Example Biofiltration Swale

Introduction to Biofiltration Swales

A Biofiltration Swale is a BMP that uses vegetation (typically grass) to provide basic treatment of stormwater runoff. In areas where the ADT exceeds 30,000 and discharges to a non-exempt surface water body enhanced treatment is required, see the Highway Runoff Manual (HRM) Table 2-1. Biofiltration Swales are sloped, vegetative channels or ditches that provide both conveyance and runoff treatment to stormwater runoff. Bioswales do not provide stormwater flow control, but can convey runoff to BMP's designed for that purpose. There are two methods for sizing Bioswales in this tutorial; the first can be used in both eastern and western Washington and the second can only be used in eastern Washington. The first section of this tutorial applies to both sides of the state and will first focus on using hand calculations to size a swale (with some StormShed) and the second half will repeat the steps using StormShed. The second section will only apply to eastern Washington (it is the same method that appeared in the 1997 HRM) and will only use StormShed to size the swale.

Eastern and Western Washington Biofiltration Swale Sizing Criteria

Biofiltration Swales shall be designed following the guidelines outlined in Section RT.04 of the HRM, Table RT.04.2 summarized the sizing criteria. This section will focus on Basic Biofiltration Swales, shown in the 2nd column of the table below. In addition to the criteria below, bioswales are sized based on flow rate and using the short duration storm as described in the Storm Shed Beginning Course.

Table RT.04.2. Biofiltration swale sizing criteria.

Design Parameter	Basic Biofiltration Swale	Wet Biofiltration Swale	Continuous Inflow Biofiltration Swale
Longitudinal slope	0.015–0.050[1] feet per foot	0.015 feet per foot or less	Same as basic swale
Maximum velocity	1 foot per second at Q_{biofil}	Same as basic swale	Same as basic swale
Maximum water depth at Q_{biofil}, y	2 inches if swale mowed frequently; 4 inches if mowed infrequently or inconsistently. For dryland grasses in eastern Washington, set depth to 3 inches.	4 inches	Same as basic swale
Manning coefficient at Q_{biofil}	See Table RT.04.1	Same as basic swale	Same as basic swale
Bed width	2–10 feet [2]	2–25 feet	Same as basic swale
Freeboard height	1 foot for the peak conveyance flow rate (Q_{convey})[3]	Same as basic swale	Same as basic swale
Minimum length	100 feet	Same as basic swale	Same as basic swale
Maximum side slope (for trapezoidal cross-section)[4]	3H:1V	Same as basic swale	Same as basic swale

[1] For basic biofiltration swale on slopes less than 1.5 percent, install an underdrain system. Underdrain backfill should be covered by at least 4 inches of amended soil or topsoil. For slopes greater than 5 percent, install energy dissipaters.

[2] Multiple parallel swales can be constructed when the calculated swale bottom width exceeds 10 feet.

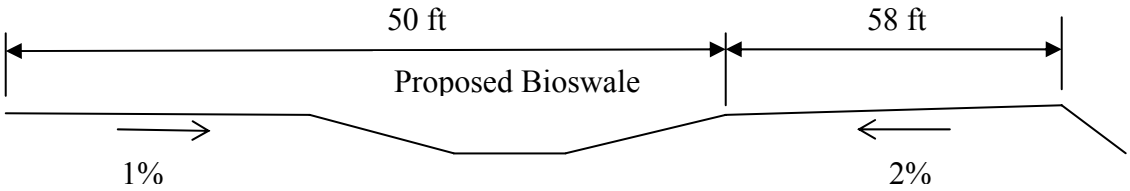
[3] Q_{convey} should be based on the design flow rate of the conveyance system downstream of the biofiltration swale. In general, this is the peak $Q_{25\text{-}year}$.

[4] From swale bed to top of water surface at Q_{biofil}.

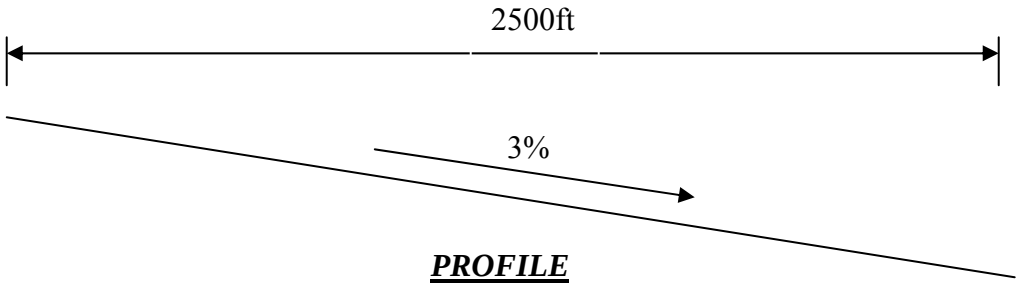
Example Biofiltration Swale

Biofiltration Swale Sample Problem Description

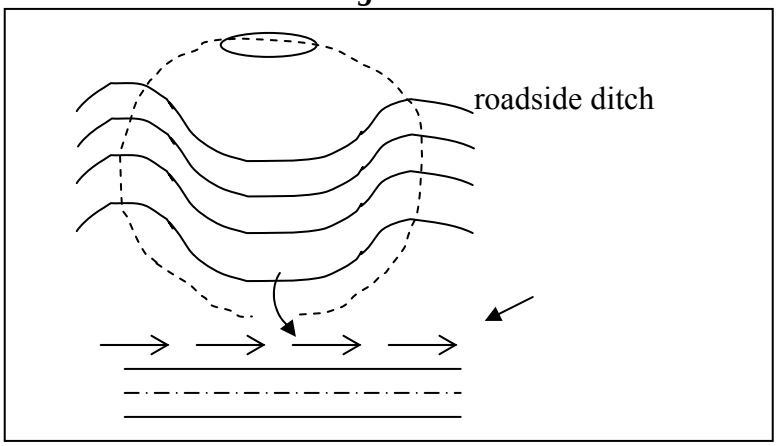
A new highway near the city of Spokane is being constructed that will add 58'x 2500' **(3.33 acres)** of roadway, all superelevated at a 2% cross slope toward the outside shoulder with a continuous 3% profile. It has been decided that a trapezoidal biofiltration swale will be constructed to provide runoff treatment and convey the stormwater to a downstream pond. In addition to **the roadway runoff**, there is also **2.87 acres** of pervious area within WSDOT Right of Way side slopes contributing to the swale **including the swale**. The SCS soil type is Type C and the ground cover is primarily forest in fair conditions. The average slope of the ground is **1%**. The calculated time of concentration should be assumed that for the forested condition will be **50 feet** of sheet flow and **2450 feet** of shallow concentrated flow.



