

# WinSLAMM v 9.3

## Grass Swales

Module 7b

Robert Pitt  
Dept. of Civil and Environmental Engineering  
University of Alabama  
and  
John Voorhees  
Earth Tech, Inc.

## We will cover . . .

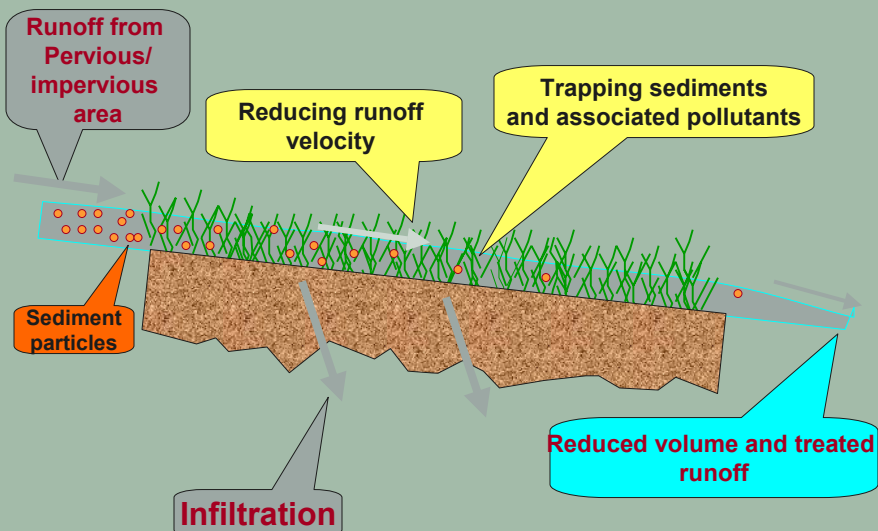
- Research Results
- Entering Grass Swale Data into the Model
- Model Output
- Variable Sensitivity

