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**Pennsylvania Stormwater  
Best Management Practices  
Manual**

DRAFT - JANUARY 2005

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**Appendix A - Water Quality**

**Pollutant Event Mean  
Concentrations by Land Cover &  
BMP Pollutant Removal Efficiencies**

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## **Pollutant Event Mean Concentrations by Land Cover**



Table A-1. Event Mean Concentrations (EMCs) For Total Suspended Solids

LAND COVER CLASSIFICATION	TSS EMC (mg/l)	SOURCES	COMMENTS
Forest	39	B, G, M	---
Meadow	47	B, N	---
Fertilized Planting Area	55	Q, R	R: "Residential" area had considerable mulched areas
Native Planting Area	55	Q, R	R: "Residential" area had considerable mulched areas
Lawn, Low-Input	180	C, O, Q, R	Median of four values
Lawn, High-Input	180	C, O, Q, R	Median of four values
Golf Course Fairway/Green	305	M, R	Average of two values
Grassed Athletic Field	200	M, N	Average of two values
Rooftop	21	Q, S, V	Average of Residential, Commercial, and Industrial Roofs
High Traffic Street / Highway	261	E, F, H, P, Q	Median of five values
Medium Traffic Street	113	A, B, H, I, J, P, Q	Median of seven values
Low Traffic / Residential Street	86	E, P, Q	Average of three values
Res. Driveway, Play Courts, etc.	60	M	"Urban Recreation"
High Traffic Parking Lot	120	J, N, Q	Median of three values
Low Traffic Parking Lot	58	I, M, N, Q	Median of 4 values w/ "comm.", "indust.", "parking" & "comm/res."

Pervious Surfaces

Impervious Surfaces

Table A-2. Event Mean Concentrations (EMCs) For Total Phosphorous

LAND COVER CLASSIFICATION	TP EMC (mg/l)	SOURCES	COMMENTS
Pervious Surfaces	Forest	B, I, J, M, R, X	---
	Meadow	F, W	Value from F, W reported no soluble phosphorus from meadow
	Fertilized Planting Area	F	Study indicated highly maintained landscapes in "High Density Resid."
	Native Planting Area	F, W	W had no soluble P from mulch, assumed equivalent to low-input lawn
	Lawn, Low-Input	F	Value for "Low Density Residential"
	Lawn, High-Input	K, L, S, V	Median of four values
	Golf Course Fairway/Green	R	---
	Grassed Athletic Field	R	No data found, assumed equivalent to golf course
	Rooftop	L, S, V	Median of three values
	High Traffic Street / Highway	L, P, S	Median of 3 values including "Arterial St." and "Urban St."
Impervious Surfaces	Medium Traffic Street	I, L, M, X	Median of 4 values including "Transportation"
	Low Traffic / Residential Street	L, P, S, V	Median of 4 values including "Feeder St." and "Rural Rd."
	Res. Driveway, Play Courts, etc.	L, M, S, V	Median of 4 values including "Urban Recreation"
	High Traffic Parking Lot	S	---
	Low Traffic Parking Lot	N, S, V	Median of three values

Table A-3. Event Mean Concentrations (EMCs) For Nitrate

LAND COVER CLASSIFICATION	Nitrate-Nitrite EMC (mg/l as N)	SOURCES	COMMENTS
Forest	0.17	J	---
Meadow	0.3	B	EMC for TN adjusted
Fertilized Planting Area	0.73	F, R	Studies indicated mulched areas & highly maintained landscapes
Native Planting Area	0.33	T	Assumed equivalent to turfgrass w/o chemical treatment
Lawn, Low-Input	0.44	T, U, W	Based on studies of lawn runoff and leachate
Lawn, High-Input	1.46	C, T, U	Median of 3 studies in T and NURP data in C - consistent with U
Golf Course Fairway/Green	1.84	M, R, U	Average of 3 values including one study of leachate
Grassed Athletic Field	1.01	M	---
Rooftop	0.32	L, U	---
High Traffic Street / Highway	0.83	D, F, I, L, P	Median of five values
Medium Traffic Street	0.58	D, I, L, P	Median of four values
Low Traffic / Residential Street	0.47	V	EMC for TN adjusted
Res. Driveway, Play Courts, etc.	0.47	V	Assumed equivalent to residential street
High Traffic Parking Lot	0.60	F	Value reported for "Retail"
Low Traffic Parking Lot	0.39	C, F, L	Median of 3 values after EMC for TN adjusted

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## **BMP Pollutant Removal Efficiencies - Percent Efficiency**



Table A-4 Summary of Pollutant Removal Percent Efficiencies of Stormwater BMPs

<b>COMPREHENSIVE BMP LIST</b>			
	<b>Pollutant Removal Efficiency %</b>		
	<b>TSS</b>	<b>TP</b>	<b>NO<sub>3</sub></b>
<b>Non-Structural BMP</b>			
5.1 Protect Sensitive / Special Value Features	SC	SC	SC
5.2 Protect / Conserve / Enhance Riparian Areas	SC	SC	SC
5.3 Protect / Utilize Natural Flow Pathways in Overall Stormwater Planning and Design	30	20	0
5.4 Cluster Uses at Each Site; Build on the Smallest Area Possible	SC	SC	SC
5.5 Concentrate Uses Areawide through Smart Growth Practices	SC	SC	SC
5.6 Minimize Total Disturbed Area - Grading	40	0	0
5.7 Minimize Soil Compaction in Disturbed Areas	30	0	0
5.8 Re-vegetate and Re-forest Disturbed Areas using Native Species	85	85	50
5.9 Reduce Street Imperviousness	SC	SC	SC
5.10 Reduce Parking Imperviousness	SC	SC	SC
5.11 Rooftop Disconnection	30	0	0
5.12 Disconnection from Storm Sewers	30	0	0
5.13 Streetsweeping	85	85	50
<b>Structural BMP</b>			
6.1 Porous Pavement with Infiltration Bed	85	85	30
6.2 Infiltration Basin	85	85	30
6.3 Subsurface Infiltration Bed	85	85	30
6.4 Infiltration Trench	85	85	30
6.5 Rain Garden / Bioretention	85	85	30
6.6 Dry Well / Seepage Pit	85	85	30
6.7 Constructed Filter	85	85	30
6.8 Vegetated Swale	50	50	20
6.9 Vegetated Filter Strip	30	20	10
6.10 Infiltration Berm and Retentive Grading	60	50	40
6.11 Vegetated Roof	85	85	30
6.12 Rooftop Runoff - Capture and Reuse	100	100	100
6.13 Constructed Wetland	85	85	30
6.14 Wet Pond / Retention Basin	70	60	30
6.15 Dry Extended Detention Basin	60	40	20
6.16 Water Quality Filter	60	50	20
6.17 Riparian Buffer Restoration	65	50	50
6.18 Landscape Restoration	85	85	50
6.19 Soils Amendment and Restoration	85	85	50
6.20 Level Spreader	20	10	5
6.21 Special Detention Areas - Parking Lot, Rooftop	0	0	0

SC, Self Crediting: The BMP reduces the pollutant load, thus is self-crediting. BMPs with this designation are labeled as "**Preventive**" in Section 5.

\*\* All values shown represent professional interpretation, based on best available data as provided in Appendix A. \*\*

Table A-5 Pollutant Removal Percent Efficiencies of Stormwater BMPs

Type	Pollutant Removal % Efficiency						TP	Primary Source	Secondary Source	Comments
	TSS	TN	NO <sub>3</sub>	NO <sub>x</sub>	TKN					
Biweekly Sweeping	40-60					20-40	Kurahashi & Associates, Inc. 1997. Port of Seattle - Stormwater Treatment BMP Evaluation. Prepared for the Port of Seattle, Pier 66. Prepared by Kurahashi & Associates, in association with AGI Technologies.	Federal Highway Administration (FHWA). "Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring - Monitoring Case Study-Street Sweeping BMP Evaluation, Port of Seattle, Washington." U.S. Department of Transportation.	Land Use = cargo container yards	
Weekly Sweeping	45-65					30-55	Kurahashi & Associates, Inc. 1997. Port of Seattle - Stormwater Treatment BMP Evaluation. Prepared for the Port of Seattle, Pier 66. Prepared by Kurahashi & Associates, in association with AGI Technologies.	Federal Highway Administration (FHWA). "Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring - Monitoring Case Study-Street Sweeping BMP Evaluation, Port of Seattle, Washington." U.S. Department of Transportation.	Land Use = cargo container yards	
Twice Weekly Sweeping	45-70					35-60	Kurahashi & Associates, Inc. 1997. Port of Seattle - Stormwater Treatment BMP Evaluation. Prepared for the Port of Seattle, Pier 66. Prepared by Kurahashi & Associates, in association with AGI Technologies.	Federal Highway Administration (FHWA). "Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring - Monitoring Case Study-Street Sweeping BMP Evaluation, Port of Seattle, Washington." U.S. Department of Transportation.	Land Use = cargo container yards	
Vacuum-assisted sweeper efficiency	42	77				74	NVPDC. 1992. Northern Virginia BMP Handbook: A Guide to Planning and Designing Best Management Practices in Northern Virginia. Prepared by Northern Virginia Planning District Commission (NVPDC) and Engineers and Surveyors Institute.	Federal Highway Administration (FHWA). "Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring: Fact Sheet Street Sweepers." U.S. Department of Transportation.		
Mechanical Sweeper	55	42				40	NVPDC. 1992. Northern Virginia BMP Handbook: A Guide to Planning and Designing Best Management Practices in Northern Virginia. Prepared by Northern Virginia Planning District Commission (NVPDC) and Engineers and Surveyors Institute.	Federal Highway Administration (FHWA). "Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring: Fact Sheet Street Sweepers." U.S. Department of Transportation.		
<b>RANGE</b>	<b>40 - 70</b>	<b>42 - 77</b>				<b>20 - 74</b>				