CROSS SECTION
Figure 1



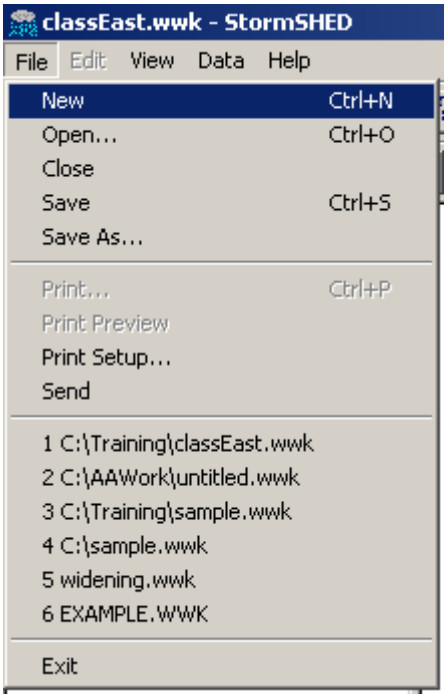
PROFILE
Figure 2

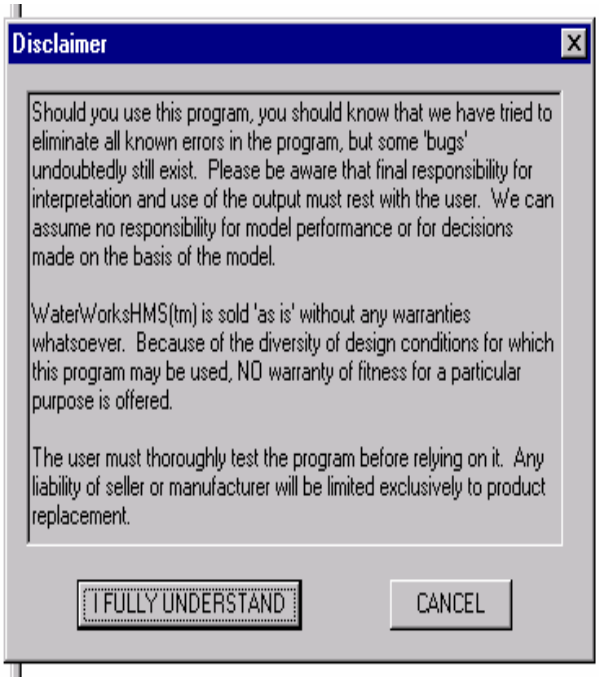


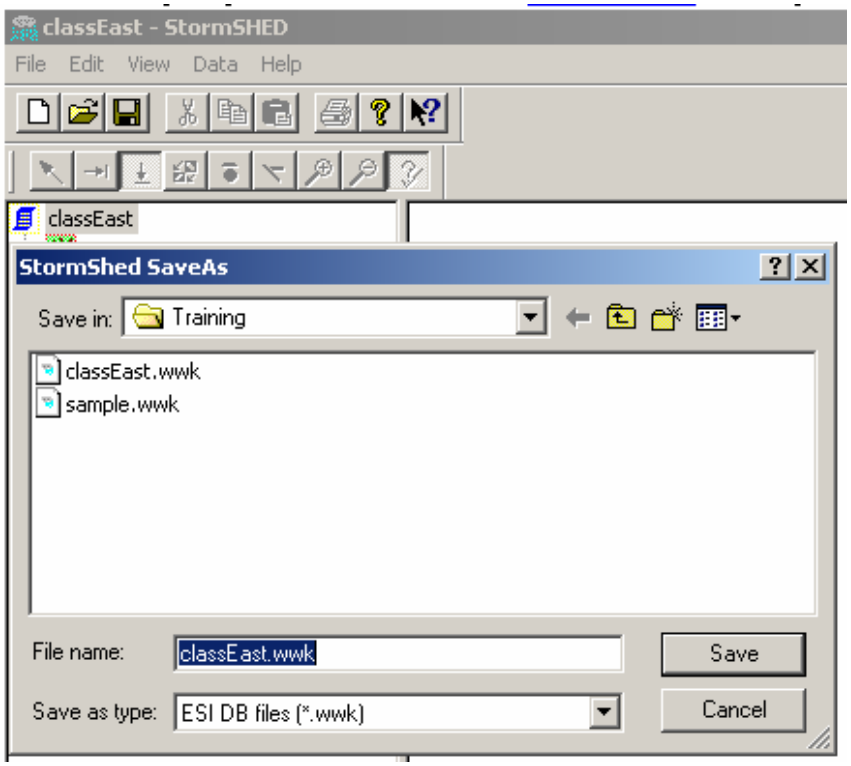
DBA Mapping Example
Figure 3

Example Biofiltration Swale

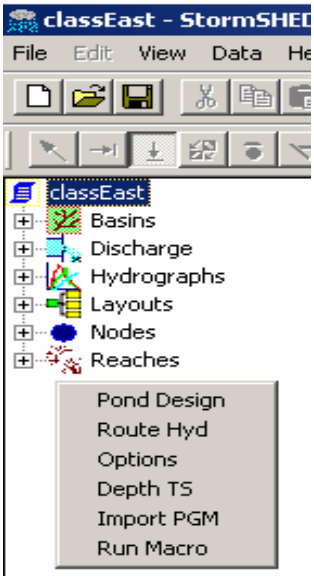
The first thing that needs to be done when starting StormSHED is to create a new project. Click on the new project icon (blank piece of paper) then use the Save As command in the File menu to give it a unique name.



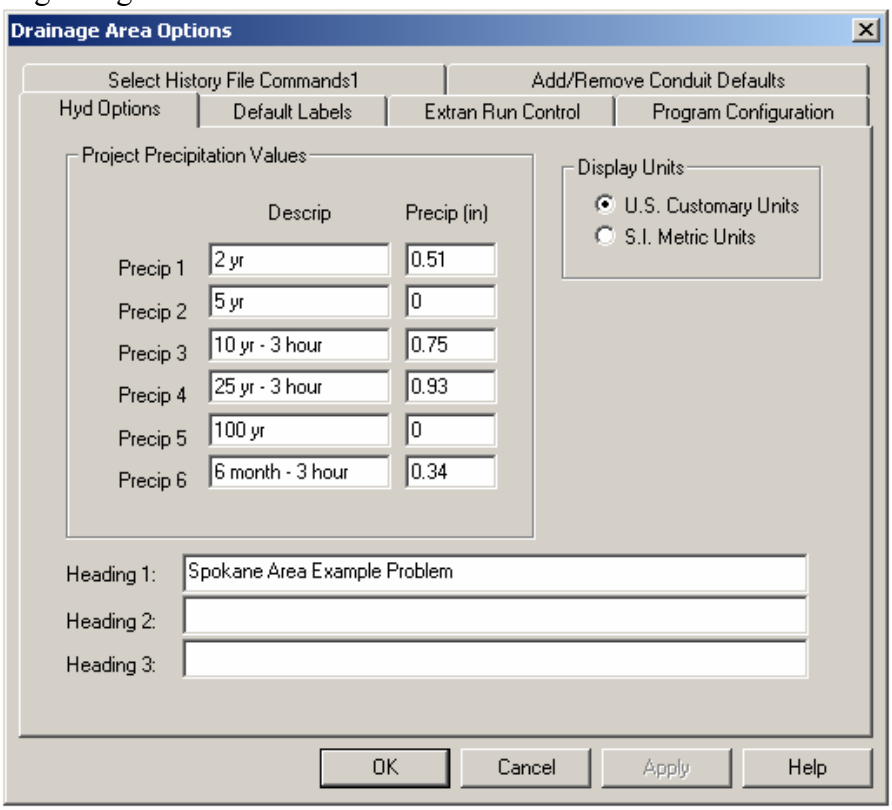




Next set the project defaults. Click with the right mouse button in a blank part of the Tree Menu.



Click Options with the left mouse button and the following menu will pop up. The values below are for the short duration storm in Spokane. For further explanation see the Beginning StormShed Tutorial.



Example Biofiltration Swale

Next, using the steps outlined in the 2004 HRM section RT.04 we will size our swale.

1. Determine the runoff treatment design flow rate (Q_{wq}), that is the runoff contributing to the bioswale. After completing steps 1-4, we will use StormShed to define the DBA for the bioswale and calculate the Q.

2. Determine the biofiltration design flow rate (Q_{biofil})

   For eastern Washington:

   $k = 1.0$

   $Q_{biofil} = kQ_{wq}$

   $Q_{biofil} = Q_{wq}$

3. Verify the longitudinal slope of the proposed biofiltration swale is within the design parameters (see Table RT.04.1 for criteria). For this example, the longitudinal slope is 3% or s = 0.03 which is within the 1.5%-5% design parameters.

4. Next select a soil and vegetation cover suitable for the biofiltration swale using Table RT.04.1 below. For this example the manning's coefficient is n = 0.20 or Grass-legume mix on compacted native soil.

Table RT.04.1. Flow resistance coefficient in basic, wet, and continuous inflow biofiltration swales.

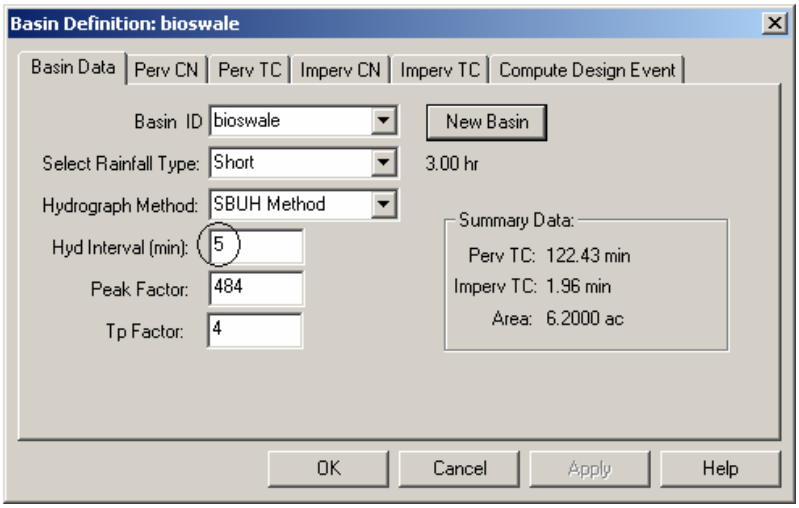
Soil and Cover	Manning's Coefficient
Grass-legume mix on compacted native soil	0.20
Grass-legume mix on lightly compacted, compost-amended[1] soil	0.22
Grass-legume mix on lightly compacted, compost-amended[1] soil with surface roughness features[2]	0.35

[1] For information on compost-amended soils, refer to Appendix 5A, Section A-2. Note that swales do not require a mulch layer and that compost amendments are incorporated into the soil.

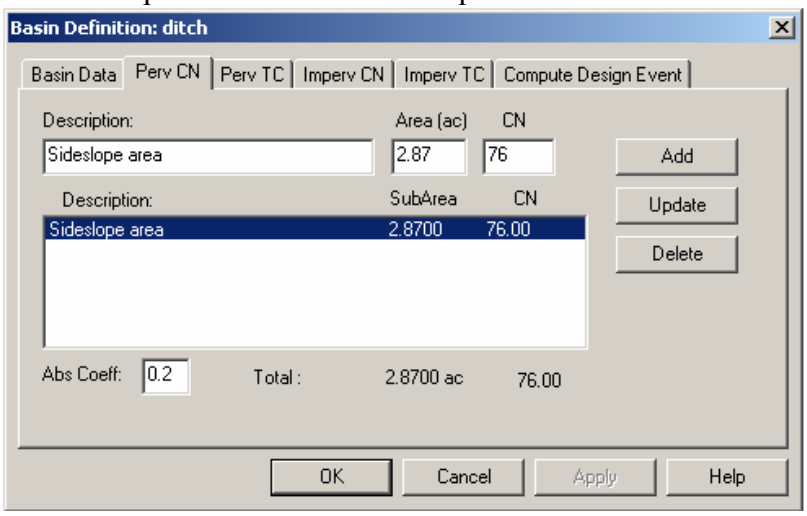
[2] Acceptable surface roughness features are wattle check dams (Std. Spec. 8-01.3(6)D), gravel filter berms (Std. Spec. 8-01.3(9)B), or compost berms (Std. Plan I-14). These features must be placed every 50 feet (or closer) and should not exceed 1.5 feet in height above finished swale bottom. These features must not be used in place of level spreaders or energy dissipaters.