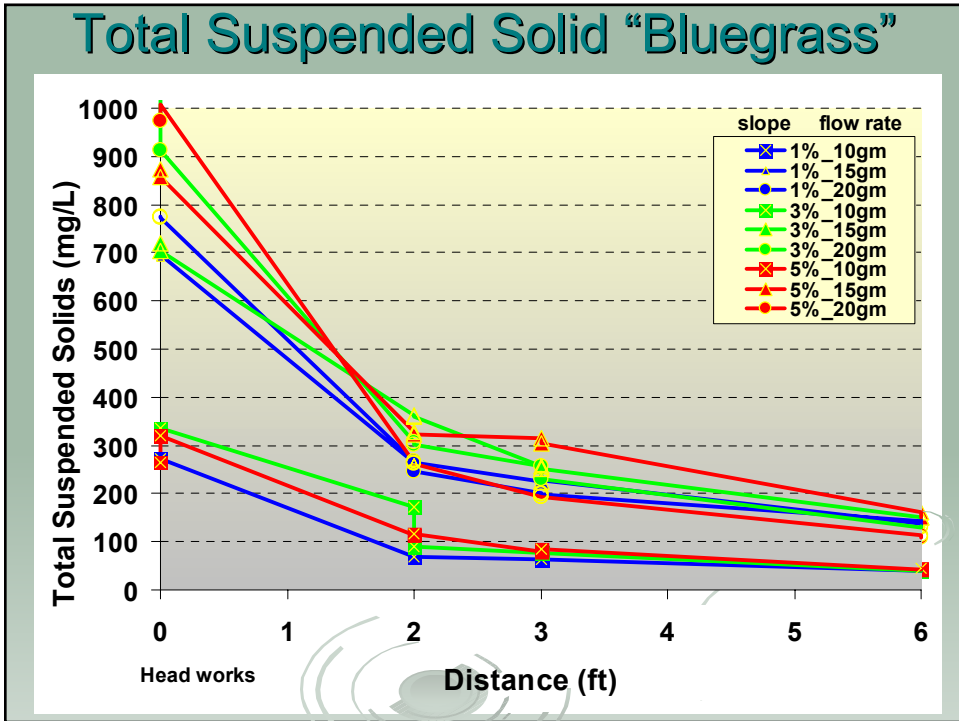


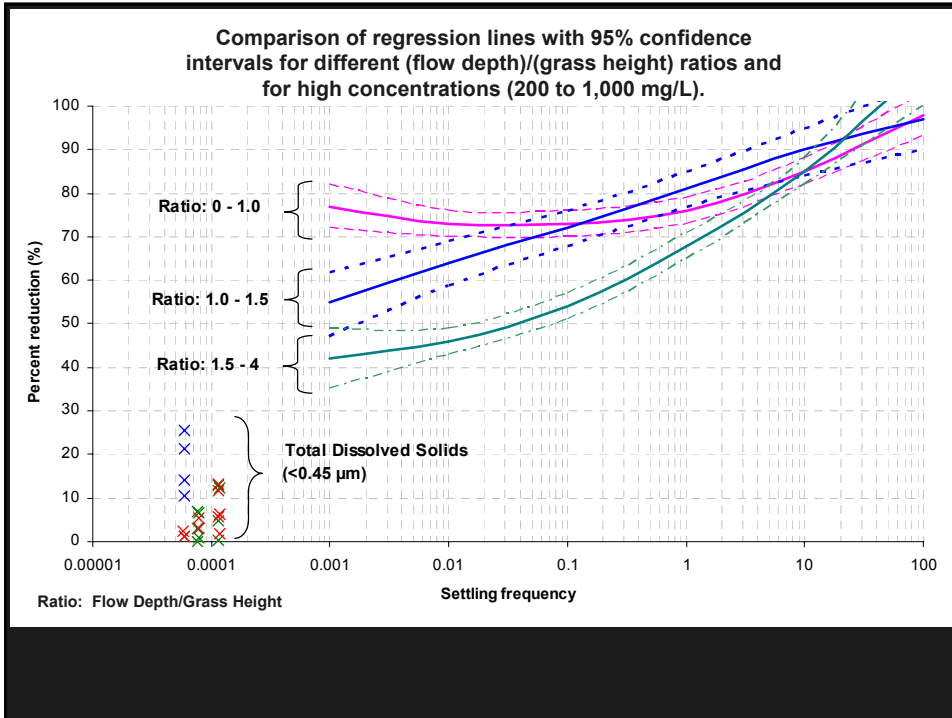
## Research Results

- IJC (1979) found swale drained areas had up to 95% less flows and pollutant yields compared to curb and gutter.
- NURP (1983) found soluble and particulate heavy metals reduced by 50% and COD, nitrate and ammonia nitrogen reduced by about 25%.
- Pitt & McLean (1986) found about 50% reductions in pollutants and runoff volume; for small frequent rains very little runoff was observed
- Current research (Nara 2005) at the Univ. of Alabama identified significant factor affecting particulate transport in grass swales and developed suitable model algorithms. Modeled procedure joins particle settling with swale hydraulics.

## Pollutant Control in Grass Swales







## Five Components to Modeling Grass Swales

- Swale Density
- Swale Infiltration Rate
- Swale Geometry
- Grass Characteristics
- Runoff Particle Size Distribution



## Swale Density

Grass Swale Data	Combined Land Uses	Residential Land Use	Institutional Land Use	Commercial Land Use	Industrial Land Use	Other Urban Land Use	Freeway Land Use
Total Area in Land Use (ac)		100.00		100.00	100.00		
Area Served by Swales (ac)		50.00		25.00	90.00		
Swale Density (ft/ac)		200.00		280.00	125.00		
Total Swale Length (ft)		10000		7000	11250		
Average Swale Length to Outlet (ft)		0		0	0		
Typical Bottom Width (ft)		2.0		5.0	4.0		
Typical Swale Side Slope (___ ft H : 1 ft V)		3.0		3.0	4.0		
Typical Longitudinal Slope (ft/ft, V/H)		0.010		0.010	0.010		
Swale Retardance Factor		C		B	D		
Typical Grass Height (in)		4.0		6.0	8.0		
Swale Dynamic Infiltration Rate (in/hr)		0.100		0.500	0.050		
Typical Swale Depth (ft) for Cost Analysis (Optional)		2.0		2.0	4.0		

