National Pollutant Removal Performance Database for Stormwater Treatment Practices

2nd Edition

March 2000

by:
Rebecca Winer
Center for Watershed Protection
8391 Main Street
Ellicott City, MD 21043
www.cwp.org

for:
EPA Office of Science and Technology
In association with
TetraTech, Inc.

Table of Contents

Acknowledgements v

Executive Summary vii

Section 1.0 **Introduction** 1

Section 2.0 **Methodology** 5

2.1 Changes in the 2nd Edition 5

2.2 Conventions 6

2.3 Caveats 9

2.4 Research Gaps in STP Performance 10

Section 3.0 **Results** 13

3.1 Phosphorus 25

3.2 Nitrogen 25

3.3 Suspended Sediment 25

3.4 Carbon 26

3.5 Metals 26

3.6 Bacteria 26

3.7 Hydrocarbons 27

3.8 Implications 27

References 29

Appendix A: Stormwater Treatment Practice Pollutant Removal Study Summaries A-1

Appendix B: Database Bibliography B-1

Appendix C: Eliminated Stormwater Treatment Practice Pollutant Removal Studies C-1

Appendix D: Comparative Pollutant Removal Capability of STPs: Technical Note #95 . . D-1

Appendix E: Irreducible Pollutant Concentrations Discharged from Stormwater Practices: Technical Note #75 . . . . . . E-1

List of Tables

Table E.1 Median Pollutant Removal (%) of Stormwater Treatment Practices viii

Table E.2 Median Effluent Concentration (mg/L) of Stormwater Treatment Practice Groups ix

Table 1.1 Stormwater Treatment Practices Group and Design Variation 2

Table 1.2 Pollutant Removal Data Sheet Fields 3

Table 2.1 Number of Studies by Stormwater Treatment Practice Group and Design Variation 7

Table 2.2 Example EMC and Mass Efficiency Calculations 9

Table 2.3 Frequency of Monitoring in Stormwater Treatment Practice Performance Studies for Select Stormwater Pollutants 11

Table 3.1 Median Pollutant Removal of Stormwater Ponds and Wetlands 14

Table 3.2 Median Pollutant Removal of Stormwater Filtering, Infiltration, Open Channel, and Other Practices 15

Table 3.3 Median Pollutant Removal of Stormwater Treatment Practices by Drainage Class 18

Table 3.4 Median Effluent Concentration from Stormwater Ponds and Wetlands 21

Table 3.5 Median Effluent Concentration from Stormwater Filtering, Infiltration, Open Channel, and Other Practices 22

Table 3.6 Median Bacteria and Organic Carbon Removal by Stormwater Treatment Practice 27

List of Figures

Figure 3.1 Stormwater Treatment Practice Pollutant Removal Efficiencies: Total Suspended Solids, Total Nitrogen, Total Khedjahl Nitrogen, and Nitrate and Nitrite Nitrogen 16

Figure 3.2 Stormwater Treatment Practice Pollutant Removal Efficiencies: Total Phosphorus, Soluble Phosphorus, Zinc, and Copper 17

Figure 3.3 Median Pollutant Removal by Drainage Class: Total Suspended Solids, Total Nitrogen, Total Khedjahl Nitrogen, and Nitrate and Nitrite Nitrogen 19

Figure 3.4 Median Pollutant Removal by Drainage Class: Total Phosphorus, Soluble Phosphorus, Copper, and Zinc 20

Figure 3.5 Stormwater Treatment Practice Median Pollutant Effluent Concentrations: Total Suspended Solids, Total Nitrogen, Total Khedjahl Nitrogen, and Nitrate and Nitrite Nitrogen 23

Figure 3.6 Stormwater Treatment Practice Median Pollutant Effluent Concentrations: Total Phosphorus, Ortho-Phosphorus, Zinc, and Copper 24

Acknowledgments

This project was prepared as a subcontract to Tetra Tech, Inc. under EPA Contract 68-C-99-263 for the U.S. EPA Office of Science and Technology. Special thanks to Jim Collins of Tetra Tech for his assistance and review. The author would also like to thank Marcus Quigley of URS Greiner, along with Woodward Clyde and Jesse Pritts of the U.S. EPA Office of Science and Technology.

The author would like to express gratitude to the staff of the Center for Watershed Protection. Deb Caraco provided invaluable guidance, advice and support throughout the entire process. Paul Sturm provided useful comment and review of the database. Tom Schueler provided technical guidance and comment. Heather Holland and Laura Thompson finalized the document.

Disclaimer

Executive Summary

The second edition of the *Stormwater Treatment Practice (STP) Pollutant Removal Performance Database* (the "Database") modifies, clarifies, and expands upon the original *National Database of BMP Pollutant Removal Performance* (the First Edition) by Brown and Schueler (1997).

The First Edition included 129 studies and spanned a 19-year period; the minimum storm sampling criteria was four sampling events, and little effluent concentration data was included. Major changes to the First Edition include the following:

- Addition of 24 studies
- Elimination of studies that did not meet the new minimum storm sample criteria of five
- Update of existing entries to include effluent concentration and other data where available
- Addition of new fields

Eight of the studies included in the First Edition were deleted because of insufficient storm sample size. In addition, concentration data were added to existing studies to make the database a more powerful analysis tool. More than half of the original studies included both influent and effluent concentration data, and these data were not consistently included in the First Edition. Finally, several fields were added since the First Edition, including *Age of the Facility*, *Drainage Class* (based on drainage area), *Land Use Quantification* (e.g., percent commercial, residential, etc.), and storage in *Watershed* and *Impervious Inches*. Unfortunately, many studies did not report these data explicitly. Consequently, the database does not currently have sufficient data to develop relationships between specific site or design characteristics and performance. One exception is the *Drainage Class* field, which classifies ponds and wetlands as Pocket, Regular, or Regional. Although the results are not conclusive, sufficient data are available to characterize each data class.

Table E.1 Median Pollutant Removal (%) of Stormwater Treatment Practices

	TSS	TP	Sol P	TN	NOx	Cu	Zn
Stormwater Dry Ponds	47	19	-6.0	25	4.0	26[1]	26
Stormwater Wet Ponds	80 (67)	51 (48)	66 (52)	33 (31)	43 (24)	57 (57)	66 (51)
Stormwater Wetlands	76 (78)	49 (51)	35 (39)	30 (21)	67 (67)	40 (39)	44 (54)
Filtering Practices[2]	86 (87)	59 (51)	3 (-31)	38 (44)	-14 (-13)	49 (39)	88 (80)
Infiltration Practices	95[1]	70	85[1]	51	82[1]	N/A	99[1]
Water Quality Swales[3]	81 (81)	34 (29)	38 (34)	84[1]	31	51 (51)	71 (71)

1. Data based on fewer than five data points
2. Excludes vertical sand filters and filter strips
3. Refers to open channel practices designed for water quality

NOTES:
- Data in parentheses represent values from the First Edition (Schueler, 1997; Appendix D).
- Shaded regions indicate a difference of at least ± 5% from the First Edition.
- N/A indicates that the data are not available.
- TSS = Total Suspended Solids; TP = Total Phosphorus; Sol P= Soluble Phosphorus; TN = Total Nitrogen; NOx = Nitrate and Nitrite Nitrogen; Cu = Copper; Zn = Zinc

The statistical reanalysis of the First Edition revealed some changes in the pollutant removal efficiencies of STPs (Table E.1). These changes can be attributed to the addition of new studies and revisions to the older studies. Most of the shaded regions represent a pollutant removal increase of at least 5%. Three exceptions are nitrogen removal for filtering practices, which decreased by 16%; and zinc and soluble phosphorus removal of stormwater wetlands, which decreased by 18% and 10% respectively. The STP group with the greatest change over original data is filtering practices. This result is not surprising, since a significant number of changes were made to this group (five studies were added to the original 14). In particular, the negative soluble phosphorus in the original was caused by a few values from organic filters, and from one perimeter filter that had become submerged, releasing soluble phosphorus.

Table E.2 Median Effluent Concentration (mg/L)[1] of Stormwater Treatment Practice Groups							
	TSS	TP	OP	TN	NOx	Cu	Zn
Stormwater Dry Ponds	28[2]	0.18[2]	0.13[2]	0.86[2]	N/A[3]	9.0[2]	98[2]
Stormwater Wet Ponds	17	0.11	0.03	1.3	0.26	5.0	30
Stormwater Wetlands	22	0.20	0.09	1.7	0.36	7.0	31
Filtering Practices[3]	11	0.10	0.08	1.1[2]	0.55[2]	10	21
Infiltration Practices	17[2]	0.05[2]	0.003[2]	3.8[2]	0.09[2]	4.8[2]	39[2]
Water Quality Swales[4]	14	0.19	0.08	1.1[2]	0.35	10	53

1. Units for Zn and Cu are micrograms per liter
2. Data based on fewer than five data points
3. Excludes vertical sand filters and filter strips
4. Refers to open channel practices designed for water quality

NOTES:
- N/A indicates that the data is not available.
- TSS = Total Suspended Solids; TP = Total Phosphorus; OP = Ortho-Phosphorus; TN = Total Nitrogen; NOx = Nitrate and Nitrite Nitrogen; Cu = Copper; Zn = Zinc

Median effluent concentrations by STP groups are summarized in Table E.2. Effluent concentration data were added to the Database as a supplement to the pollutant removal capability of STPs. In some instances, pollutant removal percentage may not be a good indicator of the overall removal capability of a STP. Pollutant removal percentages can be strongly influenced by the variability of the pollutant concentrations in incoming stormwater. If the concentration is near the "irreducible level" (Schueler, 1996), a low or negative removal percentage can be recorded even though outflow concentrations discharged from the STP were relatively low. Although these data represent a median, unlike the group mean reported in Schueler (1996), the data suggest that the typical concentration data reported in this initial study and are high compared with the results from the Database (see Appendix E).

The data presented in this study support the contention that most STP designs can remove significant amounts of sediment and total phosphorus in urban runoff. Most STP groups, on the other hand, showed a lower ability to remove nitrogen. This result suggests that non-structural nutrient reduction methods, in addition to stormwater STPs, may be needed to meet nutrient reduction targets.

Section 1.0 Introduction

Since the First Edition was compiled in 1997, a significant number of new monitoring studies have been performed. The Center recognized the need to incorporate the new studies and reevaluate the quality of the previous entries. The Database is a national compilation of 139 individual STP performance studies. The Database is intended for use by engineers, planners, and municipal officials as they consider STPs in conjunction with watershed restoration and protection efforts, stormwater management strategies, and stormwater design manuals and criteria.

The First Edition included 123 studies and spanned a 19-year period; the minimum storm sampling criteria was four storm sampling events and little effluent concentration data was included. Major changes to the Database include the addition of 24 new performance monitoring studies, the elimination of eight studies which did not meet the new minimum storm sample criteria of five, an update of existing entries to include concentration and other data where available, and the addition of new fields.

The research summaries are presented in Microsoft Access® format. Included in each summary are general site and location information, bibliographic information, and pollutant removal and concentration data for a variety of nutrient, metal, bacteria, organic and other parameters. These summaries are presented in Appendix A.

We have used the Database to update national pollutant removal statistics for various STP groups (e.g., wetlands, filters) as individual design variations (e.g., wet extended detention pond, perimeter sand filter) and to identify performance research needs. This report describes the methodology used to compile and update the Database and presents the summary pollutant removal data.

The Database consists of two components: (1) a dynamic computer database and (2) a series of STP pollutant removal efficiency summaries. The first component is described in detail in the following discussion. Section 3 provides the pollutant removal summaries.

The Database includes 139 data sheets cataloged in Microsoft® Access format. The Microsoft® Access format allows users to extract specific data, perform statistical analysis and enter additional study data. Each data sheet corresponds to an individual study or research effort. Each study is categorized according to STP group and design variation as shown in Table 1.1. Additional information provided on the data sheet includes bibliographic references, facility name and location, site descriptions, drainage class, STP design characteristics, and pollutant removal data. A complete listing of information provided on each data sheet is provided in Table 1.2.

Table 1.1 Stormwater Treatment Practices Group and Design Variation		
Group	**Design Variation**	
Stormwater Pond		
	Quantity Control Pond	Wet Extended Detention Pond
	Dry Extended Detention Pond	Wet Pond
	Multiple Pond System	
Stormwater Wetland		
	Shallow Marsh	Pond/Wetland System
	Extended Detention Wetland	Submerged Gravel Wetland
Open Channel Practice		
	Grass Channel	Dry Swale
	Ditch*	Wet Swale
Filtering Practice		
	Perimeter Sand Filter	Bioretention
	Surface Sand Filter	Organic Filter
	Vertical Sand Filter	Multi-Chambered Treatment Train
Infiltration Practice		
	Porous Pavement	Infiltration Trench
Other STPs		
	Stormceptor	Oil-grit separator

* Refers to an open channel practice not explicitly designed for water quality

Table 1.2 Pollutant Removal Data Sheet Fields	
Field	**Description**
Study Number	Unique number assigned to each study
Facility	STP or development name
State	State where STP is located
STP Group	Pond, wetland, filter, infiltration practice, open channel, or other
STP Design Variation	Specific type of STP (e.g., vertical sand filter or wet pond)
Drainage Class	Based on drainage area; STP is classified as pocket, regular, or regional
Author	Study author and year of publication
Reference	Bibliographic reference
No. of Storms	Number of storms or samples represented by data
Treatment Volume	Criteria for design and sizing of the STP
Watershed Inches	Runoff inches STP was designed to treat off entire drainage area
Impervious Inches	Runoff inches STP was designed to treat off the impervious portion of the drainage area
Drainage Area	STP catchment area (acres)
Slope	Slope of the STP (applicable to open channel practices)
Land Use	Dominant land use in the STP catchment area
Soil Type	Description of the underlying soil at site
STP Size	STP dimensions
Age of Facility	Number of years since installation of STP
STP Notes	Additional information regarding the STP
Performance Notes	Additional information regarding the study
% Efficiency Mass	Removal efficiency reported as mass or load reduction
% Efficiency Conc.	Removal efficiency reported as a concentration reduction
% Efficiency Other	Removal efficiency determined using a non-specified method
Concentration Inflow	Measurement of a specific pollutant concentration at the inflow
Concentration Outflow	Measurement of a specific pollutant concentration at the outflow
Organic Name	Specific organic parameter: BOD, TOC, or COD
Bacteria Type	Specific bacteria parameter: fecal coliform, total coliform, E. coli, streptococci or enterococci

Section 2.0 Methodology

The Database was compiled through a comprehensive literature search focusing on STP monitoring studies from 1990 to the present. In addition, approximately 60 previously collected STP monitoring studies from 1977 and 1989 were included in the Database (Strecker *et al.*, 1992 and Schueler, 1994). All STP studies considered for inclusion were reviewed with respect to three target criteria:

1. Five or more storm samples were collected
2. Automated equipment that enabled flow or time-based composite samples were used
3. The method used to compute removal efficiency was documented

All 139 studies included in the Database meet the second and third criteria. With respect to the number of storms sampled, more than three-quarters of the studies explicitly stated that they were based on five or more storm samples. Although the remaining studies did not report sample size, they were included if report text suggested a significant sampling effort.

2.1 Changes in the 2nd Edition

The primary purpose of this project was to improve upon the quality and size of the First Edition. Changes in the number of studies included in the Database are presented in Table 2.1. As previously stated, 24 studies were added since the First Edition, and eight studies were deleted because of insufficient storm sample size.

Pollutant removal percentages can be strongly influenced by the concentration of the pollutant in the incoming stormwater. If the concentration is near the "irreducible level" (Schueler, 1996), a low or negative removal percentage can be recorded, even though outflow concentrations discharged from the STP are relatively low. For this reason, concentration data was added to STP studies where available. Over half of the studies provided pollutant concentration data.

Several fields were added to provide a more comprehensive summary of each study, including *Age of Facility, Land Use Quantification, Drainage Class, Watershed Inches,* and *Impervious Inches*. The age of the facility is an important consideration, as factors such as sedimentation and maintenance needs can decrease pollutant removal efficiency over time. Unfortunately, less then 25% of the studies documented age. In order to provide a quantitative description of the land draining to the STP, the land use category was further divided into four classes: percent impervious cover, percent residential, percent commercial, and percent industrial. The new *Drainage Class* field classified ponds and wetlands as either Pocket, Regular or Regional based on their contributing drainage area. Stormwater ponds and wetlands that served a drainage area less than 10 acres were classified as Pocket; those with drainage areas greater than 10 acres but less than 300 acres were classified as Regular; and those with a drainage areas greater than 300 acres were classified as Regional. This new field eliminated the need for the pocket wetland design variation that was included in the First Edition, and thus it was removed as a STP type. Additional reorganization of STPs included the reclassification of the Filter/Wetland Systems into a more descriptive subcategory: Submerged Gravel Wetlands.

2.2 Conventions

During the development of the Database, several conventions were used to facilitate and simplify statistical analysis. These conventions are described below.

Database Entry Conventions

1. When more than one method was used to calculate pollutant removal in a specific STP study, mass- or loading-based measurements of removal efficiency were entered into the Database rather than concentration-based measurements.

2. Removal efficiency data generally correspond to the median values reported in the studies. When removal efficiencies were reported as a range of values, the average of the range was recorded in the Database.

3. Removal data reported as "no significant difference" were entered into the Database as zero removals. Removal data reported as "not detected" were not included in the Database.

4. Removal data reported as unspecified negative removals were entered as negative 25%. Negative removal data greater than 100% in magnitude were entered as negative 100% to prevent undue weighting in subsequent statistical analysis.

5. Organic carbon data included biological oxygen demand (BOD), chemical oxygen demand (COD), and total organic carbon (TOC) removal data.

6. Nitrate-Nitrite (NO_x) data include removal data for nitrate as well as combined nitrate-nitrite.

7. Ammonium (NH_4) data include ammonium and ammonia data.

8. Bacteria data include fecal streptococci, enterococci, fecal coliform, *E. coli* and total coliform.

9. Soluble phosphorus used to calculate efficiencies represented lumped data that includes ortho-phosphorus and dissolved phosphorus. Effluent concentrations, on the other hand, were calculated based only on ortho-phosphorus.

Table 2.1 Number of Studies by Stormwater Treatment Practice Group and Design Variation			
STP Type	**First Edition # of Studies (1997)**	**Database # of Studies (2000)**	**# of Studies with Concentration Data**
Pond			
Quantity Control Pond	2	3	0
Dry Extended Detention Pond	6	6	3
Wet Extended Detention Pond	7	14	11
Multiple Pond System	0	1	0
Wet Pond	29	29	15
Total	***44***	***53***	***29***
Wetland			
Shallow Marsh	17	23	9
Extended Detention Wetland	4	4	2
Pond/Wetland System	10	10	7
Pocket Wetland	1	0	0
Submerged Gravel Wetland	0	2	0
Filter/Wetland System	3	0	0
Total	***35***	***39***	***18***
Filtering Practice			
Organic Filter	5	7	5
Perimeter Sand Filter	3	3	3
Surface Sand Filter	6	8	2
Vertical Sand Filter	2	2	2
Vegetated Filter Strip	2	0	0
Bioretention	0	1	1
Total	***18***	***21***	***13***
Infiltration Practice			
Infiltration Trench	3	3	3
Porous Pavement	2	3	1
Total	***5***	***6***	***4***
Open Channel Practice			
Grass Channel	3	3	3
Ditch	11	9	3
Dry Swale	4	4	2
Wet Swale	2	2	2
Total	***20***	***18***	***10***
Other			
Oil-Grit Separator	1	1	1
Stormceptor	0	1	1
Total	***1***	***2***	***2***
Total for All STP Types	**123**	**139**	**76**

Statistical Conventions

The median removal efficiencies and effluent concentrations were computed for each STP group and each STP design variation for select pollutants. The box and whisker plot computations, including median, and 75th and 25th percentile values, are presented in Section 3. Computations for the box and whisker plots were performed only for water quality parameters that were sampled in five or more studies.

Monitoring Methodology

Monitoring methodology refers to field methods, laboratory analysis techniques, number of storms sampled, and pollutant removal efficiency computations. All of the studies included in the Database used automated sampling equipment. With respect to laboratory methods, it was assumed that appropriate analysis methods and quality assurance and quality controls were used. Individual studies often differed in the number of storms sampled, ranging from five to 81 storm events.

Efficiency Calculations

Pollutant removal efficiency, usually represented by a percentage, specifically refers to the pollutant reduction from the inflow to the outflow of a system. The two most common computation methods are event mean concentration (EMC) efficiency and mass or load efficiency. EMC efficiency is calculated by averaging the inflow and outflow concentrations for all storm events. This method gives equal weight to both small and large storms and does not account for water volume. Rainfall input is not considered. Event mean concentration efficiency is typically calculated as follows:

EMC efficiency (%) = $[(Conc_{in} - Conc_{out})/Conc_{in}] * 100$

where:

$Conc_{in}$ is the average of EMC at inflow.
$Conc_{out}$ is the average of EMC at outflow.

Mass efficiency is influenced by volume of water entering the STP and water losses within the STP (e.g., evapotranspiration and infiltration). Mass efficiency is typically calculated as follows:

Mass Efficiency (%) = $[(SOL_{in} - SOL_{out})/(SOL_{in})] * 100$

where:

SOL_{in} is the sum of incoming loads. This value may include sources other than the inflow such as rainfall or atmospheric deposition.
SOL_{out} is the sum of all outgoing loads at the outfall, calculated by multiplying the pollutant concentration by the outgoing volume of water from the STP.

The two equations presented above are methodologies to calculate efficiencies using EMC and mass techniques, but there are many variations of these two equations. As Table 2.2 illustrates, the specific methodology chosen can influence pollutant removals.

Table 2.2 Example EMC and Mass Efficiency Calculations

Storm No.	Flow in Fi (ft3)	Flow Out Fo (ft3)	Concentration In Ci (mg/L)	Concentration Out Co (mg/L)	Event Efficiency Concentration E(c)	Mass In (Ci*Fi)	Mass Out (Co*Fo)	Event Efficiency Mass (F)
1	16200	13680	0.35	0.13	63%	5670	1778	69%
2	7560	7200	0.12	0.15	-25%	907	1080	-19%
3	21960	19800	0.80	0.26	68%	17568	5148	71%
4	19080	19080	0.48	0.33	31%	9158	6296	31%
5	32760	31680	0.19	0.10	47%	6224	3168	49%
Avg.			**0.39**	**0.19**	**37%**			**40%**
Sum	**97560**	**91440**				**39528**	**17471**	

***Method 1*: 50%**
The average Ci and Co for all five storm events was applied to the EMC equation presented above. (0.39 - 0.19)/0.39
***Method 2*: 37%**
In this method, an average was taken of the EMCs calculated for individual storm events.
***Method 3*: 56%**
Method 3 used the average Fi and Fo in the Mass Efficiency equation provided above. (39528 - 17471)/39528
***Method 4*: 40%**
This removal efficiency was derived by taking an overall average of the Mass Efficiency calculated for each storm event.

Other methods that do not fall within the two categories presented above may also be used to compute removal efficiency. Methods classified as "Other" included mass balance and flux analysis. Several studies classified as "Other" determined the removal efficiency using inflow and outflow regression curves based on field data.

Strecker *et al.* (2000) also reported the discrepancies described in Table 2.2, and recommended that future monitoring efforts be standardized to yield fair comparisons between practices. When developing the Database, we did not adjust the technique used in the original study. However, when concentration data were reported, we did add the concentration-based efficiency as a field in the Database.

2.3 Caveats

The statistical analysis results should be used to examine the general removal capability of various groups and design variations of STPs. The computed median removal values are based on the broad spectrum of studies entered in the Database and represented removal capability under a variety of climatic and physiographic conditions. Furthermore, the data used to determine general removal capability are based on "best condition" values. In particular, most of the studies focused on STPs that were constructed within three years of monitoring.

The actual performance of a specific STP in the field may be influenced by a variety of factors, including the following:

- STP geometry
- Site characteristics
- Monitoring methodology (see Table 2.2)
- Influent pollutant concentrations

It is suspected that removal capability is influenced by the internal geometry and storage volume provided by the STP. Inappropriate internal geometry can sharply limit STP pollutant removal mechanisms. For example, closely located inlet and outlet may "short-circuit" the STP, allowing stormwater to exit before being treated. Site characteristics that can also influence removal capability include soil type, rainfall, latitude, catchment size, watershed land use, and percent impervious. However, it is not possible to quantify the relative influence of each of these factors on reported STP performance with currently available data.

2.4 Research Gaps in STP Performance

A key element of the 2nd Edition was the identification of current gaps in STP monitoring research. To this end, the entire Database was analyzed to identify the STP groups and design variations that have seldom been monitored and key stormwater pollutants that are infrequently sampled in monitoring studies. This information can be used to set future monitoring and research priorities.

The number of studies included in the Database for various STP groups and design variations and key stormwater pollutants are shown in Table 2.1. This table reveals critical gaps in current knowledge about urban STP performance. Several STPs have been tested fewer than four times. Given the limited number of research studies available for these STPs, there is less confidence in the computed removal rates for these practices. The STP designs that have been tested fewer than four times include the following:

- All Infiltration Practices
- Bioretention
- Swales (dry swales, wet swales, and grass channels)
- Filters (except for surface sand filters)
- Proprietary Products

While proprietary products have been extensively studied, many of the studies were restricted because they were conducted in the lab, rather than field-tested. Further, many proprietary products have been tested only by the manufacturer. Only independent monitoring studies were included in the database.

Perhaps the most critical gap in STP performance research exists for infiltration and bioretention practices, which have not yet been adequately monitored in the field. To some extent, the lack of performance monitoring reflects the fact that stormwater enters these practices in sheetflow and often leaves them by exfiltration into the soil over a broad area. Since runoff is never concentrated, it is extremely difficult to collect the representative samples of either flow or concentration that are needed to evaluate removal performance. This sampling limitation has also made assessment of filter strips problematic. More research on the performance of water quality swales (e.g., biofilters, dry swales and wet swales) appears warranted, not only because so few have been monitored, but because of the wide removal variability among those that have been sampled. Other STPs have been the subject of scant performance research either because they are relatively new (e.g., organic filters and submerged gravel wetlands) or are smaller versions of frequently sampled practices (e.g., pocket wetlands and ponds).

While ponds, wetlands and open channels have been extensively monitored in the field (10 to 30 studies each), significant gaps exist with respect to individual stormwater parameters (Table 2.3). In particular, bacteria and hydrocarbons, and dissolved metal data are scarce. Despite well-established correlations with human health, recreation, and aquatic toxicity, these three parameters were measured in only 10 to 20% of the STP performance studies included in the Database. A greater focus on these important parameters is warranted in future STP monitoring efforts.

Table 2.3 Frequency of Monitoring in Stormwater Treatment Practice Performance Studies for Select Stormwater Pollutants

Stormwater Pollutant	% of Studies Monitored
Bacteria	19
Cadmium, Total	19
Copper, Total	46
Hydrocarbons	9
Lead, Total	65
Nitrate-Nitrite Nitrogen	71
Nitrogen, Total	54
Organic Carbon	56
Phosphorus, Soluble	55
Phosphorus, Total	94
Total Dissolved Solids	13
Total Suspended Solids	94
Zinc, Total	71

Another remaining research gap is the ability to determine the relative benefits of various design features. For example, while it is assumed that increasing storage volume will improve treatment capability, it is not possible to develop a statistically significant relationship using the Database in its current form. One reason for this result is that storage in "impervious inches" is rarely reported. This value would most likely provide the best regression. Descriptions of other design features are also rarely reported.

Section 3.0 Results

In this section, pollutant removal and effluent data are presented in both tabular and graphical format. Tables 3.1 and 3.2 include pollutant removal efficiencies for various STP group and design variations. Table 3.3 presents pollutant removal data for ponds and wetlands of different drainage classes. Finally, Tables 3.4 and 3.5 include effluent concentration data for various STPs.

Removal and effluent concentration data are presented graphically in Figures 3.1-3.6. In these "box and whisker" plots, the "whiskers" represent the maximum and minimum values. The "box" represents the first and third quartile values, as well as the median.

As Figures 3.1 and 3.2 show, STP removal efficiency can vary significantly both between STP groups and among STPs within the same design variation. Consequently, estimates of STP efficiency should not be regarded as a fixed or constant value, but rather as a general estimate of long-term performance. Nevertheless, some generalizations can be made regarding the relative performance of STP groups based on the data in these figures, and in Tables 3.1 and 3.2. Overall, dry ponds perform worse than any other STP group, particularly for soluble pollutant forms. Infiltration practices appear to have the highest removal rates. This result should be viewed with some scrutiny, however, because of the difficulties associated with monitoring infiltration practices, and the fact that few have been monitored. Ponds and wetlands appear to have similar removal rates, with a few exceptions. Ponds have higher removal rates for metals. In addition, while the two groups have similar removal rates for total nutrient removal, ponds have much higher removal rates for soluble phosphorus, while wetlands are more effective at removing soluble nitrogen (i.e., NO_x).

Filters perform relatively well, with the exception of removals for soluble forms of nutrients. Filters do have reasonably high rates for total nitrogen and total phosphorus, however. Most likely, nutrients are transformed from the organic or sediment-bound form of the nutrient within the filter, and flushed out during subsequent storm events. This phenomenon would explain the very low removals for soluble phosphorus and nitrate. Water quality swales appear to perform similarly to ponds or wetlands. Some of these removal rates for TN are very high, and are based on very few data points.

In general, it is difficult to distinguish between specific design variations due to limited data. A few exceptions are the vertical sand filter and the ditch, which consistently perform poorly when compared with other design variations within the same STP group.

Table 3.1 Median Pollutant Removal (%) of Stormwater Ponds and Wetlands

	TSS	TP	Sol P	TN	NO_x	Cu	Zn
Stormwater Dry Ponds							
Quantity Control Pond*	3	19	0	5	9	10	5
Dry Extended Detention Pond	61	20	-11	31*	-2*	29*	29*
Group Median ± 1 St. Dev	**47** ±32	**19** ±13	**-6** ±8.7	**25** ±16	**3.5** ±23	**26***	**26** ±37
Stormwater Wet Ponds							
Wet Extended Detention Pond	80	55	67	35	63	44	69
Multiple Pond System*	91	76	69	N/A	87	N/A	N/A
Wet Pond	79	49	62	32	36	58	65
Group Median ± 1 St. Dev	**80** ±27	**51** ±21	**66** ±27	**33** ±20	**43** ±39	**57** ±22	**66** ±22
Stormwater Wetlands							
Shallow Marsh	83	43	29	26	73	33	42
Extended Detention Wetland*	69	39	32	56	35	N/A	-74
Pond/Wetland System	71	56	43	19	40	58*	56
Submerged Gravel Wetland*	83	64	-10	19	81	21	55
Group Median ± 1 St. Dev	**76** ±43	**49** ±36	**36** ±45	**30** ±34	**67** ±54	**40** ±45	**44** ±40

* Data based on fewer than five data points
NOTES:
- N/A indicates that the data is not available.
- TSS = Total Suspended Solids; TP = Total Phosphorus; Sol P = Soluble Phosphorus; TN = Total Nitrogen; NO_x = Nitrate and Nitrite Nitrogen; Cu = Copper; Zn = Zinc

Table 3.2 Median Pollutant Removal (%) of Stormwater Filtering, Infiltration, Open Channel, and Other Practices

	TSS	TP	Sol P	TN	NO_x	Cu	Zn
Filtering Practices[1]							
Organic Filter	88	61	30[2]	41[2]	-15	66[2]	89
Perimeter Sand Filter[2]	79	41	68	47	-53	25	69
Surface Sand Filter	87	59	-17[2]	32	-13	49	80
Vertical Sand Filter[2]	58	45	21	5	-87	32	56
Bioretention[2]	N/A	65	N/A	49	16	97	95
Group Median ± 1 St. Dev	**86** ±23	**59** ±38	**3** ±46	**38** ± 16	**-14** ±47	**49** ±26	**88** ±17
Infiltration Practices							
Infiltration Trench[2]	N/A	100	100	42	82	N/A	N/A
Porous Pavement[2]	95	65	10	83	N/A	N/A	99
Group Median ± 1 St. Dev	**95**[2]	**80** ±24	**85**[2]	**51** ±24	**82**[2]	N/A	**99**[2]
Open Channels							
Ditches[3]	31	-16	-25[2]	-9	24[2]	14[2]	0[2]
Grass Channel[2]	68	29	40	N/A	-25	42	45
Dry Swale[2]	93	83	70	92	90	70	86
Wet Swale[2]	74	28	-31	40	31	11	33
Group Median[4] ± 1 St. Dev	**81** ±14	**34** ±33	**38** ±46	**84**[2]	**31** ±49	**51** ±40	**71** ±36
Other							
Oil-Grit Separator[2]	-8	-41	40	N/A	47	-11	17
Stormceptor®[2]	25	19	21	N/A	6	30	21

1. Excludes vertical sand filters and filter strips
2. Data based on fewer than five data points
3. Refers to open channel practices not designed for water quality
4. Median value excludes ditches

NOTES:
- N/A indicates that the data is not available.
- TSS = Total Suspended Solids; TP = Total Phosphorus; Sol P = Soluble Phosphorus; TN = Total Nitrogen; NO_x = Nitrate and Nitrite Nitrogen; Cu = Copper; Zn = Zinc

Figure 3.1 Stormwater Treatment Practice Pollutant Removal Efficiencies: Total Suspended Solids, Total Nitrogen, Total Khedjahl Nitrogen, and Nitrate and Nitrite Nitrogen

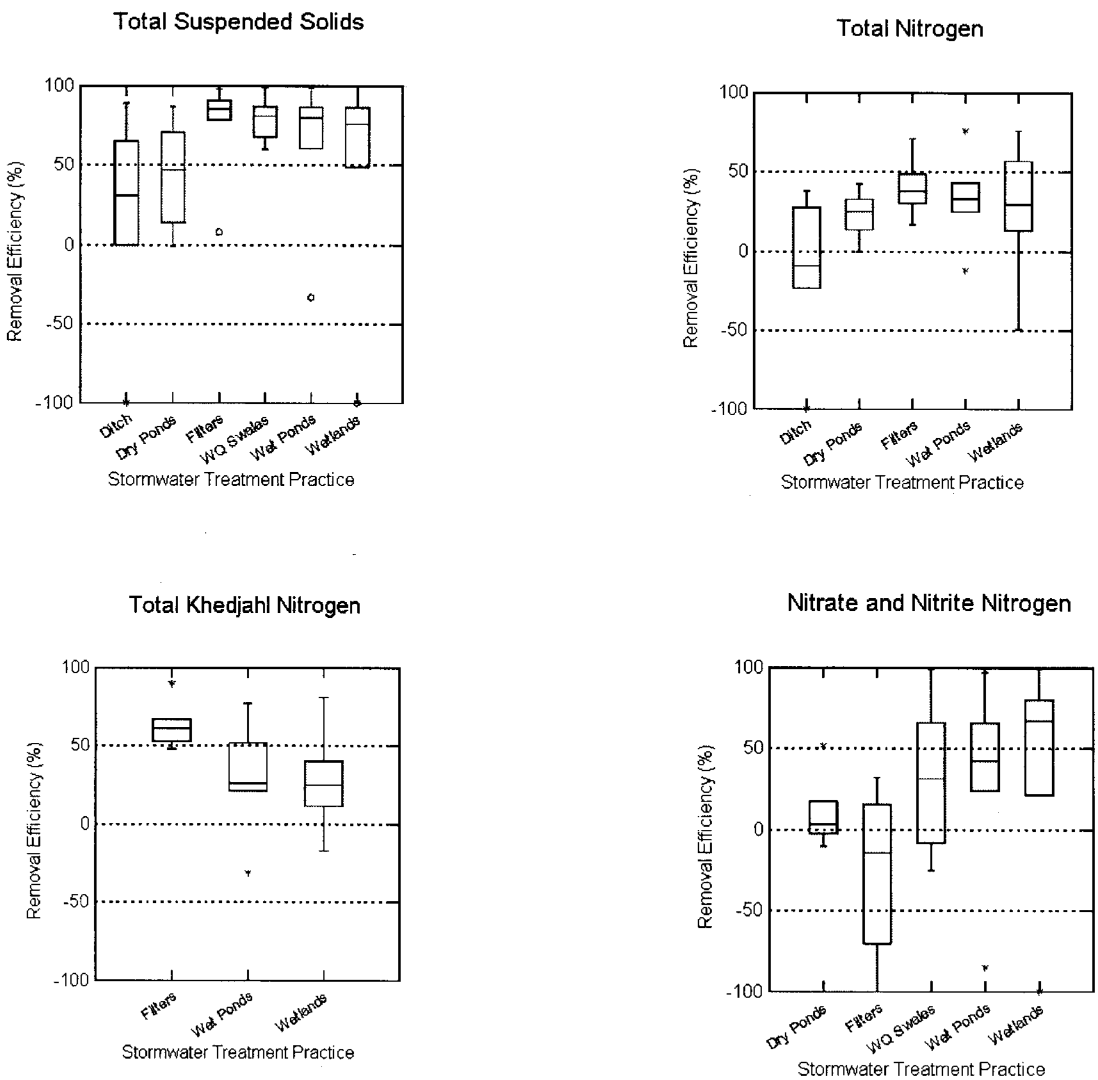
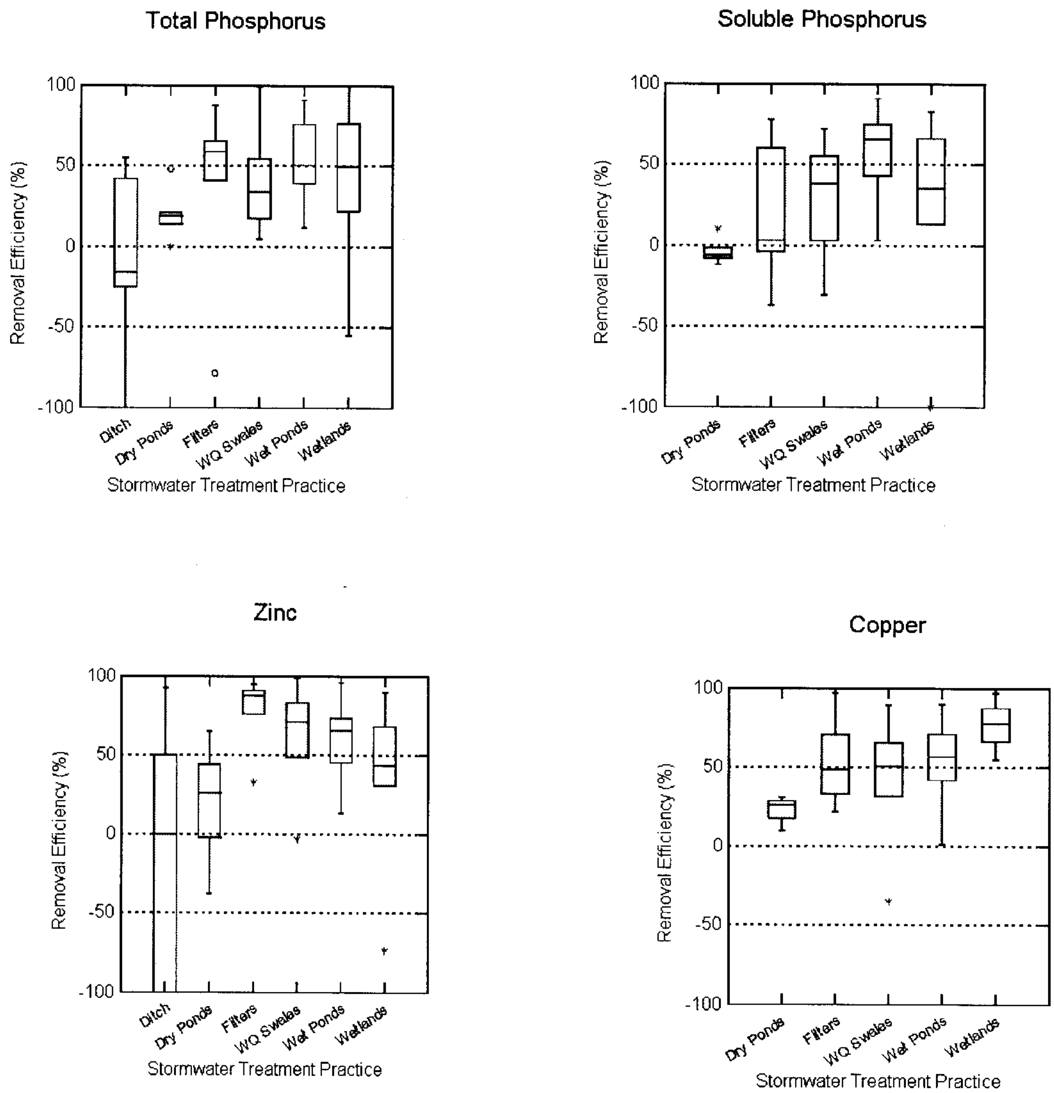


Figure 3.2 Stormwater Treatment Practice Pollutant Removal Efficiencies: Total Phosphorus, Soluble Phosphorus, Zinc, and Copper



A supplementary analysis compared removal rates of ponds and wetlands in different drainage classes (Table 3.3). Overall, these data do not support many conclusions regarding pollutant removal differences between drainage classes. In particular, data for Pocket ponds are sparse, with fewer than five studies represented. Based on the limited analysis conducted here, it appears that Regional wetlands have higher pollutant removal overall than other wetland designs. Regional ponds, on the other hand, have slightly lower efficiencies. The poor performance of Regional ponds may be caused by the influence of baseflow on these larger systems.

