

## **Conservation Practice Modeling Guide for SWAT and APEX**

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# Conservation Practice Modeling Guide for SWAT and APEX



*David Waidler, Mike White, Evelyn Steglich  
Susan Wang, Jimmy Williams, C. A. Jones, R. Srinivasan*

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## Conservation Practice Modeling Guide

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Present day watershed management and water quality research strategies require an inclusive approach allowing for analysis of pollutant loadings from multiple sources including rural lands, urbanized areas, and riparian corridors. The selection and implementation of management strategies is dependent upon accurate modeling of proposed management scenarios.

The use of computer driven soil and water modeling systems such as the Soil and Water Assessment Tool (SWAT) and Agricultural Policy Extender (APEX) has enhanced the ability of environmental managers, researchers, government officials, and urban planners to analyze current conditions and predict future impacts of land use changes on water quality. Despite the innovation of these technologies, modelers are often required to account for the changes in pollutant and sediment loadings resulting from the implementation of approved conservation practices such as filter strips, bioretention areas, and pervious pavement.

This parallel development of computer modeling and sound conservation practices calls for the creation of a comprehensive guide to modeling that will provide traditional and new constituencies the convenience of a single source for information to assist water quality planning efforts. By assembling the existing data for practice design, application, and model inputs into a user-friendly manual, the modelers and other beneficiaries will no longer need to engage in lengthy and exhaustive research to determine the conservation practices that will allow for the desired pollutant reductions.

The Conservation Practice Modeling Guide is a “living” document formatted to allow for innovations in modeling inputs for existing and new practices as each are developed.

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# Check Dam

## DESCRIPTION

Check dams are small, temporary dams constructed across a swale or channel. They can be constructed using gravel, straw bales, sand bags, or fiber rolls. They are used to reduce the velocity of concentrated flow and, therefore, to reduce the erosion in a swale or channel. Check dams should be used when it is not feasible or practical to line the channel or implement permanent flow-control practices. Check dams are usually installed such that the crest of a dam is level with the toe of the next check dam upslope.

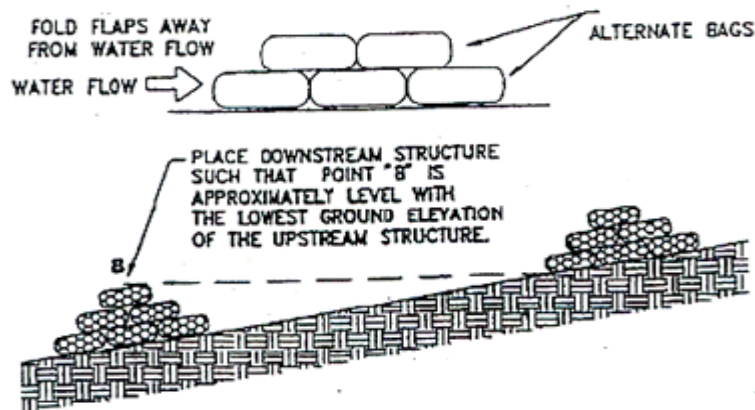
University of Missouri Extension

<http://extension.missouri.edu/explore/agguides/agengin/g01509.htm#Check>



Colorado Department of Transportation

[www.dot.state.co.us/.../envwaterqual/ECS.asp](http://www.dot.state.co.us/.../envwaterqual/ECS.asp)



Washington State University <http://lakewhatcom.wsu.edu/display.asp?ID=104>

## SWAT INPUT

Check dams can be simulated as ponds. Check dams are impoundments located within the subbasin area. These impoundments receive loadings only from the land area in the subbasin. The .pnd file contains parameter information used to model the water, sediment, and nutrient balance for ponds.

**PND\_FR (\*.pnd):** Fraction of subbasin area that drains into ponds.

**PND\_PSA (\*.pnd):** Surface area of ponds when filled to principal spillway (ha). smaller impoundments usually do not have both a principal and emergency spillway. However, for



SWAT to calculate the pond surface area each day the surface area at two different water volumes must be defined. For simplicity, the same parameters required in reservoir input are used for ponds also. Variables referring to the principal spillway can be thought of as variables referring to the normal pond storage volume while variables referring to the emergency spillway can be thought of as variables referring to maximum pond storage volume. If users do not have information for the two water storage volumes, they may enter information for only one and allow SWAT to set values for the other based on the known surface area/volume.