Use One Swale System For All Land Uses

Select Critical Particle Size File

**Particle Size Distribution File Data Grid**

Combined Land Uses	Particle Size File
Residential LU	C:\Program Files\WinSLAMM\NURP.CPZ
Institutional LU	

Apply the Residential Land Use Particle Size File to All Active Land Uses

**Select infiltration rate by soil type**

- Sand - 4 in/hr
- Loamy sand - 1.25 in/hr
- Sandy loam - 0.5 in/hr
- Loam - 0.25 in/hr
- Silt loam - 0.15 in/hr
- Sandy silt loam - 0.1 in/hr
- Clay loam - 0.05 in/hr
- Silty clay loam - 0.025 in/hr
- Sandy clay - 0.025 in/hr
- Silty clay - 0.02 in/hr
- Clay - 0.01 in/hr

**Select Swale Density by Land Use**

- Low density residential - 160 ft/ac
- Shopping center - 280 ft/ac
- Medium density residential - 350 ft/ac
- Industrial - 125 ft/ac
- High density residential - 375 ft/ac
- Freeways (shoulder only) - 270 ft/ac
- Strip commercial - 630 ft/ac
- Freeways (center and shoulder) - 410 ft/ac

Total area served by swales (acres): 165.00  
Total area (acres): 300.00

## Swale Geometry

Grass Swale Data	Combined Land Uses	Residential Land Use	Institutional Land Use	Commercial Land Use	Industrial Land Use	Other Urban Land Use	Freeway Land Use
Total Area in Land Use (ac)		100.00		100.00	100.00		
Area Served by Swales (ac)		50.00		25.00	90.00		
Swale Density (ft/ac)		200.00		280.00	125.00		
Total Swale Length (ft)		10000		7000	11250		
Average Swale Length to Outlet (ft)		0		0	0		
Typical Bottom Width (ft)		2.0		5.0	4.0		
Typical Swale Side Slope (___ ft H : 1 ft V)		3.0		3.0	4.0		
Typical Longitudinal Slope (ft/ft, V/H)		0.010		0.010	0.010		
Swale Retardance Factor		C		B	D		
Typical Grass Height (in)		4.0		6.0	8.0		
Swale Dynamic Infiltration Rate (in/hr)		0.100		0.500	0.050		
Typical Swale Depth (ft) for Cost Analysis (Optional)		2.0		2.0	4.0		

Use One Swale System For All Land Uses

Select Critical Particle Size File

**Particle Size Distribution File Data Grid**

Combined Land Uses	Particle Size File
Residential LU	C:\Program Files\WinSLAMM\NURP.CPZ
Institutional LU	

Apply the Residential Land Use Particle Size File to All Active Land Uses

**Select infiltration rate by soil type**

- Sand - 4 in/hr
- Loamy sand - 1.25 in/hr
- Sandy loam - 0.5 in/hr
- Loam - 0.25 in/hr
- Silt loam - 0.15 in/hr
- Sandy silt loam - 0.1 in/hr
- Clay loam - 0.05 in/hr
- Silty clay loam - 0.025 in/hr
- Sandy clay - 0.025 in/hr
- Silty clay - 0.02 in/hr
- Clay - 0.01 in/hr

**Select Swale Density by Land Use**

- Low density residential - 160 ft/ac
- Shopping center - 280 ft/ac
- Medium density residential - 350 ft/ac
- Industrial - 125 ft/ac
- High density residential - 375 ft/ac
- Freeways (shoulder only) - 270 ft/ac
- Strip commercial - 630 ft/ac
- Freeways (center and shoulder) - 410 ft/ac