Table 3.3 Median Pollutant Removal (%) of Stormwater Treatment Practices by Drainage Class

		TSS	TP	Sol P	TN	NO_x	Cu	Zn
Stormwater Wet Ponds	Pocket[1]	87	78	65[2]	28[2]	67[2]	55	65
	Regular[3]	80	49	70	32	62	58	66
	Regional[4]	70	48	42	37	23	55[2]	43
Stormwater Wetlands	Pocket[1]	57[2]	57[2]	66[2]	44[2]	67[2]	25[2]	52[2]
	Regular[2]	61	36	37	15	45	60	36
	Regional[3]	80	43	35	35	68	57[2]	52[2]

1. Drainage area < 10 acres
2. Data based on fewer than five data points
3. Drainage area <= 300 acres and >= 10 acres
4. Drainage area > 300 acres

NOTES:
- TSS = Total Suspended Solids; TP = Total Phosphorus; Sol P = Soluble Phosphorus; TN = Total Nitrogen; NO_x = Nitrate and Nitrite Nitrogen; Cu = Copper; Zn = Zinc

Figure 3.3 Median Pollutant Removal (%) by Drainage Class: Total Suspended Solids, Total Nitrogen, Total Khedjahl Nitrogen, and Nitrate and Nitrite Nitrogen

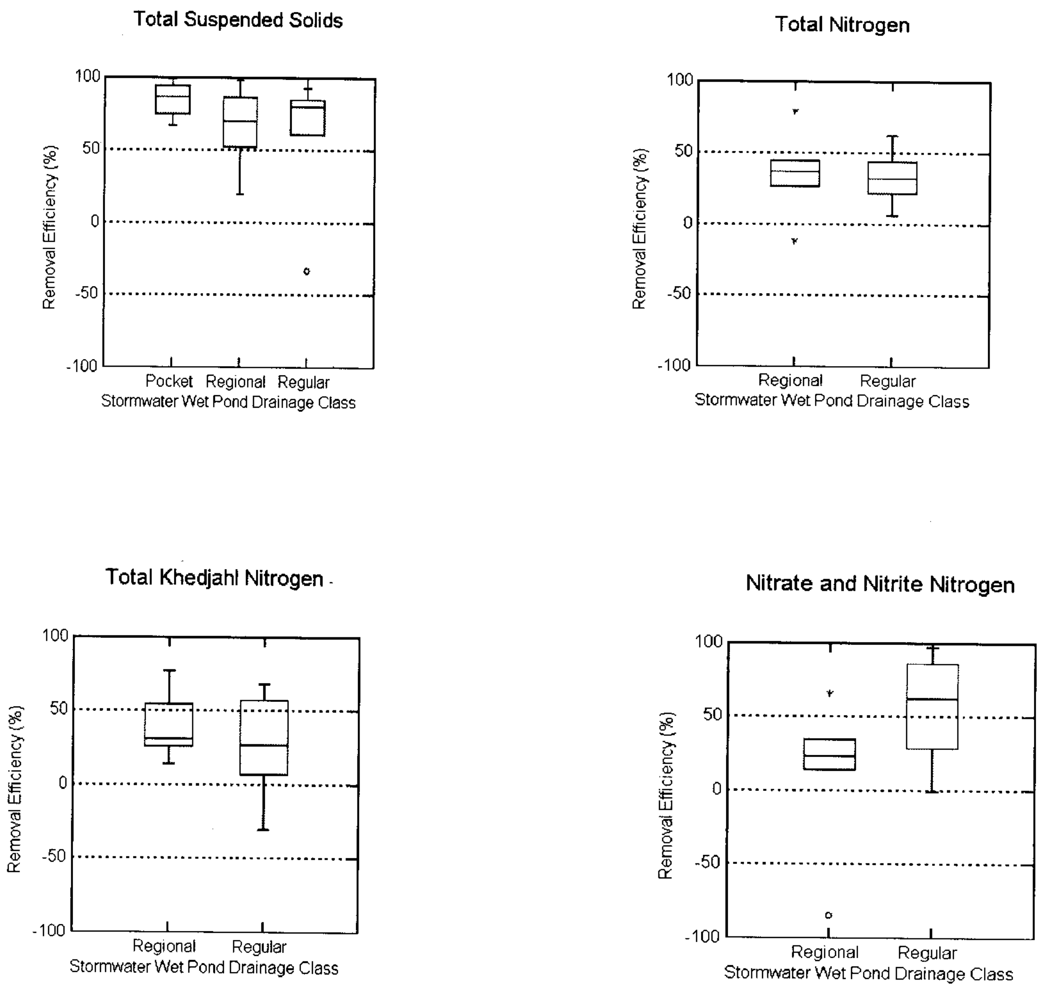
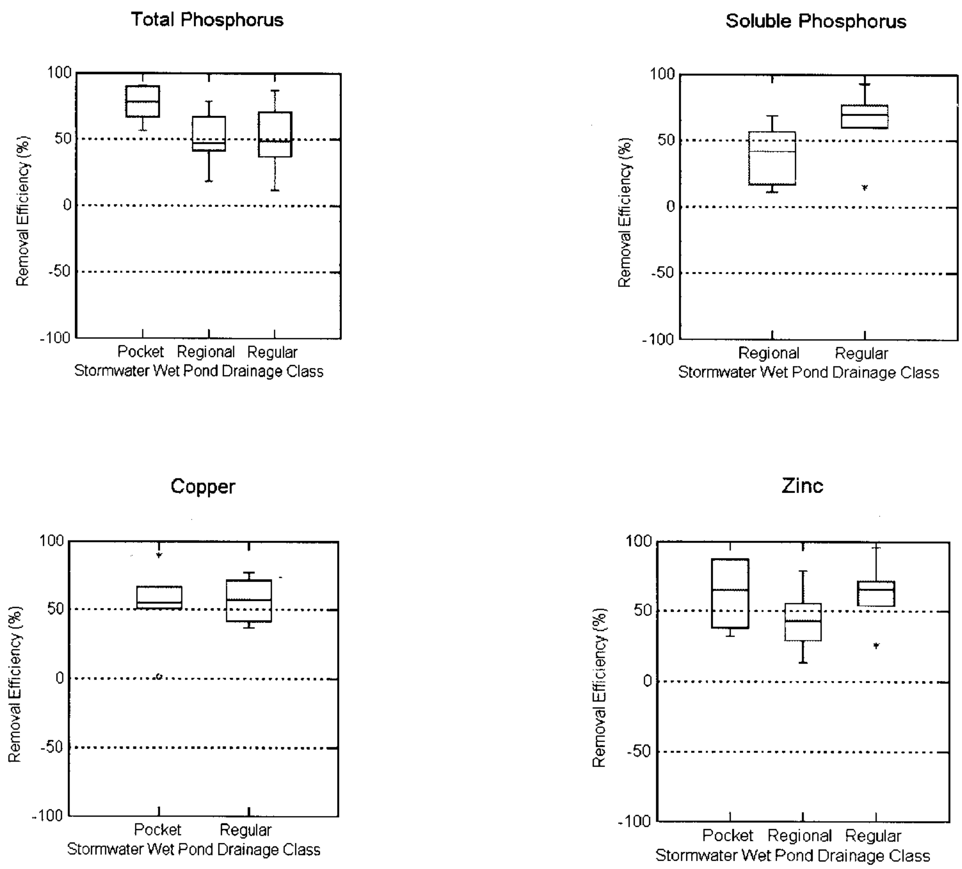


Figure 3.4 Median Pollutant Removal (%) by Drainage Class: Total Phosphorus, Soluble Phosphorus, Copper, and Zinc



A final analysis compared effluent concentrations in various STP groups and design variations. The effluent concentration is an important measure of practice performance, and some research suggests that this parameter may reflect practice performance better than removal efficiency (Schueler, 1996; Strecker *et al.*, 2000). Overall, the data reported in Tables 3.4 and 3.5 and in Figures 3.3 and 3.4 suggest that, for the studies included in the database, practices with high removal efficiencies also tend to have lower effluent concentrations. It is important to note that the removal data are highly variable. Furthermore, only a few studies were available to characterize each STP design variation, and some STP groups. Like efficiencies reported in this document, the effluent concentration represents a general trend in performance, and cannot be used to predict results from an individual practice.

For the most part, the effluent concentrations derived from the database are lower than those reported by Schueler (1996), who evaluated *irreducible concentrations* from stormwater treatment practices (see Appendix E). Part of this discrepancy may be caused by the fact that medians, rather than group means, are presented here.

Table 3.4 Median Effluent Concentration (mg/L)[1] from Stormwater Ponds and Wetlands

	TSS	TP	OP	TN	NO_x	Cu	Zn
Stormwater Dry Ponds[2,3]	**28**	**0.18**	**N/A**	**0.86**	**N/A**	**9.0**	**98**
Stormwater Wet Ponds							
Wet Extended Detention Pond	14	0.11	0.03	1.0	0.08	4.5	26
Wet Pond	18	0.12	0.03	1.5	0.30	6.0	30
Group Median ± 1 St. Dev	**17** ±17	**0.11** ±0.08	**0.03** ±0.03	**1.3** ±0.8	**0.26** ±0.6	**5.0** ±5.7	**30** ±16
Stormwater Wetlands							
Shallow Marsh	12	0.12	0.09[3]	1.7	0.90	4.5	30
Extended Detention Wetland[3]	29	0.27	N/A	1.6	0.84	N/A	N/A
Pond/Wetland System	23	0.20	0.05[3]	1.7	0.31	7.0	28
Group Median ± 1 St. Dev	**22** ±14	**0.20** ±0.81	**0.07** ±0.03	**1.7** ±8.8	**0.36**[3]	**7.0** ±5.0	**31** ±14

1. Units for Zn and Cu are micrograms per liter
2. Data available for Dry Extended Detention Ponds only
3. Data based on fewer than five data points

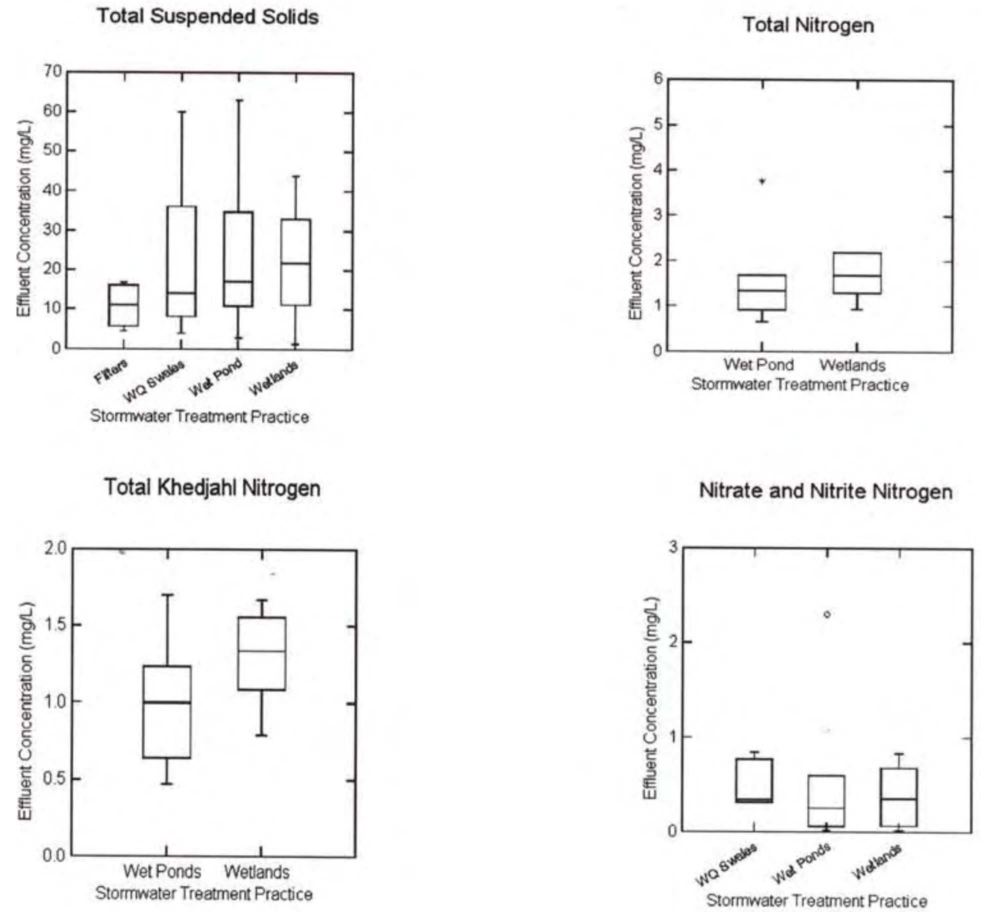
NOTES:
- N/A indicates that the data is not available.
- TSS = Total Suspended Solids; TP = Total Phosphorus; OP = Ortho-Phosphorus; TN = Total Nitrogen; NO_x = Nitrate and Nitrite Nitrogen; Cu = Copper; Zn = Zinc

Table 3.5 Median Effluent Concentration (mg/L)[1] from Stormwater Filtering, Infiltration, Open Channel, and Other Practices							
	TSS	**TP**	**OP**	**TN**	**NO_x**	**Cu**	**Zn**
Filtering Practices[2]							
Organic Filter	12	0.10	0.50[3]	0.99[3]	0.60[3]	10[3]	22
Perimeter Sand Filter[3]	12	0.07	0.09	3.8	2.0	49	21
Surface Sand Filter[3]	38	0.13	N/A	1.8	N/A	2.9	23
Vertical Sand Filter[3]	74	0.14	0.04	1.3	0.60	5.5	20
Bioretention[3]	N/A	0.18	N/A	1.7	N/A	2.0	25
Group Median ± 1 St. Dev	**11** ±4.8	**0.10** ±0.14	**0.07**[3]	1.1[3]	0.60[3]	**9.7** ±0.3	**21** ±23
Infiltration Practices							
Infiltration Trench[3]	N/A	0.63	0.01	3.8	0.09	N/A	N/A
Porous Pavement[3]	17	0.10	0.01	N/A	N/A	N/A	39
Group Median ± 1 St. Dev	**17**[3]	**0.05**[3]	**0.003**[3]	**3.8**[3]	**0.09**[3]	**4.8**[3]	**39**[3]
Open Channels							
Ditch[3, 4]	29	0.31	N/A	2.4	0.72	18	32
Grass Channel[3]	15	0.14	0.09	N/A	0.07	10	60
Dry Swale[3]	16	0.40	0.24	1.4	0.35	23	87
Wet Swale[3]	8.2	0.13	0.08	0.96	31	13	39
Group Median ± 1 St. Dev	**14** ±19	**0.19** ±0.15	**0.09**[3]	**1.1**[3]	**0.35** ±0.27	**10** ±10	**53** ±46
Other							
Oil-Grit Separator[3]	48	0.41	0.05	1.9	0.20	13	170
Stormceptor®[3]	7.5	0.02	N/A	N/A	0.27	3.0	19
ALL Stormwater Treatment Practices	**17** ±19	**0.15** ±3.1	**0.04** ±0.05	**1.6** ±1.0	**0.38** ±0.70	**7** ±13	**30** ±41

1. Units for Zn and Cu are micrograms per liter
2. Excludes vertical sand filters
3. Data based on fewer than five data points
4. Refers to open channel practices not designed for water quality
5. Excludes ditches

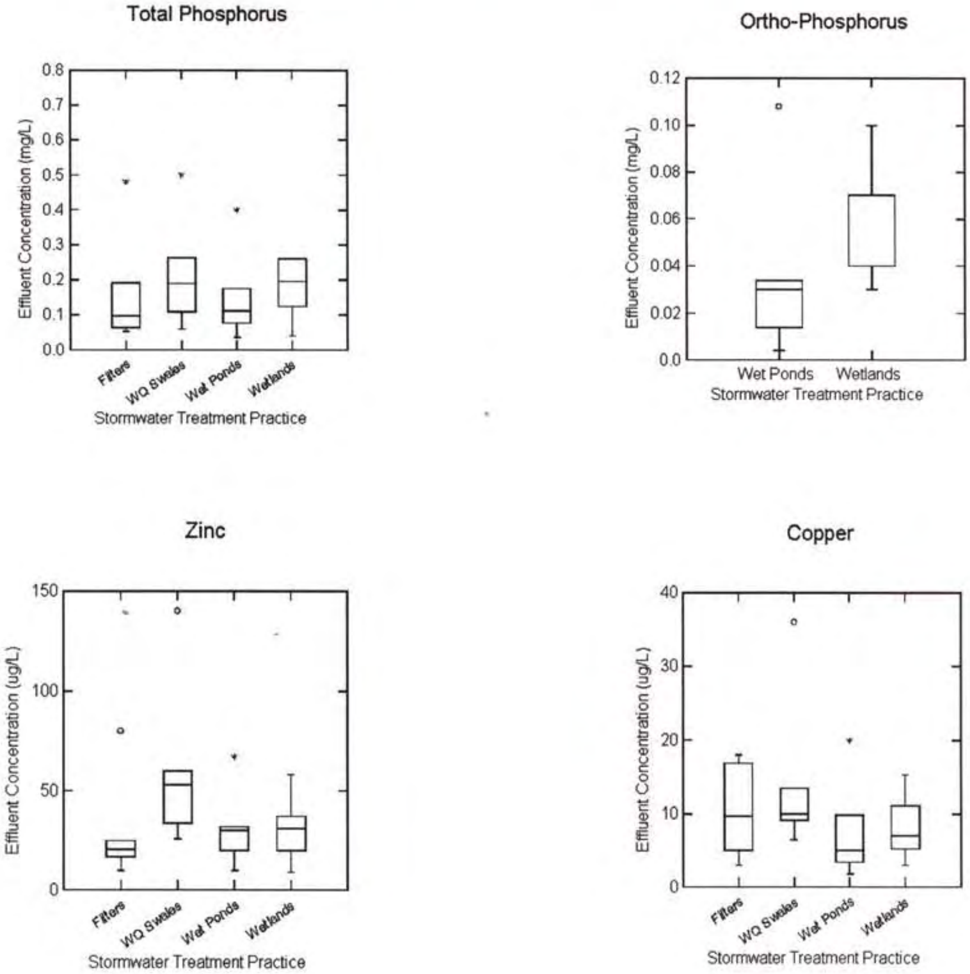
NOTES:
- N/A indicates that the data is not available.
- TSS = Total Suspended Solids; TP = Total Phosphorus; OP = Ortho-Phosphorus; TN = Total Nitrogen; NO_x = Nitrate and Nitrite Nitrogen; Cu = Copper; Zn = Zinc

Figure 3.5 Stormwater Treatment Practice Median Pollutant Effluent Concentrations: Total Suspended Solids, Total Nitrogen, Total Khedjahl Nitrogen, and Nitrate and Nitrite Nitrogen*



* The maximum wetland total nitrogen effluent concentration is 34.5 mg/L.

Figure 3.6 Stormwater Treatment Practice Median Pollutant Effluent Concentrations: Total Phosphorus, Ortho-Phosphorus, Zinc, and Copper*



* The maximum wetland total phosphorus effluent concentration is 26.5 mg/L.

3.1 Phosphorus

While results are variable, most STP design variations had median removal rates in the 30 to 60% range for both soluble and total phosphorus. Water quality swales showed poor removal relative to other practices. Pocket ponds appear to have the highest removal rate among the drainage classes at 78%. While submerged gravel wetlands were effective in removing total phosphorus, this STP was very ineffective in removing soluble phosphorus. Groups that exhibited very wide variation in phosphorus removal included wetlands, water quality swales, and ditches.

While there is some variability between outflow concentrations, most of the outliers have a low sample size of fewer than five studies. The median value for all studies containing phosphorus effluent concentrations is 0.15 mg/L. The median ortho-phosphorus concentration is 0.04 mg/L.

3.2 Nitrogen

Most STP design variations exhibited a limited ability to remove total nitrogen, with typical median removal rates on the order of 15 to 35%. With respect to soluble forms of nitrogen (e.g. nitrate), the STP groups differed greatly in their pollutant removal ability. In a broad sense, the STP groups could be divided into two categories: "nitrate leakers" and "nitrate keepers." "Nitrate leakers" tend to have low or even negative removal of this soluble form of nitrogen, and include filtering practices and dry ponds. In these practices, organic nitrogen is converted to nitrate in the nitrification process, but conditions do not allow for the subsequent denitrification process. Thus, these "leakers" produce more nitrate than is delivered to them. "Nitrate keepers" tend to have moderate removal rates and include wet ponds, wet extended detention ponds and shallow marshes. In these STPs, algae and other plants take up nitrate and incorporate it into organic nitrogen. Thus, "keepers" tend to remove more nitrate than is delivered to them.

Median effluent concentration for total nitrogen and nitrate and nitrite nitrogen are 1.60 mg/L and 0.38 mg/L respectively. In this case, there does not appear to be a strong correlation between low effluent concentrations and low removal efficiencies.

3.3 Suspended Sediment

Most STP groups exhibit strong ability to remove suspended sediment, with median removals ranging from 60 to 85% for most STP groups. Highest median removals were noted for sand filters, water quality swales, infiltration practices, and shallow marshes (all slightly above 80%). Most pond and wetland designs approached, but did not surpass, the 80% TSS removal threshold specified in CZARA 6217 guidance. Ditches exhibited the greatest removal variability, and had a median sediment removal rate of 31%. All pond drainage classes exhibited fairly high removal rates for suspended solids.

The majority of the effluent concentrations range from 10 to 30 mg/L with an overall median concentration of 16.7 mg/L.

3.4 Carbon

The ability of stormwater STPs to remove organic carbon or oxygen-demanding material was generally modest, with median removal rates in the order of 20 to 40% (Table 3.6). A notable exception was water quality swales, which exhibited median removal rates in excess of 65%. However, water quality swale carbon removal data were only based on three studies. It should be noted that variability in carbon removal rates could be attributed to the combination of total organic carbon, BOD and COD data.

3.5 Metals

Most STP groups displayed moderate to high pollutant removal rates for zinc. Typical median removal rates were on the order of 50 to 80%. Exceptions included open channels and dry ED ponds that were generally ineffective at promoting settling. Median copper removal rates ranged from 40 to 60%, with highest removals noted for the water quality swales, stormwater wet ponds, and filter groups. Figure 3.6 shows that regional ponds were ineffective at reducing zinc. Zinc and copper median effluent concentrations for all STPs are seven and 30 ug/L. It should be noted that only 10% of all STP studies measure soluble metal removal. Soluble metal concentration is thought to be a better indicator of potential aquatic toxicity than total metals (which includes metals that are tightly bound to particles). A quick review of the few STP studies that examined soluble metals suggests that while removal is usually positive, it is almost always lower than total metal removal.

3.6 Bacteria

Bacteria median removal rates for select STPs are also provided in Table 3.6. The limited bacteria monitoring data did not allow for intensive statistical analysis. Preliminary mean bacteria removal rates ranged from 65 to 75% for ponds and wetlands and 55% for filters. Based on very limited data, ditches were found to have no bacteria removal capability, while water quality swales consistently exported bacteria. To put the removal data in perspective, a 95 to 99% removal rate is generally needed in most regions to keep bacteria levels under recreational water quality standards (Schueler, 1999).

Table 3.6 Median Bacteria and Organic Carbon Removal (%) by Stormwater Treatment Practice			
	Bacteria[1]	Organic Carbon[2]	Hydrocarbons
Stormwater Wet Ponds	70	43	81[5]
Stormwater Dry Ponds	78[5]	25	N/A[6]
Stormwater Wetlands	78[5]	18	85[5]
Filtering Practices[3]	37	54	84[5]
Water Quality Swales	-25[5]	69[5]	62[5]
Ditches[4]	5	18	N/A

1. Bacteria data include fecal streptococci, enterococci, fecal coliform, *E. coli.* and total coliform
2. Organic carbon data includes BOD, COD, and TOC removal data
3. Excludes vertical sand filters and filter strips
4. Refers to open channel practices not designed for water quality
5. Data based on fewer than five data points
6. N/A indicates that the data are not available

3.7 Hydrocarbons

The limited monitoring data available suggest that most STP groups can remove most petroleum hydrocarbons from stormwater runoff (Table 3.6). For example, ponds, wetlands, and filters all had median removal rates on the order of 80 to 90%, and water quality swales were rated at 62%. In general, the ability of a STP group to remove hydrocarbons was closely related to its ability to remove suspended sediment. In nearly every case, hydrocarbon removal was within 15% of observed sediment removal.

3.8 Implications

This analysis of stormwater STP removal efficiency has several implications for the watershed manager:

- Pond and wetland STPs have similar removal capabilities, although the pollutant removal capability of wetlands appears to be more variable than ponds.
- Infiltration practices appear to have the highest overall removal capability of any STP group, although this is based on only a few data points.
- Dry ED ponds and ditches have extremely limited removal capability.
  Water quality swales show promise for most pollutants, but not for biologically available phosphorus.

Significant gaps do exist in our knowledge of the removal capability of certain STP designs and stormwater parameters. Filling these gaps should be the major focus of future STP monitoring research. The more well-studied STP groups (ponds, wetlands, and filters) should be re-directed to investigate internal factors (i.e., geometry and sediment/water column interactions) that may create the wide variability in pollutant removal that is characteristic of STP monitoring. Finally, more research is needed with respect to bacteria, dissolved metals, and hydrocarbons; all of these are pollutants associated with human health impacts. Such research could be of great value in developing better designs and reducing pollutant removal variability, allowing for more reliable pollutant reduction at the watershed scale.

The Center will continue to maintain and update the Database as new studies become available. Studies and research submitted to the Center for inclusion into the Database will be incorporated subject to examination for accuracy and appropriateness.

References

Schueler, T. 1994. "Review of Pollutant Removal Performance of Stormwater Ponds and Wetlands." Technical Note 6. *Watershed Protection Techniques*. 1(1):17-18. Center for Watershed Protection, Ellicott City, Maryland.

Schueler, T. 1996. "Irreducible Pollutant Concentrations Discharged from Urban BMPs." Technical Note 75. *Watershed Protection Techniques*. 2(2):369-371. Center for Watershed Protection, Ellicott City, Maryland.

Strecker, E., J. Kersnar, E. Driscoll, and R. Horner. 1992. *The Use of Wetlands for Controlling Stormwater Pollution.* EPA/600. Prepared for U.S. EPA, Region V Water Division. Woodward-Clyde. Portland, Oregon.

Strecker, E., M. Quigley, and B. Urbonas. 2000. *Determining Stormwater BMP Effectiveness.* National Conference on Tools for Urban Water Resource Management and Protection: February 7-10, 2000. Proceedings. U.S. Environmental Protection Agency. Washington, District of Columbia.

Appendix A: STP Pollutant Removal Database Summaries

STP Pollutant Removal Database

Indices

Study #: 1

STP Category Stormwater Pond

Facility Oakhampton

STP Type Dry Extended Detention Pond

State Maryland **Country** USA

Drainage Class

Bibliographic Information

Baltimore Department of Public Works. 1989. Detention Basin Retrofit Project and Monitoring Study Results. Water Quality Management Office. Baltimore, MD. 42 p.

Study Notes

No. of Storms 9

Treatment Volume/ Design Basis

0.50 inch/acre (inferred value).

Watershed in. 0.5

Impervious in.

Drainage Area 16.8 **ac**

Slope **%**

Land Use

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility **yrs**

STP Notes

Performance Notes

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS			87	77	10
TDS					
TP			26	0.188	0.112
DP			-12	0.1	0.112
PP					
Ortho-P					
TN					
ON					
NH4			53.5	0.43	0.2
TKN					
NO3			-10	0.673	0.742
NOx					
Organic					
Lead					
Zinc					
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 2

STP Category Stormwater Pond

Facility Maple Run III

STP Type Dry Extended Detention Pond

State Texas **Country** USA

Drainage Class

Bibliographic Information

City of Austin, TX. 1991. Design Guidelines for Water Quality Control Basins. Public Works Department. Austin, TX. 64 p.

Study Notes

No. of Storms 17

Treatment Volume/ Design Basis

0.50 inch/acre.

Watershed in. 0.5

Impervious in.

Drainage Area 28 **ac**

Slope **%**

Land Use

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility **yrs**

STP Notes

Performance Notes

Originally a dry stormwater pond but due too poor maintenance, 3-6 hours of extended detention achieved.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS			30		
TDS					
TP			18		
DP					
PP					
Ortho-P					
TN			35		
ON					
NH4					
TKN					
NO3			52		
NOx					
COD			22		
Lead			29		
Zinc			-38		
Copper			31		
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Fecal coliform			78		
Turbidity					
TOC			30		
BOD			35		

STP Pollutant Removal Database

Indices

Study #: 3

STP Category Stormwater Pond

Facility Hawthorn Ditch

STP Type Dry Extended Detention Pond

State Oregon **Country** USA

Drainage Class

Bibliographic Information

Miller, T. 1987. Appraisal of Storm-Water Quality Near Salem, Oregon. US Geological Survey. Water Resources Report 87-4064.

Study Notes

No. of Storms 11

Treatment Volume/ Design Basis

Watershed in.

Impervious in.

Drainage Area 512 **ac**

Slope **%**

Land Use

% Impervious Cover 53

% Residential 39

% Commercial 38

% Industrial 1

Soil Type HSG: C

STP Size

Age of Facility **yrs**

STP Notes

No. of Storms represents an average.

Performance Notes

Inflow and Outflow units for Lead are micrgrams per liter. The efficiency was determined from inflow and outflow regression curves based on field data.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS			47	68	38
TDS					
TP			21	0.21	0.18
DP					
PP					
Ortho-P					
TN					
ON					
NH4					
TKN					
NO3					
NOx					
Organic					
Lead			29	110	86
Zinc					
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 4

Facility London Commons

State Virginia **Country** USA

STP Category Stormwater Pond

STP Type Dry Extended Detention Pond

Drainage Class

Bibliographic Information

Occoquan Watershed Monitoring Laboratory. 1987. Final Report: London Commons Extended Detention Facility. Urban BMP Research and Demonstration Project. Virginia Tech University. Manassas, VA. 68 p.

Study Notes

No. of Storms 27

Treatment Volume/ Design Basis

0.22 in/acre. Extended detention provided up to 20 hours.

Watershed in. 0.22

Impervious in.

Drainage Area 11.4 **ac**

Slope **%**

Land Use

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility **yrs**

STP Notes

Performance Notes

Data based on average of two experiments, totalling 27 samples. Exfiltration of runoff accounts for some pollutant removal.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS			51.5		
TDS					
TP			48		
DP					
PP					
Ortho-P					
TN			42.5		
ON					
NH4					
TKN					
NO3					
NOx					
COD			29		
Lead			32		
Zinc			32		
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 5

STP Category Stormwater Pond

Facility Stedwick

STP Type Dry Extended Detention Pond

State Maryland **Country** USA

Drainage Class

Bibliographic Information

Schueler, T.R. and M. Helfrich. 1988. Design of Extended Detention Wet Pond Systems. In: Design of Urban Runoff Quality Controls. L.A. Roesner, B. Urbonas and M.B. Sonnen (Eds.). American Society of Civil Engineers. New York, New York. p. 280-281.

Study Notes

No. of Storms 25

Treatment Volume/ Design Basis

0.30 inch/acre.

Watershed in. 0.3

Impervious in.

Drainage Area 34 **ac**

Slope **%**

Land Use

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility **yrs**

STP Notes

Performance Notes

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS			70		
TDS					
TP			13		
DP					
PP					
Ortho-P					
TN			24		
ON					
NH4					
TKN			30		
NO3					
NOx					
COD			27		
Lead			62		
Zinc			57		
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 6

Facility Greenville

State North Carolina **Country** USA

STP Category Stormwater Pond

STP Type Dry Extended Detention Pond

Drainage Class

Bibliographic Information

Stanley, D. 1994. An Evaluation of the Pollutant Removal of a Demonstration Urban Stormwater Detention Pond. Albermarle-Pamlico Estuary Study. APES Report 94-07. 112 p. Also in: Performance of a Dry Extended Detention Pond in North Carolina. Watershed Protection Techniques. Center for Watershed Protection. Fall 1995. Vol. 2(1): 294-295.

Study Notes

No. of Storms 8

Treatment Volume/ Design Basis

72 hours detention for first 0.5."

Watershed in. 0.5

Impervious in.

Drainage Area 200 **ac**

Slope **%**

Land Use Residential/commercial
.

% Impervious Cover 31

% Residential

% Commercial

% Industrial

Soil Type Soil

STP Size Pond depth= 8-11'. 1.75 acre grass bottom.

Age of Facility 0 **yrs**

STP Notes

Performance Notes

Organic refers to particulate organic carbon. One large storm event caused 70% of runoff volume to be shortcircuited. Dissolved organic carbon= -6. Inlfow and Outflow units for metals are micrograms per liter.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS	71			98	28
TDS					
TP	14			0.35	0.27
DP	-9			0.17	0.14
PP	33			0.19	0.13
Ortho-P					
TN	26			1.04	0.86
ON					
NH4	9			0.11	0.1
TKN				0.72	0.56
NO3	-2			0.32	0.3
NOx					
Organic	45				
Lead	55			27	10
Zinc	26			163	98
Copper	26			14	9
Cadmium	54			1	1
Chromium	49			5	2
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					
Ni	43			5	2
PN	43			0.56	0.37

STP Pollutant Removal Database

Indices

Study #: 7

Facility Boynton Beach Mall

State Florida **Country** USA

STP Category Stormwater Pond

STP Type Multiple Pond System

Drainage Class Regular

Bibliographic Information

Holler, J.D. 1989. Water Quality Efficiency of an Urban Commercial Wet Detention Stormwater Management System at Boynton Beach Mall In South Palm Beach County, FL. Florida Scientist. Winter 1989. Vol. 52(1): 48-57.

Study Notes

No. of Storms 8

Treatment Volume/ Design Basis

First 1" of runoff or 2.5" x % impervious area. Detention storage volume= 2.2"

Watershed in. 1

Impervious in. 2.5

Drainage Area 105.7 **ac**

Slope **%**

Land Use Commercial mall

% Impervious Cover 90

% Residential

% Commercial 100

% Industrial

Soil Type

STP Size 3 interconnected ponds each @ 3 acres; total= 8.7 acres.

Age of Facility **yrs**

STP Notes

Did not examine constituent mass losses/gains to and from groundwater seepage. Results attributed to sedimentation & settling involving the water column.

Performance Notes

Does not include mass losses or gains due to ground seepage.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS	91				
TDS					
TP	76				
DP	69				
PP					
Ortho-P					
TN					
ON					
NH4	55				
TKN	58				
NO3	87				
NOx					
Organic					
Lead					
Zinc					
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 8

STP Category Stormwater Pond

Facility Lake Ridge

STP Type Quantity Control Pond

State Virginia **Country** USA

Drainage Class

Bibliographic Information

Metropolitan Washington Council of Governments. 1983. Final Report: Pollutant Removal Capability of Urban BMPs in the Washington Metropolitan Area. Prepared for the U.S. Environmental Protection Agency. 64 p.

Study Notes

No. of Storms 28

Treatment Volume/ Design Basis

Watershed in. 0.66

Impervious in. 2.12

Drainage Area 88 **ac**

Slope 7.9 **%**

Land Use townhouses

% Impervious Cover 31

% Residential

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility **yrs**

STP Notes
210000 ft3

Performance Notes
Frequent resuspension by clogging of lowflow orifice. Minor extended detention provided (1-2 hours).

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS	14				
TDS					
TP	20				
DP	-6				
PP					
Ortho-P					
TN	10				
ON					
NH4					
TKN					
NO3	9				
NOx					
COD	-1				
Lead					
Zinc	-10				
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 9

STP Category Stormwater Pond

Facility

STP Type Quantity Control Pond

State Kansas **Country** USA

Drainage Class

Bibliographic Information

Pope, L.M. and L.G. Hess. 1988. Load-Detention Efficiencies in a Dry Pond Basin. In: Design of Urban Runoff Quality Controls. L.A. Roesner, B. Urbonas and M.B. Sonnen (Eds.). American Society of Civil Engineers. New York, New York. p. 258-267.

Study Notes

No. of Storms 19

Treatment Volume/ Design Basis

3.42 watershed inches.

Watershed in. 3.42

Impervious in.

Drainage Area 12.3 **ac**

Slope **%**

Land Use

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility **yrs**

STP Notes

Performance Notes

Resuspension. Extended volume was high.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS			3		
TDS					
TP			19		
DP			0		
PP					
Ortho-P					
TN					
ON					
NH4					
TKN					
NO3			20		
NOx					
COD			16		
Lead			66		
Zinc			65		
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 10

STP Category Stormwater Pond

Facility Potomac Mills Plaza

STP Type Quantity Control Pond

State Virginia **Country** USA

Drainage Class

Bibliographic Information

Schehl, T.P. and T.J. Grizzard. 1995. Runoff Characterization From an Urban Commercial Catchment and Performance of an Existing Undeground Detention Facility in Reducing Constituent Transport. Proceedings of the 4th Biennial Stormwater Research Conference. October 18-20, 1995. Clearwater, FL. Sponsored by the Southwest Florida water Management District. p. 190-199.

Study Notes

No. of Storms 15

Treatment Volume/ Design Basis

2 year design storm. Runoff coefficient= 0.85. Median detention

Watershed in.

Impervious in.

Drainage Area 57.8 **ac**

Slope 0.15 **%**

Land Use Stripmall and parking.

% Impervious Cover

% Residential

% Commercial 100

% Industrial

Soil Type

STP Size 5- 70' long pipes.

Age of Facility **yrs**

STP Notes

Performance Notes

Seepage and infiltration altered runoff (greater volume at outflow). Concentration at inflow was low. TSS values based only on events where settling occurred (4 events). Metal values based on extractability. As designed the facility did not yield any water quality improvements.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS		-1.1			
TDS					
TP		0			
DP		10			
PP					
Ortho-P					
TN		0			
ON					
NH4		6.3			
TKN		10			
NO3		-2.8			
NOx					
Organic					
Lead		5.1			
Zinc		5.2			
Copper		9.5			
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					
OP					

STP Pollutant Removal Database

Indices

Study #: 11

Facility Davis

State North Carolina **Country** USA

STP Category Stormwater Pond

STP Type Wet Extended Detention Pond

Drainage Class Regional

Bibliographic Information

Borden, R. C., J.L. Dorn, J.B. Stillman and S.K. Liehr. 1996. Draft Report. Evaluation of Ponds and Wetlands For Protection of Public Water Supplies. Water Resources Research Institute of the University of North Carolina. Department of Civil Engineering. North Carolina State University. Raleigh, North Carolina.

Study Notes

No. of Storms 22

Treatment Volume/ Design Basis

Permanent pool surface area/drainage area ratio= 1.01%. Detention time= 20

Watershed in. 0.65

Impervious in.

Drainage Area 1258 **ac**

Slope **%**

Land Use Dairy farms, woodland.

% Impervious Cover 16

% Residential

% Commercial

% Industrial

Soil Type

STP Size Average pond depth= 5.3'

Age of Facility **yrs**

STP Notes

Performance Notes

Efficiency varied according to influent quality, flow rate, thermal stratification, seasonal algal growth variation. Low efficiency rate for fecal coliform; one storm tended to skew results. Inflow and Outflow units for metals are micrograms per liter. Inflow and Outflow units for Fe. Col are ct/100mL.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS	60.4			177	39
TDS	1.7			276	145
TP	46.2			0.761	0.214
DP	58.3			0.471	0.102
PP					
Ortho-P					
TN	16			3.352	1.459
ON					
NH4	10.4			0.302	0.142
TKN					
NO3	18.2				
NOx					
TOC	21.6			22.8	9.6
Lead	51.2			40	3
Zinc	38.5			66.5	41.5
Copper	14.7			40	20
Cadmium					
Chromium	28.6				350
Iron	28.9			7360	2870
TPH					
Oil/Grease					
Fecal coliform	48.1			17619	4764
Turbidity					
VSS	42				
Alkalinity	7.8			86.6	42.5

STP Pollutant Removal Database

Indices

Study #: 12

Facility Piedmont

State North Carolina **Country** USA

STP Category Stormwater Pond

STP Type Wet Extended Detention Pond

Drainage Class Regional

Bibliographic Information

Borden, R. C., J.L. Dorn, J.B. Stillman and S.K. Liehr. 1996. Draft Report. Evaluation of Ponds and Wetlands For Protection of Public Water Supplies. Water Resources Research Institute of the University of North Carolina. Department of Civil Engineering. North Carolina State University. Raleigh, North Carolina.

Study Notes

No. of Storms 25

Treatment Volume/ Design Basis

Permanent pool surface area/drainage area ratio= 0.97%. Detention time= 8.6

Watershed in. 0.5

Impervious in.

Drainage Area 1220 **ac**

Slope **%**

Land Use Commercial, woodland, highway,

% Impervious Cover 30

% Residential

% Commercial

% Industrial

Soil Type

STP Size Average pond depth= 4.1'

Age of Facility **yrs**

STP Notes

48% of inflow pretreated by wet detention pond on tank farm.

Performance Notes

Efficiency varied according to influent quality, flow rate, thermal stratification, seasonal algal growth variation. Inflow and Outflow units for metals are micrograms per liter. Inflow and Outflow units for Fe. Col. are ct/100mL

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS	19.6			61	49
TDS	5			101	96
TP	36.5			0.162	0.103
DP	18.3			0.033	0.027
PP					
Ortho-P					
TN	35.1			1.132	0.734
ON					
NH4	-64.1			24	39
TKN	25.7			0.867	0.644
NO3	65.9				
NOx					
TOC	26.8			8	6
Lead	-96.7			1	1
Zinc					
Copper					
Cadmium					
Chromium					
Iron	-4.3			2660	2780
TPH					
Oil/Grease					
Fecal coliform	-5.8				
Turbidity					
VSS	30				
Alkalinity	4.8				

STP Pollutant Removal Database

Indices

Study #: 13

Facility Woodhollow

State Texas **Country** USA

STP Category Stormwater Pond

STP Type Wet Extended Detention Pond

Drainage Class Regional

Bibliographic Information

City of Austin, TX. 1991. Design Guidelines for Water Quality Control Basins. Public Works Department. Austin, TX. 64 p.