## 6.1 POROUS PAVEMENT

Type	Pollutant Removal % Efficiency					TKN	TP	Secondary Source	Comments
	TSS	TN	NO <sub>3</sub>	NO <sub>x</sub>	NO <sub>x</sub>				
Porous Pavement	80	80							
Porous Pavement	95	88							
Porous Pavement	82	80			65		Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection, Ellicott City, MD.	# of storms = 13; STP Size = 0.553acres; Percent efficiency calculated using mass efficiency method.	
Porous Pavement	95	85			65		Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection, Ellicott City, MD.	Percent efficiency calculated using mass efficiency method.	
Porous Pavement	97				94		Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection, Ellicott City, MD.	*Asphalt void volume 22%; # of storms = 9	
Porous Pavement	95	82					Schueler, T.R. 1987. Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMP's. Metropolitan Washington Council of Governments. Department of Environmental Programs.		
Porous Pavement	65-100	65-100			30-65		USEPA. 1999. Preliminary Data Summary of Urban Stormwater BMPs.		
<b>RANGE</b>	<b>65-100</b>	<b>65-100</b>			<b>30 - 94</b>				

## 6.2 INFILTRATION BASIN

Type	Pollutant Removal % Efficiency					TKN	TP	Secondary Source	Comments
	TSS	TN	NO <sub>3</sub>	NO <sub>x</sub>	NO <sub>x</sub>				
Infiltration Basin	95	65							
Infiltration Basin	75	45 - 55			50 - 55		FHWA, 1999. Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring. Federal Highway Administration, U.S. Department of Transportation.	Capture of 12.7 mm (0.5 in) of runoff (first flush)	
Infiltration Basin	99	60 - 70			65 - 75		FHWA, 1999. Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring. Federal Highway Administration, U.S. Department of Transportation.	Capture of 25.4 mm (1 in) of runoff	
Infiltration Basin	90	55 - 60			60 - 70		FHWA, 1999. Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring. Federal Highway Administration, U.S. Department of Transportation.	Capture of 50.8 mm (2 in) of runoff	
Infiltration Basin	50-80	50-80			50-80		USEPA. Preliminary Data Summary of Urban Storm Water Best Management Practices. Aug. 1999.		
<b>RANGE</b>	<b>50 - 99</b>	<b>45 - 80</b>			<b>50 - 80</b>				

6.3 SUBSURFACE INFILTRATION BED

Type	Pollutant Removal % Efficiency					TKN	TP	Primary Source	Secondary Source	Comments
	TSS	TN	NO <sub>3</sub>	NO <sub>x</sub>						
Subsurface Infiltration Bed	90	60	27					Cahill Assoc. Technical BMP Manual & Infiltration Feasibility Report. Infiltration of Stormwater in Areas Underlain by Carbonate Bedrock within the Little Lehigh Creek Watershed. Nov 2002.		
Subsurface Infiltration Bed	95	51				70		Chester County Conservation District. <i>Chester County Stormwater BMP Tour Guide: Infiltration Beds</i> . 2002.		
<b>RANGE</b>	<b>90 - 95</b>	<b>51 - 60</b>	<b>27</b>			<b>70</b>				

6.4 INFILTRATION TRENCH

Type	Pollutant Removal % Efficiency					TKN	TP	Primary Source	Secondary Source	Comments
	TSS	TN	NO <sub>3</sub>	NO <sub>x</sub>						
Infiltration Trench		3.4	100		-12.3	4.5		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.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection. Ellicott City, MD.	"49.5 hours detention time", soil type = loam; Percent efficiency calculated using event mean concentration (EMC) efficiency method.
Infiltration Trench		42.3	-100		100	100		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.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection. Ellicott City, MD.	"47.75 hours detention time", soil type = sandy, loam; Percent efficiency calculated using event mean concentration (EMC) efficiency method.
Infiltration Trench		50.5	82		70.1	100		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.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection. Ellicott City, MD.	"51.5 hours detention time", soil type = sandy; Percent efficiency calculated using event mean concentration (EMC) efficiency method.
Infiltration Trench	50-80	50-80				15-45		USEPA. <i>Preliminary Data Summary of Urban Storm Water Best Management Practices</i> . Aug 1999.	United States Environmental Protection Agency (USEPA). <i>Storm Water Technology Fact Sheet: Infiltration Trench</i> (EPA 832-F-99-019). 1999.	
Infiltration Trench	90	60						Schueler, T.R., 1992. A Current Assessment of Urban Best Management Practices. Metropolitan Washington Council of Governments.		
W/Q Trench	75	45 - 55				50 - 55		Schueler, T. 1987. Controlling urban runoff – a practical manual for planning and designing urban best management practices. Metropolitan Washington Council of Governments, Washington, DC.	FHWA. 1999. <i>Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring</i> . Federal Highway Administration, U.S. Department of Transportation.	Capture of 12.7 mm (0.5 in) of runoff (first flush)
W/Q Trench	90	55 - 60				55 - 60		Schueler, T. 1987. Controlling urban runoff – a practical manual for planning and designing urban best management practices. Metropolitan Washington Council of Governments, Washington, DC.	FHWA. 1999. <i>Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring</i> . Federal Highway Administration, U.S. Department of Transportation.	Capture of 50.8 mm (2 in) of runoff
<b>RANGE</b>	<b>50 - 90</b>	<b>3.4 - 80</b>	<b>(-100) - 100</b>		<b>(-12.3) - 100</b>	<b>4.5 - 100</b>				



## 6.5 RAIN GARDEN / BIORETENTION

Type	Pollutant Removal % Efficiency					TP	TKN	Secondary Source	Comments
	TSS	TN	NO <sub>3</sub>	NO <sub>x</sub>					
Rain Garden	53	49	16						
Rain Garden	87							Low Impact Development Center. "Watershed Benefits of Bioretention Techniques". <a href="http://www.id-stormwater.net/bioreten/bio_benefits.htm">http://www.id-stormwater.net/bioreten/bio_benefits.htm</a> . Accessed: December 13, 2002.	
Rain Garden		57						Tetra Tech, Inc., 2003. Mecklenburg County Site Evaluation Tool Model Documentation.	
Rain Garden	91		-16		63			Hsieh, C. and A.P. Davis. Multiple-event Study of Bioretention for Treatment of Urban Storm Water Runoff. 2003. Percent efficiency calculated using mass efficiency method.	
Rain Garden	90							United States Environmental Protection Agency (USEPA). <i>Storm Water Technology Fact Sheet: Bioretention</i> (EPA 832-F-99-012). 1999.	
<b>RANGE</b>	<b>53 - 91</b>	<b>49 - 57</b>	<b>(-16) - 16</b>		<b>63</b>				

## 6.6 DRY WELL / SEEPAGE PIT

Type	Pollutant Removal % Efficiency					TP	TKN	Secondary Source	Comments
	TSS	TN	NO <sub>3</sub>	NO <sub>x</sub>					
Dry Well	50-80	50-80			15-45			USEPA. Preliminary Data Summary of Urban Storm Water Best Management Practices. Aug. 1999.	
<b>RANGE</b>	<b>50 - 80</b>	<b>50 - 80</b>			<b>15 - 45</b>				

## 6.7 CONSTRUCTED FILTER

Type	Pollutant Removal % Efficiency					TP	TKN	Secondary Source	Comments
	TSS	TN	NO <sub>3</sub>	NO <sub>x</sub>					
Filtering Practice	48				-78.5			Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection. Ellicott City, MD.	# of storms = 8; Drainage area = 0.69acres; "Filter is 12" deep"; Percent efficiency calculated using event mean concentration (EMC) efficiency method.
Organic Filter	98			32	88			Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = City Maintenance yard (pavement); %Impervious Cover = 100%; "treatment provided for the first 1/2in of runoff. (80% of the annual water load)"; # of storms = 5; Percent efficiency calculated using event mean concentration (EMC) efficiency method.
Organic Filter	88				47			Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = Large parking lot; % Impervious Cover = 82%; "Peat/sand filter media wit surface ED. Retrofit. Site. Steep Slopes. Retention Capacity calculated using event mean concentration (EMC) efficiency method.
Organic Filter	90				73			Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = Large parking lot; % Impervious Cover = 82%; "Peat/sand filter media wit surface ED. Retrofit. Site. Steep Slopes. Retention Capacity calculated using mass efficiency method.