Example Biofiltration Swale

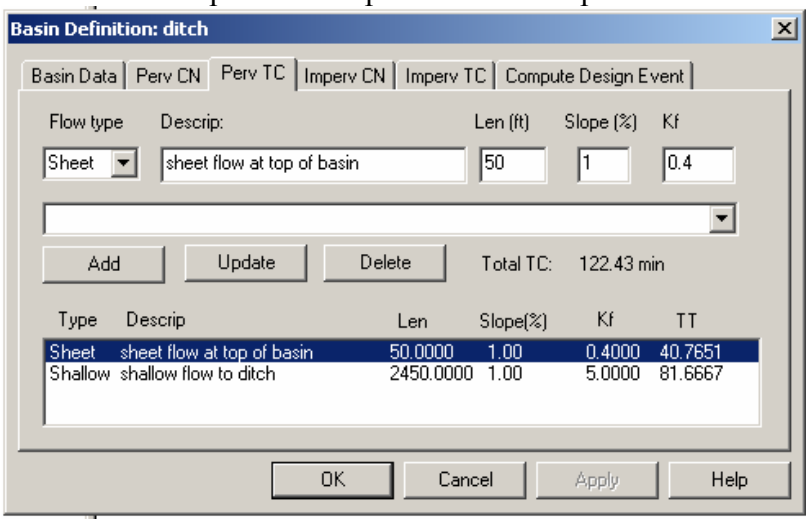
Next, we will create a basin**.** In the tree view, click on the basin plus symbol using the Left Mouse Button. Then double click on the prototype and select new basin and type bioswale and input the data shown below. Note the interval is changed from 10 minutes to 5 as shown below.



Define the pervious surface side slope area.

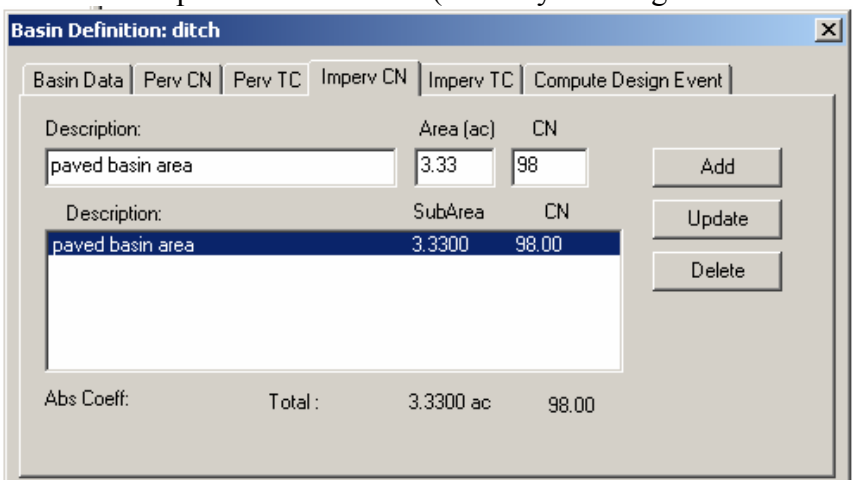


Define the flow path for the pervious side slope area.

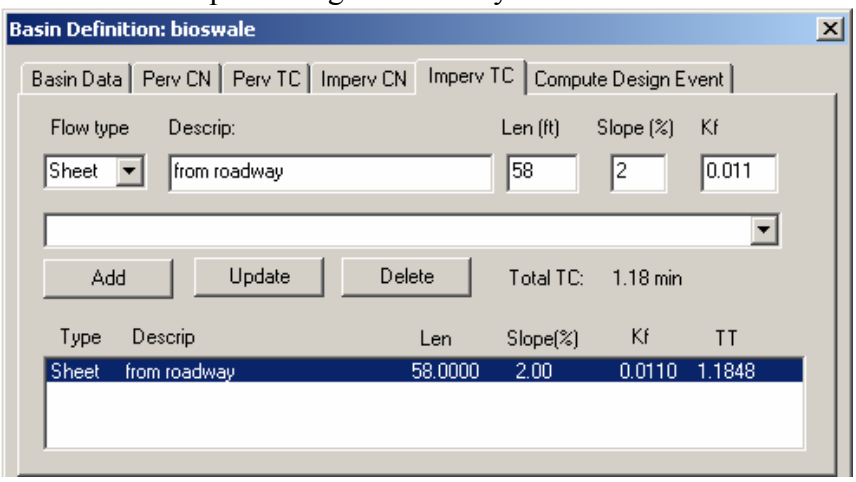


Example Biofiltration Swale

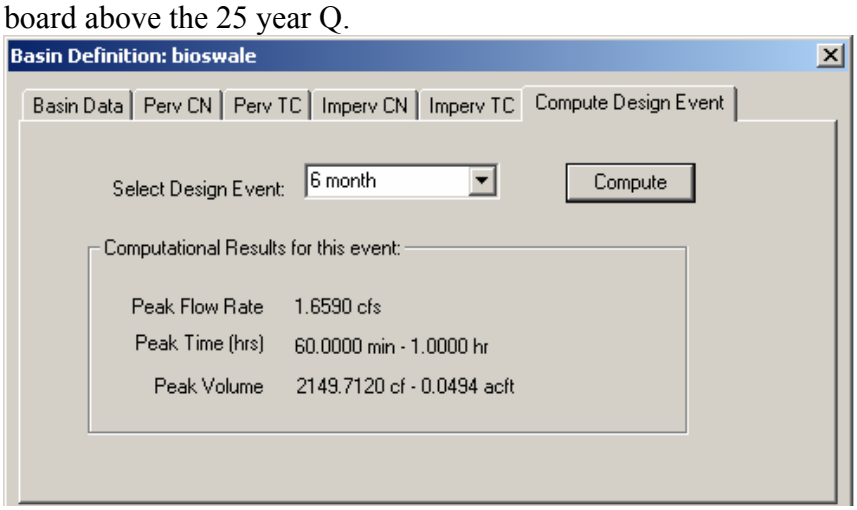
Define the impervious basin area (roadway draining toward the ditch)

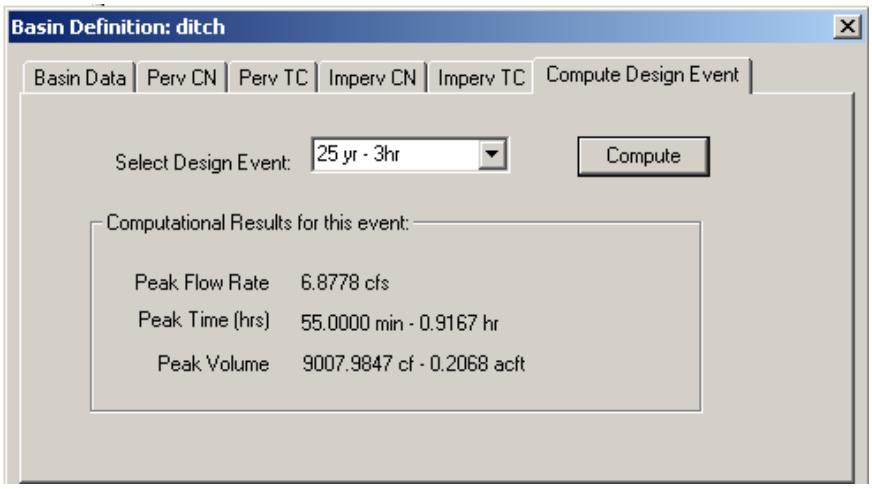


Define the flow path along the roadway and in the ditch.



Finally compute the 6 month 3 hour MRI and the 25 year 3 hour MRI. While bioswales are designed for the 6 month 3 hour MRI, the 25 year 3 hour should be run through the ditch to determine the freeboard depth of the swale. The HRM requires a foot of free board above the 25 year Q.





5. Next select a swale cross-sectional shape (trapezoidal is preferred but rectangular or triangular cross-sections can be used if site-specific constraints so dictate). For this example we will use a trapezoidal shape.

6. Now we will determine the width of our swale. Use Manning's equation (RT.04-1) and first approximations relating hydraulic radius and dimensions for the selected swale shape from Table RT.04.1 on the next page, to obtain a value for the width of the biofiltration swale:

$$Q_{biofil} = \frac{1.49 A R^{2/3} s^{1/2}}{n} \qquad \text{(RT.04-1)}$$

where: Q_{biofi} = runoff treatment design flow rate (cfs)

A = wetted area (ft^2)

R = hydraulic radius (ft)

s = longitudinal slope of swale (ft/ft)

n = Manning's coefficient (see Table RT.04.1).

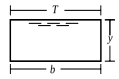
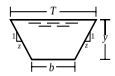
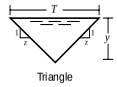
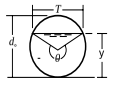
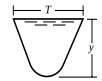
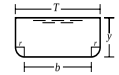
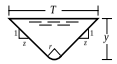
To solve for the cross-sectional width of the swale, the HRM offers 3 methods. This example will focus of the third method as described below:

Method 3:

For a trapezoidal swale that is flowing very shallow, the hydraulic radius, *R*, can be set equal to the depth of flow (y). Based on discussions with maintenance, the swale will not be mowed, so from Table RT.04.2 the maximum depth y is 4 inches (0.33 ft) or 3 inches for erosion control grasses (for this tutorial we will assume 4 inches). Using this assumption, the equation in above can be changed as shown on the top of the next page.

It should be noted that the equation is incorrect in the March 2004 HRM. Designers should use the equation at the top of the next page for projects.

Figure RT.04.1. Geometric elements of common cross-sections.