Study Notes

No. of Storms 14

Treatment Volume/ Design Basis

0.55 inch/acre

Watershed in. 0.55

Impervious in.

Drainage Area 381 **ac**

Slope **%**

Land Use

% Impervious Cover 39

% Residential

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility **yrs**

STP Notes

Performance Notes

Negative removal for TDS off-line facility.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS			54		
TDS					
TP			46		
DP					
PP					
Ortho-P					
TN			39		
ON					
NH4			28		
TKN			26		
NO3			45		
NOx					
COD			41		
Lead			76		
Zinc			69		
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Fecal coliform			46		
Turbidity					
BOD			39		

STP Pollutant Removal Database

Indices

Study #: 14

Facility Eastgate Business Park Pond C

State Washington **Country** USA

STP Category Stormwater Pond

STP Type Wet Extended Detention Pond

Drainage Class Regular

Bibliographic Information

Comings, K.; D. Booth; and R. Horner. Stormwater Pollutant Removal by Two Wet Ponds in Bellevue, WA. University of Washington.

Study Notes

No. of Storms 17

Treatment Volume/ Design Basis

Watershed in. 1.73

Impervious in. 3.04

Drainage Area 12.35 **ac**

Slope **%**

Land Use

% Impervious Cover 57

% Residential

% Commercial

% Industrial

Soil Type

STP Size Surface Area: 0.42 ac
Permanent pool depth: 6.56 in.
Permanent pool volume: 77692 ft3 Live

Age of Facility **yrs**

STP Notes

First pond of a two pond system; see study #27

Performance Notes

Inflow and Outflow units for metals are micrograms per liter

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS		81		16.2	2.9
TDS					
TP		46		0.087	0.045
DP		62		0.026	0.01
PP				0.061	0.035
Ortho-P		54		0.033	0.014
TN					
ON					
NH4					
TKN					
NO3					
NOx					
Organic					
Lead		76		2.2	0.5
Zinc		72		83	22
Copper		47		3.5	1.8
Cadmium		52		0.25	0.12
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 15

Facility Rouge River

State Ontario **Country** Canada

STP Category Stormwater Pond

STP Type Wet Extended Detention Pond

Drainage Class Regional

Bibliographic Information

Fellows, D.; W. Liang; S. Ristic; and M. Thompson. 1999. Performance Assessment of MTOs Rouge River, Highway 40, Stormwater Management Pond. SWAMP. Ontario Ministry of Environment and Energy.

Study Notes

No. of Storms 18

Treatment Volume/ Design Basis

Watershed in. 0.64

Impervious in. 1.88

Drainage Area 320 **ac**

Slope **%**

Land Use mostly residential and some residential

% Impervious Cover 34

% Residential

% Commercial

% Industrial

Soil Type

STP Size Avg. Permanent Pool Depth: 8.2 ft Length to Width Ratio: 10:1 Permanent Pool Volume:

Age of Facility 2 **yrs**

STP Notes

Performance Notes

While the study also provides performance data for winter, the data here only represents growing season performance. Ouflow units for metals are micrograms per liter. Outflow units for Fe. Col. are colonies per 100 mL.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS	87				37
TDS					
TP	79				0.06
DP					
PP					
Ortho-P	69				0.006
TN					1.58
ON					
NH4					
TKN	59				
NO3					
NOx	24				0.97
Organic					
Lead	84				
Zinc	79				67
Copper	79				10
Cadmium	46				
Chromium					
Iron					
TPH					
Oil/Grease		79			1.5
Bacteria					
Turbidity					
Cl		-100			580
NH3		70			

STP Pollutant Removal Database

Indices

Study #: 16

Facility Harding Park

State Ontario **Country** Canada

STP Category Stormwater Pond

STP Type Wet Extended Detention Pond

Drainage Class Regular

Bibliographic Information

Fellows, D.; W. Liang; S. Ristic; and S. Smith. 1999. Performance Assessment of Richmond Hill's Harding Park Stormwater Retrofit Pond. SWAMP. Ontario Ministry of Environment and Energy.

Study Notes

No. of Storms 10

Treatment Volume/ Design Basis

Detention time: 6 to 12 hours

Watershed in. 0.64

Impervious in.

Drainage Area 41.5 **ac**

Slope **%**

Land Use

% Impervious Cover 45

% Residential

% Commercial

% Industrial

Soil Type

STP Size Surface Area: 1.7 ac Permanent Pool Volume: 35314.67 ft3 Active Storage Capacity:

Age of Facility 1 **yrs**

STP Notes

Pre-existing stormwater facility was a 1 ac dry pond which was retrofitted to incorporate a three-cell system: a sediment settling basin, wet pond, and a small wetland area

Performance Notes

Study looked at both snowmelt and growing season removal rates. Data only represents pollutant load reduction during growing season. Ouflow units for metals are micrograms per liter. Outflow units for Fe. Col. Are colonies per 100 mL.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS		80			48
TDS					
TP		37			0.11
DP					
PP					
Ortho-P		87			0.014
TN		28			1.66
ON					
NH4					
TKN		-24			1
NO3					
NOx		29			0.66
Organic					
Lead		84			
Zinc		69			16
Copper		41			5
Cadmium		0			
Chromium					
Iron					
TPH					
Oil/Grease		37			0.8
Fecal coliform		64			783
Turbidity					
E. Coli.		51			
Cl		-100			580
NH3		-24			0.102

STP Pollutant Removal Database

Indices

Study #: 17

Facility Lake Tohopekaliga District

State Florida **Country** USA

STP Category Stormwater Pond

STP Type Wet Extended Detention Pond

Drainage Class Regular

Bibliographic Information

Holler, J.D. 1990. Nonpoint Source Phosphorous Control By a Combination Wet Detention/Filtration Facility In Kissimmee, FL. Florida Scientist. Vol. 53(1). p. 28-37.

Study Notes

No. of Storms 6

Treatment Volume/ Design Basis

Storage= 1.46 acre ft. (first 0.5" of runoff). Residence time= 2 days.

Watershed in. 0.5

Impervious in.

Drainage Area 75 **ac**

Slope **%**

Land Use Urban/Commercial

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type Limestone, sand

STP Size Pond= 200' x 400' slope= 1:6. 10 filters on pond bottom each 100' long, covered by 1' of filter media

Age of Facility **yrs**

STP Notes

Performance Notes

Concentration units= mg/L. Filter berm clogging significant. Wet detention reduced both TP and ortho-P. No significant additional teatment provided by filtration. Study also refers to TP as PO4-P+OP.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS					
TDS					
TP		85		0.88	0.13
DP					
PP					
Ortho-P		60		0.88	0.03
TN					
ON					
NH4					
TKN					
NO3					
NOx					
Organic					
Lead					
Zinc					
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 18

Facility LCRA Office Pond

State Texas **Country** USA

STP Category Stormwater Pond

STP Type Wet Extended Detention Pond

Drainage Class Regular

Bibliographic Information

Lower Colorado River Authority. 1997. Innovative NPS Pollution Control Program for Lake Travis in Central Texas. LCRA.

Study Notes

No. of Storms 17

Treatment Volume/ Design Basis

Watershed in.

Impervious in.

Drainage Area 12 **ac**

Slope **%**

Land Use parking lot/commercial

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility **yrs**

STP Notes

Retrofit site
During dry weather, the pool was maintained by draining excess condensation water from the air conditioning systems in the office park. Clay liner was installed to prevent infiltration losses

Performance Notes

Problems encountered measuring flow Inflow and Outflow units for metals are in micrograms per liter

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS		83		71	12
TDS					
TP		52		0.232	0.112
DP					
PP					
Ortho-P		76		0.138	0.034
TN		55		1.713	0.769
ON					
NH4					
TKN		52		1.423	0.688
NO3					
NOx		85		0.416	0.062
TOC		45		15.7	8.7
Lead		90		25	3
Zinc		86		220	30
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 19

Facility East Barrhaven

State Ontario **Country** Canada

STP Category Stormwater Pond

STP Type Wet Extended Detention Pond

Drainage Class Regional

Bibliographic Information

Ontario Ministry of the Environment. 1991. Stormwater Quality Best Management Practices. Marshall Macklin Monaghan Limited. Toronto, Ontario. 177 p.

Study Notes

No. of Storms

Treatment Volume/ Design Basis

0.12 inch/acre

Watershed in. 0.12

Impervious in.

Drainage Area 2139 **ac**

Slope **%**

Land Use

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility **yrs**

STP Notes

Performance Notes

No winter data. Manual extended detention.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS			52		
TDS					
TP			47		
DP					
PP					
Ortho-P					
TN					
ON					
NH4					
TKN					
NO3					
NOx					
Organic					
Lead					
Zinc					
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Fecal coliform			56		
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 20

STP Category Stormwater Pond

Facility Kennedy-Burnett

STP Type Wet Extended Detention Pond

State Ontario **Country** Canada

Drainage Class Regional

Bibliographic Information

Ontario Ministry of the Environment. 1991. Stormwater Quality Best Management Practices. Marshall Macklin Monaghan Limited. Toronto, Ontario. 177 p.

Study Notes

No. of Storms 6

Treatment Volume/ Design Basis

0.62 watershed inches.

Watershed in. 0.62

Impervious in.

Drainage Area 395 **ac**

Slope **%**

Land Use

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility **yrs**

STP Notes

Performance Notes

No winter data. Manual extended detention.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS			98		
TDS					
TP			79		
DP					
PP					
Ortho-P					
TN			54		
ON					
NH4					
TKN					
NO3					
NOx					
BOD			36		
Lead			39		
Zinc			21		
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Fecal coliform			99		
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 21

STP Category Stormwater Pond

Facility Uplands

STP Type Wet Extended Detention Pond

State Ontario **Country** Canada

Drainage Class Regional

Bibliographic Information

Ontario Ministry of the Environment. 1991. Stormwater Quality Best Management Practices. Marshall Macklin Monaghan Limited. Toronto, Ontario. 177 p.

Study Notes

No. of Storms 5

Treatment Volume/ Design Basis

Watershed in. 0.08

Impervious in.

Drainage Area 860 **ac**

Slope **%**

Land Use

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size Storage volume: 254265.60 ft3

Age of Facility **yrs**

STP Notes

Performance Notes

No winter data. Manual extended detention.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS			82		
TDS					
TP			69		
DP					
PP					
Ortho-P					
TN					
ON					
NH4					
TKN					
NO3					
NOx					
Organic					
Lead					
Zinc					
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Fecal coliform			97		
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 22

STP Category Stormwater Pond

Facility Tampa Office Park- 5 day

STP Type Wet Extended Detention Pond

State Florida **Country** USA

Drainage Class Pocket

Bibliographic Information

Rushton, B., C. Miller and H. Hull. 1995. The Effect of Residence Time on the Efficiency of a Wet Detention Stormwater Treatment Pond. Presented at the 31st Annual Conference and Symposium in Urban Areas. November 10-12, 1995. Houston, TX. Also in Three Design Alternatives for Stormwater Detention Ponds. 1997. Southwest Florida Water Management District.

Study Notes

No. of Storms 20

Treatment Volume/ Design Basis

Residence time: 5 days

Watershed in. 1.36

Impervious in. 4.54

Drainage Area 6.5 **ac**

Slope **%**

Land Use

% Impervious Cover 30

% Residential

% Commercial

% Industrial

Soil Type

STP Size Volume: 32192 ft3

Age of Facility 0 **yrs**

STP Notes

Performance Notes

Same pond was modified three times 1990: residence time: 2 days 1993: residence time: 5 days 1994: residence time: 14 days See study #s 23 and 24 Inflow and Outflow units for metals are in ug/L.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS	67	69		45	14
TDS					
TP	57	75		0.651	0.164
DP					
PP					
Ortho-P	39	66		0.248	0.084
TN		28		1.27	0.91
ON	15	24		1.089	0.823
NH4	-31	35		0.077	0.05
TKN		25		1.17	0.87
NO3					
NOx	61	67		0.096	0.032
TOC		28		15.23	10.9
Lead					
Zinc	32	16		25	21
Copper	1	-9		2.59	2.83
Cadmium	42				
Chromium					
Iron	76	69		1517	463
TPH					
Oil/Grease					
Bacteria					
Turbidity					
Mn	61	69		33.4	10.2

STP Pollutant Removal Database

Indices

Study #: 23

Facility Tampa Office Park - 2 day

State Florida **Country** USA

STP Category Stormwater Pond

STP Type Wet Extended Detention Pond

Drainage Class Regular

Bibliographic Information

Rushton, B., C. Miller and H. Hull. 1995. The Effect of Residence Time on the Efficiency of a Wet Detention Stormwater Treatment Pond. Presented at the 31st Annual Conference and Symposium in Urban Areas. November 10-12, 1995. Houston, TX. Also in Three Design Alternatives for Stormwater Detention Ponds. 1997. Southwest Florida Water Management District.

Study Notes

No. of Storms 21

Treatment Volume/ Design Basis

Watershed in. 0.488

Impervious in. 1.6

Drainage Area ac

Slope %

Land Use

% Impervious Cover 30

% Residential

% Commercial

% Industrial

Soil Type

STP Size Volume: 11508 ft3

Age of Facility 4 yrs

STP Notes

Performance Notes

Same pond was modified three times 1990: residence time: 2 days 1993: residence time: 5 days 1994: residence time: 14 days See study #s 22 and 24 Inflow and Outflow units for metals are in ug/L.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS	71	61		28	11
TDS					
TP	62	56		0.4	0.176
DP					
PP					
Ortho-P	69	68		0.336	0.108
TN				1.35	1.16
ON	30	2		1.025	1.002
NH4	58	18		0.083	0.068
TKN				1.11	1.07
NO3					
NOx	64	63		0.24	0.09
Organic					
Lead					
Zinc	56	39		51	31
Copper					
Cadmium	55	-20		0.5	0.6
Chromium					
Iron	40	29		555	396
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 24

STP Category Stormwater Pond

Facility Tampa Office Park-14 day

STP Type Wet Extended Detention Pond

State Florida **Country** USA

Drainage Class Pocket

Bibliographic Information

Rushton, B., C. Miller and H. Hull. 1995. The Effect of Residence Time on the Efficieny of a Wet Detention Stormwater Treatment Pond. Presented at the 31st Annual Conference and Symposium in Urban Areas. November 10-12, 1995. Houston, TX. Also in Three Design Alternatives for Stormwater Detention Ponds. 1997. Southwest Florida Water Management District.

Study Notes

No. of Storms 39

Treatment Volume/ Design Basis

Residence time 14 days;

Watershed in. 3.88

Impervious in. 12.94

Drainage Area 6.5 **ac**

Slope **%**

Land Use Rooftops, parking lot, vehicle storage.

% Impervious Cover 30

% Residential

% Commercial

% Industrial

Soil Type

STP Size Permanent pool average depth 2.8'; Pond size= 0.57 ac Volume: 91598 ft3

Age of Facility 0 **yrs**

STP Notes

0.32 acre pond surface. runoff conveyed via 200' grass channel. pond depth max 18".

Performance Notes

Same pond was modified three times 1990: residence time: 2 days 1993: residence time: 5 days 1994: residence time: 14 days See study #s 22 and 23 Inflow and Outflow units for metals are in ug/L.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS	94	95		131	7
TDS					
TP	90	89		0.497	0.053
DP					
PP					
Ortho-P	92	91		0.305	0.027
TN				1.61	0.722
ON	51	43		1.09	0.62
NH4	90	72		0.123	0.035
TKN				1.21	0.66
NO3		73			
NOx	88	84		0.396	0.062
TOC	42	-9		19.7	21.4
Lead	92	89		5	0.5
Zinc	87	83		81	14
Copper	55	39		6.52	3.96
Cadmium	87	80		0.28	0.06
Chromium					
Iron	94	93		3200	220
TPH		90			
Oil/Grease					
Bacteria					
Turbidity					
Mn	79	67		31.1	10.3

STP Pollutant Removal Database

Indices

Study #: 25

STP Category Stormwater Pond

Facility Monroe Street

STP Type Wet Pond

State Wisconsin **Country** USA

Drainage Class Regular

Bibliographic Information

Bannerman, R. and R. Dodds. 1992. Unpublished data. Bureau of Water Resources Management. Wisconsin Department of Natural Resources. Madison, WI.

Study Notes

No. of Storms

Treatment Volume/ Design Basis

0.26 inch/acre

Watershed in. 0.26

Impervious in.

Drainage Area 238 **ac**

Slope **%**

Land Use

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility **yrs**

STP Notes

Performance Notes

Data represents an average of a range for some parameters.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS			90		
TDS					
TP			65		
DP			70		
PP					
Ortho-P					
TN					
ON					
NH4					
TKN					
NO3					
NOx					
COD			70		
Lead			70		
Zinc			65		
Copper			75		
Cadmium					
Chromium					
Iron					
TPH			82.5		
Oil/Grease					
Fecal coliform			70		
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 26

Facility St. Elmo

State Texas **Country** USA

STP Category Stormwater Pond

STP Type Wet Pond

Drainage Class Regular

Bibliographic Information

City of Austin, TX. 1996. Evaluation of Nonpoint Source Controls, a 319 Grant Report. Final Report. Water Quality Report Series. COA-ERM-1996-03.

Study Notes

No. of Storms 5

Treatment Volume/ Design Basis

Watershed in. 1.8

Impervious in. 2.71

Drainage Area 27.11 **ac**

Slope **%**

Land Use Industrial

% Impervious Cover 66

% Residential

% Commercial

% Industrial 100

Soil Type

STP Size Surface area: 1.65 ac

Age of Facility **yrs**

STP Notes

To prevent evaporation losses the bottom of the pond was sealed by a liner.

Performance Notes

No. of storms is an estimated average for all pollutant parameters. Inflow and Outflow units for metals are micrograms per liter. Pollutant removal rates for metals were computed based on means of instantaneous individual inflow and outflow concentrations.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS		93		128	9
TDS					
TP		87		0.3	0.04
DP		66		0.09	0.03
PP					
Ortho-P					
TN		50		1.85	0.92
ON					
NH4					
TKN		57		1.1	0.47
NO3					
NOx		40		0.75	0.45
COD		50		46	23
Lead		39		6.45	3.9
Zinc		60		81.07	59.59
Copper		58		10	4.2
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Fecal coliform		98		83633	1324
Turbidity					
TOC		36		9	5.7
Fecal Strep		96		34426	1265
BOD		61		6	2.4

STP Pollutant Removal Database

Indices

Study #: 27

STP Category Stormwater Pond

Facility Eastgate Business Park Pond A

STP Type Wet Pond

State Washington **Country** USA

Drainage Class Regular

Bibliographic Information

Comings, K.; D. Booth; and R. Horner. Stormwater Pollutant Removal by Two Wet Ponds in Bellevue, WA. University of Washington.

Study Notes

No. of Storms 17

Treatment Volume/ Design Basis

Watershed in. 0.1

Impervious in. 0.25

Drainage Area 98.84 **ac**

Slope **%**

Land Use

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size Surface Area: 0.5 ac
Permanent pool depth:
3.38 in.
Permanent pool volume:
35314.67 ft3 Live

Age of Facility **yrs**

STP Notes

Second pond of a two pond system; see study #12

Performance Notes

Inflow and Outflow units for metals are micrograms per liter.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS		61		22.8	8.9
TDS					
TP		19		0.095	0.077
DP		3		0.015	0.014
PP		25		0.08	0.06
Ortho-P		19		0.023	0.019
TN					
ON					
NH4					
TKN					
NO3					
NOx					
Organic					
Lead		73		4.7	1.3
Zinc		45		54	30
Copper		37		3.9	2.4
Cadmium		68		0.31	0.1
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 28

Facility Timbercreek

State Florida **Country** USA

STP Category Stormwater Pond

STP Type Wet Pond

Drainage Class Regular

Bibliographic Information

Cullum, M. 1984. Volume II Evaluation of the Water Management System at a Single Family Residential Site: Water Quality Analysis for Selected Storm Events at Timbercreek Subdivision in Boca Raton, FL. South Florida Water Management District.

Study Notes

No. of Storms 9

Treatment Volume/ Design Basis

3.11 inch/acre (inferred value).

Watershed in. 3.11

Impervious in.

Drainage Area 122 **ac**

Slope **%**

Land Use single family residential runoff

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type Group A

STP Size

Age of Facility **yrs**

STP Notes

Effective detention volume: 1.03 in.

Performance Notes

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS		68		20.6	6.5
TDS					
TP		55		0.136	0.035
DP		80			
PP					
Ortho-P		93		0.084	0.004
TN		12		0.93	0.65
ON					
NH4		54		0.13	0.05
TKN		-31		0.75	0.63
NO3					
NOx		93		0.18	0.02
Organic					
Lead					
Zinc					
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					
Cl		-100		8.6	17

STP Pollutant Removal Database

Indices

Study #: 29

Facility I-4

State Florida **Country** USA

STP Category Stormwater Pond

STP Type Wet Pond

Drainage Class Regular

Bibliographic Information

Dorman, M.E., J. Hartigan, R.F. Steg and T. Quasebarth. 1989. Retention, Detention and Overland Flow for Pollutant Removal From Highway Stormwater Runoff. Vol. 1 Research Report. Federal Highway Administration. FHWA/RD 89/202. 179 p.

Study Notes

No. of Storms 6

Treatment Volume/ Design Basis

2.35 inch/acre.

Watershed in. 2.35

Impervious in.

Drainage Area 26.3 **ac**

Slope **%**

Land Use Highway

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility **yrs**

STP Notes

Performance Notes

Data based on an average of a range for some parameters. Inflow and Outflow units for metals are micrograms per liter.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS	54			7	15
TDS					
TP	69			0.272	0.155
DP					
PP					
Ortho-P					
TN				1.5	1.29
ON					
NH4					
TKN	68			1.2	1.27
NO3					
NOx	97			0.304	0.018
TOC	45			10.1	9.33
Lead	73.5			32	28
Zinc	69			51	19
Copper	73.5			13	6
Cadmium	47			8	5
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 30

Facility West Pond

State Minnesota **Country** USA

STP Category Stormwater Pond

STP Type Wet Pond

Drainage Class Regular

Bibliographic Information

Dorman, M.E., J. Hartigan, R.F. Steg and T. Quasebarth. 1989. Retention, Detention and Overland Flow for Pollutant Removal From Highway Stormwater Runoff. Vol. 1 Research Report. Federal Highway Administration. FHWA/RD 89/202. 179 p.

Study Notes

No. of Storms 8

Treatment Volume/ Design Basis

0.15 inch/acre

Watershed in. 0.15

Impervious in.

Drainage Area 76 **ac**

Slope **%**

Land Use Highway

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility **yrs**

STP Notes

Performance Notes

Data represents an average of a range for some parameters. Inflow and Outflow units for metals are micrograms per liter.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS	65			52	23
TDS					
TP	25			0.3	0.4
DP					
PP					
Ortho-P					
TN				2.62	1.92
ON					
NH4					
TKN	23			1.89	1.7
NO3					
NOx	61			0.729	0.224
TOC	19			16.5	16.8
Lead	43.5				
Zinc	66			76	31
Copper				17.5	13.5
Cadmium	51.5				
Chromium	62				
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 31

Facility Buckland

State Connecticut **Country** USA

STP Category Stormwater Pond

STP Type Wet Pond

Drainage Class Regular

Bibliographic Information

Dorman, M.E., J. Hartigan, R.F. Steg and T. Quasebarth. 1989. Retention, Detention and Overland Flow for Pollutant Removal From Highway Stormwater Runoff. Vol. 1 Research Report. Federal Highway Administration. FHWA/RD 89/202. 179 p.

Study Notes

No. of Storms 7

Treatment Volume/ Design Basis

0.4 inch/acre

Watershed in. 0.4

Impervious in.

Drainage Area 20 **ac**

Slope **%**

Land Use

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility **yrs**

STP Notes

8,000' of grassed swale treatment prior to pond. Very shallow permanent pool.

Performance Notes

Data based on an average of a range for some parameters. Cd= originally an unspecified negative value (represented here as -25). Inflow and Outflow units for metals are micrograms per liter

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS	61			47	54
TDS					
TP	45			0.247	0.195
DP					
PP					
Ortho-P					
TN				3.06	2.74
ON					
NH4					
TKN	24			1.23	1.23
NO3					
NOx	22			1.53	1.37
TOC	33			10	9.51
Lead	38.5				
Zinc	51			30	26
Copper	38			14	9.8
Cadmium	-25				12
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 32

Facility Westleigh

State Maryland **Country** USA

STP Category Stormwater Pond

STP Type Wet Pond

Drainage Class Regular

Bibliographic Information

Driscoll, E.D. 1983. Performance of Detention Basins for Control of Urban Runoff Quality. Presented at the 1983 International Symposium on Urban Hydrology, Hydraulics and Sedimentation Control. University of Kentucky. Lexington, KY. 40 p.

Study Notes

No. of Storms 32

Treatment Volume/ Design Basis

1.27 inch/acre

Watershed in. 1.27

Impervious in.

Drainage Area 48 **ac**

Slope **%**

Land Use

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility **yrs**

STP Notes

Performance Notes

High algal uptake.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS			81		
TDS					
TP			54		
DP			71		
PP					
Ortho-P					
TN			37		
ON					
NH4					
TKN			27		
NO3					
NOx					
COD			35		
Lead			82		
Zinc			26		
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 33

STP Category Stormwater Pond

Facility Grace Street

STP Type Wet Pond

State Michigan **Country** USA

Drainage Class Regular

Bibliographic Information

Driscoll, E.D. 1983. Performance of Detention Basins for Control of Urban Runoff Quality. Presented at the 1983 International Symposium on Urban Hydrology, Hydraulics and Sedimentation Control. University of Kentucky. Lexington, KY. 40 p.

Study Notes

No. of Storms 18

Treatment Volume/ Design Basis

VB/VR=.52

Watershed in.

Impervious in.

Drainage Area ac

Slope %

Land Use

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility yrs

STP Notes

Performance Notes

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS			32		
TDS					
TP			12		
DP					
PP					
Ortho-P					
TN			6		
ON					
NH4					
TKN			7		
NO3			-1		
NOx					
BOD			3		
Lead			26		
Zinc					
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 34

STP Category Stormwater Pond

Facility Unqua

STP Type Wet Pond

State New York **Country** USA

Drainage Class Regular

Bibliographic Information

Driscoll, E.D. 1983. Performance of Detention Basins for Control of Urban Runoff Quality. Presented at the 1983 International Symposium on Urban Hydrology, Hydraulics and Sedimentation Control. University of Kentucky. Lexington, KY. 40 p.

Study Notes

No. of Storms 8

Treatment Volume/ Design Basis

VB/VR=3.07

Watershed in.

Impervious in.

Drainage Area ac

Slope %

Land Use

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility yrs

STP Notes

Performance Notes

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS			60		
TDS					
TP			45		
DP					
PP					
Ortho-P					
TN					
ON					
NH4					
TKN					
NO3					
NOx					
TOC			7		
Lead			80		
Zinc					
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Fecal coliform			86		
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 35

STP Category Stormwater Pond

Facility Waverly Hills

STP Type Wet Pond

State Michigan **Country** USA

Drainage Class Regular

Bibliographic Information

Driscoll, E.D. 1983. Performance of Detention Basins for Control of Urban Runoff Quality. Presented at the 1983 International Symposium on Urban Hydrology, Hydraulics and Sedimentation Control. University of Kentucky. Lexington, KY. 40 p.

Study Notes

No. of Storms 29

Treatment Volume/ Design Basis

VB/VR=7.57

Watershed in.

Impervious in.

Drainage Area ac

Slope %

Land Use

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility yrs

STP Notes

Performance Notes

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS			91		
TDS					
TP			79		
DP					
PP					
Ortho-P					
TN			62		
ON					
NH4					
TKN			60		
NO3			66		
NOx					
COD			69		
Lead			95		
Zinc			91		
Copper			57		
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					
BOD			69		

STP Pollutant Removal Database

Indices

Study #: 36

STP Category Stormwater Pond

Facility Pitt- AA

STP Type Wet Pond

State Michigan **Country** USA

Drainage Class Regional

Bibliographic Information

Driscoll, E.D. 1983. Performance of Detention Basins for Control of Urban Runoff Quality. Presented at the 1983 International Symposium on Urban Hydrology, Hydraulics and Sedimentation Control. University of Kentucky. Lexington, KY. 40 p.

Study Notes

No. of Storms 6

Treatment Volume/ Design Basis

VB/VR=0.52

Watershed in.

Impervious in.

Drainage Area 4872 **ac**

Slope **%**

Land Use

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility **yrs**

STP Notes

Performance Notes

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS			32		
TDS					
TP			18		
DP					
PP					
Ortho-P					
TN					
ON					
NH4					
TKN			14		
NO3			7		
NOx					
COD			23		
Lead			62		
Zinc			13		
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					
BOD			21		

STP Pollutant Removal Database

Indices

Study #: 37

STP Category Stormwater Pond

Facility Lake Ellyn

STP Type Wet Pond

State Illinois **Country** USA

Drainage Class Regular

Bibliographic Information

Driscoll, E.D. 1983. Performance of Detention Basins for Control of Urban Runoff Quality. Presented at the 1983 International Symposium on Urban Hydrology, Hydraulics and Sedimentation Control. University of Kentucky. Lexington, KY. 40 p.

Study Notes

No. of Storms 23

Treatment Volume/ Design Basis

VB/VR=10.7

Watershed in.

Impervious in.

Drainage Area ac

Slope %

Land Use

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility yrs

STP Notes

Performance Notes

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS			84		
TDS					
TP			34		
DP					
PP					
Ortho-P					
TN					
ON					
NH4					
TKN					
NO3					
NOx					
Organic					
Lead			78		
Zinc			71		
Copper			71		
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 38

STP Category Stormwater Pond

Facility FDOT Pond

STP Type Wet Pond

State Florida **Country** USA

Drainage Class Regular

Bibliographic Information

Gain, W.S. 1996. The Effects of Flow Path Modification on Water Quality Constituent Retention in an Urban Stormwater Detention Pond and Wetland System. Orlando, FL. U.S. Geological Survey. Water Resources Investigations Report 95-4297. Tallahassee, FL

Study Notes

No. of Storms 22

Treatment Volume/ Design Basis

Pond= 0.55 watershed inches.

Watershed in. 0.55

Impervious in.

Drainage Area 41.6 **ac**

Slope **%**

Land Use

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility 0 **yrs**

STP Notes

Pond was modified to increase detention time and was previously studied by Martin and Smoot (1988). Pond component of a pond/wetland system; see study #s 59 and 72

Performance Notes

Concentration based efficiencies assume that concentration data are log normally distributed. Inflow and Outflow units for metals are micrograms per liter. Inflow and Outflow are reported as a mean concentration.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS		54		45	19
TDS		-19		117	130
TP		30		0.17	0.12
DP		35		0.05	0.03
PP					
Ortho-P		26		0.05	0.05
TN		16		1.64	1.39
ON		20		1.25	0.99
NH4		17		0.09	0.09
TKN					
NO3					
NOx		24		0.31	0.31
TOC		-30		10	11.9
Lead		73		19	16
Zinc		52		65	32
Copper		42		7	5
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					
Dissolved Z		48		21	11
Dissolved C		24		4	3
Chloride		-38			

STP Pollutant Removal Database

Indices

Study #: 39

Facility Seattle

State Washington **Country** USA

STP Category Stormwater Pond

STP Type Wet Pond

Drainage Class Pocket

Bibliographic Information

Horner, R.R., J. Guedry and M.H. Kortenhoff. 1990. Final Report: Improving the Cost Effectiveness of Highway Construction Site Erosion and Pollution Control. Prepared for the Washington State Transportation Commission. 51 p.

Study Notes

No. of Storms 5

Treatment Volume/ Design Basis

Watershed in.

Impervious in.

Drainage Area 0.75 **ac**

Slope **%**

Land Use

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility **yrs**

STP Notes

Performance Notes

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS			86.7		
TDS					
TP			78.4		
DP					
PP					
Ortho-P					
TN					
ON					
NH4					
TKN					
NO3					
NOx					
COD			64.4		
Lead			65.1		
Zinc			65.2		
Copper			66.5		
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 40
STP Category Stormwater Pond
Facility SR 204
STP Type Wet Pond
State Washington **Country** USA
Drainage Class Pocket

Bibliographic Information

Horner, R.R., J. Guedry and M.H. Kortenhoff. 1990. Final Report: Improving the Cost Effectiveness of Highway Construction Site Erosion and Pollution Control. Prepared for the Washington State Transportation Commission. 51 p.

Study Notes

No. of Storms 5

Treatment Volume/ Design Basis

0.6 inch/acre

Watershed in. 0.6

Impervious in.

Drainage Area 1.8 **ac**

Slope **%**

Land Use

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility **yrs**

STP Notes

Performance Notes

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS			99		
TDS					
TP			91		
DP					
PP					
Ortho-P					
TN					
ON					
NH4					
TKN					
NO3					
NOx					
COD			69.1		
Lead			88.2		
Zinc			87		
Copper			90		
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 41

Facility Mercer

State Washington ***Country*** USA

STP Category Stormwater Pond

STP Type Wet Pond

Drainage Class Pocket

Bibliographic Information

Horner, R.R., J. Guedry and M.H. Kortenhoff. 1990. Final Report: Improving the Cost Effectiveness of Highway Construction Site Erosion and Pollution Control. Prepared for the Washington State Transportation Commission. 51 p.

Study Notes

No. of Storms 5

Treatment Volume/ Design Basis

1.72 inch/acre

Watershed in. 1.72

Impervious in.

Drainage Area 7.6 **ac**

Slope **%**

Land Use

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility **yrs**

STP Notes

Performance Notes

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS			75		
TDS					
TP			67		
DP					
PP					
Ortho-P					
TN					
ON					
NH4					
TKN					
NO3					
NOx					
COD			76.9		
Lead			23		
Zinc			38		
Copper			51		
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 42

STP Category Stormwater Pond

Facility Saint Joe's Creek

STP Type Wet Pond

State Florida **Country** USA

Drainage Class Regional

Bibliographic Information

Kantrowitz, I. and W. Woodham. 1995. Efficiency of a Stormwater Detention Pond in Reducing Loads of Chemical and Physical Constituents in Urban Streamflow, Pinellas County, Florida. U.S. Geological Survey. Water Resources Investigations Report: 94-4217. Tallahassee, FL. 18 p.

Study Notes

No. of Storms 6

Treatment Volume/ Design Basis

Pool provides approximately 0.21 - 0.26 watershed inches of storage.

Watershed in. 0.235

Impervious in.

Drainage Area 1280 **ac**

Slope **%**

Land Use

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility 0 **yrs**

STP Notes

Very large on-line wet pond with detention.

Performance Notes

Values in "other" column represent efficiencies from data collected during 16 baseflow events (efficiencies computed using before and after median baseflow loads). Stormflow efficiencies were adjusted to account for non-monitored area directly contributing to pond. Value for NO3 is variable. Cl = -28, 27 respectively. Outflow values for metals are

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS		7	45		16
TDS		-22	17		
TP		40	45		0.09
DP					
PP					
Ortho-P		52	51		0.03
TN					
ON		2	19		0.62
NH4		40	83		0.04
TKN					
NO3					
NOx		23	36		0.04
BOD		49	65		2.1
Lead		60	82		
Zinc		48	50		20
Copper		52	38		2
Cadmium					
Chromium		25	50		2
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					
COD		16	43		19
VSS		11	34		6
Al		35			60

STP Pollutant Removal Database

Indices

Study #: 43

STP Category Stormwater Pond

Facility Heritage Park

STP Type Wet Pond

State Ontario **Country** Canada

Drainage Class Regular

Bibliographic Information

Liang, W. 1996. Performance Assessment of an Off-Line Stormwater Management Pond. Ontario Ministry of Environment and Energy.

Study Notes

No. of Storms 11

Treatment Volume/ Design Basis

Watershed in. 0.51

Impervious in. 0.94

Drainage Area 130 **ac**

Slope **%**

Land Use residenital land use

% Impervious Cover 55

% Residential 100

% Commercial

% Industrial

Soil Type clay till and clay loam s

STP Size Permanent pool volume: 243177 ft3

Age of Facility 7 **yrs**

STP Notes

Performance Notes

Study presents both growing and winter season performance data. Data presented here represents pollutant load reduction during growing season only. Outflow units for metals are micrograms per liter. Outflow units for Fe. Col. Are colonies per 100 mL.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS	80				19
TDS					
TP	80				0.07
DP					
PP					
Ortho-P	91				0.03
TN					
ON					
NH4					
TKN	0				
NO3					
NOx	62				0.65
Organic					
Lead	15				
Zinc	68				10
Copper	70				8
Cadmium	10				
Chromium					
Iron					
TPH					
Oil/Grease					
Fecal coliform	90				1779
Turbidity					
E. Coli	86				
Cl	-100				81
Pentachloro	80				

STP Pollutant Removal Database

Indices

Study #: 44

STP Category Stormwater Pond

Facility Highway Site

STP Type Wet Pond

State Florida **Country** USA

Drainage Class Regular

Bibliographic Information

Martin, E. 1988. Effectiveness of an Urban Runoff Detention Pond/Wetland System. Journal of Environmental Engineering. Vol. 114(4): 810-827.

Study Notes

No. of Storms 11

Treatment Volume/ Design Basis

0.55 inch/acre

Watershed in. 0.55

Impervious in.

Drainage Area 41.6 **ac**

Slope **%**

Land Use

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility **yrs**

STP Notes

Part of a pond/wetland system. See study #62

Performance Notes

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS	83	75			
TDS	32	16			
TP	37	22			
DP	42	15			
PP	35	25			
Ortho-P	15	-7			
TN	30	15			
ON	34	25			
NH4	34	4			
TKN					
NO3	28	14			
NOx					
Organic					
Lead	81	77			
Zinc	62	50			
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					
Dissolved P		66			
Dissolved Z		48			
Chloride	1	-11			

STP Pollutant Removal Database

Indices

Study #: 45

Facility McCarrons

State Minnesota **Country** USA

STP Category Stormwater Pond

STP Type Wet Pond

Drainage Class Regional

Bibliographic Information

Oberst, G. and R. Osgood. 1998. Lake McCarrons: Final Report on the Function of the Wetland Treatment System and the Impacts on Lake McCarrons. Metropolitian Council of the Twin Cities Area. St. Paul, MN.

Study Notes

No. of Storms 21

Treatment Volume/ Design Basis

0.19 inch/acre

Watershed in. 0.2

Impervious in.

Drainage Area 583 **ac**

Slope **%**

Land Use

% Impervious Cover 20

% Residential

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility 1.75 **yrs**

STP Notes

Wet Pond component of a pond/wetland system; see study #s 64 and 81.

Performance Notes

Efficiency is based on a regression line of inflow vs outflow. Inflow and Outflow units for Pb are micrograms per liter.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS	93		91	1113	63
TDS					
TP	79		78	2.91	0.27
DP	57		57	0.68	0.1
PP					
Ortho-P					
TN	76		85	12.92	1.76
ON					
NH4					
TKN	77		88	10.91	1.41
NO3	62		60	2.01	0.35
NOx					
COD	88		90	726	58
Lead	88		85	319	24
Zinc					
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 46

STP Category Stormwater Pond

Facility Lake Ridge

STP Type Wet Pond

State Minnesota **Country** USA

Drainage Class Regional

Bibliographic Information

Oberts, G.L., P.J. Wotzka and J.A. Hartsoe. 1989. The Water Quality Performance of Select Urban Runoff Treatment Systems. Prepared for the Legislative Commission on Minnesota Resources. Metropolitan Council. St. Paul, MN. Publication No. 590-89-062a 170 p.

Study Notes

No. of Storms 20

Treatment Volume/ Design Basis

0.08 inch/acre

Watershed in. 0.08

Impervious in.

Drainage Area 315 **ac**

Slope **%**

Land Use

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility 6 **yrs**

STP Notes

Performance Notes

Data refers to rainfall events only.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS			90		18
TDS					
TP			61		0.21
DP			11		0.12
PP					
Ortho-P					
TN			41		1.68
ON					
NH4					
TKN			50		1.01
NO3			10		0.29
NOx					
Organic					
Lead			73		2
Zinc					
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 47

STP Category Stormwater Pond

Facility McKnight

STP Type Wet Pond

State Minnesota **Country** USA

Drainage Class Regional

Bibliographic Information

Oberts, G.L., P.J. Wotzka and J.A. Hartsoe. 1989. The Water Quality Performance of Select Urban Runoff Treatment Systems. Prepared for the Legislative Commission on Minnesota Resources. Metropolitan Council. St. Paul, MN. Publication No. 590-89-062a 170 p.

Study Notes

No. of Storms 16

Treatment Volume/ Design Basis

0.22 inch/acre

Watershed in. 0.22

Impervious in.

Drainage Area 725 **ac**

Slope **%**

Land Use

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility 4 **yrs**

STP Notes

Performance Notes

Pertains to monitored rainfall events only. Outflow units for Pb are micrograms per liter.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS	85				10
TDS					
TP	48				0.12
DP	13				0.09
PP					
Ortho-P					
TN	30				1.2
ON					
NH4					
TKN	31				1
NO3	24				0.15
NOx					
Organic					
Lead	67				2
Zinc					
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 48

Facility Burke

State Virginia **Country** USA

STP Category Stormwater Pond

STP Type Wet Pond

Drainage Class Regular

Bibliographic Information

Occoquan Watershed Monitoring Laboratory. 1983. Final Report: Metropolitan Washington Urban Runoff Project. Prepared for the Metropolitan Washington Council of Governments. Manassas, VA. 460 p.