6.7 CONSTRUCTED FILTER (cont.)

Type	Pollutant Removal % Efficiency						TKN	TP	Comments
	TSS	TN	NO <sub>3</sub>	NO <sub>x</sub>	TKN	TP			
Organic Filter	83		14			80		Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection, Ellicott City, MD. Land Use = Parking Lot, vehicle service area, Treatment provided for 0.25-0.8in of rain; # of storms = 14; Percent efficiency calculated using event mean concentration (EMC) efficiency method.	
Organic Filter	85					80		Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection, Ellicott City, MD. Land Use = Commercial Parking Lot; # of storms = 7; Drainage area = 2.5 acres; Percent efficiency calculated using event mean concentration (EMC) efficiency method.	
Organic Filter	95		-34			41		Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection, Ellicott City, MD. Land Use = 95% Residential, rest roadway; # of storms = 7; Drainage area = 73.9; "Compost media filter"; Percent efficiency calculated using event mean concentration (EMC) efficiency method.	
Organic Media Filters	92		-145		57	49		US Department of Transportation, Federal Highway Administration. "Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring. Fact Sheet - Organic Media Filters."	
Other Media Filters	65-100	15-45				<30		"3-year results for CSF@ Type I system"	
Packed Bed Filter	81	63	75					Center for Watershed Protection. <i>Design of Stormwater Filtering Systems</i> . Dec 1996. (pg 4-8)	
Sand Filter	98		64		65	66		Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection, Ellicott City, MD. Land Use = 67% Highway/33% Commercial; Drainage area = 82.95 acres; # of storms = 10; Treatment Vol = first 0.5in of runoff; Percent efficiency calculated using mass efficiency method.	
Sand Filter	79	47	-53.3		70.6	65.5		Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection, Ellicott City, MD. Land Use = Parking Lot; STP Size = 477.6ft <sup>3</sup> ; Drainage area = 0.7 acres; # of storms = 20; "Perimeter sand filter"; Percent efficiency calculated using mass efficiency method.	
Sand Filter	86	31	-5		48	19		Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection, Ellicott City, MD. Land Use = Multi-family housing; Impervious Cover = 50%; # of storms = 18; Drainage area = 3.1 acres; Treatment Vol = 0.5in; "Surface sand filter"; Percent efficiency calculated using mass efficiency method.	
Sand Filter	87	32	-79		62	61		Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection, Ellicott City, MD. Land Use = Road; Impervious Cover = 81%; # of storms = 16; Drainage area = 9.5 acres; "Surface sand filter"; Percent efficiency calculated using mass efficiency method.	
Sand Filter	75	44	-13		64	59		Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection, Ellicott City, MD. Land Use = Mall 86%; Commercial Cover = 86%; # of storms = 18; Drainage area = 79 acres; Treatment Vol = 0.5in; STP Size = 3.5 acre/ft; "Surface sand filter"; Percent efficiency calculated using mass efficiency method.	

## 6.7 CONSTRUCTED FILTER (cont.)

Type	Pollutant Removal % Efficiency					TKN	TP	Comments
	TSS	TN	NO <sub>3</sub>	NO <sub>x</sub>	TKN			
Sand Filter	92	71	23		90	80	Impervious Cover = 68%; # of storms = 17; Drainage area = 50acres; "Surface sand filter"; Percent efficiency calculated using mass efficiency method.	
Sand Filters	70	21						
Sand Filter	78	27	-100		57	27	Land Use = Commercial; Drainage area = 80acres; # of storms = 22; "Surface sand filter"; Percent efficiency calculated using mass efficiency method.	
Surface Sand Filters	50-80	<-30				50-80		
<b>RANGE</b>	<b>48 - 100</b>	<b>21 - 71</b>	<b>(-145) - 75</b>	<b>32</b>	<b>48 - 90</b>	<b>-78.5) - 88</b>		

## 6.8 VEGETATED SWALE

Type	Pollutant Removal % Efficiency					TKN	TP	Comments
	TSS	TN	NO <sub>3</sub>	NO <sub>x</sub>	TKN			
100 Foot Swale	60						Delaware DNREC and Brandywine Conservancy. <i>Conservation Design for Stormwater Management</i> . Sep. 1997.	
200 Foot Swale	83						Delaware DNREC and Brandywine Conservancy. <i>Conservation Design for Stormwater Management</i> . Sep. 1997.	
Drainage Channel	65		11				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.	
Drainage Channel	33						Oakland H. An evaluation of Stormwater Pollutant Removal Through Grassed Swale Treatment. Proceedings of the International Symposium of Urban Hydrology, Hydraulics and Sediment Control. 1983.	
Drainage Channel	31	37					Ocoquan Watershed Monitoring Laboratory (OWML) Final Report. Washington Area NURP Report. VPI/SU. Metropolitan Washington Council of Governments. Manassas, VA. 1983.	
Drainage Channel		13	11				Yoursef, Y. et al. Best Management Practices - Removal of Highway Contaminants by Roadside Swales. Final Report. University of Central Florida. Florida Department of Transportation. Orlando, FL. 1985.	
Dry Swale	87	84	80			83	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.	
Dry Swale	99	99	99			99	Kercher, W.C., J.C. Landon and R. Massarelli. 1983. Grassy Swales Prove Cost-Effective for Water Pollution Control. Public Works. Vol. 16. 55-55.	

6.8 VEGETATED SWALE (cont.)

Type	Pollutant Removal % Efficiency						TP	TKN	Secondary Source	Comments	
	TSS	TN	NO <sub>3</sub>	NO <sub>x</sub>							
Grass Channel	60			-25	45			Seattle Metro and Washington Department of Ecology, 1992. Biofiltration Swale Performance: Recommendations and Design Considerations. Publication No. 657. Water Pollution Control Department, Seattle Washington.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection, Ellicott City, MD.	Land Use = Major roadway, residences, parks; impervious Cover = 47%; grass channel design. 10 minute residence time for design storm; Drainage area = 15.5acres; slope = 4%; Length 200ft. 5ft wide"; Percent efficiency calculated using event mean concentration (EMC) efficiency method.	
Grass Channel	67.8			31.4	4.5			Gddberg, 1993. Dayton Avenue Swale Biofiltration Study, Seattle Engineering Department. Seattle, WA.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection, Ellicott City, MD.	%Impervious Cover = 20; "600ft long grass channel"; # of storms = 8; Drainage area = 90acres; Percent efficiency calculated using event mean concentration (EMC) efficiency method.	
Grass Channel	83			-25	29			Seattle Metro and Washington Department of Ecology, 1992. Biofiltration Swale Performance: Recommendations and Design Considerations. Publication No. 657. Water Pollution Control Department, Seattle Washington.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection, Ellicott City, MD.	Land Use = Major roadway, residences, parks; impervious Cover = 47%; grass channel design. 10 minute residence time for design storm; Drainage area = 15.5acres; slope = 4%; Length 200ft. 5ft wide"; Percent efficiency calculated using event mean concentration (EMC) efficiency method.	
Grassed Swales	30-65	15-45			15-45			USEPA, 1999. Preliminary Data Summary of Urban Stormwater BMPs.			
Swales		24	-21					Yousef, Y.A., M.P. Wanielista, H.H. Harper, D.B. Pearce, and R.D. Tolbert. 1985. Best Management Practices Removal of Highway Contaminants by Roadside Swales. Final Report. Florida Department of Transportation, Tallahassee.			
Swales		27	-2					Yousef, Y.A., M.P. Wanielista, H.H. Harper, D.B. Pearce, and R.D. Tolbert. 1985. Best Management Practices Removal of Highway Contaminants by Roadside Swales. Final Report. Florida Department of Transportation, Tallahassee.			
Swales		39	48					Yousef, Y.A., M.P. Wanielista, H.H. Harper, D.B. Pearce, and R.D. Tolbert. 1985. Best Management Practices Removal of Highway Contaminants by Roadside Swales. Final Report. Florida Department of Transportation, Tallahassee.			
Swales		61	57					Yousef, Y.A., M.P. Wanielista, H.H. Harper, D.B. Pearce, and R.D. Tolbert. 1985. Best Management Practices Removal of Highway Contaminants by Roadside Swales. Final Report. Florida Department of Transportation, Tallahassee.			
Swales		73	67					Yousef, Y.A., M.P. Wanielista, H.H. Harper, D.B. Pearce, and R.D. Tolbert. 1985. Best Management Practices Removal of Highway Contaminants by Roadside Swales. Final Report. Florida Department of Transportation, Tallahassee.			
Swales		100	100					Yousef, Y.A., M.P. Wanielista, H.H. Harper, D.B. Pearce, and R.D. Tolbert. 1985. Best Management Practices Removal of Highway Contaminants by Roadside Swales. Final Report. Florida Department of Transportation, Tallahassee.			