Section	Area A	Wetted perimeter P	Hydraulic radius R	Top width W	Hydraulic depth D	Section factor Z
 Rectangle	by	$b + 2y$	$\frac{by}{b + 2y}$	b	y	$by^{1.5}$
 Trapezoid	$(b + zy)y$	$b + 2y\sqrt{1 + z^2}$	$\frac{(b + zy)y}{b + 2y\sqrt{1 + z^2}}$	$b + 2zy$	$\frac{(b + zy)y}{b + 2zy}$	$\frac{[(b + zy)y]^{1.5}}{\sqrt{b + 2zy}}$
 Triangle	zy^2	$2y\sqrt{1+ z^2}$	$\frac{zy}{2\sqrt{1 + z^2}}$	$2zy$	$^1/_2 y$	$\frac{\sqrt{2}}{2} zy^{2.5}$
 Circle	$^1/_8(\theta - \sin\theta)d_\circ^2$	$^1/_2\theta d_\circ$	$^1/_4\left(1-\frac{\sin\theta}{\theta}\right)d_\circ$	$(\sin(^1/_2\theta)d_\circ)$ or $2\sqrt{y\,(d_\circ - y)}$	$^1/_8\left(\frac{\theta - \sin\theta}{\sin {}^1/_2\theta}\right)d_\circ$	$\frac{\sqrt{2}}{32}\frac{(\theta - \sin\theta)^{1.5}}{(\sin {}^1/_2\theta)^{0.5}} d_\circ^{2.5}$
 Parabola	$^2/_3 Ty$	$T + \frac{8y^2}{3T}$ *	$\frac{2T^2 y}{3T^2 + 8y^2}$ *	$\frac{3A}{2y}$	$^2/_3 y$	$^2/_9\sqrt{6}Ty^{1.5}$
 Round-cornered Rectangle ($y>r$)	$(\frac{\pi}{2} - 2)r^2 + (b + 2r)y$	$(\pi - 2)r + b + 2y$	$\frac{(\frac{\pi}{2} - 2)r^2 + (b + 2r)y}{(\pi - 2)r + b + 2y}$	$b + 2r$	$\frac{(\frac{\pi}{2} - 2)r^2}{(b + 2r)} + y$	$\frac{[(\frac{\pi}{2} - 2)r^2 + (b + 2r)y]^{1.5}}{\sqrt{b + 2y}}$
 Round-bottomed Triangle	$\frac{T^2}{4z} - \frac{r^2}{z}(1 - z\cot^{-1}z)$	$\frac{T}{z}\sqrt{1 + z^2} - \frac{2r}{z}(1 - z\cot^{-1} z)$	$\frac{A}{P}$	$2[z(y - r) + r\sqrt{1 + z^2}]$	$\frac{A}{T}$	$A\sqrt{\frac{A}{T}}$

*Satisfactory approximation for the interval 0<x≤1, where x=4y/T. When x>1, use the exact expression $P = (^T/_2)\left[\sqrt{1 + x^2} + {}^1/_x \ln\left(x + \sqrt{1 + x^2}\right)\right]$

$b = [(nQ_{biofil})/(1.49y^{1.67}s^{0.5})] - zy$

$b = [((0.2)(1.66))/(1.49(0.33)^{1.67}(0.03)^{0.5})] - 3x0.33$

$b = 7.22$ ft

For constructability, the swale will be increased to 8 ft. Designers should consult the project engineer to determine a swale width that is constructible.

Note: If a value for *b* or *T* is calculated less than 2 feet, then set bed width to 2 feet.

6. Designers next need to verify the velocity is less than 1 ft/s using equation RT.04-2 below.

   Compute the flow velocity at Q_{biofil}.

$$V_{biofil} = \frac{Q_{biofil}}{A} \qquad \text{(RT.04-2)}$$

   where: V_{biofil} = flow velocity at Q_{biofil} (ft/sec).

   Before computing the velocity, *A* will need to be calculated using the at Q_{biofil} by using the equations in Figure RT.04.1. For a trapezoid, the area can be computed as follows:

   $A=(b+yz)y$

   $A=(8+0.33x3)0.33$

   $A=2.97$ sqft

   Next apply equation RT.04-2:

$$V_{biofil} = \frac{1.66}{2.97} = 0.56 \text{ft/s}$$

   Since $V_{biofil} < 1.0$ ft/sec, the width (*b* or *T*) is acceptable. If the $V_{biofil} > 1.0$ ft/sec the channel width should be increased or investigate ways to reduce Q_{WQ} and then repeat the steps above until $V_{biofil} \leq 1.0$ ft/sec. A velocity greater than 1.0 ft/sec is found to flatten grasses, thus reducing filtration.

7. Compute the required swale length, *L* (ft).

$$L = V_{biofil}\, t \text{ (60 sec/min)}$$

   where: t = hydraulic residence time (min)

   = 9 minutes for basic biofiltration swales.

$$L = (0.56 \text{ ft/s})(9\text{min})(60 \text{ sec/min}) = 302.4 \text{ ft}$$

If there is not sufficient space for the biofiltration swale, consider the suggested solutions provided in the 2004 HRM RT.04 BMP design. For this example, assume there is more than enough space.

8. Lastly, the free board check should be performed for the combination of highest expected flow and least vegetation coverage and height. The highest expected flow rate (Q_{convey}) is the design flow rate of the downstream conveyance system to which the swale discharges.

Note: Use the same units as in the biofiltration swale design steps.

Select the lowest possible roughness coefficient for the biofiltration swale (assume n = 0.03). Since the 25 year storm produces a larger flow rate, the affects of the 25 year storm going through the grass will be less and thus the n value can be reduced to reflect this.

Again, use the implicit equation $AR^{0.67} = Q_{convey}n/(1.49s^{0.5})$ (Figure RT.04.1) and with a known *b* (or *T*), solve for depth, *y*. Select the lowest *y* that provides a solution. For trapezoidal swales, Figures RT.04.2 and RT.04.3 can be used directly.

$$b = [(nQ_{biofil})/(1.49y^{1.67}s^{0.5})] - zy$$

$$8 = [(0.03x6.88)/(1.49y^{1.67}(0.03)^{0.5})] - 3y$$

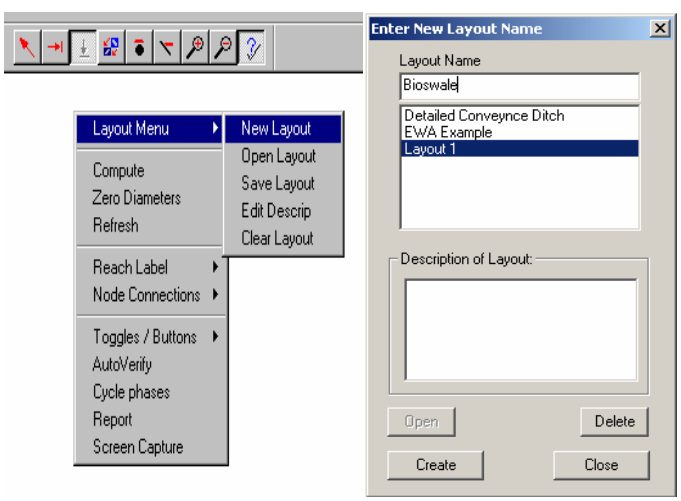
$$y=0.25ft$$

Ensure that swale depth exceeds flow depth at Q_{convey} by a minimum of 1 foot (1 foot minimum freeboard). For this example the depth of the swale should be:

$$1' + 0.25ft = 1.25ft$$

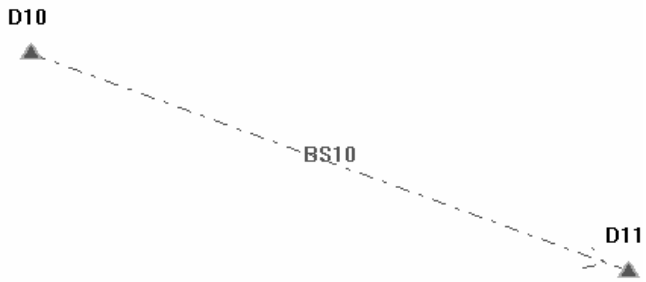
Now we will repeat the process using StormShed.

Next we will create a new layout. Click anywhere in the Layout View area with the right mouse button. From the menu that appears, select Layout and then New Layout and select or type Layout 1.



Example Biofiltration Swale

After creating a new layout, insert 2 nodes and 1 reaches by clicking both the 'Insert a Node' and 'Insert a Reach' radio button on the tool bar. Place the node and reach by clicking anywhere in the Layout View area with the left mouse button. The structures do not have to be in their exact location, they can be moved later. Every node and reach entered this way will be assigned "Prototype", later we will define them.



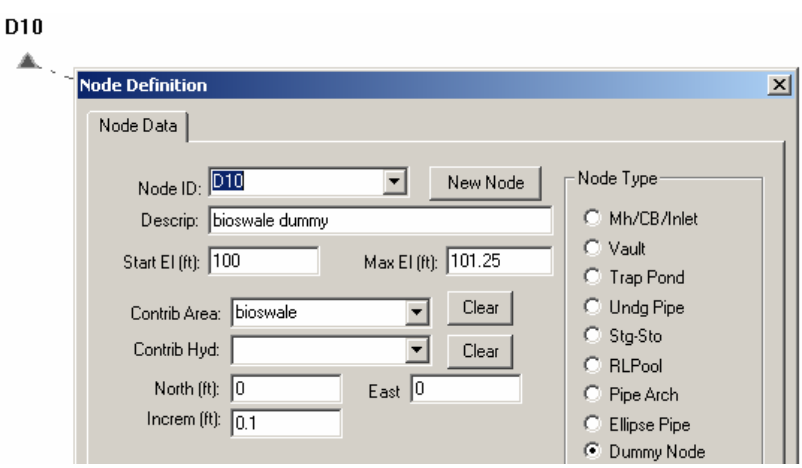
After all both structures and the reach are entered, toggle off the "Insert a Node" and "Insert Reach" radio buttons. Now we will define the Nodes and Reaches for the Bioswale layout we just created, using the data from the tables below. The basin 'bioswale' we created at the beginning of this tutorial will be the contributing area for the upstream node. Both nodes will be defined as a Dummy Node, there is no actual structure at these locations, StormShed needs a node to represent the beginning and end of the reach to perform the calculations.