Total area served by swales (acres): 165.00  
Total area (acres): 300.00

# Swale Infiltration Rate

**Grass Swale Data**

	Combined Land Uses	Residential Land Use	Institutional Land Use	Commercial Land Use	Industrial Land Use	Other Urban Land Use	Freeway Land Use
Total Area in Land Use (ac)		100.00		100.00	100.00		
Area Served by Swales (ac)		50.00		25.00	90.00		
Swale Density (ft/ac)		200.00		280.00	125.00		
Total Swale Length (ft)		10000		7000	11250		
Average Swale Length to Outlet (ft)		0		5.0	4.0		
Typical Bottom Width (ft)		2.0		0.00	0.00		
Typical Swale Side Slope (ft H : 1 ft V)		3.0		0.00	0.00		
Typical Longitudinal Slope (ft/ft, V/H)		0.010		0.00	0.00		
Swale Retardance Factor		C					
Typical Grass Height (in)		4.0		6.0	8.0		
Swale Dynamic Infiltration Rate (in/hr)		0.100		2.0	0.050		
Typical Swale Depth (ft) for Cost Analysis (Optional)		2.0		2.0	4.0		

**Swale Dynamic Infiltration Rate**

Total area served by swales (acres): 165.00  
Total area (acres): 300.00

**Select infiltration rate by soil type**

- Sand - 4 in/hr
- Loamy sand - 1.25 in/hr
- Sandy loam - 0.5 in/hr
- Loam - 0.25 in/hr
- Silt loam - 0.15 in/hr
- Sandy silt loam - 0.1 in/hr
- Clay loam - 0.05 in/hr
- Silty clay loam - 0.025 in/hr
- Sandy clay - 0.025 in/hr
- Silty clay - 0.02 in/hr
- Clay - 0.01 in/hr

**Values listed in WinSLAMM are about 1/2 of the static infiltration rate for a given soil**

**Swale Retardance Factor**

Swale Retardance Factor

Retardance Classification system is from HEC-15, Classification of Vegetal Covers

# Swale Retardance Factor

**Grass Swale Data**

	Combined Land Uses	Residential Land Use	Institutional Land Use	Commercial Land Use	Industrial Land Use	Other Urban Land Use	Freeway Land Use
Total Area in Land Use (ac)		100.00		100.00	100.00		
Area Served by Swales (ac)		50.00		25.00	90.00		
Swale Density (ft/ac)		200.00		280.00	125.00		
Total Swale Length (ft)		10000		7000	11250		
Average Swale Length to Outlet (ft)		0		5.0	4.0		
Typical Bottom Width (ft)		2.0		0.00	0.00		
Typical Swale Side Slope (ft H : 1 ft V)		3.0		0.00	0.00		
Typical Longitudinal Slope (ft/ft, V/H)		0.010		0.00	0.00		
Swale Retardance Factor		C					
Typical Grass Height (in)		4.0		6.0	8.0		
Swale Dynamic Infiltration Rate (in/hr)		0.100		2.0	0.050		
Typical Swale Depth (ft) for Cost Analysis (Optional)		2.0		2.0	4.0		

**Swale Retardance Factor**

Retardance Classification system is from HEC-15, Classification of Vegetal Covers