**PND\_PVOL (\*.pnd):** Volume of water stored in ponds when filled to the principal spillway (104 m<sup>3</sup> H<sub>2</sub>O).

**PND\_ESA (\*.pnd):** Surface area of ponds when filled to emergency spillway (ha).

**PND\_EVOL (\*.pnd):** Volume of water stored in ponds when filled to the emergency spillway (104 m<sup>3</sup> H<sub>2</sub>O).

**PND\_VOL (\*.pnd):** Initial volume of water in ponds (104 m<sup>3</sup> H<sub>2</sub>O). It was recommended using a 1-year equilibration period for the model where the watershed simulation is set to start 1 year prior to the period of interest. This allows the model to get the water cycling properly before any comparisons between measured and simulated data are made. When an equilibration period is incorporated, the value for PND\_VOL is not going to impact model results if the pond is small. However, if the pond is large a reasonably accurate value needs to be input for this value.

**PND\_SED (\*.pnd):** Initial sediment concentration in pond water (mg/L). It was recommended using a 1-year equilibration period for the model where the watershed simulation is set to start 1 year prior to the period of interest. This allows the model to get the water cycling properly before any comparisons between measured and simulated data are made. When an equilibration period is incorporated, the value for PND\_SED is not going to impact model results.

**PND\_NSED (\*.pnd):** Equilibrium sediment concentration in pond water (mg/L). The amount of suspended solid settling that occurs in the water body on a given day is calculated as a function of concentration. Settling occurs only when the sediment concentration in the water body exceeds the equilibrium sediment concentration specified by the user.

**PND\_K (\*.pnd):** Hydraulic conductivity through bottom of ponds (mm/hr). If seepage occurs in the water body, the hydraulic conductivity must be set to a value other than 0.

**IFLOD1 (\*.pnd):** Beginning month of non-flood season. See explanation for IFLOD1 for more information on this variable.

**IFLOD2 (\*.pnd):** Ending month of non-flood season.

**NDTARG (\*.pnd):** Number of days needed to reach target storage from current pond storage. The default value for NDTARG is 15 days.

**PSETLP1 (\*.pnd):** Phosphorus settling rate in wetland for months IPND1 through IPND2 (m/year). The apparent settling velocity is most commonly reported in units of m/year and this is how the values are input to the model. For natural lakes, measured phosphorus settling velocities most frequently fall in the range of 5 to 20 m/year although values less than 1 m/year to over 200 m/year have been reported (Chapra, 1997). Panuska and Robertson (1999) noted that the range in apparent settling velocity values for man-made reservoirs tends to be significantly greater than for natural lakes. Higgins and Kim (1981) reported phosphorus apparent settling velocity values from -90 to 269 m/year for 18 reservoirs in Tennessee with a median value of 42.2 m/year. For 27 Midwestern reservoirs, Walker and Kiihner (1978) reported phosphorus apparent settling velocities ranging from -1 to 125 m/year with an average value of 12.7 m/year. A negative settling rate indicates that the reservoir sediments are a source of N or P; a positive settling rate indicates that the reservoir sediments are a sink for N or P.

**PSETLP2 (\*.pnd):** Phosphorus settling rate in wetlands for months other than IPND1-IPND2 (m/year). See explanation for PSETLW1, IPND1 and IPND2 for more information about this variable.

**NSETLP1 (\*.pnd):** Nitrogen settling rate in pond for months IPND1 through IPND2 (m/year).

**NSETLP2 (\*.pnd):** Nitrogen settling rate in pond for months other than IPND1-IPND2 (m/year).

**CHLAP (\*.pnd):** Chlorophyll a production coefficient for ponds. The user-defined coefficient, Chlaco, is included to allow the user to adjust the predicted chlorophyll a concentration for limitations of nutrients other than phosphorus. When Chlaco is set to 1.00, no adjustments are made (the original equation is used). For most water bodies, the original equation will be adequate. The default value for CHLAP is 1.00, which uses the original equation.

**SECCIP (\*.pnd):** Water clarity coefficient for ponds. The clarity of the pond is expressed by the secchi-disk depth (m), which is calculated as a function of chlorophyll *a*. The user-defined coefficient, *SDco*, is included to allow the user to adjust the predicted secchi-disk depth for impacts of suspended sediment and other particulate matter on water clarity that are ignored by the original equation. When *SDco* is set to 1.00, no adjustments are made (the original equation is used). For most water bodies, the original equation will be adequate. The default value for SECCIP is 1.00, which uses the original equation.