For each node and reach use the following tables:

Dummy Node	Outlet Inv El.	Rim El.
D10	100	101.25
D11	25	26.25

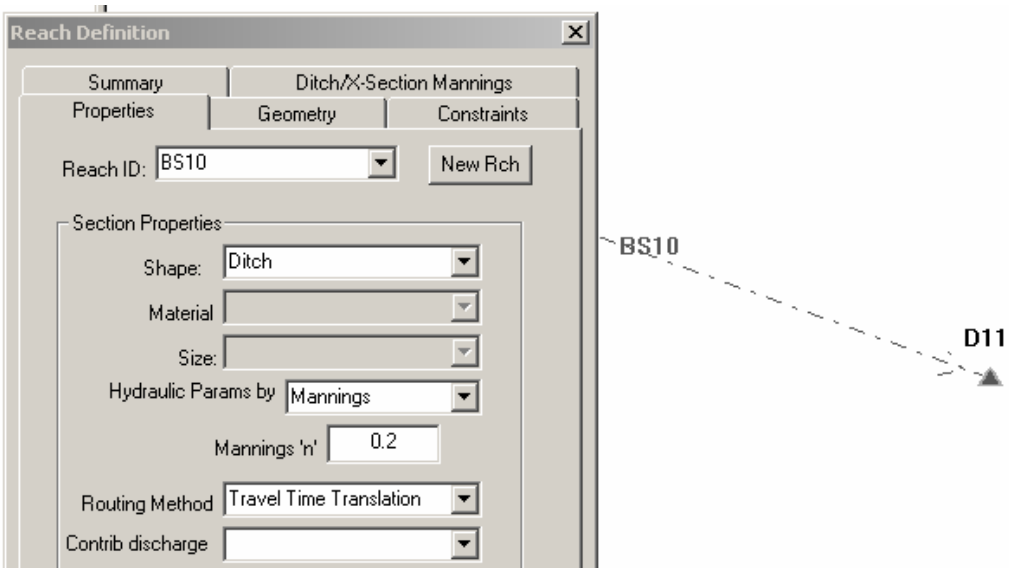
Pipe	Length	Upstream Inv.	Slope
BS10	2500	100	3%

With the left mouse button double click on the first node and define the node with the data shown below.



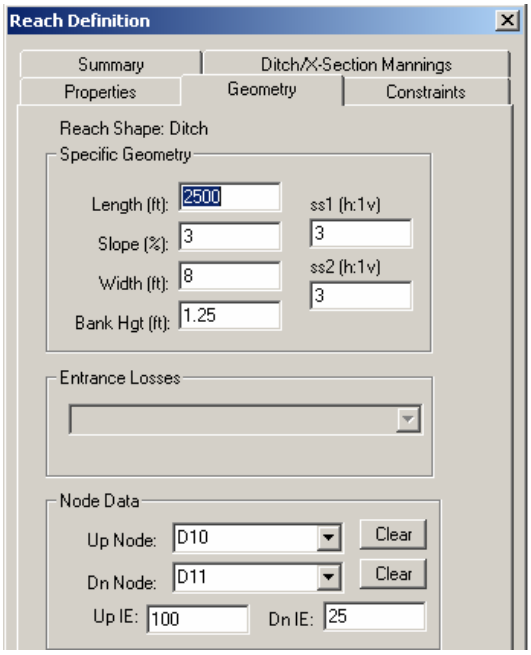
Example Biofiltration Swale

Next we will define the reach by double clicking on the reach with the left mouse button and input the data shown below. Both ditches and bioswales should use the Muskingum-Cunge method for a more accurate representation of runoff in a ditch compared to the Travel Time Translation method, however the result will be slightly different than if compared with the hand calculation method used in the first part of this tutorial. The Travel Time Translation method uses the Manning's equation to compute hydraulic parameters based of the peak flow rate from the upper end to the lower end of the reach and should be used in culverts. The Muskingum-Cunge method actually routes the hydrograph through the reach***, taking advantage of the storage that is available in the reach.*** Unlike the Travel Time Translation, it does not assume that the flow depth is the same through the reach length infact the inflow rate is not the same as the outflow rate. To duplicate efforts from the hand calculation method we will use the Travel Time Translation method for this section of the tutorial and then in the last section we will use the Muskingum-Cunge method.

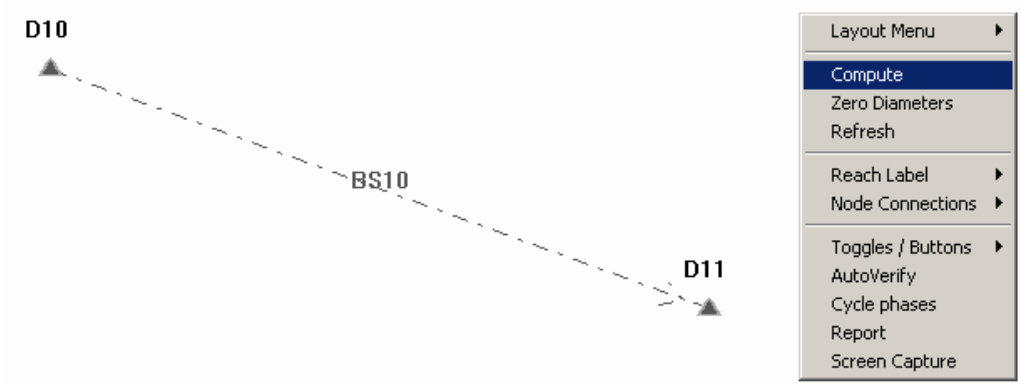


Next select the Geometry tab and input the information below. Note that when after apply is hit, the upstream node will be input automatically from the layout.

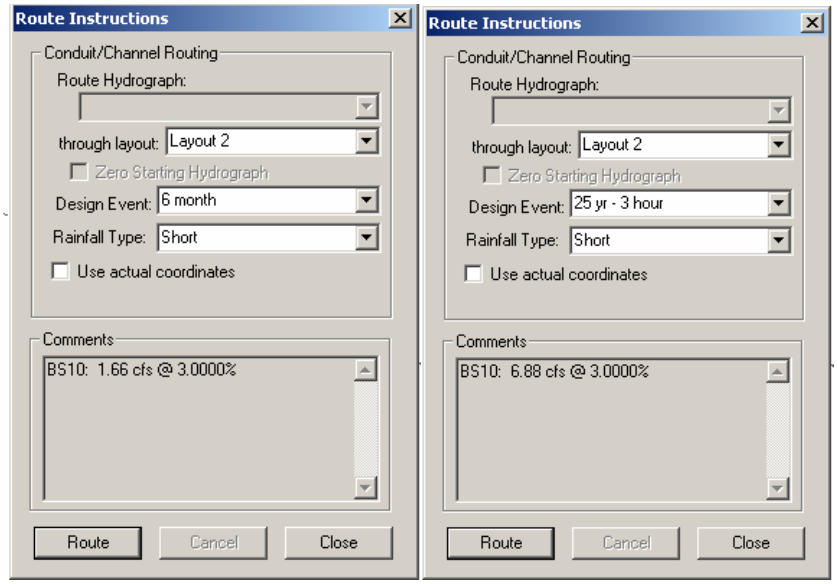
Example Biofiltration Swale



Now that the network is completely defined, we are ready to start the analysis. Using the right mouse button, click anywhere in the Layout View area that is blank. From the pop-up menu select the Compute option.



Next we will enter the design storms we want to compute and route them through the system. First we will run the 6 month and then, we need to go back and change the Mannings n = 0.03 for the 25 year 3 hour (see page 11 number 8). Be sure the rainfall type is defined as 'short'.



The results of the analysis will be written to the History View area. The results of any specific pipe can also be viewed by double clicking on the pipe and going to the Summary tab.

The History Summary for the 6 month 3 hour event is shown below. There are several things to look at when reviewing the results.

- First verify the depth in the swale is 4" or less, for the 6 month storm, by reviewing the 'nDepth' column. For this tutorial the depth is the same as the hand calculations at 0.33'.
- Next verify the velocity is less than 1 ft/s by reviewing the 'nVel' column for the 6 month storm. For this tutorial, the velocity is less than 1 ft/s.

Since both the depth and velocity are within an acceptable range, the 8 foot width is also acceptable. If either had been larger than acceptable, the swale width would need to be increased and the analysis rerun.

Note that the area for the 6 month storm is smaller than actual, that is because there is not enough runoff from the pervious surface to generate runoff. Note under the 25 year storm, the full area is shown (including the pervious surface), this is because there is enough runoff to generate a flow.

ROUTEHYD [] THRU [Layout 2] USING Short AND [6 month] NOTZERO RELATIVE

Reach	**Area**	**Flow**	**Full Q**	**% Full**	**nDepth**	**Size**	**nVel**	**fVel**	**CBasin/Hyd**
-----	**ac**	**cfs**	**cfs**	**ratio**	**ft**	**----**	**ft/s**	**ft/s**	**----------**
BS10	3.3300	1.6590	----	1.00	0.3261	Ditch	0.5666	-----	bioswale

-----	**-----**	**Rch**	**App**	**Bend**	**Junct**	**HW**	**Max El/**
-----	**-----**	**Loss**	**Head**	**Loss**	**Loss**	**Elev**	**Rim El**
From Node	**To Node**	**ft**	**ft**	**ft**	**ft**	**ft**	**ft**
	D11	25.3261					
D10	D11	100.3261	--na--	--na--	--na--	100.3261	101.2500

Example Biofiltration Swale

Lastly we will review the 25 year 3 hour data. As mentioned earlier, the depth of the swale needs a foot of freeboard starting from the top of the 25 year storm. The greatest depth for the 25 year storm is 0.25 ft, so the swale depth will need to be 1.25 ft.