6.8 VEGETATED SWALE (cont.)

Type	Pollutant Removal % Efficiency					TKN	TP	Comments
	TSS	TN	NO <sub>3</sub>	NO <sub>x</sub>				
Vegetated Filter Strip	87		50		44		Site 1; Treatment Length = 7.5 to 8.8m; slope = 73%; vegetation = buffalo grass; higher traffic than site 2; Percent efficiency calculated using event mean concentration (EMC) efficiency method.	
Vegetated Filter Strip	85		23		34		Site 2; Treatment Length = 7.8 to 8.1m; slope = 17%; vegetation = mixed; lower traffic than site 1; Percent efficiency calculated using event mean concentration (EMC) efficiency method.	
Vegetated Swales	81		38				Length= 210ft; Land Use = Interstate highway (100% impervious); Treatment Vol= 2year critical velocity, 10 year capacity; Soil Type = saturated sandy; # of storms = 11; drainage area = 1.17 acres; slope = 1.8%; Percent efficiency calculated using mass efficiency method.	
Wet Swale	81	40	52		17		Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection. Ellicott City, MD.	
W/Q Swale	98		45		48		Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection. Ellicott City, MD.	
W/Q Swale	80						Center for Watershed Protection. <i>Design of Stormwater Filtering Systems</i> . Dec 1996. (pg 4-19)	
<b>RANGE</b>	<b>30 - 99</b>	<b>13 - 100</b>	<b>(-21) - 100</b>	<b>(-25) - 31.4</b>	<b>48</b>	<b>4.5 - 99</b>		

6.9 VEGETATED FILTER STRIP

Type	Pollutant Removal % Efficiency					TKN	TP	Comments
	TSS	TN	NO <sub>3</sub>	NO <sub>x</sub>				
15 Foot Grass Filter Strip	70						Klapproth, J.C. and J.E. Johnson. <i>Understanding the Science Behind Riparian Forest Buffers: Effects on Water Quality</i> . Virginia Tech, Oct 2000.	
30 Foot Grass Filter Strip	84						Klapproth, J.C. and J.E. Johnson. <i>Understanding the Science Behind Riparian Forest Buffers: Effects on Water Quality</i> . Virginia Tech, Oct 2000.	
75 Foot Filter Strip	54		-27				Center for Watershed Protection. <i>Design of Stormwater Filtering Systems</i> . Dec 1996. (pg 4-26)	
150 Foot Filter Strip	84		20				Center for Watershed Protection. <i>Design of Stormwater Filtering Systems</i> . Dec 1996. (pg 4-26)	
Grass/Grass-Forest Filter Strip	60-90						Klapproth, J.C. and J.E. Johnson. <i>Understanding the Science Behind Riparian Forest Buffers: Effects on Water Quality</i> . Virginia Tech, Oct 2000.	
Vegetated Filter Strip	70	30	0				Center for Watershed Protection. <i>Design of Stormwater Filtering Systems</i> . Dec 1996. (pg 4-33)	
Vegetated Filter Strip	75	45	22				Carhill Assoc. Technical BMP Manual & Infiltration Feasibility Report: Infiltration of Stormwater in Areas Underlain by Carbonate Bedrock within the Little Lethigh Creek Watershed. Nov 2002.	
<b>RANGE</b>	<b>54 - 90</b>	<b>30 - 45</b>	<b>(-27) - 22</b>					

6.13 CONSTRUCTED WETLAND										
Type	Pollutant Removal % Efficiency					TKN	TP	Primary Source	Secondary Source	Comments
	TSS	TN	NO <sub>3</sub>	NO <sub>x</sub>						
Constructed Wetlands	50-80	<30					15-45	USEPA. 1999. Preliminary Data Summary of Urban Stormwater BMPs.		
Extended Detention Wetland	24			35			16	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.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection, Ellicott City, MD.	Treatment volume = 0.1in/acre; Drainage area = 97acres
Extended Detention Wetland	76				25		54	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.E. Dris coll (Eds.). Woodward-Clyde Consultants. Portland, Oregon. Prepared for the USEPA, Region V, Water Division, Watershed Management Unit. EPA/600 February 1992.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection, Ellicott City, MD.	Treatment volume = 0.15in/acre; Drainage area = 1070acres
Extended Detention Wetland	62		23		40		24	Oberfs, G.L., P.J. Wotzka and J.A. Hertssoe. 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	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection, Ellicott City, MD.	# of storms = 10; Treatment volume = 0.1in/acre; Drainage area = 4.13acres
Extended Detention Wetland	62	-2.1	1.2		15		8.3	Ocoquan 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.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection, Ellicott City, MD.	Treatment volume = 0.1in/acre; Drainage area = 40acres; "Data collected from Large storms >0.1watershed inch. Large storms overwhelm capacity of wetlands to remove nutrients."
Extended Detention Wetland	93	76	68		81		76	Ocoquan 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.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection, Ellicott City, MD.	Impervious Cover = 30%; # of storms = 23; Treatment volume = 0.1in/acre; Drainage area = 40acres; "Data collected from Small storms <0.1watershed inch." ; Percent efficiency calculated using mass efficiency method.
Shallow Marsh	65	22.8	54.9	54.5			39.1	Athanas, C. and C. Stevenson. 1991. The Use of Artificial Wetlands in Treating Stormwater Runoff. Prepared for the Maryland Sediment and Stormwater Administration, Maryland Department of the Environment.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection, Ellicott City, MD.	Land Use = High School roof, parking lot, athletic; Surface area of wetland = 0.6acres; Treatment volume = 0.5in/acre; Drainage area = 16acres; Percent efficiency calculated using mass efficiency method.
Shallow Marsh	37.5	13	25.5		11.5		47.5	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.E. Dris coll (Eds.). Woodward-Clyde Consultants. Portland, Oregon. Prepared for the USEPA, Region V, Water Division, Watershed Management Unit. EPA/600 February 1992.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection, Ellicott City, MD.	Land use = Golf Course; Size of Wetland = 296acres; # of storms = 72; Treatment volume = 1in; Drainage area = 2340acres; Percent efficiency calculated using event mean concentration (EMC) efficiency method.
Shallow Marsh	86	46		94	34		70	Carr, D. and B. Rushton. 1995. Integrating a Herbaceous Wetland into Stormwater Management. Stormwater Research Program. Southwest Florida Water Management District. Brooksville, FL.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection, Ellicott City, MD.	# of storms = 81; Drainage area = 15.3; STP size = 3acres; Percent efficiency calculated using mass efficiency method.
Shallow Marsh	82.9	-1.6	80.2				7	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.E. Dris coll (Eds.). Woodward-Clyde Consultants. Portland, Oregon. Prepared for the USEPA, Region V, Water Division, Watershed Management Unit. EPA/600 February 1992.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection, Ellicott City, MD.	"Runoff enters through a small shallow canal. This is a NATURAL WETLAND." Land Use = Large Residential Community; Treatment Volume = 1.08in/acre; Drainage area = 55.4acres; STP size = 2.47acres; Percent efficiency calculated using mass efficiency method.