**PND\_NO3 (\*.pnd):** Initial concentration of NO<sub>3</sub>-N in pond (mg N/L). It was recommended using a 1-year equilibration period for the model where the watershed simulation is set to start 1 year prior to the period of interest. This allows the model to get the water cycling properly before any comparisons between measured and simulated data are made. When an equilibration period is incorporated, the value for PND\_NO3 is not going to be important.

**PND\_SOLP (\*.pnd):** Initial concentration of organic N in pond (mg N/L).

**PND\_ORGP (\*.pnd):** Initial concentration of organic P in pond (mg P/L).

**IPND1 (\*.pnd):** The model allows the user to define two settling rates for each nutrient and the time of the year during which each settling rate is used. A variation in settling rates is allowed so that impact of temperature and other seasonal factors may be accounted for in the modeling of nutrient settling. To use only one settling rate for the entire year, both variables for the nutrient may be set to the same value. Setting all variables to zero will cause the model to ignore settling of nutrients in the water body.

**IPND2 (\*.pnd):** Ending month of mid-year nutrient settling "season".

R. Srinivasan. Unpublished SWAT Calibration Instructions for Best Management Practices.

## **APEX INPUT**

Check dams are simulated with the reservoir component assuming little or no storage. The principle spillway elevation is set at the base of the dam and the release rate is set to reflect the flow rate through the dam. The emergency spillway is set at the top of the dam.

### **Subarea file (.sub) – Reservoir**

**RSEE:** Elevation at emergency spillway (m). This is the height to the top of the dam.

**RSAE:** Total reservoir surface area at emergency spillway elevation (ha)

**RSVE:** Runoff volume from reservoir catchment area at emergency spillway elevation (mm)

**RSEP:** Elevation at principal spillway (m). This is the height to the base of the dam.

**RSAP:** Total reservoir surface area at principal spillway elevation (ha)

**RSVP:** Volume at principal spillway elevation (mm)

**RSV:** Initial reservoir volume (mm). This should be 0 in most cases.

**RSRR:** Average principal spillway release rate (mm/h). This will be the rate at which the water seeps through the straw bale, sand bags, etc.

**RSYS:** Initial sediment concentration in reservoir (ppm)

**RSYN:** Normal sediment concentration in reservoir (ppm)

**RSHC:** Hydraulic conductivity of reservoir bottom (mm/h)

**RSDP:** Time for sediment concentrations to return to normal (days) following a runoff event

**RSBD:** Bulk density of sediment in reservoir ( $t/m^3$ )



# Diversion Dike

## DESCRIPTION

A barrier constructed of earth or manufactured materials. To protect people and property from floods and to control water level in connection with crop production; fish and wildlife management; or wetland maintenance, improvement, restoration, or construction. Diversion dikes can work to control the flow and velocity of stormwater.

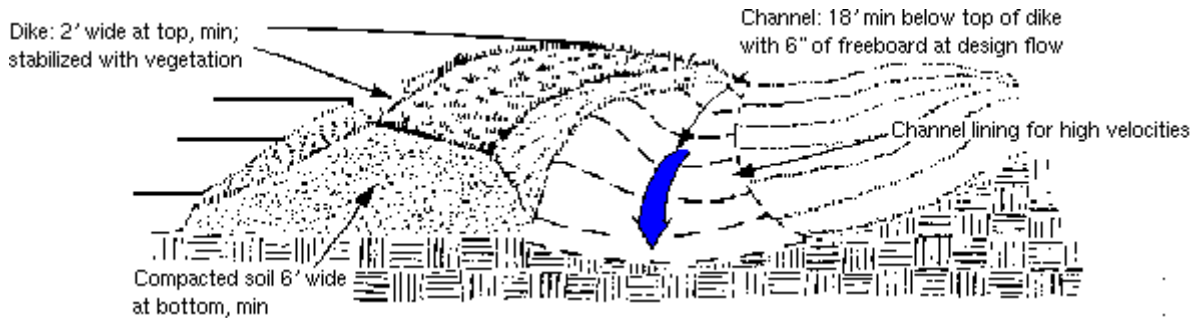
USDA-NRCS, 2006. *National Conservation Practice Standards*.