ROUTEHYD [] THRU [Layout 2] USING Short AND [25 yr - 3 hour] NOTZERO RELATIVE

Reach	Area	Flow	Full Q	% Full	nDepth	Size	nVel	fVel	CBasin/Hyd
-----	ac	cfs	cfs	ratio	ft	----	ft/s	ft/s	----------
BS10	6.2000	6.8778	----	1.00	0.2463	Ditch	3.1951	-----	bioswale

-----	-----	Rch	App	Bend	Junct	HW	Max El/
-----	-----	Loss	Head	Loss	Loss	Elev	Rim El
From Node	To Node	ft	ft	ft	ft	ft	ft
	D11					25.2743	
D10	D11	100.2743	--na--	--na--	--na--	100.2743	101.2500

Example Biofiltration Swale

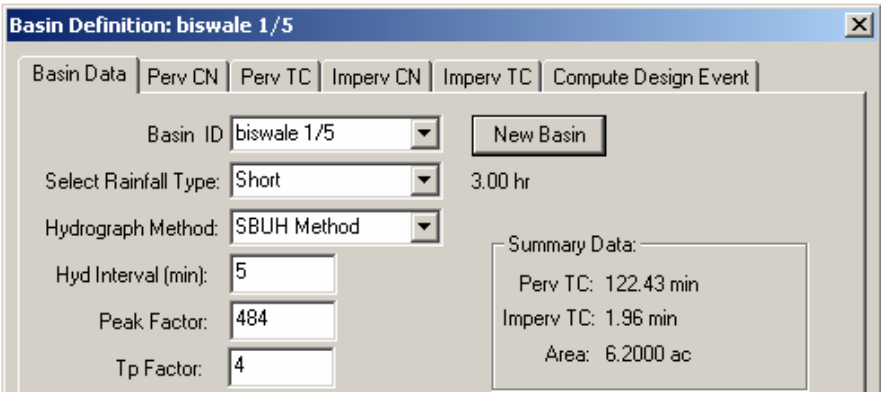
Eastern Washington
Biofiltration Swale Sizing Criteria

This is the same method that was described in the 1997 HRM manual. The difference between this method and the method for the east and west method is there is no residence time requirement, the swale needs to be 200 feet long. All the hand calculations from the previous section are the same except step #7, the swale length calculation.

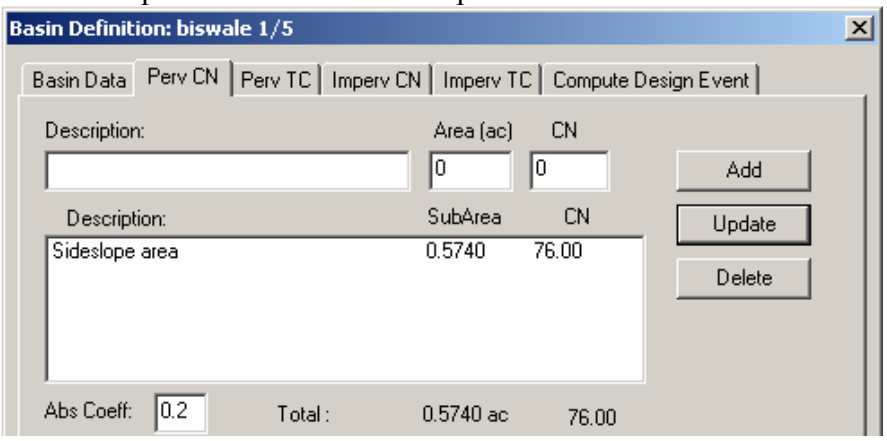
Biofiltration Swale Sample Problem Description

We will use the same sample problem as in the previous section, except the runoff will be conveyed through a v-bottom ditch for the 2500 feet parallel to the road and then a 200 foot long swale will be constructed after the ditch. Both the ditch and swale will also have an infiltration rate of 1 in/hr. Infiltration can be considered in both the ditch or bioswales as long as the infiltration rate does not exceed 2.4 in/hr. Additionally, the Muskingum-Cunge method will be used. We will also reduce the original DBA we developed at the beginning of this tutorial by a fifth. The reason for this is we will be dividing the 2500 ft ditch into 500 ft increments to develop a more accurate analysis to account for infiltration. This example assumes the biofiltration swale starts at the end of ditch.

Create a new basin

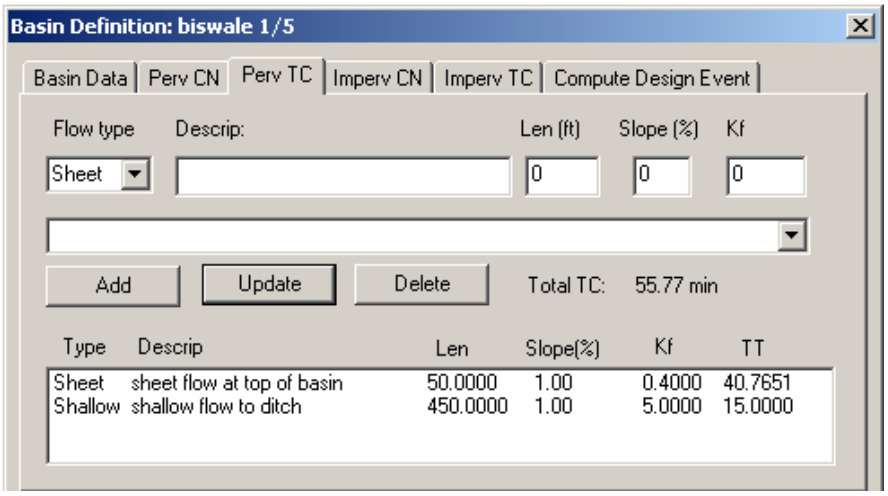


Define the pervious surface side slope area.

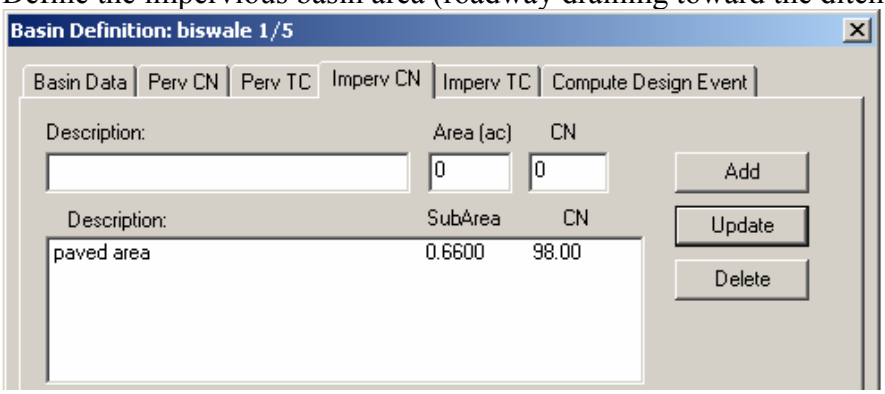


Define the flow path for the pervious side slope area.

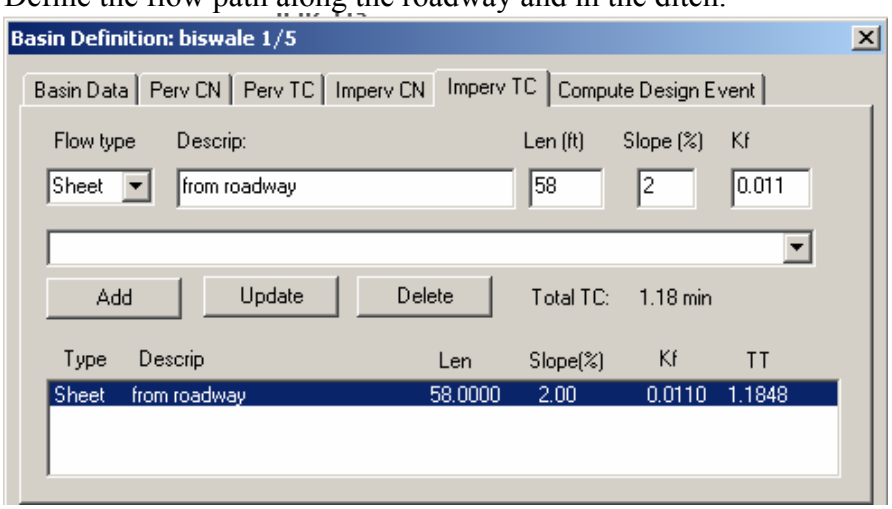
Example Biofiltration Swale



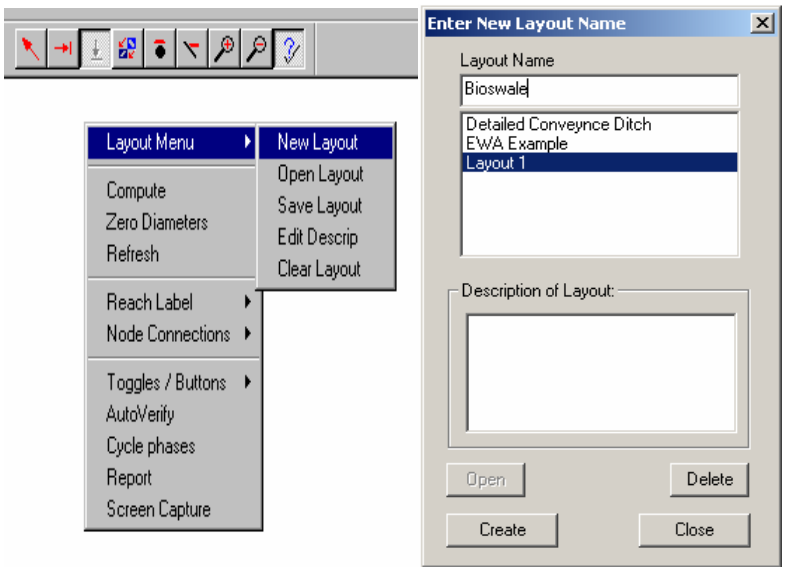
Define the impervious basin area (roadway draining toward the ditch)



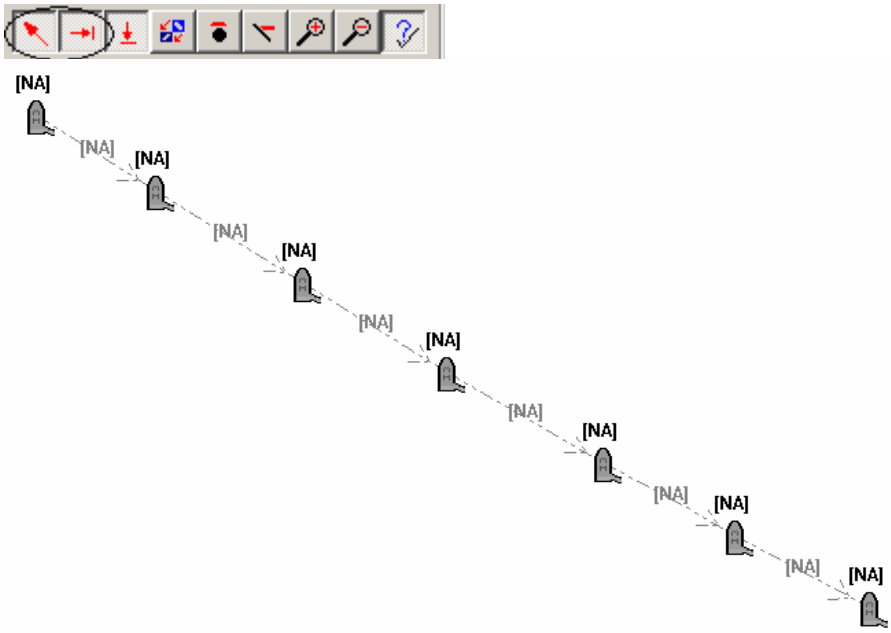
Define the flow path along the roadway and in the ditch.