Study Notes

No. of Storms 29

Treatment Volume/ Design Basis

1.22 inch/acre

Watershed in. 1.22

Impervious in.

Drainage Area 27.1 **ac**

Slope 4.5 **%**

Land Use medium density residential

% Impervious Cover 25

% Residential

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility **yrs**

STP Notes

Storage Volume: 353,000 ft3
Average Surface Area: 0.9 ac
Mean Depth: ranged from 3.3 to 3.5ft

Performance Notes

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS			-33.3		
TDS					
TP			39		
DP			77		
PP					
Ortho-P					
TN			32		
ON					
NH4					
TKN					
NO3					
NOx					
COD			21		
Lead			84		
Zinc			38		
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 49

STP Category Stormwater Pond

Facility Farm Pond

STP Type Wet Pond

State Virginia **Country** USA

Drainage Class Regular

Bibliographic Information

Occoquan Watershed Monitoring Laboratory. 1983. Final Report: Metropolitan Washington Urban Runoff Project. Prepared for the Metropolitan Washington Council of Governments. Manassas, VA. 460 p.

Study Notes

No. of Storms

Treatment Volume/ Design Basis

1.13 inch/acre

Watershed in. 1.13

Impervious in.

Drainage Area 51.4 **ac**

Slope **%**

Land Use Agriculture

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility **yrs**

STP Notes

Performance Notes

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS			85		
TDS					
TP			86		
DP			73		
PP					
Ortho-P					
TN			34		
ON					
NH4			-107		
TKN					
NO3					
NOx					
Organic					
Lead					
Zinc					
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 50

Facility Shop Creek

State Colorado **Country** USA

STP Category Stormwater Pond

STP Type Wet Pond

Drainage Class Regional

Bibliographic Information

Urbonas, B., J. Carlson and B. Vang. 1994. Joint Pond-Wetland System in Colorado. An Internal Report of the Denver Urban Drainage and Flood Control District. Also in: Performance of a Storage Pond/Wetland System in Colorado. Watershed Protection Techniques. Center for Watershed Protection. Summer 1994. Vol. 1(2): 68-69.

Study Notes

No. of Storms 36

Treatment Volume/ Design Basis

0.3 watershed inches (permanent pool= 0.1; extended detention= 0.2).

Watershed in. 0.3

Impervious in.

Drainage Area 550 **ac**

Slope **%**

Land Use Detached single family residences.

% Impervious Cover 40

% Residential 100

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility **yrs**

STP Notes

Pond component of a pond/wetland system; see study #s 67 and 88

Performance Notes

Inflow and Outflow units for metals are mircrograms per liter.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS			78	134	28
TDS					
TP			49	0.45	0.21
DP			32	0.31	0.129
PP					
Ortho-P					
TN			-12	3.54	3.76
ON			32		
NH4					
TKN				2.31	1.46
NO3			-85	1.23	2.3
NOx					
COD			44	75	44
Lead					
Zinc			51	109.67	45
Copper			57	36.33	17.33
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					
Dissolved C			53	41	18.5
Dissolved Z			34	46.67	27

STP Pollutant Removal Database

Indices

Study #: 51

Facility Runaway Bay

State North Carolina **Country** USA

STP Category Stormwater Pond

STP Type Wet Pond

Drainage Class Regional

Bibliographic Information

Wu, J. 1989. Evaluation of Detention Basin Performance in the Piedmont Region of North Carolina. North Carolina Water Resources Research Institute. Report No. 89-248. Raleigh, NC. 46 p. Also in: Performance of two Wet Ponds in the Piedmont of North Carolina. Watershed Protection Techniques. Center for Watershed Protection. Fall 1995. Vol. 2(1): 296-297.

Study Notes

No. of Storms 11

Treatment Volume/ Design Basis

0.33 watershed inches. Runoff coefficient= 0.68. Surface

Watershed in. 0.33

Impervious in.

Drainage Area 437 **ac**

Slope **%**

Land Use Multi-unit housing, woodland

% Impervious Cover 38

% Residential

% Commercial

% Industrial

Soil Type Clay

STP Size Surface area= 3.3 acres. Mean pond depth= 3.8'. Volume= 12.3 acre feet.

Age of Facility **yrs**

STP Notes

Performance Notes

Metal values based on extractabilty. No geese present. Shortcircuiting due to location of inlets near outlets.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS	62				
TDS					
TP	36			0.12	0.08
DP					
PP					
Ortho-P					
TN					
ON					
NH4					
TKN	21			0.79	0.63
NO3					
NOx					
Organic					
Lead					
Zinc	32				
Copper					
Cadmium					
Chromium					
Iron	52				
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 52

STP Category Stormwater Pond

Facility Lakeside Pond

STP Type Wet Pond

State North Carolina **Country** USA

Drainage Class Regular

Bibliographic Information

Wu, J. 1989. Evaluation of Detention Basin Performance in the Piedmont Region of North Carolina. North Carolina Water Resources Research Institute. Report No. 89-248. Raleigh, NC. 46 p. Also in: Performance of two Wet Ponds in the Piedmont of North Carolina. Watershed Protection Techniques. Center for Watershed Protection. Fall 1995. Vol. 2(1): 296-297.

Study Notes

No. of Storms 11

Treatment Volume/ Design Basis

7.1 watershed inches. Runoff coefficient= 0.68. Surface area to

Watershed in. 7.1

Impervious in.

Drainage Area 65 **ac**

Slope **%**

Land Use Mixed residential.

% Impervious Cover 46

% Residential 100

% Commercial

% Industrial

Soil Type Clay

STP Size Pond= 4.9 acres. Mean pond depth= 8'. Volume= 38.8 acre feet.

Age of Facility **yrs**

STP Notes

Performance Notes

Metal values based on extractabilty. Geese population present increased N and P values. Short-circuiting due to location of inlets near outlets.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS	93				
TDS					
TP	45			0.14	0.08
DP					
PP					
Ortho-P					
TN					
ON					
NH4					
TKN	32			0.86	0.59
NO3					
NOx					
Organic					
Lead					
Zinc	80				
Copper					
Cadmium					
Chromium					
Iron	87				
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 53

STP Category Stormwater Pond

Facility Maitland

STP Type Wet Pond

State Florida **Country** USA

Drainage Class Regular

Bibliographic Information

Yousef, Y., M. Wanielista and H. Harper. 1986. Design and Effectiveness of Urban Retention Basins. In: Urban Runoff Quality- Impact and Quality Enhancement Technology. B. Urbonas and L.A. Roesner (Eds.). American Society of Civil Engineering. New York, New York. p. 338-350.

Study Notes

No. of Storms 35

Treatment Volume/ Design Basis

3.65 inch/acre

Watershed in. 3.65

Impervious in.

Drainage Area 49 **ac**

Slope **%**

Land Use

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility **yrs**

STP Notes

Multiple cell wet pond.

Performance Notes

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS					
TDS					
TP					
DP			90		
PP			11		
Ortho-P					
TN					
ON					
NH4			82		
TKN					
NO3			87		
NOx					
Organic					
Lead			95		
Zinc			96		
Copper			77		
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 54

Facility Mays Chapel

State Maryland **Country** USA

STP Category Stormwater Wetland

STP Type Extended Detention Wetland

Drainage Class Regular

Bibliographic Information

Athanas C. and C. Stevenson. 1986. Nutrient Removal from Stormwater Runoff by a Vegetated Collection Pond - The Mays Chapel Wetland Basin Project. Prepared for the City of Baltimore, Department of Public Works, Bureau of Water and Wastewater, Water Quality Management Office. 42 p.

Study Notes

No. of Storms

Treatment Volume/ Design Basis

0.1 inch/acre (inferred value).

Watershed in. 0.1

Impervious in.

Drainage Area 97 **ac**

Slope **%**

Land Use

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility **yrs**

STP Notes

Performance Notes

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS			24		32.38
TDS					
TP			16		0.188
DP			24		0.058
PP					
Ortho-P					
TN					
ON					
NH4			43		0.07
TKN					
NO3					
NOx			35		0.839
Organic					
Lead					
Zinc					
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 55

STP Category Stormwater Wetland

Facility Clear Lake

STP Type Extended Detention Wetland

State Minnesota **Country** USA

Drainage Class Regional

Bibliographic Information

Barten, J.M. 1983. Treatment of Stormwater Runoff Using Aquatic Plants. The Use of Wetlands for Controlling Stormwater Pollution. Strecker, E.W., J.M. Kersnar and E.D. Driscoll (Eds.). Woodward-Clyde Consultants. Portland, Oregon. Prepared for U.S. EPA, Region V, Water Division, Watershed Management Unit. EPA/600 February 1992.

Study Notes

No. of Storms

Treatment Volume/ Design Basis

0.15 inch/acre (inferred value).

Watershed in. 0.15

Impervious in.

Drainage Area 1070 **ac**

Slope **%**

Land Use

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility **yrs**

STP Notes

Performance Notes

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS			76		
TDS					
TP			54		
DP			40		
PP					
Ortho-P					
TN					
ON					
NH4			55		
TKN			25		
NO3					
NOx					
Organic					
Lead					
Zinc					
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 56

Facility Tanner's Lake

State Minnesota **Country** USA

STP Category Stormwater Wetland

STP Type Extended Detention Wetland

Drainage Class Regional

Bibliographic Information

Oberts, G.L., P.J. Wotzka and J.A. Hartsoe. 1989. The Water Quality Performance of Select Urban Runoff Treatment Systems. Prepared for the Legislative Commission on Minnesota Resources. Metropolitan Council. St. Paul, MN. Publication No. 590-89-062a 170 p.

Study Notes

No. of Storms 10

Treatment Volume/ Design Basis

0.1 inch/acre.

Watershed in. 0.1

Impervious in.

Drainage Area 413 **ac**

Slope **%**

Land Use

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility 0 **yrs**

STP Notes

Performance Notes

Data set refers to rainfall events only. Outflow units for Pb are micrograms per liter.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS			62		26
TDS					
TP			24		0.35
DP			10		0.18
PP					
Ortho-P					
TN			36		1.55
ON					
NH4					
TKN			40		1.05
NO3			23		0.4
NOx					
Organic					
Lead			63		8
Zinc					
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 57

Facility Ben Franklin

State Virginia **Country** USA

STP Category Stormwater Wetland

STP Type Extended Detention Wetland

Drainage Class Regular

Bibliographic Information

Occoquan Watershed Monitoring Laboratory and George Mason University. 1990. Final Report: The Evaluation of a Created Wetland as an Urban Best Management Practice. Prepared for the Northern Virginia Soil and Water Conservation District. 175 p. Also in: Adequate Treatment Volume Critical in Virginia Stormwater Wetland. Watershed Protection Techniques. Center for Watershed Protection. February 1994. Vol. 1(1): 25-25.

Study Notes

No. of Storms 23

Treatment Volume/ Design Basis

0.1 watershed inch.

Watershed in. 0.1

Impervious in.

Drainage Area 40 **ac**

Slope **%**

Land Use Residential/ commercial;

% Impervious Cover 30

% Residential

% Commercial

% Industrial

Soil Type

STP Size 0.3 acres

Age of Facility 0 **yrs**

STP Notes

Performance Notes

Columns refer to data collected during small storms and all storms, respectively. Small storms= runoff volume <0.1 watershed inch. Large storms overwhelm capacity of wetlands to remove nutrients.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS	93		62		
TDS					
TP	76		8.3		
DP	66				
PP					
Ortho-P	59		-5.5		
TN	76		-2.1		
ON					
NH4	68		-3.4		
TKN	81		15		
NO3	68		1.2		
NOx					
Organic					
Lead					
Zinc			-73.5		
Copper					
Cadmium			-79.8		
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 58

Facility Lake Jackson

State Florida **Country** USA

STP Category Stormwater Wetland

STP Type Pond/Wetland System

Drainage Class Regional

Bibliographic Information

Esry and Cairns. 1988. The Use of Wetlands for Controlling Stormwater Pollution. Strecker, E.W., J.M. Kersnar and E.D. Driscoll (Eds.). Woodward-Clyde Consultants. Portland, Oregon. Prepared for U.S. EPA, Region V, Water Division, Watershed Management Unit. EPA/600 February 1992.

Study Notes

No. of Storms

Treatment Volume/ Design Basis

0.88 inch/acre (inferred value).

Watershed in. 0.88

Impervious in.

Drainage Area 2230 **ac**

Slope **%**

Land Use

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility **yrs**

STP Notes

Pond to filter wetlands.

Performance Notes

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS			96		
TDS					
TP			90		
DP					
PP					
Ortho-P					
TN			75		
ON					
NH4			37		
TKN					
NO3			70		
NOx					
Organic					
Lead					
Zinc					
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 59

Facility FDOT Pond/Wetland

State Florida **Country** USA

STP Category Stormwater Wetland

STP Type Pond/Wetland System

Drainage Class Regular

Bibliographic Information

Gain, W.S. 1996. The Effects of Flow Path Modification on Water Quality Constituent Retention in an Urban Stormwater Detention Pond and Wetland System. Orlando, FL. U.S. Geological Survey. Water Resources Investigations Report 95-4297. Tallahassee, FL

Study Notes

No. of Storms 22

Treatment Volume/ Design Basis

Pond= 0.55 watershed inches.
Wetland= 0.8 watershed inches.

Watershed in. 1.35

Impervious in.

Drainage Area 41.6 **ac**

Slope **%**

Land Use

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility 0 **yrs**

STP Notes

Pond was modified to increase detention time and was previously studied by Martin and Smoot (1988). This is the efficiency of the entire pond/wetland system; see study # 38 and 72

Performance Notes

Concentration based efficiencies assume that concentration data are log normally distributed. Original NO3 value= -125. Inflow and Outflow units are micrograms per liter. Inflow and Outflow are reported as a mean concentration.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS		-24		45	42
TDS		-24		117	138
TP		-9		0.17	0.19
DP		5		0.05	0.05
PP					
Ortho-P		-24		0.05	0.07
TN		-25		1.64	2.19
ON		-7		1.25	1.47
NH4		50		0.09	0.09
TKN		-17		1.33	1.56
NO3					
NOx		-100		0.31	0.63
TOC		-31		10	12.3
Lead		23		19	13
Zinc		45		65	39
Copper		3		7	7
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					
Dissolved Z		40		21	6
Dissolved C		-1		4	6
Chloride		-67			

STP Pollutant Removal Database

Indices

Study #: 60

STP Category Stormwater Wetland

Facility Long Lake

STP Type Pond/Wetland System

State Maine **Country** USA

Drainage Class Regular

Bibliographic Information

Jolly, J.W. 1990. The Efficiency of Constructed Wetlands in the Reduction of Phosphorous and Sediment Discharges From Agriculture Wetlands. The Use of Wetlands for Controlling Stormwater Pollution. Strecker, E.W., J.M. Kersnar and E.D. Driscoll (Eds.). Woodward-Clyde Consultants. Portland, Oregon. Prepared for U.S. EPA, Region V, Water Division, Watershed Management Unit. EPA/600 February 1992.

Study Notes

No. of Storms 11

Treatment Volume/ Design Basis

2 inch/acre (inferred value).

Watershed in. 2

Impervious in.

Drainage Area 18 **ac**

Slope **%**

Land Use Agricultural

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size 1 acre.

Age of Facility **yrs**

STP Notes

5 components: initial sedimentation basin, grass filter strip, constructed wetlands, deep detention pond.

Performance Notes

Study period did not cover high P loading or Spring thaw (snowmelt).

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS			95		
TDS					
TP			92		
DP					
PP					
Ortho-P					
TN					
ON					
NH4					
TKN					
NO3					
NOx					
Organic					
Lead					
Zinc					
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 61

STP Category Stormwater Wetland

Facility Pacific Steel

STP Type Pond/Wetland System

State Auckland **Country** New Zealand

Drainage Class Regular

Bibliographic Information

Leersnyder, H. 1993. The Performance of Wet Detention Basins for the Removal of Urban Stormwater Contaminantion in the Auckland Region. M.S. Thesis. University of Auckland. Department of Environmental Sciences and Geography. 118 p. Also in: Pond/Wetland System Proves Effective in New Zealand. Watershed Protection Techniques. Center for Watershed Protection. February 1994. Vol. 1(1): 10-11.

Study Notes

No. of Storms 6

Treatment Volume/ Design Basis

0.9 watershed inches. 90% treatment volume in pool. 10% treatment volume

Watershed in. 0.9

Impervious in.

Drainage Area 24 **ac**

Slope **%**

Land Use Industrial (automotive steel recycling).

% Impervious Cover 66

% Residential

% Commercial

% Industrial 100

Soil Type Fine-grained

STP Size Surface area= 1.65 acres (53%= pond; 47%= wetland).

Age of Facility 0 **yrs**

STP Notes

Performance Notes

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS	78			123.6	26.9
TDS					
TP	79			0.447	0.11
DP	75				
PP					
Ortho-P					
TN					
ON					
NH4	-43			0.015	0.019
TKN					
NO3	62			0.167	0.031
NOx					
COD	2			61	51.2
Lead	93			22.6	6.5
Zinc	88			278.5	230
Copper	84			75	6
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 62

STP Category Stormwater Wetland

Facility Highway Site

STP Type Pond/Wetland System

State Florida **Country** USA

Drainage Class Regular

Bibliographic Information

Martin, E. 1988. Effectiveness of an Urban Runoff Detention Pond/Wetland System. Journal of Environmental Engineering. Vol. 114(4): 810-827.

Study Notes

No. of Storms 11

Treatment Volume/ Design Basis

>1.35 inch/acre.

Watershed in.

Impervious in.

Drainage Area 41.6 **ac**

Slope **%**

Land Use

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility **yrs**

STP Notes

Wetpond to wetland. See study #44

Performance Notes

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS	61	50			
TDS					
TP	33	28			
DP	55	45			
PP	20	17			
Ortho-P	37	35			
TN	13	10			
ON	9	5			
NH4	54	57			
TKN					
NO3					
NOx					
COD	4	0			
Lead	32	31			
Zinc	10	-17			
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					
Dissolved P	26	22			
Dissolved Z	-30	-81			

STP Pollutant Removal Database

Indices

Study #: 63

Facility Greenwood

State Florida **Country** USA

STP Category Stormwater Wetland

STP Type Pond/Wetland System

Drainage Class Regional

Bibliographic Information

McCann K. and L. Olson. 1994. Final Report on Greenwood Urban Wetland Treatment Effectiveness. City of Orlando, FL, Stormwater Utility Bureau.

Study Notes

No. of Storms 11

Treatment Volume/ Design Basis

Watershed in.

Impervious in.

Drainage Area 522 **ac**

Slope **%**

Land Use 93% urban

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size Detain runoff from 2.5" of rainfall for 3 hours.

Age of Facility **yrs**

STP Notes

13 acres of ponds and wetlands with aeration and water reuse.

Performance Notes

Original TDS value= -147.8.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS	68.3				5.9
TDS	-100				
TP	61.5				0.1
DP					
PP					
Ortho-P	76.7				0.03
TN	-11				0.98
ON					
NH4	16				
TKN	-10.3				0.79
NO3	-13.2				0.18
NOx					
Organic					
Lead	60				
Zinc	69				
Copper	58				
Cadmium	0				
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 64

Facility McCarrons

State Minnesota **Country** USA

STP Category Stormwater Wetland

STP Type Pond/Wetland System

Drainage Class Regional

Bibliographic Information

Oberst, G. and R. Osgood. 1998. Lake McCarrons: Final Report on the Function of the Wetland Treatment System and the Impacts on Lake McCarrons. Metropolitian Council of the Twin Cities Area. St. Paul, MN.

Study Notes

No. of Storms 21

Treatment Volume/ Design Basis

>0.5 inch/acre.

Watershed in. 0.32

Impervious in.

Drainage Area 608 **ac**

Slope **%**

Land Use mostly single family residential

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size Wet Pond Surface Area: 2.5ac 5 cell
Linear Wetland: 6 ac

Age of Facility **yrs**

STP Notes

This is the efficiency of the entire pond/wetland system; see study #s 45 and 81.

Performance Notes

Mass Efficiency based on storm and base flow. Other efficiency is based on a regression line of inflow vs outflow.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS	96		94	74.7	20.8
TDS					
TP	70		78	0.35	0.26
DP	45				
PP					
Ortho-P					
TN	58		83	2.19	1.7
ON					
NH4					
TKN	55				
NO3	63				
NOx					
COD	80		93	66.8	41.2
Lead	93.2		90		
Zinc					
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 65

Facility McCarrons

State Minnesota **Country** USA

STP Category Stormwater Wetland

STP Type Pond/Wetland System

Drainage Class Regional

Bibliographic Information

Oberts, G. 1997. Lake McCarrons Wetland Treatment System - Phase III Study Report. Metroplitian Council of Environmental Services. St. Paul, Minnesota.

Study Notes

No. of Storms 35

Treatment Volume/ Design Basis

Watershed in. 0.32

Impervious in. 1.19

Drainage Area 736 **ac**

Slope **%**

Land Use mostly single family residential, some

% Impervious Cover 27

% Residential

% Commercial

% Industrial

Soil Type

STP Size Wet pond surface area: 2.5 ac. 6 ac linear wetland composed of 5 cells

Age of Facility 10 **yrs**

STP Notes

This study presents data from the 1995/1996 reevaluation of the McCarrons system. Since the first study, 100 ac. of new D.A. was connected to the system downstream of the detention pond. Main pond was dredged shortly before second round of

Performance Notes

Pollutant removal performance was first evaluated in 1985 - see study #s 45, 64, and 81. Outflow values for Zinc are micrograms per liter.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS	66				22.6
TDS					
TP	4				0.25
DP	23				0.13
PP					0.12
Ortho-P					
TN	33				1.64
ON					
NH4					
TKN	19				1.42
NO3	68				0.27
NOx					
COD	32				
Lead					
Zinc	38				9
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					
VSS	56				

STP Pollutant Removal Database

Indices

Study #: 66

STP Category Stormwater Wetland

Facility Carver Ravine

STP Type Pond/Wetland System

State Minnesota **Country** USA

Drainage Class Regular

Bibliographic Information

Oberts, G.L., P.J. Wotzka and J.A. Hartsoe. 1989. The Water Quality Performance of Select Urban Runoff Treatment Systems. Prepared for the Legislative Commission on Minnesota Resources. Metropolitan Council. St. Paul, MN. Publication No. 590-89-062a 170 p.

Study Notes

No. of Storms 15

Treatment Volume/ Design Basis

0.3 inch/acre (inferred value).

Watershed in. 0.3

Impervious in.

Drainage Area 170 **ac**

Slope **%**

Land Use

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility 10 **yrs**

STP Notes

Performance Notes

Data set refers to rainfall events only. Outflow units for Pb are micrograms per liter.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS			46		11
TDS					
TP			24		0.255
DP			21		0.175
PP					
Ortho-P					
TN			15		1.625
ON					
NH4					
TKN			14		1.25
NO3			18		0.35
NOx					
Organic					
Lead			42		2
Zinc					
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 67

Facility Shop Creek

State Colorado **Country** USA

STP Category Stormwater Wetland

STP Type Pond/Wetland System

Drainage Class Regional

Bibliographic Information

Urbonas, B., J. Carlson and B. Vang. 1994. Joint Pond-Wetland System in Colorado. An Internal Report of the Denver Urban Drainage and Flood Control District. Also in: Performance of a Storage Pond/Wetland System in Colorado. Watershed Protection Techniques. Center for Watershed Protection. Summer 1994. Vol. 1(2): 68-69.

Study Notes

No. of Storms 36

Treatment Volume/ Design Basis

Watershed in.

Impervious in.

Drainage Area 550 **ac**

Slope **%**

Land Use Detached single family residences.

% Impervious Cover 40

% Residential 100

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility **yrs**

STP Notes

This is the efficiency of the entire pond/wetland system; see study #s 50 and 88

Performance Notes

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS			72	134	33
TDS					
TP			51	0.45	0.201
DP			40	0.307	0.13
PP					
Ortho-P					
TN			19	3.54	3.91
ON			31		
NH4					
TKN				2.31	1.67
NO3			-76	1.23	2.24
NOx					
COD			56	75	37
Lead					
Zinc			66	109	32
Copper			57	36.33	15.33
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					
Dissolved C			58	41	15.33
Dissolved Z			30	46.67	29

STP Pollutant Removal Database

Indices

Study #: 68

STP Category Stormwater Wetland

Facility Queen Anne's

STP Type Shallow Marsh

State Maryland **Country** USA

Drainage Class Regular

Bibliographic Information

Athanas, C. and C. Stevenson. 1991. The Use of Artificial Wetands in Treating Stormwater Runoff. Prepared for the Maryland Sediment and Stormwater Administration. Maryland Department of the Environment. 66 p.

Study Notes

No. of Storms

Treatment Volume/ Design Basis

0.5 inch/acre (inferred value).

Watershed in. 0.5

Impervious in.

Drainage Area 16 **ac**

Slope **%**

Land Use High school roof, parking lot, athletic

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size surface area= 0.6 acre (30% 0-12" depth; 70% 12-24" depth).

Age of Facility **yrs**

STP Notes

Performance Notes

Sand substrate did not contain enough organic matter to trap pollutants.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS	65				
TDS					
TP	39.1				
DP	44.3				
PP	7.2				
Ortho-P	68.7				
TN	22.8				
ON	-5.4				
NH4	55.8				
TKN					
NO3	54.9				
NOx	54.5				
Organic					
Lead					
Zinc					
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 69

STP Category Stormwater Wetland

Facility Palm Beach Gardens

STP Type Shallow Marsh

State Florida **Country** USA

Drainage Class Regional

Bibliographic Information

Blackburn, R., P.L. Pimentel and G.E. French. 1986. Treatment of Stormwater Runoff Using Aquatic Plants. The Use of Wetlands for Controlling Stormwater Pollution. Strecker, E.W., J.M. Kersnar and E.D. Driscoll (Eds.). Woodward-Clyde Consultants. Portland, Oregon. Prepared for U.S. EPA, Region V, Water Division, Watershed Management Unit. EPA/600 February 1992.

Study Notes

No. of Storms 72

Treatment Volume/ Design Basis

1 watershed inch. (2 inferred).

Watershed in. 1

Impervious in.

Drainage Area 2340 **ac**

Slope **%**

Land Use Golf Course

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size 296 acres

Age of Facility **yrs**

STP Notes

Performance Notes

Data based on the average of two annual averages (1982 and 1985). Parameters measured in ppm except for turbidity which is measured in NTU.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS		37.5		11.85	7.85
TDS					
TP		47.5		0.085	0.045
DP					
PP					
Ortho-P					
TN		13		1.14	0.99
ON					
NH4		14.5		0.2	0.17
TKN		11.5		0.94	0.835
NO3		25.5		0.2	0.15
NOx					
BOD		15		3.55	3
Lead					
Zinc					
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity		68.5		5.8	1.8
Alkalinity		27.5		180.5	130
TOC		0		10	9.75

STP Pollutant Removal Database

Indices

Study #: 70

STP Category Stormwater Wetland

Facility Hidden River

STP Type Shallow Marsh

State Florida **Country** USA

Drainage Class Regular

Bibliographic Information

Carr, D. and B. Rushton. 1995. Integrating a Herbaceous Wetland into Stormwater Management. Stormwater Research Program. Southwest Flordia Water Management District. Brooksville, FL.

Study Notes

No. of Storms 81

Treatment Volume/ Design Basis

Watershed in.

Impervious in.

Drainage Area 15.3 **ac**

Slope **%**

Land Use

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size Area:3 acres

Age of Facility **yrs**

STP Notes

Performance Notes

n=15 for TOC, Chloride, and Sulfate. Inflow and Outflow units for metals are micrograms per liter.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS	86			7.55	1.801
TDS					
TP	70			0.98	0.04
DP					
PP					
Ortho-P	67			0.035	0.04
TN	46			0.756	1.206
ON	29			0.614	1.155
NH4	79			0.0275	0.022
TKN	34			0.644	1.188
NO3					
NOx	94			0.0845	0.016
TOC	9			5.21	16.1
Lead	83			206	298
Zinc	84			47	15
Copper	79			4	3
Cadmium	88				
Chromium					
Iron	5				
TPH					
Oil/Grease					
Bacteria					
Turbidity					
Chloride	-100			1.05	2.551
Sulfate	53			5	4.05
Mn	2				

STP Pollutant Removal Database

Indices

Study #: 71

Facility Swift Run

State Michigan **Country** USA

STP Category Stormwater Wetland

STP Type Shallow Marsh

Drainage Class Regional

Bibliographic Information

Driscoll, E.D. 1983. Performance of Detention Basins for Control of Urban Runoff Quality. Presented at the 1983 International Symposium on Urban Hydrology, Hydraulics and Sedimentation Control. University of Kentucky. Lexington, KY. 40 p.

Study Notes

No. of Storms 5

Treatment Volume/ Design Basis

0.6 inch/acre

Watershed in. 0.6

Impervious in.

Drainage Area 1207 **ac**

Slope **%**

Land Use

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility **yrs**

STP Notes
Shallow pond with wetlands.

Performance Notes

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS			85		
TDS					
TP			3		
DP			29		
PP					
Ortho-P					
TN					
ON					
NH4					
TKN					
NO3			80		
NOx					
COD			2		
Lead			82		
Zinc					
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					
BOD			4		

STP Pollutant Removal Database

Indices

Study #: 72

STP Category Stormwater Wetland

Facility FDOT Wetland

STP Type Shallow Marsh

State FL ***Country*** USA

Drainage Class Regular

Bibliographic Information

Gain, W.S. 1996. The Effects of Flow Path Modification on Water Quality Constituent Retention in an Urban Stormwater Detention Pond and Wetland System. Orlando, FL. U.S. Geological Survey. Water Resources Investigations Report 95-4297. Tallahassee, FL

Study Notes

No. of Storms 22

Treatment Volume/ Design Basis

Pond= 0.55 watershed inches.
Wetland= 0.8 watershed inches.

Watershed in. 0.8

Impervious in.

Drainage Area 41.6 **ac**

Slope **%**

Land Use

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility 0 **yrs**

STP Notes

Pond was modified to increase detention time and was previously studied by Martin and Smoot (1988). Wetland component of a pond/wetland system; see study #s 38 and 59

Performance Notes

Concentration based efficiencies assume that concentration data are log normally distributed. Inflow and Outflow units for metals are micrograms per liter. Inflow and Outflow are reported as a mean concentration.

Pollutant Removal Data

Pollutant	***% Mean Efficiency***			***Concentration***	
	Mass	***Conc.***	***Other***	***Inflow***	***Outflow***
TSS		-100		45	42
TDS		-4		117	138
TP		-55		0.17	0.19
DP		-46		0.05	0.05
PP					
Ortho-P		-67		0.05	0.07
TN		-49		1.64	2.19
ON		17		1.25	1.47
NH4		40		0.09	0.09
TKN				1.33	1.56
NO3					
NOx		-100		0.31	0.63
TOC		-1		10	12.3
Lead		-100		19	13
Zinc		-14		65	39
Copper		-67		7	7
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					
Dissolved Z		-15		21	6
Dissolved C		-33		4	6

STP Pollutant Removal Database

Indices

Study #: 73

Facility Hidden Lake

State Florida **Country** USA

STP Category Stormwater Wetland

STP Type Shallow Marsh

Drainage Class Regular

Bibliographic Information

Harper, H.H., M.P. Wanielista, B.M. Fries and D.M. Baker. 1986. The Use of Wetlands for Controlling Stormwater Pollution. Strecker, E.W., J.M. Kersnar and E.D. Driscoll (Eds.). Woodward-Clyde Consultants. Portland, Oregon. Prepared for U.S. EPA, Region V, Water Division, Watershed Management Unit. EPA/600 February 1992.

Study Notes

No. of Storms

Treatment Volume/ Design Basis

1.08 inch/acre (inferred value).

Watershed in. 1.08

Impervious in.

Drainage Area 55.4 **ac**

Slope 0.005 **%**

Land Use Large residential community.

% Impervious Cover 26

% Residential 100

% Commercial

% Industrial

Soil Type

STP Size 2.47 acres

Age of Facility **yrs**

STP Notes

Runoff enters through a small shallow canal. This is a natural wetland.

Performance Notes

Approximately 70% of total inputs are retained. Data units = kg/yr. Original ortho-P value= -109.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS	82.9				
TDS					
TP	7				
DP					
PP					
Ortho-P	-100				
TN	-1.6				
ON	-24				
NH4	62.2				
TKN					
NO3	80.2				
NOx					
BOD	81.3				
Lead	54.8				
Zinc	40.9				
Copper	39.9				
Cadmium	70.7				
Chromium	72.6				
Iron	-90.1				
TPH					
Oil/Grease					
Bacteria					
Turbidity					
Mg	7.7				
Al	63.1				
Ni	70				

STP Pollutant Removal Database

Indices

Study #:	74	**STP Category**	Stormwater Wetland
Facility	EW3	**STP Type**	Shallow Marsh
State	Illinois	**Drainage Class**	Regional
Country	USA		

Bibliographic Information

Hey, D.L., A.L. Kenimer and K.R. Barrett. 1994. Water Quality Improvement by Four Experimental Wetlands. Ecological Engineering Vol. 3: 381- 397. Also in: Pollutant Removal by Constructed Wetlands in an Illinois River Floodplain. Watershed Protection Techniques. Center for Watershed Protection. Spring 1996. Vol. 2(2): 376-379.

Study Notes

No. of Storms

Treatment Volume/ Design Basis

Watershed in.

Impervious in.

Drainage Area 128000 **ac**

Slope **%**

Land Use 80% agriculture, 20% urban.

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility 4 **yrs**

STP Notes

5- 8.6 acre wetland. max depth 5'. subject to high-flow conditions (13.4-38.2 in/wk).

Performance Notes

Data represents the average of two annual averages for 1990 and 1991; Removal efficiencies caculated using mass balance and flux analysis.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS	87				
TDS					
TP	77.5				
DP					
PP					
Ortho-P					
TN					
ON					
NH4					
TKN					
NO3	82.5				
NOx					
Organic					
Lead					
Zinc					
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 75

STP Category Stormwater Wetland

Facility EW5

STP Type Shallow Marsh

State Illinois **Country** USA

Drainage Class Regional

Bibliographic Information

Hey, D.L., A.L. Kenimer and K.R. Barrett. 1994. Water Quality Improvement by Four Experimental Wetlands. Ecological Engineering Vol. 3: 381- 397. Also in: Pollutant Removal by Constructed Wetlands in an Illinois River Floodplain. Watershed Protection Techniques. Center for Watershed Protection. Spring 1996. Vol. 2(2): 376-379.

Study Notes

No. of Storms

Treatment Volume/ Design Basis

Watershed in.

Impervious in.

Drainage Area 128000 **ac**

Slope **%**

Land Use 80% agriculture, 20% urban.

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility 4 **yrs**

STP Notes

5- 8.6 acre wetland. max depth 5'. subject to high-flow conditions (13.4-38.2 in/wk).

Performance Notes

Data represents the average of two annual averages for 1990 and 1991; Removal efficiencies caculated using mass balance and flux analysis.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS	95.5				
TDS					
TP	87				
DP					
PP					
Ortho-P					
TN					
ON					
NH4					
TKN					
NO3	86				
NOx					
Organic					
Lead					
Zinc					
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 76

Facility EW6

State Illinois **Country** USA

STP Category Stormwater Wetland

STP Type Shallow Marsh

Drainage Class Regional

Bibliographic Information

Hey, D.L., A.L. Kenimer and K.R. Barrett. 1994. Water Quality Improvement by Four Experimental Wetlands. Ecological Engineering Vol. 3: 381- 397. Also in: Pollutant Removal by Constructed Wetlands in an Illinois River Floodplain. Watershed Protection Techniques. Center for Watershed Protection. Spring 1996. Vol. 2(2): 376-379.

Study Notes

No. of Storms

Treatment Volume/ Design Basis

Watershed in.

Impervious in.

Drainage Area 128000 **ac**

Slope **%**

Land Use 80% agriculture, 20% urban.

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility 4 **yrs**

STP Notes

5- 8.6 acre wetland. max depth 5'. subject to low-flow conditions (2.8- 6.3 in/wk).

Performance Notes

Data represents the average of two annual averages for 1990 and 1991; Removal efficiencies caculated using mass balance and flux analysis.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS	99.5				
TDS					
TP	99.5				
DP					
PP					
Ortho-P					
TN					
ON					
NH4					
TKN					
NO3	99				
NOx					
Organic					
Lead					
Zinc					
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 77

Facility EW4

State Illinois **Country** USA

STP Category Stormwater Wetland

STP Type Shallow Marsh

Drainage Class Regional

Bibliographic Information

Hey, D.L., A.L. Kenimer and K.R. Barrett. 1994. Water Quality Improvement by Four Experimental Wetlands. Ecological Engineering Vol. 3: 381- 397. Also in: Pollutant Removal by Constructed Wetlands in an Illinois River Floodplain. Watershed Protection Techniques. Center for Watershed Protection. Spring 1996. Vol. 2(2): 376-379.

Study Notes

No. of Storms

Treatment Volume/ Design Basis

Watershed in.

Impervious in.

Drainage Area 128000 **ac**

Slope **%**

Land Use 80% agriculture, 20% urban.

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility 4 **yrs**

STP Notes

5- 8.6 acre wetland. max depth 5'. subject to low-flow conditions (2.8- 6.3 in/wk).

Performance Notes

Data represents the average of two annual averages for 1990 and 1991; Removal efficiencies caculated using mass balance and flux analysis.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS	85.5				
TDS					
TP	75				
DP					
PP					
Ortho-P					
TN					
ON					
NH4					
TKN					
NO3	67				
NOx					
Organic					
Lead					
Zinc					
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #:	78	**STP Category**	Stormwater Wetland
Facility	Wayzata	**STP Type**	Shallow Marsh
State	Minnesota	**Country** USA	**Drainage Class** Regular

Bibliographic Information

Hickok, E.A., M.C. Hannaman and N.C. Wenck. 1977. Urban Runoff Treatment Methods. Volume 1: Non-structural Wetland Treatment. The Use of Wetlands for Controlling Stormwater Pollution. Strecker, E.W., J.M. Kersnar and E.D. Driscoll (Eds.). Woodward-Clyde Consultants. Portland, Oregon. Prepared for U.S. EPA, Region V, Water Division, Watershed Management Unit. EPA/600 February 1992.

Study Notes

No. of Storms

Treatment Volume/ Design Basis

1.25 inch/acre (inferred value).

Watershed in. 1.25

Impervious in.

Drainage Area 73.2 **ac**

Slope **%**

Land Use Residential= 34.1 acres. Highway= 31.5

% Impervious Cover

% Residential 47

% Commercial

% Industrial

Soil Type

STP Size 7.6 acres.

Age of Facility **yrs**

STP Notes

This is a natural wetland.

Performance Notes

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS			94		
TDS					
TP			78		
DP					
PP					
Ortho-P					
TN					
ON					
NH4			-44		
TKN					
NO3					
NOx					
Organic					
Lead			94		
Zinc			82		
Copper			80		
Cadmium			67		
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 79

Facility Kingston

State Massachusetts **Country** USA

STP Category Stormwater Wetland

STP Type Shallow Marsh

Drainage Class Pocket

Bibliographic Information

Horsley, S.W. 1995. The StormTreat System- A New Technology for Treating Stormwater Runoff. Watershed Protection Techniques. Center for Watershed Protection. Fall 1995. Vol. 2(1): 304-305.

Study Notes

No. of Storms 5

Treatment Volume/ Design Basis

How many tanks were used in this study is unspecified.

Watershed in.

Impervious in.

Drainage Area 0.43 **ac**

Slope **%**

Land Use 850 ' of roadway

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility **yrs**

STP Notes

Performance Notes

Units for metals are ug/L. TSS, COD, TPH units are mg/L. Fecal coliform= #/100ml. TN refers to total dissolved nitrogen.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS			99	93	1.3
TDS					
TP			89	3	0.027
DP					
PP					
Ortho-P					
TN			44	1.64	0.922
ON					
NH4					
TKN					
NO3					
NOx					
COD			82	95	17
Lead			77	6.5	1.5
Zinc			90	590	58
Copper					
Cadmium					
Chromium			98	60	1
Iron					
TPH			90	3.4	0.34
Oil/Grease					
Fecal coliform			97	690	20
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 80

Facility Glenwood

State Washington **Country** USA

STP Category Stormwater Wetland

STP Type Shallow Marsh

Drainage Class Pocket

Bibliographic Information

Koon J. 1995. Evaluation of Water Quality Ponds and Swales in the Issaquah/East Lake Sammamish Basins. King County Surface Water Management and Washington Department of Ecology. Seattle, WA. 75 p.

Study Notes

No. of Storms 5

Treatment Volume/ Design Basis

2 & 25 year quantity control only (some dead storage for pool); 0.25 watershed

Watershed in. 0.25

Impervious in.

Drainage Area 7.7 **ac**

Slope **%**

Land Use

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size Two cell wetland; first cell 2' deep pool with emergent wetlands; second cell is free draining; 7:1 length to width ratio

Age of Facility **yrs**

STP Notes

Performance Notes

Biologically active P= 56. Inflow and Outflow values are presented as mean concentrations. Inflow and Outflow units for metals are micrograms per liter. Fe. Col. Are organisms per 100 mL

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS		20		14	12
TDS					
TP		33		0.097	0.071
DP		66		0.023	0.008
PP					
Ortho-P					
TN					
ON					
NH4		72			
TKN					
NO3					
NOx		67			
Organic					
Lead		35		5.5	3.5
Zinc		52		32	19
Copper		25		5.6	4.5
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Fecal coliform		55		1350	768
Turbidity					
Dissolved P		0			
Dissolved Z		27		33	24
Dissolved		39		5.1	3.1

STP Pollutant Removal Database

Indices

Study #: 81

STP Category Stormwater Wetland

Facility McCarrons

STP Type Shallow Marsh

State Minnesota **Country** USA

Drainage Class Regional

Bibliographic Information

Oberst, G. and R. Osgood. 1988. Lake McCarrons: Final Report on the Function of the Wetland Treatment System and the Impacts on Lake McCarrons. Metropolitian Council of the Twin Cities Area. St. Paul, MN.