<http://www.nrcs.usda.gov/technical/standards/nhcp.html>



Purdue University

[cobweb.ecn.purdue.edu/~sedspec/sedspec/perl/m..](http://cobweb.ecn.purdue.edu/~sedspec/sedspec/perl/m..)



North Carolina Cooperative Extension Service 1996 [www.p2pays.org/ref/01/images/000553.qi](http://www.p2pays.org/ref/01/images/000553.qi)

**APEX INPUT**

Runoff from the subarea above the dike is routed along the dike channel to the outlet thus preventing flow onto the natural downstream subarea.

To accomplish this, water must be rerouted away from the natural downstream subarea and to an alternate outlet. The reach channel length will be increased greatly and the reach slope will be lessened to a very minimal slope. The subarea in which the diversion dike is installed should be split into two subareas. The upper subarea will drain to the diversion dike and the flow will then be routed down the diversion dike to an adjacent subarea. The CHL (distance from outlet to most distant point on the watershed) will be decreased for the lower subarea.

**Subarea file – Subarea geometry**

**RCHL:** Channel length of routing reach (km). The length between where the channel starts or enters the subarea and leaves the subarea. This will be the length of the diversion dike.

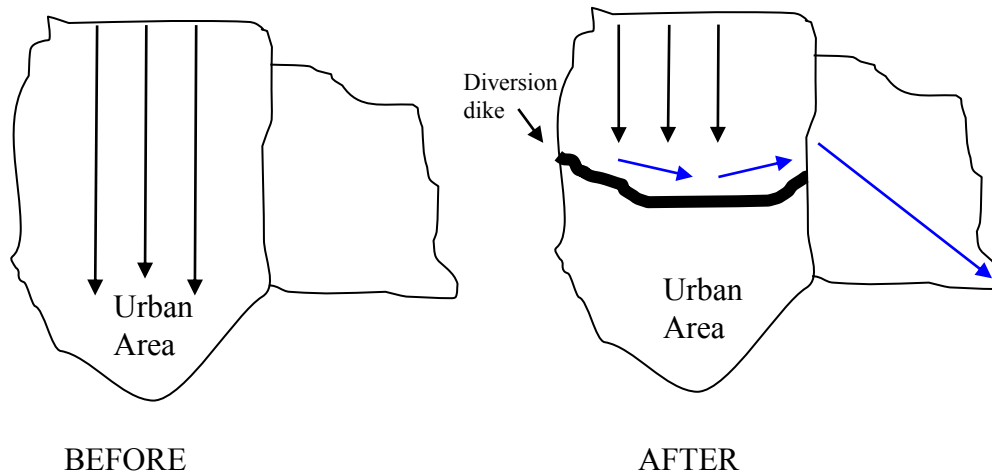
The diversion dike will be treated as the channel (routing reach) of the upper subarea.

**RCHD:** Channel depth of routing reach (m)

**RCBW:** Bottom width of routing reach channel (m)

**RCTW:** Top width of routing reach channel (m)

**RCHS:** Channel slope of routing reach (m/m)



# Filter Strips

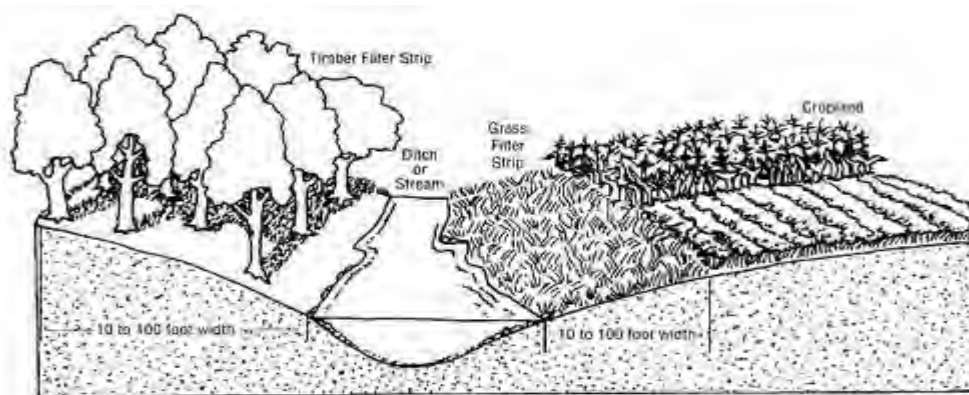
## DESCRIPTION

Filter strips are vegetated areas that are situated between surface water bodies (i.e. streams and lakes) and cropland, grazing land, forestland, or disturbed land. They are generally in locations when runoff water leaves a field with the intention that sediment, organic material, nutrients, and chemicals can be filtered from the runoff water. Filter strips are also known as vegetative filter or buffer strips. Strips slow runoff water leaving a field so that larger particles, including soil and organic material can settle out. Due to entrapment of sediment and the establishment of vegetation, nutrients can be absorbed into the sediment that is deposited and remain on the field landscape, enabling plant uptake.

