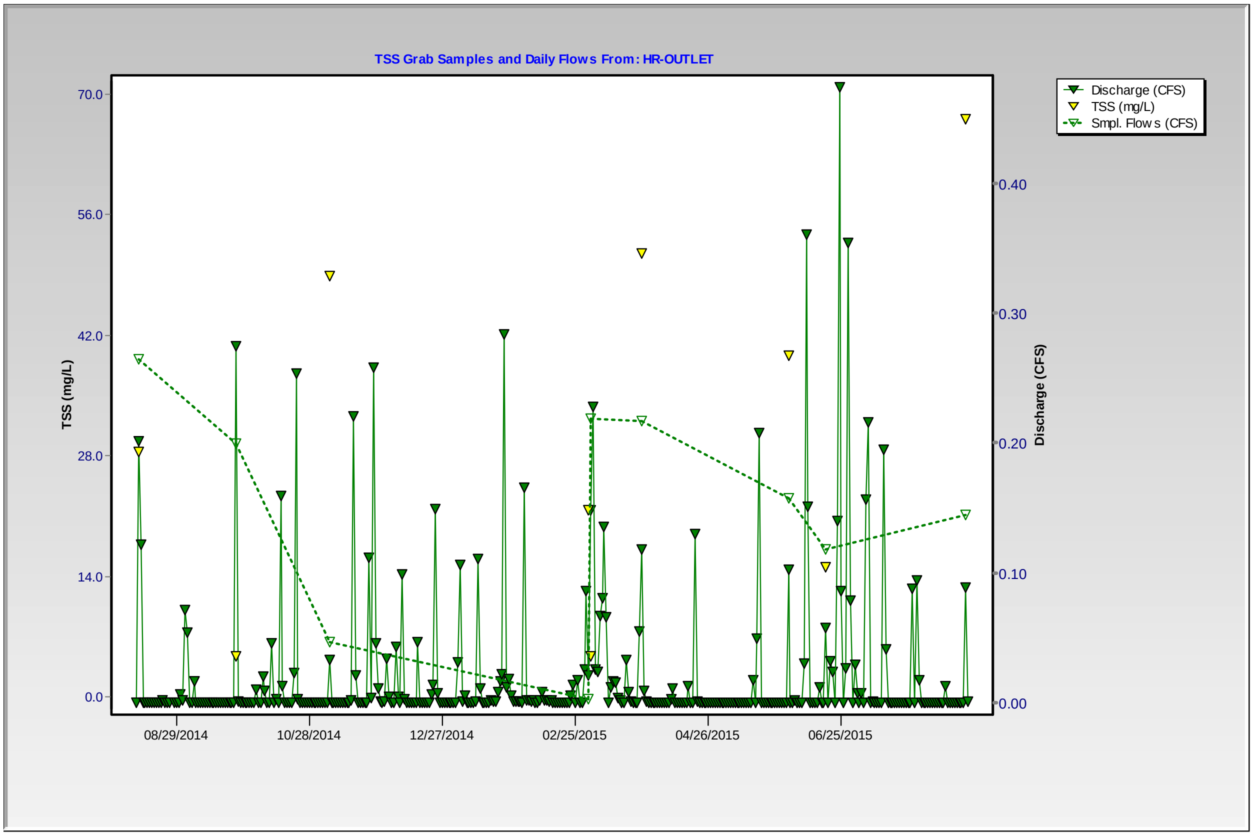
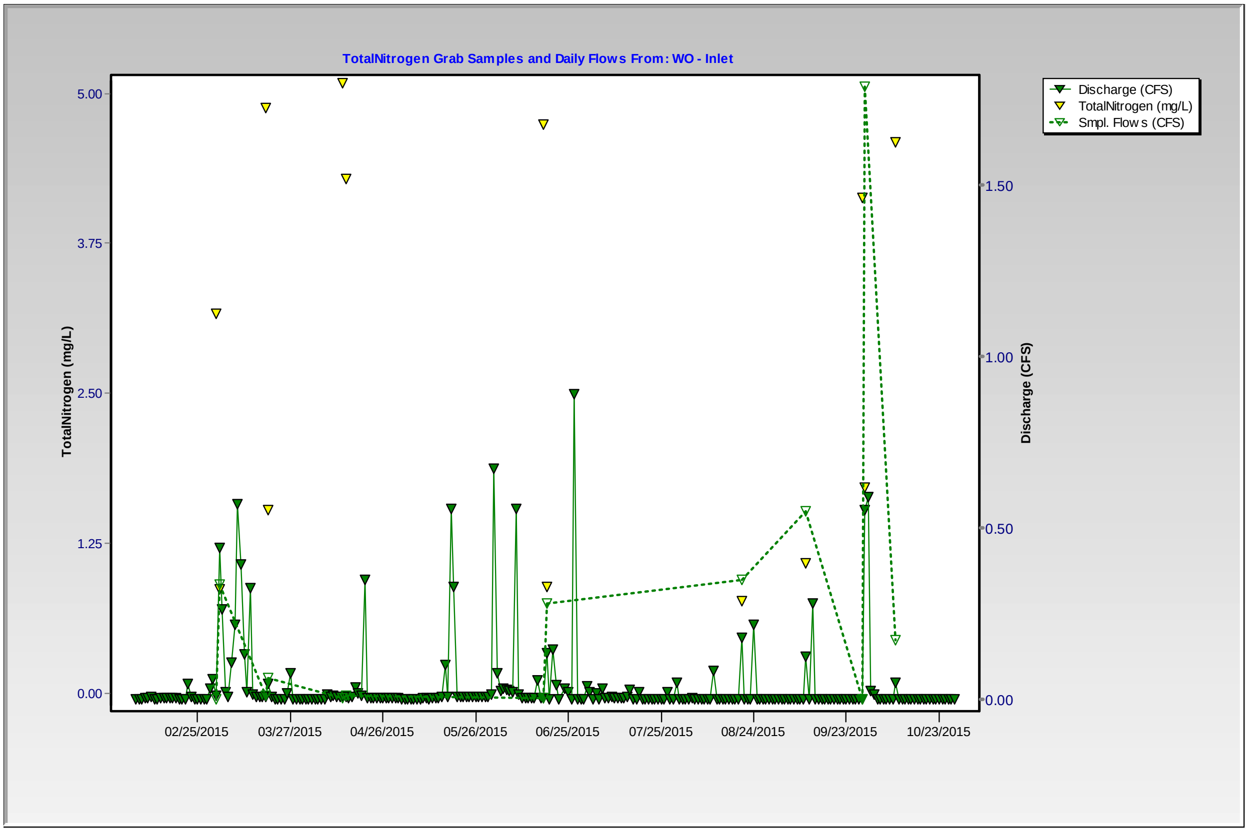
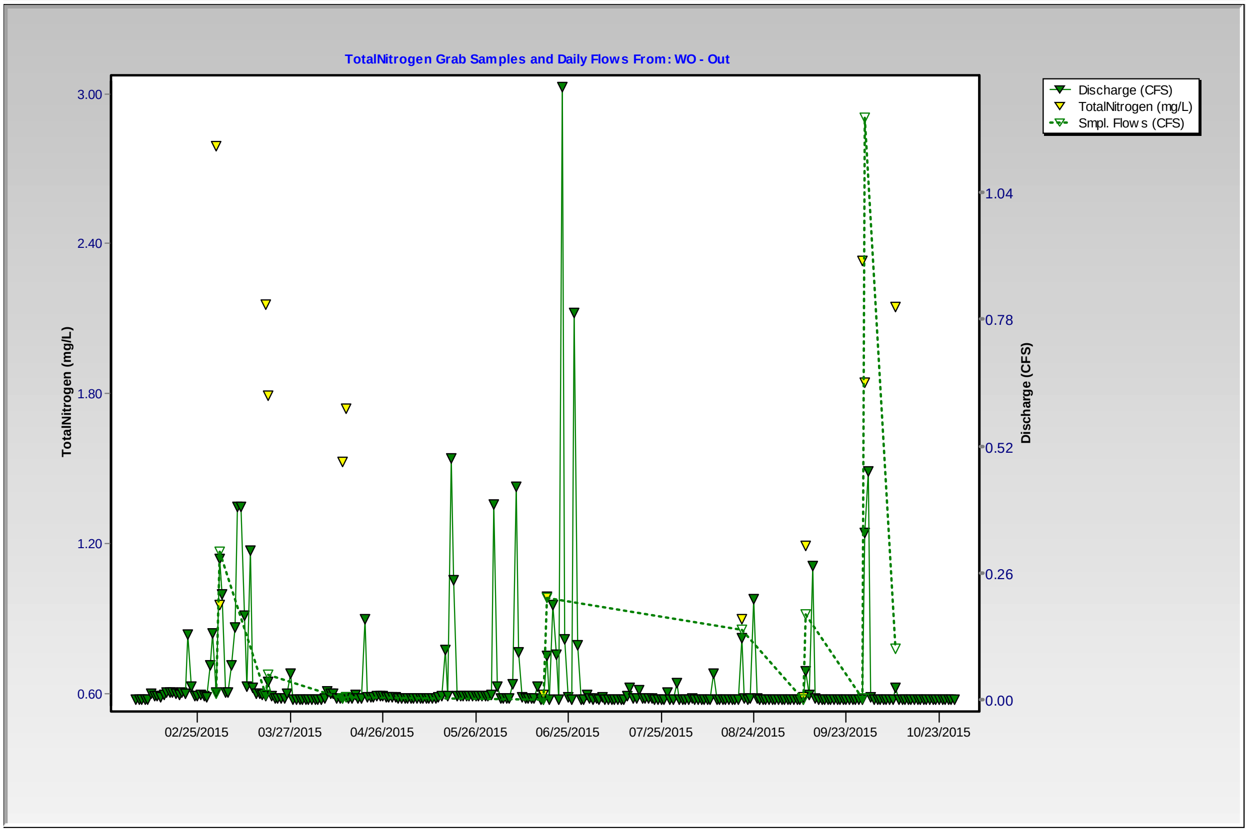


Worthington – FLUX32 Average Daily Discharge





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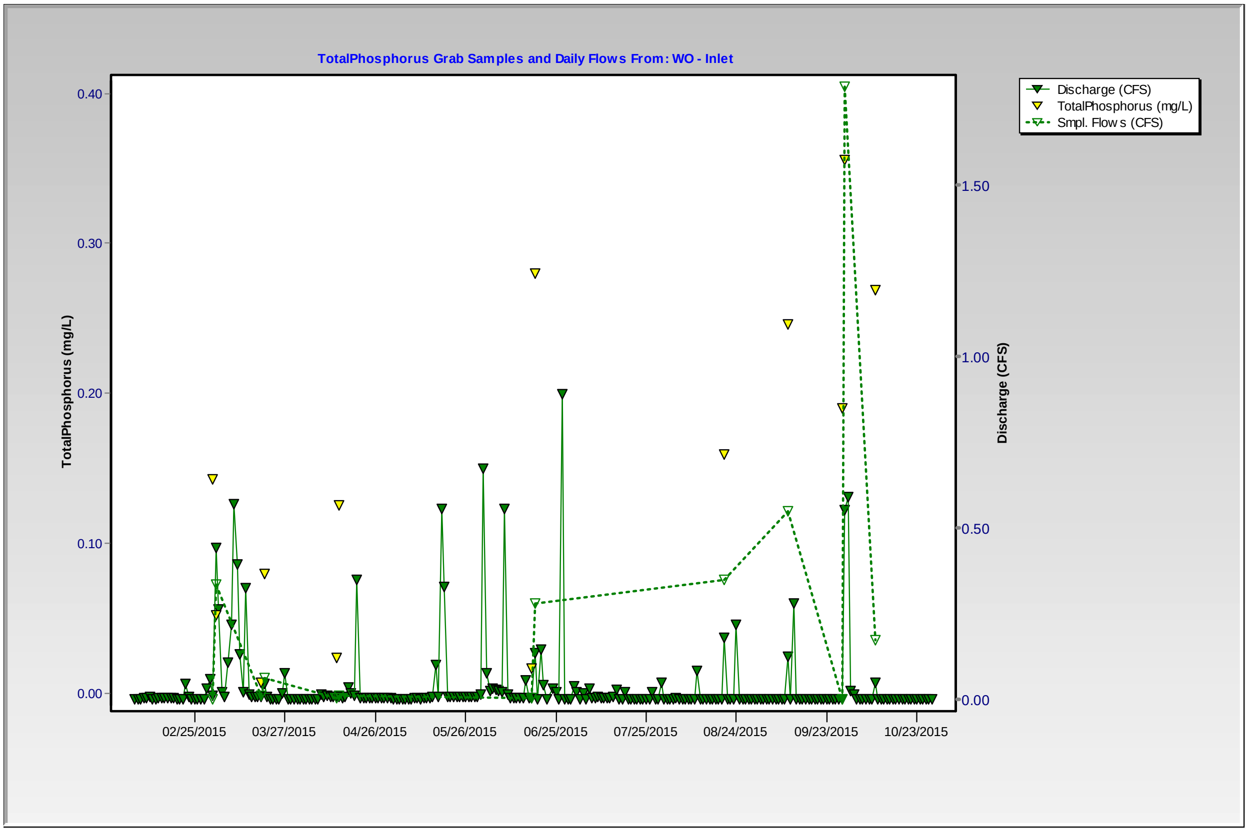