6.13 CONSTRUCTED WETLAND (cont.)

Type	Pollutant Removal % Efficiency						TKN	TP	Secondary Source	Comments
	TSS	TN	NO <sub>3</sub>	NO <sub>x</sub>						
Shallow Marsh	85.5		67				75	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Wetland 4. Land Use = 80% Agriculture, 20% Urban; "5 - 8.6 acre wetland. Max depth 5ft. Subject to low flow conditions (2.8-6.3 in/week)" Drainage area = 128000acres; Percent efficiency calculated using mass efficiency method.	
Shallow Marsh	87		82.5				77.5	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Wetland 1. Land Use = 80% Agriculture, 20% Urban; "5 - 8.6 acre wetland. Max depth 5ft. Subject to high flow conditions (13.4 - 38.2 in/week)" Drainage area = 128000acres; Percent efficiency calculated using mass efficiency method.	
Shallow Marsh	95.5		86				87	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Wetland 2. Land Use = 80% Agriculture, 20% Urban; "5 - 8.6 acre wetland. Max depth 5ft. Subject to high flow conditions (13.4 - 38.2 in/week)" Drainage area = 128000acres; Percent efficiency calculated using mass efficiency method.	
Shallow Marsh	99.5		99				99.5	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Wetland 3. Land Use = 80% Agriculture, 20% Urban; "5 - 8.6 acre wetland. Max depth 5ft. Subject to low flow conditions (2.8-6.3 in/week)" Drainage area = 128000acres; Percent efficiency calculated using mass efficiency method.	
Shallow Marsh	94						78	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Land use = 47% Residential. "This is a NATURAL WETLAND." STP size = 7.6acres. Treatment volume = 1.25 in/acre; Drainage area = 73.2acres; "Two cell wetland; first cell 2ft deep pool with emergent wetlands; second cell is free." # of storms = 5; Design Basis = 2 & 25 year quantity control only; Drainage area = 7.7acres; Percent efficiency calculated using event mean concentration (EMC) efficiency method.	
Shallow Marsh	20			67			33	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	"High Hydraulic Loading." Average Detention Time = 12days; Land Use = 80% Ag; STP size = 5.9acres; avg 24in deep; Drainage area = 128000acres; Percent efficiency calculated using mass efficiency method.	
Shallow Marsh	54		78					Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	"High Hydraulic Loading." Average Detention Time = 13days; Land Use = 80% Ag; STP size = 4.7acres; avg 28in deep; Drainage area = 128000acres; Percent efficiency calculated using mass efficiency method.	
Shallow Marsh	59		84					Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	"Low Hydraulic Loading." Average Detention Time = 95days; Land Use = 80% Ag; STP size = 5.9acres; avg 28in deep; Drainage area = 128000acres; Percent efficiency calculated using mass efficiency method.	
Shallow Marsh	75		95					Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.		



6.13 CONSTRUCTED WETLAND (cont.)

Type	Pollutant Removal % Efficiency						TKN	TP	Secondary Source	Comments
	TSS	TN	NO <sub>3</sub>	NO <sub>x</sub>	TKN	TP				
Stormwater Wetland	67	28						United States Environmental Protection Agency (USEPA). <i>Storm Water Technology Fact Sheet: Storm Water Wetlands</i> (EPA 832-F-99-025) 1999.		
Stormwater Wetland	56		20			-2		Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	# of storms = 13; Treatment Volume = 0.03in/acre; Drainage Area = 214.8acres; "Channelization reduced effectiveness."	
Stormwater Wetland	14		4			-2		Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	# of storms = 13; Treatment Volume = 0.01in/acre; Drainage Area = 461.7acres; "Channelization reduced effectiveness."	
Stormwater Wetland	57			67		57		Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	# of storms = 25; Drainage Area = 6acres; Surface Area = 0.32acres, Max Depth = 18ft; Runoff conveyed by 200ft drainage channel; BMP approx. 3-5 years old.; Percent efficiency calculated using event mean concentration (EMC) efficiency method.	
Stormwater Wetland	-1.32					14.86		Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = parking lot and highway; # of storms = 5; STP size = 0.7acres; Percent efficiency calculated using event mean concentration (EMC) efficiency method.	
Stormwater Wetland	30.1					27.46		Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = parking lot and highway; # of storms = 5; STP size = 0.7acres; Percent efficiency calculated using mass efficiency method.	
Stormwater Wetland	52.02					68.09		Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = Highway; # of storms = 13; STP size = 5acres; Percent efficiency calculated using mass efficiency method.	
Stormwater Wetland	56.96					68.61		Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = Highway; # of storms = 13; STP size = 5acres; Percent efficiency calculated using event mean concentration (EMC) efficiency method.	
<b>RANGE</b>	<b>(-1.32) - 99.5</b>	<b>(-2.1) - 76</b>	<b>1.2 - 99</b>	<b>35 - 94</b>	<b>11.5 - 81</b>	<b>(-2) - 95.5</b>				



6.14 WET POND / RETENTION BASIN

Type	Pollutant Removal % Efficiency						TKN	TP	Secondary Source	Comments
	TSS	TN	NO <sub>3</sub>	NO <sub>x</sub>	TKN	TP				
Retention Basin	50-80	30-65				30-65		USEPA, 1999. Preliminary Data Summary of Urban Stormwater BMPs.		
Wet Extended Detention Pond	60.4	16	18.2			46.2		Borden, R.C., J.L. Dom, 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, NC.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection, Ellicott City, MD.	Land Use = Dairy Farms, woodland, Impervious Cover = 16%; Percent efficiency calculated using mass efficiency method.
Wet Extended Detention Pond	54	39	45		26	46		City of Austin, TX. 1991. Design Guidelines for Water Quality Control Basins. Public Works Department. Austin, TX.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection, Ellicott City, MD.	Impervious cover = 39%
Wet Extended Detention Pond	87			24	59	79		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.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection, Ellicott City, MD.	Land Use = Mostly residential; Impervious Cover = 34%; Percent efficiency calculated using mass efficiency method.
Wet Extended Detention Pond	83	55		85	52	52		Lower Colorado River Authority. 1997. Innovative NPS Pollution Control Program for Lake Travis in Central Texas. LORA.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection, Ellicott City, MD.	Land Use = parking lot/commercial
Wet Extended Detention Pond	98	54				79		Ontario Ministry of the Environment. 1991. Stormwater Quality Best Management Practices. Marshall Macklin Monaghan Limited, Toronto, Ontario.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection, Ellicott City, MD.	
Wet Extended Detention Pond	61			63		56		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.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection, Ellicott City, MD.	Impervious Cover = 30%
Wet Extended Detention Pond	67			61		57		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.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection, Ellicott City, MD.	Impervious Cover = 30%; Residence time = 5 days
Wet Extended Detention Pond	69	28		67	25	75		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.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection, Ellicott City, MD.	Impervious Cover = 30%; Residence time = 5 days
Wet Extended Detention Pond	71			64		62		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.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection, Ellicott City, MD.	Impervious Cover = 30%
Wet Extended Detention Pond	94			88		90		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.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection, Ellicott City, MD.	Impervious Cover = 30%; Land Use = rooftops, parking lots, vehicle storage; Residence Time = 14days

6.14 WET POND / RETENTION BASIN (cont.)

Type	Pollutant Removal % Efficiency						TP	Primary Source	Secondary Source	Comments
	TSS	TN	NO <sub>3</sub>	NO <sub>x</sub>	TKN					
Wet Extended Detention Pond	95			88		89	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.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection. Ellicott City, MD.	Impervious Cover = 30%; Land Use = rooftops, parking lots, vehicle storage; Residence Time = 14days	
Wet Extended Detention Pond	78		75		65	70	Yu, S.L. and D.E. Benelouf. 1998. Field Testing of Selected Urban BMPs in Critical Water Issues and Computer Applications. In Proceedings of the 15th Annual Water Resources Conference. American Society of Civil Engineers. New York, NY.	Federal Highway Administration (FHWA). "Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring; Fact Sheet Detention Ponds." U.S. Department of Transportation.		
Wet Pond	46		36		14	37	City of Austin. 1990. Removal Efficiencies of Stormwater Control Structures. Environmental Resources Management Division, Environmental and Conservation Services Department, City of Austin, Austin, TX.	Federal Highway Administration (FHWA). "Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring; Fact Sheet Detention Ponds." U.S. Department of Transportation.		
Wet Pond	94		64		44	81	City of Austin. 1995 (Draft). Characterization of Stormwater Pollution for Austin, Texas Area. Environmental Resources Management Division, Environmental and Conservation Services Department, City of Austin, Austin, TX.	Federal Highway Administration (FHWA). "Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring; Fact Sheet Detention Ponds." U.S. Department of Transportation.		
Wet Pond	68	12		93	-31	55	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.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = single family residential; Soil type = group A; Treatment Vol = 3.11in/acre; Percent efficiency calculated using event mean concentration (EMC) efficiency method.	
Wet Pond	54			97	68	69	Domnan, 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. FHWARD 89/202.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection. Ellicott City, MD.		
Wet Pond	65			61	23	25	Domnan, 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. FHWARD 89/202.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = Highway; Percent efficiency calculated using mass efficiency method.	
Wet Pond	32	6	-1		7	12	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.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection. Ellicott City, MD.		
Wet Pond	32		7		14	18	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.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection. Ellicott City, MD.		
Wet Pond	60					45	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.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection. Ellicott City, MD.		
Wet Pond	81	37			27	54	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.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection. Ellicott City, MD.		