USDA-NRCS, 2006. *National Conservation Practice Standards*.  
<http://www.nrcs.usda.gov/technical/standards/nhcp.html>



Photo Courtesy USDA- NRCS Online Photo Gallery



Ohio State University Extension  
[http://ohioline.osu.edu/aex-fact/images/467\\_1.jpg](http://ohioline.osu.edu/aex-fact/images/467_1.jpg)

## SWAT INPUT

Note : Recent versions of SWAT contain an improved filter strip submodel. This documentation may not be applicable to older versions of SWAT.

Filter strips can be simulated in SWAT by modifying or creating an optional Scheduled Management Operations (.ops) file for each HRU in which the practice will be implemented. Filter strips may be implemented anytime during the simulation period by specifying the implementation date in the .ops file. The following parameters are required to simulate filter strips (**MGT\_OP** code = 4) in SWAT:

***VFSCON (.ops):*** Fraction of the total runoff from the entire field entering the most concentrated 10% of the VFS. Set to a value between 0.25 and 0.75, recommend 0.5.

***VFSRATIO (.ops):*** Field area to VFS area ratio. Recommend value of 40 – 60.

***VFSCH (.ops):*** Fraction of flow through the most concentrated 10% of the VFS that is fully channelized. Recommend value of 0 unless VFS has failed.

## **APEX INPUT:**

There are two ways to simulate filter strips in APEX. The original method is to route flow from an upstream area through a filter strip. In this case the filter strip is a separate subarea and is considered a routing reach. The second method of filter strip simulation is useful in watersheds with fairly large subareas where the exact location of the filter strips is not known. In this case the user simply inputs the filter strip flow length and the fraction of the subarea that is controlled by filter strips. In all cases sediment, nutrient, and pesticide loads in surface runoff are reduced as the surface runoff passes through the filter strip.

### ***Filter strip as separate subarea***

#### **Subarea file – Subarea geometry**

For filter strips, the channel dimensions are required, however the channel is very small—essentially nonexistent.

***CHL:*** Distance from outlet to most distant point in the subarea (km).

***CHD:*** Channel depth (m)

***CHS:*** Mainstream channel slope (m/m). The average channel slope is computed by dividing the difference in elevation between the watershed outlet and the most distant point by CHL.

***CHN:*** Manning's N for channel. Should be set to 0.2-0.4

***SLP:*** Average upland slope (m/m)

***SPLG:*** Average upland slope length (m). This is the distance that sheet flow is the dominant surface runoff flow process. Slope length should be measured to the point that flow begins to concentrate.

***UPN:*** Manning's N for upland. Should be set to 0.2-0.4

***FFPQ:*** Fraction of floodplain flow. Range is 0 – 1. This is the fraction of the flow that travels through the filter strip or buffer from the subarea entering the filter strip. If the filter strip could be placed perfectly on a contour, all upstream flow would flow through as sheet flow. However, it is impossible to locate a filter strip on contour in nature. FFPQ is used to account for uneven topography. For example, if the factor is set to 1.0 all runoff flows through the filter. At 0.25 only 25% flows through the filter and the remainder flows through channels.

***RCHL:*** Channel length of routing reach (km). The length between where the channel starts or enters the subarea and leaves the subarea.

***RCHD:*** Channel depth of routing reach (m)

***RCBW:*** Bottom width of routing reach channel (m)

***RCTW:*** Top width of routing reach channel (m)

***RCHS:*** Channel slope of routing reach (m/m)

***RCHN:*** Channel Manning's N of routing reach. Should be set to 0.2-0.4.

***RCHC:*** USLE Crop Management channel factor. If the channel has very good land cover, it should be set to 0.0001.

***RCHK:*** USLE Erodibility channel factor. Should be set to 0.3.

***RFPW:*** Filter strip (reach floodplain) width (m)

***RFPL:*** Flow length (routing reach length) (km)

**Subarea file – Management**

***IOPS:*** Crop operation schedule

***LUNS:*** Land use number. This number is from the NRCS land use-hydrologic soil group table.

**Filter strip as a fraction of subarea****Subarea file – Management**

***BCOF:*** Fraction of subarea controlled by vegetated buffers or filter strips

***BWTH:*** Vegetated buffer width (m). This is the distance flow must travel through the buffer strip. This is the cumulative flow length if several separate buffers are located in succession within the subarea.