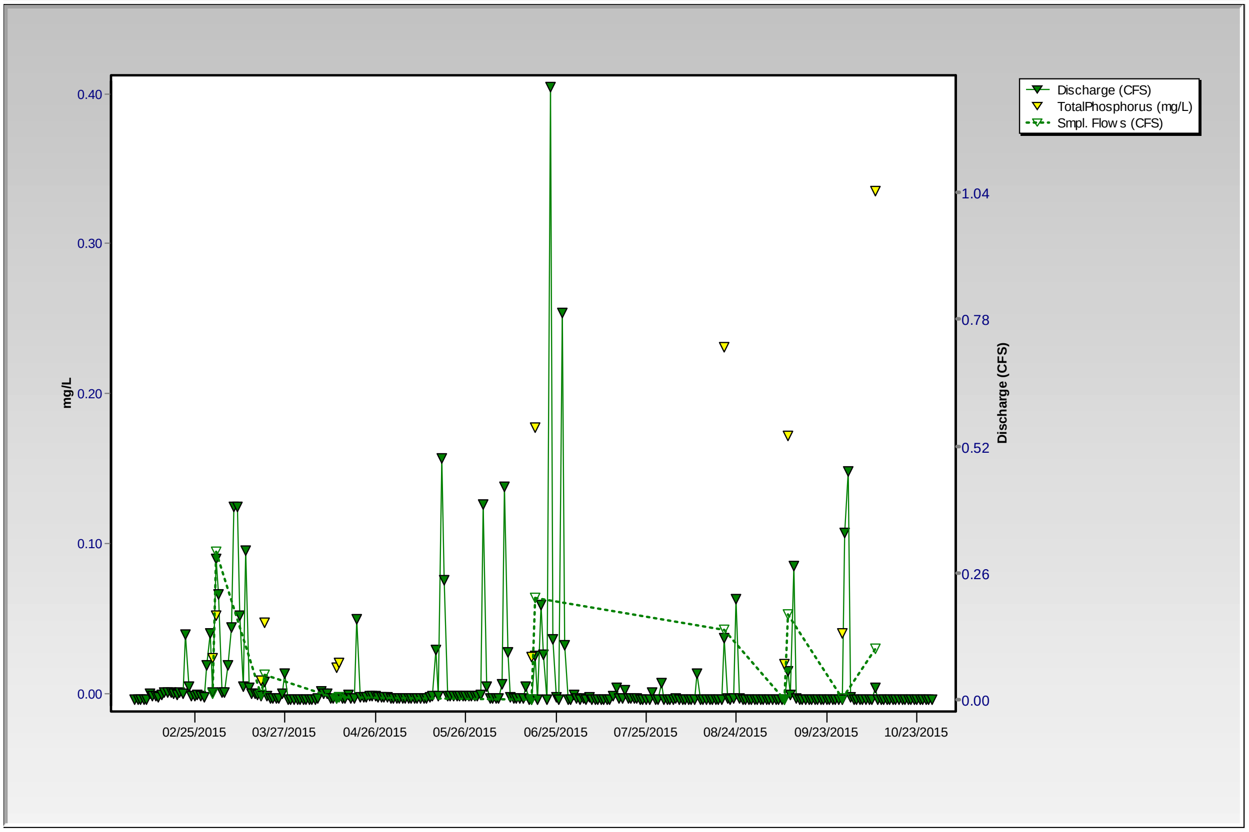

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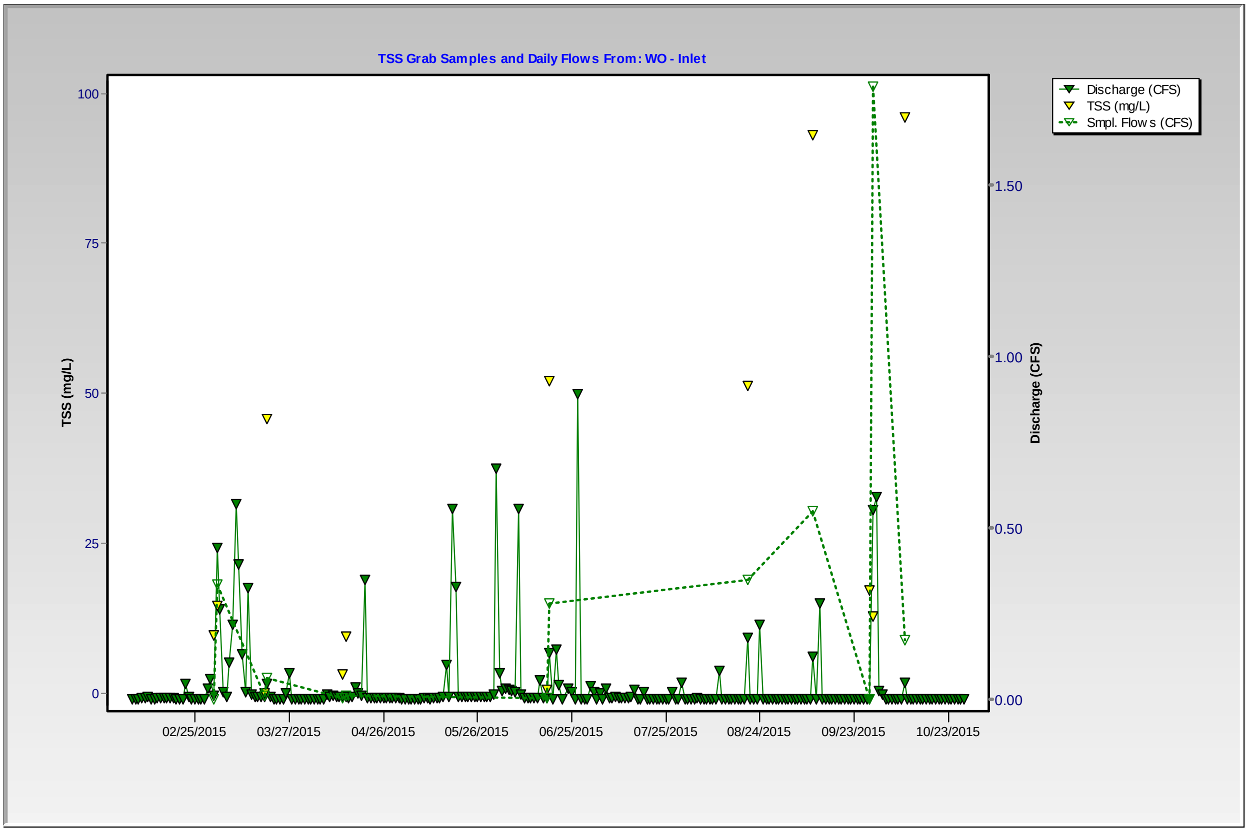
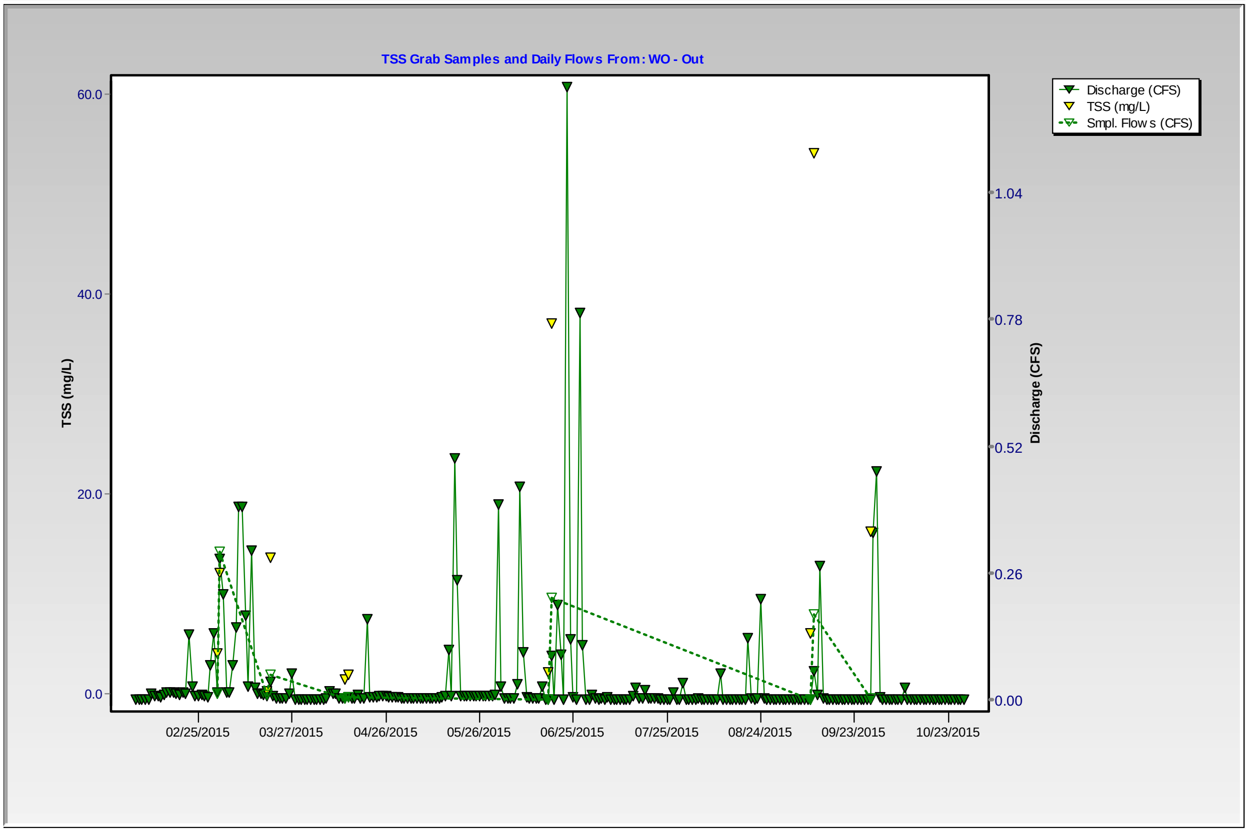
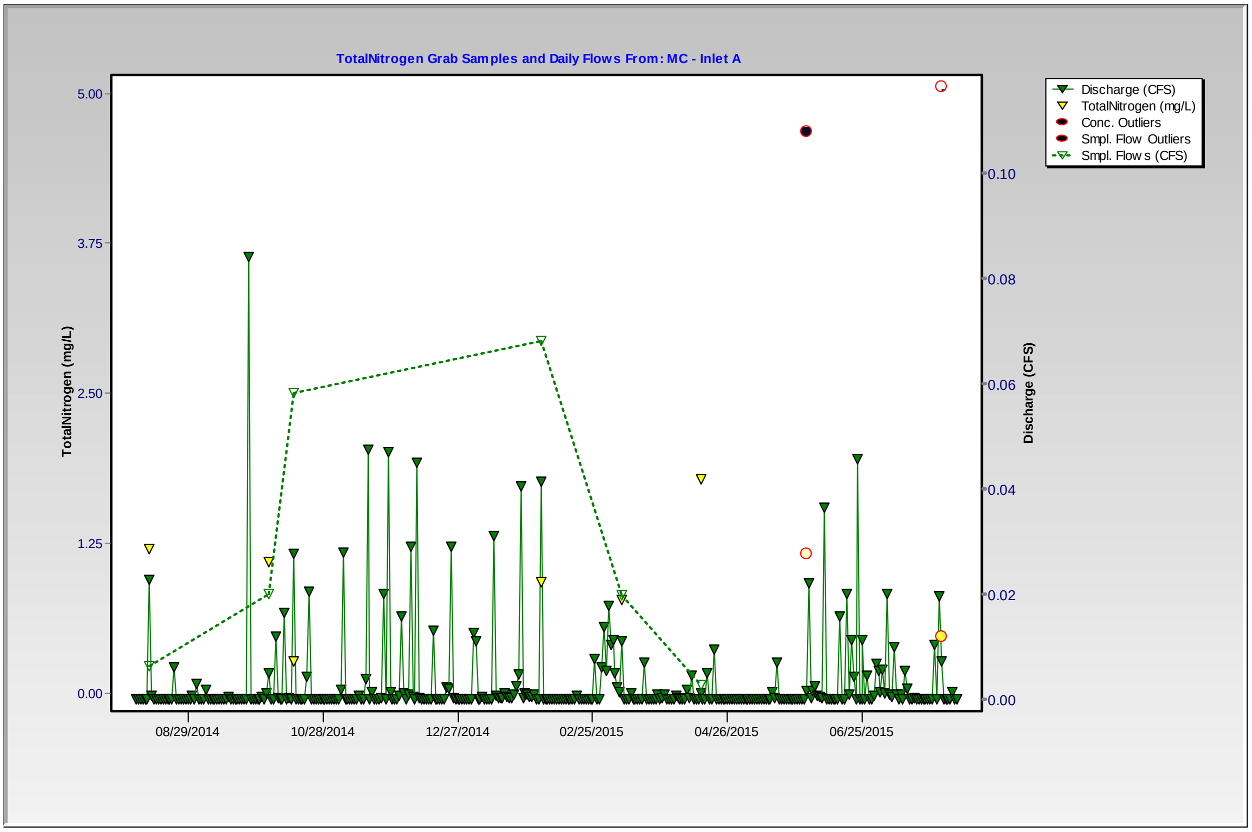
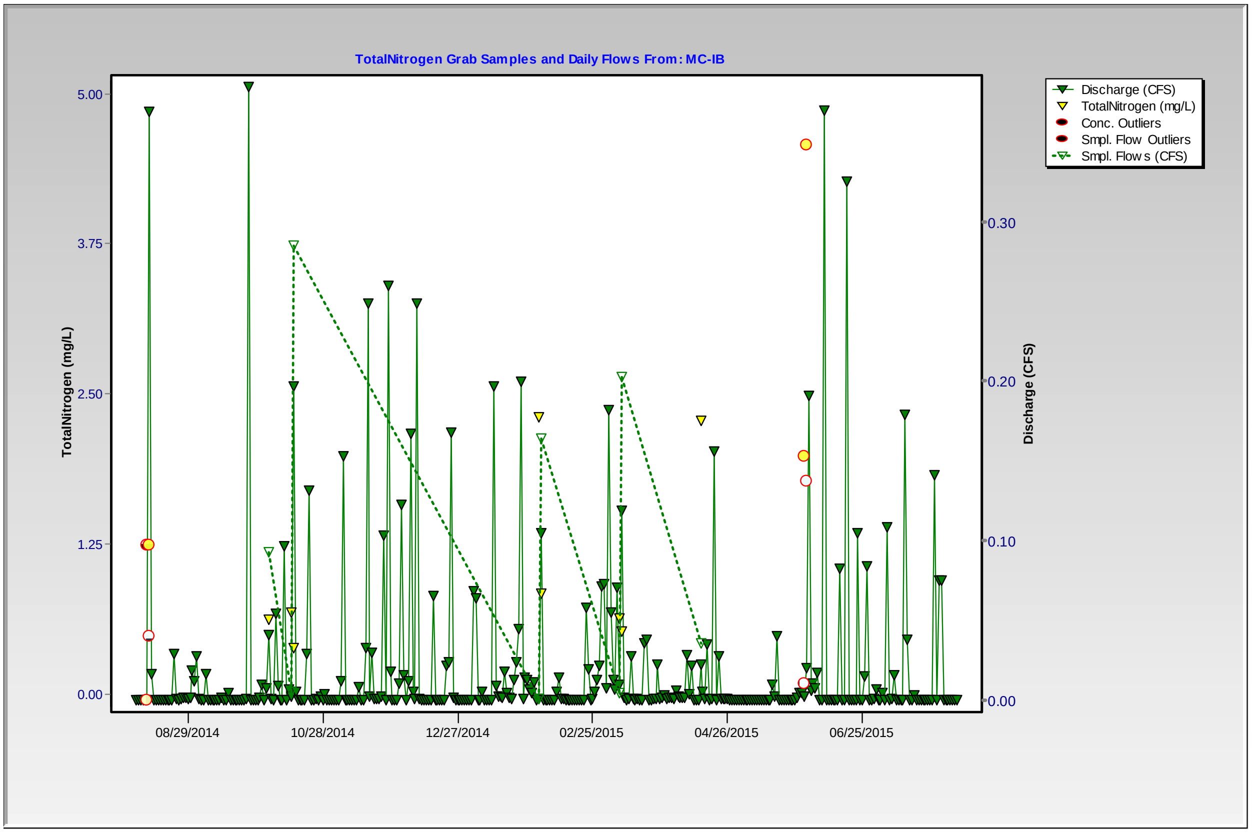