6.14 WET POND / RETENTION BASIN (cont.)

Type	Pollutant Removal % Efficiency					TKN	TP	Secondary Source	Comments
	TSS	TN	NO <sub>3</sub>	NO <sub>x</sub>	TKN				
Wet Pond	84					34	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection. Ellicott City, MD.		
Wet Pond	91	62	66		60	79	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection. Ellicott City, MD.		
Wet Pond	54	16		24		30	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection. Ellicott City, MD.	"Pond was modified to increase detention time and was previously studied by Marin and Smoot (1988)." Percent efficiency calculated using event mean concentration (EMC) efficiency method.	
Wet Pond	85		92		26	54	Claytor, Richard, and T. Schueler. 1996. Design of Stormwater Filtering Systems. Center for Watershed Protection. Silver Spring, MD		
Wet Pond	7			23		40	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection. Ellicott City, MD.	"Very large online wet pond with detention" Percent efficiency calculated using event mean concentration (EMC) efficiency method.	
Wet Pond	45			36		45	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection. Ellicott City, MD.	"Very large online wet pond with detention"	
Wet Pond	80			62	0	80	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = Residential. Impervious Cover = 55%; Residential cover = 100%; Soil Type = clay till and clay loam	
Wet Pond	85								
Wet Pond	85	30	24		31	48	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection. Ellicott City, MD.	Age of Facility = 4years; Percent efficiency calculated using mass efficiency method.	
Wet Pond	90	41	10		50	61	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection. Ellicott City, MD.	Age of Facility = 6years	

6.14 WET POND / RETENTION BASIN (cont.)

Type	Pollutant Removal % Efficiency					TKN	TP	Primary Source	Secondary Source	Comments
	TSS	TN	NO <sub>3</sub>	NO <sub>x</sub>						
Wet Pond	-33.3	32				39	Ocoquan Watershed Monitoring Laboratory. 1983. Final Report: Metropolitan Washington Urban Runoff Project. Prepared for the Metropolitan Washington Council of Governments. Manassas, VA.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = Medium density residential; Impervious cover = 25%	
Wet Pond	85	34				86	Ocoquan Watershed Monitoring Laboratory. 1983. Final Report: Metropolitan Washington Urban Runoff Project. Prepared for the Metropolitan Washington Council of Governments. Manassas, VA.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = Agriculture	
Wet Pond	80-90						United States Environmental Protection Agency (USEPA). Storm Water Technology Fact Sheet: Wet Detention Ponds (EPA 832-F-99-048). 1999.			
Wet Pond	62				21	36	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.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection. Ellicott City, MD.	Land use = multi-unit housing, woodland; Impervious cover = 38%; Soil type = clay; Surface area = 3.3 acres; Mean pond depth = 3.8'; Volume=12.3acre feet. "No geese present." Percent efficiency calculated using mass efficiency method.	
Wet Pond	93				32	45	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.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection. Ellicott City, MD.	Land use = mixed residential; Impervious cover = 46%; Residential = 100%; Pond = 4.9 acres; Mean pond depth = 8'; Volume = 38.8 acre feet; "Geese population present increase N and P values." Percent efficiency calculated using mass efficiency method.	
<b>RANGE</b>	<b>(-33.3) - 98</b>	<b>6 - 65</b>	<b>(-) - 92</b>	<b>23 - 97</b>	<b>(-31) - 68</b>	<b>12 - 90</b>				

6.15 DRY EXTENDED DETENTION BASIN

Type	Pollutant Removal % Efficiency						TKN	TP	Primary Source	Secondary Source	Comments
	TSS	TN	NO <sub>3</sub>	NO <sub>x</sub>							
Dry Detention Basins	30-65	15-45					15-45	USEPA, 1999. Preliminary Data Summary of Urban Stormwater BMPs. Yu, S.L., M. Barnes, R.J. Kaighn, and S.L. Lalo. 1994. Field Test of Stormwater Best Management Practices in Watershed Wastewater Treatment. In Proceedings of the 1994 National Conference on Environmental Engineering. American Society of Civil Engineers, New York, NY.	Federal Highway Administration (FHWA). "Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring. Fact Sheet Detention Ponds." U.S. Department of Transportation.	"Removal efficiencies based on mass loading."	
Dry Detention Pond	96		64		44		81	Baltimore Department of Public Works, 1989. Detention Basin Retrofit Project and Monitoring Study Results. Water Quality Management Office, Baltimore, MD.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection, Ellicott City, MD.	# of storms = 9; Treatment Vol = 0.50in/acre; drainage area = 16.8acres	
Dry Extended Detention Pond	87		-10				26	Barnett, M.E. et al., 1997. <i>Evaluation of the Performance of Permanent Runoff Controls: Summary and Conclusions</i> . CRWR Online Report 97-3. Center for Research in Water Resources, Bureau of Engineering Research, The University of Texas at Austin, TX.		Land Use = Highway; Percent efficiency calculated using mass efficiency method.	
Dry Extended Detention Pond	89		-3		26		51	City of Austin, TX, 1991. Design Guidelines for Water Quality Control Basins. Public Works Department, Austin, TX.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection, Ellicott City, MD.	# of storms = 17; Treatment Vol = 0.50in/acre; drainage area= 28 acres	
Dry Extended Detention Pond	30	35	52				18	Miller, T., 1987. Appraisal of Storm-Water Quality Near Salem, Oregon. US Geological Survey. Water Resources Report 87-4064.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection, Ellicott City, MD.	Impervious = 53%; Residential = 39%; Commercial = 38%; Industrial = 1%; # of storms = 11; soil = HSG-C; Drainage area = 512acres	
Dry Extended Detention Pond	47						21	Ocoquan Watershed Monitoring Laboratory, 1987. Final Report: London Commons Extended Detention Facility. Urban BMP Research and Demonstration Project. Virginia Tech University, Manassas, VA.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection, Ellicott City, MD.	# of storms = 27; Treatment Vol = 0.22in/acre; detention provided up to 20hours; drainage area = 11.4 acres	
Dry Extended Detention Pond	51.5	42.5					48	Schueler, T.R. and M. Helfrich, 1988. Design of Extended Detention Wet Pond Systems. In: Design of Urban Runoff Quality Controls. L.L. Roesser, B. Urbonas and M.B. Sonnen (Eds.), American Society of Civil Engineers, New York, NY.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection, Ellicott City, MD.	# of storms = 25; Treatment Vol = 0.30in/acre; drainage area = 34acres	
Dry Extended Detention Pond	70	24			30		13	Stanley, D., 1994. An Evaluation of the Pollutant Removal of a Demonstration Urban Stormwater Detention Pond: Albermarle-Pamlico Estuary Study. APES Report 94-07.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection, Ellicott City, MD.	Impervious Cover = 31%; Land Use = Residential/Commercial; # of storms = 8; Treatment Vol = 72hours detention for the first 0.5in; drainage area = 200acres; Percent efficiency calculated using mass efficiency method.	
<b>RANGE</b>	<b>30 - 96</b>	<b>15 - 45</b>	<b>(-10) - 64</b>		<b>26 - 44</b>		<b>13 - 81</b>				

6.16 WATER QUALITY FILTER

Type	Pollutant Removal % Efficiency						TKN	TP	Primary Source	Secondary Source	Comments
	TSS	TN	NO <sub>3</sub>	NO <sub>x</sub>							
Catch Basins	60 - 97							Aronson, G. et al. Evaluation of Catch Basin Performance for Urban Stormwater Pollution Control. EPA-600/2-83-043.	Stormwater Manager's Resource Center (SMRC). <i>Pollution Prevention Fact Sheet: Catch Basins</i> .	Only very small storms used	
Catch Basins	10 - 25						5 - 10	Pitt, R. and G. Shawley, 1982. <i>A Demonstration of Non-Point Pollution Management on Castro Valley Creek</i> , Alameda County Flood Control District (Hayward, California) and U.S. EPA, Washington, DC.	Stormwater Manager's Resource Center (SMRC). <i>Pollution Prevention Fact Sheet: Catch Basins</i> .		
Catch Basins	32							Pitt, R. et al., 1997. Guidance Manual for Integrated Wet Weather Flow Collection and Treatment Systems for Newly Urbanized Areas. US EPA, Office of Research and Development. Cincinnati, OH.	Stormwater Manager's Resource Center (SMRC). <i>Pollution Prevention Fact Sheet: Catch Basins</i> .		
<b>RANGE</b>	<b>10 - 97</b>						<b>5 - 10</b>				