**Table 4.1. Retardance Classification of Vegetal Covers**

Retardance Class	Cover <sup>1</sup>	Condition
A	Weeping Love Grass	Excellent stand, tall, average 760 mm (30 in)
	Yellow Bluestem Ischaemum	Excellent stand, tall, average 910 mm (36 in)
B	Kudzu	Very dense growth, uncut
	Bermuda Grass	Good stand, tall, average 300 mm (12 in)
	Native Grass Mixture (little bluestem, bluestem, blue gamma, and other long and short midwest grasses)	Good stand, unmowed
	Weeping lovegrass	Good stand, tall, average 610 mm (24 in)
	Lespedeza sericea	Good stand, not woody, tall, average 480 mm (19 in)
	Alfalfa	Good stand, uncut, average 280 mm (11 in)
C	Weeping lovegrass	Good stand, unmowed, average 330 mm (13 in)
	Kudzu	Dense growth, uncut
	Blue Gamma	Good stand, uncut, average 280 mm (11 in)
	Crabgrass	Fair stand, uncut 250 to 1200 mm (10 to 48 in)
	Bermuda grass	Good stand, mowed, average 150 mm (6 in)
	Common Lespedeza	Good stand, uncut, average 280 mm (11 in)
	Grass-Legume mixture—summer (orchard grass, redtop, Italian ryegrass, and common lespedeza)	Good stand, uncut, 150 to 200 mm (6 to 8 in)
	Centpede grass	Very dense cover, average 150 mm (6 in)
	Kentucky Bluegrass	Good stand, headed, 150 to 300 mm (6 to 12 in)
	D	Bermuda Grass
Common Lespedeza		Excellent stand, uncut, average 110 mm (4.5 in)
Buffalo Grass		Good stand, uncut, 80 to 150 mm (3 to 6 in)
Grass-Legume mixture—fall, spring (orchard grass, redtop, Italian ryegrass, and common lespedeza)		Good stand, uncut, 100 to 130 mm (4 to 5 in)
E	Lespedeza sericea	After cutting to 50 mm (2 in) height. Very good stand before cutting
	Bermuda Grass	Good stand, cut to height, 40 mm (1.5 in)
	Bermuda Grass	Burned stubble

<sup>1</sup> Covers classified have been tested in experimental channels. Covers were green and generally uniform.

## Particle Size File

Grass Swale Data	Combined Land Uses	Residential Land Use	Institutional Land Use	Commercial Land Use	Industrial Land Use	Other Urban Land Use	Freeway Land Use
Total Area in Land Use (ac)		100.00		100.00	100.00		
Area Served by Swales (ac)		50.00		25.00	90.00		
Swale Density (ft/ac)		200.00		280.00	125.00		
Total Swale Length (ft)		10000		7000	11250		
Average Swale Length to Outlet (ft)		0		0	0		
Typical Bottom Width (ft)		2.0		5.0	4.0		
Typical Swale Side Slope (___ ft H : 1 ft V)		3.0		3.0	4.0		
Typical Longitudinal Slope (ft/ft, V/H)		0.010		0.010	0.010		
Swale Retardance Factor							
Typical Grass Height (in)		4.0		6.0	8.0		
Swale Dynamic Infiltration Rate (in/hr)				0.500	0.050		
Typical Swale Depth (ft) for Cost Analysis (Optional)		2.0		2.0	4.0		

**Enter Grass Height and Particle Size Distribution to Determine Particle Size Filtering**

Use One Swale System For All Land Uses

Select Critical Particle Size File

**Particle Size Distribution File Data Grid**

Combined Land Uses	Particle Size Distribution File
Residential LU	C:\Program Files\WinSLAMM\NURP.CPZ
Institutional LU	

Apply the Residential Land Use Particle Size File to All Active Land Uses

**Select Swale Density by Land Use**

Low density residential - 160 ft/ac     Shopping center - 280 ft/ac  
 Medium density residential - 350 ft/ac     Industrial - 125 ft/ac  
 High density residential - 375 ft/ac     Freeways (shoulder only) - 270 ft/ac  
 Strip commercial - 630 ft/ac     Freeways (center and shoulder) - 410 ft/ac

Total area served by swales (acres): 165.00  
Total area (acres): 300.00

**Select infiltration rate by soil type**

Sand - 4 in/hr  
 Loamy sand - 1.25 in/hr  
 Sandy loam - 0.5 in/hr  
 Loam - 0.25 in/hr  
 Silt loam - 0.15 in/hr  
 Sandy silt loam - 0.1 in/hr  
 Clay loam - 0.05 in/hr  
 Silty clay loam - 0.025 in/hr  
 Sandy clay - 0.025 in/hr  
 Silty clay - 0.02 in/hr  
 Clay - 0.01 in/hr