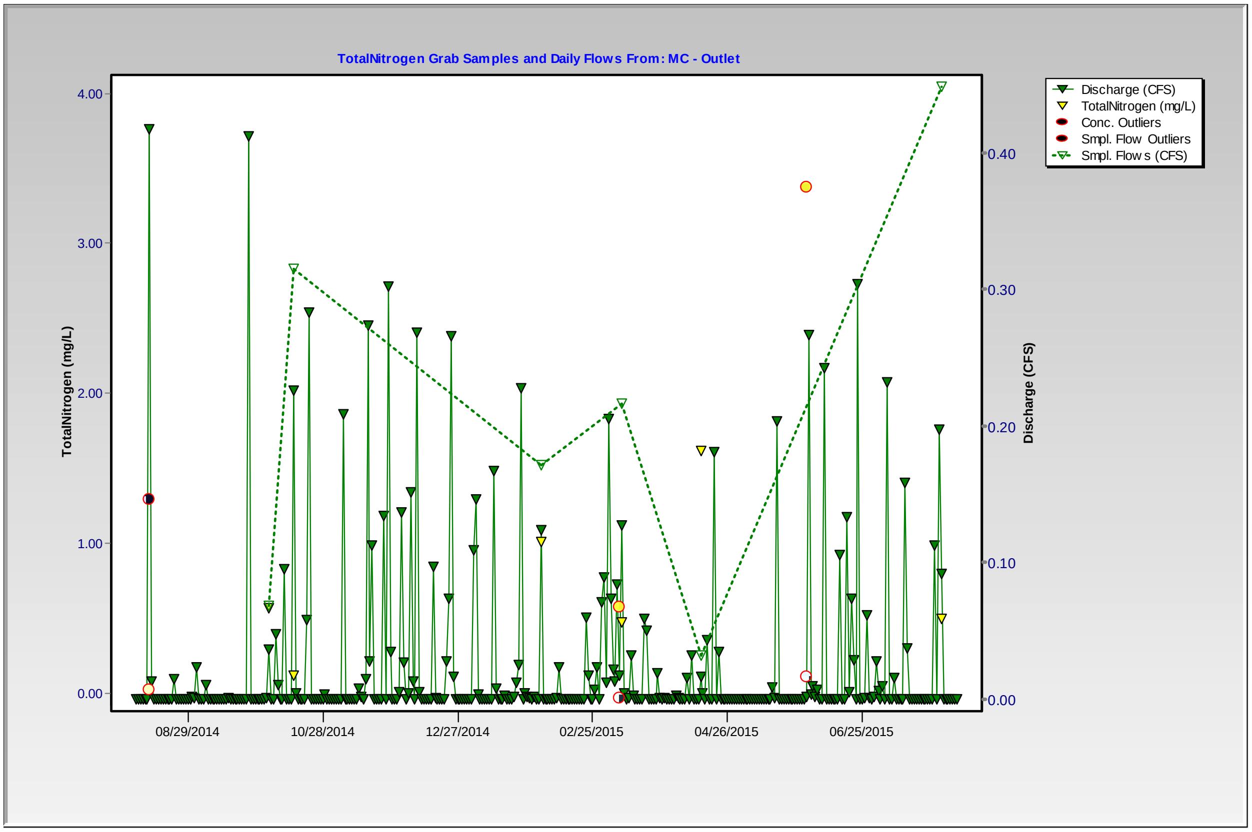


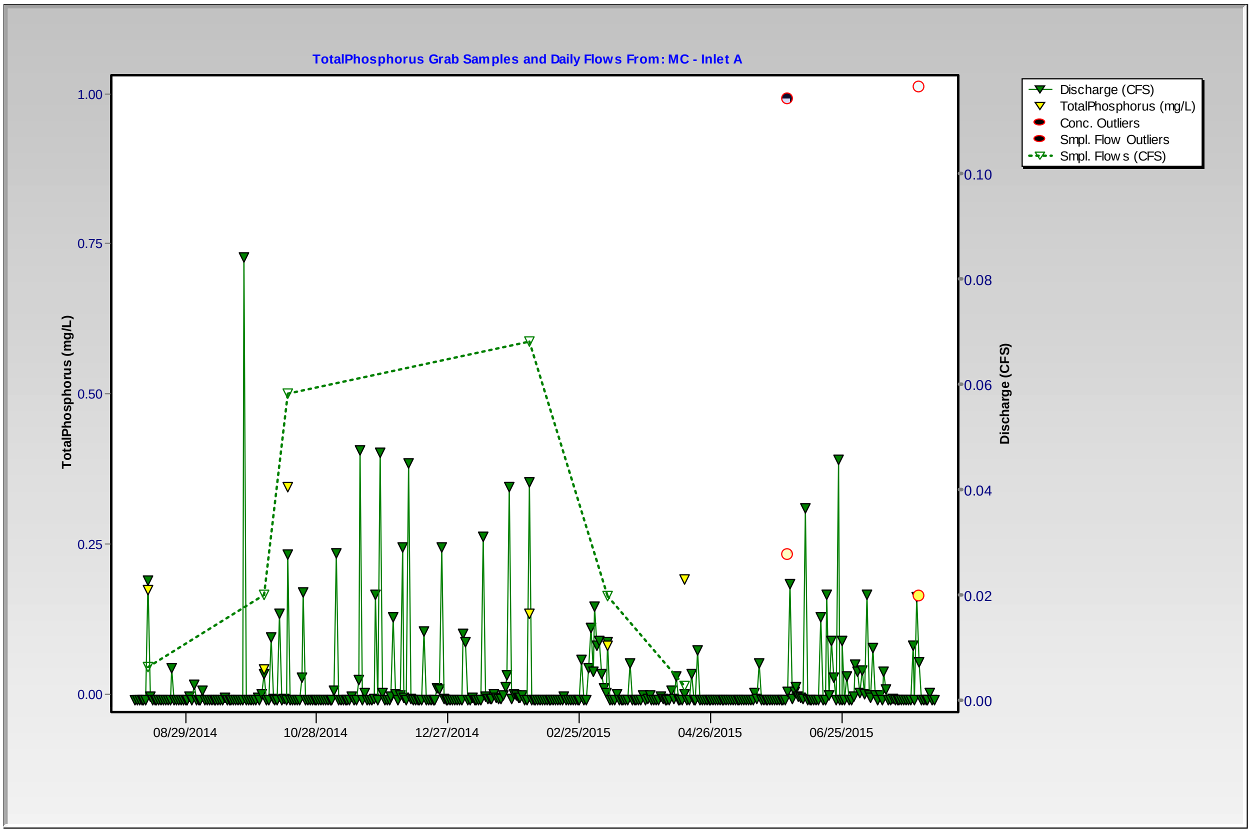
McCormick – FLUX32 Average Daily Discharge