## 6.17 RIPARIAN BUFFER RESTORATION

Type	Pollutant Removal % Efficiency						TKN	TP	Primary Source	Secondary Source	Comments
	TSS	TN	NO <sub>3</sub>	NO <sub>x</sub>	TKN	TP					
25' buffer	57	27				34		Desbonnet, A., P. Pogue, V. Lee, and N. W. Off. 1994. Vegetated Buffers in the Coastal Zone: An Annotated Review and Bibliography. Coastal Resources Center, University of RI.	Schueler, T., 1995. Site Planning for Urban Stream Protection. The Center for Watershed Protection.		
50' buffer	62	31				38		Desbonnet, A., P. Pogue, V. Lee, and N. W. Off. 1994. Vegetated Buffers in the Coastal Zone: An Annotated Review and Bibliography. Coastal Resources Center, University of RI.	Schueler, T., 1995. Site Planning for Urban Stream Protection. The Center for Watershed Protection.		
75' buffer	65	33				41		Desbonnet, A., P. Pogue, V. Lee, and N. W. Off. 1994. Vegetated Buffers in the Coastal Zone: An Annotated Review and Bibliography. Coastal Resources Center, University of RI.	Schueler, T., 1995. Site Planning for Urban Stream Protection. The Center for Watershed Protection.		
100' buffer	67	34				43		Desbonnet, A., P. Pogue, V. Lee, and N. W. Off. 1994. Vegetated Buffers in the Coastal Zone: An Annotated Review and Bibliography. Coastal Resources Center, University of RI.	Schueler, T., 1995. Site Planning for Urban Stream Protection. The Center for Watershed Protection.		
200' buffer	72	38				47		Desbonnet, A., P. Pogue, V. Lee, and N. W. Off. 1994. Vegetated Buffers in the Coastal Zone: An Annotated Review and Bibliography. Coastal Resources Center, University of RI.	Schueler, T., 1995. Site Planning for Urban Stream Protection. The Center for Watershed Protection.		
Deciduous Forest Buffers								Lowrance, R., R. Todd, J. Fall, Jr., O. Hendrickson, Jr., R. Leonard, and L. Asmussen. 1984b. Riparian forests as nutrient filters in agricultural watersheds. <i>Bioscience</i> 34:374-377.	Klapproth, J.C. and J.E. Johnson. <i>Understanding the Science Behind Riparian Forest Buffers: Effects on Water Quality</i> . Virginia Tech. Oct 2000.		
Hardwood Riparian Area	84-90	68						Cooper, J.R., J.W. Gilliam, R.B. Daniels, and W.P. Robarge. 1987. Riparian areas as filters for agricultural sediment. <i>Soil Science Society of America Journal</i> 51:416-420.	Klapproth, J.C. and J.E. Johnson. <i>Understanding the Science Behind Riparian Forest Buffers: Effects on Water Quality</i> . Virginia Tech. Oct 2000.		
Riparian Buffer								Jordan, T.E., D.L. Correll, and D.E. Weller. 1993. Nutrient interception by a riparian forest receiving inputs from adjacent croplands. <i>Journal of Environmental Quality</i> 22:467-473.	Klapproth, J.C. and J.E. Johnson. <i>Understanding the Science Behind Riparian Forest Buffers: Effects on Water Quality</i> . Virginia Tech. Oct 2000.		
Riparian Buffer		89	95					Peterjohn, W.T. and D.L. Correll. 1984. Nutrient dynamics in an agricultural watershed: observations on the role of a riparian forest. <i>Ecology</i> 65:1466-1475.	Klapproth, J.C. and J.E. Johnson. <i>Understanding the Science Behind Riparian Forest Buffers: Effects on Water Quality</i> . Virginia Tech. Oct 2000.		
Riparian Buffer						48		Snyder, N.J., S. Mostaghimi, D.F. Berry, R.B. Reneau, E.P. Smith. 1995. Evaluation of a riparian wetland as a naturally occurring decontamination zone. Pages 259-262. In: <i>Clean Water, Clean Environment - 21st Century</i> . Volume III: Practices, Systems, and Adoption. Proceedings of a conference March 5-8, 1995 Kansas City, Mo. American Society of Agricultural Engineers, St. Joseph, Mich. 318 pages.			
Switchgrass Buffer (7.1m)	95	80	62			78		Lee, K.H., T.M. Isenhardt, and R.C. Schultz. "Sediment and nutrient removal in an established multi-species riparian buffer," <i>Journal of Water Conservation</i> , Vol. 58, No. 1.	SWCS. 2003. <i>Soil and Water Conservation Society</i> .		
Switchgrass/Woody Buffer (16.3m)	97	94	85			91		Lee, K.H., T.M. Isenhardt, and R.C. Schultz. "Sediment and nutrient removal in an established multi-species riparian buffer," <i>Journal of Water Conservation</i> , Vol. 58, No. 1.	SWCS. 2003. <i>Soil and Water Conservation Society</i> .		
<b>RANGE</b>	<b>57 - 97</b>	<b>27 - 94</b>	<b>48 - 95</b>			<b>34 - 91</b>					

## **BMP Pollutant Removal Efficiencies - Inflow vs. Outflow Pollutant Concentrations**





Table A-6 Inflow Versus Outflow Concentrations of Pollutants in Stormwater BMPs

6.4 INFILTRATION TRENCH

Type	TSS		TN		NO <sub>3</sub>		NO <sub>2</sub>		TKN		TP		Secondary Source	Comments
	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow		
Infiltration Trench			6.59	3.8	0.95	3.8					0.24	0	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection. Ellicott City, MD.	"47.75 hours detention time", soil type = sandy loam
Infiltration Trench			5.38	5.2	0.75	0					0.66	0.63	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection. Ellicott City, MD.	"49.5 hours detention time", soil type = loam
Infiltration Trench			2.04	1.01	0.5	0.09					0.2	0	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection. Ellicott City, MD.	"51.5 hours detention time", soil type = sandy

\*\*UNITS ARE IN MG/L UNLESS OTHERWISE NOTED\*\*

6.5 RAIN GARDEN

Type	TSS		TN		NO <sub>3</sub>		NO <sub>2</sub>		TKN		TP		Secondary Source	Comments
	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow		
Rain Garden	87.4g	7.6g			1.60g	1.85g					1.62g	0.60g	Hsieh, C. and A.P. Davis. Multiple-event Study of Bioretention for Treatment of Urban Storm Water Runoff. 2003. Percent efficiency calculated using mass efficiency method.	

\*\*UNITS ARE IN MG/L UNLESS OTHERWISE NOTED\*\*

6.7 CONSTRUCTED FILTER

\*\*UNITS ARE IN MG/L UNLESS OTHERWISE NOTED\*\*

Type	TSS		TN		NO <sub>3</sub>		NO <sub>x</sub>		TKN		TP		Primary Source	Secondary Source	Comments
	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow			
Organic Filter	35.5	16											Leif, W. 1999. Compost Stormwater Filter Evaluation. Snohomish County Public County Works. Everett, WA.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection. Ellicott City, MD.	# of storms = 8; Drainage area = 0.69acres; "Filter is 12" deep".
Organic Filter	49	6	1.76	0.858			0.481	0.552					Lower Colorado River Authority. 1997. Innovative NPS Pollution Control Program for Lake Travis in Central Texas. LCRA.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = Large parking lot; % Impervious Cover = 82%; "Peat/sand filter media wit surface ED. Retrofit Site. Steep Slopes. Retention Capacity 1420ft <sup>3</sup> "; # of storms = 21
Organic Filter	39.95	4.47					0.3	0.4					Stewart, W. 1992. Compost Stormwater Treatment System. W&H Pacific Consultants. Draft Report. Portland, OR.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = 95%Residential, rest roadway; # of storms = 7. Drainage area = 73.9; "Compost media filter"
Sand Filter	204	3.5	2.83	1.065			1.24	0.474					Barrett, M.; M. Koblin; 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.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = 67% Highway/33%Commercial; Drainage area = 82.9acres; # of storms = 10; Treatment Vd = first 0.5in of runoff
Sand Filter	76.2	16.84	7.93	3.8			1.27	1.99					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.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = Parking Lot; STP Size = 477.6ft <sup>3</sup> ; Drainage area = 0.7acres; # of storms = 20; "Perimeter sand filter"

6.8 VEGETATED SWALE

\*\*UNITS ARE IN MG/L UNLESS OTHERWISE NOTED\*\*

Type	TSS		TN		NO <sub>3</sub>		NO <sub>x</sub>		TKN		TP		Secondary Source	Comments
	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow		
Dry Swale	50	4			0.549	0.347	0.83	0.74	0.218	0.304			Whier, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection. Elliccott City, MD.	Land use = highway, impervious cover = 63%, soil type = sandy; length 186'; Age of facility = 5 years
Grass Channel	47	15.13			1.24	0.85			0.228	0.22			Whier, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection. Elliccott City, MD.	% Impervious Cover = 20; 600ft. long grass channel"; # of storms = 8; Drainage area = 90 acres
Grass Channel	94.67	14			0.35	0.77			0.2	0.14			Whier, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection. Elliccott City, MD.	Land Use = Major roadway, residences, parks; Impervious Cover = 47%; "grass channel design. 10 minute residence time for design storm; Drainage area = 15.5 acres; slope = 4%; " Length 200ft. 5ft wide; Soil Type = glacial till
Grass Channel	128	30			0.26	0.31			0.1	0.06			Whier, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection. Elliccott City, MD.	Land Use = Major roadway, residences, parks; Impervious Cover = 47%; "grass channel design. 10 minute residence time for design storm; Drainage area = 15.5 acres; slope = 4%; " Length 100ft. 5ft wide; Soil Type = glacial till
Vegetated Swale	157	21	0.91	0.46			2.17	1.46	0.55	0.31			Barrett, M.E. et al. Evaluation of the Performance of Permanent Runoff Controls: Summary and Conclusions. Center for Research in Water Resources, University of Texas at Austin. Austin, TX: Nov. 1997.	Site 1; Treatment Length = 7.5 to 8.8m; slope = .73%; vegetation = buffalo grass; higher traffic than site 2; Percent efficiency calculated using event mean concentration (EMC) efficiency method.
Vegetated Swale	190	29	1.27	0.97			2.61	1.45	0.24	0.16			Barrett, M.E. et al. Evaluation of the Performance of Permanent Runoff Controls: Summary and Conclusions. Center for Research in Water Resources, University of Texas at Austin. Austin, TX: Nov. 1997.	Site 2; Treatment Length = 7.8 to 8.1m; slope = 1.7%; vegetation = mixed; lower traffic than site 1; Percent efficiency calculated using event mean concentration (EMC) efficiency method.