# Grade Stabilization Structure

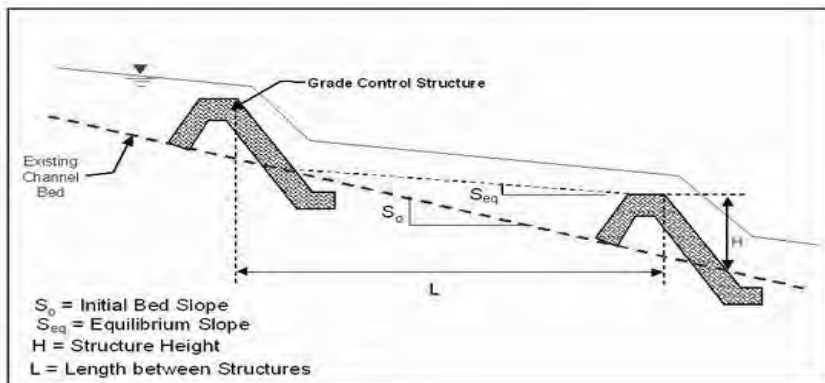
## DESCRIPTION

Grade stabilization is a practice that involves the strategic installation of a structure made of earth, rock, concrete, or steel into a slope adjacent to a reservoir or tributary stream. Grade stabilization is designed to prevent the erosion of channel or reservoir embankments and thus prevent sedimentation and a degradation of water quality.

USDA-NRCS, 2006. *National Conservation Practice Standards*.  
<http://www.nrcs.usda.gov/technical/standards/nhcp.html>



Photo Courtesy of: Natural Resources Conservation Service Photo Gallery



City of Austin, Texas [https://www.ci.austin.tx.us/watershed/images/Grade\\_Control\\_Concept.JPG](https://www.ci.austin.tx.us/watershed/images/Grade_Control_Concept.JPG)

## SWAT INPUT

**PRE INSTALLATION:**  
**POST INSTALLATION:**

***CH\_S(1) (\*.sub):*** Average slope of tributary channels (m/m). The average channel slope is computed by taking the difference in elevation between the subbasin outlet and the most distance point in the subbasin and dividing by CH\_L. However, in this case the channel slope will be reduced by constructing the grade stabilization structures.

R. Srinivasan. Unpublished SWAT Calibration Instructions for Best Management Practices.

**APEX INPUT**

The effect of placing grade stabilization structures along a channel is simulated by reducing the channel slope to account for elevation differences caused by the structures.

**Subarea file – Subarea geometry**

**RGHS:** Channel slope of routing reach (m/m). The slope should be decreased to account for the elevation differences caused by the structures.