McCormick – FLUX32 Average Daily Discharge





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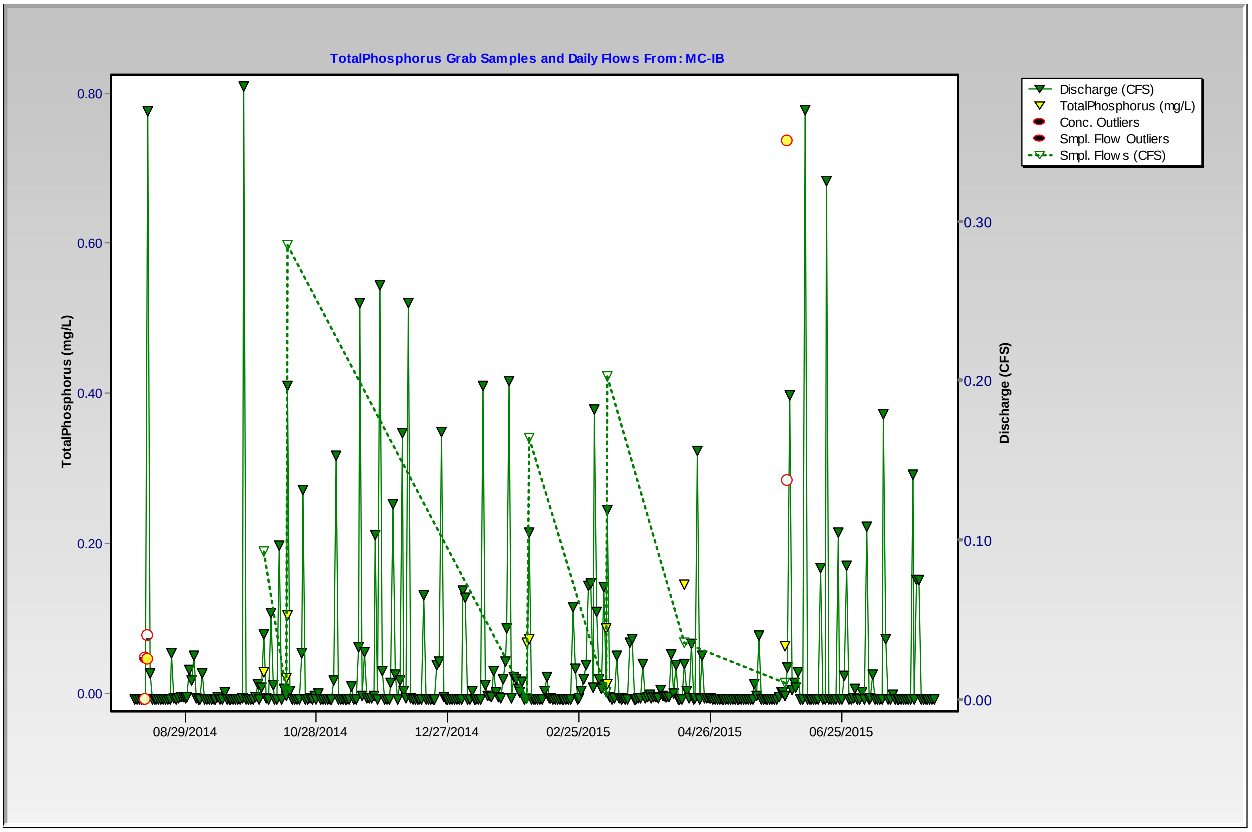