6.9 VEGETATED FILTER STRIP

\*\*UNITS ARE IN MG/L UNLESS OTHERWISE NOTED\*\*

Type	TSS		TN		NO <sub>3</sub>		NO <sub>x</sub>		TKN		TP		Secondary Source	Comments
	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow		
Vegetated Filter Strip	157	21	0.91	0.46									Barrett, M.E. et al. Evaluation of the Performance of Permanent Runoff Controls: Summary and Conclusions. Center for Research in Water Resources, University of Texas at Austin. Austin, TX: Nov. 1997.	Site 1; Treatment Length = 7.5 to 8.8m; slope = .73%; vegetation = buffalo grass; higher traffic than site 2; Percent efficiency calculated using event mean concentration (EMC) efficiency method.
Vegetated Filter Strip	190	29	1.27	0.97									Barrett, M.E. et al. Evaluation of the Performance of Permanent Runoff Controls: Summary and Conclusions. Center for Research in Water Resources, University of Texas at Austin. Austin, TX: Nov. 1997.	Site 2; Treatment Length = 7.8 to 8.1m; slope = 1.7%; vegetation = mixed; lower traffic than site 1; Percent efficiency calculated using event mean concentration (EMC) efficiency method.

6.13 CONSTRUCTED WETLAND

\*\*UNITS ARE MG/L UNLESS OTHERWISE NOTED\*\*

Type	TSS		TN		NO <sub>3</sub>		NO <sub>x</sub>		TKN		TP		Primary Source	Secondary Source	Comments
	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow			
Shallow Marsh	11.85 ppm	7.85 ppm	1.14 ppm	0.99 ppm	0.2 ppm	0.15 ppm	0.085ppm	0.045ppm					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.E. Dils coll (Eds.). Woodward-Clyde Consultants. Portland, Oregon. Prepared for the USEPA, Region V, Water Division, Watershed Management Unit. EPA/600 February 1992.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection. Ellicott City, MD.	Land use = Golf Course; Size of Wetland = 296acres; # of storms = 72; Treatment volume = 1in; Drainage area = 2340acres
Shallow Marsh	7.55	1.801	0.756	1.206	0.085	0.016	0.98	0.04					Carr, D. and B. Rushton. 1995. Integrating a Herbaceous Wetland into Stormwater Management. Stormwater Research Program. Southwest Florida Water Management District. Brooksville, FL.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection. Ellicott City, MD.	# of storms = 81; Drainage area = 15.3; STP size = 3acres
Shallow Marsh	14	12					0.097	0.071					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.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection. Ellicott City, MD.	"Two cell wetland; first cell 2ft deep pool with emergent wetlands; second cell is free." # of storms = 5; Design basis = 2 & 25 year quantity control only; Drainage area = 7.7 acres; "Inflow and Outflow values are presented as mean concentrations."

## 6.14 WET POND / RETENTION BASIN

\*\*UNITS ARE MG/L UNLESS OTHERWISE NOTED\*\*

Type	TSS		TN		NO <sub>3</sub>		NO <sub>x</sub>		TKN		TP		Primary Source	Secondary Source	Comments
	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow			
Wet Extended Detention Pond	177	39	3.352	1.459							0.761	0.214	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection. Ellicott City, MD.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = Dairy Farms, woodland; Impervious Cover = 16
Wet Extended Detention Pond	71	12	1.713	0.769	0.416	0.062					0.232	0.112	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection. Ellicott City, MD.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = parking lot/commercial
Wet Extended Detention Pond	45	14	1.27	0.91	0.096	0.032					0.651	0.164	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.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection. Ellicott City, MD.	Impervious Cover = 30%; Residence time = 5 days
Wet Extended Detention Pond	28	11	1.35	1.16	0.24	0.09					0.4	0.176	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.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection. Ellicott City, MD.	Impervious Cover = 30%; Residence Time = 2 days
Wet Extended Detention Pond	131	7	1.61	0.722	0.396	0.062					0.497	0.053	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.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection. Ellicott City, MD.	Impervious Cover = 30%; Land Use = rooftops, parking lots, vehicle storage; Residence Time = 14days
Wet Pond	20.6	6.5	0.93	0.65	0.18	0.02					0.136	0.035	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.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = single family residential; Soil type = group A; Treatment Vd = 3.11in/acre
Wet Pond	7	15							1.2	1.27	0.272	0.155	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.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = Highway

6.14 WET POND / RETENTION BASIN (cont.)

\*\*UNITS ARE MG/L UNLESS OTHERWISE NOTED\*\*

Type	TSS		TN		NO <sub>x</sub>		TKN		TP		Primary Source	Secondary Source	Comments
	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow			
Wet Pond	52	23	2.62	1.92	0.729	0.224	1.89	1.7	0.3	0.4	Dorman, M.E., J. Heritigan, 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.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = Highway Inflow and Outflow are reported as a mean concentration. "Pond was modified to increase detention time and was previously studied by Martin and Smoot (1988)." Percent efficiency calculated using event mean concentration (EMC) efficiency method.
Wet Pond	45	19	1.64	1.39	0.31	0.31	0.31	0.17	0.12	0.12	Gain, S.W. The effects of Flow-Path Modifications on Urban Water-Quality Constituent Retention in Urban Stormwater Detention Pond and Wetland System. Orlando, Florida. Florida Department of Transportation, Orlando, FL. 1996.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection. Ellicott City, MD.	Land use = multi-unit housing, woodland; Impervious cover = 38%; Soil type = clay; Surface area = 3.3 acres. Mean pond depth = 3.8'; Volume=12.3acre feet; "No geese present." Percent efficiency calculated using mass efficiency method.
Wet Pond					0.79	0.63	0.12	0.08	0.08	0.08	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.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection. Ellicott City, MD.	Land use = mixed residential; Impervious cover = 46%; Residential = 100%; Pond = 4.9 acres; Mean pond depth = 8'; Volume = 38.8 acre feet; "Geese population present increase N and P values." Percent efficiency calculated using mass efficiency method.
Wet Pond					0.86	0.59	0.14	0.08	0.08	0.08	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.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection. Ellicott City, MD.	

6.15 DRY EXTENDED DETENTION BASIN

\*\*UNITS ARE MG/L UNLESS OTHERWISE NOTED\*\*

Type	TSS		TN		NO <sub>x</sub>		TKN		TP		Primary Source	Secondary Source	Comments
	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow			
Dry Extended Detention Pond	77	10	0.673	0.742					0.188	0.112	Baltimore Department of Public Works. 1989. Detention Basin Retrofit Project and Monitoring Study Results. Water Quality Management Office, Baltimore, MD.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection. Ellicott City, MD.	# of storms = 8; Treatment Vol = 0.50in/acre; drainage area = 16.8acres
Dry Extended Detention Pond	204	24	1.24	1.28	1.59	1.24	1.24	0.356	0.181	0.181	Barrett, M.E. et al., 1997. Evaluation of the Performance of Permanent Runoff Controls: Summary and Conclusions. CRWR Online Report 97-3. Center for Research in Water Resources, Bureau of Engineering Research, The University of Texas at Austin, TX.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection. Ellicott City, MD.	Land Use = Highway Impervious = 63%; Residential = 39%; Commercial = 38%; Industrial = 1%; # of storms = 11; sol = HSG-C; Drainage area = 51.2acres
Dry Extended Detention Pond	98	28	0.32	0.3				0.21	0.18	0.27	Miller, T. 1987. Appraisal of Storm-Water Quality Near Salem, Oregon. US Geological Survey. Water Resources Report 87-4084.	Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2 <sup>nd</sup> Edition. Center for Watershed Protection. Ellicott City, MD.	Impervious Cover = 31%; Land Use = Residential/Commercial; # of storms = 8; Treatment Vol = 72hours detention for the first 0.5in, drainage area = 200acres