Study Notes

No. of Storms 21

Treatment Volume/ Design Basis

0.31 inch/acre

Watershed in. 0.31

Impervious in.

Drainage Area 636 **ac**

Slope **%**

Land Use

% Impervious Cover 19

% Residential

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility **yrs**

STP Notes

Wetland component of a pond/wetland system; see study #s 45 and 64.

Performance Notes

Efficiency is based on a regression line of inflow vs outflow.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS	84		87	128.5	20.8
TDS					
TP	32		36	0.62	0.26
DP			25		
PP					
Ortho-P					
TN	26		24	2.54	1.7
ON					
NH4					
TKN	27		26		
NO3	22		22		
NOx					
COD	63		79	77.3	41.2
Lead	74		68		10
Zinc					
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 82

Facility EW5

State Illinois **Country** USA

STP Category Stormwater Wetland

STP Type Shallow Marsh

Drainage Class Regional

Bibliographic Information

Phipps, R.G. and W.G. Crumpton. 1994. Factors Affecting Nitrogen Loss In Experimental Wetlands With Different Hydrologic Loads. Ecological Engineering. December 1994. Vol. 3(4): 399-408.

Study Notes

No. of Storms

Treatment Volume/ Design Basis

Average detention time= 13 days

Watershed in.

Impervious in.

Drainage Area 128000 **ac**

Slope **%**

Land Use Agriculture 80%

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size Wetland= 4.7 acre. average depth= 28"

Age of Facility **yrs**

STP Notes

High hydraulic loading.

Performance Notes

High hydraulic loading rates= export of ON. Seasonal variation in NO3 and ON loads. Significant effects on effectiveness of wetlands as TN sinks.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS					
TDS					
TP					
DP					
PP					
Ortho-P					
TN	59				
ON	-22				
NH4					
TKN					
NO3	84				
NOx					
Organic					
Lead					
Zinc					
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 83

Facility EW4

State Illinois **Country** USA

STP Category Stormwater Wetland

STP Type Shallow Marsh

Drainage Class Regional

Bibliographic Information

Phipps, R.G. and W.G. Crumpton. 1994. Factors Affecting Nitrogen Loss In Experimental Wetlands With Different Hydrologic Loads. Ecological Engineering. December 1994. Vol. 3(4): 399-408.

Study Notes

No. of Storms

Treatment Volume/ Design Basis

Average detention time= 95 days

Watershed in.

Impervious in.

Drainage Area 128000 **ac**

Slope **%**

Land Use Agriculture 80%

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size Wetland= 5.9 acre.
average depth= 28"

Age of Facility **yrs**

STP Notes

Low hydraulic loading.

Performance Notes

Seasonal variation in NO3 and ON loads. Significant effects on effectiveness of wetlands as TN sinks.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS					
TDS					
TP					
DP					
PP					
Ortho-P					
TN	75				
ON	8				
NH4					
TKN					
NO3	95				
NOx					
Organic					
Lead					
Zinc					
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 84

Facility EW3

State Illinois **Country** USA

STP Category Stormwater Wetland

STP Type Shallow Marsh

Drainage Class Regional

Bibliographic Information

Phipps, R.G. and W.G. Crumpton. 1994. Factors Affecting Nitrogen Loss In Experimental Wetlands With Different Hydrologic Loads. Ecological Engineering. December 1994. Vol. 3(4): 399-408.

Study Notes

No. of Storms

Treatment Volume/ Design Basis

Average detention time= 12 days.

Watershed in.

Impervious in.

Drainage Area 128000 **ac**

Slope **%**

Land Use Agriculture 80%

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size wetland= 5.9 acre.
average depth= 24"

Age of Facility **yrs**

STP Notes

High hydraulic loading.

Performance Notes

High hydraulic loading rates= export of ON. Seasonal variation in NO3 and ON loads. Significant effects on effectiveness of wetlands as TN sinks.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS					
TDS					
TP					
DP					
PP					
Ortho-P					
TN	54				
ON	-31				
NH4					
TKN					
NO3	78				
NOx					
Organic					
Lead					
Zinc					
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 85

STP Category Stormwater Wetland

Facility PC12

STP Type Shallow Marsh

State Washington **Country** USA

Drainage Class Regular

Bibliographic Information

Reinelt et al., 1990. In: The Use of Wetlands for Controlling Stormwater Pollution. Strecker, E.W., J.M. Kersnar and E.D. Driscoll (Eds.). Woodward-Clyde Consultants. Portland, Oregon. Prepared for U.S EPA, Region V, Water Division, Watershed Management Unit. EPA/600 February 1992.

Study Notes

No. of Storms 13

Treatment Volume/ Design Basis

0.03 inch/acre

Watershed in. 0.03

Impervious in.

Drainage Area 214.8 **ac**

Slope **%**

Land Use

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility **yrs**

STP Notes

Performance Notes

Channelization reduced effectiveness.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS			56		
TDS					
TP			-2		
DP					
PP					
Ortho-P					
TN					
ON					
NH4					
TKN					
NO3			20		
NOx					
Organic					
Lead					
Zinc					
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 86

Facility B31

State Washington **Country** USA

STP Category Stormwater Wetland

STP Type Shallow Marsh

Drainage Class Regional

Bibliographic Information

Reinelt et al., 1992. In: The Use of Wetlands for Controlling Stormwater Pollution. Strecker, E.W., J.M. Kersnar and E.D. Driscoll (Eds.). Woodward-Clyde Consultants. Portland, Oregon. Prepared for U.S EPA, Region V, Water Division, Watershed Management Unit. EPA/600 February 1992.

Study Notes

No. of Storms 13

Treatment Volume/ Design Basis

0.01 inch/acre

Watershed in. 0.01

Impervious in.

Drainage Area 461.7 **ac**

Slope **%**

Land Use

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility **yrs**

STP Notes

Performance Notes

Channelization reduced effectiveness.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS			14		
TDS					
TP			-2		
DP					
PP					
Ortho-P					
TN					
ON					
NH4					
TKN					
NO3			4		
NOx					
Organic					
Lead					
Zinc					
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 87

Facility Tampa Office Park- 3.7 day

State Florida **Country** USA

STP Category Stormwater Wetland

STP Type Shallow Marsh

Drainage Class Pocket

Bibliographic Information

Rushton, B. and C. Dye. 1993. An In-Depth Analysis of a Wet Detention Stormwater Sytem. Southwest Florida Water Management District. Brooksville, FL. 60 p. Also in: Pollutant Removal Capability of a "Pocket" Wetland. Watershed Protection Techniques. Center for Watershed Protection. Spring 1996. Vol. 2(2): 374-376.

Study Notes

No. of Storms 25

Treatment Volume/ Design Basis

WQV= 0.5 inch of runoff. Annual mean residence time 3.7 days. Runoff

Watershed in.

Impervious in.

Drainage Area 6 **ac**

Slope **%**

Land Use

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size Surface area= 0.32 acres. Max depth= 18'.

Age of Facility **yrs**

STP Notes

Runoff conveyed by 200' drainage channel; BMP approximately 3-5 years old.

Performance Notes

Cd, Cr= not detected frequently enough to calculate removal efficiency. Outflow units for Zinc are micrograms per liter.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS		57			11.8
TDS					
TP		57			0.17
DP					
PP					
Ortho-P		66			0.1
TN					
ON		3			0.93
NH4		20			
TKN					
NO3					
NOx		67			0.08
Organic					
Lead					
Zinc		42			30
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 88

Facility Shop Creek

State Colorado **Country** USA

STP Category Stormwater Wetland

STP Type Shallow Marsh

Drainage Class Regional

Bibliographic Information

Urbonas, B., J. Carlson and B. Vang. 1994. Joint Pond-Wetland System in Colorado. An Internal Report of the Denver Urban Drainage and Flood Control District. Also in: Performance of a Storage Pond/Wetland System in Colorado. Watershed Protection Techniques. Center for Watershed Protection. Summer 1994. Vol. 1(2): 68-69.

Study Notes

No. of Storms 36

Treatment Volume/ Design Basis

Velocity: less than 3 fps for major floods; less than 0.3 fps for smaller

Watershed in.

Impervious in.

Drainage Area 550 **ac**

Slope **%**

Land Use Detached single family residences.

% Impervious Cover 40

% Residential 100

% Commercial

% Industrial

Soil Type

STP Size Six wetland cells. Surface area= 3.8 acres.

Age of Facility **yrs**

STP Notes

Water velocity= <3 fps during floods; <0.3 fps during small storms. Wetland component of a pond/wetland system; see study #s 50 and 67

Performance Notes

Wetland receives pretreated runoff from wet pond.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS			-29	28	33
TDS					
TP			3	0.212	0.201
DP			12	0.129	0.13
PP				0.083	0.071
Ortho-P					
TN			1	3.76	3.91
ON			-1		
NH4					
TKN				1.46	1.67
NO3			5	2.3	2.24
NOx					
COD			21	44	36.67
Lead					
Zinc			31	45	32
Copper			2	17.33	15.33
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					
Dissolved C			-1	18.5	15.67
Dissolved Z			-5	53.5	42

STP Pollutant Removal Database

Indices

Study #: 89

STP Category Stormwater Wetland

Facility Rt. 288

STP Type Shallow Marsh

State Virginia **Country** USA

Drainage Class Regular

Bibliographic Information

Yu, S; G. Fitch; and T. Earles. 1998. Constructed Wetlands for Stormwater Management. Virginia Transportation Research Council. Charlottesville, VA.

Study Notes

No. of Storms 13

Treatment Volume/ Design Basis

Watershed in.

Impervious in.

Drainage Area ac

Slope %

Land Use Highway

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size 5 ac wetland

Age of Facility yrs

STP Notes

Performance Notes

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS	52.02	56.96			
TDS					
TP	68.09	68.61			
DP					
PP					
Ortho-P	82.46	81.5			
TN					
ON					
NH4					
TKN					
NO3					
NOx					
COD	24.23	23.24			
Lead					
Zinc	31.63	43.01			
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 90

STP Category Stormwater Wetland

Facility Rio Hill

STP Type Shallow Marsh

State Wisconsin **Country** USA

Drainage Class Regular

Bibliographic Information

Yu, S; G. Fitch; and T. Earles. 1998. Constructed Wetlands for Stormwater Management. Virginia Transportation Research Council. Charlottesville, VA.

Study Notes

No. of Storms 5

Treatment Volume/ Design Basis

Watershed in.

Impervious in.

Drainage Area 75 **ac**

Slope **%**

Land Use parking lot, highway

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size 0.7 ac wetland

Age of Facility **yrs**

STP Notes

Performance Notes

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS	30.1	-1.32			
TDS					
TP	27.46	14.86			
DP					
PP					
Ortho-P	0.67	-8			
TN					
ON					
NH4					
TKN					
NO3					
NOx					
COD	-22.8	-31.6			
Lead					
Zinc	29.47	24.23			
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 91

STP Category Stormwater Wetland

Facility Lake Beardall

STP Type Submerged Gravel Wetland

State Florida **Country** USA

Drainage Class

Bibliographic Information

Egan, T., J.S. Burroughs and T. Attaway. 1995. Packed Bed Filter. Proceedings of the 4th Biennial Research Conference. Southwest Florida Water Management District. Brookeville, FL p. 264-274. Also in: Vegetated Rock Filter Treats Stormwater Pollutants in Florida. Watershed Protection Techniques. Center for Watershed Protection. Spring 1996. Vol. 2(2):372-374.

Study Notes

No. of Storms 15

Treatment Volume/ Design Basis

0.1 to 0.5 acre-feet of runoff treated per cell per day.

Watershed in.

Impervious in.

Drainage Area 121 **ac**

Slope **%**

Land Use Industrial

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size 10 cells each 30' length, 80' width, 3' deep.

Age of Facility **yrs**

STP Notes

Off-line system. Lined bottom.

Performance Notes

30 to 120 gpm/cfs system. Data doesn't reflect prior treatment by sediment chamber during first flush. Concrete better than granite rock. pH difference result in differing amount/type of epilithic algae. Vegetated beds do no better than concrete. Wetland vegetation did help the granite. Incoming metal concentration at or below detection

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS	81				
TDS	8				
TP	82				
DP					
PP					
Ortho-P	14				
TN	63				
ON					
NH4					
TKN	63				
NO3	75				
NOx					
TOC	38				
Lead	73				
Zinc	55				
Copper	21				
Cadmium	80				
Chromium	38				
Iron					
TPH	80				
Oil/Grease					
Fecal coliform	78				
Turbidity					
pH	7.2				

STP Pollutant Removal Database

Indices

Study #: 92

STP Category Stormwater Wetland

Facility Tahoe

STP Type Submerged Gravel Wetland

State California **Country** USA

Drainage Class

Bibliographic Information

Reuter, J., T. Djihan and C. Goldman. 1992. The Use of Wetlands for Nutrient Removal From Surface Runoff in a Cold-Climate Region of California: Results From a Newly Constructed Wetland at Lake Tahoe. Journal of Environmental Management. Vol. 36: 35-53. Also in: Performance of a Gravel-Based Wetland in a Cold, Hugh Altitude Climate. Watershed Protection Techniques. Center for Watershed Protection. Fall 1995. Vol. 2(1): 297-299.

Study Notes

No. of Storms 15

Treatment Volume/ Design Basis

Watershed in.

Impervious in.

Drainage Area 2.5 **ac**

Slope **%**

Land Use Pervious athletic fields.

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type Nutrient poor granitic

STP Size Surface area= 0.16 acres.

Age of Facility 0 **yrs**

STP Notes

3' deep fine gravel bed. Lined bottom

Performance Notes

TN= originally an unspecified negative value (represented here as -25). Data represents an average of a range for some parameters. Wetland plantings not fully established at time of study.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS		84			
TDS					
TP		45.5			
DP		-34.5			
PP					
Ortho-P					
TN		-25			
ON					
NH4		-55.5			
TKN		-8.5			
NO3		86			
NOx					
Organic					
Lead					
Zinc					
Copper					
Cadmium					
Chromium					
Iron		84			
TPH					
Oil/Grease					
Bacteria					
Turbidity					
Soluble Fe		75			

STP Pollutant Removal Database

Indices

Study #: 93

STP Category Filtering Practice

Facility Beltway Plaza

STP Type Bioretention

State Maryland **Country** USA

Drainage Class

Bibliographic Information

Davis, A.; M. Shokouhian; H. Sharma; and C. Minami. 1998. Optimization of Bioretention Design for Water Quality and Hydrologic Characteristics. Department of Civil Engineering, University of Maryland, College Park.

Study Notes

No. of Storms 15

Treatment Volume/ Design Basis

Watershed in.

Impervious in.

Drainage Area ac

Slope %

Land Use parking lot

% Impervious Cover 100

% Residential

% Commercial

% Industrial

Soil Type

STP Size Area: 50 ft2
Depth: 42 in.

Age of Facility 5 yrs

STP Notes

Synthetic stormwater runoff was pumped to the system at a flow rate of 1.6 in/hr

Performance Notes

Inflow and Outflow units for metals are micrograms per liter. Pollutant levels in the synthetic stormwater runoff were based on sampling performed by Prince George's County, MD in urban/suburban runoff

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS					
TDS					
TP	65			0.52	0.18
DP					
PP					
Ortho-P					
TN	49			2	1.7
ON				0.9	1.48
NH4	92			2.6	0.22
TKN	52			3.5	1.7
NO3	16			0.33	0.67
NOx					
Organic					
Lead	95			42	2
Zinc	95			530	25
Copper	97			66	2
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 94

STP Category Filtering Practice

Facility Ruby Street Garage

STP Type Organic Filter

State Wisconsin **Country** USA

Drainage Class

Bibliographic Information

Corsi, S. and S. Greb. 1997. Demonstration project of Wisconsin Department of Natural Resources, United States Geological Survey and the City of Milwaukee. Personal communication with R. Pitt. 1997. In: Multi-Chamber Treatment Train Developed for Stormwater Hot Spots. Watershed Protection Techniques. Center for Watershed Protection. February 1997. 2(3): 445-449.

Study Notes

No. of Storms 5

Treatment Volume/ Design Basis

treatment provided for the first 1/2" of runoff. (80% of annual water load)

Watershed in.

Impervious in.

Drainage Area 0.25 **ac**

Slope **%**

Land Use City maintenance yard (pavement and

% Impervious Cover 100

% Residential

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility **yrs**

STP Notes

Performance Notes

Value for Pyrene= >80. Metal values= total reactive elements. Inflow and outflow units for all metals are mircrograms per liter.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS		98			5
TDS		-40			885
TP		88			0.23
DP		78			0.002
PP					
Ortho-P					
TN					
ON					
NH4		47			0.062
TKN					
NO3					
NOx		32			0.273
TOC		56			4.4
Lead		96			0.4
Zinc		91			19
Copper		90			3
Cadmium		91			0.1
Chromium		78			
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					
Flouranthen		92			

STP Pollutant Removal Database

Indices

Study #: 95

STP Category Filtering Practice

Facility Lake Stevens

STP Type Organic Filter

State WA **Country** USA

Drainage Class

Bibliographic Information

Leif, W. 1999. Compost Stormwater Filter Evaluation. Snohomish County Public County Works. Everett, WA.

Study Notes

No. of Storms 8

Treatment Volume/ Design Basis

Watershed in.

Impervious in.

Drainage Area 0.69 **ac**

Slope **%**

Land Use

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility 0.5 **yrs**

STP Notes
Filter is 12" deep.

Performance Notes
Outflow units for Zn, Pb, and Cu are micrormas per liter. COD analysis was discontinued after the first five storms due to low influent concentrations.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS		48		35.5	16
TDS					
TP		-78.5		0.03	0.053
DP					
PP					
Ortho-P					
TN					
ON					
NH4					
TKN					
NO3					
NOx					
COD		37		0.011	0.01
Lead		50		9	4
Zinc		35.5		65.5	34
Copper		34		8.5	5
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 96

STP Category Filtering Practice

Facility LCRA Office Complex

STP Type Organic Filter

State Texas **Country** USA

Drainage Class

Bibliographic Information

Lower Colorado River Authority. 1997. Innovative NPS Pollution Control Program for Lake Travis in Central Texas. LCRA.

Study Notes

No. of Storms 16

Treatment Volume/ Design Basis

Watershed in.

Impervious in.

Drainage Area 1.5 **ac**

Slope **%**

Land Use office parking lot

% Impervious Cover 100

% Residential

% Commercial

% Industrial

Soil Type

STP Size retention capacity: 605 ft3 Filter bed area: 3200

Age of Facility 0 **yrs**

STP Notes

Catch basin pretreatment
Retrofit site
Liner in filter may have allowed for infiltration

Performance Notes

Inflow and Outflow units for Zn are micrograms per liter.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS		84		74	12
TDS					
TP		48		0.367	0.191
DP					
PP					
Ortho-P		2.7		0.073	0.071
TN		30		1.612	1.122
ON					
NH4					
TKN		61		1.393	0.55
NO3					
NOx		-96		0.286	0.561
TOC		11.1		10.4	9.25
Lead					
Zinc		89		90	10
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 97

STP Category Filtering Practice

Facility McGregor Park

STP Type Organic Filter

State Texas **Country** USA

Drainage Class

Bibliographic Information

Lower Colorado River Authority. 1997. Innovative NPS Pollution Control Program for Lake Travis in Central Texas. LCRA.

Study Notes

No. of Storms 21

Treatment Volume/ Design Basis

Watershed in. 1.02

Impervious in.

Drainage Area ac

Slope %

Land Use large parking lot

% Impervious Cover 82

% Residential

% Commercial

% Industrial

Soil Type

STP Size Retention capacity: 1420 ft3 Filter surface area: 200 ft2 Filter bed depth: 3 ft

Age of Facility 0 yrs

STP Notes

Peat/sand filter media with surface ED.
Retrofit site
Steep slopes

Performance Notes

Inflow and Outflow untis for Zn are micrograms per liter

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS	90	88		49	6
TDS					
TP	73	47		0.185	0.098
DP					
PP					
Ortho-P		57		0.028	0.012
TN		51		1.76	0.858
ON					
NH4					
TKN	68	61		1.12	0.443
NO3					
NOx		-15		0.481	0.552
TOC	32	18		11.9	9.75
Lead	57				
Zinc	86	83		60	10
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 98

Facility Prototype

State Alabama **Country** USA

STP Category Filtering Practice

STP Type Organic Filter

Drainage Class

Bibliographic Information

Pitt, R. 1996. The Control of Toxicants at Critical Source Areas. The University of Alabama at Birmingham. 22 pp. (paper presented at the ASCE/Engineering Foundation Conference, August 1996 at Snowbird, Utah. Will be published by ASCE in 1997. Also in: Multi-Chamber Treatment Train Developed for Stormwater Hot Spots. Watershed Protection Techniques. Center for Watershed Protection. February 1997. Vol. 2(3): 445-449.

Study Notes

No. of Storms 13

Treatment Volume/ Design Basis

Treatment provided for 0.25- 0.8" of rain.

Watershed in.

Impervious in.

Drainage Area ac

Slope %

Land Use Parking lot, vehicle service area.

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility 0 yrs

STP Notes

Performance Notes

n-Nitro-di-n-propylamine= 100; bis(2-ethylhexy)phthalate)= 99; Conductivity= 11; pH= 7.9; color= -46; hexachlorobutane= 34. Original NH4 value= -400.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS		83			
TDS		32			
TP					
DP					
PP					
Ortho-P					
TN					
ON					
NH4		-100			
TKN					
NO3		14			
NOx					
COD					
Lead		100			
Zinc		91			
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity		40			
Toxicity (su		96			
Toxicity (dis		98			
Pyrene		100			

STP Pollutant Removal Database

Indices

Study #: 99

Facility Minocqua

State Wisconsin **Country** USA

STP Category Filtering Practice

STP Type Organic Filter

Drainage Class

Bibliographic Information

Pitt, R. 1997. Multi-Chamber Treatment Train Developed for Stormwater Hot Spots. Watershed Protection Techniques. Center for Watershed Protection. February 1997. Vol. 2(3): 445-449.

Study Notes

No. of Storms 7

Treatment Volume/ Design Basis

Watershed in.

Impervious in.

Drainage Area 2.5 **ac**

Slope **%**

Land Use Commercial parking lot.

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility **yrs**

STP Notes

Performance Notes

Pyrene= >75; Flouranthene= >90.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS		85			
TDS					
TP		80			
DP					
PP					
Ortho-P					
TN					
ON					
NH4					
TKN					
NO3					
NOx					
Organic					
Lead					
Zinc		90			
Copper		65			
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 100

Facility W & H Pacific

State Washington **Country** USA

STP Category Filtering Practice

STP Type Organic Filter

Drainage Class

Bibliographic Information

Stewart, W. 1992. Compost Stormwater Treatment System. W&H Pacific Consultants. Draft Report. Portland, OR. Also in: Innovative Leaf Compost System Used to Filter Runoff at Small Sites in the Northwest. Watershed Protection Techniques. Center for Watershed Protection. February 1994. Vol. 1(1): 13-14.

Study Notes

No. of Storms 7

Treatment Volume/ Design Basis

200 sf/cfs. 0.1 watershed inches.

Watershed in. 0.1

Impervious in.

Drainage Area 73.9 **ac**

Slope **%**

Land Use Mixed residential= 70 acres. Roadway= 3.9

% Impervious Cover

% Residential 95

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility **yrs**

STP Notes

Compost filter media.

Performance Notes

Pb, Cd= not detected. Excellent removal of sediment, particulate nutrients, organic carbon, hydrocarbons and some heavy metals. System does export soluble nutrients. Most effective during first flush and small storms. DP, B, Ca, K, Mg, Na= originally an unspecified negative value (represented here as -25).

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS		95		39.95	4.47
TDS		-31		108.08	141.2
TP		41		1.31	0.48
DP		-25		0.13	0.48
PP					
Ortho-P					
TN					
ON		56			
NH4					
TKN					
NO3		-34		0.3	0.4
NOx					
COD					
Lead					
Zinc		88		188.73	22.04
Copper		67		29.19	9.73
Cadmium					
Chromium		61		12.77	4.95
Iron					
TPH		87			
Oil/Grease					
Bacteria					
Turbidity					
Ca		-25		16.99	16.41
K		-25		2.73	5.95
Na		-25		4.65	4.13

STP Pollutant Removal Database

Indices

Study #: 101

STP Category Filtering Practice

Facility National Airport

STP Type Sand Filter (P)

State Virginia **Country** USA

Drainage Class

Bibliographic Information

Bell, W., L. Stokes, L.J. Gavan and T.N. Nguyen. 1995. Assessment of the Pollutant Removal Efficiencies of Delaware Sand Filter BMPs. Final Report. Department of Transportation and Environmental Services. Alexandria, VA. 140 p. Also in: Performance of Delaware Sand Filter Assessed. Watershed Protection Techniques. Center for Watershed Protection. Fall 1995. Vol. 2(1): 291-293.

Study Notes

No. of Storms 20

Treatment Volume/ Design Basis

Watershed in. 0.19

Impervious in.

Drainage Area 0.7 **ac**

Slope **%**

Land Use Parking lot.

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size 95' length. Filter bed area= 238 square feet. Volume: 477.6 ft3

Age of Facility 2 **yrs**

STP Notes

Perimeter sand filter.

Performance Notes

TP and ortho-P Removal rates higher when four anaerobic events are excluded. Data represents an average of a range for some parameters. TPH= not detected. Inflow and Outflow units for Zn in micrograms per liter.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS	79			76.2	16.84
TDS					
TP	65.5			0.52	0.18
DP					
PP					
Ortho-P	68			0.33	0.09
TN	47			7.93	3.8
ON				4.57	0.39
NH4				1.98	1.35
TKN	70.6			6.55	1.74
NO3	-53.3			1.27	1.99
NOx					
TOC	66			36.37	11.95
Lead					
Zinc	91			130	20
Copper	25				
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					
BOD5	78			35.08	9.51

STP Pollutant Removal Database

Indices

Study #: 102

Facility AML-6

State Washington **Country** USA

STP Category Filtering Practice

STP Type Sand Filter (P)

Drainage Class

Bibliographic Information

Horner, R.R., and C.R. Horner. 1995. Design, Construction and Evaluation of a Sand Filter Stormwater Treatment System. Part II. Performance Monitoring. Report to Alaska Marine Lines, Seattle, WA. 38 p. Also in: Performance of Delaware Sand Filter Assessed. Watershed Protection Techniques. Center for Watershed Protection. Fall 1995. Vol. 2(1): 291-293.

Study Notes

No. of Storms 6

Treatment Volume/ Design Basis

Watershed in. 1.23

Impervious in.

Drainage Area 1.5 **ac**

Slope 1 **%**

Land Use Marine industrial parking lot.

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size 540 sq. ft. area.

Age of Facility **yrs**

STP Notes

Perimeter sand filter.

Performance Notes

Poor removal TSS due to very low inflow concentrations (4-24 mg/L). Data is based on 3 real storms and 3 artifical. Mean efficiency was computed for each storm basis for overall efficiency. Inflow and Outflow units for metals are micrograms per liter.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS		8		16.1	10.3
TDS					
TP		20		0.08	0.06
DP					
PP					
Ortho-P					
TN					
ON					
NH4					
TKN					
NO3					
NOx					
Organic					
Lead					
Zinc		69		81	21
Copper		31		31	18
Cadmium					
Chromium					
Iron					
TPH		55			
Oil/Grease		69			
Bacteria					
Turbidity		-81		10.5	16.3

STP Pollutant Removal Database

Indices

Study #: 103

STP Category Filtering Practice

Facility AML-3

STP Type Sand Filter (P)

State Washington **Country** USA

Drainage Class

Bibliographic Information

Horner, R.R., and C.R. Horner. 1995. Design, Construction and Evaluation of a Sand Filter Stormwater Treatment System. Part II. Performance Monitoring. Report to Alaska Marine Lines, Seattle, WA. 38 p. Also in: Performance of Delaware Sand Filter Assessed. Watershed Protection Techniques. Center for Watershed Protection. Fall 1995. Vol. 2(1): 291-293.

Study Notes

No. of Storms 14

Treatment Volume/ Design Basis

Watershed in. 1.23

Impervious in.

Drainage Area 0.64 **ac**

Slope 1 **%**

Land Use Marine industrial/ parking lot

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size Length: 190 ft
Width: 2.33 ft
Depth: 1.5 ft 2
Chambers

Age of Facility **yrs**

STP Notes

Perimeter sand filter.
Length: 165 ft
Width: 4.75 ft
Depth: 1.5 ft 2
Chambers

Performance Notes

Concentration data is mean. Data is based on 6 real storms and 8 artifical. Inflow and Outflow units for metals are micrograms per liter.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS		83		97.2	11.8
TDS					
TP		41		0.123	0.065
DP					
PP					
Ortho-P					
TN					
ON					
NH4					
TKN					
NO3					
NOx					
TOC					
Lead					
Zinc		33		267	80
Copper		22		69	79
Cadmium					
Chromium					
Iron					
TPH		84			
Oil/Grease		84			
Bacteria					
Turbidity		17		53.8	26.5

STP Pollutant Removal Database

Indices

Study #: 104

STP Category Filtering Practice

Facility Seton Pond

STP Type Sand Filter (S)

State Texas **Country** USA

Drainage Class

Bibliographic Information

Barrett, M.; M. Keblin; J. Malina; R. Charbeneau. 1998. Evaluation of the Performance of Permanent Runoff Controls: Summary and Conclusions. Center for Transportation Research. Texas Department of Transportation. University of Texas. Austin, TX.

Study Notes

No. of Storms 10

Treatment Volume/ Design Basis

fist 0.5 in. of runoff

Watershed in.

Impervious in.

Drainage Area 82.95 **ac**

Slope **%**

Land Use 67% highway

% Impervious Cover

% Residential

% Commercial 33

% Industrial

Soil Type

STP Size

Age of Facility 1 **yrs**

STP Notes

Performance Notes

Other represents the removal efficiencies including bypass. 20% of total flow bypassed the system.
Inflow and Outflow units for metals are micrograms per liter.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS	98		79	204	3.5
TDS					
TP	66		53	0.356	0.126
DP					
PP					
Ortho-P					
TN				2.83	1.065
ON					
NH4					
TKN	65		52	1.59	0.591
NO3	64		51	1.24	0.474
NOx					
COD	88		71	90.6	11
Lead					
Zinc	94		76	143	8
Copper					
Cadmium					
Chromium					
Iron	95		76	3250	175
TPH					
Oil/Grease					
Bacteria					
Turbidity	92		73	53	4.6
TOC	62		50	32	12.6

STP Pollutant Removal Database

Indices

Study #: 105

Facility Joleyville

State Texas **Country** USA

STP Category Filtering Practice

STP Type Sand Filter (S)

Drainage Class

Bibliographic Information

City of Austin, TX. 1990. Removal Efficiencies of Stormwater Control Structures. Final Report. Environmental Resource Management Division. 36 p. Also in: Developments in Sand Filter Technology to Improve Stormwater Runoff Quality. Watershed Protection Techniques. Center for Watershed Protection. Summer 1994. Vol. 1(2): 47-54.

Study Notes

No. of Storms 16

Treatment Volume/ Design Basis

Watershed in.

Impervious in.

Drainage Area 9.5 **ac**

Slope **%**

Land Use Road

% Impervious Cover 81

% Residential

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility **yrs**

STP Notes
Surface sand filter.

Performance Notes
Data represents an average of a range.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS	87				
TDS	31				
TP	61				
DP					
PP					
Ortho-P					
TN	32				
ON					
NH4	77				
TKN	62				
NO3	-79				
NOx					
TOC	57				
Lead	81				
Zinc	80				
Copper	60				
Cadmium					
Chromium					
Iron	86				
TPH					
Oil/Grease					
Fecal coliform	37				
Turbidity					
BOD5	52				
Streptococc	65				

STP Pollutant Removal Database

Indices

Study #: 106

STP Category Filtering Practice

Facility Brodie Oaks

STP Type Sand Filter (S)

State Texas **Country** USA

Drainage Class

Bibliographic Information

City of Austin, TX. 1990. Removal Efficiencies of Stormwater Control Structures. Final Report. Environmental Resource Management Division. 36 p. Also in: Developments in Sand Filter Technology to Improve Stormwater Runoff Quality. Watershed Protection Techniques. Center for Watershed Protection. Summer 1994. Vol. 1(2): 47-54.

Study Notes

No. of Storms 17

Treatment Volume/ Design Basis

1.7 inches.

Watershed in. 1.7

Impervious in.

Drainage Area 50 **ac**

Slope **%**

Land Use

% Impervious Cover 68

% Residential

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility **yrs**

STP Notes

Surface sand filter.

Performance Notes

Data represents an average of a range for some parameters

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS	92				43
TDS	46				
TP	80				0.145
DP					
PP					
Ortho-P					
TN	71				1.7
ON					
NH4	94				
TKN	90				0.7
NO3	23				1
NOx					
Organic	85				
Lead	89				
Zinc	91				
Copper	84				
Cadmium					
Chromium					
Iron	84				
TPH					
Oil/Grease					
Fecal coliform	83				
Turbidity					
BOD5	77				7.5
TOC	93				
Streptococc	81				

STP Pollutant Removal Database

Indices

Study #: 107

STP Category Filtering Practice

Facility Barton Creek

STP Type Sand Filter (S)

State Texas **Country** USA

Drainage Class

Bibliographic Information

City of Austin, TX. 1990. Removal Efficiencies of Stormwater Control Structures. Final Report. Environmental Resource Management Division. 36 p. Also in: Developments in Sand Filter Technology to Improve Stormwater Runoff Quality. Watershed Protection Techniques. Center for Watershed Protection. Summer 1994. Vol. 1(2): 47-54.

Study Notes

No. of Storms 18

Treatment Volume/ Design Basis

0.5 inch

Watershed in. 0.5

Impervious in.

Drainage Area 79 **ac**

Slope **%**

Land Use Mall 86%

% Impervious Cover

% Residential

% Commercial 86

% Industrial

Soil Type

STP Size Volume= 3.5 acre/ft

Age of Facility **yrs**

STP Notes

Surface sand filter.

Performance Notes

Organic = COD/BOD or TOC. Data represents an average of a range for some parameters.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS	75				
TDS	1				
TP	59				
DP					
PP					
Ortho-P					
TN	44				
ON					
NH4	43				
TKN	64				
NO3	-13				
NOx					
Organic	44				
Lead	88				
Zinc	82				
Copper	34				
Cadmium					
Chromium					
Iron	67				
TPH					
Oil/Grease					
Fecal coliform	36				
Turbidity					
BOD5	39				
TOC	49				
Streptococc	25				

STP Pollutant Removal Database

Indices

Study #: 108

Facility Highwood

State Texas **Country** USA

STP Category Filtering Practice

STP Type Sand Filter (S)

Drainage Class

Bibliographic Information

City of Austin, TX. 1990. Removal Efficiencies of Stormwater Control Structures. Final Report. Environmental Resource Management Division. 36 p. Also in: Developments in Sand Filter Technology to Improve Stormwater Runoff Quality. Watershed Protection Techniques. Center for Watershed Protection. Summer 1994. Vol. 1(2): 47-54.

Study Notes

No. of Storms 18

Treatment Volume/ Design Basis

0.5 inch

Watershed in. 0.5

Impervious in.

Drainage Area 3.1 **ac**

Slope **%**

Land Use Multi-family housing.

% Impervious Cover 50

% Residential

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility **yrs**

STP Notes

Surface sand filter.

Performance Notes

Organic = COD/BOD or TOC. Layer of grass covering. Data represents an average of a range for some parameters.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS	86				
TDS	35				
TP	19				
DP					
PP					
Ortho-P					
TN	31				
ON					
NH4	59				
TKN	48				
NO3	-5				
NOx					
Organic	41				
Lead	71				
Zinc	49				
Copper	33				
Cadmium					
Chromium					
Iron	63				
TPH					
Oil/Grease					
Fecal coliform	37				
Turbidity					
BOD5	29				
TOC	53				
Streptococc	50				

STP Pollutant Removal Database

Indices

Study #: 109

Facility Barton Ridge Plaza

State Texas **Country** USA

STP Category Filtering Practice

STP Type Sand Filter (S)

Drainage Class

Bibliographic Information

City of Austin, TX. 1996. Evaluation of Non-point Source Controls; a 319 Grant Project. Final Report. Water Quality Report Series. COA-ERM-1996-03.

Study Notes

No. of Storms 8

Treatment Volume/ Design Basis

Watershed in. 0.65

Impervious in. 0.8

Drainage Area 2.95 **ac**

Slope **%**

Land Use 15.78% lawn

% Impervious Cover 81.42

% Residential

% Commercial 100

% Industrial

Soil Type

STP Size Volume of Sedimentation Pond: 7000 ft3
Sand Bed Area: 390 ft2

Age of Facility **yrs**

STP Notes

Performance Notes

Inflow and Outflow units for Fe. Col. and Fe. Strep. are colonies per 100 mL. Inflow and Outflow units for metals are micrograms per liter.
Removal rates drop by about 20% if the untreated stormwater bypass is factored in.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS		89		273	32
TDS					
TP		59		0.37	0.11
DP		3		0.14	0.09
PP					
Ortho-P					
TN		17		2.43	1.83
ON				2.05	1.03
NH4				0.29	0.14
TKN		50		1.76	0.89
NO3					
NOx		-76		0.67	0.96
BOD		51		12.7	4.7
Lead		86		16.9	2.31
Zinc		76		92.5	22.6
Copper		72		10.2	2.9
Cadmium		44		0.87	0.49
Chromium					
Iron					
TPH					
Oil/Grease					
Fecal coliform		-85		5695	18528
Turbidity					
COD		55		77	25
TOC		-4		7	7
Streptococc		69		12576	2573

STP Pollutant Removal Database

Indices

Study #: 110

Facility AML-6

State Florida **Country** USA

STP Category Filtering Practice

STP Type Sand Filter (S)

Drainage Class

Bibliographic Information

Harper, H. and J. Herr. 1993. Treatment Efficiency of Detention With Filtration Systems. Environmental Research and Design, Inc. Final Report Submitted to Florida Department of Environmental Regulation. Orlando, FL 164 p.

Study Notes

No. of Storms 33

Treatment Volume/ Design Basis

Watershed in.

Impervious in.

Drainage Area ac

Slope %

Land Use

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility yrs

STP Notes

Surface sand filter.

Performance Notes

Organic= COD/BOD or TOC. Majority of removal occurs within wet pond and not the filter media. Poor N removal due to trapping of organic N in filter media. Does not reccommend filters with ponds.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS	98				
TDS					
TP	61				
DP	-37				
PP					
Ortho-P					
TN					
ON	0				
NH4					
TKN					
NO3	27				
NOx					
Organic	99				
Lead	71				
Zinc	89				
Copper	37				
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 111

STP Category Filtering Practice

Facility Barton Creek Square

STP Type Sand Filter (S)

State Texas **Country** USA

Drainage Class

Bibliographic Information

Welborn, C. and J. Veenhuis. 1987. Effects of Runoff Controls on the Quantity and Quality of Urban Runoff in Two Locations in Austin, TX. USGS Water Resources Investigations Report. 87-4004. 88 p.

Study Notes

No. of Storms 22

Treatment Volume/ Design Basis

Watershed in.

Impervious in.

Drainage Area 80 **ac**

Slope **%**

Land Use Commercial

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility **yrs**

STP Notes
Surface sand filter.

Performance Notes
Original NO3 value= -111.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS	78				
TDS	-13				
TP	27				
DP					
PP					
Ortho-P					
TN	27				
ON					
NH4					
TKN	57				
NO3	-100				
NOx					
BOD	76				
Lead	33				
Zinc	60				
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Fecal coliform	81				
Turbidity					
TOC	60				
COD	62				

STP Pollutant Removal Database

Indices

Study #: 112

STP Category Filtering Practice

Facility Sand Filter #6

STP Type Sand Filter (V)

State Texas **Country** USA

Drainage Class

Bibliographic Information

Barton Springs/Edwards Aquifer Conservation District. 1996. Final Report: Enhanced Roadway Runoff Best Management Practices. City of Austin, Drainage Utility, LCRA, TDOT. Austin, TX. 200 p.

Study Notes

No. of Storms 8

Treatment Volume/ Design Basis

WQV= 0.61"

Watershed in. 0.61

Impervious in. 1.04

Drainage Area 4.93 **ac**

Slope **%**

Land Use Highway

% Impervious Cover 58.5

% Residential

% Commercial

% Industrial

Soil Type

STP Size Length of Pond: 99 ft
Width of Pond: 55 ft
Volume of Haz Mat Trap: 1407 ft3 Filtration Area: 90 ft2

Age of Facility **yrs**

STP Notes

Vertical filter of 36" limestone and gabion, preceded by filtration pond.