## Land Use Options

Grass Swale Data	Combined Land Uses	Residential Land Use	Institutional Land Use	Commercial Land Use	Industrial Land Use	Other Urban Land Use	Freeway Land Use
Total Area in Land Use (ac)		100.00		100.00	100.00		
Area Served by Swales (ac)		50.00		25.00	90.00		
Swale Density (ft/ac)		200.00		280.00	125.00		
Total Swale Length (ft)		10000		7000	11250		
Average Swale Length to Outlet (ft)		0		0	0		
Typical Bottom Width (ft)		2.0		5.0	4.0		
Typical Swale Side Slope (___ ft H : 1 ft V)		3.0		3.0	4.0		
Typical Longitudinal Slope (ft/ft, V/H)		0.010		0.010	0.010		
Swale Retardance Factor		C		B	D		
Typical Grass Height (in)		4.0		6.0	8.0		
Swale Dynamic Infiltration Rate (in/hr)		0.100		0.500	0.050		
Typical Swale Depth (ft) for Cost Analysis (Optional)		2.0		2.0	4.0		

**Enter Data by Land Use, or ...**

Use One Swale System For All Land Uses

Select Critical Particle Size File

**Particle Size Distribution File Data Grid**

Combined Land Uses	Particle Size Distribution File
Residential LU	C:\Program Files\WinSLAMM\NURP.CPZ
Institutional LU	

Apply the Residential Land Use Particle Size File to All Active Land Uses

**Select Swale Density by Land Use**

Low density residential - 160 ft/ac     Shopping center - 280 ft/ac  
 Medium density residential - 350 ft/ac     Industrial - 125 ft/ac  
 High density residential - 375 ft/ac     Freeways (shoulder only) - 270 ft/ac  
 Strip commercial - 630 ft/ac     Freeways (center and shoulder) - 410 ft/ac

Total area served by swales (acres): 165.00  
Total area (acres): 300.00

**Select infiltration rate by soil type**

Sand - 4 in/hr  
 Loamy sand - 1.25 in/hr  
 Sandy loam - 0.5 in/hr  
 Loam - 0.25 in/hr  
 Silt loam - 0.15 in/hr  
 Sandy silt loam - 0.1 in/hr  
 Clay loam - 0.05 in/hr  
 Silty clay loam - 0.025 in/hr  
 Sandy clay - 0.025 in/hr  
 Silty clay - 0.02 in/hr  
 Clay - 0.01 in/hr

**Grass Swales**

Grass Swale Data	Combined Land Uses	Residential Land Use	Institutional Land Use	Commercial Land Use	Industrial Land Use	Other Urban Land Use	Freeway Land Use
Total Area in Land Use (ac)	40.00						
Area Served by Swales (ac)	40.00						
Swale Density (ft/ac)	203						
Total Swale Length (ft)	8100						
Average Swale Length to Outlet (ft)	1980						
Typical Bottom Width (ft)	3						
Typical Swale Side Slope ( __ ft H : 1 ft V)	3						
Typical Longitudinal Slope (ft/ft, V/H)	.005						
Swale Retardance Factor	C						
Typical Grass Height (in)	3						
Swale Dynamic Infiltration Rate (in/hr)	0.25						
Typical Swale Depth (ft) for Cost Analysis (Optional)	4						

**Enter Data to route all Land Uses to a Combined Swale System**

Use One Swale System For All Land Uses

Total area served by swales (acres): 40.00  
Total area (acres): 40.00

**Particle Size Distribution File Data Grid**

Combined Land Uses	File
Combined Land Uses	C:\Program Files\WinSLAMM\NURP.CPZ
Residential LU	
Institutional LU	

Apply the Residential Land Use Particle Size File to All Active Land Uses

**Select infiltration rate by soil type**

- Sand - 4 in/hr
- Loamy sand - 1.25 in/hr
- Sandy loam - 0.5 in/hr
- Loam - 0.25 in/hr
- Silt loam - 0.15 in/hr
- Sandy silt loam - 0.1 in/hr
- Clay loam - 0.05 in/hr
- Silty clay loam - 0.025 in/hr
- Sandy clay - 0.025 in/hr
- Silty clay - 0.02 in/hr
- Clay - 0.01 in/hr

**Select Swale Density by Land Use**

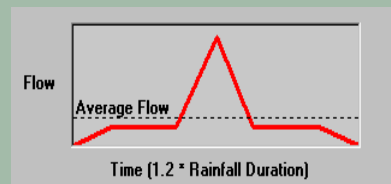
- Low density residential - 160 ft/ac
- Medium density residential - 350 ft/ac
- High density residential - 375 ft/ac
- Strip commercial - 630 ft/ac
- Shopping center - 280 ft/ac
- Industrial - 125 ft/ac
- Office - 370 ft/ac
- Multi-family (apartment) - 370 ft/ac

**Land Use Options**

Cancel Continue

## Dynamic Wetted Width Calculation

- Calculate event volume
- Convert volume to flow with:
  - Runoff duration = 1.2 times rainfall duration
  - Complex triangular hydrograph peak to average ratio = 3.8
- Flow rate calculated for each six minute interval
- Calculate the wetted width from the flow rate and swale geometry using Manning's open channel flow equation



- Width
- Side slope
- Slope
- Manning's n from Retardance Factor





# Swale Output

WinSLAMM Model Output

File Name: C:\Files\SLAMM\WinSLAMM\Test Files\9.2.0 Test Files\Distribution Files\Standard Data Files\Control Demo Files\Swale Demo ClayMad81.dat

### Drainage System and Outfall Output Summary

	Runoff Volume (cu. ft.)	Percent Runoff Reduction	Runoff Coefficient (Rv)	Particulate Solids Conc. (mg/L)	Particulate Solids Yield (lbs)	Percent Particulate Solids Reduction
Source Area Total without Controls	270807	<= Percent Reduction Basis Value	0.22	172.0		
Outfall Total without Controls					2905	<= Basis Value
Current File Output: Total Before Drainage System	270807	0.00 %	0.22	172.0	2905	
Current File Output: Total After Drainage System	91692	66.14 %	0.07	191.2	1094	
Current File Output: Total After Outfall Controls	91692	66.14 %	0.07	191.2	1094	62.34 %

Total Area Modeled (ac) 100.00

Print Output Summary to Text File

### Total Control Practice Costs

Capital Cost	N/A
Land Cost	N/A
Annual Maintenance Cost	N/A
Present Value of All Costs	N/A
Annualized Value of All Costs	N/A

### Receiving Water Impacts Due To Stormwater Runoff

Perform Flow Duration Curve Calculations	Calculated Rv	Approx. Biological Condition of Receiving Water
Without Controls	0.22	Poor
With Controls	0.07	Good

## Grass Swale Model Results

WinSLAMM Model Output

Runoff Volume | Particulate Solids | Pollutants | Output Summary

### Runoff Volume (cu ft)

Data File: SwaleDemoClayMad81.DAT  
 Rain File: MAD5289.RAN  
 Date: 02-27-07 Time: 3:08:33 PM  
 Site Description: Swale in clayey soil area

Total Area, with Drainage and Outfall Controls - Runoff Volume (cu ft)