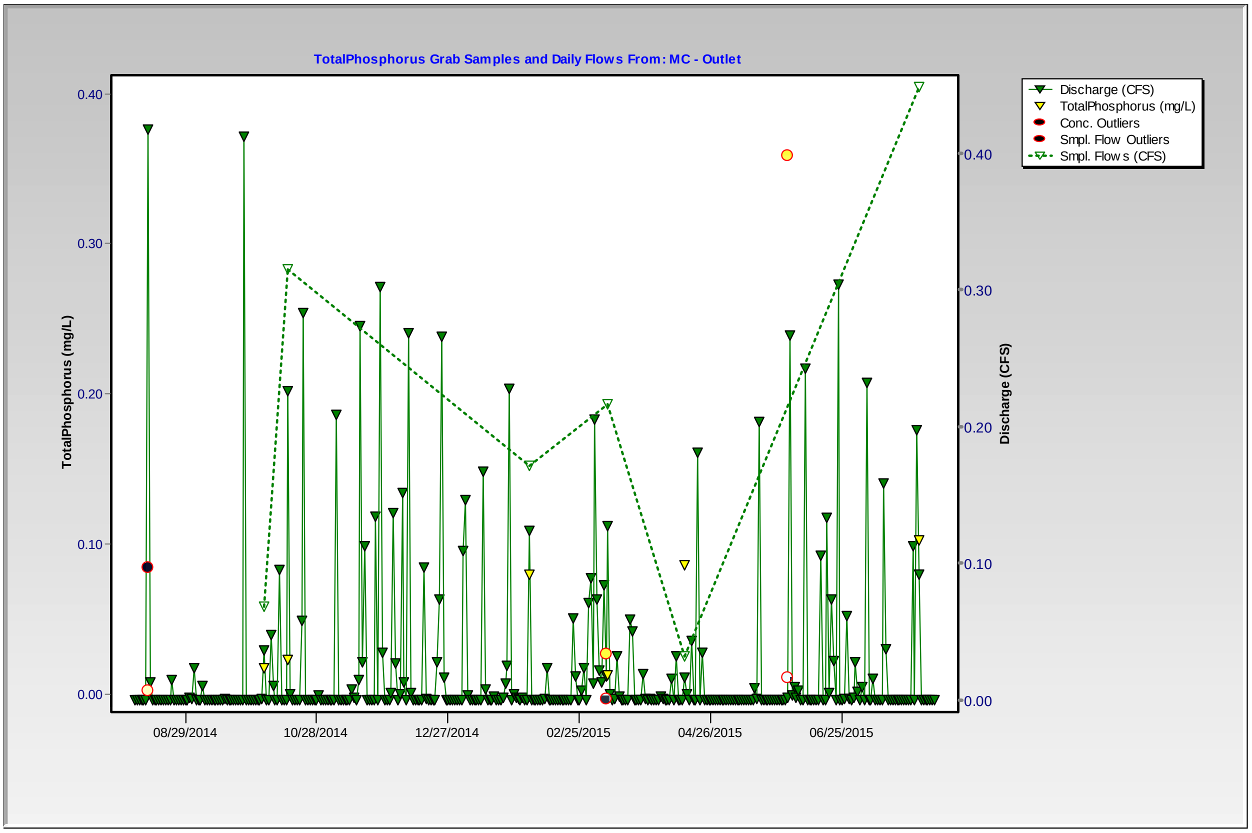

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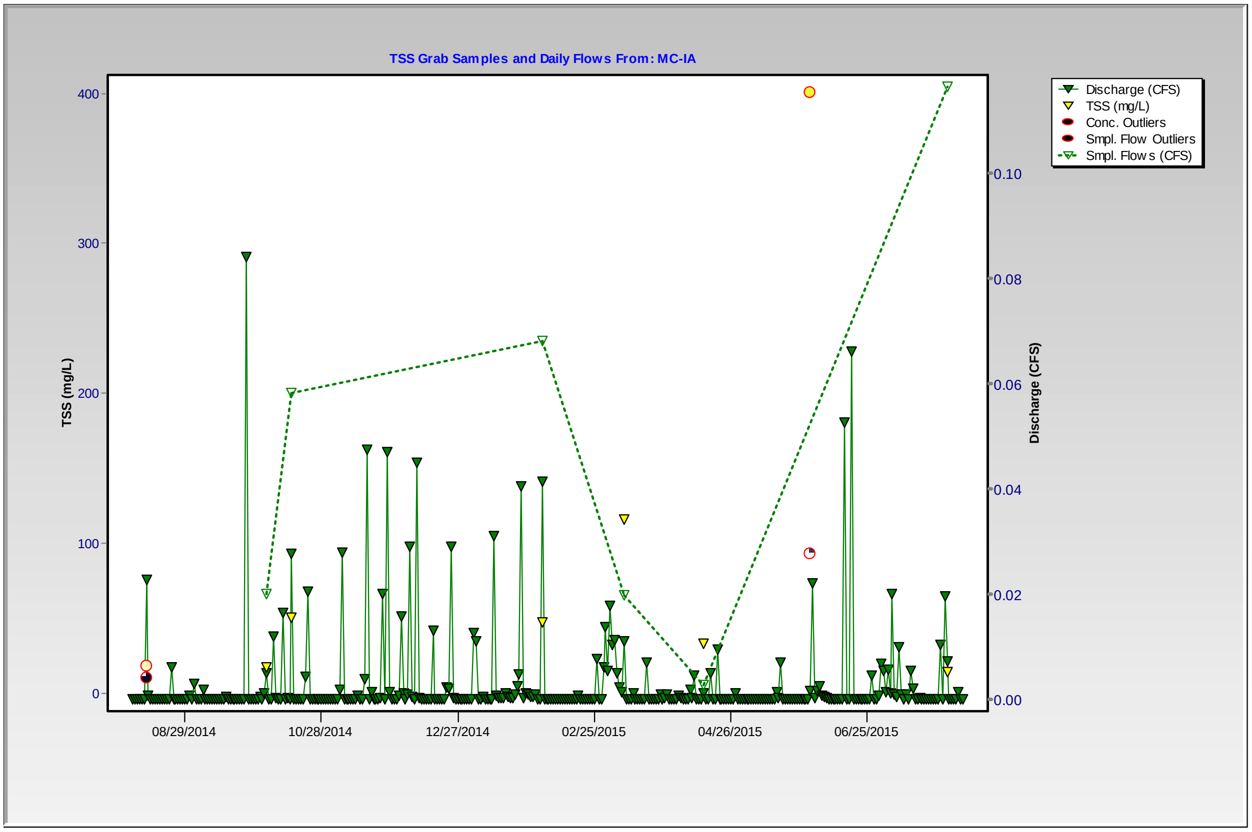
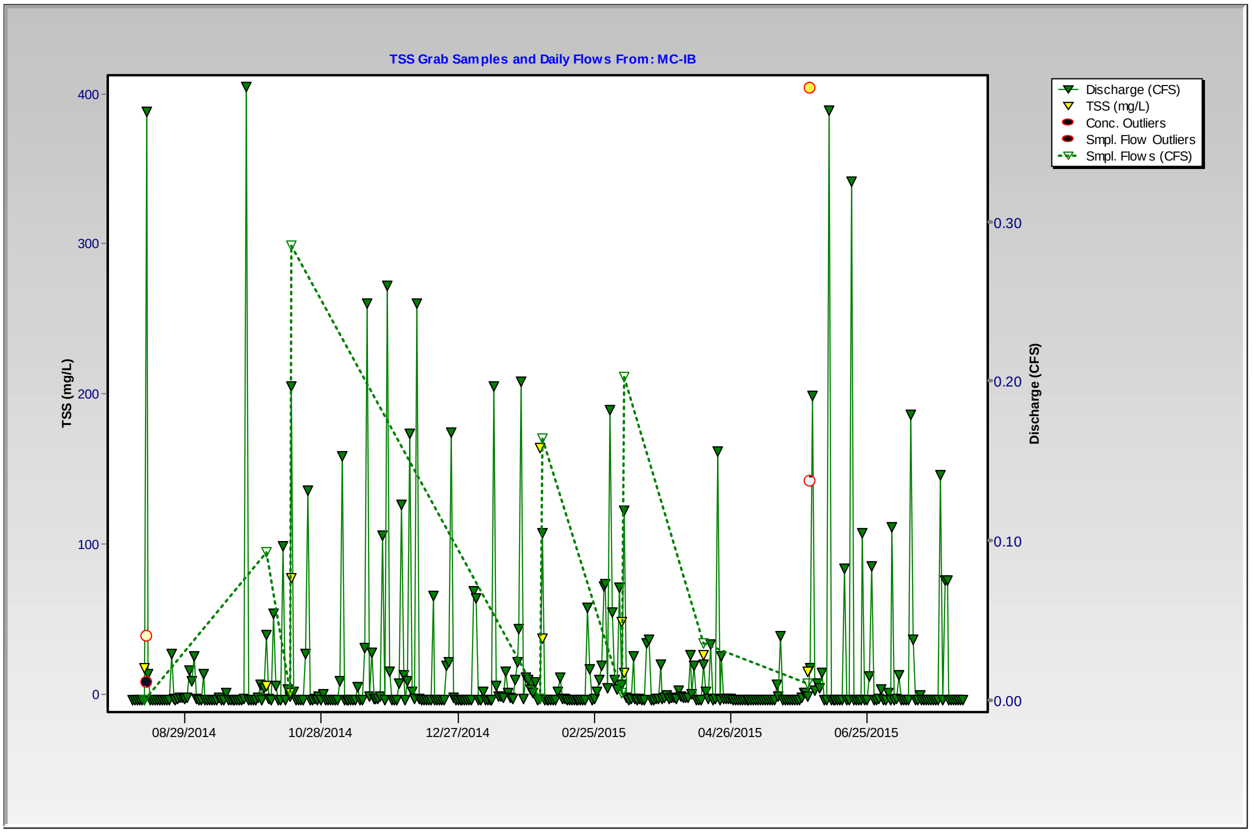
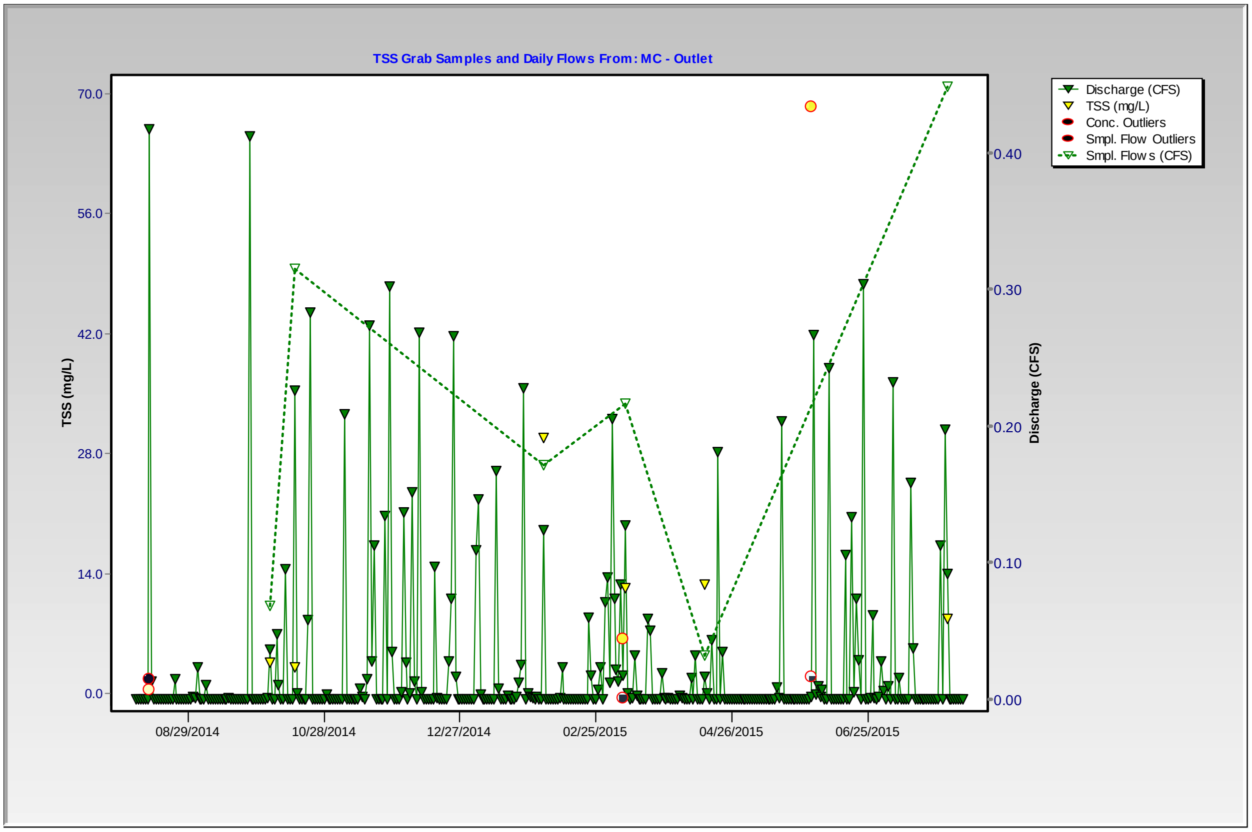
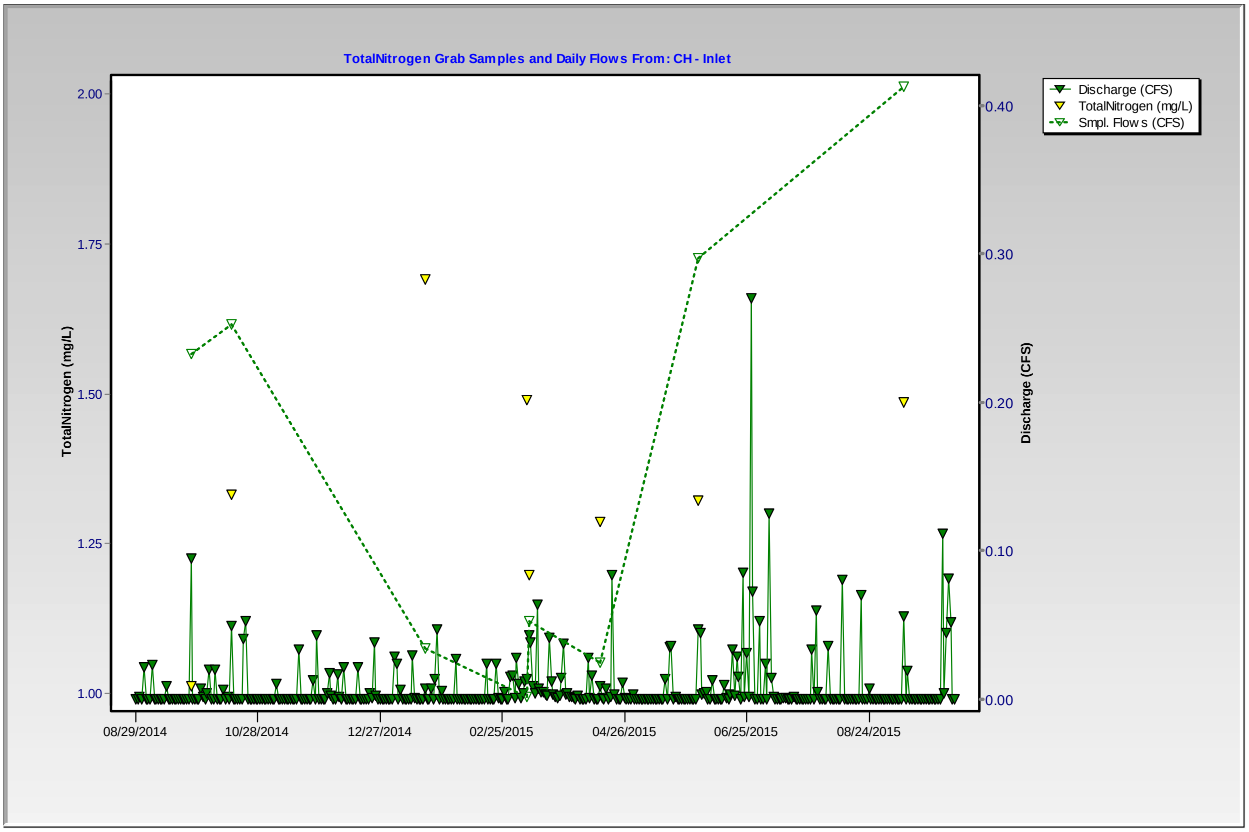


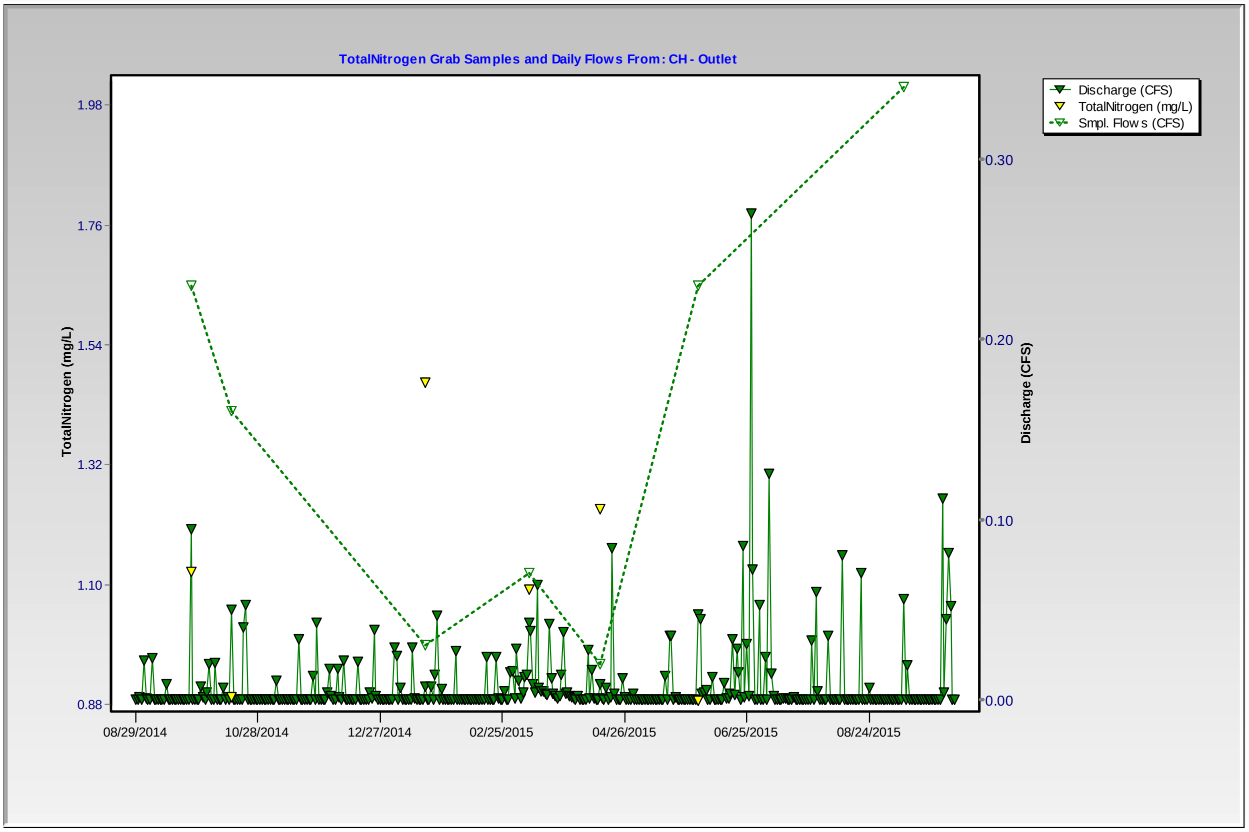


McCormick – FLUX32 Average Daily Discharge



College Hills – FLUX32 Average Daily Discharge





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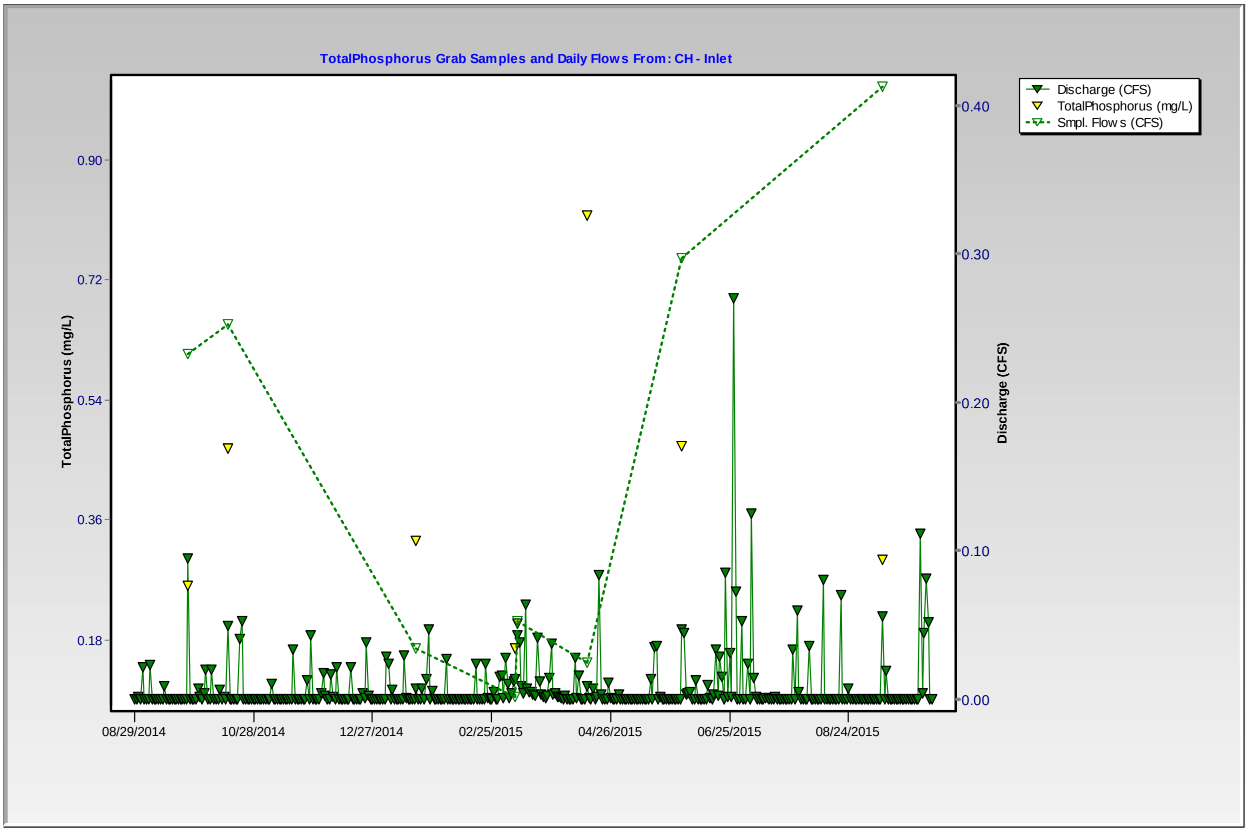
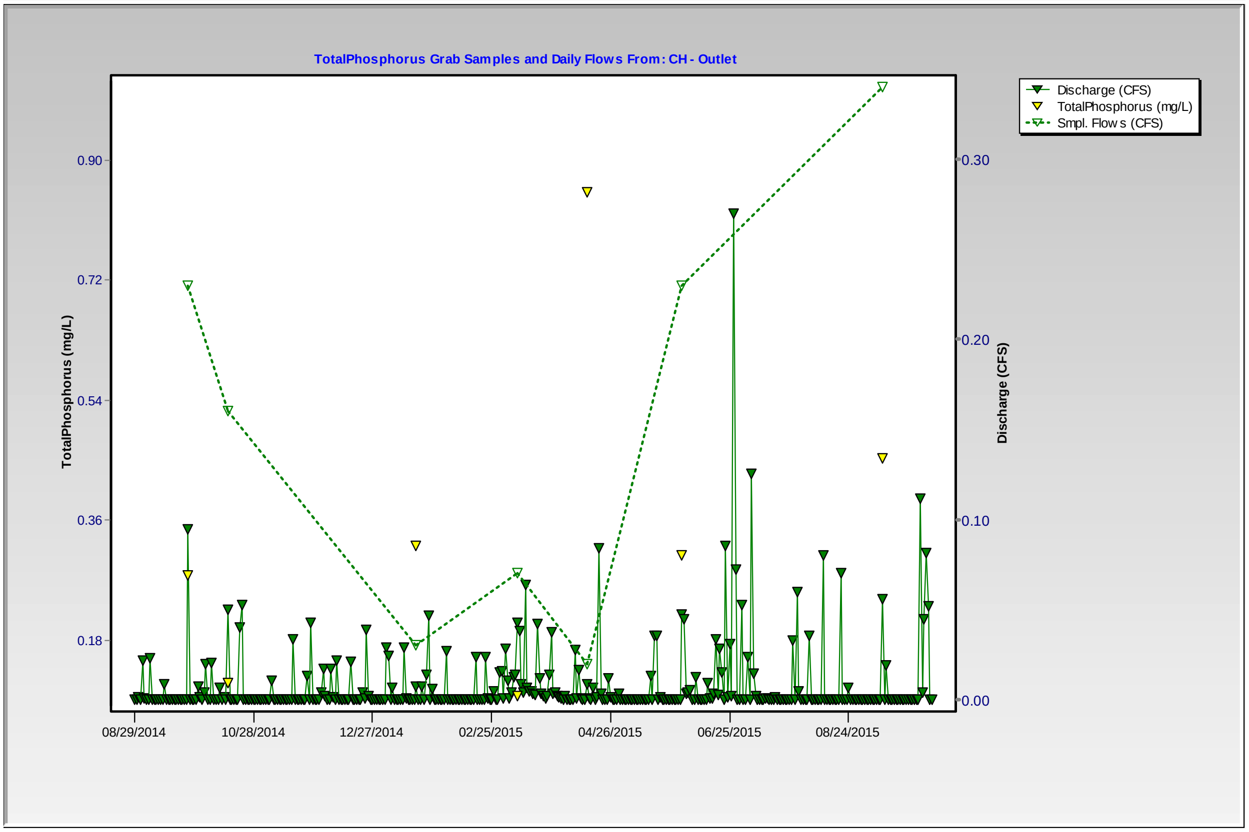
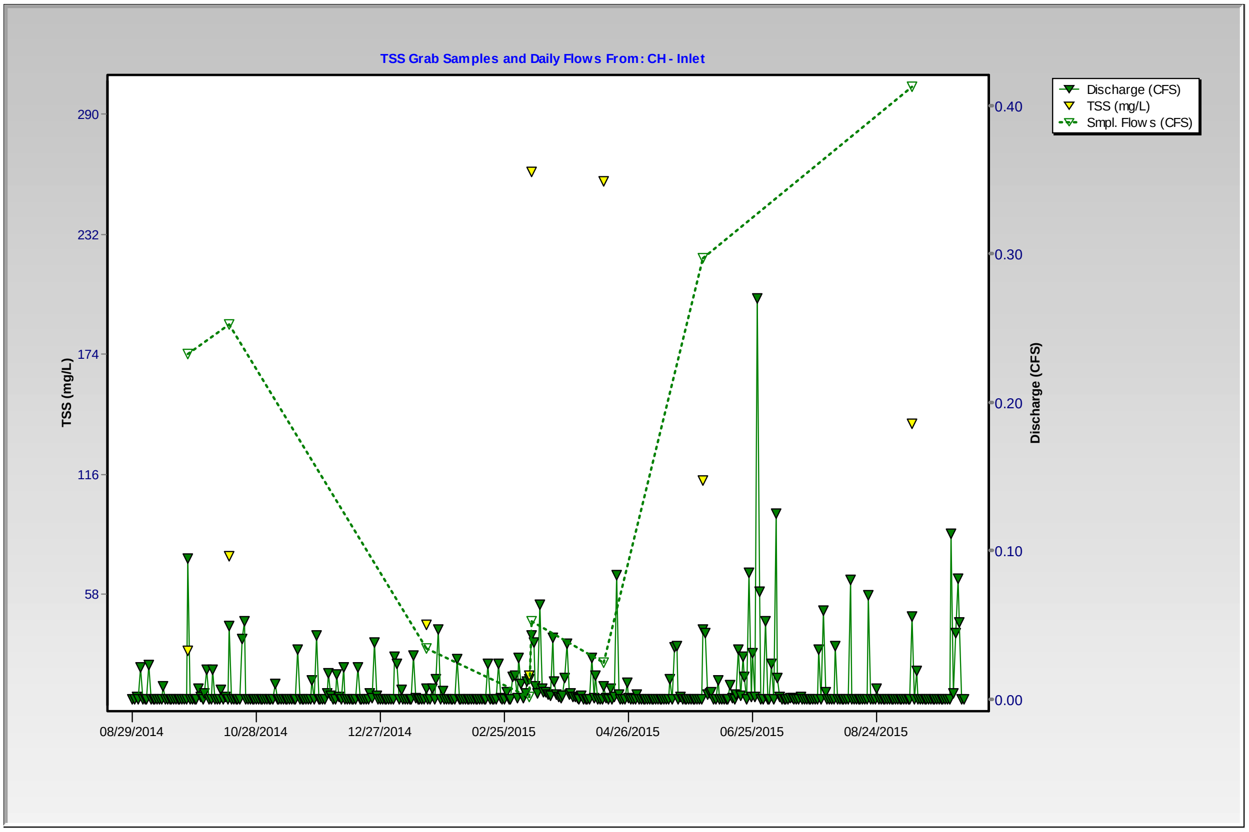
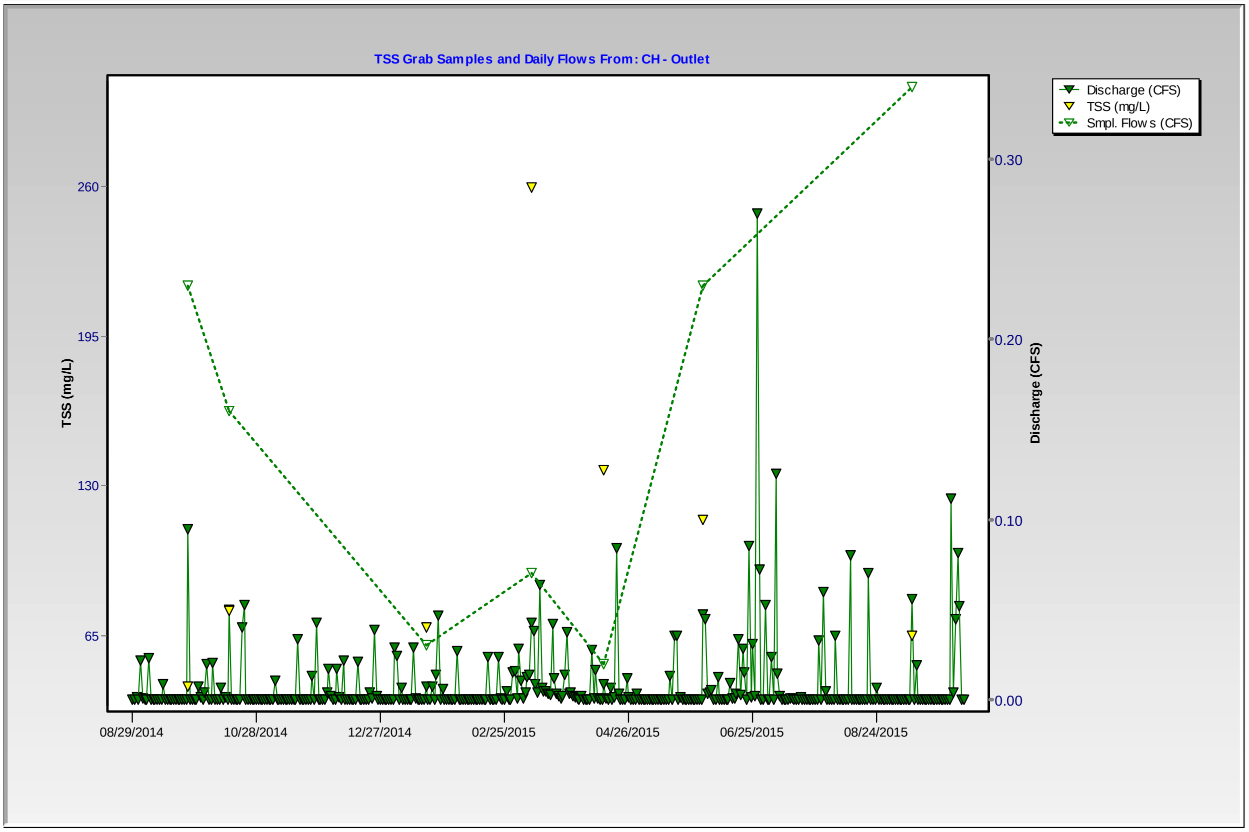


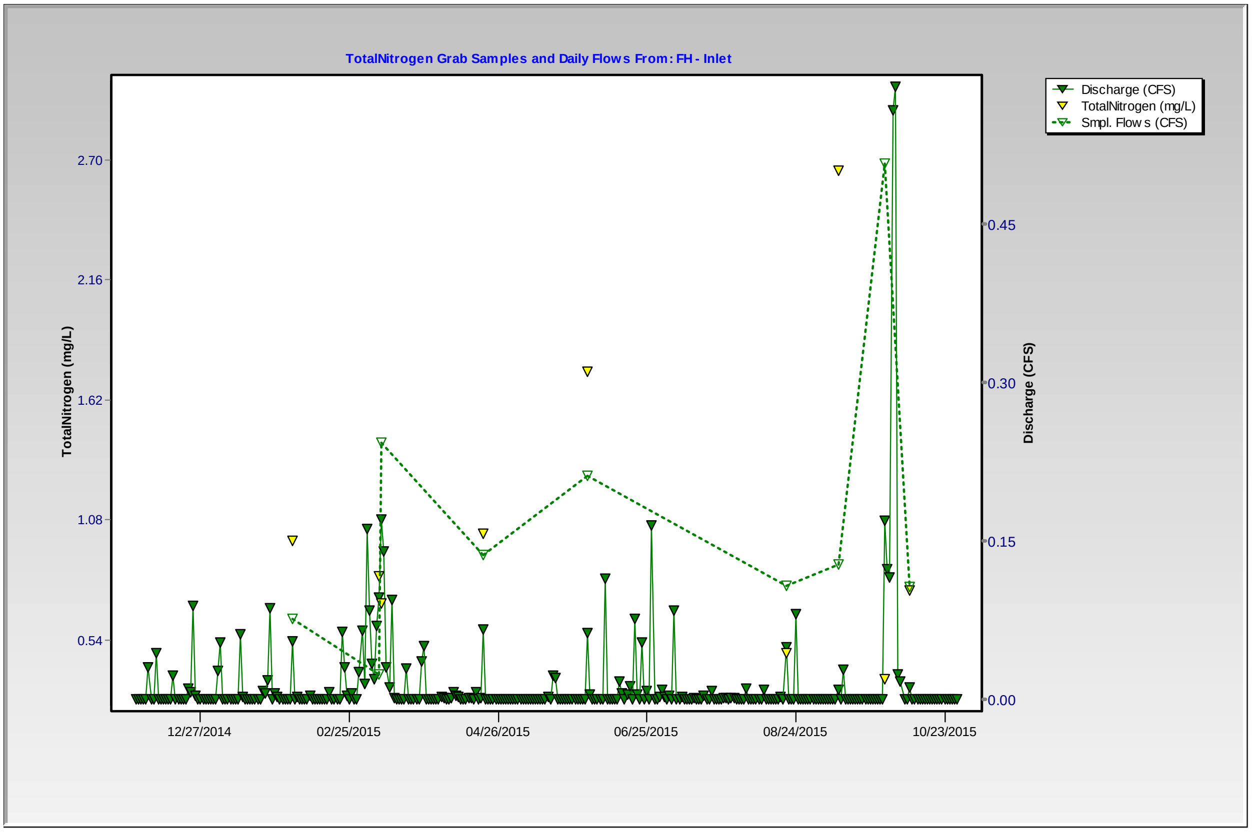


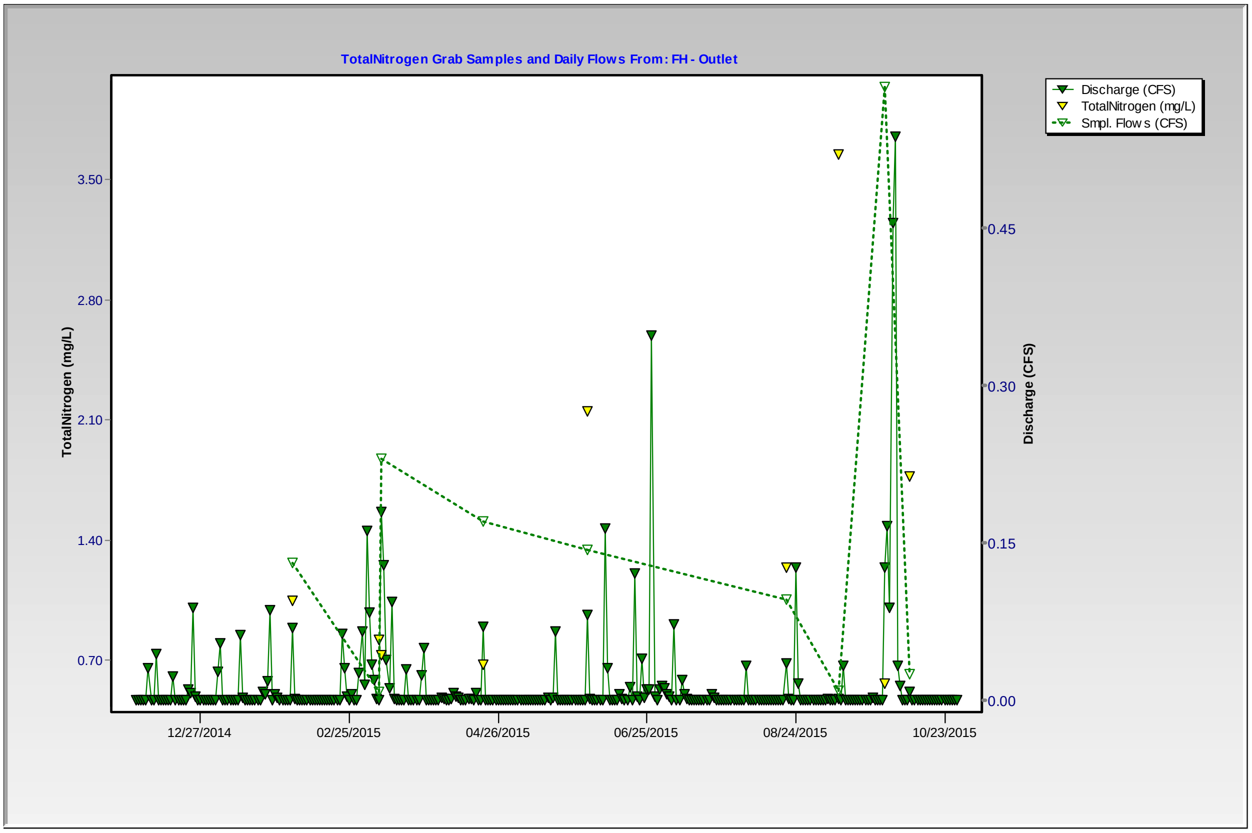
College Hills – FLUX32 Average Daily Discharge



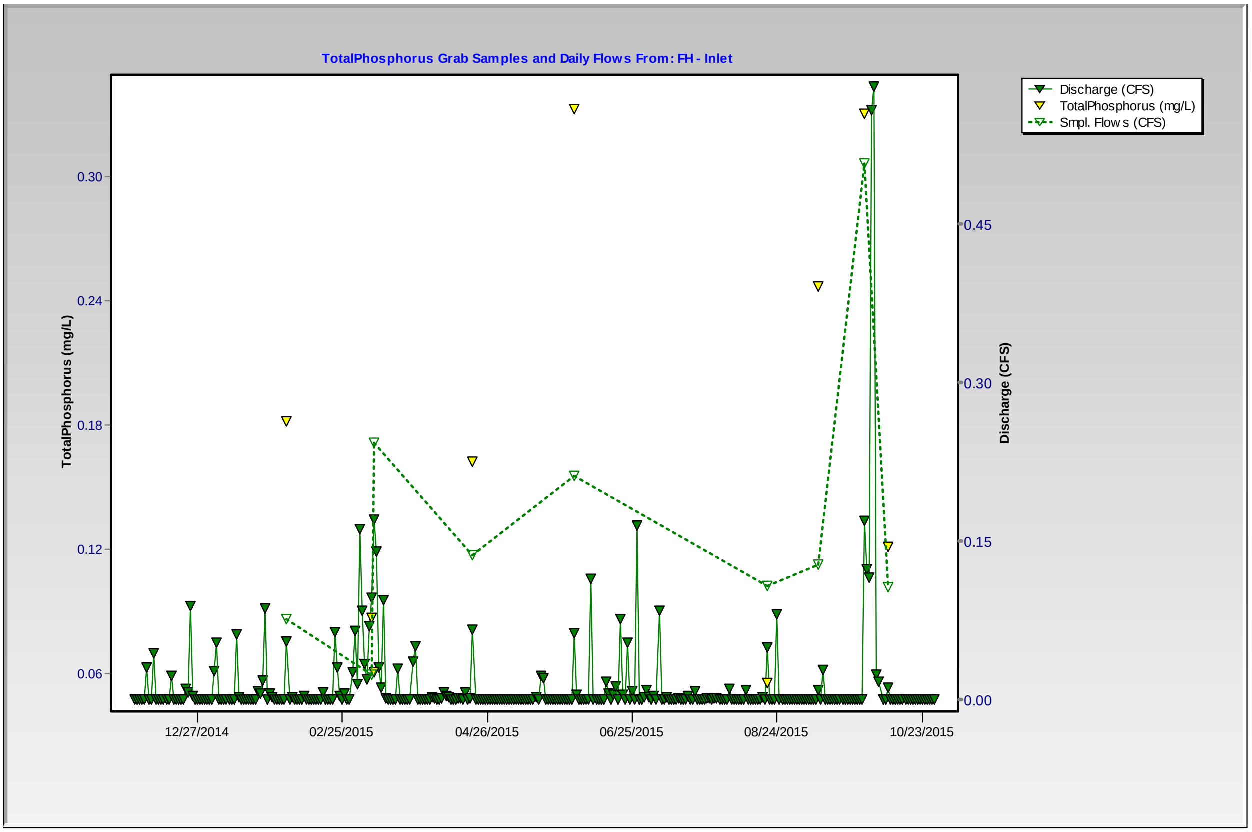


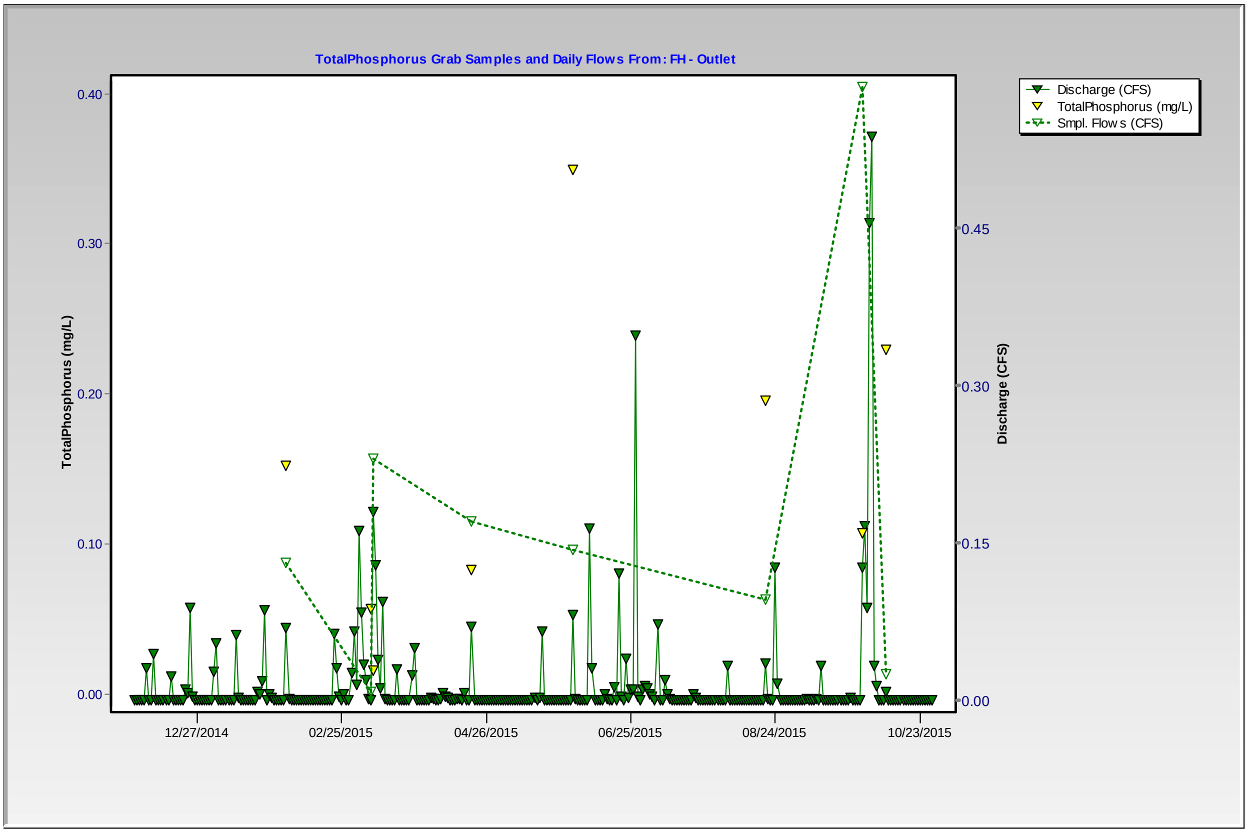
Fields of Harvest – FLUX32 Average Daily Discharge



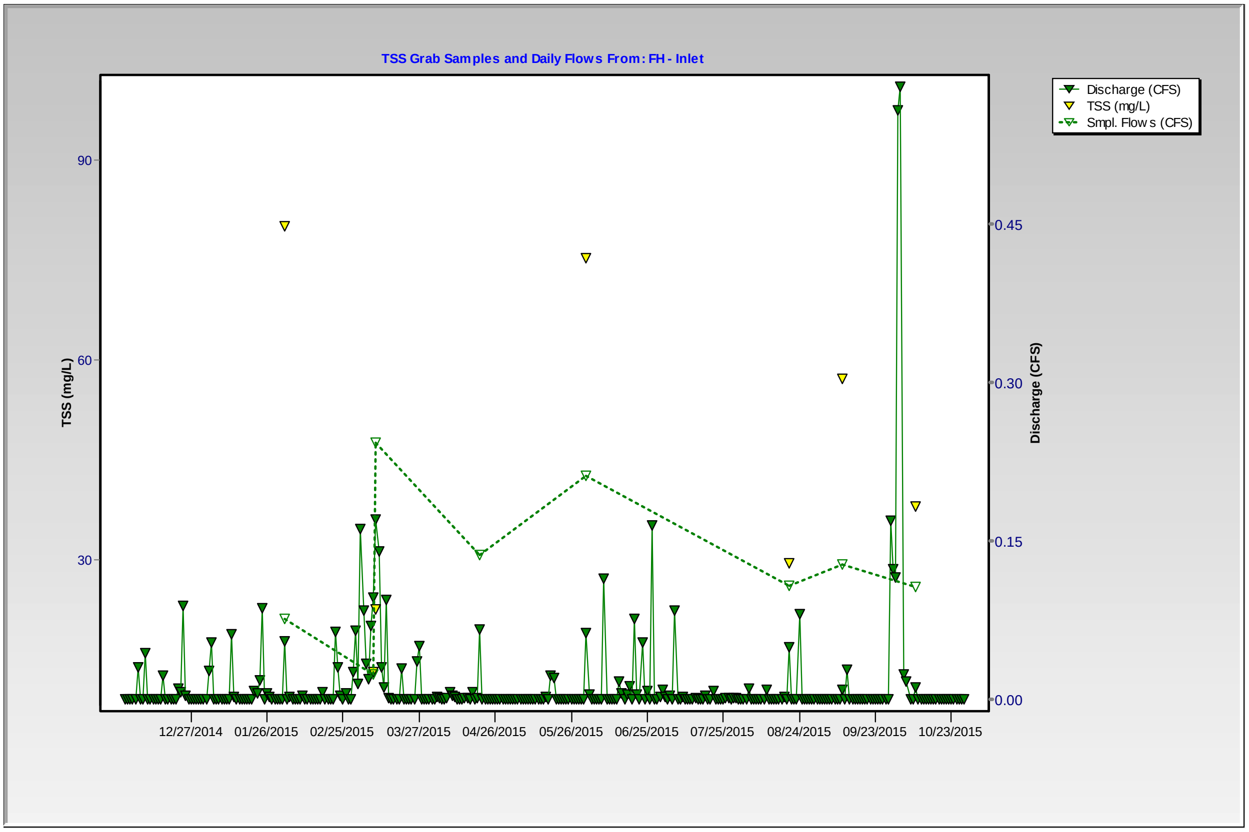


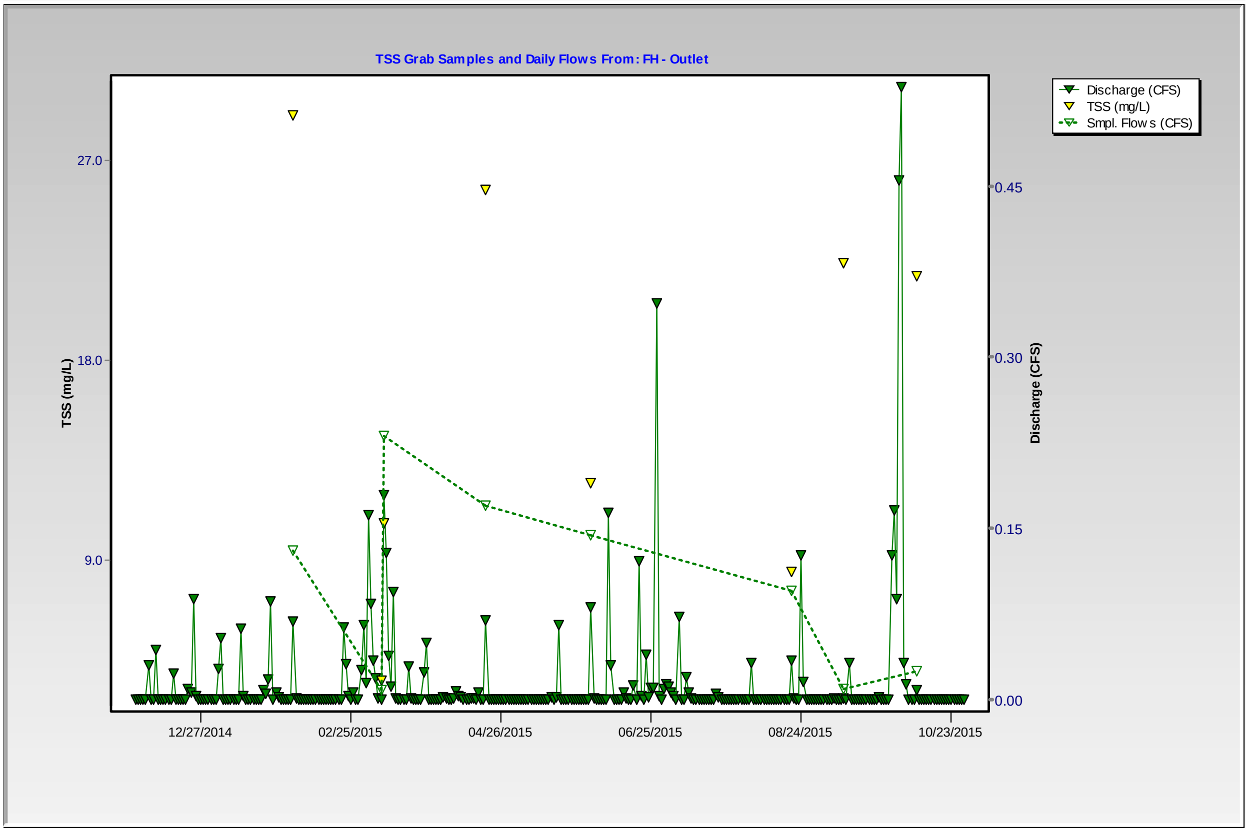
Fields of Harvest – FLUX32 Average Daily Discharge





Fields of Harvest – FLUX32 Average Daily Discharge





Appendix H: Towson UEBL QA/QC

Appendix H: Quality Assurance/Quality Control Results for Laboratory Analysis

To ensure high quality analysis and consistency of measurements for the chemical analysis of samples, two measures of accuracy and precision of the sample processing were performed:

- Check Standards within each sample group
- Relative Percent Difference of duplicate samples

Certified check standards within the calibration range for each analyte were included with each group of samples analyzed (Table 1). For TP, TN, and TSS 94% of the check standards were within the targeted 80-120% recovery range demonstrating excellent analytical accuracy of the analysis performed. For the ion chromatographic analysis of nitrate and nitrite, there was excellent recovery of nitrite with 98.9% of the samples in the goal recovery range, however with nitrate 83.3% of the check standards were in range.

Table 1. Check Standard recovery for chemical analysis used in loading and EMC calculations.

Parameter	Number of Check Standards	Average Percent Recovery	Percent in 80-120% Recovery Range
Total P	89	100.1	94.4
Total N	119	96.8	94.1
TSS	39	94.8	94.6
Nitrate	94	107.8	83.3
Nitrite	94	93.4	98.9

A second quality control analysis that was performed was the calculation of relative percent difference (RPD) for duplicate samples. Upon receipt by the UEBL, selected water samples (approximately one per pond, per storm event) were split and analyzed in duplicate (Table 2). The average RPD for all samples for each analyte was less than 20% indicating good precision for all analysis. When split out by ponds there was only one case that exceeded the 20% goal and it was at 20.8 for TP for pond FH. For all other analysis most RPD were less than 10%. Values for TKN are not shown, since TKN was calculated using TN – (Nitrite + Nitrate). In many cases with elevated RPDs, it was at the low end of the detection range, so those values would have minimal effect on total loads and EMC calculations.

Table 2. Relative percent difference for duplicate sample analysis by pond.

Pond	# of Duplicates	TP	TN	TSS	Nitrate	Nitrite
CH	8	4.8	2.7	15.5	8.1	0.8
FH	8	20.8	2.8	6.7	9.5	10.0
GS	8	8.5	5.2	18.1	12.4	4.6
HR	7	7.5	2.3	17.8	0.9	0.7
MC	7	11.5	2.9	6.0	9.9	0.2
WO	8	6.5	3.7	17.5	4.1	1.6
Average		10.0	3.3	13.6	7.5	3.0