Performance Notes

Efficiency calculation= paired EMC. Inlfow and Outflow units for metals are micrograms per liter.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS		55		449	112
TDS					
TP		45		0.4	0.14
DP					
PP					
Ortho-P		21		0.062	0.043
TN		15		1.84	1.32
ON					
NH4					
TKN		35		1.46	0.76
NO3					
NOx		-87		0.38	0.56
COD		10		46	42
Lead		60		23	9
Zinc		48		50	24
Copper					
Cadmium				10	10
Chromium				44	30
Iron		36		12.29	4.83
TPH					
Oil/Grease					
Bacteria					
Turbidity					
TOC		9		8.6	8.1

STP Pollutant Removal Database

Indices

Study #: 113

STP Category Filtering Practice

Facility Danz Creek Control N

STP Type Sand Filter (V)

State Texas **Country** USA

Drainage Class

Bibliographic Information

Tenney, S.; M. Barrett; J. Malina; R. Charbeneau; and G. Ward. 1995. An Evaluation of Highway Runoff Filtration Systems. Center for Research in Water Resources. University of Texas at Austin.

Study Notes

No. of Storms 10

Treatment Volume/ Design Basis

Watershed in. 0.61

Impervious in.

Drainage Area 5.21 **ac**

Slope **%**

Land Use highway and grass

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size Vol. of Haz. Mat. Trap: 1980 ft3 Detention Pond Volume: 9534.96 ft3 Filter Width: 18.04 ft Filter Thickness:

Age of Facility 1 **yrs**

STP Notes

Performance Notes

Sources of organic carbon may be due to the decay of leaf litter trapped in the sedimentation basin. Inflow and Outflow units for all metals are micrograms per liter.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS	60				36
TDS					
TP					
DP					
PP					
Ortho-P					
TN					
ON					
NH4					
TKN					
NO3					
NOx					
TOC	-48				7.5
Lead					
Zinc	63				15.5
Copper	32				5.5
Cadmium					
Chromium	-28				
Iron	23				1803
TPH					
Oil/Grease					
Bacteria					
Turbidity					
DOC	-100				2.7
BOD	26				
COD	1				19

STP Pollutant Removal Database

Indices

Study #: 114

STP Category Open Channel Practice

Facility

STP Type Ditch

State Virginia **Country** USA

Drainage Class

Bibliographic Information

Dorman, M.E., J. Hartigan, R.F. Steg and T. Quasebarth. 1989. Retention, Detention and Overland Flow for Pollutant Removal From Highway Stormwater Runoff. Vol. 1. Research Report. Federal Highway Administration. FHWA/RD 89/202. 179 p. Also in: Performance of Grassed Swales Along East Coast Highways. Watershed Protection Techniques. Center for Watershed Protection. Fall 1994. Vol. 1(3): 122-123.

Study Notes

No. of Storms 9

Treatment Volume/ Design Basis

2 year erosive velocity. 10 year capacity.

Watershed in.

Impervious in.

Drainage Area 1.27 **ac**

Slope 4.7 **%**

Land Use Highway.

% Impervious Cover 67

% Residential

% Commercial

% Industrial

Soil Type Silt loam

STP Size Length 185'

Age of Facility **yrs**

STP Notes

20 year old facility. Moderate erosion. Poor vegetative cover.

Performance Notes

Mass efficiency removal rate assumes inflow equals outflow. Data represents an average of a range for some parameters. Metal removal was a function of TSS removal. Inflow and Outflow units for metals are micrograms per liter.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS	65			200.5	52.5
TDS					
TP	41			0.444	0.355
DP					
PP					
Ortho-P					
TN				2.91	2.74
ON					
NH4					
TKN	17			2.08	1.74
NO3					
NOx	11			0.831	1
TOC	76			17.7	18.2
Lead	48			132	119
Zinc	49			80	58.5
Copper	28			16	18
Cadmium	55				
Chromium	14				
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 115

STP Category Open Channel Practice

Facility

STP Type Ditch

State New Hampshire **Country** USA

Drainage Class

Bibliographic Information

Oakland, P.H. 1983. An Evaluation of Stormwater Pollutant Removal Through Grassed Swale Treatment. Proceedings of the International Symposium of Urban Hydrology, Hydraulics and Sediment Control. H. J. Sterling (Ed.). Lexington, KY. p. 173-182.

Study Notes

No. of Storms 11

Treatment Volume/ Design Basis

2 year erosive.

Watershed in.

Impervious in.

Drainage Area ac

Slope 2 %

Land Use Commercial

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type Clay-lined

STP Size Length 100'

Age of Facility yrs

STP Notes

Performance Notes

NO3, Bacteria= no statistical difference between inflow data and the outflow data at the 95% confidence interval was recorded. TP, DP= originally an unspecified negative value (represented here as -25). Data represents an average of a range for some parameters. Low grass area.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS		33			
TDS					
TP		-25			
DP		-25			
PP					
Ortho-P					
TN					
ON					
NH4					
TKN		28			
NO3					
NOx					
Organic		18			
Lead		57.5			
Zinc		50			
Copper		48			
Cadmium		20			
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria		0			
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 116

STP Category Open Channel Practice

Facility Dufief

STP Type Ditch

State Maryland **Country** USA

Drainage Class

Bibliographic Information

Occoquan Watershed Monitoring Laboratory. 1983. Final Report: Metropolitan Washington Urban Runoff Project. Prepared for the Metropolitan Washington Council of Governments. Manassas, VA. 460 p.

Study Notes

No. of Storms 8

Treatment Volume/ Design Basis

2 year erosive velocity. 10 year capacity.

Watershed in.

Impervious in.

Drainage Area 12 **ac**

Slope 5.1 **%**

Land Use Residential, large lot

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type Silt loam

STP Size Length 423'

Age of Facility **yrs**

STP Notes

Comparison to control sites.
NEG=negative value.

Performance Notes

Original Zn value= -173.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS		31			
TDS					
TP		-23			
DP					
PP					
Ortho-P					
TN		36.5			
ON					
NH4					
TKN					
NO3					
NOx					
TOC		17.8			
Lead		33			
Zinc		-100			
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 117

Facility Fairridge

State Maryland **Country** USA

STP Category Open Channel Practice

STP Type Ditch

Drainage Class

Bibliographic Information

Occoquan Watershed Monitoring Laboratory. 1983. Final Report: Metropolitan Washington Urban Runoff Project. Prepared for the Metropolitan Washington Council of Governments. Manassas, VA. 460 p.

Study Notes

No. of Storms 50

Treatment Volume/ Design Basis

2 year control velocity. 10 year capacity.

Watershed in.

Impervious in.

Drainage Area 19 **ac**

Slope 4.1 **%**

Land Use Residential, MSDF

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type Silt loam

STP Size Length 445'

Age of Facility **yrs**

STP Notes

Performance Notes

Significant fractions of P found in soluble forms. Removal method measured in comparison to control sites. Original Pb, Zn values = -328, -140 respectively.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS		-50			
TDS					
TP		-9.1			
DP					
PP					
Ortho-P					
TN		-18.2			
ON					
NH4					
TKN					
NO3					
NOx					
Organic		-48.1			
Lead		-100			
Zinc		-100			
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 118

Facility Stratton Woods

State Virginia **Country** USA

STP Category Open Channel Practice

STP Type Ditch

Drainage Class

Bibliographic Information

Occoquan Watershed Monitoring Laboratory. 1983. Final Report: Metropolitan Washington Urban Runoff Project. Prepared for the Metropolitan Washington Council of Governments. Manassas, VA. 460 p.

Study Notes

No. of Storms 33

Treatment Volume/ Design Basis

2 year erosive velocity. 10 year capacity.

Watershed in.

Impervious in.

Drainage Area 9.5 **ac**

Slope 1.8 **%**

Land Use Residential, large lot.

% Impervious Cover 22

% Residential

% Commercial

% Industrial

Soil Type Silt loam

STP Size Length 260'

Age of Facility **yrs**

STP Notes

Performance Notes

High metals export due to leaching of metals from culverts. Poor performance can be due to site and rainfall differences among two sites. Also lbs/ac/in of rainfall used to normalize comparisons, but this may not account for the role of small storms that fully infiltrate runoff "the large effect." Original TSS, TP, TN, TOC, Pb, Zn values = -153, -220, -187, -224, -

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS		-100			
TDS					
TP		-100			
DP					
PP					
Ortho-P					
TN		-100			
ON					
NH4					
TKN					
NO3					
NOx					
TOC		-100			
Lead		-100			
Zinc		-100			
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 119

STP Category Open Channel Practice

Facility

STP Type Ditch

State Ontario **Country** Canada

Drainage Class

Bibliographic Information

Pitt, R. and J. McLean.1986. Toronto Area Watershed Management Strategy Study: Humber River Pilot Watershed Project. Ontario Ministry of Environment.

Study Notes

No. of Storms 50

Treatment Volume/ Design Basis

Watershed in.

Impervious in.

Drainage Area ac

Slope %

Land Use

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility yrs

STP Notes

Performance Notes

Organic dry, Pb= 90. Organic wet*, Pb= 13. No change in pollutant concentration between drainage channels and curb/gutters, but 25% less annual runoff volume. Storms less than 0.5" produced little surface runoff. Much lower performance under snowmelt conditions. TSS, TN, Pb, Zn, Cu, Fecal coliform= no statistical difference between inflow data and the

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS		0			
TDS					
TP					
DP					
PP					
Ortho-P					
TN		0			
ON					
NH4					
TKN					
NO3					
NOx					
Organic					
Lead		0			
Zinc		0			
Copper		0			
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Fecal coliform		0			
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 120

STP Category Open Channel Practice

Facility US 183 Swale

STP Type Ditch

State Texas **Country** USA

Drainage Class

Bibliographic Information

Walsh, P.; M. Barrett; J. Malina; R. Charbeneau; and G. Ward. 1995. Use of Vegetative Controls for Treatment of Highway Runoff. Center for Research in Water Resources. Also in: Barrett, et al. Evaluation of the Performance of Permanent Runoff Controls: Summary and Conclusions. Center for Transporation Research. TX Dept. of Transportation. and Center for Watershed Protection. Watershed Protection Techniques 3(2)

Study Notes

No. of Storms 34

Treatment Volume/ Design Basis

Watershed in.

Impervious in.

Drainage Area 3.21 **ac**

Slope **%**

Land Use

% Impervious Cover 52

% Residential

% Commercial

% Industrial

Soil Type

STP Size Filter strip treatment length: 24.6 to 28.9 ft Width of entire median: 48.9 to 64 ft Centerline length: 1197.98

Age of Facility **yrs**

STP Notes

Performance Notes

Inflow and Outflow units for Fe. Col. and Fe. Strep. Are CFU/100mL. Inflow and Outflow units for turbidity are NTU. Inflow and Outflow units for metlas are micrograms per liter

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS	89	87		157	21
TDS					
TP	55	44		0.55	0.31
DP					
PP					
Ortho-P					
TN				3.62	1.92
ON					
NH4					
TKN	33	46		2.71	1.46
NO3	59	50		0.91	0.46
NOx					
TOC	60	51		33.9	16.7
Lead	52	41		138	82
Zinc	93	91		347	32
Copper					
Cadmium					
Chromium					
Iron	83	79		3330	
TPH					
Oil/Grease					
Fecal coliform	-100	-100		96000	3E+05
Turbidity	75	69		55	17
Fe. Strep.	-41	-74		23000	40000
COD	68	61		94	37

STP Pollutant Removal Database

Indices

Study #: 121

Facility Walnut Creek

State Texas **Country** USA

STP Category Open Channel Practice

STP Type Ditch

Drainage Class

Bibliographic Information

Walsh, P.; M. Barrett; J. Malina; R. Charbeneau; and G. Ward. 1995. Use of Vegetative Controls for Treatment of Highway Runoff. Center for Research in Water Resources. Also in: Barrett, et al. Evaluation of the Performance of Permanent Runoff Controls: Summary and Conclusions. Center for Transporation Research. TX Dept. of Transportation. and Center for Watershed Protection. Watershed Protection Techniques 3(2)

Study Notes

No. of Storms 34

Treatment Volume/ Design Basis

Watershed in.

Impervious in.

Drainage Area 25.84 **ac**

Slope **%**

Land Use mostly commercial and high density

% Impervious Cover 37

% Residential

% Commercial

% Industrial

Soil Type

STP Size Filter strip treatment length: 25.6 ft to 26.6 ft Width of entire median: 50.9 to 53.2 ft Centerline length: 3451.3 ft

Age of Facility **yrs**

STP Notes

Performance Notes

Inflow and Outflow units for Fe. Col. and Fe. Strep. Are CFU/100mL. Inflow and Outflow units for turbidity are NTU. Inflow and Outflow units for metals are micrograms per liter

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS	87	85		190	29
TDS					
TP	45	34		0.24	0.16
DP					
PP					
Ortho-P					
TN		38		3.88	2.42
ON					
NH4					
TKN	54	44		2.61	1.45
NO3	36	23		1.27	0.97
NOx					
TOC	61	53		41.3	19.5
Lead	31	17		93	77
Zinc	79	75		129	32
Copper					
Cadmium					
Chromium					
Iron	79	75		2040	510
TPH					
Oil/Grease					
Fecal coliform					2E+05
Turbidity	81	78		70	16
Fecal Strep.	-100	-100		7100	41000
COD	69	63		109	41

STP Pollutant Removal Database

Indices

Study #: 122

STP Category Open Channel Practice

Facility Alta Vista

STP Type Ditch

State Texas **Country** USA

Drainage Class

Bibliographic Information

Welborn, C. and J. Veenhuis. 1987. Effects of Runoff Controls on the Quantity and Quality of Urban Runoff in Two Locations in Austin, TX. USGS Water Resources Investigations Report. 87-4004. 88 p.

Study Notes

No. of Storms 19

Treatment Volume/ Design Basis

Watershed in.

Impervious in.

Drainage Area 2.88 **ac**

Slope **%**

Land Use Townhouses.

% Impervious Cover 62

% Residential

% Commercial

% Industrial

Soil Type

STP Size Length Approximately 200'.

Age of Facility **yrs**

STP Notes

Performance Notes

TP, DP, TN, NO3, TOC= originally an unspecified negative value (represented here as -25). TSS, Pb, Zn, Cu= no statistical difference between inflow data and the outflow data at the 95% confidence interval was recorded. Fecal coliform= not detected.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS		0			
TDS					
TP		-25			
DP		-25			
PP					
Ortho-P					
TN		-25			
ON					
NH4					
TKN					
NO3		-25			
NOx					
TOC		-25			
Lead		0			
Zinc		0			
Copper		0			
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Fecal coliform					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 123

STP Category Open Channel Practice

Facility

STP Type Dry Swale

State Florida **Country** USA

Drainage Class

Bibliographic Information

Dorman, M.E., J. Hartigan, R.F. Steg and T. Quasebarth. 1989. Retention, Detention and Overland Flow for Pollutant Removal From Highway Stormwater Runoff. Vol. 1. Research Report. Federal Highway Administration. FHWA/RD 89/202. 179 p. Also in: Performance of Grassed Swales Along East Coast Highways. Watershed Protection Techniques. Center for Watershed Protection. Fall 1994. Vol. 1(3): 122-123.

Study Notes

No. of Storms 8

Treatment Volume/ Design Basis

2 year critical velocity.

Watershed in.

Impervious in.

Drainage Area 0.56 **ac**

Slope 1 **%**

Land Use Highway.

% Impervious Cover 63

% Residential

% Commercial

% Industrial

Soil Type Sandy

STP Size Length 185'

Age of Facility 5 **yrs**

STP Notes

Performance Notes

Good cover, no erosion. Mass efficiency removal rate calculation assumes inflow= outflow. Data represents an average of a range for some parameters. Practice acts like a dry swale. Inflow and Outflow units for metals are micrograms per liter.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS	98			50	4
TDS					
TP	18			0.218	0.304
DP					
PP					
Ortho-P					
TN				1.38	1.09
ON					
NH4					
TKN	48			0.83	0.74
NO3					
NOx	45			0.549	0.347
TOC				11.6	7
Lead	80.5				
Zinc	81			121.5	34
Copper	64.5			14	9.35
Cadmium	37			7.9	9.8
Chromium	56			6.6	5.6
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 124

STP Category Open Channel Practice

Facility I-4 Dry Swale

STP Type Dry Swale

State Florida **Country** USA

Drainage Class

Bibliographic Information

Harper, H. 1988. Effects of Stormwater Management Systems on Groundwater Quality. Final Report. Environmental Research and Design, Inc. Prepared for Florida Department of Environmental Regulation. 460 p. Also in: Runoff and Groundwater Dynamics of Two Swales in Florida. Watershed Protection Techniques. Center for Watershed Protection. Fall 1994. Vol. 1(3): 120-121.

Study Notes

No. of Storms 16

Treatment Volume/ Design Basis

2 year erosive velocity. 10 year capacity.

Watershed in.

Impervious in.

Drainage Area 0.83 **ac**

Slope 0.7 **%**

Land Use Interstate highway. 70% impervious.

% Impervious Cover 70

% Residential

% Commercial

% Industrial

Soil Type Sandy <5% silt/clay

STP Size Length 210'. Sideslopes= 6:1 (h:v).

Age of Facility **yrs**

STP Notes

Infiltration rate= 13.4 inch/hour. Time of concentration= 45 minutes. Swale age= 16 years.

Performance Notes

BOD value refers to 5 day average. Concentration values in mg/L, excluding metals which are in ug/L.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS	87				28
TDS					91
TP	83				0.5
DP					
PP					
Ortho-P	70				0.24
TN	84				1.7
ON	86				1.35
NH4	78				0.15
TKN					1.2
NO3	80				0.5
NOx					
TOC	69				
Lead	90				705
Zinc	90				140
Copper	89				36
Cadmium	89				4
Chromium	88				8
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					
Ni	88				11
Chlorides					8

STP Pollutant Removal Database

Indices

Study #: 125

Facility

State Florida **Country** USA

STP Category Open Channel Practice

STP Type Dry Swale

Drainage Class

Bibliographic Information

Kercher, W.C., J.C. Landon and R. Massarelli. 1983. Grassy Swales Prove Cost-Effective for Water Pollution Control. Public Works. Vol. 16: 53-55.

Study Notes

No. of Storms 13

Treatment Volume/ Design Basis

Watershed in.

Impervious in.

Drainage Area 14 **ac**

Slope 2 **%**

Land Use Residential

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type Sandy

STP Size

Age of Facility **yrs**

STP Notes

Performance Notes

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS	99				
TDS					
TP	99				
DP					
PP					
Ortho-P					
TN	99				
ON					
NH4					
TKN					
NO3	99				
NOx					
TOC	99				
Lead	99				
Zinc	99				
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 126

STP Category Open Channel Practice

Facility

STP Type Dry Swale

State Washington **Country** USA

Drainage Class

Bibliographic Information

Wang, T., D. Spyridakis, B. Mar and R. Horner. 1981. Transport, Deposition and Control of Heavy Metals in Highway Runoff. FHWA-WA-RD-39-10. Department of Civil Engineering. University of Washington. Seattle, WA.

Study Notes

No. of Storms

Treatment Volume/ Design Basis

Watershed in.

Impervious in.

Drainage Area ac

Slope %

Land Use

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size Length 200'

Age of Facility yrs

STP Notes

Performance Notes

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS	80				
TDS					
TP					
DP					
PP					
Ortho-P					
TN					
ON					
NH4					
TKN					
NO3					
NOx					
Organic					
Lead	80				
Zinc	60				
Copper	70				
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 127

Facility Dayton Avenue

State Washington **Country** USA

STP Category Open Channel Practice

STP Type Grass Channel

Drainage Class

Bibliographic Information

Goldberg. 1993. Dayton Avenue Swale Biofiltration Study. Seattle Engineering Department. Seattle, WA. 36 p.

Study Notes

No. of Storms 8

Treatment Volume/ Design Basis

Watershed in.

Impervious in.

Drainage Area 90 **ac**

Slope 1 **%**

Land Use

% Impervious Cover 20

% Residential

% Commercial

% Industrial

Soil Type Upper 3" made soil

STP Size 600' long designed grass channel (parabolic, water quality channel 5').

Age of Facility **yrs**

STP Notes

Performance Notes

Data set was adjusted by applying Bootstrap method to censored data technique (change in concentration). Biologically active P= 31.9; Oil/Grease= ND. Original Fecal coliform value= -264. Fe. Col. Inflow and Outflow units are org/100mL

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS		67.8		47	15.13
TDS					
TP		4.5		0.228	0.22
DP		35.3		0.136	0.087
PP					
Ortho-P		31.9		0.133	0.09
TN					
ON					
NH4					
TKN					
NO3					
NOx		31.4		1.24	0.85
Organic					
Lead		62.1		37	14.02
Zinc					
Copper		41.7		11	6.413
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Fecal coliform		-100		3725	13596
Turbidity		44.1		31	17.33
Al		60.9			
Dissolved C		20.9		6	4.746

STP Pollutant Removal Database

Indices

Study #: 128

Facility Mountlake Terrace-200

State Washington **Country** USA

STP Category Open Channel Practice

STP Type Grass Channel

Drainage Class

Bibliographic Information

Seattle Metro and Washington Department of Ecology. 1992. Biofiltration Swale Performance: Recommendations and Design Considerations. Publication No. 657. Water Pollution Control Department, Seattle Washington. 220 p. Also in: Watershed Protection Techniques. Center for Watershed Protection. Fall 1994. Vol. 1(3): 117-119.

Study Notes

No. of Storms 6

Treatment Volume/ Design Basis

grass channel design. 10 minute residence time for design storm.

Watershed in.

Impervious in.

Drainage Area 15.5 **ac**

Slope 4 **%**

Land Use Major roadway, residences, parks.

% Impervious Cover 47

% Residential

% Commercial

% Industrial

Soil Type Glacial till.

STP Size Length 200'. 5' bottom width. Sideslopes= 3:1 (h:v)

Age of Facility **yrs**

STP Notes

Mowed twice a year.

Performance Notes

Quickly saturated soil prevents pollutant loss within channel by infiltration. NO3, Fecal coliform= originally an unspecified negative value (represented here as -25). Inflow and Outflow units for turbidity are NTU. Inflow and Outflow units for metals are micrograms per liter. Inflow and Ourflow units for Fe. Col. are CFU/100 ml

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS		83		94.67	14
TDS					
TP		29		0.2	0.14
DP		40		0.07	0.05
PP				0.13	0.09
Ortho-P					
TN					
ON					
NH4					
TKN					
NO3					
NOx		-25		0.35	0.77
Organic					
Lead		67		20	10
Zinc		73		11	
Copper		46		20	10
Cadmium					
Chromium					
Iron					
TPH		75		9.58	
Oil/Grease					
Fecal coliform		-25		3012.5	3970
Turbidity		65		19.48	5.95
Al		63		1040	310
Dissolved Z		30			

STP Pollutant Removal Database

Indices

Study #: 129

STP Category Open Channel Practice

Facility Mountlake Terrace-100

STP Type Grass Channel

State Washington **Country** USA

Drainage Class

Bibliographic Information

Seattle Metro and Washington Department of Ecology. 1992. Biofiltration Swale Performance: Recommendations and Design Considerations. Publication No. 657. Water Pollution Control Department, Seattle Washington. 220 p. Also in: Watershed Protection Techniques. Center for Watershed Protection. Fall 1994. Vol. 1(3): 117-119.

Study Notes

No. of Storms 6

Treatment Volume/ Design Basis

grass channel design. 5 minute residence time for design storm.

Watershed in.

Impervious in.

Drainage Area 15.5 **ac**

Slope 4 **%**

Land Use Major roadway, residences, parks.

% Impervious Cover 47

% Residential

% Commercial

% Industrial

Soil Type Glacial till.

STP Size Length 100'. 5' bottom width. Sideslopes= 3:1 (h/v)

Age of Facility **yrs**

STP Notes

Mowed twice per year.

Performance Notes

Quickly saturated soil prevents pollutant loss within channel by infiltration. P removal influenced by low inflow concentration. NO3, Bacteria, Dissolved Zn= originally an unspecified negative value (represented here as -25). Inflow and Outflow units for turbidity are NTU. Inflow and Outflow units for metals are micrograms per liter. Inflow and Ourflow units for Fe

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS		60		128	60
TDS					
TP		45		0.1	0.06
DP		72		0.05	0.02
PP				0.05	0.04
Ortho-P					
TN					
ON					
NH4					
TKN					
NO3					
NOx		-25		0.26	0.31
Organic					
Lead		15		20	10
Zinc		16		90	60
Copper		2		10	10
Cadmium					
Chromium					
Iron					
TPH		49			
Oil/Grease					
Fecal coliform		-25		136.67	10.75
Turbidity		60		33.05	
Al		16		1930	1690
Dissolved Z		-25			

STP Pollutant Removal Database

Indices

Study #: 130

STP Category Open Channel Practice

Facility

STP Type Wet Swale

State Florida **Country** USA

Drainage Class

Bibliographic Information

Harper, H.1988. Effects of Stormwater Management Systems on Groundwater Quality. Final Report. Environmental Research and Design, Inc. Prepared for Florida Department of Environmental Regulation. 460 p. Also in: Runoff and Groundwater Dynamics of Two Swales in Florida. Watershed Protection Techniques. Center for Watershed Protection. Fall 1994. Vol. 1(3): 120-121.

Study Notes

No. of Storms 11

Treatment Volume/ Design Basis

2 year critical velocity. 10 year capacity.

Watershed in.

Impervious in.

Drainage Area 1.17 **ac**

Slope 1.8 **%**

Land Use Interstate highway.

% Impervious Cover 100

% Residential

% Commercial

% Industrial

Soil Type Saturated sandy soil.

STP Size Length 210'. Sideslopes= 3:1 (h:v).

Age of Facility **yrs**

STP Notes

Groundwater depth= 0-2' above swale bottom. Time of concentration= 9 minutes. Swale age= 23 years.

Performance Notes

Negative removal of Chlorides (irreducible concentration). BOD value is for 5 day average. Concentration values in mg/L, excluding metals which are in ug/L.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS	81				6.4
TDS					114
TP	17				0.19
DP					
PP					
Ortho-P	-30				0.08
TN	40				0.96
ON	39				0.67
NH4	-11				0.1
TKN					0.77
NO3	52				0.19
NOx					
TOC	48				
Lead	50				112
Zinc	69				53
Copper	56				17
Cadmium	42				5
Chromium	37				8
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					
Ni	32				32
Chlorides					21

STP Pollutant Removal Database

Indices

Study #: 131

STP Category Open Channel Practice

Facility The Uplands

STP Type Wet Swale

State Washington **Country** USA

Drainage Class

Bibliographic Information

Koon, J. 1995. Evaluation of Water Quality Ponds and Swales in the Issaquah/East Lake Sammamish Basins. King County Surface Water Management and Washington Department of Ecology. Seattle, WA. 75 p.

Study Notes

No. of Storms 17

Treatment Volume/ Design Basis

Watershed in.

Impervious in.

Drainage Area 17 **ac**

Slope 1.1 **%**

Land Use Single family residential

% Impervious Cover

% Residential 100

% Commercial

% Industrial

Soil Type ND

STP Size Length= 350'; Base width= 6.8' trapezoidal shape.

Age of Facility **yrs**

STP Notes

grass channel with standing water and wetland vegetation.

Performance Notes

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS		67		30.3	10
TDS					
TP		39		0.13	0.08
DP		-45		0.04	0.058
PP					
Ortho-P		-31		0.06	0.079
TN					
ON					
NH4		16		0.352	0.296
TKN					
NO3					
NOx		9		0.345	0.314
Organic					
Lead		6		2.3	2.16
Zinc		-3		25	25.75
Copper		-35		6.6	8.9
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 132

STP Category Infiltration Practice

Facility Blacksburg/loam

STP Type Infiltration Trench

State Virginia **Country** USA

Drainage Class

Bibliographic Information

Kuo, C.Y., G.D. Boardman and K.T. Laptos. 1990. Phosphorous and Nitrogen Removal Efficiencies of Infiltration Trenches. Dept. of Civil Engineering. VA Polytechnic Institute and State University. Prepared for: No. VA Planning District Commission, Occoquan Technical Advisory Committee and VA State Water Control Board. 129 p.

Study Notes

No. of Storms

Treatment Volume/ Design Basis

Watershed in.

Impervious in.

Drainage Area ac

Slope %

Land Use

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type Loam

STP Size Soil= 4' length; 4' width; 4' depth. Stone in soil= 4' length; 2' width; 1' depth.

Age of Facility yrs

STP Notes

49.5 hours detention time.

Performance Notes

Concentration at inlet (top of trench) may have decreased/increasd within the top portion of the trench, however this reduction/increase may not yet be evident at the outflow (trench bottom) within the specified detention time. Concentration units in ppm. Test column.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS					
TDS					
TP		4.5		0.66	0.63
DP					
PP					
Ortho-P		70.6		0.17	0.05
TN		3.4		5.38	5.2
ON		-16.2		4.39	5.1
NH4		58.3		0.24	0.1
TKN		-12.3		4.63	5.2
NO3		100		0.75	0
NOx					
Organic					
Lead					
Zinc					
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 133

Facility Blacksburg/sand

State Virginia **Country** USA

STP Category Infiltration Practice

STP Type Infiltration Trench

Drainage Class

Bibliographic Information

Kuo, C.Y., G.D. Boardman and K.T. Laptos. 1990. Phosphorous and Nitrogen Removal Efficiencies of Infiltration Trenches. Dept. of Civil Engineering. VA Polytechnic Institute and State University. Prepared for: No. VA Planning District Commission, Occoquan Technical Advisory Committee and VA State Water Control Board. 129 p.

Study Notes

No. of Storms

Treatment Volume/ Design Basis

Watershed in.

Impervious in.

Drainage Area ac

Slope %

Land Use

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type Sandy

STP Size Soil= 4' length; 4' width; 4' depth. Stone in soil= 4' length; 2' width; 1' depth.

Age of Facility yrs

STP Notes

51.5 hours detention time.

Performance Notes

Concentration at inlet (top of trench) may have decreased/increasd within the top portion of the trench, however this reduction/increase may not yet be evident at the outflow (trench bottom) within the specified detention time. Concentration units in ppm. Test column.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS					
TDS					
TP		100		0.2	0
DP					
PP					
Ortho-P		100		0.2	0
TN		50.5		2.04	1.01
ON		69.6		1.48	0.45
NH4		83.3		0.06	0.01
TKN		70.1		1.54	0.46
NO3		82		0.5	0.09
NOx					
Organic					
Lead					
Zinc					
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 134

Facility Blacksburg/sandy loam

State Virginia **Country** USA

STP Category Infiltration Practice

STP Type Infiltration Trench

Drainage Class

Bibliographic Information

Kuo, C.Y., G.D. Boardman and K.T. Laptos. 1990. Phosphorous and Nitrogen Removal Efficiencies of Infiltration Trenches. Dept. of Civil Engineering. VA Polytechnic Institute and State University. Prepared for: No. VA Planning District Commission, Occoquan Technical Advisory Committee and VA State Water Control Board. 129 p.

Study Notes

No. of Storms

Treatment Volume/ Design Basis

Watershed in.

Impervious in.

Drainage Area ac

Slope %

Land Use

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type Sandy loam

STP Size Soil= 4' length; 4' width; 4' depth. Stone in soil= 4' length; 2' width; 1' depth.

Age of Facility yrs

STP Notes

47.75 hours detention time.

Performance Notes

Concentration at inlet (top of trench) may have decreased/increasd within the top portion of the trench, however this reduction/increase may not yet be evident at the outflow (trench bottom) within the specified detention time. Concentration units in ppm. Test column. Original NO3 value= -300.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS					
TDS					
TP		100		0.24	0
DP					
PP					
Ortho-P		100		0.22	0
TN		42.3		6.59	3.8
ON		100		5.17	0
NH4		100		0.47	0
TKN		100		5.64	0
NO3		-100		0.95	3.8
NOx					
Organic					
Lead					
Zinc					
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 135

STP Category Infiltration Practice

Facility Prince William

STP Type Porous Pavement

State Virginia **Country** USA

Drainage Class

Bibliographic Information

Schueler, T.R. 1987. Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs. Metropolitan Washington Council of Governments. Department of Environmental Programs. Also in: Weand, B., Grizzard, T. 1986. Interim Progress Report-Davis Ford Park-Urban BMP Demonstration Project. Occoquan Watershed Monitoring Laboratory-Department of Civil Engineering-Virginia Polytechnic Institute and State University.

Study Notes

No. of Storms 13

Treatment Volume/ Design Basis

Watershed in.

Impervious in.

Drainage Area ac

Slope %

Land Use

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size 0.553 acre

Age of Facility yrs

STP Notes

Performance Notes

Pollutant export measured at terminal underdrain and compared to runoff loads from adjacent porous pavemement. High removal capabilities exhibited.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS	82				
TDS					
TP	65				
DP					
PP					
Ortho-P					
TN	80				
ON					
NH4					
TKN					
NO3					
NOx					
Organic					
Lead					
Zinc					
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 136

Facility Rockville

State Maryland **Country** USA

STP Category Infiltration Practice

STP Type Porous Pavement

Drainage Class

Bibliographic Information

Schueler, T.R. 1987. Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs. Metropolitan Washington Council of Governments. Department of Environmental Programs.

Study Notes

No. of Storms

Treatment Volume/ Design Basis

Watershed in.

Impervious in.

Drainage Area ac

Slope %

Land Use

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size

Age of Facility yrs

STP Notes

Performance Notes

Pollutant export measured at terminal underdrain and compared to runoff loads from adjacent porous pavemement. High removal capabilities exhibited.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS	95				
TDS					
TP	65				
DP					
PP					
Ortho-P					
TN	85				
ON					
NH4					
TKN					
NO3					
NOx					
COD	82				
Lead	98				
Zinc	99				
Copper					
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					

STP Pollutant Removal Database

Indices

Study #: 137

Facility Cottage Lake Park - porous pavement

State Washington **Country** USA

STP Category Infiltration Practice

STP Type Porous Pavement

Drainage Class

Bibliographic Information

St. John, M. 1997. Effect of Road Shoulder Treatments on Highway Runoff Quality and Quantity. University of Washington.

Study Notes

No. of Storms 9

Treatment Volume/ Design Basis

Watershed in.

Impervious in.

Drainage Area ac

Slope %

Land Use

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size Asphalt void volume: 22%
Shoulder width: 10 ft
Shoulder length: 600 ft
Depth of porous pavement:

Age of Facility 0 **yrs**

STP Notes

Porous pavement based on the design developed by AZ DOT was applied to the shoulder of the NE Woodingville-Duvall Road. Runoff coefficient of porous pavement: 0.12

Performance Notes

Three shoulder treatments were applied to the same highway shoulder: gravel (see study #138), porous pavement, and conventional asphalt. Removal efficiencies were derived as a percentage of the load from the conventional asphalt shoulder. Outflow units for metals are micrograms per liter

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS			97		16.6
TDS					
TP			94		0.101
DP					
PP					
Ortho-P			10		0.006
TN					
ON					
NH4					
TKN					
NO3					
NOx					
COD			94		22.5
Lead					4.7
Zinc					38.7
Copper					4.8
Cadmium					
Chromium					
Iron					
TPH					
Oil/Grease					7.82
Bacteria					
Turbidity					11
BOD			84		6.72

STP Pollutant Removal Database

Indices

Study #: 138

Facility McDonald's

State Maryland **Country** USA

STP Category Other

STP Type Oil-Grit Separator

Drainage Class

Bibliographic Information

Shepp, D. 1995. A Performance Assessment of an Oil-Grit Separator in Suburban Maryland. Final Report prepared for the Maryland Department of the Environment. Metropolitan Washington Council of Governments. Washington, DC. 46 p.

Study Notes

No. of Storms 13

Treatment Volume/ Design Basis

0.1 watershed inch water quality volume.

Watershed in. 0.1

Impervious in.

Drainage Area 1.01 **ac**

Slope **%**

Land Use Commercial parking lot

% Impervious Cover

% Residential

% Commercial

% Industrial

Soil Type

STP Size 3 chamber unit

Age of Facility **yrs**

STP Notes

On-line system

Performance Notes

Efficiency was derived as an average median of the inflow and outflow. Outflow units are micrograms per liter.

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS		-7.5			48.3
TDS					
TP		-41			0.41
DP					
PP					
Ortho-P		40			0.05
TN					1.94
ON					1.63
NH4		20			0.11
TKN		-44			1.74
NO3					
NOx		47			0.2
TOC		-36			17.5
Lead		8.2			8
Zinc		17			174
Copper		-11			13
Cadmium		0			1.1
Chromium		-19			6.5
Iron					
TPH		-29			
Oil/Grease					
Bacteria					
Turbidity		-17			
Soluble Cu		3.5			40
Soluble Zn		21.1			71
Hg		20			1

STP Pollutant Removal Database

Indices

Study #: 139

Facility Badger Road Public Works Maintenance Yard

State WI **Country** USA

STP Category Other

STP Type Stormceptor

Drainage Class

Bibliographic Information

Waschbusch, R. 1999. Evaluation of the Effectiveness of an Urban Stormwater Treatment Unit in Madison, WI, 1996 - 97. USGS. Water Resources Investigations Report 99-4195. Also in Watershed Protection Techniques. Center for Watershed Protection. Spring 99. Vol. 3(1): 605-608.

Study Notes

No. of Storms 45

Treatment Volume/ Design Basis

Watershed in.

Impervious in.

Drainage Area 4.3 **ac**

Slope **%**

Land Use

% Impervious Cover 100

% Residential

% Commercial

% Industrial

Soil Type

STP Size 10' diameter, 10' deep Stormceptor model: STC 6000 Capacity of 6130 gallons

Age of Facility **yrs**

STP Notes

Performance Notes

Other represents the removal efficiencies including bypass. Inflow and Outflow units for metals are micrograms per liter

Pollutant Removal Data

Pollutant	% Mean Efficiency			Concentration	
	Mass	Conc.	Other	Inflow	Outflow
TSS		25	21		7.5
TDS		-21	-21		885
TP		19	17		0.023
DP		21	17		0.003
PP					
Ortho-P					
TN					
ON					
NH4		19	16		0.085
TKN					
NO3					
NOx		6	5		0.273
COD		21	20		13.5
Lead		28	24		1.9
Zinc		21	17		19
Copper		30	25		3
Cadmium		30	27		0.1
Chromium					2
Iron					
TPH					
Oil/Grease					
Bacteria					
Turbidity					
Cl		-27	-25		
BOD		16	14		5.75
TOC		2	2		4.4

Appendix B: Bibliography

BMP Category	BMP Type	Reference
Filtering Practice	Bioretention	Davis, A.; M. Shokouhian; H. Sharma; and C. Minami. 1998. Optimization of Bioretention Design for Water Quality and Hydrologic Characteristics. Department of Civil Engineering, University of Maryland, College Park.
Filtering Practice	Organic Filter	Corsi, S. and S. Greb. 1997. Demonstration project of Wisconsin Department of Natural Resources, United States Geological Survey and the City of Milwaukee. Personal communication with R. Pitt. 1997. In: Multi-Chamber Treatment Train Developed for Stormwater Hot Spots. Watershed Protection Techniques. Center for Watershed Protection. February 1997. 2(3): 445-449.
Filtering Practice	Organic Filter	Leif, W. 1999. Compost Stormwater Filter Evaluation. Snohomish County Public County Works. Everett, WA.
Filtering Practice	Organic Filter	Lower Colorado River Authority. 1997. Innovative NPS Pollution Control Program for Lake Travis in Central Texas. LCRA.
Filtering Practice	Organic Filter	Lower Colorado River Authority. 1997. Innovative NPS Pollution Control Program for Lake Travis in Central Texas. LCRA.
Filtering Practice	Organic Filter	Pitt, R. 1996. The Control of Toxicants at Critical Source Areas. The University of Alabama at Birmingham. 22 pp. (paper presented at the ASCE/Engineering Foundation Conference, August 1996 at Snowbird, Utah. Will be published by ASCE in 1997. Also in: Multi-Chamber Treatment Train Developed for Stormwater Hot Spots. Watershed Protection Techniques. Center for Watershed Protection. February 1997. Vol. 2(3): 445-449.
Filtering Practice	Organic Filter	Pitt, R. 1997. Multi-Chamber Treatment Train Developed for Stormwater Hot Spots. Watershed Protection Techniques. Center for Watershed Protection. February 1997. Vol. 2(3): 445-449.

BMP Category	BMP Type	Reference
Filtering Practice	Organic Filter	Stewart, W. 1992. Compost Stormwater Treatment System. W&H Pacific Consultants. Draft Report. Portland, OR. Also in: Innovative Leaf Compost System Used to Filter Runoff at Small Sites in the Northwest. Watershed Protection Techniques. Center for Watershed Protection. February 1994. Vol. 1(1): 13-14.
Filtering Practice	Sand Filter (P)	Bell, W., L. Stokes, L.J. Gavan and T.N. Nguyen. 1995. Assessment of the Pollutant Removal Efficiencies of Delaware Sand Filter BMPs. Final Report. Department of Transportation and Environmental Services. Alexandria, VA. 140 p. Also in: Performance of Delaware Sand Filter Assessed. Watershed Protection Techniques. Center for Watershed Protection. Fall 1995. Vol. 2(1): 291-293.
Filtering Practice	Sand Filter (P)	Horner, R.R., and C.R. Horner. 1995. Design, Construction and Evaluation of a Sand Filter Stormwater Treatment System. Part II. Performance Monitoring. Report to Alaska Marine Lines, Seattle, WA. 38 p. Also in: Performance of Delaware Sand Filter Assessed. Watershed Protection Techniques. Center for Watershed Protection. Fall 1995. Vol. 2(1): 291-293.
Filtering Practice	Sand Filter (P)	Horner, R.R., and C.R. Horner. 1995. Design, Construction and Evaluation of a Sand Filter Stormwater Treatment System. Part II. Performance Monitoring. Report to Alaska Marine Lines, Seattle, WA. 38 p. Also in: Performance of Delaware Sand Filter Assessed. Watershed Protection Techniques. Center for Watershed Protection. Fall 1995. Vol. 2(1): 291-293.
Filtering Practice	Sand Filter (S)	Barrett, M.; M. Keblin; J. Malina; R. Charbeneau. 1998. Evaluation of the Performance of Permanent Runoff Controls: Summary and Conclusions. Center for Transportation Research. Texas Department of Transportation. University of Texas. Austin, TX.