Start Date	Rain Total (inches)	Total Before Drainage System	Total After Drainage System	Total After Outfall Controls	Rv	Total Losses (in)	Calculated CN*	Peak Reduction Factor	F
04/03/81	0.02	86.83	0	0	0.00	0.02	N/A		
04/03/81	0.26	16422	0	0	0.00	0.26	N/A		
04/07/81	0.71	65184	9072	9072	0.04	0.69	81.4		
04/08/81	0.41	30105	0	0	0.00	0.41	N/A		
04/10/81	1.06	104763	80728	80728	0.21	0.84	85.8		
04/12/81	0.13	7317	0	0	0.00	0.13	N/A		
04/13/81	0.32	21504	0	0	0.00	0.32	N/A		
04/16/81	0.01	4748	0	0	0.00	0.01	N/A		
04/19/81	0.04	1367	0	0	0.00	0.04	N/A		
04/22/81	0.01	4748	0	0	0.00	0.01	N/A		
04/22/81	0.02	86.83	0	0	0.00	0.02	N/A		
04/23/81	0.05	1814	0	0	0.00	0.05	N/A		
04/28/81	0.30	19757	1892	1892	0.02	0.29	90.0		
04/28/81	0.06	2304	0	0	0.00	0.06	N/A		
04/30/81	0.02	86.83	0	0	0.00	0.02	N/A		

Summary for All Events: \*Note: NRCS does not recommend using CN method for rains < 0.5 in. See PreDevelopment Areas z

	Rain Total (inches)	Total Before Drainage System	Total After Drainage System	Total After Outfall Controls	Rv	Total Losses (in)	Calculated CN*	Peak Reduction Factor	F
Number of Rains:	14	14	14	14					
Minimum:	0.01	4748	0	0	0.00	0.01	N/A		
Maximum:	1.06	104763	80728	80728	0.21	0.84	90.0		
Average:	0.24	19343	6549	6549	0.07	0.21	94.4		
Total:	3.42	270807	91692	91692	0.07	3.17			

# Drainage System Runoff Volume

Before Drainage System Total

After Drainage System Total

WinSLAMM Model Output

File View

Runoff Volume    Particulate Solids    Pollutants    Output Summary

Concentration    Yield    SA Yield Contribution

Data File: SwaleDemoClayMad81.DAT  
 Rain File: MAD55289.RAN  
 Date: 02-27-07 Time: 3:08:33 PM  
 Site Description: Swale in clayey soil area

Total Area, with Drainage and Outfall Controls - Yield of PARTICULATE SOLIDS (lbs)

Start Date	Rain Total (inches)	Total Before Drainage System	Total After Drainage System	Catch basin Volume % Full	Upflow Filter Volume % Full	Total After Outfall Controls	Flow-wtd Min. Part. Size Controlled (microns)
04/03/81	0.02	3.190	0	0	0	0	
04/03/81	0.26	240.7	0	0	0	0	
04/07/81	0.71	688.1	95.78	0	0	95.78	
04/08/81	0.41	269.9	0	0	0	0	
04/10/81	1.06	1273	980.6	0	0	980.6	
04/12/81	0.13	53.46	0	0	0	0	
04/13/81	0.32	158.6	0	0	0	0	
04/16/81	0.01	0.001730	0	0	0	0	
04/19/81	0.04	8.462	0	0	0	0	
04/22/81	0.01	0.001730	0	0	0	0	
04/22/81	0.02	1.451	0	0	0	0	
04/23/81	0.05	11.57	0	0	0	0	
04/28/81	0.30	181.4	17.37	0	0	17.37	
04/28/81	0.06	14.02	0	0	0	0	
04/30/81	0.02	1.402	0	0	0	0	

Summary for Runoff Producing Events

	Rain Total (inches)	Total Before Drainage System	Total After Drainage System	Catch basin Volume % Full	Upflow Filter Volume % Full	Total After Outfall Controls	Flow-wtd Min. Part. Size Controlled (microns)
Minimum:	0.01	0.001730	17.37	0	0	17.37	
Maximum:	1.06	1273	980.6	0	0	980.60	
FltWt Ave:	N/A	730.0	873.2			873.2	
Total:	3.42	2905	1094			1093.75	

# Drainage System Particulate Solids Yield

Before Drainage System Total

After Drainage System Total

Questions?