Next we will create a new layout. Click anywhere in the Layout View area with the right mouse button. From the menu that appears, select Layout and then New Layout. Give the layout a name that makes sense to you for the project, for this tutorial we will call our layout **Bioswale**.



After creating a new layout, insert 7 nodes and 6 reaches by clicking both the 'Insert a Node' and 'Insert a Reach' radio button on the tool bar. Place the node and reach by clicking anywhere in the Layout View area with the left mouse button. The structures do not have to be in their exact location, they can be moved later. Every node and reach entered this way will be assigned "Prototype", later we will define them. Each reach represents the (5)-500' lengths of the ditch and the (1)-200' section of the swale with a node on both the upstream and down streamside.



Example Biofiltration Swale

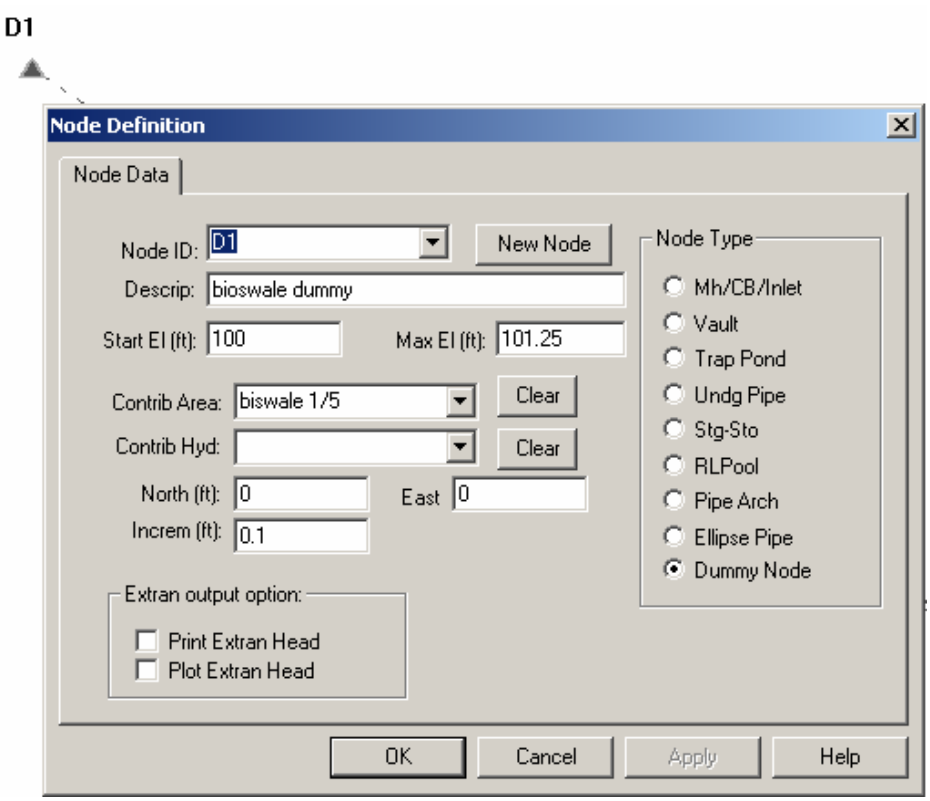
After all 7 structures and 6 reaches are entered, toggle off the "Insert a Node" and "Insert Reach" radio buttons. Now we will define the Nodes and Reaches for the Bioswale layout we just created, using the data from the tables below. The basin 'bioswale 1/5' we created will be the contributing area for all the nodes except the D6 and D7, the last node of the ditch and swale on the down stream. Each node will be defined as a Dummy Node, there is no actual structure at these locations, StormShed needs a node to represent the beginning and end of the reach to perform the calculations.

For each node and reach use the following tables:

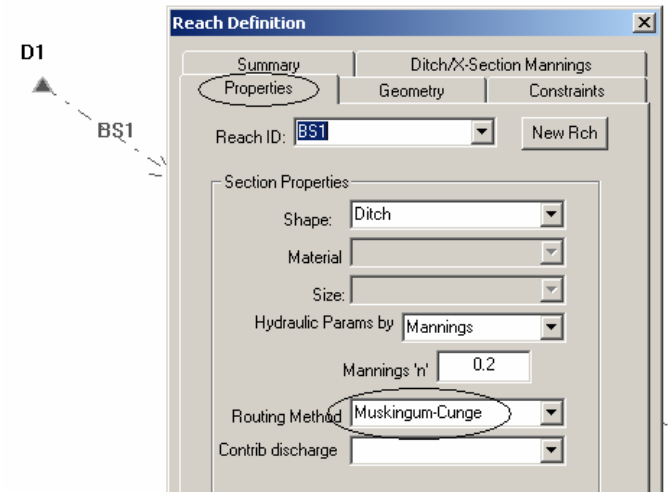
Dummy Node	Outlet Inv El.	Rim El.
D1	100	101.25
D2	85	86.25
D3	70	71.25
D4	55	56.25
D5	40	41.25
D6	25	26.25
D7	19	20.25

Pipe	Length	Upstream Inv.	Slope
BS1	500	100	3%
BS2	500	85	3%
BS3	500	70	3%
BS4	500	55	3%
BS5	500	40	3%
BS6	200	25	3%

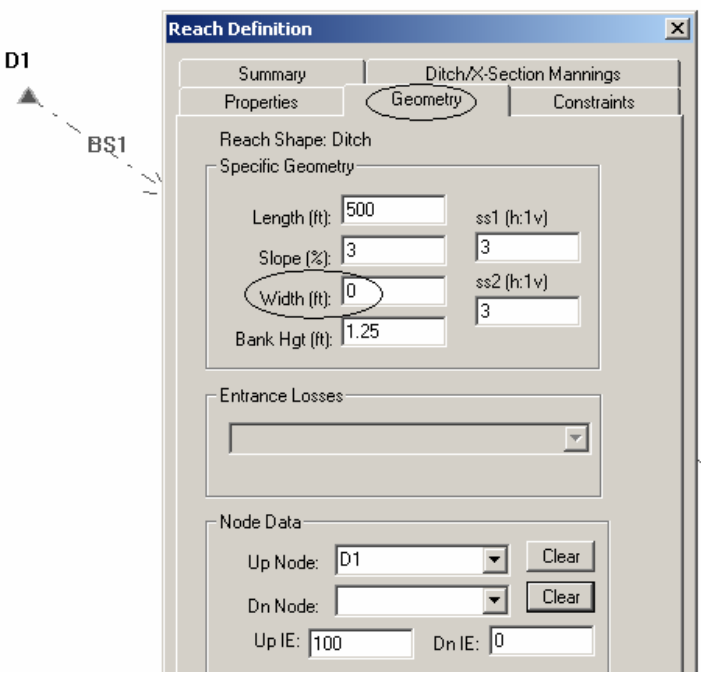
With the left mouse button double click on the first node and define the node with the data shown below.



Next we will define the first reach by double clicking on the reach with the left mouse button and input the data shown below. As previously mentioned, the best routing method for ditches and bioswales is the Muskingum-Cunge.

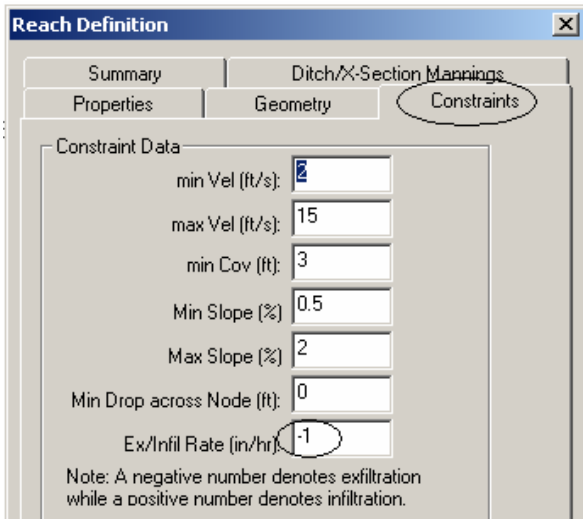


Next select the Geometry tab and input the information below. For ditches the width should be set at '0'. We will need to verify this width in the final analysis by verifying the depth of flow does not saturate the subgrade. Note that after apply is hit, the upstream node will be input automatically from the layout.