BMP Category	BMP Type	Reference
Filtering Practice	Sand Filter (S)	City of Austin, TX. 1990. Removal Efficiencies of Stormwater Control Structures. Final Report. Environmental Resource Management Division. 36 p. Also in: Developments in Sand Filter Technology to Improve Stormwater Runoff Quality. Watershed Protection Techniques. Center for Watershed Protection. Summer 1994. Vol. 1(2): 47-54.
Filtering Practice	Sand Filter (S)	City of Austin, TX. 1990. Removal Efficiencies of Stormwater Control Structures. Final Report. Environmental Resource Management Division. 36 p. Also in: Developments in Sand Filter Technology to Improve Stormwater Runoff Quality. Watershed Protection Techniques. Center for Watershed Protection. Summer 1994. Vol. 1(2): 47-54.
Filtering Practice	Sand Filter (S)	City of Austin, TX. 1990. Removal Efficiencies of Stormwater Control Structures. Final Report. Environmental Resource Management Division. 36 p. Also in: Developments in Sand Filter Technology to Improve Stormwater Runoff Quality. Watershed Protection Techniques. Center for Watershed Protection. Summer 1994. Vol. 1(2): 47-54.
Filtering Practice	Sand Filter (S)	City of Austin, TX. 1990. Removal Efficiencies of Stormwater Control Structures. Final Report. Environmental Resource Management Division. 36 p. Also in: Developments in Sand Filter Technology to Improve Stormwater Runoff Quality. Watershed Protection Techniques. Center for Watershed Protection. Summer 1994. Vol. 1(2): 47-54.
Filtering Practice	Sand Filter (S)	City of Austin, TX. 1996. Evaluation of Non-point Source Controls; a 319 Grant Project. Final Report. Water Quality Report Series. COA-ERM-1996-03.

BMP Category	BMP Type	Reference
Filtering Practice	Sand Filter (S)	Harper, H. and J. Herr. 1993. Treatment Efficiency of Detention With Filtration Systems. Environmental Research and Design, Inc. Final Report Submitted to Florida Department of Environmental Regulation. Orlando, FL 164 p.
Filtering Practice	Sand Filter (S)	Welborn, C. and J. Veenhuis. 1987. Effects of Runoff Controls on the Quantity and Quality of Urban Runoff in Two Locations in Austin, TX. USGS Water Resources Investigations Report. 87-4004. 88 p.
Filtering Practice	Sand Filter (V)	Barton Springs/Edwards Aquifer Conservation District. 1996. Final Report: Enhanced Roadway Runoff Best Management Practices. City of Austin, Drainage Utility, LCRA, TDOT. Austin, TX. 200 p.
Filtering Practice	Sand Filter (V)	Tenney, S.; M. Barrett; J. Malina; R. Charbeneau; and G. Ward. 1995. An Evaluation of Highway Runoff Filtration Systems. Center for Research in Water Resources. University of Texas at Austin.
Infiltration Practice	Infiltration Trench	Kuo, C.Y., G.D. Boardman and K.T. Laptos. 1990. Phosphorous and Nitrogen Removal Efficiencies of Infiltration Trenches. Dept. of Civil Engineering. VA Polytechnic Institute and State University. Prepared for: No. VA Planning District Commission, Occoquan Technical Advisory Committee and VA State Water Control Board. 129 p.
Infiltration Practice	Infiltration Trench	Kuo, C.Y., G.D. Boardman and K.T. Laptos. 1990. Phosphorous and Nitrogen Removal Efficiencies of Infiltration Trenches. Dept. of Civil Engineering. VA Polytechnic Institute and State University. Prepared for: No. VA Planning District Commission, Occoquan Technical Advisory Committee and VA State Water Control Board. 129 p.

BMP Category	BMP Type	Reference
Infiltration Practice	Infiltration Trench	Kuo, C.Y., G.D. Boardman and K.T. Laptos. 1990. Phosphorous and Nitrogen Removal Efficiencies of Infiltration Trenches. Dept. of Civil Engineering. VA Polytechnic Institute and State University. Prepared for: No. VA Planning District Commission, Occoquan Technical Advisory Committee and VA State Water Control Board. 129 p.
Infiltration Practice	Porous Pavement	Schueler, T.R. 1987. Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs. Metropolitan Washington Council of Governments. Department of Environmental Programs. Also in: Weand, B., Grizzard, T. 1986. Interim Progress Report-Davis Ford Park-Urban BMP Demonstration Project. Occoquan Watershed Monitoring Laboratory-Department of Civil Engineering-Virginia Polytechnic Institute and State University.
Infiltration Practice	Porous Pavement	Schueler, T.R. 1987. Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs. Metropolitan Washington Council of Governments. Department of Environmental Programs.
Infiltration Practice	Porous Pavement	St. John, M. 1997. Effect of Road Shoulder Treatments on Highway Runoff Quality and Quantity. University of Washington.
Open Channel Practice	Ditch	Dorman, M.E., J. Hartigan, R.F. Steg and T. Quasebarth. 1989. Retention, Detention and Overland Flow for Pollutant Removal From Highway Stormwater Runoff. Vol. 1. Research Report. Federal Highway Administration. FHWA/RD 89/202. 179 p. Also in: Performance of Grassed Swales Along East Coast Highways. Watershed Protection Techniques. Center for Watershed Protection. Fall 1994. Vol. 1(3): 122-123.

BMP Category	BMP Type	Reference
Open Channel Practice	Ditch	Oakland, P.H. 1983. An Evaluation of Stormwater Pollutant Removal Through Grassed Swale Treatment. Proceedings of the International Symposium of Urban Hydrology, Hydraulics and Sediment Control. H. J. Sterling (Ed.). Lexington, KY. p. 173-182.
Open Channel Practice	Ditch	Occoquan Watershed Monitoring Laboratory. 1983. Final Report: Metropolitan Washington Urban Runoff Project. Prepared for the Metropolitan Washington Council of Governments. Manassas, VA. 460 p.
Open Channel Practice	Ditch	Occoquan Watershed Monitoring Laboratory. 1983. Final Report: Metropolitan Washington Urban Runoff Project. Prepared for the Metropolitan Washington Council of Governments. Manassas, VA. 460 p.
Open Channel Practice	Ditch	Occoquan Watershed Monitoring Laboratory. 1983. Final Report: Metropolitan Washington Urban Runoff Project. Prepared for the Metropolitan Washington Council of Governments. Manassas, VA. 460 p.
Open Channel Practice	Ditch	Pitt, R. and J. McLean.1986. Toronto Area Watershed Management Strategy Study: Humber River Pilot Watershed Project. Ontario Ministry of Environment.
Open Channel Practice	Ditch	Walsh, P.; M. Barrett; J. Malina; R. Charbeneau; and G. Ward. 1995. Use of Vegetative Controls for Treatment of Highway Runoff. Center for Research in Water Resources. Also in: Barrett, et al. Evaluation of the Performance of Permanent Runoff Controls: Summary and Conclusions. Center for Transporation Research. TX Dept. of Transportation. and Center for Watershed Protection. Watershed Protection Techniques 3(2)

BMP Category	BMP Type	Reference
Open Channel Practice	Ditch	Walsh, P.; M. Barrett; J. Malina; R. Charbeneau; and G. Ward. 1995. Use of Vegetative Controls for Treatment of Highway Runoff. Center for Research in Water Resources. Also in: Barrett, et al. Evaluation of the Performance of Permanent Runoff Controls: Summary and Conclusions. Center for Transporation Research. TX Dept. of Transportation. and Center for Watershed Protection. Watershed Protection Techniques 3(2)
Open Channel Practice	Ditch	Welborn, C. and J. Veenhuis. 1987. Effects of Runoff Controls on the Quantity and Quality of Urban Runoff in Two Locations in Austin, TX. USGS Water Resources Investigations Report. 87-4004. 88 p.
Open Channel Practice	Dry Swale	Dorman, M.E., J. Hartigan, R.F. Steg and T. Quasebarth. 1989. Retention, Detention and Overland Flow for Pollutant Removal From Highway Stormwater Runoff. Vol. 1. Research Report. Federal Highway Administration. FHWA/RD 89/202. 179 p. Also in: Performance of Grassed Swales Along East Coast Highways. Watershed Protection Techniques. Center for Watershed Protection. Fall 1994. Vol. 1(3): 122-123.
Open Channel Practice	Dry Swale	Harper, H. 1988. Effects of Stormwater Management Systems on Groundwater Quality. Final Report. Environmental Research and Design, Inc. Prepared for Florida Department of Environmental Regulation. 460 p. Also in: Runoff and Groundwater Dynamics of Two Swales in Florida. Watershed Protection Techniques. Center for Watershed Protection. Fall 1994. Vol. 1(3): 120-121.
Open Channel Practice	Dry Swale	Kercher, W.C., J.C. Landon and R. Massarelli. 1983. Grassy Swales Prove Cost-Effective for Water Pollution Control. Public Works. Vol. 16: 53-55.

BMP Category	BMP Type	Reference
Open Channel Practice	Dry Swale	Wang, T., D. Spyridakis, B. Mar and R. Horner. 1981. Transport, Deposition and Control of Heavy Metals in Highway Runoff. FHWA-WA-RD-39-10. Department of Civil Engineering. University of Washington. Seattle, WA.
Open Channel Practice	Grass Channel	Goldberg. 1993. Dayton Avenue Swale Biofiltration Study. Seattle Engineering Department. Seattle, WA. 36 p.
Open Channel Practice	Grass Channel	Seattle Metro and Washington Department of Ecology. 1992. Biofiltration Swale Performance: Recommendations and Design Considerations. Publication No. 657. Water Pollution Control Department, Seattle Washington. 220 p. Also in: Watershed Protection Techniques. Center for Watershed Protection. Fall 1994. Vol. 1(3): 117-119.
Open Channel Practice	Grass Channel	Seattle Metro and Washington Department of Ecology. 1992. Biofiltration Swale Performance: Recommendations and Design Considerations. Publication No. 657. Water Pollution Control Department, Seattle Washington. 220 p. Also in: Watershed Protection Techniques. Center for Watershed Protection. Fall 1994. Vol. 1(3): 117-119.
Open Channel Practice	Wet Swale	Harper, H.1988. Effects of Stormwater Management Systems on Groundwater Quality. Final Report. Environmental Research and Design, Inc. Prepared for Florida Department of Environmental Regulation. 460 p. Also in: Runoff and Groundwater Dynamics of Two Swales in Florida. Watershed Protection Techniques. Center for Watershed Protection. Fall 1994. Vol. 1(3): 120-121.
Open Channel Practice	Wet Swale	Koon, J. 1995. Evaluation of Water Quality Ponds and Swales in the Issaquah/East Lake Sammamish Basins. King County Surface Water Management and Washington Department of Ecology. Seattle, WA. 75 p.

BMP Category	BMP Type	Reference
Other	Oil-Grit Separator	Shepp, D. 1995. A Performance Assessment of an Oil-Grit Separator in Suburban Maryland. Final Report prepared for the Maryland Department of the Environment. Metropolitan Washington Council of Governments. Washington, DC. 46 p.
Other	Stormceptor	Waschbusch, R. 1999. Evaluation of the Effectiveness of an Urban Stormwater Treatment Unit in Madison, WI, 1996 - 97. USGS. Water Resources Investigations Report 99-4195. Also in Watershed Protection Techniques. Center for Watershed Protection. Spring 99. Vol. 3(1): 605-608.
Stormwater Pond	Dry Extended Detention Pond	Baltimore Department of Public Works. 1989. Detention Basin Retrofit Project and Monitoring Study Results. Water Quality Management Office. Baltimore, MD. 42 p.
Stormwater Pond	Dry Extended Detention Pond	City of Austin, TX. 1991. Design Guidelines for Water Quality Control Basins. Public Works Department. Austin, TX. 64 p.
Stormwater Pond	Dry Extended Detention Pond	Miller, T. 1987. Appraisal of Storm-Water Quality Near Salem, Oregon. US Geological Survey. Water Resources Report 87-4064.
Stormwater Pond	Dry Extended Detention Pond	Occoquan Watershed Monitoring Laboratory. 1987. Final Report: London Commons Extended Detention Facility. Urban BMP Research and Demonstration Project. Virginia Tech University. Manassas, VA. 68 p.
Stormwater Pond	Dry Extended Detention Pond	Schueler, T.R. and M. Helfrich. 1988. Design of Extended Detention Wet Pond Systems. In: Design of Urban Runoff Quality Controls. L.A. Roesner, B. Urbonas and M.B. Sonnen (Eds.). American Society of Civil Engineers. New York, New York. p. 280-281.

BMP Category	BMP Type	Reference
Stormwater Pond	Dry Extended Detention Pond	Stanley, D. 1994. An Evaluation of the Pollutant Removal of a Demonstration Urban Stormwater Detention Pond. Albermarle-Pamlico Estuary Study. APES Report 94-07. 112 p. Also in: Performance of a Dry Extended Detention Pond in North Carolina. Watershed Protection Techniques. Center for Watershed Protection. Fall 1995. Vol. 2(1): 294-295.
Stormwater Pond	Multiple Pond System	Holler, J.D. 1989. Water Quality Efficiency of an Urban Commercial Wet Detention Stormwater Management System at Boynton Beach Mall In South Palm Beach County, FL. Florida Scientist. Winter 1989. Vol. 52(1): 48-57.
Stormwater Pond	Quantity Control Pond	Metropolitan Washington Council of Governments. 1983. Final Report: Pollutant Removal Capability of Urban BMPs in the Washington Metropolitan Area. Prepared for the U.S. Environmental Protection Agency. 64 p.
Stormwater Pond	Quantity Control Pond	Pope, L.M. and L.G. Hess. 1988. Load-Detention Efficiencies in a Dry Pond Basin. In: Design of Urban Runoff Quality Controls. L.A. Roesner, B. Urbonas and M.B. Sonnen (Eds.). American Society of Civil Engineers. New York, New York. p. 258-267.
Stormwater Pond	Quantity Control Pond	Schehl, T.P. and T.J. Grizzard. 1995. Runoff Characterization From an Urban Commercial Catchment and Performance of an Existing Undeground Detention Facility in Reducing Constituent Transport. Proceedings of the 4th Biennial Stormwater Research Conference. October 18-20, 1995. Clearwater, FL. Sponsored by the Southwest Florida water Management District. p. 190-199.

BMP Category	BMP Type	Reference
Stormwater Pond	Wet Extended Detention Pond	Borden, R. C., J.L. Dorn, J.B. Stillman and S.K. Liehr. 1996. Draft Report. Evaluation of Ponds and Wetlands For Protection of Public Water Supplies. Water Resources Research Institute of the University of North Carolina. Department of Civil Engineering. North Carolina State University. Raleigh, North Carolina.
Stormwater Pond	Wet Extended Detention Pond	Borden, R. C., J.L. Dorn, J.B. Stillman and S.K. Liehr. 1996. Draft Report. Evaluation of Ponds and Wetlands For Protection of Public Water Supplies. Water Resources Research Institute of the University of North Carolina. Department of Civil Engineering. North Carolina State University. Raleigh, North Carolina.
Stormwater Pond	Wet Extended Detention Pond	City of Austin, TX. 1991. Design Guidelines for Water Quality Control Basins. Public Works Department. Austin, TX. 64 p.
Stormwater Pond	Wet Extended Detention Pond	Comings, K.; D. Booth; and R. Horner. Stormwater Pollutant Removal by Two Wet Ponds in Bellevue, WA. University of Washington.
Stormwater Pond	Wet Extended Detention Pond	Fellows, D.; W. Liang; S. Ristic; and M. Thompson. 1999. Performance Assessment of MTOs Rouge River, Highway 40, Stormwater Management Pond. SWAMP. Ontario Ministry of Environment and Energy.
Stormwater Pond	Wet Extended Detention Pond	Fellows, D.; W. Liang; S. Ristic; and S. Smith. 1999. Performance Assessment of Richmond Hill's Harding Park Stormwater Retrofit Pond. SWAMP. Ontario Ministry of Environment and Energy.
Stormwater Pond	Wet Extended Detention Pond	Holler, J.D. 1990. Nonpoint Source Phosphorous Control By a Combination Wet Detention/Filtration Facility In Kissimmee, FL. Florida Scientist. Vol. 53(1). p. 28-37.
Stormwater Pond	Wet Extended Detention Pond	Lower Colorado River Authority. 1997. Innovative NPS Pollution Control Program for Lake Travis in Central Texas. LCRA.

BMP Category	BMP Type	Reference
Stormwater Pond	Wet Extended Detention Pond	Ontario Ministry of the Environment. 1991. Stormwater Quality Best Management Practices. Marshall Macklin Monaghan Limited. Toronto, Ontario. 177 p.
Stormwater Pond	Wet Extended Detention Pond	Ontario Ministry of the Environment. 1991. Stormwater Quality Best Management Practices. Marshall Macklin Monaghan Limited. Toronto, Ontario. 177 p.
Stormwater Pond	Wet Extended Detention Pond	Ontario Ministry of the Environment. 1991. Stormwater Quality Best Management Practices. Marshall Macklin Monaghan Limited. Toronto, Ontario. 177 p.
Stormwater Pond	Wet Extended Detention Pond	Rushton, B., C. Miller and H. Hull. 1995. The Effect of Residence Time on the Efficiency of a Wet Detention Stormwater Treatment Pond. Presented at the 31st Annual Conference and Symposium in Urban Areas. November 10-12, 1995. Houston, TX. Also in Three Design Alternatives for Stormwater Detention Ponds. 1997. Southwest Florida Water Management District.
Stormwater Pond	Wet Extended Detention Pond	Rushton, B., C. Miller and H. Hull. 1995. The Effect of Residence Time on the Efficieny of a Wet Detention Stormwater Treatment Pond. Presented at the 31st Annual Conference and Symposium in Urban Areas. November 10-12, 1995. Houston, TX. Also in Three Design Alternatives for Stormwater Detention Ponds. 1997. Southwest Florida Water Management District.
Stormwater Pond	Wet Extended Detention Pond	Rushton, B., C. Miller and H. Hull. 1995. The Effect of Residence Time on the Efficiency of a Wet Detention Stormwater Treatment Pond. Presented at the 31st Annual Conference and Symposium in Urban Areas. November 10-12, 1995. Houston, TX. Also in Three Design Alternatives for Stormwater Detention Ponds. 1997. Southwest Florida Water Management District.

BMP Category	BMP Type	Reference
Stormwater Pond	Wet Pond	Bannerman, R. and R. Dodds. 1992. Unpublished data. Bureau of Water Resources Management. Wisconsin Department of Natural Resources. Madison, WI.
Stormwater Pond	Wet Pond	City of Austin, TX. 1996. Evaluation of Nonpoint Source Controls, a 319 Grant Report. Final Report. Water Quality Report Series. COA-ERM-1996-03.
Stormwater Pond	Wet Pond	Comings, K.; D. Booth; and R. Horner. Stormwater Pollutant Removal by Two Wet Ponds in Bellevue, WA. University of Washington.
Stormwater Pond	Wet Pond	Cullum, M. 1984. Volume II Evaluation of the Water Management System at a Single Family Residential Site: Water Quality Analysis for Selected Storm Events at Timbercreek Subdivision in Boca Raton, FL. South Florida Water Management District.
Stormwater Pond	Wet Pond	Dorman, M.E., J. Hartigan, R.F. Steg and T. Quasebarth. 1989. Retention, Detention and Overland Flow for Pollutant Removal From Highway Stormwater Runoff. Vol. 1 Research Report. Federal Highway Administration. FHWA/RD 89/202. 179 p.
Stormwater Pond	Wet Pond	Dorman, M.E., J. Hartigan, R.F. Steg and T. Quasebarth. 1989. Retention, Detention and Overland Flow for Pollutant Removal From Highway Stormwater Runoff. Vol. 1 Research Report. Federal Highway Administration. FHWA/RD 89/202. 179 p.
Stormwater Pond	Wet Pond	Dorman, M.E., J. Hartigan, R.F. Steg and T. Quasebarth. 1989. Retention, Detention and Overland Flow for Pollutant Removal From Highway Stormwater Runoff. Vol. 1 Research Report. Federal Highway Administration. FHWA/RD 89/202. 179 p.

BMP Category	BMP Type	Reference
Stormwater Pond	Wet Pond	Driscoll, E.D. 1983. Performance of Detention Basins for Control of Urban Runoff Quality. Presented at the 1983 International Symposium on Urban Hydrology, Hydraulics and Sedimentation Control. University of Kentucky. Lexington, KY. 40 p.
Stormwater Pond	Wet Pond	Driscoll, E.D. 1983. Performance of Detention Basins for Control of Urban Runoff Quality. Presented at the 1983 International Symposium on Urban Hydrology, Hydraulics and Sedimentation Control. University of Kentucky. Lexington, KY. 40 p.
Stormwater Pond	Wet Pond	Driscoll, E.D. 1983. Performance of Detention Basins for Control of Urban Runoff Quality. Presented at the 1983 International Symposium on Urban Hydrology, Hydraulics and Sedimentation Control. University of Kentucky. Lexington, KY. 40 p.
Stormwater Pond	Wet Pond	Driscoll, E.D. 1983. Performance of Detention Basins for Control of Urban Runoff Quality. Presented at the 1983 International Symposium on Urban Hydrology, Hydraulics and Sedimentation Control. University of Kentucky. Lexington, KY. 40 p.
Stormwater Pond	Wet Pond	Driscoll, E.D. 1983. Performance of Detention Basins for Control of Urban Runoff Quality. Presented at the 1983 International Symposium on Urban Hydrology, Hydraulics and Sedimentation Control. University of Kentucky. Lexington, KY. 40 p.
Stormwater Pond	Wet Pond	Driscoll, E.D. 1983. Performance of Detention Basins for Control of Urban Runoff Quality. Presented at the 1983 International Symposium on Urban Hydrology, Hydraulics and Sedimentation Control. University of Kentucky. Lexington, KY. 40 p.

BMP Category	BMP Type	Reference
Stormwater Pond	Wet Pond	Gain, W.S. 1996. The Effects of Flow Path Modification on Water Quality Constituent Retention in an Urban Stormwater Detention Pond and Wetland System. Orlando, FL. U.S. Geological Survey. Water Resources Investigations Report 95-4297. Tallahassee, FL
Stormwater Pond	Wet Pond	Horner, R.R., J. Guedry and M.H. Kortenhoff. 1990. Final Report: Improving the Cost Effectiveness of Highway Construction Site Erosion and Pollution Control. Prepared for the Washington State Transportation Commission. 51 p.
Stormwater Pond	Wet Pond	Horner, R.R., J. Guedry and M.H. Kortenhoff. 1990. Final Report: Improving the Cost Effectiveness of Highway Construction Site Erosion and Pollution Control. Prepared for the Washington State Transportation Commission. 51 p.
Stormwater Pond	Wet Pond	Horner, R.R., J. Guedry and M.H. Kortenhoff. 1990. Final Report: Improving the Cost Effectiveness of Highway Construction Site Erosion and Pollution Control. Prepared for the Washington State Transportation Commission. 51 p.
Stormwater Pond	Wet Pond	Kantrowitz, I. and W. Woodham. 1995. Efficiency of a Stormwater Detention Pond in Reducing Loads of Chemical and Physical Constituents in Urban Streamflow, Pinellas County, Florida. U.S. Geological Survey. Water Resources Investigations Report: 94-4217. Tallahassee, FL. 18 p.
Stormwater Pond	Wet Pond	Liang, W. 1996. Performance Assessment of an Off-Line Stormwater Management Pond. Ontario Ministry of Environment and Energy.
Stormwater Pond	Wet Pond	Martin, E. 1988. Effectiveness of an Urban Runoff Detention Pond/Wetland System. Journal of Environmental Engineering. Vol. 114(4): 810-827.

BMP Category	BMP Type	Reference
Stormwater Pond	Wet Pond	Oberst, G. and R. Osgood. 1998. Lake McCarrons: Final Report on the Function of the Wetland Treatment System and the Impacts on Lake McCarrons. Metropolitian Council of the Twin Cities Area. St. Paul, MN.
Stormwater Pond	Wet Pond	Oberts, G.L., P.J. Wotzka and J.A. Hartsoe. 1989. The Water Quality Performance of Select Urban Runoff Treatment Systems. Prepared for the Legislative Commission on Minnesota Resources. Metropolitan Council. St. Paul, MN. Publication No. 590-89-062a 170 p.
Stormwater Pond	Wet Pond	Oberts, G.L., P.J. Wotzka and J.A. Hartsoe. 1989. The Water Quality Performance of Select Urban Runoff Treatment Systems. Prepared for the Legislative Commission on Minnesota Resources. Metropolitan Council. St. Paul, MN. Publication No. 590-89-062a 170 p.
Stormwater Pond	Wet Pond	Occoquan Watershed Monitoring Laboratory. 1983. Final Report: Metropolitan Washington Urban Runoff Project. Prepared for the Metropolitan Washington Council of Governments. Manassas, VA. 460 p.
Stormwater Pond	Wet Pond	Occoquan Watershed Monitoring Laboratory. 1983. Final Report: Metropolitan Washington Urban Runoff Project. Prepared for the Metropolitan Washington Council of Governments. Manassas, VA. 460 p.
Stormwater Pond	Wet Pond	Urbonas, B., J. Carlson and B. Vang. 1994. Joint Pond-Wetland System in Colorado. An Internal Report of the Denver Urban Drainage and Flood Control District. Also in: Performance of a Storage Pond/Wetland System in Colorado. Watershed Protection Techniques. Center for Watershed Protection. Summer 1994. Vol. 1(2): 68-69.

BMP Category	BMP Type	Reference
Stormwater Pond	Wet Pond	Wu, J. 1989. Evaluation of Detention Basin Performance in the Piedmont Region of North Carolina. North Carolina Water Resources Research Institute. Report No. 89-248. Raleigh, NC. 46 p. Also in: Performance of two Wet Ponds in the Piedmont of North Carolina. Watershed Protection Techniques. Center for Watershed Protection. Fall 1995. Vol. 2(1): 296-297.
Stormwater Pond	Wet Pond	Wu, J. 1989. Evaluation of Detention Basin Performance in the Piedmont Region of North Carolina. North Carolina Water Resources Research Institute. Report No. 89-248. Raleigh, NC. 46 p. Also in: Performance of two Wet Ponds in the Piedmont of North Carolina. Watershed Protection Techniques. Center for Watershed Protection. Fall 1995. Vol. 2(1): 296-297.
Stormwater Pond	Wet Pond	Yousef, Y., M. Wanielista and H. Harper. 1986. Design and Effectiveness of Urban Retention Basins. In: Urban Runoff Quality- Impact and Quality Enhancement Technology. B. Urbonas and L.A. Roesner (Eds.). American Society of Civil Engineering. New York, New York. p. 338-350.
Stormwater Wetland	Extended Detention Wetland	Athanas C. and C. Stevenson. 1986. Nutrient Removal from Stormwater Runoff by a Vegetated Collection Pond - The Mays Chapel Wetland Basin Project. Prepared for the City of Baltimore, Department of Public Works, Bureau of Water and Wastewater, Water Quality Management Office. 42 p.
Stormwater Wetland	Extended Detention Wetland	Barten, J.M. 1983. Treatment of Stormwater Runoff Using Aquatic Plants. The Use of Wetlands for Controlling Stormwater Pollution. Strecker, E.W., J.M. Kersnar and E.D. Driscoll (Eds.). Woodward-Clyde Consultants. Portland, Oregon. Prepared for U.S. EPA, Region V, Water Division, Watershed Management Unit. EPA/600 February 1992.

BMP Category	BMP Type	Reference
Stormwater Wetland	Extended Detention Wetland	Oberts, G.L., P.J. Wotzka and J.A. Hartsoe. 1989. The Water Quality Performance of Select Urban Runoff Treatment Systems. Prepared for the Legislative Commission on Minnesota Resources. Metropolitan Council. St. Paul, MN. Publication No. 590-89-062a 170 p.
Stormwater Wetland	Extended Detention Wetland	Occoquan Watershed Monitoring Laboratory and George Mason University. 1990. Final Report: The Evaluation of a Created Wetland as an Urban Best Management Practice. Prepared for the Northern Virginia Soil and Water Conservation District. 175 p. Also in: Adequate Treatment Volume Critical in Virginia Stormwater Wetland. Watershed Protection Techniques. Center for Watershed Protection. February 1994. Vol. 1(1): 25-25.
Stormwater Wetland	Pond/Wetland System	Esry and Cairns. 1988. The Use of Wetlands for Controlling Stormwater Pollution. Strecker, E.W., J.M. Kersnar and E.D. Driscoll (Eds.). Woodward-Clyde Consultants. Portland, Oregon. Prepared for U.S. EPA, Region V, Water Division, Watershed Management Unit. EPA/600 February 1992.
Stormwater Wetland	Pond/Wetland System	Gain, W.S. 1996. The Effects of Flow Path Modification on Water Quality Constituent Retention in an Urban Stormwater Detention Pond and Wetland System. Orlando, FL. U.S. Geological Survey. Water Resources Investigations Report 95-4297. Tallahassee, FL
Stormwater Wetland	Pond/Wetland System	Jolly, J.W. 1990. The Efficiency of Constructed Wetlands in the Reduction of Phosphorous and Sediment Discharges From Agriculture Wetlands. The Use of Wetlands for Controlling Stormwater Pollution. Strecker, E.W., J.M. Kersnar and E.D. Driscoll (Eds.). Woodward-Clyde Consultants. Portland, Oregon. Prepared for U.S. EPA, Region V, Water Division, Watershed Management Unit. EPA/600 February 1992.

BMP Category	BMP Type	Reference
Stormwater Wetland	Pond/Wetland System	Leersnyder, H. 1993. The Performance of Wet Detention Basins for the Removal of Urban Stormwater Contaminantion in the Auckland Region. M.S. Thesis. University of Auckland. Department of Environmental Sciences and Geography. 118 p. Also in: Pond/Wetland System Proves Effective in New Zealand. Watershed Protection Techniques. Center for Watershed Protection. February 1994. Vol. 1(1): 10-11.
Stormwater Wetland	Pond/Wetland System	Martin, E. 1988. Effectiveness of an Urban Runoff Detention Pond/Wetland System. Journal of Environmental Engineering. Vol. 114(4): 810-827.
Stormwater Wetland	Pond/Wetland System	McCann K. and L. Olson. 1994. Final Report on Greenwood Urban Wetland Treatment Effectiveness. City of Orlando, FL, Stormwater Utility Bureau.
Stormwater Wetland	Pond/Wetland System	Oberst, G. and R. Osgood. 1998. Lake McCarrons: Final Report on the Function of the Wetland Treatment System and the Impacts on Lake McCarrons. Metropolitian Council of the Twin Cities Area. St. Paul, MN.
Stormwater Wetland	Pond/Wetland System	Oberts, G. 1997. Lake McCarrons Wetland Treatment System - Phase III Study Report. Metroplitian Council of Environmental Services. St. Paul, Minnesota.
Stormwater Wetland	Pond/Wetland System	Oberts, G.L., P.J. Wotzka and J.A. Hartsoe. 1989. The Water Quality Performance of Select Urban Runoff Treatment Systems. Prepared for the Legislative Commission on Minnesota Resources. Metropolitan Council. St. Paul, MN. Publication No. 590-89-062a 170 p.
Stormwater Wetland	Pond/Wetland System	Urbonas, B., J. Carlson and B. Vang. 1994. Joint Pond-Wetland System in Colorado. An Internal Report of the Denver Urban Drainage and Flood Control District. Also in: Performance of a Storage Pond/Wetland System in Colorado. Watershed Protection Techniques. Center for Watershed Protection. Summer 1994. Vol. 1(2): 68-69.

BMP Category	BMP Type	Reference
Stormwater Wetland	Shallow Marsh	Athanas, C. and C. Stevenson. 1991. The Use of Artificial Wetands in Treating Stormwater Runoff. Prepared for the Maryland Sediment and Stormwater Administration. Maryland Department of the Environment. 66 p.
Stormwater Wetland	Shallow Marsh	Blackburn, R., P.L. Pimentel and G.E. French. 1986. Treatment of Stormwater Runoff Using Aquatic Plants. The Use of Wetlands for Controlling Stormwater Pollution. Strecker, E.W., J.M. Kersnar and E.D. Driscoll (Eds.). Woodward-Clyde Consultants. Portland, Oregon. Prepared for U.S. EPA, Region V, Water Division, Watershed Management Unit. EPA/600 February 1992.
Stormwater Wetland	Shallow Marsh	Carr, D. and B. Rushton. 1995. Integrating a Herbaceous Wetland into Stormwater Management. Stormwater Research Program. Southwest Flordia Water Management District. Brooksville, FL.
Stormwater Wetland	Shallow Marsh	Driscoll, E.D. 1983. Performance of Detention Basins for Control of Urban Runoff Quality. Presented at the 1983 International Symposium on Urban Hydrology, Hydraulics and Sedimentation Control. University of Kentucky. Lexington, KY. 40 p.
Stormwater Wetland	Shallow Marsh	Gain, W.S. 1996. The Effects of Flow Path Modification on Water Quality Constituent Retention in an Urban Stormwater Detention Pond and Wetland System. Orlando, FL. U.S. Geological Survey. Water Resources Investigations Report 95-4297. Tallahassee, FL
Stormwater Wetland	Shallow Marsh	Harper, H.H., M.P. Wanielista, B.M. Fries and D.M. Baker. 1986. The Use of Wetlands for Controlling Stormwater Pollution. Strecker, E.W., J.M. Kersnar and E.D. Driscoll (Eds.). Woodward-Clyde Consultants. Portland, Oregon. Prepared for U.S. EPA, Region V, Water Division, Watershed Management Unit. EPA/600 February 1992.

BMP Category	BMP Type	Reference
Stormwater Wetland	Shallow Marsh	Hey, D.L., A.L. Kenimer and K.R. Barrett. 1994. Water Quality Improvement by Four Experimental Wetlands. Ecological Engineering Vol. 3: 381- 397. Also in: Pollutant Removal by Constructed Wetlands in an Illinois River Floodplain. Watershed Protection Techniques. Center for Watershed Protection. Spring 1996. Vol. 2(2): 376-379.
Stormwater Wetland	Shallow Marsh	Hey, D.L., A.L. Kenimer and K.R. Barrett. 1994. Water Quality Improvement by Four Experimental Wetlands. Ecological Engineering Vol. 3: 381- 397. Also in: Pollutant Removal by Constructed Wetlands in an Illinois River Floodplain. Watershed Protection Techniques. Center for Watershed Protection. Spring 1996. Vol. 2(2): 376-379.
Stormwater Wetland	Shallow Marsh	Hey, D.L., A.L. Kenimer and K.R. Barrett. 1994. Water Quality Improvement by Four Experimental Wetlands. Ecological Engineering Vol. 3: 381- 397. Also in: Pollutant Removal by Constructed Wetlands in an Illinois River Floodplain. Watershed Protection Techniques. Center for Watershed Protection. Spring 1996. Vol. 2(2): 376-379.
Stormwater Wetland	Shallow Marsh	Hey, D.L., A.L. Kenimer and K.R. Barrett. 1994. Water Quality Improvement by Four Experimental Wetlands. Ecological Engineering Vol. 3: 381- 397. Also in: Pollutant Removal by Constructed Wetlands in an Illinois River Floodplain. Watershed Protection Techniques. Center for Watershed Protection. Spring 1996. Vol. 2(2): 376-379.
Stormwater Wetland	Shallow Marsh	Hickok, E.A., M.C. Hannaman and N.C. Wenck. 1977. Urban Runoff Treatment Methods. Volume 1: Non-structural Wetland Treatment. The Use of Wetlands for Controlling Stormwater Pollution. Strecker, E.W., J.M. Kersnar and E.D. Driscoll (Eds.). Woodward-Clyde Consultants. Portland, Oregon. Prepared for U.S. EPA, Region V, Water Division, Watershed Management Unit. EPA/600 February 1992.

BMP Category	BMP Type	Reference
Stormwater Wetland	Shallow Marsh	Horsley, S.W. 1995. The StormTreat System- A New Technology for Treating Stormwater Runoff. Watershed Protection Techniques. Center for Watershed Protection. Fall 1995. Vol. 2(1): 304-305.
Stormwater Wetland	Shallow Marsh	Koon J. 1995. Evaluation of Water Quality Ponds and Swales in the Issaquah/East Lake Sammamish Basins. King County Surface Water Management and Washington Department of Ecology. Seattle, WA. 75 p.
Stormwater Wetland	Shallow Marsh	Oberst, G. and R. Osgood. 1988. Lake McCarrons: Final Report on the Function of the Wetland Treatment System and the Impacts on Lake McCarrons. Metropolitian Council of the Twin Cities Area. St. Paul, MN.
Stormwater Wetland	Shallow Marsh	Phipps, R.G. and W.G. Crumpton. 1994. Factors Affecting Nitrogen Loss In Experimental Wetlands With Different Hydrologic Loads. Ecological Engineering. December 1994. Vol. 3(4): 399-408.
Stormwater Wetland	Shallow Marsh	Phipps, R.G. and W.G. Crumpton. 1994. Factors Affecting Nitrogen Loss In Experimental Wetlands With Different Hydrologic Loads. Ecological Engineering. December 1994. Vol. 3(4): 399-408.
Stormwater Wetland	Shallow Marsh	Phipps, R.G. and W.G. Crumpton. 1994. Factors Affecting Nitrogen Loss In Experimental Wetlands With Different Hydrologic Loads. Ecological Engineering. December 1994. Vol. 3(4): 399-408.
Stormwater Wetland	Shallow Marsh	Reinelt et al., 1990. In: The Use of Wetlands for Controlling Stormwater Pollution. Strecker, E.W., J.M. Kersnar and E.D. Driscoll (Eds.). Woodward-Clyde Consultants. Portland, Oregon. Prepared for U.S EPA, Region V, Water Division, Watershed Management Unit. EPA/600 February 1992.

BMP Category	BMP Type	Reference
Stormwater Wetland	Shallow Marsh	Reinelt et al., 1992. In: The Use of Wetlands for Controlling Stormwater Pollution. Strecker, E.W., J.M. Kersnar and E.D. Driscoll (Eds.). Woodward-Clyde Consultants. Portland, Oregon. Prepared for U.S EPA, Region V, Water Division, Watershed Management Unit. EPA/600 February 1992.
Stormwater Wetland	Shallow Marsh	Rushton, B. and C. Dye. 1993. An In-Depth Analysis of a Wet Detention Stormwater Sytem. Southwest Florida Water Management District. Brooksville, FL. 60 p. Also in: Pollutant Removal Capability of a "Pocket" Wetland. Watershed Protection Techniques. Center for Watershed Protection. Spring 1996. Vol. 2(2): 374-376.
Stormwater Wetland	Shallow Marsh	Urbonas, B., J. Carlson and B. Vang. 1994. Joint Pond-Wetland System in Colorado. An Internal Report of the Denver Urban Drainage and Flood Control District. Also in: Performance of a Storage Pond/Wetland System in Colorado. Watershed Protection Techniques. Center for Watershed Protection. Summer 1994. Vol. 1(2): 68-69.
Stormwater Wetland	Shallow Marsh	Yu, S; G. Fitch; and T. Earles. 1998. Constructed Wetlands for Stormwater Management. Virginia Transportation Research Council. Charlottesville, VA.
Stormwater Wetland	Shallow Marsh	Yu, S; G. Fitch; and T. Earles. 1998. Constructed Wetlands for Stormwater Management. Virginia Transportation Research Council. Charlottesville, VA.
Stormwater Wetland	Submerged Gravel Wetland	Egan, T., J.S. Burroughs and T. Attaway. 1995. Packed Bed Filter. Proceedings of the 4th Biennial Research Conference. Southwest Florida Water Management District. Brookeville, FL p. 264-274. Also in: Vegetated Rock Filter Treats Stormwater Pollutants in Florida. Watershed Protection Techniques. Center for Watershed Protection. Spring 1996. Vol. 2(2):372-374.

BMP Category	BMP Type	Reference
Stormwater Wetland	Submerged Gravel Wetland	Reuter, J., T. Djihan and C. Goldman. 1992. The Use of Wetlands for Nutrient Removal From Surface Runoff in a Cold-Climate Region of California: Results From a Newly Constructed Wetland at Lake Tahoe. Journal of Environmental Management. Vol. 36: 35-53. Also in: Performance of a Gravel-Based Wetland in a Cold, Hugh Altitude Climate. Watershed Protection Techniques. Center for Watershed Protection. Fall 1995. Vol. 2(1): 297-299.