# Grassed Waterway

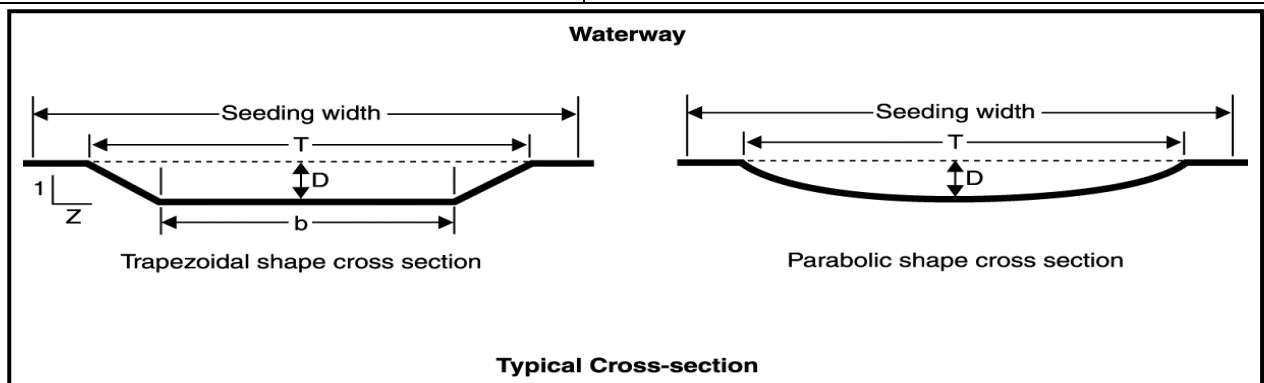
## DESCRIPTION

Grassed waterways are natural or constructed channels established for the transport of concentrated flow at safe velocities using adequate vegetation. The vegetative cover slows the water flow, minimizing channel surface erosion. This BMP can reduce sedimentation of nearby water bodies and pollutants in runoff. The vegetation improves the soil aeration and water quality due to its nutrient removal through plant uptake and sorption by the soil. Entrapment of sediment and the establishment of vegetation allow nutrients to be absorbed into trapped sediments to remain in the agricultural field rather than being deposited into waterways.

USDA-NRCS, 2006. *National Conservation Practice Standards*.  
<http://www.nrcs.usda.gov/technical/standards/nhcp.html>



Photo courtesy NRCS Photo Gallery.



USDA-NRCS, 2006. *National Conservation Practice Standards*. <http://www.nrcs.usda.gov/technical/standards/nhcp.html>

## SWAT INPUT

Note : Recent versions of SWAT contain a grassed waterway submodel. This documentation may not be applicable to older versions of SWAT.

Grass waterways can be simulated in SWAT by modifying or creating an optional Scheduled Management Operations (.ops) file for each HRU in which the practice will be implemented. Grass waterways may be implemented anytime during the simulation period by specifying the implementation date in the .ops file. The following parameters are required to simulate waterways (**MGT\_OP** code = 7) in SWAT:

**GWATI (.ops):** Flag to turn on grassed waterways. Set to 1 for enable. (Required)  
**GWATn (.ops):** Manning's "n" value for the main channel. This value should be adjusted based on vegetative cover in the waterway. Optional - Default value is 0.35.  
**GWATL(.ops):** Grass waterway length in km. Optional - If blank length is assumed to be equal to one side of a square HRU.  
**GWATA(.ops):** Area drained by grass waterways in square km. Drainage is limited to the area of the HRU internally. (Required)  
**GWATW(.ops):** Top width of grassed waterway in meters. (Required)  
**GWATD (.ops):** Depth of grassed waterway in meters. Optional - Will be calculated based on depth and fixed shallow trapezoidal geometry if blank.  
**GWATS (.ops):** Slope of waterway in %. Optional - Calculated based on HRU slope \*0.75 if blank.  
**GWATSPCON (.ops):** Linear parameter for calculating sediment re-entrained in channel sediment routing. Optional - Default value is 0.005.

**APEX INPUT:**

Usually a waterway is constructed by shaping an existing eroding channel. Thus, the channel dimensions must be changed to reflect the waterway geometry.

If the waterway is to be modeled in detail, it should be designated as a separate subarea. Both options are detailed below

**Waterway as part of a subarea**

**Subarea file (.sub) – Subarea geometry**

- RCHD:** Channel depth of routing reach (m)
- RCBW:** Bottom width of routing reach channel (m)
- RCTW:** Top width of routing reach channel (m)
- RCHS:** Channel slope of routing reach (m/m)
- RCHN:** Channel Manning's N of routing reach. Should be set to 0.2-0.4 (0.25 used in Tuppard, et al., 2009).
- RCHC:** USLE Crop Management channel factor. If the channel has very good land cover, it should be set to 0.0001.
- RCHK:** USLE Erodibility channel factor. Should be set to 0.3

Will not be able to designate a separate crop to be grown on the waterway. Crop will be identical to the crop designated for subarea.

**Waterway as a separate subarea**

**Subarea file (.sub)– Subarea geometry**

- RCHD:** Channel depth of routing reach (m)
- RCBW:** Bottom width of routing reach channel (m)
- RCTW:** Top width of routing reach channel (m)
- RCHS:** Channel slope of routing reach (m/m)
- RCHN:** Channel Manning's N of routing reach. Should be set to 0.2-0.4.
- RCHC:** USLE Crop Management channel factor. If the channel has very good land cover, it should be set to 0.0001.
- RCHK:** USLE Erodibility channel factor. Should be set to 0.3.

**Subarea file (.sub)– