WATER ENVIRONMENT & REUSE FOUNDATION

Final **Report**

International Stormwater BMP Database

2016 Summary Statistics

International Stormwater BMP Database

2016 SUMMARY STATISTICS

by

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2017

The Water Environment & Reuse Foundation (WE&RF) is a nonprofit (501c3) organization officially formed in July 2016 as the result of the merger of Water Environment Research Foundation and the WateReuse Research Foundation. The merged research foundation, with a combined research portfolio representing over $200 million, conducts research to treat and recover beneficial materials from wastewater, stormwater, and seawater including water, nutrients, energy, and biosolids.
The Foundation also plays an important role in the translation and dissemination of applied research, technology demonstration, and education, through creation of research-based educational tools and technology exchange opportunities. WE&RF materials can be used to inform policymakers and the public on the science, economic value, and environmental benefits of wastewater and recovering its resources, as well as the feasibility of new technologies.

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About WE&RF

The Water Environment & Reuse Foundation (WE&RF) is a 501c3 charitable corporation which conducts research to treat and recover beneficial materials from wastewater, stormwater, and seawater including water, nutrients, energy, and biosolids while facilitating interaction among practitioners, educators, researchers, decision makers, and the public. Our research represents a portfolio of more than $200 million in water quality research.

WE&RF operates with funding from subscribers, donors, state agencies, and the federal government. Our supporters include wastewater treatment facilities, stormwater utilities, state and federal government agencies, technology vendors and equipment companies, engineers, and environmental consultants. WE&RF takes a progressive approach to research, stressing collaboration among teams of researchers, environmental professionals, scientists, and staff. All research is peer reviewed by leading experts.

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- Applied research in water and the environment – Providing greater value to the industry by linking research with practical applications in the field.
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- Initiate transformative, integrated, and collaborative research and demonstrations.
- Fund and conduct independent and unbiased, actionable water research.
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Abstract and Benefits

Abstract:

The International Stormwater BMP Database is a publically accessible repository for BMP performance, design, and cost information. The overall purpose of the project is to provide scientifically sound information to improve the design, selection and performance of BMPs. Continued population of the database and assessment of its data supports improved understanding of the factors influencing BMP performance and supports improvements in BMP design, selection, and implementation.

This report provides a summary of BMP performance for total suspended solids, nutrients, metals, and bacteria for the most commonly monitored and reported BMP types available in the 2016 release of the BMP Database, updating previous performance summary reports. BMPs include grass strips, bioretention, bioswales, composite/treatment train BMPs, extended detention basins, media filters (mostly sand filters), porous pavement, retention ponds (wet ponds), wetland basins, and wetland channels. Data summaries include basic summary statistics for influent and effluent concentrations, graphical summaries, and hypothesis test results for various pollutant-BMP combinations.

Benefits:

- Provides consolidated summary statistics for the 2016 version of the International Stormwater BMP Database.
- Provides hypothesis testing results to indicate which BMPs demonstrate statistically significant differences in influent and effluent concentrations.
- Helps researchers identify potential data gaps for BMPs and pollutant types that warrant additional research.
- Synthesizes national BMP performance research that can be used for comparative purposes for local BMP studies or to support local planning efforts.

Keywords: Performance evaluation, best management practice, stormwater control measure, green infrastructure, nutrients, bacteria, metals, sediment, water quality.

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Acronyms and Abbreviations

APWA	American Public Works Association
BMP	Best Management Practice
EPA	U.S. Environmental Protection Agency
EWRI-ASCE	Environmental and Water Resources Institute of the American Society of Civil Engineers
FHWA	Federal Highway Administration
GI	Green Infrastructure
LID	Low Impact Development
mg/L	milligrams per liter
MPN/100 mL	Most Probable Number per 100 milliters
N	Nitrogen
NOx	Nitrate+Nitrite and Nitrate
NSQD	National Stormwater Quality Database
P	Phosphorus
ROS	Regression on Statistics
SRP	Soluble Reactive Phosphorus
TKN	Total Kjeldahl Nitrogen
TSS	Total Suspended Solids
µg/L	micrograms per liter
WE&RF	Water Environment & Reuse Foundation

Executive Summary

The International Stormwater BMP Database is a publically accessible repository for BMP performance, design, and cost information. The overall purpose of the project is to provide scientifically sound information to improve the design, selection and performance of BMPs. Continued population of the database and assessment of its data supports improved understanding of the factors influencing BMP performance and supports improvements in BMP design, selection, and implementation.

Since the initial development of the BMP Database in 1996, the Water Environment and Reuse Foundation (WE&RF) and various funding partners, including the Federal Highway Administration (FHWA), the Environmental and Water Resources Institute (EWRI), the U.S. Environmental Protection Agency (EPA), and American Public Works Association (APWA) have contributed to its continued development and growth. As of the most recent release in November 2016, the BMP Database contains data sets from nearly 650 BMP studies through the U.S. and several other countries that are publicly accessible on the project website (www.bmpdatabase.org).

The BMP Database project website provides consolidated access to a variety of guidance and interpretive reports related to BMP performance, in addition to access to the BMP Database itself. For example, monitoring guidance, recommendations for statistically sound approaches for performance analysis, reporting protocols (e.g., data entry spreadsheets and user’s guide), on-line statistical analysis tools, presentations, and summary reports are freely available and accessible to the public on the website. BMP performance summary reports focus on solids, nutrients, metals, and bacteria for the most commonly monitored and reported BMP types. These include grass strips, bioretention, bioswales, composite/treatment train BMPs, extended detention basins, media filters (mostly sand filters), porous pavement, retention ponds (wet ponds), wetland basins, and wetland channels.

This 2016 report summarizes influent and effluent concentrations for various pollutant-BMP combinations utilizing basic summary statistics, graphical summaries and hypothesis test results. The performance data sets selected for this report include total suspended solids, nutrients, bacteria, and metals based on data in the 2016 release of the BMP Database. This report serves as a data summary and does not provide detailed discussion or interpretation of findings.

CHAPTER 1.0

Introduction

The International Stormwater Best Management Practice (BMP) Database is a long-term project that has grown and evolved over the past 20 years to help document the performance of urban stormwater BMPs (www.bmpdatabase.org). The database has recently expanded to include performance modules for agricultural practices and for stream restoration practices. The project now also houses the National Stormwater Quality Database (NSQD) which provides runoff characterization data for urban land uses. With this expansion, the BMP Database has become an integrated repository of available data on the efficacy of BMPs from a variety of sectors for reducing pollutant loading and improving water quality (Figure 11-1). This BMP performance report provides statistical characterization of urban stormwater BMP performance data, updating similar previously completed reports (Geosyntec and WWE 2012b & 2014).

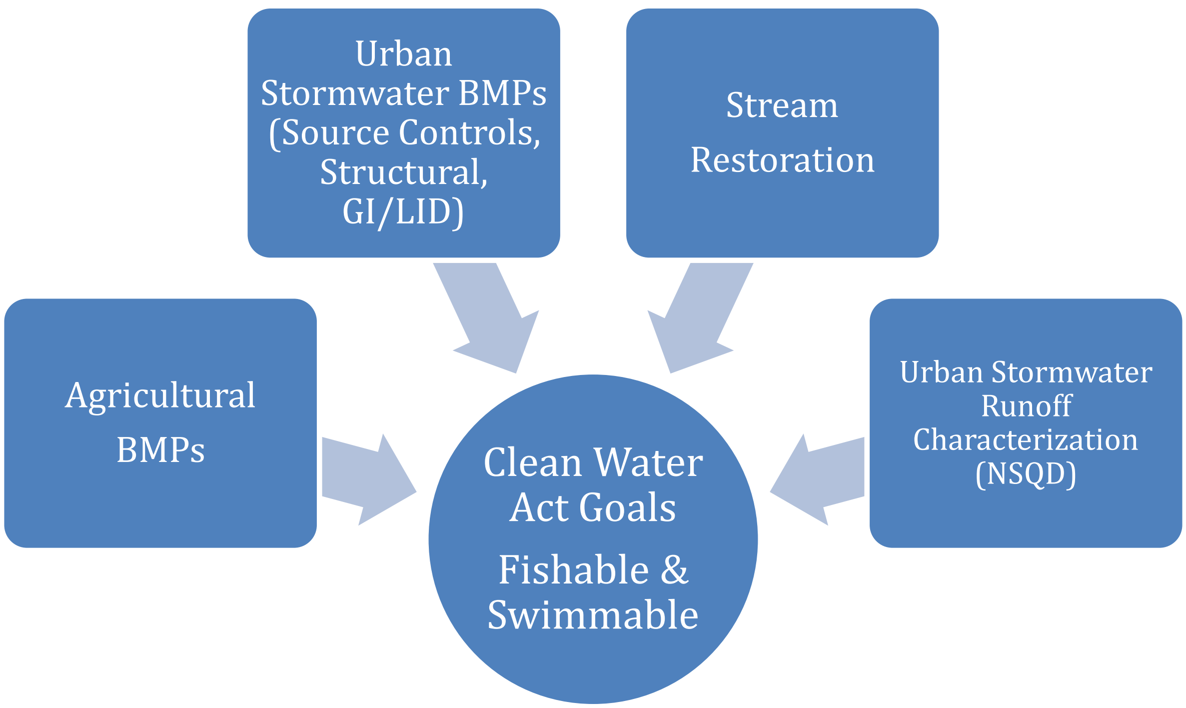

Figure 1-1. Overview of BMP database.

In 2010-2011, the Water Environment & Reuse Foundation (WE&RF), Federal Highway Administration (FHWA), and the American Society of Civil Engineers' Environmental and Water Resources Institute (EWRI-ASCE) co-sponsored a comprehensive stormwater BMP performance analysis technical paper series relying on data contained in the BMP Database .[1] This series included papers for solids, bacteria, nutrients, and metals. Each paper summarized the regulatory context of the constituent category, primary sources, fate and transport processes, removal mechanisms, and statistical summaries of BMP performance for data contained in the BMP Database. In 2012 and 2014, updates of the statistical summaries provided in that series were prepared to include the data from new studies added to the database. This 2016 report updates the 2014 statistical summaries to include analysis for data sets entered into the BMP database during 2015-2016. During 2016, 78 new data sets were added to the BMP Database, including new data for existing BMPs and new BMP studies. This report is not intended to replace the discussion and context provided in the previous technical papers (accessible at http://www.bmpdatabase.org/performance-summaries.html); instead, this report provides updated statistical summaries only. Constituents summarized in this report are listed in Table 1-1-1.

Table 1-1. Constituents Summarized by Pollutant Category

Pollutant Category	Summarized Constituent
Solids	Total suspended solids (TSS)
Bacteria	Fecal coliform *Escherichia coli* (*E. coli*) Enterococcus
Metals	Arsenic (total and dissolved) Cadmium (total and dissolved) Chromium (total and dissolved) Copper (total and dissolved) Iron (total and dissolved) Lead (total and dissolved) Nickel (total and dissolved) Zinc (total and dissolved)
Nutrients	Total phosphorus Orthophosphate Dissolved phosphorus Total nitrogen Total Kjeldahl nitrogen (TKN) Nitrate (NO_3) Nitrate plus nitrite ($NO_3 + NO_2$) Nitrate and Nitrate plus nitrite (NOx)

[1] The BMP Database is a long-term project that began in 1994 through the vision of members active in the Urban Water Resources Research Council of ASCE and the leadership of EPA. Funded for many years by EPA, the project is currently supported by a coalition of partners including WE&RF, FHWA, and EWRI. The American Public Works Association (APWA) has also supported the project in the past.

1.1 Data Summary Approach

The BMP performance analyses provided in this report are based on the BMP performance data in the BMP Database as of November 2016. The analyses are based upon the distributions of influent and effluent water quality sample data for individual events by BMP category, thereby providing greater weight to those BMPs for which there are a larger number of data points reported. In other words, the performance analysis presented in this technical summary is "storm-weighted," as opposed to "BMP weighted."[2]

A summary of the BMPs analyzed and data screening approach is provided below followed by descriptions of the graphical and tabular summaries provided in this report. The statistical analysis is organized by constituent and BMP type for three main constituent categories: Solids, Bacteria, Metals, and Nutrients.

1.2 BMPs Analyzed and Data Screening Approach

The BMP categories included in this analysis are grass strips, bioretention, bioswales, composite/treatment train BMPs, detention basins (surface/grass-lined), media filters (mostly sand filters), porous pavement, retention ponds (surface pond with a permanent pool), wetland basins (basins with open water surface), a combined category including both retention ponds and wetland basins, and wetland channels (swales and channels with wetland vegetation). The effectiveness and range of unit treatment processes present in a particular BMP may vary depending on the BMP design. Several other BMP categories and sub-classes are included in the database, but these have been excluded from this analysis due to limited data sets available for meaningful categorical comparisons. Additionally, the BMP Database contains approximately 100 manufactured devices, which are no longer provided as a general BMP category for analysis in this report because of the wide range of unit treatment processes present among various manufactured devices. Green roof data sets have also been excluded from this report due to relatively small numbers of comparable data sets and significant variation in monitoring program designs. Individual BMP performance analysis reports can be viewed and downloaded from www.bmpdatabase.org for manufactured devices, green roofs, and other BMP types not included in this summary report. For example, see http://www.bmpdatabase.org/map.html to view monitoring locations with other BMP types not included in this report.

To be included in this category-level summary, at least three BMP studies must be included in the BMP category, with each BMP study having influent and effluent data for at least three storms. A variety of additional screening criteria are applied for purposes of category-level analysis to make sure that the data sets and BMP designs are reasonably representative, as documented in the "Monitoring Station" table of the BMP Database, which can be downloaded from www.bmpdatabase.org. Poor performance of a BMP is not a reason for data exclusion.

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[2] There are several viable approaches to evaluating data in the BMP Database. Two general approaches that have been presented in the past (Geosyntec Consultants and Wright Water Engineers, 2008) are the "BMP-weighted" and "storm-weighted" approaches. The BMP-weighted approach represents each BMP with one value representing the central tendency and variability of each individual BMP study, whereas the storm-weighted approach combines all of the storm events for the BMPs in each category and analyzes the overall storm-based data set. The storm-weighted approach has been selected for this report because it provides a much larger data set for analysis.

1.3 Graphical Summaries

In the subsections below, side-by-side box plots for the various BMP categories have been generated using the influent and effluent concentrations from the studies. For each BMP category, the influent box plots are provided on the left and the effluent box plots are provided on the right. A key to the box plots is provided in Figure 1-2.

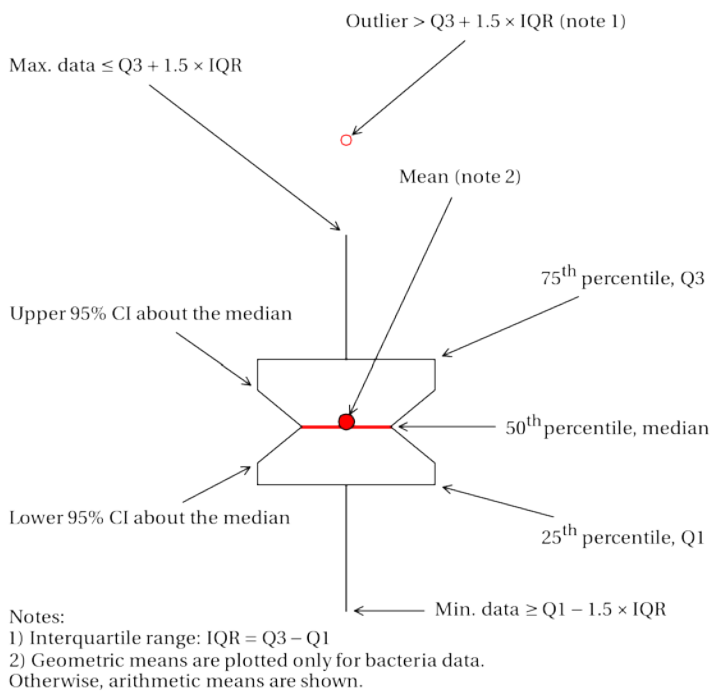

Figure 1-2. Box plot key.

1.4 Tabular Summaries

In addition to the box plots, tables of influent/effluent medians, 25th and 75th percentiles, and number of studies and data points are provided, along with 95% confidence intervals about the medians. The median and interquartile ranges were selected as descriptive statistics for BMP performance because they are non-parametric (do not require distributional assumptions for the underlying data set) and are less affected by extreme values than means and standard deviations. Additionally, the median is less affected by assumptions regarding values below detection limits and varying detection limits for studies conducted by independent parties over many years.

Since confidence intervals about the median can still be affected by outliers if simple substitution is used, a robust regression-on-order statistics (ROS) method as described by Helsel and Cohn (1988) was utilized to provide probabilistic estimates of non-detects before computing descriptive statistics. Despite use of this robust method, conclusions regarding BMP performance should carefully consider the influence of large percentages of non-detects. For example, pollutant removals may be found to be statistically insignificant for a BMP, but that BMP may still provide removals at higher influent concentrations. The number of influent and effluent non-detects should be reviewed before making conclusions, particularly for dissolved metals where non-detects are most prevalent. Footnotes have been added to summary tables where greater than 50% non-detects were present for the influent data set. For more information on the influence of non-detects on dissolved metals data in the BMP Database, see the discussion in the Metals Technical Summary (Wright Water Engineers and Geosyntec, 2011), accessible at www.bmpdatabase.org).

Confidence intervals in the boxplots and tables were generated using the bias corrected and accelerated (BCa) bootstrap method described by Efron and Tibishirani (1993). This method is a robust approach for computing confidence intervals that is resistant to outliers and does not require any restrictive distributional assumptions. Comparison of the confidence intervals about the influent and effluent medians can be used to roughly identify statistically significant differences between the central tendencies of the data. However, non-parametric hypothesis tests, such as the Mann-Whitney rank sum test or the Wilcoxon signed-rank test, can provide additional and more robust results for evaluating significant differences between medians. The Mann-Whitney test applies to independent data sets, whereas the Wilcoxon test applies to paired data sets (Helsel and Hirsch, 1992). Results of these tests are summarized in Chapter 2 for solids, bacteria, metals, and nutrients. In some cases, the Mann-Whitney and Wilcoxon hypothesis test results produce conflicting conclusions regarding statistically significant differences. Such cases are more likely to occur where there are imbalances in the number of influent and effluent samples for a particular data set because the Mann-Whitney test operates on the entire data set whereas the Wilcoxon test only operates on data pairs. For BMPs with long residence times and/or permanent pools (e.g., wet ponds), the paired storm event hypothesis test results relying on the Wilcoxon test may be less representative than the Mann-Whitney test because of variations in sampling program designs for collection of influent and effluent samples that may not enable event-based pairing of monitoring data. For example, inflow for a storm event on a particular date may mix with water from a previous event that has been stored since the previous storm. Thus, in cases where the Mann-Whitney and Wilcoxon test results conflict for BMPs with permanent pools, the Mann-Whitney results may provide a better indicator of pollutant removal performance.

In the summary tables which follow, results of comparisons for statistical differences are shown by three diamonds according to the key described in Table 1-2. If differences in inflow and outflow concentrations are identified for all three interpretation methods, then all three diamonds will be shaded. Be aware that some identified differences may indicate export of pollutants rather than reductions.

Table 1-2. Legend for Interpretation of Hypothesis Test Results

Inflow-Outflow Concentration Differences	Interpretation
◆◇◇	95% confidence intervals around influent/effluent medians do not overlap.
◇◆◇	P-value of the Mann-Whitney test is less than 0.05.
◇◇◆	P-value of the Wilcoxon test is less than 0.05.

Be aware that for some BMP types, a statistically significant difference between influent and effluent concentrations may not be present, but the effluent concentrations achieved by the BMP are relatively low and may be comparable to the performance of other BMPs that have statistically significant differences between inflow and outflow. For example, data sets that have low influent concentrations and similarly low effluent concentration (i.e., clean water in = clean water out) may not show statistically significant differences. However this does not necessarily imply that the BMP would not have been effective at higher influent concentrations.

Lastly, this report focuses solely on influent and effluent concentrations and does not characterize influent and effluent loads. For BMPs that provide significant volume reduction, load reductions may still occur in the absence of concentration reductions. Volume-related data can also be retrieved from the BMP Database and have been evaluated in detail for some BMP categories. For example, see *International Stormwater Best Management Practices (BMP) Database Addendum 1 to Volume Reduction Technical Summary (January 2011) Expanded Analysis of Volume Reduction in Bioretention BMPs* (Geosyntec and Wright Water Engineers 2012a), accessible at www.bmpdatabase.org.

CHAPTER 2.0

BMP Performance Summary Statistics

Graphical and tabular summary statistics are provided in this chapter by pollutant category, with data summaries provided for each BMP category with sufficient data to generate statistical summaries.

2.1 Total Suspended Solids

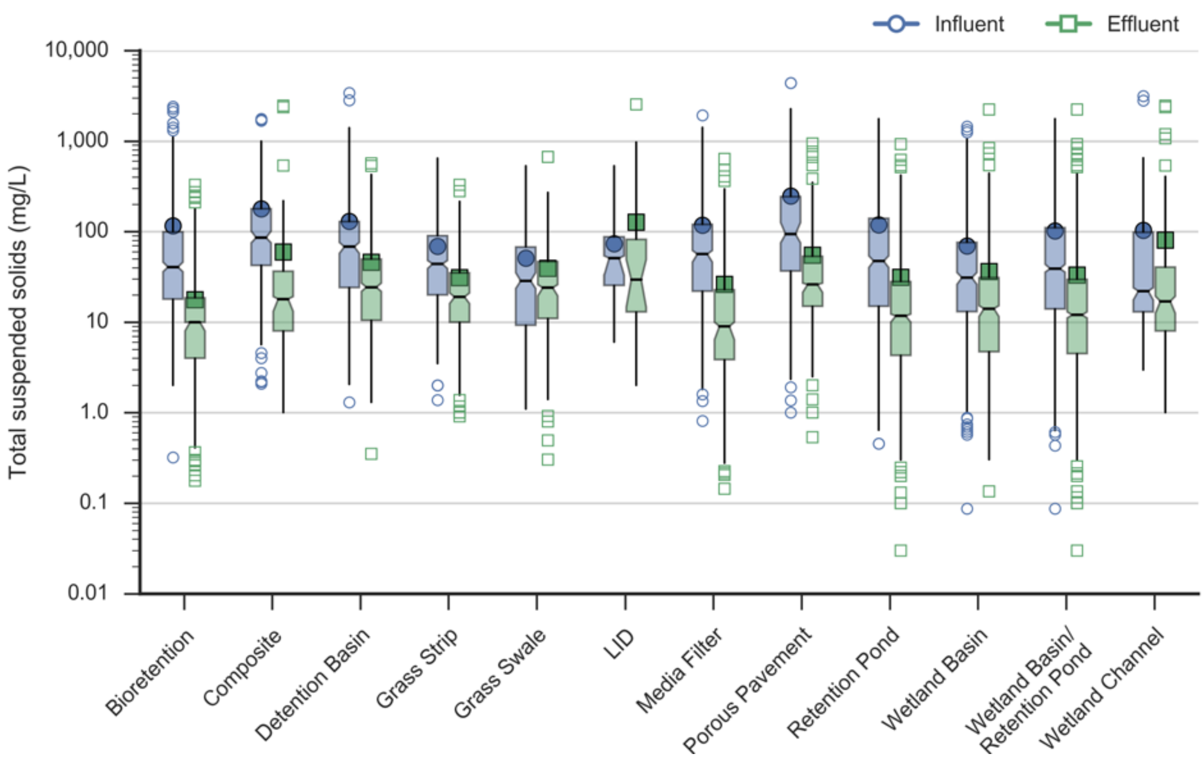

Figure 2-1. Box plots of influent/effluent TSS concentrations.

Table 2-1. Influent/Effluent Summary Statistics for TSS (mg/L)

BMP Category	BMPs		EMCs		25th		Median			75th	
	In	Out	In	Out	In	Out	In	Out	Difference	In	Out
Bioretention	25	25	520	463	18.0	4.0	40.6 (36.0, 46.0)	10.0 (8.0, 10.0)	◆◆◆	99.2	18.5
Composite	10	10	202	174	42.4	8.0	85.7 (75.0, 101.3)	18.0 (12.8, 19.2)	◆◆◆	178.8	36.5
Detention Basin	32	33	411	436	24.1	10.5	68.0 (57.4, 76.2)	24.3 (21.8, 27.0)	◆◆◆	129.0	49.6
Grass Strip	19	19	361	282	20.0	10.0	44.0 (39.0, 48.0)	19.0 (15.5, 21.0)	◆◆◆	90.0	35.0
Grass Swale	24	24	442	418	9.2	11.0	28.6 (23.0, 35.0)	24.0 (19.0, 26.0)	◇◇◆	67.5	46.7
LID	3	3	131	62	25.5	13.0	51.0 (32.0, 54.0)	29.5 (15.0, 49.3)	◇◇◇	87.5	82.0
Media Filter	25	25	400	377	22.0	3.9	56.4 (46.0, 61.9)	9.0 (6.4, 10.0)	◆◆◆	120.0	22.8
Porous Pavement	9	9	404	248	36.8	15.0	93.7 (75.0, 126.0)	26.0 (20.6, 27.0)	◆◆◆	243.0	53.2
Retention Pond	56	56	923	933	15.0	4.3	47.2 (40.0, 54.0)	11.7 (10.0, 12.3)	◆◆◆	139.8	28.0
Wetland Basin	22	22	492	486	13.1	4.7	31.0 (26.4, 35.5)	14.1 (11.6, 15.2)	◆◆◆	75.9	31.0
Wetland Basin/ Retention Pond	78	78	1415	1419	14.0	4.5	38.9 (35.6, 43.6)	12.0 (11.1, 13.0)	◆◆◆	110.3	29.6
Wetland Channel	12	12	199	178	13.0	8.0	22.0 (18.0, 24.0)	17.0 (13.0, 19.0)	◇◆◆	98.4	40.5

2.2 Bacteria

Fecal indicator bacteria data summaries are provided for enterococcus, *Escherichia coli* (*E. coli*), and fecal coliform. Performance data remain limited for EPA's currently recommended fecal indicator bacteria, enterococcus and *E. coli*.

2.2.1 Enterococcus

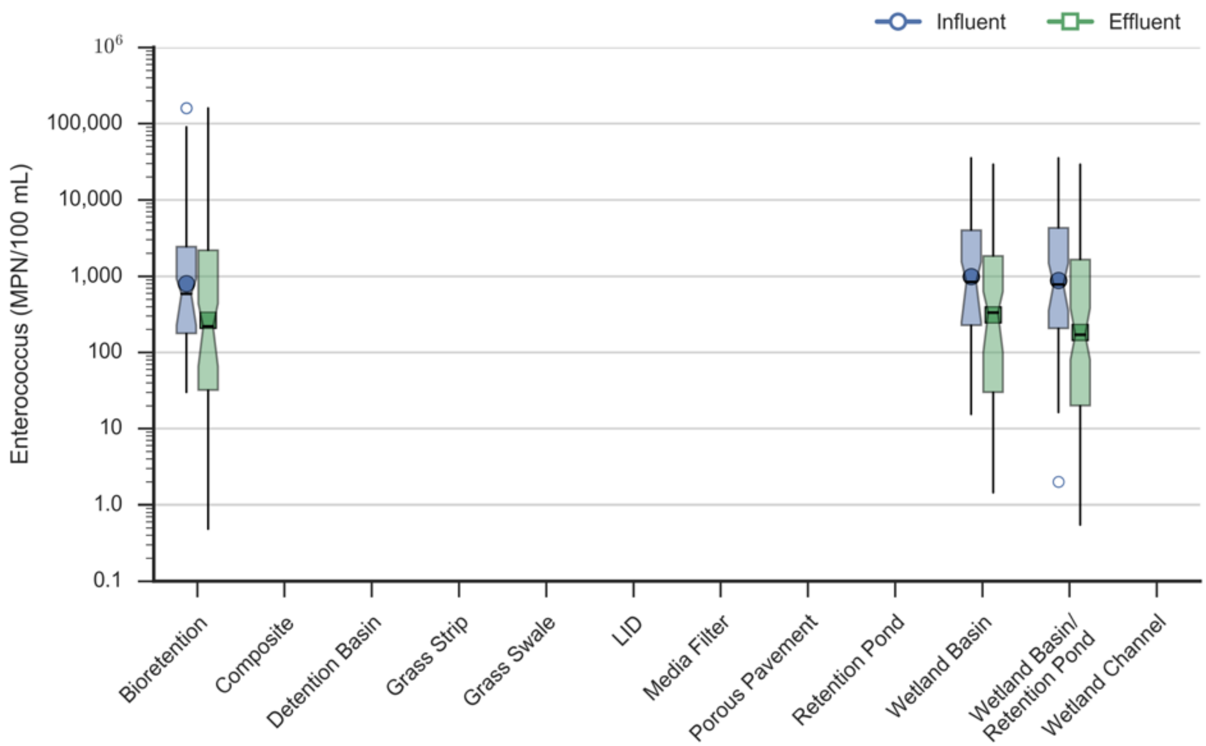

Figure 2-2. Box plots of influent/effluent enterococcus concentrations.

Table 2-2. Influent/Effluent Summary Statistics for Enterococcus (MPN/100 mL)

BMP Category	BMPs		EMCs		25th		Median			75th	
	In	Out	In	Out	In	Out	In	Out	Difference	In	Out
Bioretention	3	3	48	49	180	32	590 (220, 920)	220 (58, 440)	◇◆◆	2,400	2,200
Wetland Basin	4	4	53	53	230	30	840 (250, 1,500)	330 (100, 630)	◇◆◆	4,000	1,800
Wetland Basin/ Retention Pond	6	6	86	86	210	20	780 (350, 1,500)	170 (80, 390)	◇◆◆	4,300	1,700

2.2.2 E. coli

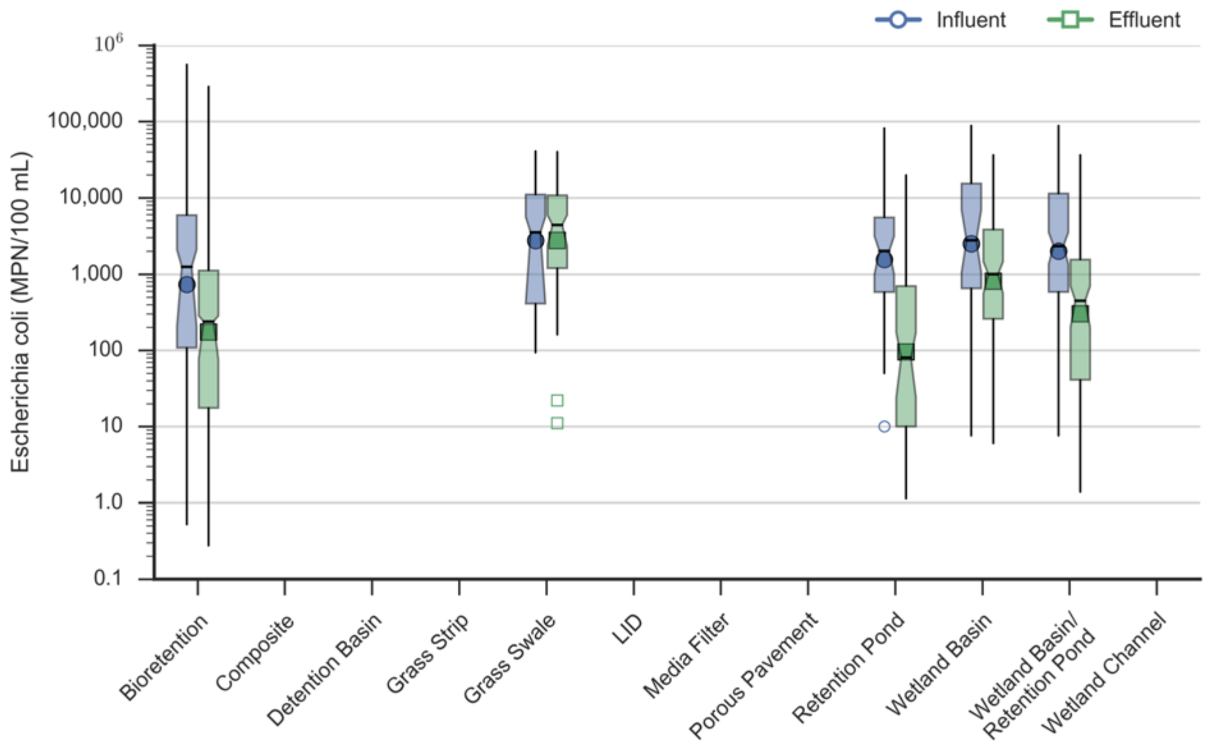

Figure 2-3. Box plots of influent/effluent *E. coli* concentrations.

Table 2-3. Influent/Effluent Summary Statistics for E. coli (MPN/100 mL)

BMP Category	BMPs		EMCs		25th		Median			75th	
	In	Out	In	Out	In	Out	In	Out	Difference	In	Out
Bioretention	7	7	97	96	110	18	1,200 (200, 2,100)	240 (77, 280)	◇◆◆	5,900	1,100
Grass Swale	5	6	39	46	410	1,200	3,500 (410, 5,600)	4,400 (2,600, 5,900)	◇◇◇	11,000	11,000
Retention Pond	4	4	69	65	580	10	2,000 (990, 3,100)	80 (24, 170)	◆◆◆	5,500	700
Wetland Basin	6	6	77	76	650	260	2,800 (870, 6,900)	1,000 (550, 1,500)	◇◆◆	15,000	3,800
Wetland Basin/ Retention Pond	10	10	146	141	580	41	2,300 (1,400, 3,500)	450 (200, 700)	◆◆◆	11,000	1,600

2.2.3 Fecal Coliform

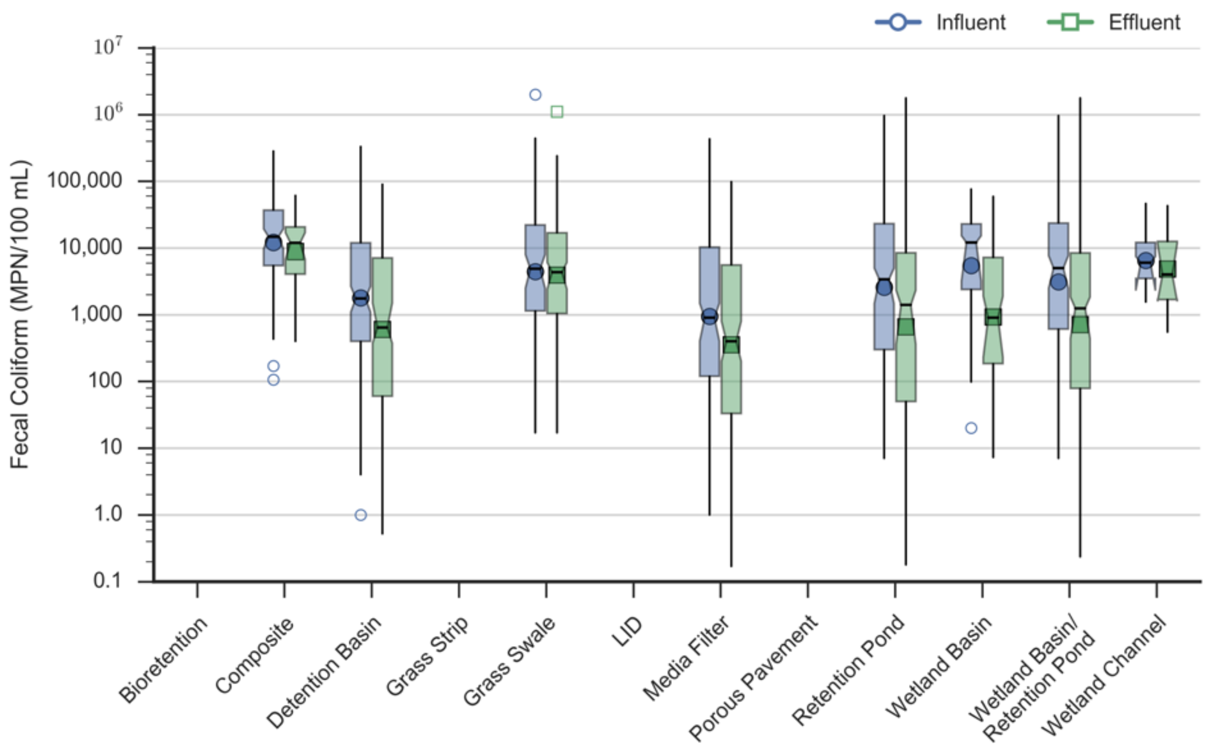

Figure 2-4. Box plots of influent/effluent fecal coliform concentrations.

Table 2-4. Influent/Effluent Summary Statistics for Fecal Coliform (MPN/100 mL)

BMP Category	BMPs		EMCs		25th		Median			75th	
	In	Out	In	Out	In	Out	In	Out	Difference	In	Out
Composite	4	4	64	56	5,500	4,100	15,000 (9,500, 19,000)	12,000 (6,800, 17,000)	◇◇◇	37,000	21,000
Detention Basin	15	15	170	194	400	60	1,800 (1,100, 2,800)	640 (370, 1,500)	◇◆◆	12,000	7,100
Grass Swale	12	11	91	82	1,100	1,000	4,900 (2,500, 7,000)	4,400 (2,400, 6,200)	◇◇◇	22,000	17,000
Media Filter	15	15	184	169	120	33	900 (400, 1,500)	400 (200, 800)	◇◆◆	10,000	5,600
Retention Pond	10	12	121	161	300	50	3,400 (1,500, 5,000)	1,400 (360, 2,300)	◇◆◆	23,000	8,500
Wetland Basin	5	5	42	39	2,400	180	12,000 (3,200, 15,000)	900 (230, 1,900)	◆◆◆	23,000	7,200
Wetland Basin/ Retention Pond	15	17	163	200	610	79	5,000 (2,600, 7,300)	1,200 (450, 1,800)	◆◆◆	23,000	8,500
Wetland Channel	3	3	21	20	3,500	1,700	6,000 (2,300, 7,500)	4,000 (1,600, 11,000)	◇◇◇	12,000	12,000

2.3 Metals

Metals performance summaries are provided for total and dissolved forms of arsenic, cadmium, chromium, copper, iron, lead, nickel, and zinc. Some inflow-outflow comparisons for certain metals are affected by large percentages of non-detects. For BMP-pollutant combinations where influent results have more than 50% non-detects in the influent, a footnote has been added to the summary table.

2.3.1 Arsenic

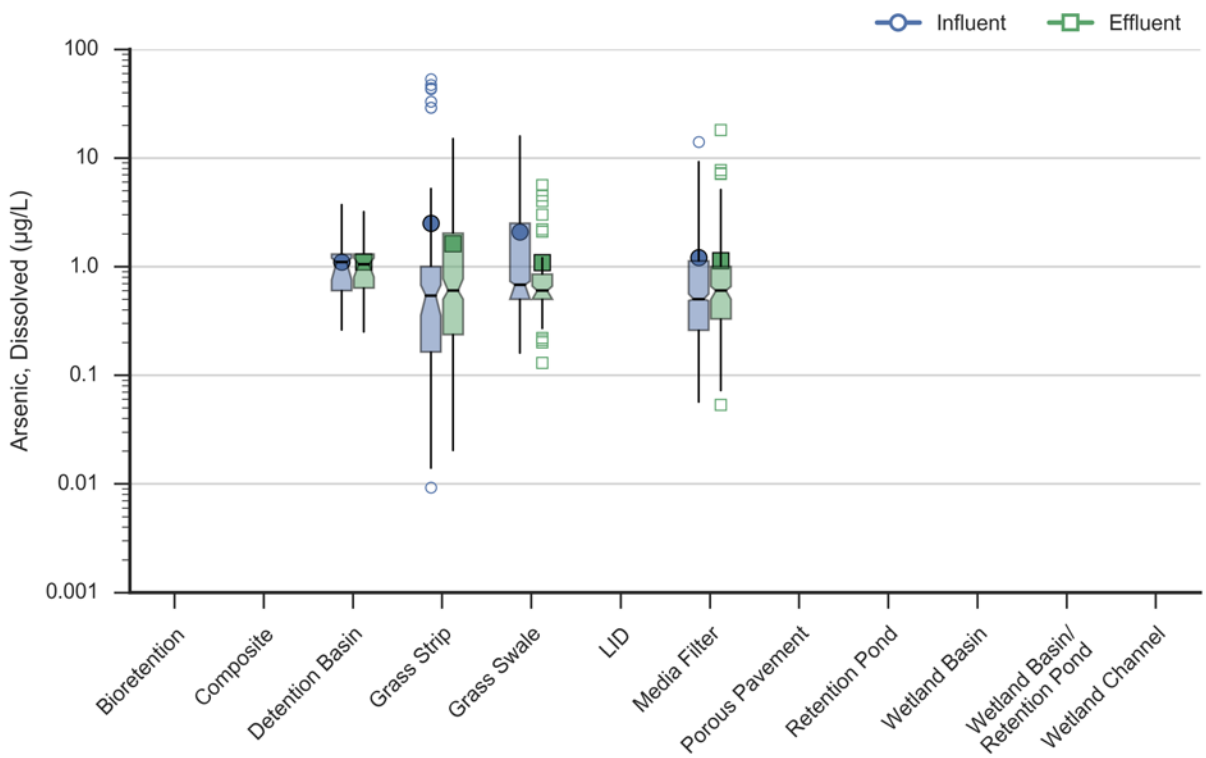

Figure 2-5. Box plots of influent/effluent dissolved arsenic concentrations.

Table 2-5. Influent/Effluent Summary Statistics for Dissolved Arsenic (µg/L)

BMP Category	BMPs		EMCs		25th		Median			75th	
	In	Out	In	Out	In	Out	In	Out	Difference	In	Out
Detention Basin	5	5	44	42	0.60	0.63	1.10 (0.77, 1.20)	1.05 (0.80, 1.20)	◇◇◇	1.30	1.30
Grass Strip	11	11	208	148	0.16	0.24	0.54 (0.35, 0.67)	0.60 (0.50, 0.77)	◇◆◆	1.00	2.02
Grass Swale	9	8	51	37	0.50	0.50	0.68 (0.50, 0.73)	0.60 (0.50, 0.62)	◇◇◇	2.50	0.85
Media Filter	9	9	104	100	0.26	0.33	0.50 (0.48, 0.56)	0.60 (0.50, 0.66)	◇◇◆	1.13	1.00

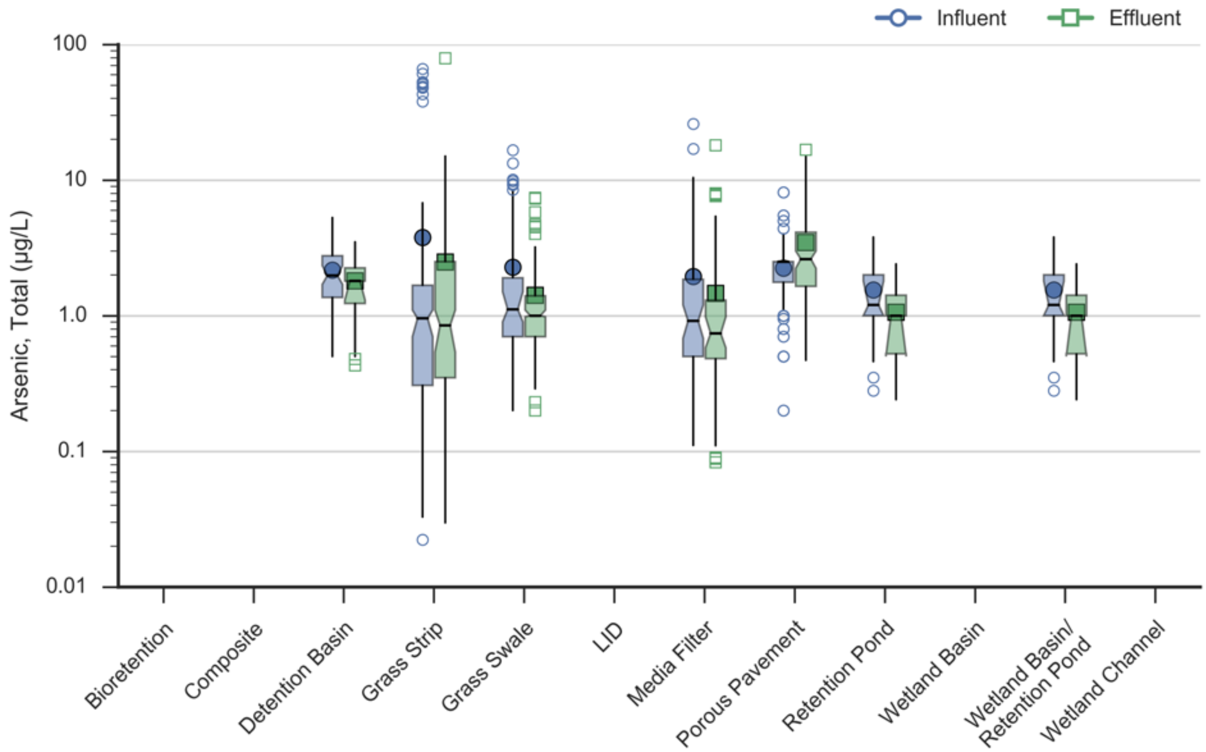

Figure 2-6. Box plots of influent/effluent total arsenic concentrations.

Table 2-6. Influent/Effluent Summary Statistics for Total Arsenic (µg/L)

BMP Category	BMPs		EMCs		25th		Median			75th	
	In	Out	In	Out	In	Out	In	Out	Difference	In	Out
Detention Basin	6	6	75	47	1.36	1.23	1.98 (1.70, 2.34)	1.80 (1.30, 1.80)	◇◇◆	2.76	2.25
Grass Strip	11	11	206	149	0.31	0.35	0.96 (0.70, 1.10)	0.85 (0.54, 1.10)	◇◇◆	1.68	2.50
Grass Swale	10	9	93	109	0.70	0.70	1.11 (0.90, 1.50)	1.00 (0.98, 1.10)	◇◇◆	1.90	1.40
Media Filter	9	9	104	100	0.50	0.48	0.91 (0.69, 1.20)	0.74 (0.58, 0.98)	◇◇◇	1.85	1.30
Porous Pavement	4	4	270	128	1.76	1.65	2.50 (2.50, 2.50)	2.62 (2.23, 2.99)	◇◆◆	2.50	4.12
Retention Pond	4	4	25	23	1.00	0.52	1.20 (1.00, 1.80)	1.00 (0.55, 1.00)	◇◇◇	2.00	1.41
Wetland Basin/ Retention Pond	4	4	25	23	1.00	0.52	1.20 (1.00, 1.80)	1.00 (0.50, 1.00)	◇◇◇	2.00	1.41

Note: Porous pavement summary statistics and statistical comparisons should be used with caution due to a high percentage of non-detects in the influent.

2.3.2 Cadmium

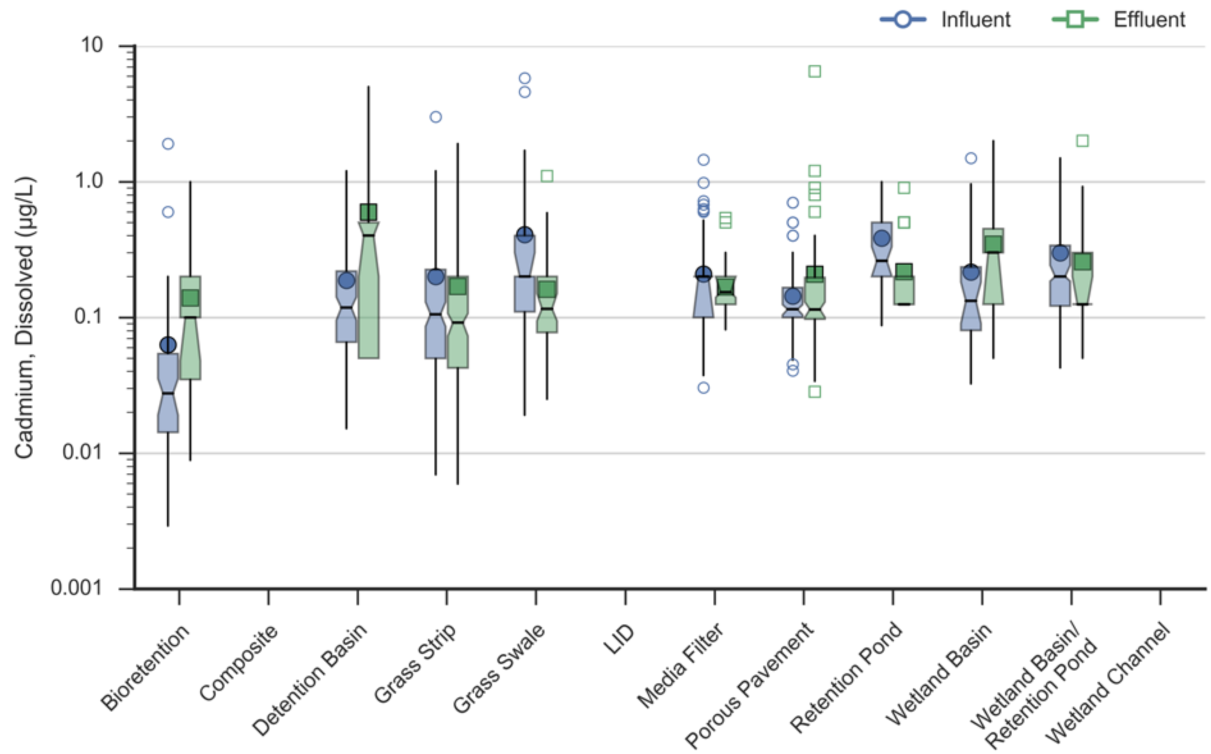

Figure 2-7. Box plots of influent/effluent dissolved cadmium concentrations.

Table 2-7. Influent/Effluent Summary Statistics for Dissolved Cadmium (µg/L)

BMP Category	BMPs		EMCs		25th		Median			75th	
	In	Out	In	Out	In	Out	In	Out	Difference	In	Out
Bioretention	4	4	105	95	0.01	0.03	0.03 (0.02, 0.04)	0.10 (0.05, 0.10)	◆◆◆	0.05	0.20
Detention Basin	8	8	126	141	0.07	0.05	0.12 (0.10, 0.14)	0.40 (0.20, 0.50)	◆◆◇	0.22	0.50
Grass Strip	11	11	207	148	0.05	0.04	0.11 (0.09, 0.19)	0.09 (0.07, 0.11)	◇◇◇	0.23	0.20
Grass Swale	13	12	88	74	0.11	0.08	0.20 (0.20, 0.30)	0.12 (0.09, 0.15)	◆◆◆	0.40	0.20
Media Filter	10	10	106	102	0.10	0.12	0.20 (0.10, 0.20)	0.15 (0.14, 0.20)	◇◇◆	0.20	0.20
Porous Pavement	4	4	280	133	0.10	0.10	0.11 (0.10, 0.12)	0.11 (0.10, 0.13)	◇◇◇	0.17	0.20
Retention Pond	3	3	40	69	0.20	0.12	0.26 (0.20, 0.33)	0.12 (0.12, 0.12)	◆◆◆	0.50	0.20
Wetland Basin	4	4	36	30	0.08	0.12	0.13 (0.09, 0.18)	0.30 (0.12, 0.30)	◇◆◇	0.24	0.45
Wetland Basin/ Retention Pond	7	7	90	99	0.12	0.12	0.20 (0.18, 0.24)	0.12 (0.12, 0.20)	◇◇◇	0.34	0.30

Note: Bioretention, detention basin, porous pavement, retention pond, wetland basin and wetland basin/retention pond summary statistics and statistical comparisons should be used with caution due to a high percentage of non-detects in the influent.

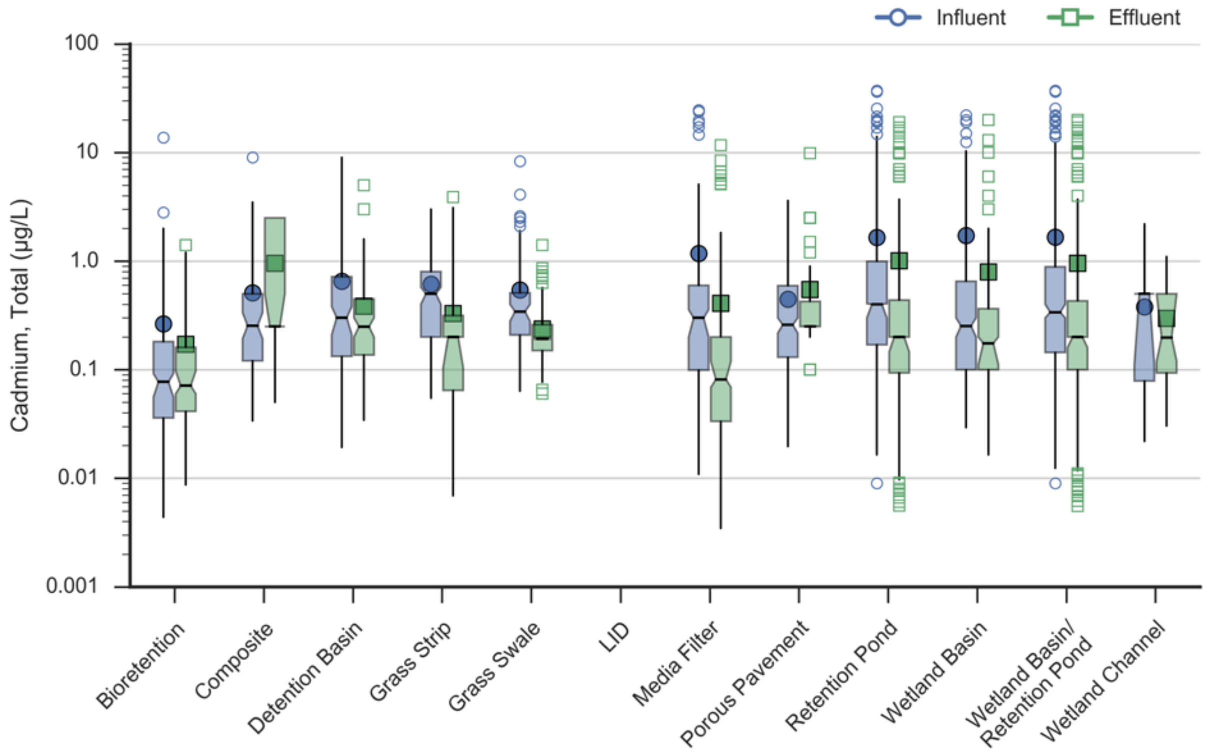

Figure 2-8. Box plots of influent/effluent total cadmium concentrations.

Table 2-8. Influent/Effluent Summary Statistics for Total Cadmium (µg/L)

BMP Category	BMPs		EMCs		25th		Median			75th	
	In	Out	In	Out	In	Out	In	Out	Difference	In	Out
Bioretention	6	6	144	110	0.04	0.04	0.08 (0.05, 0.09)	0.07 (0.06, 0.10)	◇◇◇	0.18	0.16
Composite	5	5	90	87	0.12	0.25	0.25 (0.19, 0.34)	0.25 (0.25, 0.50)	◇◆◇	0.50	2.50
Detention Basin	12	12	150	154	0.13	0.14	0.30 (0.21, 0.39)	0.25 (0.20, 0.30)	◇◇◆	0.72	0.45
Grass Strip	11	11	208	148	0.20	0.06	0.50 (0.40, 0.57)	0.20 (0.11, 0.20)	◆◆◆	0.80	0.32
Grass Swale	16	15	185	195	0.21	0.15	0.34 (0.28, 0.40)	0.19 (0.19, 0.20)	◆◆◆	0.51	0.26
Media Filter	16	16	194	194	0.10	0.03	0.30 (0.20, 0.36)	0.08 (0.07, 0.12)	◆◆◆	0.60	0.20
Porous Pavement	4	4	270	140	0.13	0.25	0.26 (0.22, 0.30)	0.25 (0.25, 0.25)	◇◇◆	0.59	0.43
Retention Pond	25	25	383	408	0.17	0.09	0.40 (0.29, 0.41)	0.20 (0.14, 0.20)	◆◆◆	1.00	0.44
Wetland Basin	7	7	125	136	0.10	0.10	0.25 (0.20, 0.30)	0.18 (0.11, 0.20)	◆◆◇	0.65	0.36
Wetland Basin/ Retention Pond	32	32	508	544	0.14	0.10	0.34 (0.30, 0.40)	0.20 (0.16, 0.20)	◆◆◆	0.89	0.43
Wetland Channel	6	6	63	49	0.08	0.09	0.50 (0.11, 0.50)	0.20 (0.12, 0.50)	◇◇◇	0.50	0.50

Note: Bioretention, composite, detention basin, and porous pavement summary statistics and statistical comparisons should be used with caution due to a high percentage of non-detects in the influent.

2.3.3 Chromium

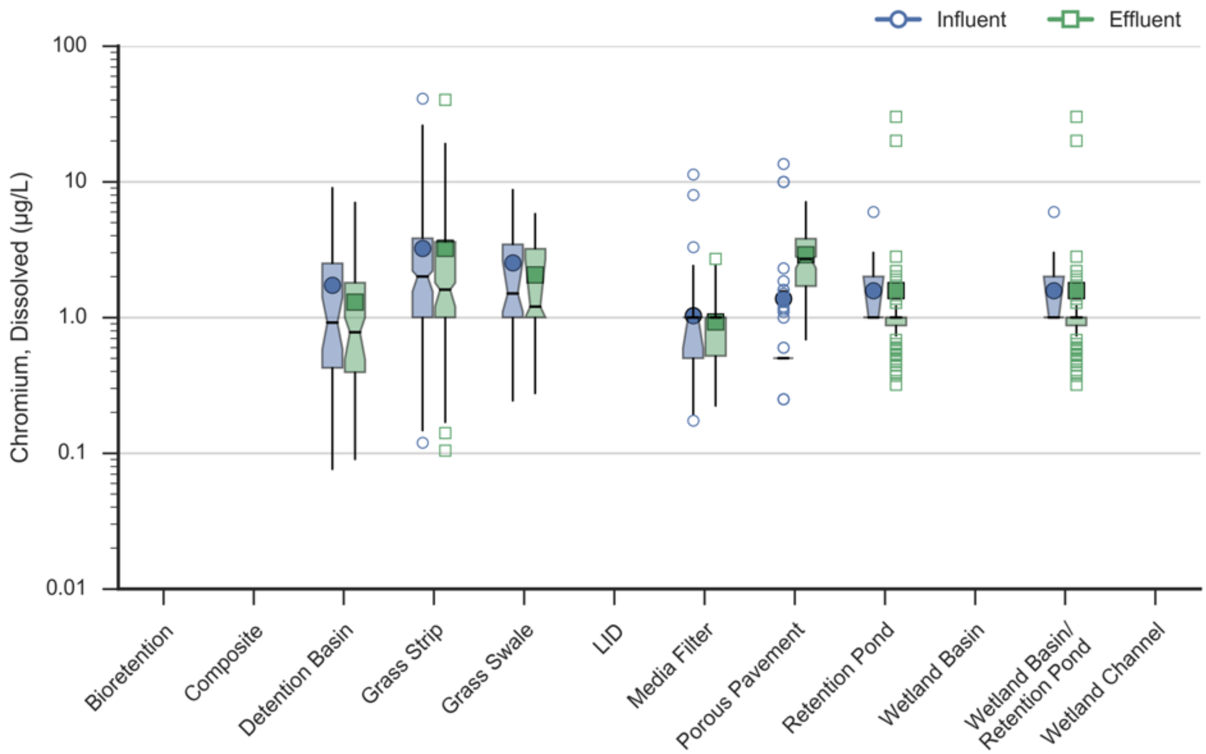

Figure 2-9. Box Plots of plots of influent/effluent dissolved chromium concentrations.

Table 2-9. Influent/Effluent Summary Statistics for Dissolved Chromium (µg/L)

BMP Category	BMPs		EMCs		25th		Median			75th	
	In	Out	In	Out	In	Out	In	Out	Difference	In	Out
Detention Basin	4	4	53	46	0.42	0.39	0.91 (0.55, 1.30)	0.78 (0.50, 1.00)	◇◇◆	2.50	1.80
Grass Strip	11	11	208	148	1.00	1.00	2.00 (1.55, 2.20)	1.60 (1.20, 1.80)	◇◇◇	3.82	3.60
Grass Swale	7	6	43	29	1.00	1.00	1.50 (1.10, 2.60)	1.20 (1.00, 2.70)	◇◇◇	3.45	3.20
Media Filter	10	10	114	99	0.50	0.52	1.00 (0.60, 1.00)	1.00 (1.00, 1.00)	◇◇◆	1.00	1.00
Porous Pavement	4	4	292	133	0.50	1.70	0.50 (0.50, 0.50)	2.70 (2.30, 2.80)	◆◆◆	0.50	3.80
Retention Pond	4	4	41	81	1.00	0.87	1.00 (1.00, 2.00)	1.00 (1.00, 1.00)	◇◆◇	2.00	1.00
Wetland Basin/ Retention Pond	4	4	41	81	1.00	0.87	1.00 (1.00, 2.00)	1.00 (1.00, 1.00)	◇◆◇	2.00	1.00

Note: Detention basin and porous pavement summary statistics and statistical comparisons should be used with caution due to a high percentage of non-detects in the influent.

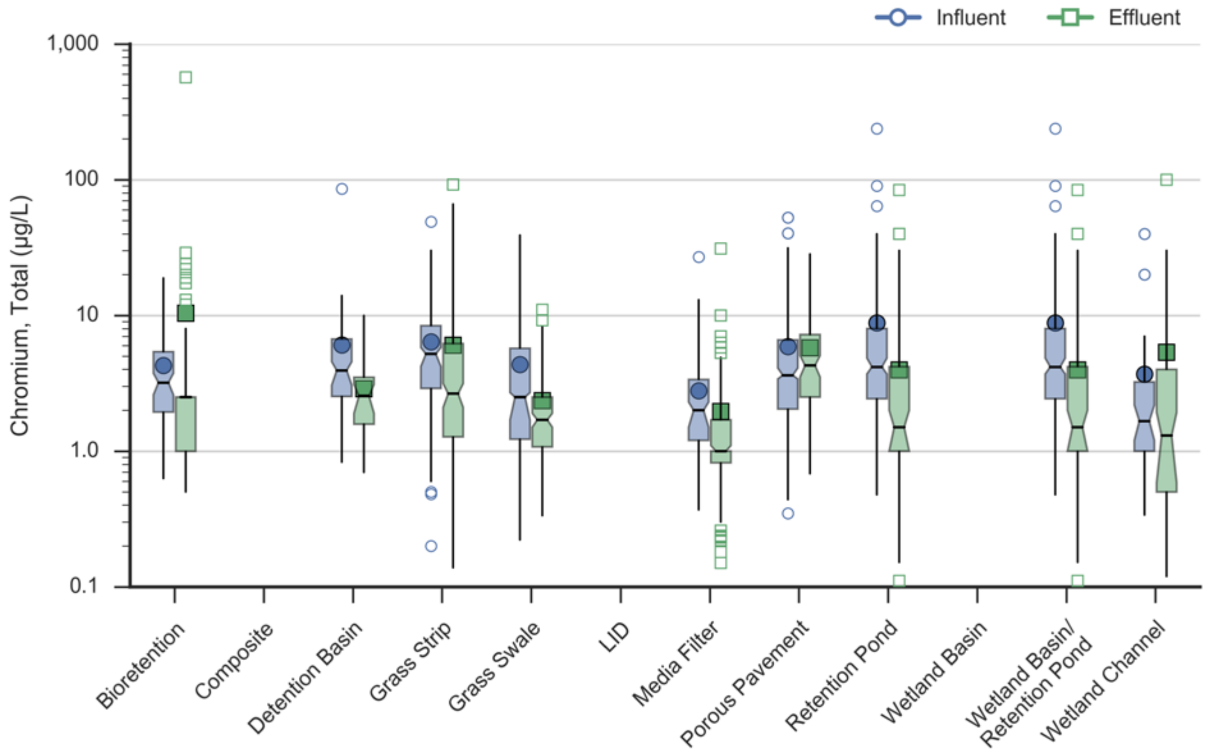

Figure 2-10. Box plots of influent/effluent total chromium concentrations.

Table 2-10. Influent/Effluent Summary Statistics for Total Chromium (µg/L)

BMP Category	BMPs		EMCs		25th		Median			75th	
	In	Out	In	Out	In	Out	In	Out	Difference	In	Out
Bioretention	3	3	89	83	1.94	1.00	3.20 (2.60, 3.75)	2.50 (2.50, 2.50)	◆◆◆	5.40	2.50
Detention Basin	5	5	68	61	2.53	1.58	3.93 (3.10, 4.62)	2.55 (1.90, 3.10)	◇◆◆	6.70	3.50
Grass Strip	12	12	211	152	2.90	1.27	5.20 (4.20, 5.80)	2.65 (2.05, 3.10)	◆◆◆	8.40	6.20
Grass Swale	8	7	86	100	1.23	1.08	2.50 (1.75, 2.70)	1.70 (1.50, 1.90)	◇◆◆	5.73	2.50
Media Filter	10	10	115	109	1.20	0.82	2.00 (1.50, 2.30)	1.00 (1.00, 1.10)	◆◆◆	3.37	1.70
Porous Pavement	4	4	300	143	2.04	2.50	3.62 (3.40, 4.10)	4.28 (3.51, 5.06)	◇◇◇	6.60	7.23
Retention Pond	13	13	170	168	2.43	1.00	4.18 (3.70, 4.85)	1.50 (1.00, 2.00)	◆◆◆	8.00	4.19
Wetland Basin/ Retention Pond	13	13	170	168	2.43	1.00	4.18 (3.70, 4.85)	1.50 (1.00, 2.00)	◆◆◆	8.00	4.19
Wetland Channel	3	3	70	55	1.00	0.50	1.67 (1.20, 2.19)	1.30 (0.59, 1.93)	◇◇◆	3.23	4.00

Note: Bioretention and porous pavement summary statistics and statistical comparisons should be used with caution due to a high percentage of non-detects in the influent.

2.3.4 Copper

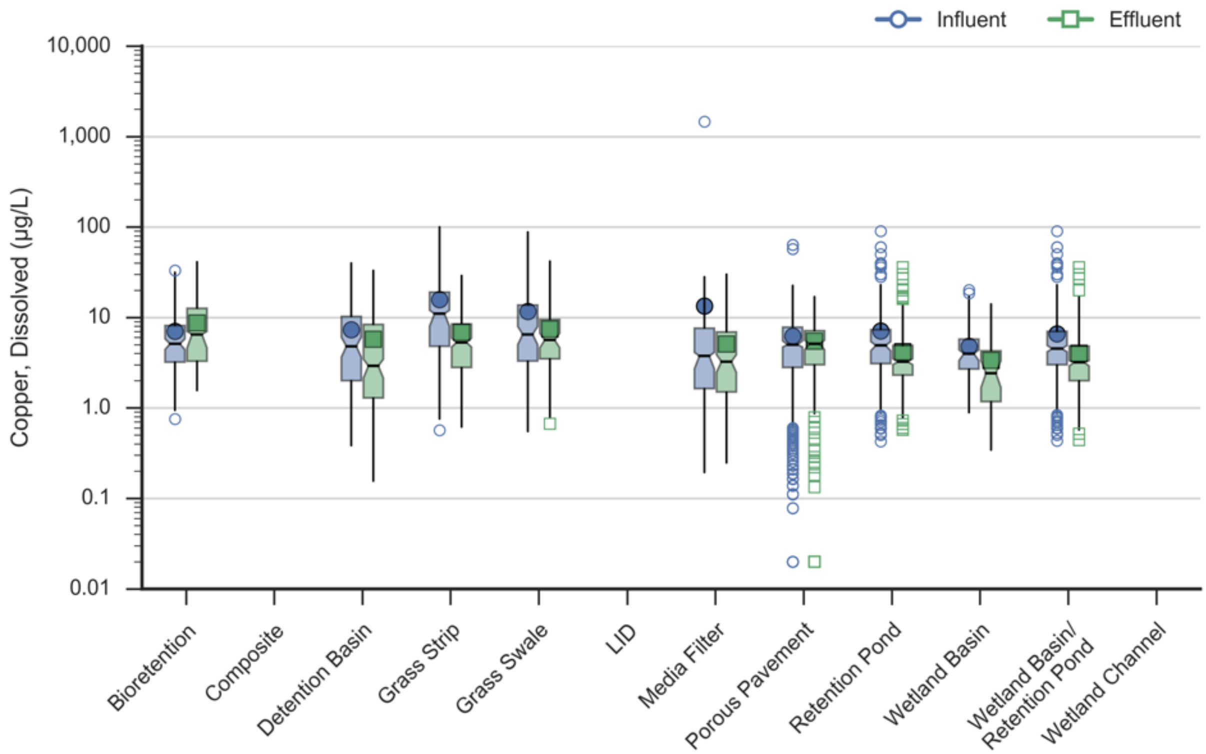

Figure 2-11. Box plots of influent/effluent dissolved copper concentrations.

Table 2-11. Influent/Effluent Summary Statistics for Dissolved Copper (µg/L)

BMP Category	BMPs		EMCs		25th		Median			75th	
	In	Out	In	Out	In	Out	In	Out	Difference	In	Out
Bioretention	7	7	143	127	3.21	3.28	5.11 (4.41, 5.80)	6.50 (4.70, 7.10)	◇◇◆	8.13	12.60
Detention Basin	9	9	186	196	2.00	1.29	4.80 (3.65, 6.00)	2.92 (2.14, 3.45)	◆◆◆	10.25	8.36
Grass Strip	11	11	221	159	4.80	2.80	11.00 (8.00, 12.00)	5.30 (4.70, 6.00)	◆◆◆	19.00	8.45
Grass Swale	16	16	172	139	3.29	3.49	6.50 (5.00, 7.93)	5.63 (4.61, 6.70)	◇◇◆	13.70	9.48
Media Filter	11	11	189	176	1.63	1.50	3.75 (2.70, 4.10)	3.25 (2.53, 3.90)	◇◇◆	7.60	6.90
Porous Pavement	7	7	381	216	2.80	3.00	5.00 (4.70, 5.50)	5.10 (4.40, 5.60)	◇◇◆	7.80	7.12
Retention Pond	16	16	363	364	3.08	2.30	4.90 (4.28, 5.40)	3.23 (3.00, 3.50)	◆◆◆	7.33	4.89
Wetland Basin	6	6	106	100	2.69	1.17	3.98 (3.33, 4.38)	2.42 (1.69, 3.33)	◇◆◆	5.75	4.27
Wetland Basin/ Retention Pond	22	22	469	464	3.00	2.00	4.51 (4.17, 4.90)	3.20 (2.90, 3.33)	◆◆◆	7.00	4.82

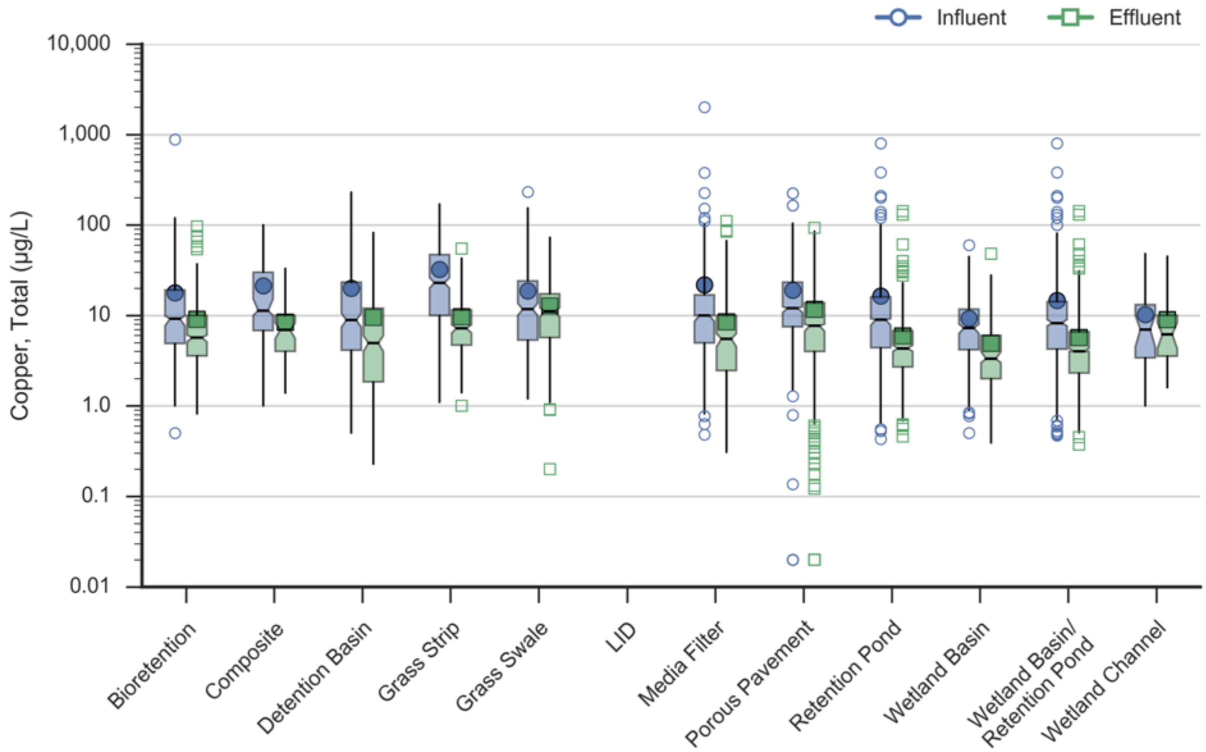

Figure 2-12. Box plots of influent/effluent total copper concentrations.

Table 2-12. Influent/Effluent Summary Statistics for Total Copper (µg/L)

BMP Category	BMPs		EMCs		25th		Median			75th	
	In	Out	In	Out	In	Out	In	Out	Difference	In	Out
Bioretention	14	14	333	300	4.90	3.57	9.20 (7.66, 9.97)	5.70 (5.09, 6.08)	◆◆◆	19.10	10.00
Composite	6	6	108	98	6.82	4.01	11.30 (10.00, 14.94)	6.89 (5.47, 8.27)	◆◆◆	30.00	10.00
Detention Basin	15	15	249	250	4.12	1.84	8.88 (7.41, 10.40)	4.95 (4.00, 6.00)	◆◆◆	23.30	12.00
Grass Strip	12	12	225	163	10.00	4.70	23.00 (19.00, 26.00)	7.20 (6.40, 7.90)	◆◆◆	47.00	11.50
Grass Swale	20	20	363	328	5.34	5.70	11.70 (10.00, 13.50)	11.10 (9.60, 12.20)	◇◆◆	24.05	17.33
Media Filter	20	20	345	330	4.97	2.46	9.98 (8.60, 10.00)	5.53 (4.58, 6.30)	◆◆◆	16.87	10.00
Porous Pavement	11	11	439	262	7.50	4.00	12.00 (10.80, 12.50)	7.70 (6.70, 8.00)	◆◆◆	23.30	13.76
Retention Pond	41	41	732	723	4.40	2.69	9.00 (7.75, 9.20)	4.32 (4.00, 4.69)	◆◆◆	16.00	6.76
Wetland Basin	10	10	243	238	4.18	2.00	7.26 (6.33, 8.00)	3.32 (3.00, 3.99)	◆◆◆	11.74	6.00
Wetland Basin/ Retention Pond	51	51	975	961	4.25	2.31	8.24 (7.69, 9.00)	4.00 (4.00, 4.33)	◆◆◆	14.20	6.58
Wetland Channel	6	6	97	80	3.40	3.55	7.00 (4.50, 10.00)	6.18 (4.42, 8.10)	◇◇◆	13.16	10.03

2.3.5 Iron

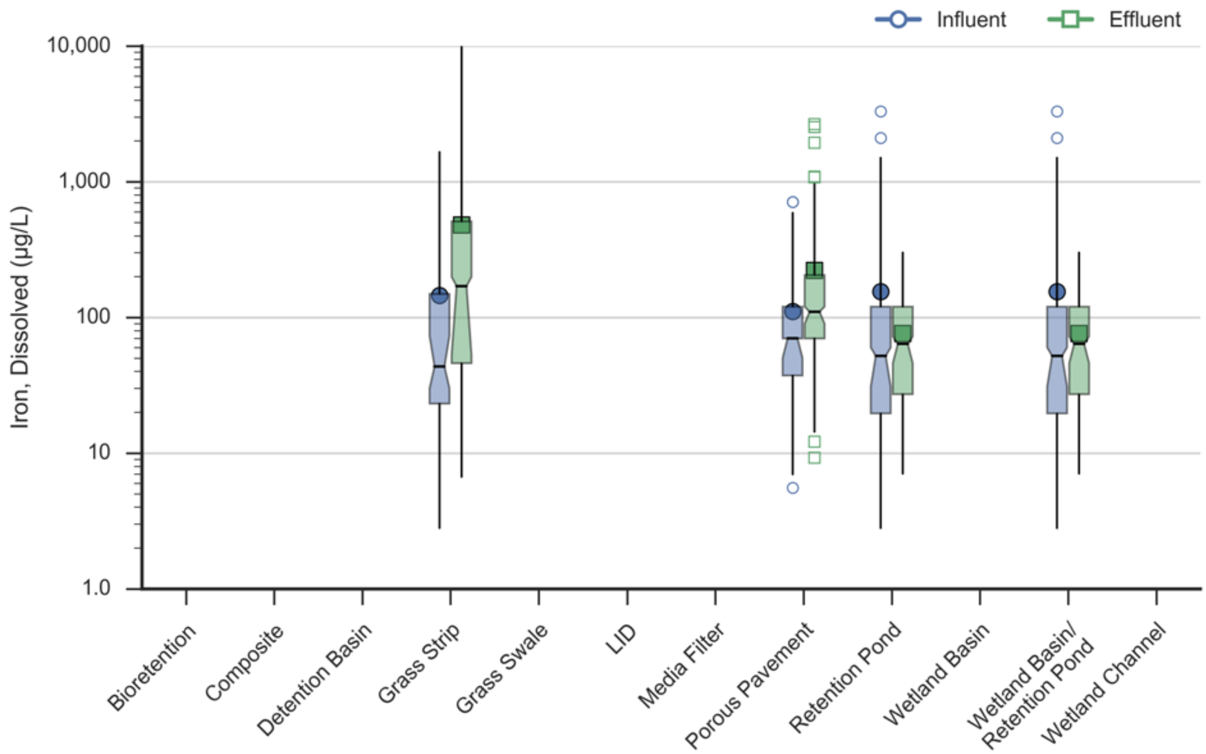

Figure 2-13. Box plots of influent/effluent dissolved iron concentrations.

Table 2-13. Influent/Effluent Summary Statistics for Dissolved Iron (µg/L)

BMP Category	BMPs		EMCs		25th		Median			75th	
	In	Out	In	Out	In	Out	In	Out	Difference	In	Out
Grass Strip	4	4	67	53	23.2	46.0	43.6 (30.0, 73.0)	170.0 (53.0, 199.0)	◇◆◆	149.0	510.0
Porous Pavement	4	4	290	139	37.3	70.0	70.0 (60.0, 70.0)	110.0 (89.7, 120.0)	◆◆◆	120.0	205.0
Retention Pond	5	5	115	125	19.6	27.2	52.0 (31.0, 60.0)	64.0 (46.0, 72.2)	◇◇◆	120.0	120.0
Wetland Basin/ Retention Pond	5	5	115	125	19.6	27.2	52.0 (31.0, 60.0)	64.0 (46.0, 71.5)	◇◇◆	120.0	120.0

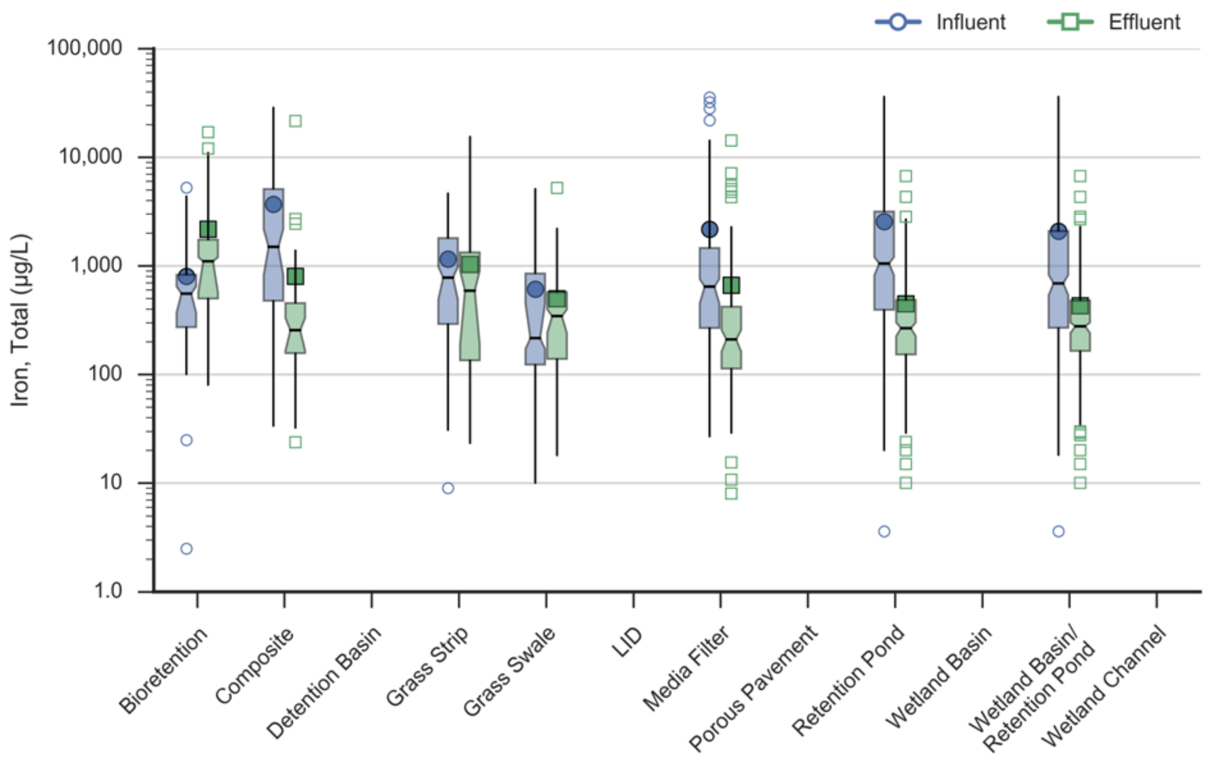

Figure 2-14. Box plots of influent/effluent total iron concentrations.

Table 2-14. Influent/Effluent Summary Statistics for Total Iron (µg/L)

BMP Category	BMPs		EMCs		25th		Median			75th	
	In	Out	In	Out	In	Out	In	Out	Difference	In	Out
Bioretention	4	4	54	52	272.5	500.0	556.3 (378.0, 645.0)	1100.0 (560.0, 1200.0)	◇◆◆	827.5	1740.0
Composite	3	3	67	56	476.8	157.1	1490.0 (820.0, 2170.0)	255.0 (165.0, 329.7)	◆◆◆	5095.0	454.0
Grass Strip	4	4	67	53	291.0	135.0	780.0 (490.0, 980.0)	590.0 (190.0, 897.0)	◇◇◆	1800.0	1330.0
Grass Swale	4	4	98	121	123.3	139.0	215.5 (171.5, 450.0)	344.0 (241.0, 390.0)	◇◇◇	850.0	572.0
Media Filter	8	7	153	132	267.8	113.2	642.3 (452.2, 755.0)	209.7 (162.8, 256.9)	◆◆◆	1460.0	420.7
Retention Pond	16	16	317	312	393.4	152.9	1051.0 (820.0, 1200.0)	266.37 (222.50, 301.0)	◆◆◆	3160.0	485.0
Wetland Basin/ Retention Pond	18	18	404	399	268.9	164.7	691.5 (543.5, 825.0)	278.0 (240.3, 300.0)	◆◆◆	2089.8	480.0

2.3.6 Lead

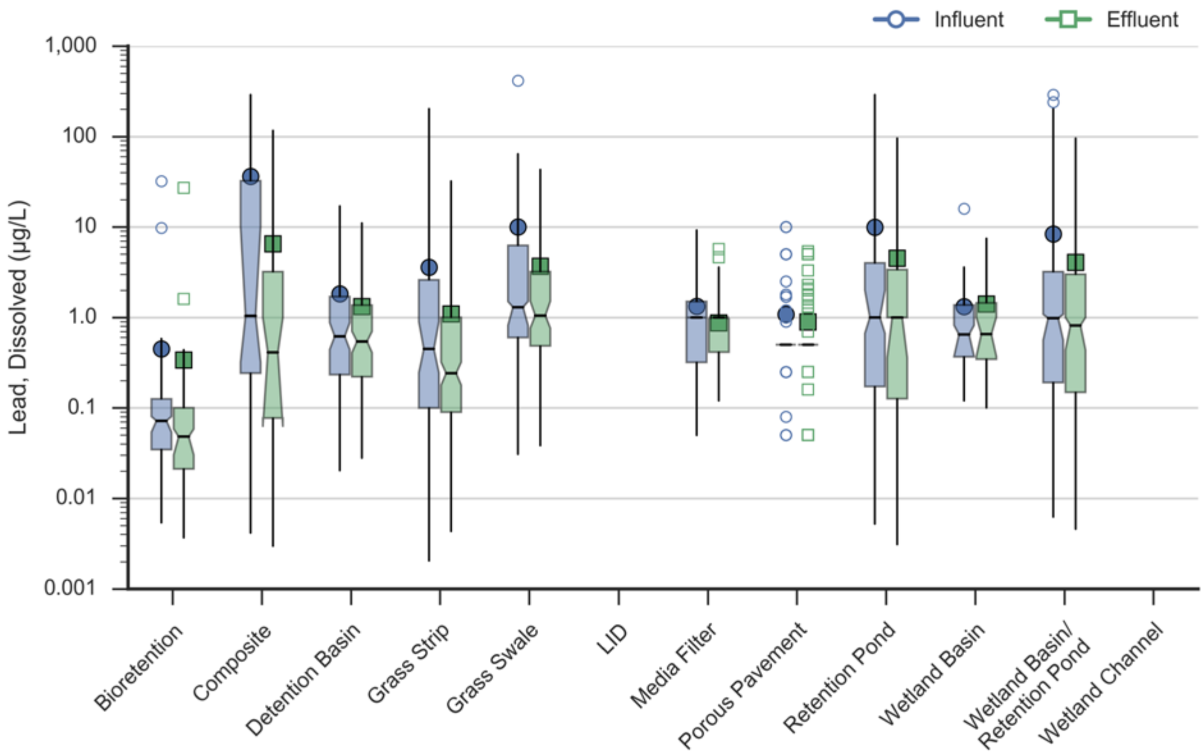

Figure 2-15. Box plots of influent/effluent dissolved lead concentrations.

Table 2-15. Influent/Effluent Summary Statistics for Dissolved Lead (µg/L)

BMP Category	BMPs		EMCs		25th		Median			75th	
	In	Out	In	Out	In	Out	In	Out	Difference	In	Out
Bioretention	5	5	118	108	0.03	0.02	0.07 (0.05, 0.08)	0.05 (0.03, 0.06)	◇◆◇	0.13	0.10
Composite	3	3	33	28	0.24	0.08	1.04 (0.32, 10.20)	0.41 (0.06, 1.00)	◇◇◆	32.40	3.20
Detention Basin	8	8	155	156	0.23	0.22	0.62 (0.44, 0.88)	0.54 (0.41, 0.70)	◇◇◇	1.70	1.37
Grass Strip	11	11	220	160	0.10	0.09	0.45 (0.25, 1.00)	0.24 (0.18, 0.32)	◇◆◆	2.60	1.00
Grass Swale	14	14	112	95	0.60	0.48	1.30 (0.79, 1.50)	1.05 (0.76, 1.60)	◇◇◆	6.25	3.21
Media Filter	10	10	144	140	0.32	0.41	1.00 (1.00, 1.00)	1.00 (0.49, 1.00)	◇◇◆	1.50	1.00
Porous Pavement	4	4	322	154	0.50	0.50	0.50 (0.50, 0.50)	0.50 (0.50, 0.50)	◇◇◇	0.50	0.50
Retention Pond	11	12	163	176	0.17	0.13	1.00 (0.66, 2.00)	1.00 (0.36, 1.00)	◇◇◇	4.00	3.38
Wetland Basin	4	4	36	30	0.37	0.35	0.65 (0.39, 0.82)	0.65 (0.37, 1.01)	◇◇◇	1.37	1.45
Wetland Basin/ Retention Pond	15	16	199	206	0.19	0.15	0.98 (0.56, 1.08)	0.82 (0.45, 1.00)	◇◇◇	3.20	3.00

Note: Bioretention, detention basin, porous pavement, and wetland basin summary statistics and statistical comparisons should be used with caution due to a high percentage of non-detects in the influent.

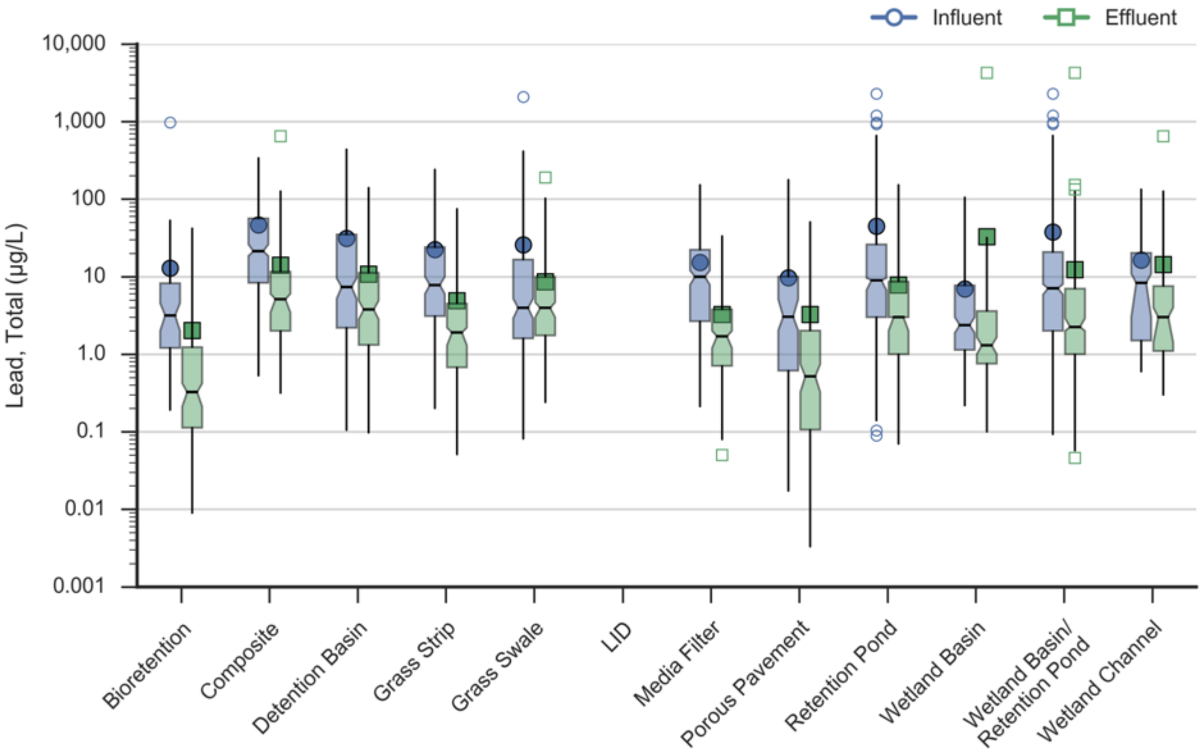

Figure 2-16. Box plots of influent/effluent total lead concentrations.

Table 2-16. Influent/Effluent Summary Statistics for Total Lead (µg/L)

BMP Category	BMPs		EMCs		25th		Median			75th	
	In	Out	In	Out	In	Out	In	Out	Difference	In	Out
Bioretention	8	8	176	162	1.20	0.11	3.16 (2.01, 4.59)	0.32 (0.21, 0.42)	◆◆◆	8.21	1.23
Composite	8	8	140	135	8.33	2.00	21.30 (18.48, 26.05)	5.12 (3.46, 6.00)	◆◆◆	56.33	11.60
Detention Basin	13	13	223	214	2.19	1.32	7.37 (5.20, 9.00)	3.76 (2.86, 5.14)	◆◆◆	35.00	11.20
Grass Strip	12	12	225	163	3.10	0.68	7.80 (6.00, 9.70)	1.90 (1.30, 2.20)	◆◆◆	24.00	4.50
Grass Swale	19	19	322	302	1.60	1.75	3.95 (2.90, 5.25)	3.95 (3.00, 4.73)	◇◇◆	16.58	9.90
Media Filter	20	19	303	289	2.66	0.71	10.00 (8.00, 12.00)	1.70 (1.20, 2.00)	◆◆◆	22.25	3.78
Porous Pavement	8	8	380	199	0.61	0.11	3.05 (1.99, 5.10)	0.52 (0.32, 0.73)	◆◆◆	10.00	2.01
Retention Pond	39	39	618	639	3.00	1.00	9.00 (6.70, 9.71)	3.00 (2.00, 3.00)	◆◆◆	26.04	8.62
Wetland Basin	8	8	145	141	1.14	0.76	2.37 (1.88, 3.00)	1.30 (1.00, 1.65)	◆◆◆	7.72	3.60
Wetland Basin/ Retention Pond	47	47	763	780	2.00	1.00	7.07 (6.00, 8.00)	2.25 (2.00, 2.89)	◆◆◆	20.80	7.00
Wetland Channel	9	9	119	105	1.50	1.10	8.30 (3.01, 10.90)	3.00 (1.67, 4.00)	◇◆◆	20.24	7.55

2.3.7 Nickel

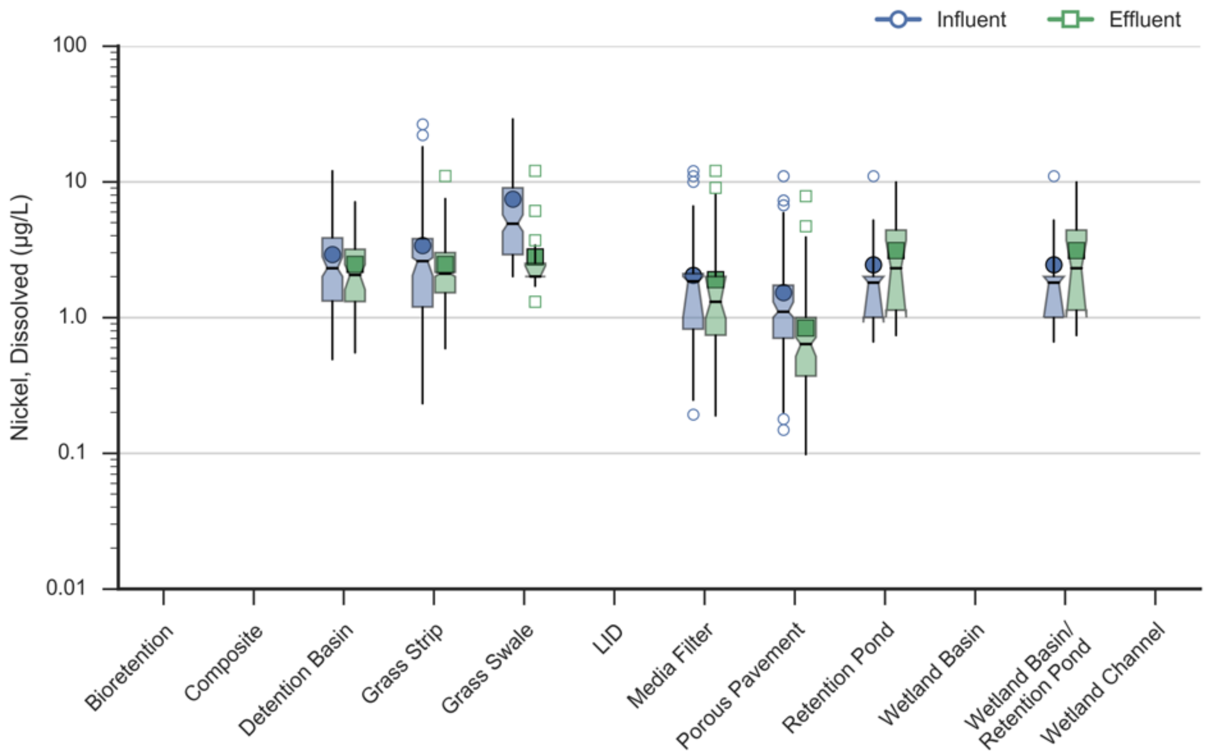

Figure 2-17. Box plots of influent/effluent dissolved nickel concentrations.

Table 2-17. Influent/Effluent Summary Statistics for Dissolved Nickel (µg/L)

BMP Category	BMPs		EMCs		25th		Median			75th	
	In	Out	In	Out	In	Out	In	Out	Difference	In	Out
Detention Basin	5	5	68	62	1.32	1.31	2.30 (2.00, 2.80)	2.05 (1.60, 2.45)	◇◇◇	3.85	3.18
Grass Strip	11	11	208	148	1.19	1.52	2.60 (2.06, 2.75)	2.10 (2.00, 2.15)	◇◇◆	3.80	3.00
Grass Swale	6	5	37	23	2.90	2.00	4.90 (3.10, 5.70)	2.00 (2.00, 2.40)	◆◆◆	9.00	2.50
Media Filter	10	10	113	109	0.82	0.74	1.85 (1.00, 2.00)	1.30 (0.98, 2.00)	◇◇◇	2.10	2.00
Porous Pavement	4	4	280	130	0.70	0.37	1.10 (1.00, 1.30)	0.63 (0.52, 0.71)	◆◆◆	1.73	1.00
Retention Pond	4	4	17	17	1.00	1.13	1.80 (1.00, 2.00)	2.30 (1.00, 3.70)	◇◇◆	2.00	4.40
Wetland Basin/ Retention Pond	4	4	17	17	1.00	1.13	1.80 (1.00, 2.00)	2.30 (1.00, 3.70)	◇◇◆	2.00	4.40

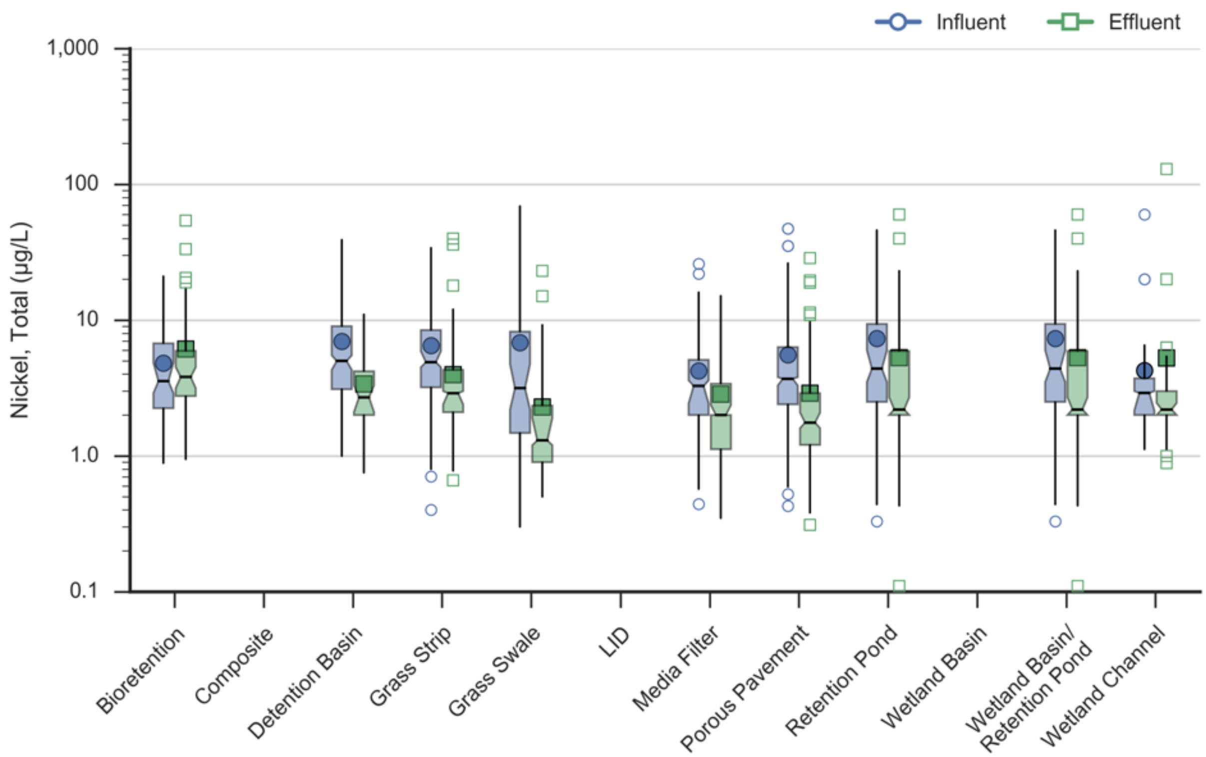

Figure 2-18. Box plots of influent/effluent total nickel concentrations.

Table 2-18. Influent/Effluent Summary Statistics for Total Nickel (µg/L)

BMP Category	BMPs		EMCs		25th		Median			75th	
	In	Out	In	Out	In	Out	In	Out	Difference	In	Out
Bioretention	3	3	82	76	2.25	2.76	3.55 (2.88, 4.84)	3.81 (3.15, 4.50)	◇◇◇	6.75	5.94
Detention Basin	6	6	76	70	3.10	2.00	5.00 (4.30, 5.50)	2.70 (2.09, 3.30)	◆◆◆	9.02	4.20
Grass Strip	11	11	207	149	3.20	2.10	4.90 (4.50, 5.90)	2.90 (2.37, 3.00)	◆◆◆	8.45	4.30
Grass Swale	7	6	80	95	1.47	0.90	3.15 (2.20, 4.80)	1.30 (1.20, 1.90)	◆◆◆	8.23	2.35
Media Filter	10	10	115	109	2.00	1.12	3.28 (2.43, 3.60)	2.00 (2.00, 2.37)	◆◆◆	5.10	3.40
Porous Pavement	4	4	300	143	2.40	1.21	3.70 (3.25, 3.80)	1.76 (1.60, 2.08)	◆◆◆	6.33	2.90
Retention Pond	10	10	113	109	2.50	2.00	4.39 (3.50, 6.00)	2.20 (2.00, 2.70)	◆◆◆	9.38	5.92
Wetland Basin/ Retention Pond	10	10	113	109	2.50	2.00	4.39 (3.50, 6.00)	2.20 (2.00, 2.70)	◆◆◆	9.38	5.92

2.3.8 Zinc

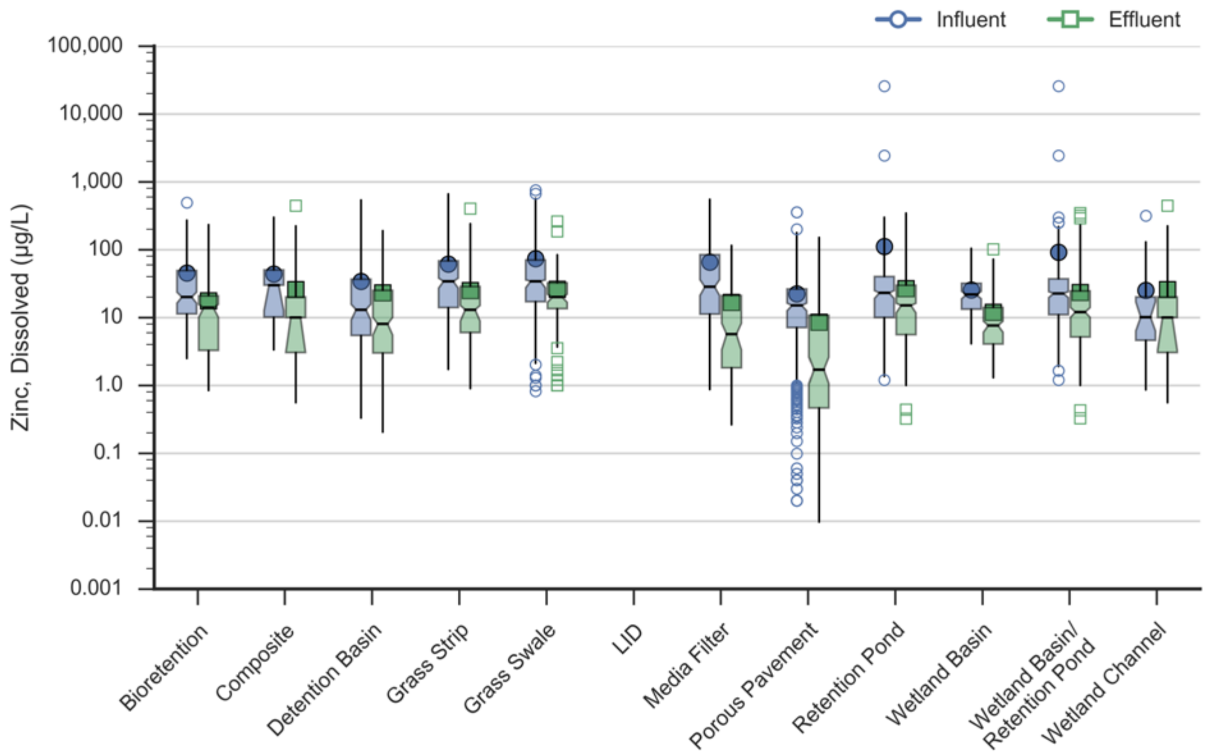

Figure 2-19. Box plots of influent/effluent dissolved zinc concentrations.

Table 2-19. Influent/Effluent Summary Statistics for Dissolved Zinc (µg/L)

BMP Category	BMPs		EMCs		25th		Median			75th	
	In	Out	In	Out	In	Out	In	Out	Difference	In	Out
Bioretention	6	6	144	132	11.30	3.28	19.95 (15.90, 23.60)	13.90 (10.00, 15.55)	◆◆◆	49.00	20.80
Composite	4	3	70	56	10.14	3.04	30.00 (13.23, 30.00)	10.00 (3.49, 10.00)	◆◆◆	50.00	20.00
Detention Basin	9	9	186	197	5.44	3.00	13.00 (9.10, 15.90)	8.00 (5.40, 10.00)	◇◆◆	36.57	25.00
Grass Strip	11	11	221	159	14.00	6.00	34.00 (27.00, 38.00)	13.00 (9.40, 15.00)	◆◆◆	68.00	28.50
Grass Swale	16	16	172	139	17.10	13.50	34.20 (27.30, 35.70)	19.90 (16.70, 22.00)	◆◆◆	70.12	32.30
Media Filter	11	11	189	174	11.20	1.81	28.20 (21.00, 36.00)	5.65 (3.37, 8.20)	◆◆◆	84.00	21.00
Porous Pavement	7	7	381	216	7.10	0.46	15.00 (12.50, 16.30)	1.70 (1.07, 2.64)	◆◆◆	26.20	10.75
Retention Pond	18	18	360	346	10.00	5.58	23.00 (18.99, 24.95)	15.00 (11.73, 16.20)	◆◆◆	40.00	29.75
Wetland Basin	6	6	106	100	13.25	4.07	21.75 (18.75, 24.25)	7.59 (6.04, 8.70)	◆◆◆	31.77	14.00
Wetland Basin/ Retention Pond	24	24	466	446	11.00	5.15	22.60 (19.55, 23.90)	12.00 (10.00, 14.00)	◆◆◆	37.00	24.53
Wetland Channel	3	3	64	56	4.61	3.04	10.09 (6.04, 16.90)	10.00 (3.04, 10.00)	◇◇◇	20.00	20.00

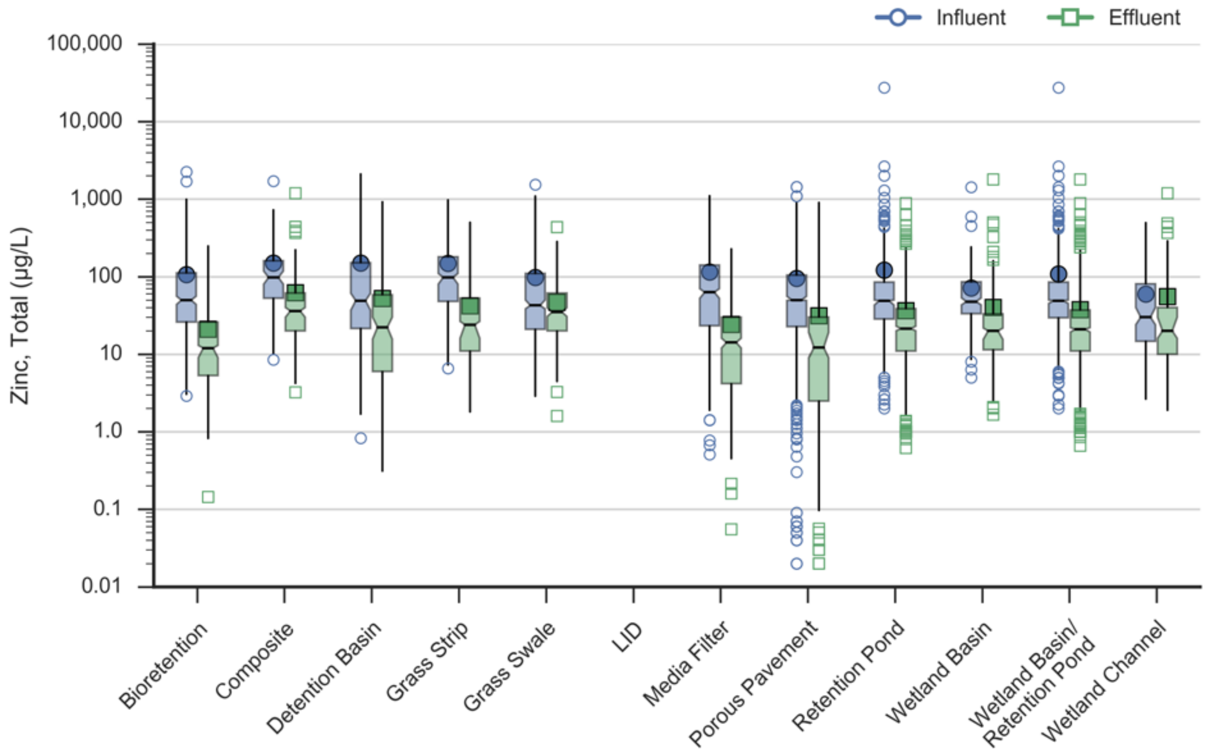

Figure 2-20. Box plots of influent/effluent total zinc concentrations.

Table 2-20. Influent/Effluent Summary Statistics for Total Zinc (µg/L)

BMP Category	BMPs		EMCs		25th		Median			75th	
	In	Out	In	Out	In	Out	In	Out	Difference	In	Out
Bioretention	15	15	367	334	26.00	5.31	49.80 (43.53, 56.00)	12.00 (9.00, 12.68)	◆◆◆	111.50	26.00
Composite	8	9	148	134	52.80	20.00	97.69 (80.00, 116.98)	36.15 (30.00, 40.00)	◆◆◆	160.30	61.56
Detention Basin	15	16	249	260	21.50	6.00	49.00 (37.00, 62.10)	22.29 (15.52, 30.00)	◆◆◆	151.00	58.25
Grass Strip	12	12	225	162	48.00	11.00	98.00 (80.00, 110.00)	24.00 (16.50, 27.00)	◆◆◆	180.00	52.75
Grass Swale	22	22	397	358	21.00	20.00	42.60 (38.40, 50.00)	35.00 (30.65, 39.80)	◇◆◆	110.00	61.40
Media Filter	23	23	387	358	23.30	4.18	62.90 (52.40, 70.00)	14.14 (12.00, 16.44)	◆◆◆	140.97	29.97
Porous Pavement	13	13	463	287	22.70	2.49	50.00 (49.20, 55.80)	12.20 (9.00, 19.10)	◆◆◆	104.75	30.05
Retention Pond	48	48	804	767	28.47	11.00	49.00 (43.10, 50.00)	21.37 (20.00, 23.00)	◆◆◆	85.00	38.60
Wetland Basin	13	13	271	266	33.35	11.42	47.63 (43.20, 54.00)	20.00 (15.17, 21.75)	◆◆◆	85.50	33.07
Wetland Basin/ Retention Pond	61	61	1075	1033	29.55	11.00	49.00 (44.23, 50.00)	21.00 (19.30, 22.00)	◆◆◆	85.00	37.00
Wetland Channel	8	8	135	113	14.70	10.00	30.00 (24.00, 40.00)	20.00 (16.00, 30.00)	◇◆◆	80.73	40.00

2.4 Nutrients

Nutrient analyses include several forms of nitrogen and phosphorus. Phosphorus analyses include total and dissolved phosphorus and orthophosphate. Nitrogen analyses include total nitrogen, total Kjeldahl nitrogen, nitrate, nitrate + nitrate, and a combined NOx category that includes both nitrate results and nitrate + nitrite results.

2.4.1 Phosphorus

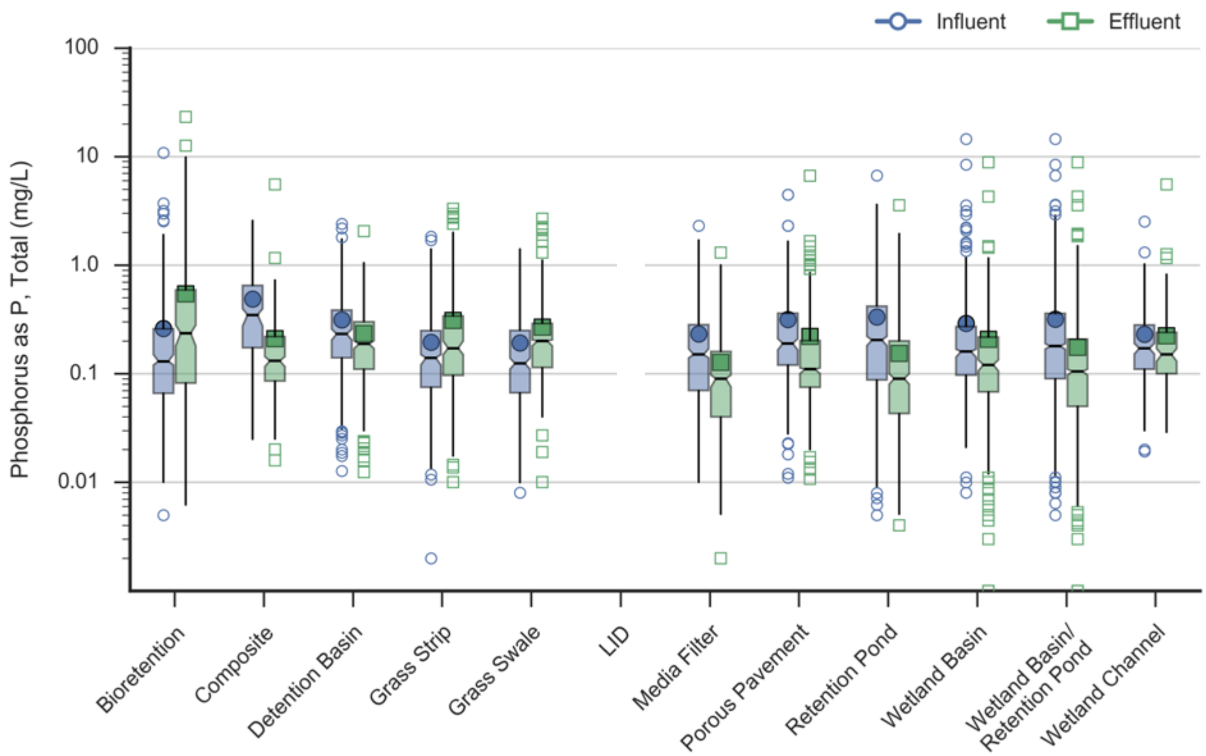

Figure 2-21. Box plots of influent/effluent total phosphorus concentrations.

Table 2-21. Influent/Effluent Summary Statistics for Total Phosphorus (mg/L)

	BMP Category	BMPs		EMCs		25th		Median			75th	
		In	Out	In	Out	In	Out	In	Out	Difference	In	Out
Phosphorus as P, Total (mg/L)	Bioretention	30	30	583	505	0.07	0.08	0.13 (0.12, 0.15)	0.24 (0.18, 0.28)	◆◆◆	0.26	0.59
	Composite	10	10	184	166	0.17	0.09	0.35 (0.28, 0.40)	0.13 (0.12, 0.14)	◆◆◆	0.65	0.22
	Detention Basin	31	31	397	412	0.14	0.11	0.23 (0.21, 0.26)	0.19 (0.17, 0.20)	◆◆◆	0.38	0.30
	Grass Strip	19	19	360	276	0.08	0.10	0.14 (0.12, 0.15)	0.17 (0.15, 0.20)	◇◆◆	0.25	0.34
	Grass Swale	23	23	436	445	0.07	0.11	0.12 (0.11, 0.14)	0.20 (0.18, 0.21)	◆◆◆	0.25	0.29
	Media Filter	23	22	372	349	0.07	0.04	0.15 (0.13, 0.15)	0.09 (0.07, 0.10)	◆◆◆	0.28	0.16
	Porous Pavement	8	8	373	219	0.12	0.07	0.19 (0.16, 0.21)	0.11 (0.10, 0.11)	◆◆◆	0.36	0.20
	Retention Pond	55	55	891	873	0.09	0.04	0.20 (0.18, 0.22)	0.09 (0.08, 0.10)	◆◆◆	0.42	0.20
	Wetland Basin	20	20	595	574	0.10	0.07	0.16 (0.14, 0.17)	0.12 (0.11, 0.13)	◆◆◆	0.27	0.22
	Wetland Basin/ Retention Pond	75	75	1486	1447	0.09	0.05	0.18 (0.17, 0.19)	0.10 (0.10, 0.11)	◆◆◆	0.36	0.21
	Wetland Channel	12	12	193	172	0.11	0.10	0.17 (0.15, 0.19)	0.15 (0.13, 0.17)	◇◇◆	0.28	0.24

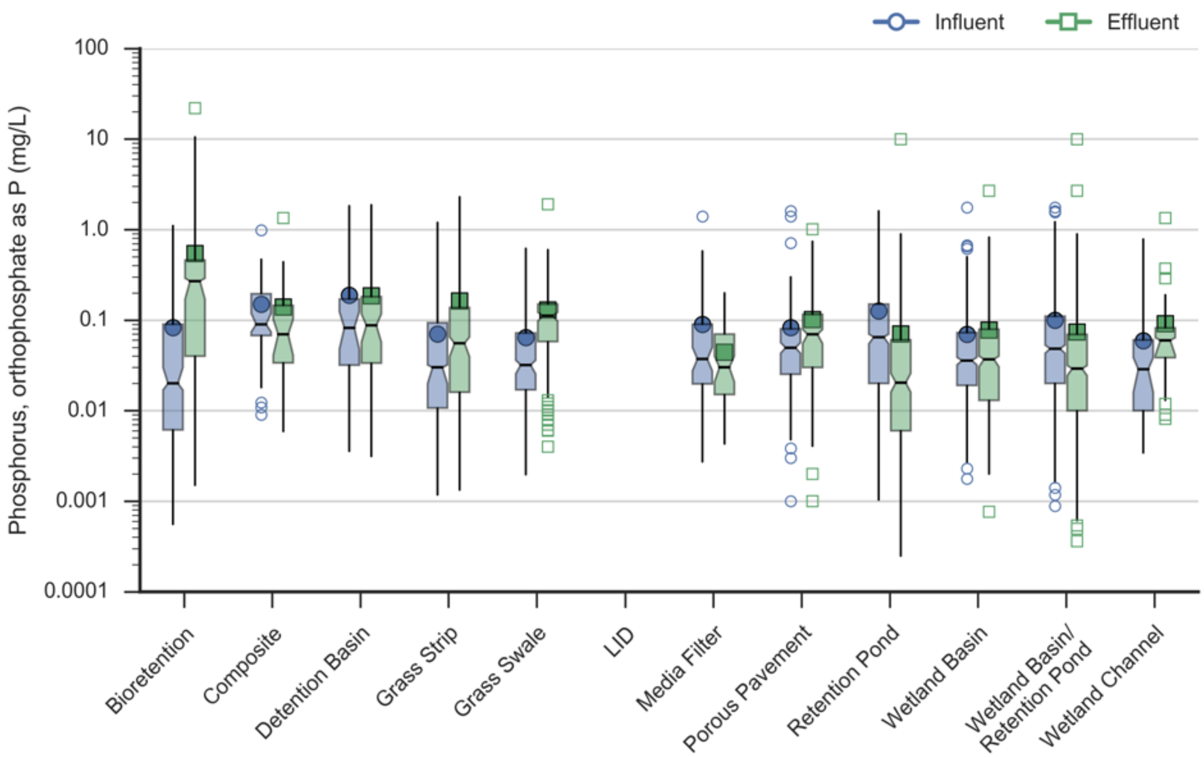

Figure 2-22. Box plots of influent/effluent orthophosphate concentrations.

Table 2-22. Influent/Effluent Summary Statistics for Orthophosphate (mg/L)

BMP Category	BMPs		EMCs		25th		Median			75th	
	In	Out	In	Out	In	Out	In	Out	Difference	In	Out
Bioretention	20	19	316	269	0.01	0.04	0.02 (0.02, 0.03)	0.27 (0.18, 0.29)	◆◆◆	0.09	0.46
Composite	4	3	54	42	0.07	0.03	0.09 (0.07, 0.12)	0.07 (0.04, 0.10)	◇◇◇	0.20	0.14
Detention Basin	8	8	72	75	0.03	0.03	0.08 (0.05, 0.12)	0.09 (0.06, 0.12)	◇◇◇	0.17	0.18
Grass Strip	13	13	275	218	0.01	0.02	0.03 (0.02, 0.03)	0.06 (0.04, 0.06)	◆◆◆	0.09	0.14
Grass Swale	7	7	218	217	0.02	0.06	0.03 (0.03, 0.04)	0.11 (0.10, 0.12)	◆◆◆	0.07	0.15
Media Filter	7	7	116	115	0.02	0.02	0.04 (0.03, 0.05)	0.03 (0.02, 0.04)	◇◇◆	0.09	0.07
Porous Pavement	6	6	174	114	0.03	0.03	0.05 (0.04, 0.06)	0.07 (0.05, 0.08)	◇◆◆	0.08	0.12
Retention Pond	33	33	524	508	0.02	0.01	0.06 (0.05, 0.07)	0.02 (0.02, 0.03)	◆◆◆	0.15	0.06
Wetland Basin	11	12	452	436	0.02	0.01	0.04 (0.03, 0.04)	0.04 (0.03, 0.04)	◇◇◆	0.07	0.08
Wetland Basin/ Retention Pond	44	45	976	944	0.02	0.01	0.05 (0.04, 0.05)	0.03 (0.02, 0.03)	◆◆◆	0.11	0.07
Wetland Channel	3	3	84	63	0.01	0.04	0.03 (0.02, 0.04)	0.06 (0.04, 0.06)	◆◆◆	0.06	0.08

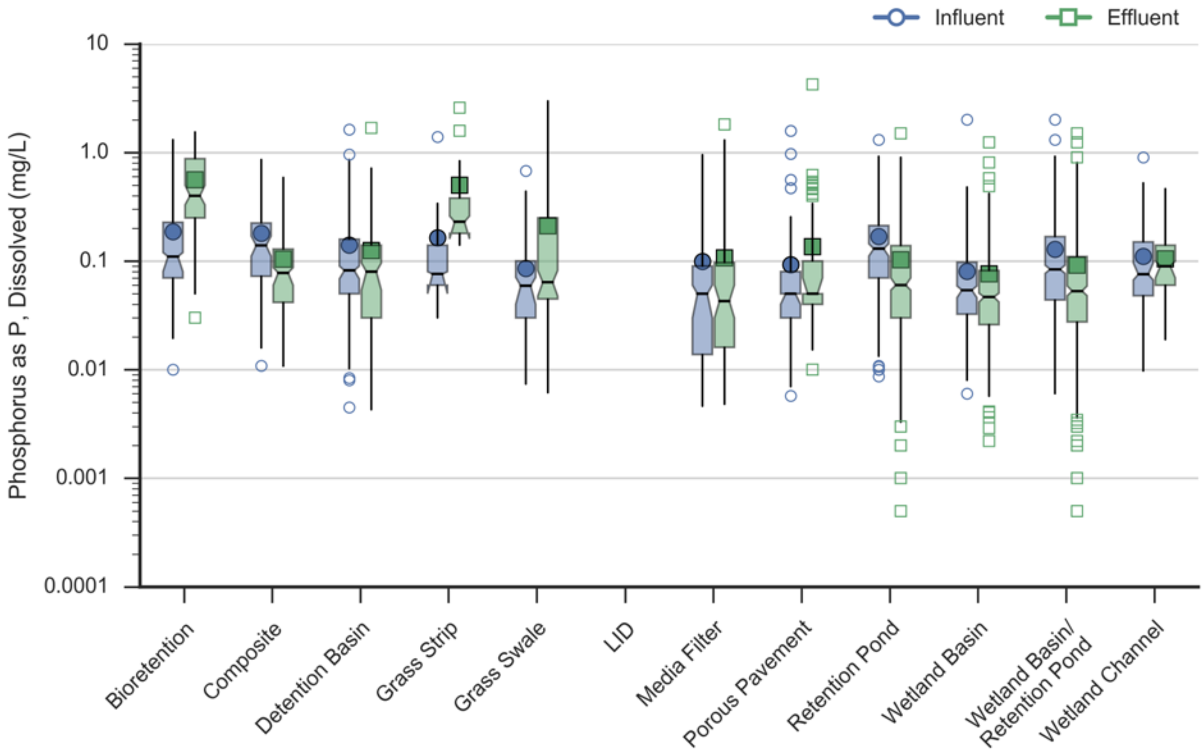

Figure 2-23. Box plots of influent/effluent dissolved phosphorus concentrations.

Table 2-23. Influent/Effluent Summary Statistics for Dissolved Phosphorus (mg/L)

BMP Category	BMPs		EMCs		25th		Median			75th	
	In	Out	In	Out	In	Out	In	Out	Difference	In	Out
Bioretention	4	4	66	62	0.07	0.25	0.11 (0.08, 0.12)	0.40 (0.33, 0.50)	◆◆◆	0.23	0.88
Composite	8	8	167	153	0.07	0.04	0.14 (0.11, 0.17)	0.08 (0.06, 0.09)	◆◆◆	0.22	0.13
Detention Basin	10	10	137	137	0.05	0.03	0.08 (0.07, 0.09)	0.08 (0.05, 0.10)	◇◇◇	0.16	0.14
Grass Strip	3	3	21	17	0.06	0.18	0.08 (0.05, 0.08)	0.23 (0.15, 0.26)	◆◆◇	0.14	0.38
Grass Swale	7	6	71	53	0.03	0.04	0.06 (0.04, 0.07)	0.06 (0.05, 0.08)	◇◆◆	0.10	0.25
Media Filter	11	10	118	100	0.01	0.02	0.05 (0.03, 0.06)	0.04 (0.03, 0.06)	◇◇◆	0.09	0.10
Porous Pavement	4	4	244	119	0.03	0.04	0.05 (0.04, 0.05)	0.05 (0.05, 0.07)	◇◆◆	0.08	0.10
Retention Pond	18	19	373	394	0.07	0.03	0.13 (0.11, 0.14)	0.06 (0.05, 0.07)	◆◆◆	0.21	0.14
Wetland Basin	7	7	311	298	0.03	0.03	0.05 (0.05, 0.06)	0.05 (0.04, 0.05)	◇◆◆	0.10	0.08
Wetland Basin/ Retention Pond	25	26	684	692	0.04	0.03	0.08 (0.08, 0.09)	0.05 (0.05, 0.06)	◆◆◆	0.17	0.11
Wetland Channel	5	5	92	89	0.05	0.06	0.08 (0.07, 0.10)	0.09 (0.07, 0.10)	◇◇◇	0.15	0.14

2.4.2 Nitrogen

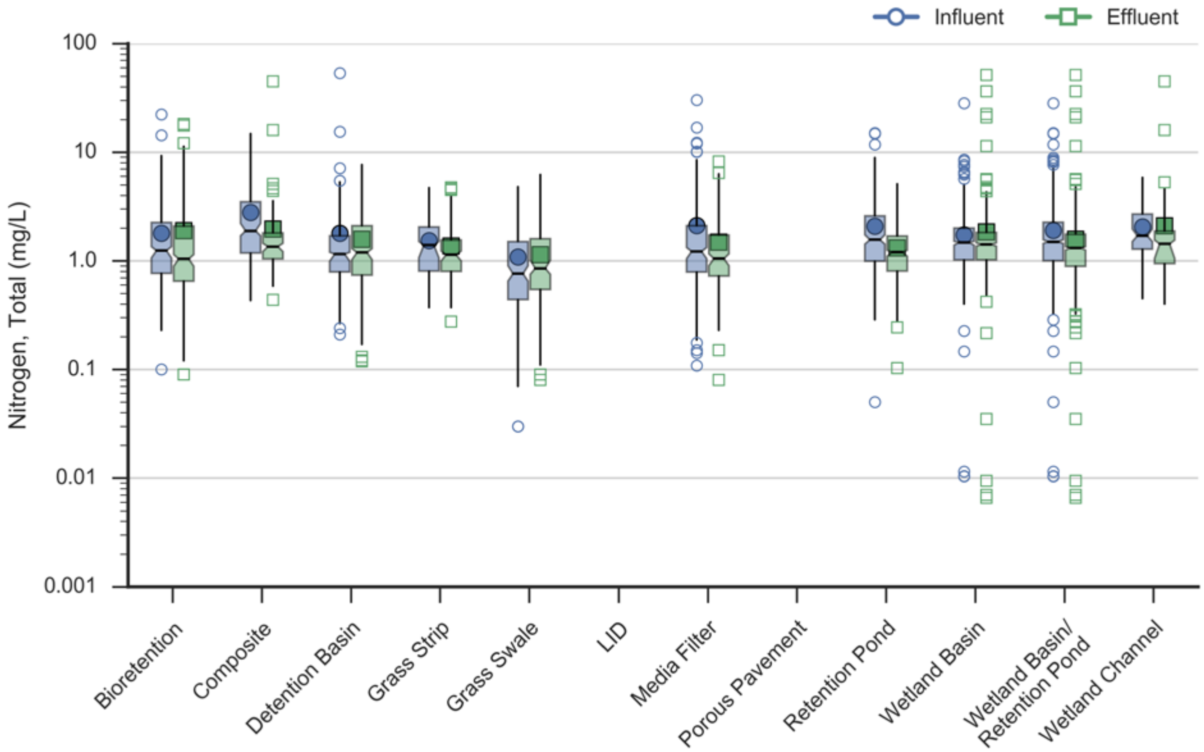

Figure 2-24. Box plots of influent/effluent total nitrogen concentrations.

Table 2-24. Influent/Effluent Summary Statistics for Total Nitrogen (mg/L)

BMP Category	BMPs		EMCs		25th		Median			75th	
	In	Out	In	Out	In	Out	In	Out	Difference	In	Out
Bioretention	17	17	289	238	0.77	0.65	1.24 (1.06, 1.35)	1.04 (0.88, 1.14)	◇◇◆	2.25	2.08
Composite	7	7	138	127	1.18	1.04	1.88 (1.69, 2.21)	1.35 (1.21, 1.45)	◆◆◆	3.49	1.80
Detention Basin	15	15	180	179	0.79	0.74	1.15 (0.99, 1.20)	1.19 (1.02, 1.30)	◇◇◆	1.70	2.10
Grass Strip	8	8	138	122	0.80	0.80	1.40 (1.08, 1.50)	1.13 (1.00, 1.23)	◇◇◆	2.04	1.55
Grass Swale	8	8	241	207	0.44	0.54	0.76 (0.65, 0.90)	0.85 (0.75, 1.01)	◇◇◆	1.50	1.60
Media Filter	10	9	160	151	0.79	0.73	1.22 (1.03, 1.33)	1.05 (0.90, 1.16)	◇◇◆	2.10	1.72
Retention Pond	27	27	414	431	0.99	0.81	1.56 (1.42, 1.74)	1.20 (1.10, 1.25)	◆◆◆	2.59	1.69
Wetland Basin	10	10	419	425	1.02	1.02	1.48 (1.39, 1.51)	1.42 (1.36, 1.46)	◇◇◇	2.00	1.82
Wetland Basin/ Retention Pond	37	37	833	856	1.00	0.89	1.50 (1.44, 1.57)	1.31 (1.25, 1.35)	◆◆◆	2.26	1.75
Wetland Channel	9	9	107	103	1.28	0.94	1.70 (1.50, 1.96)	1.43 (1.05, 1.55)	◇◆◆	2.69	1.87

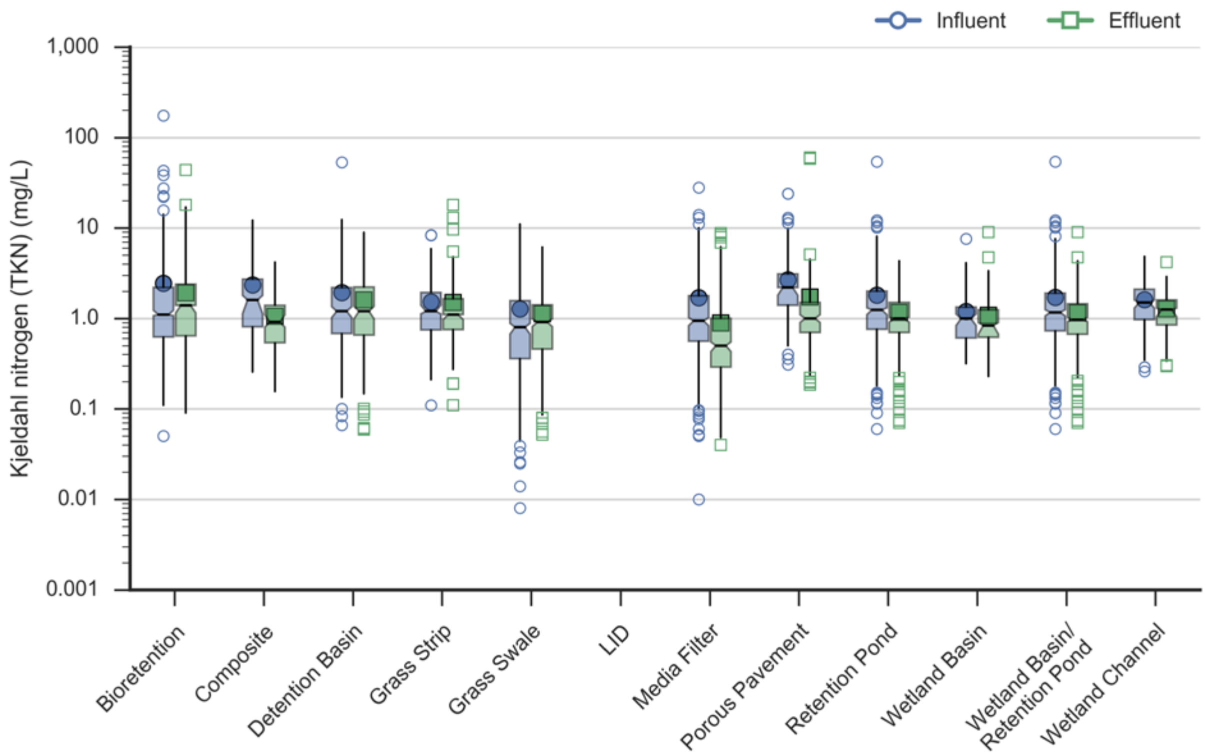

Figure 2-25. Box plots of influent/effluent total Kjeldahl nitrogen concentrations

Table 2-25. Influent/Effluent Summary Statistics for Total Kjeldahl Nitrogen (mg/L)

BMP Category	BMPs		EMCs		25th		Median			75th	
	In	Out	In	Out	In	Out	In	Out	Difference	In	Out
Bioretention	23	23	451	390	0.62	0.64	1.10 (1.07, 1.24)	1.39 (1.14, 1.40)	◇◇◇	2.20	2.39
Composite	8	7	139	127	0.81	0.54	1.60 (1.13, 1.80)	0.91 (0.80, 1.09)	◆◆◆	2.71	1.39
Detention Basin	19	19	258	248	0.68	0.65	1.20 (1.02, 1.35)	1.20 (0.99, 1.36)	◇◇◆	2.19	2.22
Grass Strip	18	18	352	268	0.75	0.75	1.20 (1.12, 1.40)	1.10 (0.97, 1.11)	◆◇◇	1.93	1.64
Grass Swale	19	19	357	337	0.36	0.46	0.80 (0.68, 0.88)	0.91 (0.81, 0.99)	◇◇◆	1.57	1.41
Media Filter	21	20	323	312	0.56	0.29	0.94 (0.83, 1.02)	0.50 (0.43, 0.55)	◆◆◆	1.78	1.00
Porous Pavement	6	6	375	206	1.40	0.70	2.20 (1.80, 2.20)	1.00 (0.90, 1.10)	◆◆◆	3.10	1.50
Retention Pond	36	36	498	493	0.76	0.70	1.24 (1.10, 1.31)	1.00 (0.91, 1.03)	◆◆◆	2.00	1.50
Wetland Basin	8	8	96	91	0.61	0.62	0.99 (0.84, 1.12)	0.84 (0.67, 0.90)	◇◇◇	1.33	1.24
Wetland Basin/ Retention Pond	44	44	594	584	0.73	0.67	1.17 (1.06, 1.25)	0.97 (0.92, 1.03)	◆◆◆	1.90	1.45
Wetland Channel	9	9	141	129	0.97	0.85	1.50 (1.30, 1.60)	1.25 (1.10, 1.30)	◇◆◆	2.10	1.60

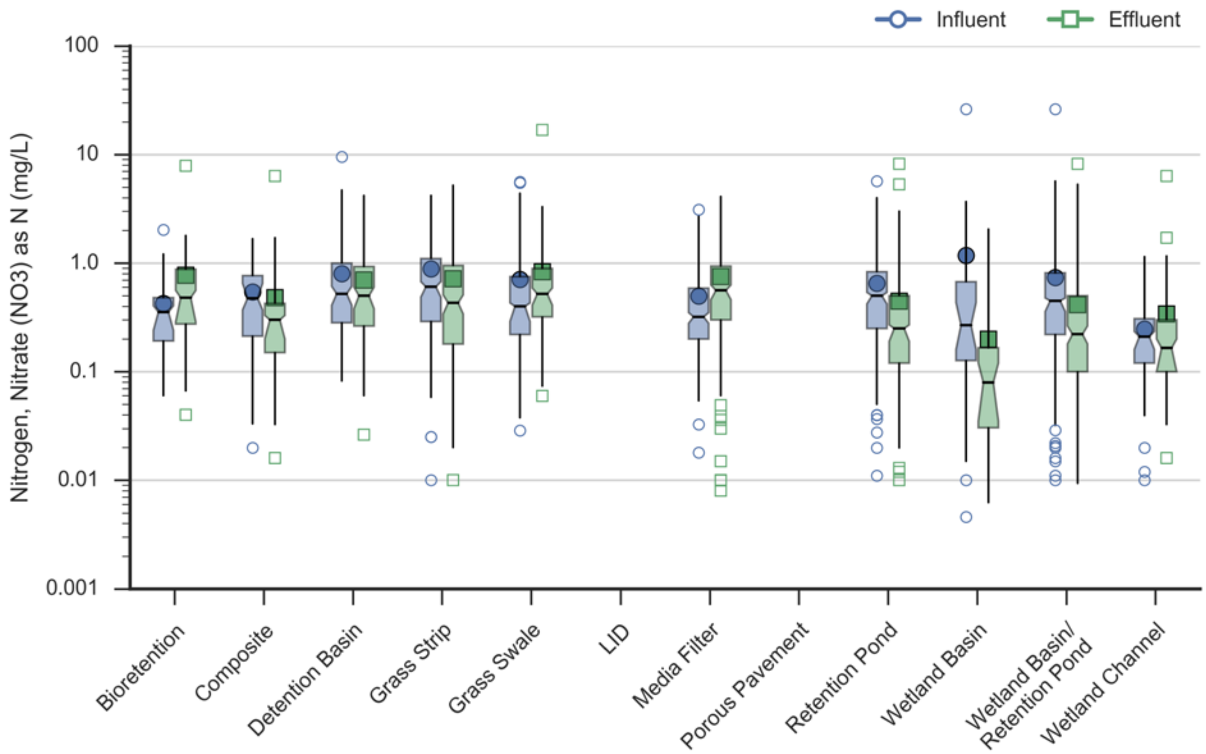

Figure 2-26. Box plots of influent/effluent NO_3 as nitrogen concentrations.

Table 2-26. Influent/Effluent Summary Statistics for NO_3 as Nitrogen (mg/L)

BMP Category	BMPs		EMCs		25th		Median			75th	
	In	Out	In	Out	In	Out	In	Out	Difference	In	Out
Bioretention	4	4	45	40	0.19	0.27	0.35 (0.24, 0.41)	0.48 (0.29, 0.56)	◇◆◆	0.48	0.88
Composite	3	3	54	55	0.21	0.15	0.47 (0.37, 0.65)	0.30 (0.18, 0.33)	◆◆◆	0.77	0.42
Detention Basin	12	12	130	123	0.28	0.26	0.52 (0.42, 0.61)	0.50 (0.38, 0.60)	◇◇◇	1.00	0.93
Grass Strip	12	12	228	165	0.29	0.18	0.61 (0.48, 0.67)	0.43 (0.34, 0.51)	◇◆◆	1.10	0.95
Grass Swale	12	12	138	149	0.22	0.32	0.40 (0.29, 0.43)	0.52 (0.41, 0.59)	◇◆◆	0.75	0.89
Media Filter	12	12	178	174	0.20	0.30	0.32 (0.28, 0.35)	0.56 (0.46, 0.63)	◆◆◆	0.59	0.94
Retention Pond	15	15	251	247	0.25	0.12	0.50 (0.40, 0.54)	0.25 (0.19, 0.27)	◆◆◆	0.83	0.50
Wetland Basin	5	5	48	37	0.13	0.03	0.27 (0.16, 0.43)	0.08 (0.03, 0.12)	◆◆◆	0.67	0.17
Wetland Basin/ Retention Pond	20	20	299	285	0.22	0.10	0.45 (0.36, 0.48)	0.22 (0.19, 0.26)	◆◆◆	0.81	0.50
Wetland Channel	4	4	82	70	0.12	0.10	0.21 (0.16, 0.23)	0.16 (0.10, 0.20)	◇◇◆	0.31	0.30

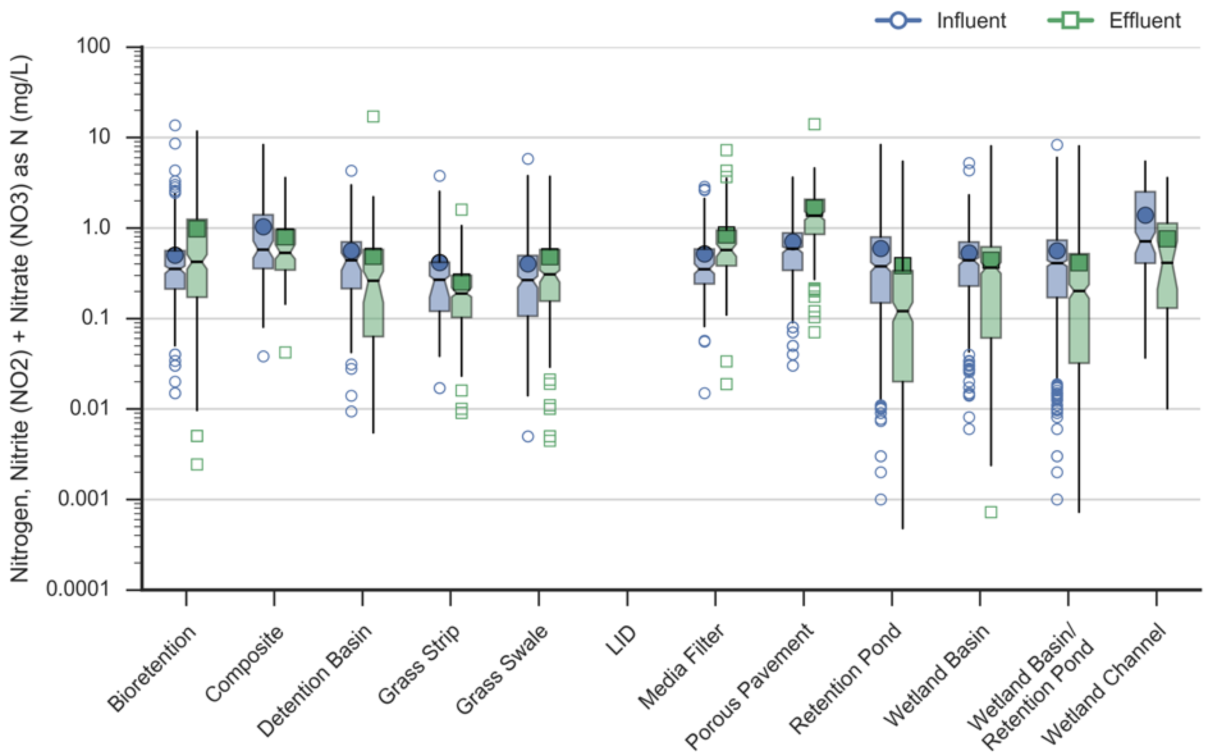

Figure 2-27. Box plots of influent/effluent $NO_2 + NO_3$ as nitrogen concentrations.

Table 2-27. Influent/Effluent Summary Statistics for $NO_2 + NO_3$ as Nitrogen (mg/L)

BMP Category	BMPs		EMCs		25th		Median			75th	
	In	Out	In	Out	In	Out	In	Out	Difference	In	Out
Bioretention	23	23	462	394	0.21	0.17	0.35 (0.31, 0.38)	0.42 (0.35, 0.51)	◇◆◆	0.56	1.24
Composite	7	7	112	99	0.36	0.34	0.57 (0.47, 0.72)	0.53 (0.45, 0.66)	◇◇◇	1.40	0.96
Detention Basin	9	9	154	154	0.21	0.06	0.44 (0.33, 0.53)	0.26 (0.16, 0.33)	◆◆◆	0.70	0.58
Grass Strip	7	7	132	116	0.12	0.10	0.27 (0.17, 0.29)	0.19 (0.18, 0.22)	◇◆◇	0.42	0.30
Grass Swale	11	11	310	305	0.11	0.16	0.26 (0.22, 0.29)	0.31 (0.25, 0.34)	◇◆◇	0.49	0.57
Media Filter	10	9	168	154	0.24	0.38	0.35 (0.31, 0.40)	0.57 (0.48, 0.68)	◆◆◆	0.58	0.94
Porous Pavement	7	7	388	220	0.34	0.85	0.59 (0.53, 0.62)	1.36 (1.22, 1.51)	◆◆◆	0.88	2.06
Retention Pond	31	31	456	457	0.15	0.02	0.38 (0.33, 0.41)	0.12 (0.09, 0.15)	◆◆◆	0.79	0.34
Wetland Basin	10	10	416	410	0.23	0.06	0.44 (0.39, 0.47)	0.37 (0.31, 0.42)	◇◆◆	0.70	0.62
Wetland Basin/ Retention Pond	41	41	872	867	0.17	0.03	0.41 (0.38, 0.44)	0.20 (0.17, 0.23)	◆◆◆	0.73	0.52
Wetland Channel	7	7	84	79	0.41	0.13	0.71 (0.52, 0.90)	0.41 (0.21, 0.72)	◇◆◆	2.51	1.12

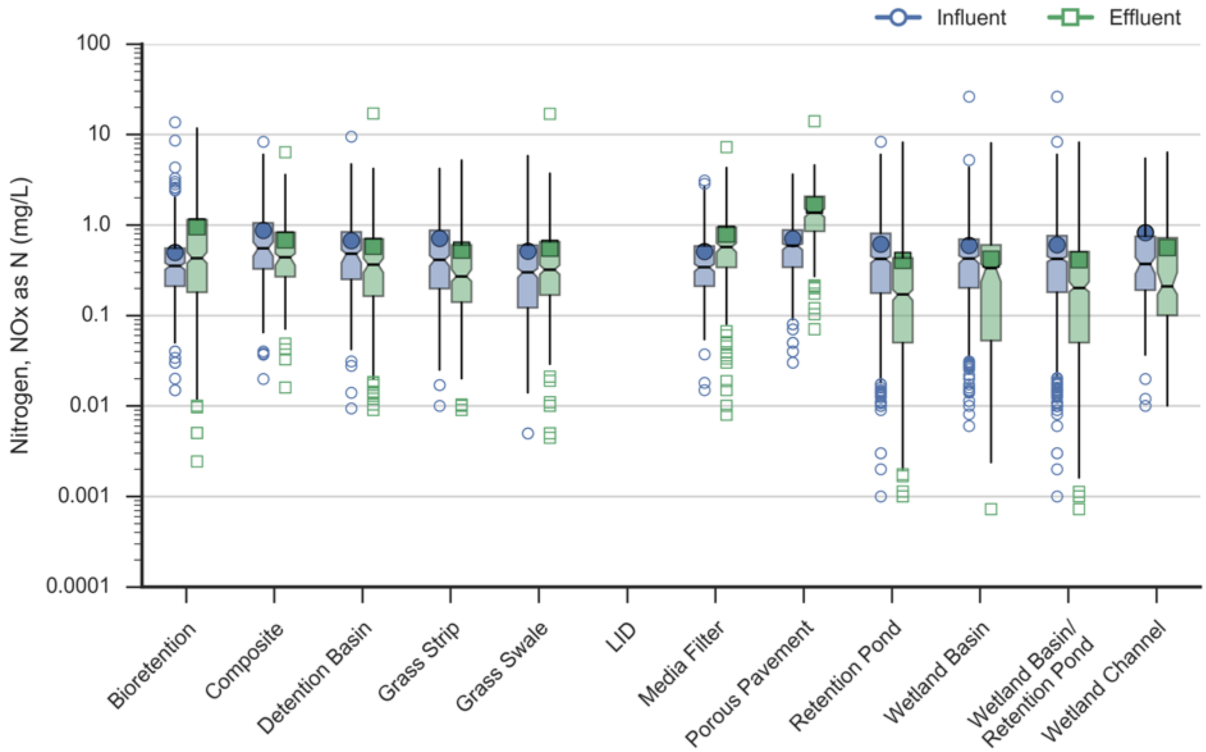

Figure 2-28. Box plots of influent/effluent NO_x as nitrogen concentrations.

Table 2-28. Influent/Effluent Summary Statistics for NO_x as Nitrogen (mg/L)

BMP Category	BMPs		EMCs		25th		Median			75th	
	In	Out	In	Out	In	Out	In	Out	Difference	In	Out
Bioretention	26	26	508	434	0.21	0.18	0.35 (0.32, 0.38)	0.43 (0.38, 0.50)	◇◆◆	0.55	1.14
Composite	10	10	166	154	0.33	0.27	0.55 (0.45, 0.65)	0.44 (0.36, 0.48)	◇◆◆	1.05	0.83
Detention Basin	21	21	284	277	0.25	0.16	0.48 (0.38, 0.53)	0.36 (0.30, 0.43)	◇◆◆	0.84	0.70
Grass Strip	19	19	360	281	0.20	0.14	0.41 (0.36, 0.46)	0.27 (0.24, 0.32)	◆◆◆	0.87	0.60
Grass Swale	22	22	406	382	0.12	0.17	0.30 (0.26, 0.33)	0.32 (0.29, 0.36)	◇◇◇	0.60	0.65
Media Filter	22	21	346	328	0.21	0.34	0.34 (0.31, 0.37)	0.57 (0.49, 0.63)	◆◆◆	0.58	0.94
Porous Pavement	7	7	388	220	0.34	0.85	0.59 (0.53, 0.62)	1.36 (1.22, 1.51)	◆◆◆	0.88	2.06
Retention Pond	46	46	707	704	0.18	0.05	0.42 (0.38, 0.45)	0.17 (0.15, 0.19)	◆◆◆	0.81	0.43
Wetland Basin	15	15	466	450	0.20	0.05	0.43 (0.38, 0.46)	0.33 (0.24, 0.37)	◆◆◆	0.69	0.60
Wetland Basin/ Retention Pond	61	61	1173	1154	0.18	0.05	0.42 (0.39, 0.45)	0.20 (0.18, 0.24)	◆◆◆	0.76	0.51
Wetland Channel	11	11	166	149	0.19	0.10	0.37 (0.29, 0.44)	0.21 (0.17, 0.30)	◇◆◆	0.75	0.72

CHAPTER 3.0

Conclusions and Research Needs

3.1 Conclusions

The International Stormwater BMP Database is an evidence-based resource for characterizing BMP performance. This summary report provides statistics useful for estimating effluent concentrations achievable by various BMP types for various pollutants and for identifying BMP types that have demonstrated ability to reduce pollutant concentrations. Although detailed interpretation of these summary statistics is beyond the scope of this data summary, basic observations from this analysis include:

1. Total Suspended Solids: All of the BMP types evaluated discharged median effluent concentrations below 30 mg/L, which is a common benchmark for TSS performance. All of the BMP types evaluated demonstrated statistically significant reduction in TSS, with the exception of LID sites. However, the number of discharging events monitored for LID facilities was approximately half of the measured inflows; therefore, comparison of influent-effluent concentration at LID sites likely underestimates the water quality benefits of these sites in terms of load reductions. The lowest effluent concentrations observed for TSS include bioretention, media filters, retention basins and wetland basins. These BMPs enable sedimentation and filtration, which are effective treatment processes for sediment removal.

2. Bacteria: The fecal indicator bacteria data set for EPA-recommended fecal indicators remains limited. Nonetheless, several observations can be made from the available data. Most BMP types analyzed are not able to reduce bacteria concentrations to primary contact recreation receiving water standards, with the possible exception of retention ponds for *E. coli.* However, several BMP types show the ability to reduce currently recommended fecal indicator bacteria concentrations, including bioretention, wetland basins, retention ponds, and media filters. Dry extended detention basins provided statistically significant reduction for fecal coliform, although it is no longer recommended for use by EPA as a fecal indicator bacteria for recreational use. Nonetheless, bacteria load reductions may be significant due to volume reduction provided by BMPs that provide infiltration. (Volume reduction is not evaluated in this report.)

3. Nutrients: Nutrients in the particulate form can be removed from a variety of BMP types; however, removal of soluble forms is more challenging. Statistically significant reductions of total phosphorus were identified for composite (treatment train) BMPs, detention basins, media filters, porous pavement, retention ponds and wetland basins. Bioretention, grass swales and grass strips tended to export phosphorus, suggesting that bioretention media mixes, fertilization practices and erosion control are important considerations for BMP design, installation and maintenance. BMPs with permanent pools (i.e., retention ponds and wetlands) appear to be able to reduce nitrate (and NOx) concentrations. As indicated by the relatively high TKN removal and lack of NOx removal for media filters, inert filtration appears capable of capturing nitrogenous solids, but the conditions are not as conducive for significant denitrification or nitrogen uptake as compared to BMPs with permanent pools (retention ponds and wetland basins). Therefore, a BMP designed for permanently reducing nitrogen may include a permanent wet pool followed by a vegetated swale or media filter. Bioretention as an overall category did not perform well for nitrogen removal; however, it may be worthwhile to evaluate bioretention

designs with internal water storage zones (e.g., pore storage above and below the underdrain providing nitrification/denitrification processes) as a separate subcategory in the future.

4. Metals: As was the case for nutrients, total forms of metals are more easily removed than dissolved forms. For example, all of the BMPs evaluated showed statistically significant reduction of total copper, lead and zinc. Performance for individual BMP-pollutant concentration varies. When evaluating metals performance, it is particularly important to be cognizant of influent concentrations – in cases where influent concentrations are already very low, then additional reductions of metals concentrations may not be feasible. See the summary tables provided in this report to assess expected performance for various BMP-metal combinations.

For more detailed discussions of unit treatment processes expected to be effective at removing various pollutants, see the BMP Database Pollutant Technical Summary paper series completed during 2010-2012 (Geosyntec and WWE 2010 & 2011; WWE and Geosyntec 2010 & 2011) and accessible at http://www.bmpdatabase.org/performance-summaries.html.

3.2 Research Needs

This report serves primarily as a statistical summary and is not intended to provide a detailed evaluation of research needs; however, several research needs are readily apparent.

1. More BMP performance data sets are needed for fecal indicator bacteria for multiple BMP types, particularly for EPA-recommended fecal indicator bacteria, enterococcus and *E. coli*.
2. More robust design information in BMP performance study submittals would be valuable for all BMP categories. This information is important for identifying the factors that lead to the best performance for various BMP types.
3. Although the 2016 data upload included more site-scale LID studies, this data set continues to be limited and would benefit from additional performance data. It is essential that runoff volume-related data be reported with these studies so that load reductions can be determined in future analyses.
4. Permeable pavement studies are relatively limited and would benefit from additional performance reporting. Permeable pavement is a BMP type that is well suited for ultra-urban retrofits, so additional performance data would be helpful for local governments considering inclusion of permeable pavement in capital improvement programs.
5. The BMP Database contains a substantial manufactured device data set that has evolved over the past 20 years. These data sets have not been included in this analysis due to the need for additional characterization of the unit treatment processes in these data sets. A stand-alone manufactured device performance analysis report is recommended as a future priority for WE&RF and the project co-sponsors.

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