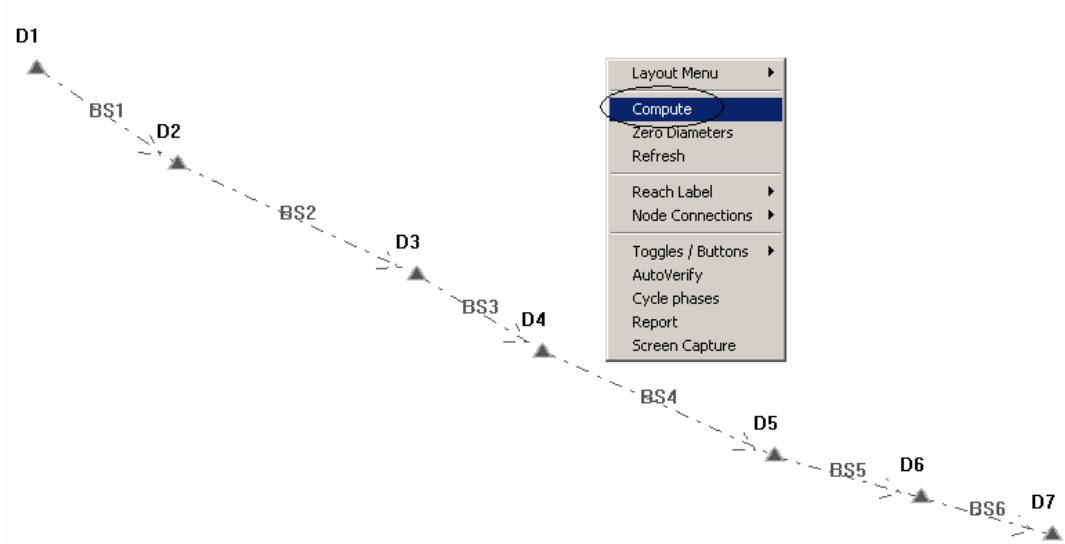
The infiltration rate of the swale can be defined in the Constraints tab under Ex/Infil Rate (in/hr) or Exfiltration/Infiltration. Since this information is for water infiltrating or exfiltrating into a pipe, it is backwards from how we normally define it for a swale. Think of a perforated pipe: exfiltration means water is leaving the pipe and should be denoted with a negative sign where as infiltration means water is infiltrating into the pipe and is

denoted as a positive number. If that is applied to our swale, we would define water infiltrating as exfiltration and define the rate as **-1 in/hr** as shown below.



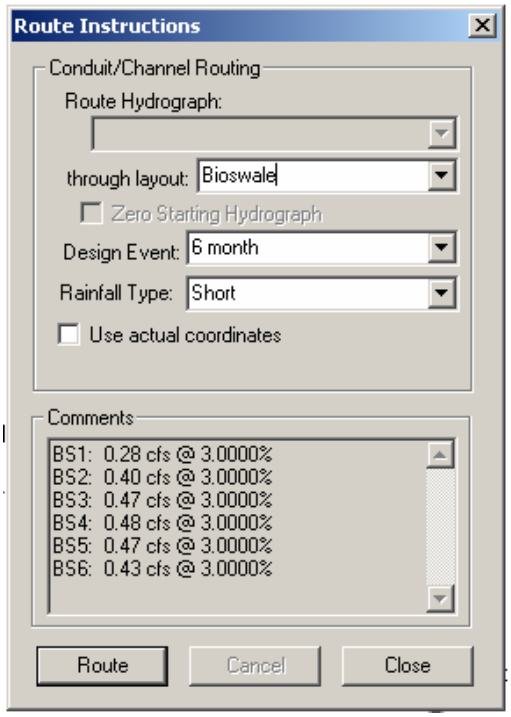
Repeat the process defining the nodes and reaches using the data in the table on page 15.

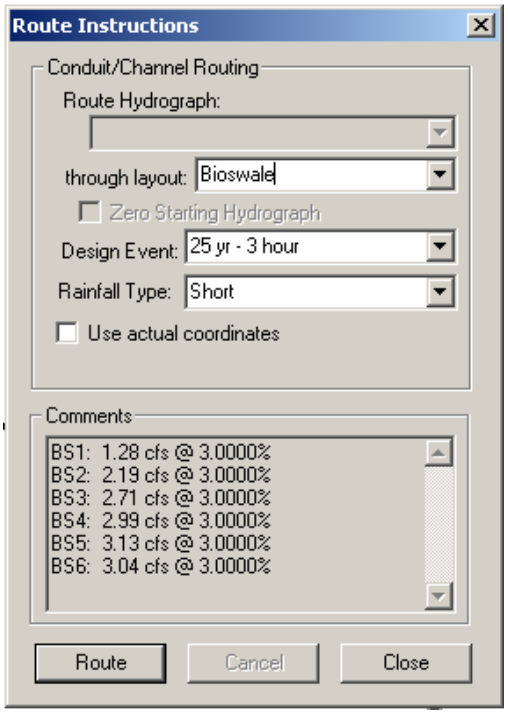
Now that the network is completely defined, we are ready to start the analysis. Using the right mouse button, click anywhere in the Layout View area that is blank. From the pop-up menu select the Compute option.



Next we will enter the design storms we want to compute and route them through the system. First we will run the 6 month and then the 25 year 3 hour. Be sure the rainfall type is defined as 'short'.

Example Biofiltration Swale





The results of the analysis will be written to the History View area.

The History Summary for the 6 month 3 hour event is shown below. There are several things to look at when reviewing the results.

- First verify the depth in the swale is 4" or less, for the 6 month storm, by reviewing the 'nDepth' column. For this tutorial the depth is 0.15 feet for an 8 foot wide swale, well below the 0.33' required.
- Next verify the velocity is less than 1 ft/s by reviewing the 'nVel' column for the 6 month storm. For this tutorial, the velocity is less than 1 ft/s.
- Last check the depth of flow in the ditch by reviewing the 'nDepth' column and make sure it does not saturate the sub-grade or is less than 6" deep. For this tutorial the depth in the ditch is less than 6".

Since both the depth and velocity are within an acceptable range, the 8 foot width is also acceptable. The designer may choose to repeat the process with a smaller swale. Or if either had been larger than acceptable, the swale width would need to be increased and the analysis rerun.

Note that the area for the 6 month storm is smaller than actual, that is because there is not enough runoff from the pervious surface to generate runoff. Note under the 25 year storm, the full area is shown (including the pervious surface), this is because there is enough runoff to generate a flow.

ROUTEHYD [] THRU [Layout 1] USING Short AND [6 month] NOTZERO RELATIVE

Reach	Area	Flow	Full Q	% Full	nDepth	Size	nVel	fVel	CBasin/Hyd
-----	ac	cfs	cfs	ratio	ft	----	ft/s	ft/s	----------
BS1	0.6600	0.2761	----	1.00	0.4477	Ditch	0.4593	-----	bioswale 1/5
BS2	1.3200	0.4034	----	1.00	0.5161	Ditch	0.5049	-----	bioswale 1/5
BS3	1.9800	0.4673	----	1.00	0.5453	Ditch	0.5238	-----	bioswale 1/5
BS4	2.6400	0.4790	----	1.00	0.5504	Ditch	0.5271	-----	bioswale 1/5
BS5	3.3000	0.4747	----	1.00	0.5485	Ditch	0.5259	-----	bioswale 1/5
BS6	3.3000	0.4322	----	1.00	0.1475	Ditch	0.3470	-----	

-----	-----		Rch	App	Bend	Junct	HW	Max El/
-----	-----		Loss	Head	Loss	Loss	Elev	Rim El
From Node		To Node	ft	ft	ft	ft	ft	ft
		D7					19.1475	
D6		D7	25.1475	--na--	--na--	--na--	25.1475	26.2500
D5		D6	40.5485	--na--	--na--	--na--	40.5485	41.2500
D4		D5	55.5504	--na--	--na--	--na--	55.5504	56.2500
D3		D4	70.5453	--na--	--na--	--na--	70.5453	71.2500
D2		D3	85.5161	--na--	--na--	--na--	85.5161	86.2500
D1		D2	110.9827	--na--	--na--	--na--	101.3500	101.2500

Lastly we will review the 25 year 3 hour data. As mentioned earlier, the depth of the swale needs a foot of freeboard starting from the top of the 25 year storm. The depth for the 25 year storm is 0.46 ft, so the swale depth will need to be 1.46 ft.

ROUTEHYD [] THRU [Bioswale] USING Short AND [25 yr - 3 hour] NOTZERO RELATIVE

Reach	Area	Flow	Full Q	% Full	nDepth		Size	nVel	fVel	CBasin / Hyd
-----	ac	cfs	cfs	ratio	ft	----	ft/s	ft/s	----------	
BS1	1.2340	1.2785	----	1.00	0.7953		Ditch	0.6737	-----	bioswale 1/5
BS2	2.4680	2.1891	----	1.00	0.9730		Ditch	0.7707	-----	bioswale 1/5
BS3	3.7020	2.7070	----	1.00	1.0537		Ditch	0.8127	-----	bioswale 1/5
BS4	4.9360	2.9920	----	1.00	1.0940		Ditch	0.8333	-----	bioswale 1/5
BS5	6.1700	3.1347	----	1.00	1.1133		Ditch	0.8430	-----	bioswale 1/5
BS6	6.1700	3.0388	----	1.00	0.4634		Ditch	0.6983	-----	

-----	-----	Rch	App	Bend	Junct	HW	Max El/
-----	-----	Loss	Head	Loss	Loss	Elev	Rim El
From Node		To Node	ft ft	ft	ft	ft	ft
	D7					19.4634	
D6	D7	25.4634	--na--	--na--	--na--	25.4634	26.2500
D5	D6	41.1133	--na--	--na--	--na--	41.1133	41.2500
D4	D5	56.0940	--na--	--na--	--na--	56.0940	56.2500
D3	D4	71.0537	--na--	--na--	--na--	71.0537	71.2500
D2	D3	85.9730	--na--	--na--	--na--	85.9730	86.2500
D1	D2	110.9736	--na--	--na--	--na--	101.3500	101.2500