Appendix C: Eliminated STP Pollutant Removal Studies

Eliminated Stormwater Treatment Practice Pollutant Removal Studies[1]
Barton Springs/Edwards Aquifer Conservation District. 1996. Final Report: Enhanced Roadway Runoff Best Management Practices. City of Austin, Drainage Utility, LCRA, TDOT. Austin, TX. 200
Yu, S., M. Kasnick and M. Byrne. 1992. A Level Spreader/Vegetative Buffer Strip System for Urban Stormwater Management. Integrated Stormwater Management. p. 93-104. R. Field et al. Editors. Lewis Publishers. Boca Raton, FL. Also in: Level Spreader/Filter Strip System Assessed in Virginia. watershed Protection Techniques. Center for Watershed Protection. February 1994. Vol. 1(1): 11-12.
Yu, S., M. Kasnick and M. Byrne. 1992. A Level Spreader/Vegetative Buffer Strip System for Urban Stormwater Management. Integrated Stormwater Management. p. 93-104. R. Field et al. Editors. Lewis Publishers. Boca Raton, FL. Also in: Level Spreader/Filter Strip System Assessed in Virginia. watershed Protection Techniques. Center for Watershed Protection. February 1994. Vol. 1(1): 11-12.
Dorman, M.E., J. Hartigan, R.F. Steg and T. Quasebarth. 1989. Retention, Detention and Overland Flow for Pollutant Removal From Highway Stormwater Runoff. Vol. 1. Research Report. Federal Highway Administration. FHWA/RD 89/202. 179 p. Also in: Performance of Grassed Swales Along East Coast Highways. Watershed Protection Techniques. Center for Watershed Protection. Fall 1994. Vol. 1(3): 122-123.
Yousef, Y., M. Wanielista, H. Harper, D. Pearce and R. Tolbert. 1985. Best Management Practices: Removal of Highway Contaminants By Roadside Swales. Final Report. University of Central Florida. Florida Department of Transportation. Orlando, FL. 122 p. Also in: Pollutant Removal Pathways in Florida Swales. Watershed Protection Techniques. Center for Watershed Protection. Fall 1995. Vol. 2(1): 299-301.
Yousef, Y., M. Wanielista, H. Harper, D. Pearce and R. Tolbert. 1985. Best Management Practices: Removal of Highway Contaminants By Roadside Swales. Final Report. University of Central Florida. Florida Department of Transportation. Orlando, FL. 122 p. Also in: Pollutant Removal Pathways in Florida Swales. Watershed Protection Techniques. Center for Watershed Protection. Fall 1995. Vol. 2(1): 299-301.
Yu, S., S. Barnes and V. Gerde. 1993. Testing of Best Management Practices for Controlling Highway Runoff. Virginia Transportation Research Council. FHWA/VA-93-R16. 60 p. Also in: Performance of Grassed Swales Along East Coast Highways. Watershed Protection Techniques. Center for Watershed Protection. Fall 1994. Vol. 1(3): 122-123.
Maristany, A.E., R.L. Bartell. 1989. Wetlands and Stormwater Management: A Case Study of Lake Munson. Part I: Long-term Treatment Efficiencies. Wetlands: Concerns and Successes. American Water Resources Association. p. 215-229.
1: All studies were eliminated because they did not meet the new minimum storm sampling criteria of five.

Appendix D: Comparative Pollutant Removal Cabability of STPs

Article 64

Technical Note #95 from Watershed Protection Techniques. 2(4): 515-520

Comparative Pollutant Removal Capability of Stormwater Treatment Practices

Over the last two decades, an impressive amount of research has been undertaken to document the pollutant removal capability of urban stormwater treatment practices. The Center has recently developed a national database that contains more than 135 individual stormwater practice performance studies. The goals for this project, were to generate national statistics about the pollutant removal capability of various groups of stormwater practices and to highlight gaps in our knowledge about pollutant removal.

The database was compiled after an exhaustive literature search of past monitoring studies from 1990 to the present. About 60 earlier monitoring studies had been collected in prior literature syntheses (Strecker *et al*., 1992; Schueler, 1994). To be included in the database, a performance monitoring study had to meet three minimum criteria: a) collect at least five storm samples, b) employ automated equipment that enabled taking flow or time-based composite samples, and c) have written documentation of the method used to compute removal efficiency. A total of 139 studies in the current phase of the project met these criteria.

Once in the database, a few general conventions were needed to facilitate the statistical analysis. First, related measurements of water quality parameters were lumped together in the pollutant removal analysis (e.g., "soluble phosphorus" included ortho-phosphorus, biologically available phosphorus, and soluble reactive phosphorus; "organic carbon" lumps biological oxygen demand, chemical oxygen demand and total organic carbon removals, "hydrocarbons" can refer to oil/grease or total petroleum hydrocarbons and "soluble nitrogen" refers to nitrate + nitrite or nitrate alone.

Second, if more than one method was used to calculate pollutant removal, methods that compared the input and output of mass rather than concentrations were used. Third, if the monitoring study only recorded removal in terms of "no significant difference" in concentrations, these were registered as zero removals. Similarly, studies that reported unspecified negative removals were entered as minus 25% (mean of negative values where specified). Finally, performance studies reporting negative removals greater than 100% were limited to minus 100% to prevent undue bias in the data set.

Each study was then assigned to one of five general stormwater practice groups: ponds, wetlands, open channels, filters, and infiltration practices. Each group was further subdivided according to design variations. For example, the pond group includes detention ponds, dry extended detention (ED) ponds, wet ponds and wet ED ponds. Medians were used as the measure of central tendency for all stormwater practice groups and design variations, and are only reported if sample size exceeded five monitoring studies. In general, pollutant removal rates should be considered as *initial* estimates of stormwater practice performance as studies occurred within three years of practice construction.

As always, extreme caution should be exercised when stormwater management performance studies are compared. Individual studies often differ in the number of storms sampled, the manner in which pollutant removal efficiency is computed (e.g., as a general rule, the concentration-based technique often results in slightly lower efficiency than the mass-based technique), the monitoring technique employed, the internal geometry and storage volume provided by the practice design, regional differences in soil type, rainfall, latitude, and the size and land use of the contributing catchment. In addition,

Table 1: Seldom-Monitored Stormwater Management Practices (National Urban BMP Database, 1997)

Stormwater Practice Design	Number of Monitoring Studies
Biofilter	0
Filter/Wetland Systems	0
Filter Strips	0
Infiltration Basins	0
Bioretention	1
Wet Swale	2
Gravel-based Wetlands	2
Infiltration Trench	3
Porous Pavement	3
Perimeter Sand Filter	3

Table 2: Frequency that Selected Stormwater Pollutants Were Monitored In 123 BMP Performance Studies

Stormwater Parameter	Percent of Studies that Measured It
Total Phosphorus	94
Total Suspended Solids (TSS)	94
Nitrate-Nitrite Nitrogen	71
Total Zinc	71
Total Lead	65
Organic Carbon	56
Soluble Phosphorus	55
Total Nitrogen	54
Total Copper [a]	46
Bacteria	19
Total Cadmium [a]	19
Total Dissolved Solids	13
Dissolved Metals	10
Hydrocarbons	9

[a] Excludes studies where parameter was below detection limits.

pollutant removal percentages can be strongly influenced by the variability of the pollutant concentrations in incoming stormwater. If the concentration is near the "irreducible level" (see Schueler, 1996), a low or negative removal percentage can be recorded, even though outflow concentrations discharged from the stormwater practice were actually relatively low.

Gaps in the Stormwater Practice Performance Database

A key element of the database project was to identify current gaps in stormwater practice monitoring research. To this end, the entire database was analyzed to find practices that had seldom been monitored and identify key stormwater pollutants that were not frequently sampled. This information is helpful for setting future monitoring priorities in order to close these research gaps.

Key gaps in our current knowledge about urban stormwater management practice performance are shown in Table 1. As can be seen, the pollutant removal performance of 10 commonly-used practice designs have been tested less than four times. Consequently, we have less confidence in the computed removal rates for these practices. Perhaps the most critical gap in stormwater practice performance research exists for infiltration and bioretention practices, which, as of yet, have never been adequately monitored in the field. To some extent, the lack of performance monitoring reflects the fact that stormwater enters these practices in sheetflow and often leaves them by exfiltrating into the soil over a broad area. Since runoff is never concentrated, it is extremely difficult to collect representative samples of either flow or concentration that are needed to evaluate removal performance. This sampling limitation has also made assessment of filter strips problematic.

More research on the performance of water quality swales (i.e., dry swales and wet swales) appears warranted, because so few have been monitored, and the recorded removal rates are so different. The performance of other stormwater practices have not been scrutinized either because they are relatively new (i.e, organic filters and submerged gravel wetlands) or are smaller versions of frequently sampled practices (i.e., pocket wetlands and ponds).

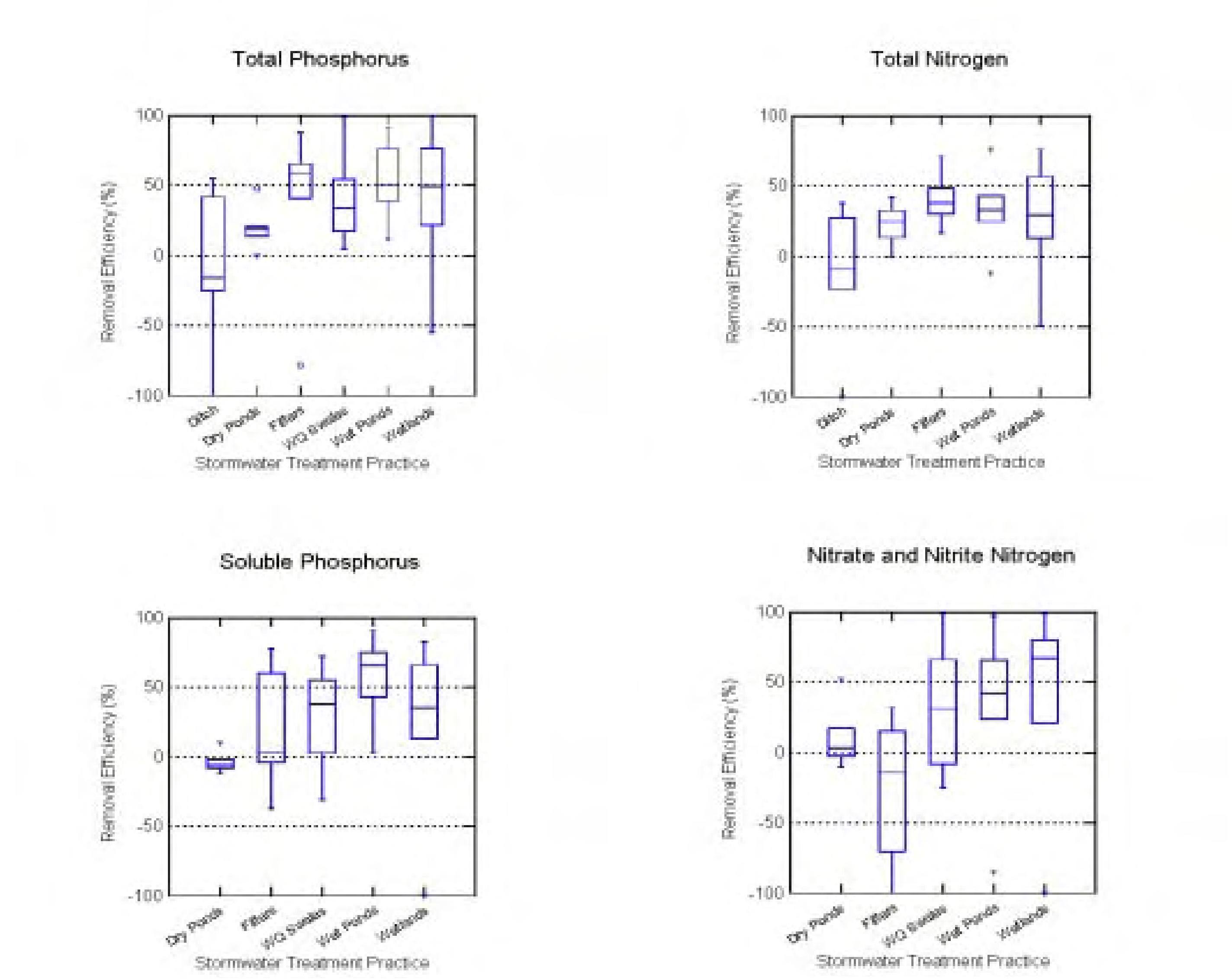
While ponds, wetlands, sand filters and open channels have been extensively monitored in the field (10 to 30 studies each), significant gaps exist with respect to individual stormwater parameters (Table 2). In particular, stormwater practice pollutant removal data is scarce with respect to bacteria, hydrocarbons, and dissolved metals. These three parameters have only been measured in 10 to 20% of all stormwater practice performance studies, despite their obvious implications for human health, recreation, and aquatic toxicity. A greater focus on these important parameters is warranted in future monitoring efforts.

Comparison of Stormwater Practice Pollutant Removal Performance

The comparative removal efficiency of stormwater practice groups is shown in Figures 1 and 2 for a series of commonly sampled parameters. These "box and whisker" plots depict the statistical distribution of removal rates: the "whiskers" show the minimum and maximum values, whereas the "box" delimits where half of all values lie (range between 25 and 75% quartile). Thus, the more compact the box, the less variable the data. The line inside the box denotes the median value. Medians and sample sizes are also shown in Tables 3 and 4.

As both plots clearly show, performance can be extremely variable for many parameters within a group of stormwater management practices. (This is in addition to similar variability frequently seen from storm to storm, within an individual stormwater practice). Consequently, estimates of stormwater practice performance should not be regarded as a fixed or constant value, but merely as a long-run average.

Figure 1: Comparative Distribution of Pollutant Removal Rates by Practice Group–Nutrients



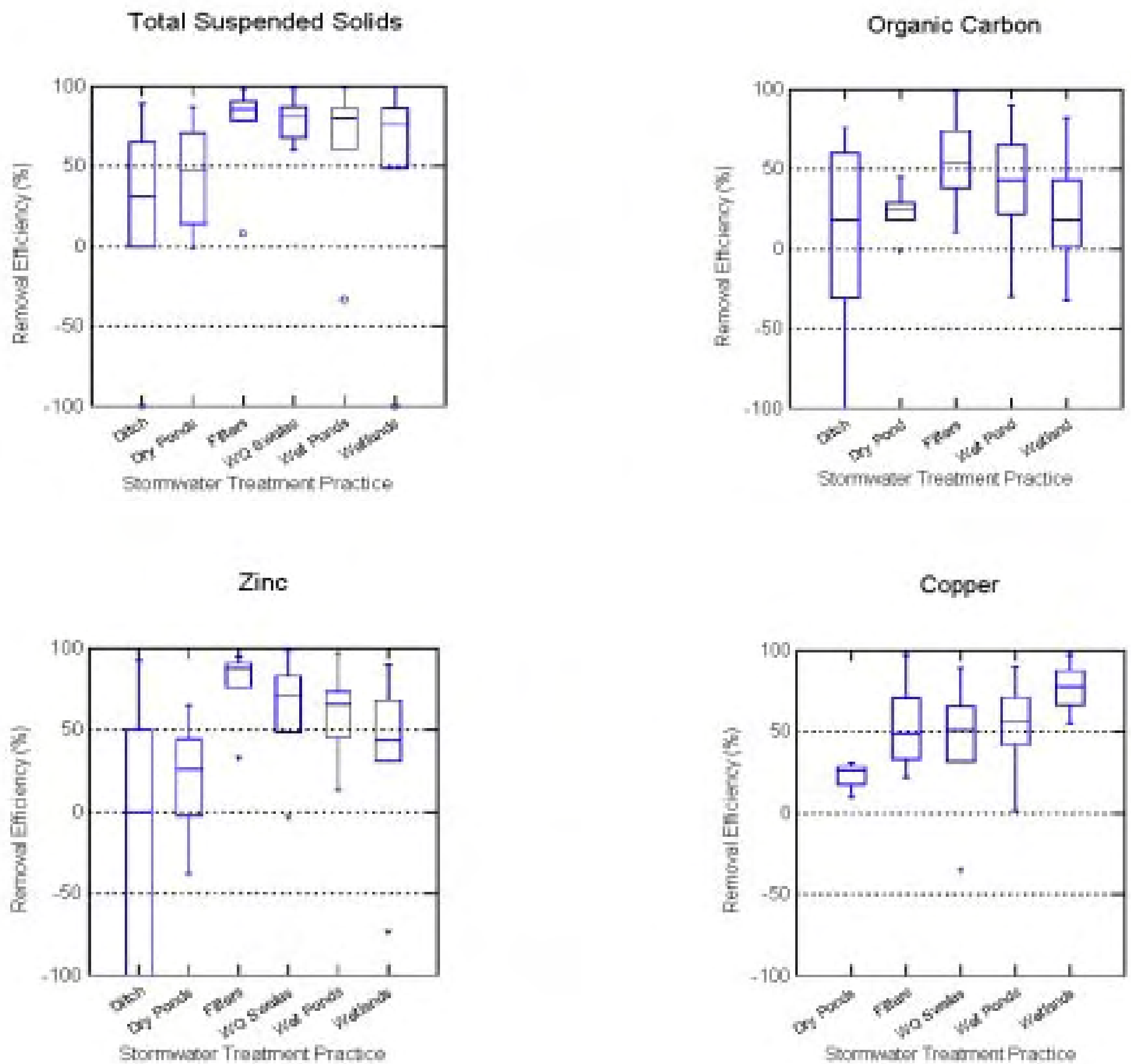
Phosphorus

While variable, most practice groups were found to have median removal rates in the 30 to 60% range for both soluble and total phosphorus. Once again, dry ponds and ditches showed low or negative ability to remove either phosphorus form. Interestingly, several practice groups exhibited very wide variation in phosphorus removal (e.g., note the large size of boxes for wetlands, water quality swales and sand filters). While sand filters were found to be effective in removing total phosphorus, they often exported soluble phosphorus.

Nitrogen

Most stormwater practice groups, on the other hand, showed a lower ability to remove total nitrogen, with typical median removal rates on the order 15 to 35%. In contrast to phosphorus, most practice groups showed relatively low variation in total nitrogen removal. The groups differed greatly in their ability to remove soluble nitrogen. In a broad sense, the stormwater practice groups could be divided into two categories: "nitrate leakers" and "nitrate-keepers." Nitrate leakers tend to have low or even negative removal of this soluble form of nitrogen, and included filters, ditches, and dry ponds. In these practices, organic nitrogen is converted to nitrate in the nitrification process, but conditions do not allow for subsequent denitrification. Thus, these "leakers" produce more nitrate than is delivered to them. Nitrate keepers tend to have moderate removal rates and include wet ponds, wet ED ponds and shallow marsh. In these practices, algal and other plants take up nitrate, and incorporate it into organic nitrogen. Thus, "keepers" tend to remove more nitrate than is delivered to them. Some practice groups, such as water quality swales and pond/wetland systems, exhibit such wide

Figure 2: Comparative Distribution of Pollutant Removal Rates for Practice Groups–TSS, Carbon, Zinc and Copper



variability, that it is likely that some practices are acting as nitrate leakers and others as nitrate keepers.

Suspended Sediment

Most stormwater practice groups exhibited a strong capability to remove suspended sediment, with median removals ranging from 60 to 85% for most groups. The highest median removal was noted for sand filters, water quality swales, infiltration practices, and shallow marsh systems (all slightly above 80%). Most pond and wetland designs approached but did not surpass the 80% TSS removal threshold specified in Costal Zone Act Reauthorization Amendments (CZARA) Section 6217 (g) guidance. Ditches exhibited the greatest variability, and had a median sediment removal rate of 31%.

Carbon

The ability of urban stormwater management practices to remove organic carbon or oxygen demanding material, while quite variable, was generally fairly modest, with median removal rates on the order of 20 to 40%. A notable exception was water quality swales, which exhibited median removal rates in excess of 65%. It should be noted that some variability in carbon removal rates could be due to the lumping of total organic carbon, BOD, and COD together.

Trace Metals

Most stormwater practice groups displayed a moderate to high ability to remove total lead, and zinc from urban runoff. Typical median removal rates were on the order of 50 to 80%. Exceptions included open

Table 3: Comparison of Median Pollutant Removal Efficiencies Among Selected Practice Groups: Conventional Pollutants

Practice Groups	N	Median Removal Rate For Stormwater Pollutants (%) TSS	TP	Sol P	Total N	NOx	Carbon
Detention Pond	3	7	19	0	5	9	8
Dry ED Pond	6	61	20	(-11)	31	(-2)	28
Wet Pond	29	79	49	62	32	36	45
Wet ED Pond	14	80	55	67	35	63	36
PONDS [a]	**44**	**80**	**51**	**66**	**33**	**43**	**43**
Shallow Marsh	23	83	43	29	26	73	18
ED Wetland	4	69	39	32	56	35	ND
Pond/Wetland	10	71	56	43	19	40	18
WETLANDS	**39**	**76**	**49**	**36**	**30**	**67**	**18**
Surface Sand Filters	8	87	59	(-17)	32	(-13)	67
FILTERS [b]	**19**	**86**	**59**	**3**	**38**	**(-14)**	**54**
INFILTRATION	**6**	**95**	**70**	**85**	**51**	**82**	**88**
WQ SWALES [c]	**9**	**81**	**34**	**38**	**84**	**31**	**69**
DITCHES	**11**	**31**	**(-16)**	**(-25)**	**(-9)**	**24**	**18**

N = Number of performance monitoring studies. The actual number for a given parameter is likely to be slightly less.
Sol P = Soluble phosphorus, as measured as ortho-P, soluble reactive phosphorus or biologically available phosphorus.
Total N = Total Nitrogen. Carbon= Measure of organic carbon (BOD, COD or TOC).
[a] Excludes conventional and dry ED ponds.
[b] Excludes vertical sand filters and vegetated filter strips.
[c] Includes biofilters, wet swales and dry swales.

Table 4: Median Stormwater Pollutant Removal Reported for Selected Practice Groups – Fecal Coliform Bacteria, Hydrocarbons and Selected Trace Metals

Practice Groups	Median Stormwater Pollutant Removal [d] Bacteria [e]	HC [f]	Cd	Copper	Lead	Zinc
Detention and Dry ED Ponds	78	ND	32%	26%	54%	26%
PONDS [a]	**70**	**81**	**50**	**57**	**74**	**66**
WETLANDS	**78**	**85**	**69**	**40**	**68**	**44**
FILTERS [b]	**37**	**84**	**68**	**49**	**84**	**88**
INFILTRATION	**ND**	**ND**	**ND**	**ND**	**98**	**99**
WQ SWALES [c]	**(-25)**	**62**	**42**	**51**	**67**	**71**
DITCHES	**5**	**ND**	**38**	**14**	**17**	**0**

[a] Excludes dry ED and conventional detention ponds.
[b] Excludes vertical sand filters and vegetated filter strips.
[c] Includes biofilters, wet swales and dry swale.
[d] N is less than 5 for some BMP groups for bacteria, TPH and Cd, and medians should be considered provisional.
[e] Bacteria values represent mean removal rates.
[f] HC = hydrocarbons measured as total petroleum hydrocarbons or oil/grease.

channels and dry ED ponds that were generally ineffective at promoting settling. Median copper removal rates ranged from 40 to 60%, with highest removals seen for the water quality swales, stormwater wet ponds, and filter groups. It should be noted that only 10% of all stormwater practice studies measured soluble metal removal which is widely thought to be a better indicator of potential aquatic toxicity than total metals (which includes metals that are tightly bound to particles). A quick review of the few studies that examined soluble metals suggests that while removal was usually positive, it was almost always lower than total metal removal.

Bacteria

The limited monitoring of fecal coliform did not allow for intensive statistical analysis of the effectiveness of stormwater practice groups in removing bacteria from urban runoff. Preliminary mean fecal coliform removal rates ranged from 65 to 75% for ponds and wetlands, and 55% for filters. Based on very limited data, ditches were found to have no bacteria removal capability, while water quality swales consistently exported bacteria. To put the removal data in perspective, a 95 to 99% removal rate is generally needed in most regions to keep bacteria levels under recreational water quality standards.

Hydrocarbons

The limited monitoring data available suggested that most stormwater practice groups can remove most petroleum hydrocarbons from stormwater runoff. For example, ponds, wetlands, and filters all had median removal rates on the order of 80 to 90%, and water quality swales were rated at 62%. In general, the ability of a practice group to remove hydrocarbons was closely related to its ability to remove suspended sediment. In nearly every case, hydrocarbon removal was within 15% of observed sediment removal.

Implications

This re-analysis of urban stormwater management practice performance has several implications for watershed managers. For the first time, there is enough data to select specific practice groups on the basis of their comparative ability to remove specific pollutants. A second implication is that the pond and wetland practice groups have similar removal capabilities, although the pollutant removal capability of wetlands appears to be more variable than ponds. Infiltration practices do appear to have the highest overall removal capability of any practice group, whereas dry ED ponds and ditches have extremely limited removal capability. Water quality swales show promise for some pollutants but not for biologically available phosphorus.

Significant gaps do exist in our knowledge in regard to the removal capability of certain practice designs and stormwater parameters. Filling these gaps should be the major focus of future stormwater practice monitoring research. For the more well-studied practice groups (ponds, wetlands, and filters) research should be re-directed to investigate internal factors (geometry, sediment/water column interactions, etc.) that can cause the wide variability in pollutant removal that is so characteristic of stormwater practice monitoring. Such research could be of great value in developing better design strategies to dampen pollutant removal variability, thereby improving reliability in achieving pollutant reduction goals at the watershed scale.

—TRS

References

Brown, W., and T. Schueler. 1997. *Final Report: National Performance Database for Urban BMPs.* Prepared for Chesapeake Research Consortium. Center for Watershed Protection. Silver Spring, MD. 208 pp.

Schueler, T. 1994. "Review of Pollutant Removal Performance of Stormwater Ponds and Wetlands." Technical Note 6. *Watershed Protection Techniques* 1(1): 17-18.

Schueler, T. 1996. "Irreducible Pollutant Concentrations Discharged from Urban BMPs." Technical Note 75. *Watershed Protection Techniques* 2(2): 369-371.

Strecker, E. 1992. "Pollutant Removal Perormance of Natural and Created Wetlands for Stormwater Runoff." Final Report to U.S. EPA. Woodward Clyde Consultants, Inc. Portland, OR. 112 pp.

Note: The Center updated its natural stormwater treatment database in 2000. While the comparative pollutant removal performance did not change greatly, the reader may want to consult this far more expanded database which is available from the Center.

Appendix E: Irreducible Pollutant Concentrations Discharged from STPs

Technical Note #75 from Watershed Protection Techniques. 2(2): 369-372

Irreducible Pollutant Concentrations Discharged From Stormwater Practices

Load reduction has traditionally been the criteria used to evaluate the performance of urban stormwater management practices. Simply put, the mass of stormwater pollutants entering a practice are compared against the mass leaving it (over a suitable time frame), and a percent removal efficiency is quickly computed. While load reduction is a useful criteria to compare the relative performance of different practices, it does have some limits. For example, it tells us very little about the concentration of pollutants leaving the practice. Outflow concentrations can be of considerable interest to a watershed manager. For example, is there a background level or irreducible concentration of stormwater pollutants discharged downstream that represents the best that can be achieved with current technology?

The concept of irreducible concentrations has been explicitly recognized for some years in process models used to design of wastewater treatment wetlands (Kadlec and Knight, 1996; Reed, 1995). The consensus of expert opinion is that surface flow wastewater wetlands cannot reduce sediment and nutrient concentrations beyond the rather low levels indicated in Table 1, no matter how much more surface area or treatment volume is provided.

Figure 1 illustrates the effect of an irreducible concentration on the treatment efficiency of a hypothetical stormwater practice. When incoming pollutant concentrations are moderate to high, for example, an increase in a treatment variable (such as area or volume) will result in a proportional reduction in the concentration of a pollutant leaving the practice (line A). If, however, the incoming pollutant concentration approaches the irreducible concentration, (denoted as C-star), it is not possible to change the outflow concentration very much, regardless of how much additional treatment is provided (line B). Indeed, when the incoming concentration is equal to or falls below the irreducible concentration, it is possible to experience negative removal, i.e., an increase pollutant concentration as it passes through the practice (line C).

Why do irreducible concentrations exist? To begin with, they often represent the internal production of nutrients and turbidity within a pond or wetland, due to biological production by microbes, wetland plants and algae. Some of these internal processes inevitably return some pollutants back into the water column, where they may be displaced during the next storm event. In other cases, the irreducible concentration may simply reflect the limitations of a particular removal pathway utilized in a stormwater practice. For example, a practice that relies heavily on sedimentation for removal can have a relatively high C*. This is evident in the settling column data presented in Figure 2 developed by Grizzard *et al.* (1986). When sedimentation is the sole removal pathway, the removal rates for a range of pollutants eventually become asymptotic, no matter much more detention time is provided.

Does a C* exist for pollutants controlled by urban stormwater practices? Two recent studies suggest that irreducible concentrations do indeed exist. In the first study, Kehoe and his colleagues systematically analyzed the quality of stormwater in a series of 36 stormwater ponds and wetlands located in the greater Tampa Bay, Florida area. Researchers characterized the sediment, metal and dissolved oxygen content of water discharged from stormwater wet ponds (N=24) and pond/wetland systems (N=12) over a two-year period. Grab samples were collected from each site one to three days after storms occurred to represent post-storm discharges.

A summary of the study results are shown in Table 2 for the wet ponds and pond/wetland systems. Outflow TSS levels were remarkably consistent, at slightly less than 10 mg/l. Dissolved oxygen levels tended to be more variable, with slightly lower oxygen levels reported in wetland systems than ponds. Similarly, pH levels of pond/wetland systems were slightly more acidic than pond systems, presumably due to the greater amount of organic matter that accumulated in the wetlands. The

Table 1: Irreducible Concentrations in Wastewater Wetlands and Stormwater Management Practices

Water Quality Parameter (mg/l)	**Wastewater** *(Kadlec and Knight 1996)*	**Wastewater** *(Reed 1995)*	**Stormwater** Practices *(this study)*
Total Suspended Solids	2 to 15	8	20 to 40
Total Phosphorus	0.02 to 0.07	0.5	0.15 to 0.2
Total Nitrogen	1.0 to 2.5	1.0	1.9
Nitrate-Nitrogen	0.05	0.00	0.7
TKN	1.0 to 2.5	1.0	1.2

Figure 1: Effect of the Irreducible Concentration on Treatment Variables

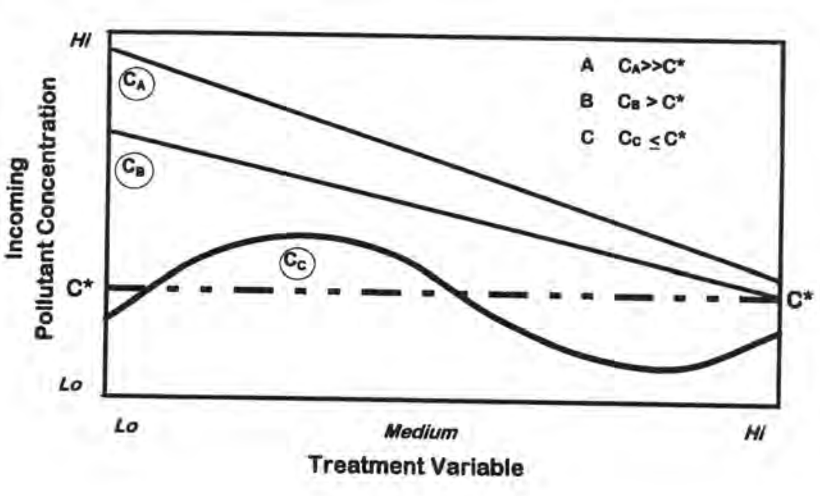
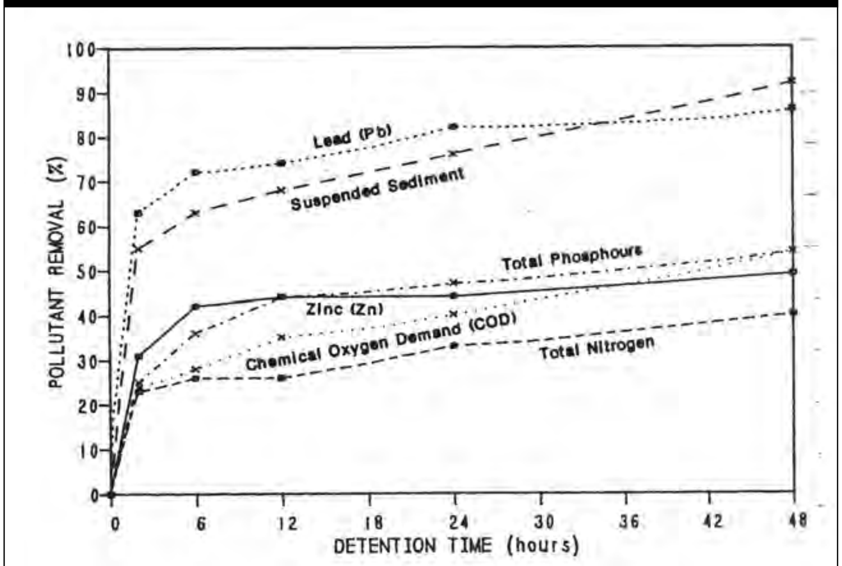


Figure 2: Removal Rate vs. Detention Time for a Series of Stormwater Pollutants (Grizzard *et al.*, 1986)



majority of the monitoring data was for the metals (cadmium, chromium, copper, lead, nickel and zinc). While detection limit problems complicated the metal analysis, most metals were occasionally detected in pond outflows, sometimes at levels exceeding Florida metal criteria.

In the second study, this author analyzed published event mean concentrations (EMCs) in the outflows of 42 stormwater practices that had been subject to intensive performance monitoring. These post-NURP stormwater practice monitoring studies were conducted in many geographic regions (FL, TX, WA, MN, WI, MD, VA, CT, CO and New Zealand), and encompassed four broad types of practices: stormwater ponds, wetlands, filtering systems, and grassed channels. For each type of practice, a group mean and standard deviation was computed based on the mean storm outflow concentrations of sediment and nutrients reported in each individual study (N ranged from three to 16) The results of the analysis are shown in Tables 3 to 6. Unlike the earlier study, these concentrations represent mean storm outflow concentrations (i.e., the partial or full displacement of runoff from the stormwater practice).

As can be seen in the tables, stormwater practice outflow concentrations exhibit a rather remarkable consistency within and among the four groups of stormwater practices, as typified by the fairly narrow range in both the computed mean and standard deviation. Interestingly, very little difference was observed in the group means of stormwater ponds and wetlands, particularly for most forms of nitrogen and phosphorus. In general, mean outflow concentrations were slightly lower for filtering systems, and somewhat higher for grass channels (this may reflect the mediocre performance of grass channels, as described in article 116). The one nitrogen form that did exhibit considerable variability in mean outflow concentrations among the four practice groups was nitrate-nitrogen. Nitrate outflow concentrations were greatest for filtering systems, intermediate for wet ponds and grassed channels, and lowest for stormwater wetlands. At the same time, total nitrogen concentrations were very consistent among the four groups of stormwater practices (1.6 to 1.9 mg/l). This result suggests that the four practice groups may differ in their internal rates of nitrification (that produces nitrate) and denitrification (that eliminates nitrate).

Based on this analysis, a preliminary estimate of the "irreducible" concentration of pollutants in stormwater practice outflows is suggested in Table 1. In general, the nutrient values are in the same range as those previously developed for wastewater wetlands, although the sediment concentrations are approximately two to four times higher.

Implications

The apparent existence of irreducible pollutant concentrations after stormwater treatment has several important ramifications for urban watershed managers. For example, an irreducible concentration can represent a real threshold for cumulative watershed impacts. The data suggests that a background storm phosphorus concentration of 0.10 to 0.15 mg/l is probably the lowest concentration that can be achieved through stormwater treatment, even when stormwater practices are widely applied and maintained. For some sensitive lake regions, this phosphorus level may still be too high to effectively prevent the onset of eutrophication.

Another ramification of irreducible concentrations relates to multiple stormwater practice systems. Some communities require that a series of practices be constructed to achieve a load reduction target of 80 or 90% removal. The existence of an irreducible concentration suggests that there are some practical limits to improving treatment efficiency with additional stormwater practices after a certain point. Quite simply, if the first practice reduces the pollutant concentration to near the irreducible concentration, it is not likely that a second or third practice will result in any further improvement.

Lastly, the existence of irreducible concentrations can help to interpret some of the notorious variability frequently seen in stormwater practice pollutant removal monitoring data. In many cases, the removal rate for a practice changes with each storm event. Some practices also exhibit wide variability in pollutant removal rates, even when their treatment volumes are similar. In both cases, a mediocre percentage pollutant removal may simply be a result of incoming pollutant concentrations that are very close to the irreducible concentration (and consequently, cannot be reduced much further). Consequently, investigators may want to look closely at their mean inflow concentrations before they assume poor performance is due to poor design or inadequate sampling.

While the concept of an irreducible concentration is an intriguing one, more outflow monitoring is needed to definitively characterize it for many stormwater practices. In particular, data are lacking on outflow concentrations for several key stormwater pollutants, such as bacteria and hydrocarbons. Based on these two studies, however, it is clear that there is a limit to stormwater treatment efficiency. Although the limit remains relatively low, both managers and regulators should keep it in mind when devising watershed protection or restoration programs.

-TRS

Note: The Center has developed more extensive statistics on the irreducible concentrators of a greater number of stormwater practices in its 2000 update of the national stormwater treatment database, which is available from the Center.

Table 2: Water Chemistry of Stormwater Pond and Wetlands in Tampa Bay, Florida (Kehoe, 1993 and Kehoe *et al.,* 1994)

Parameter (Units)	**Stormwater Ponds** N = 24 (236)	**Pond/Wetlands** N = 12 (83)
TSS (mg/l)	8.8 ± 11.4	9.1 ± 12.1
DO (mg/l)	5.7 ± 2.8	4.1 ± 3.8
pH	7.2	6.7 ± 0.9
Cadmium* (µg/l)	3 ± 6	6 ± 7
Chromium* (µg/l)	12 ± 26	5 ± 3
Copper* (µg/l)	16 ± 25	10 ± 10
Lead* (µg/l)	12 ± 28	BDL
Nickel* (µg/l)	9 ± 36	BDL
Zinc* (µg/l)	37 ± 73	33 ± 30
Water temperature (°C)	22.8	23.7

Notes: Grab samples taken 1 to 3 days following storm
Means plus or minus one standard deviation
N = Sites sampled (Total Samples all Sites)
BDL = Below detection limits
* Wide standard deviations may reflect detection limit problems for metals

Table 3: Mean Storm Outflow Concentrations From Stormwater Wetlands (Leersnyder, 1994; Rushton, 1995; Urbonas *et al.,* 1994; Oberts 1990, 1992; OWML, 1988, 1990; Athanas *et al.,* 1989; Martin, 1988; City of Baltimore, 1988; Barten, 1988; and Reinelt *et al.,* 1990.)

Parameter	**N**	**Concentration (mg/l)**
Total Suspended Solids	15	32 ± 25.8
Total Phosphorus	16	0.19 ± 0.13
Ortho-Phosphorus	14	0.08 ± 0.04
Total Nitrogen	11	1.63 ± 0.48
Total Kjeldahl Nitrogen	11	1.29 ± 0.43
Nitrate-Nitrogen	11	0.35 ± 0.28

Notes: Group means plus or minus one standard deviation

Table 4: Mean Storm Outflow Concentrations From Wet and Extended Detention Ponds (Urbonas *et al*., 1995; Oberts and Osgood, 1989; Yousef *et al.,* 1989; City of Austin, 1990; Stanley, 1994; Martin, 1988; and Dorfman *et al*., 1989)

Parameter	**N**	**Concentration (mg/l)**
Total Suspended Solids	11	35.0 ± 19.0
Total Phosphorus	11	0.22 ± 0.12
Ortho-Phosphorus	6	0.08 ± 0.04
Total Nitrogen	11	1.91 ± 0.56
Total Kjeldahl Nitrogen	11	1.21 ± 0.36
Nitrate-Nitrogen	11	0.70 ± 0.36

Notes: Group means plus or minus one standard deviation

Table 5: Storm Outflow Concentrations From Stormwater Filtering Systems (Sand Filters and Compost Filters) (Horner, 1995; City of Austin, 1990; Bell, 1995; CSF, 1994)

Parameter	N	Concentration (mg/l)
Total Suspended Solids	10	19.3 ± 10.1
Total Phosphorus	10	0.14 ± 0.13
Ortho-Phosphorus	ND	–
Total Nitrogen	6	1.93 ± 1.02
Total Kjeldahl Nitrogen	6	0.90 ± 0.52
Nitrate-Nitrogen	6	1.13 ± 0.55

Notes: Group means plus or minus one standard deviation

Table 6: Storm Outflow Concentrations From Grass Drainage Channels (Harper, 1987 and Dorfman et al., 1989)

Parameter	N	Concentration (mg/l)
Total Suspended Solids	5	43.4 ± 47.0
Total Phosphorus	5	0.33 ± 0.15
Ortho-Phosphorus	3	0.16
Total Nitrogen	5	1.74 ± 0.71
Total Kjeldahl Nitrogen	5	1.19 ± 0.41
Nitrate-Nitrogen	5	0.55 ± 0.29

Notes: Group means plus or minus one standard deviation
The limited number of studies available limits the accuracy of the estimates

References

Grizzard, T, C. Randall, B. Weand, and K. Ellis. 1986. "Effectiveness of Extended Detention Ponds." in *Urban Runoff Quality-Impact and Quality Enhancement Technology*. B. Urbonas and L. Roesner (editor). American Society of Civil Engineers. New York, NY. pp. 323-338.

Kadlec, R and R. Knight. 1996. *Treatment Wetlands*. CRC Press and Lewis Publishers. Boca Raton, FL. 894 pp.

Kehoe, M. J. 1993. *Water Quality Survey of Twenty-Four Stormwater Wet Detention Ponds - Final Report*. Southwest Florida Water Management District. Brooksville, FL. 84 pp.

Kehoe, M, C. Dye and B. Rushton. 1994. *A Survey of Water Quality of Wetlands-Treatment Stormwater Ponds.* Southwest Florida Water Management District. Brooksville, FL. 40 pp.

Reed, S. 1995. *Surface Flow Wetlands: A Technology Assessment.* USEPA. Office of Wastewater. Washington, DC.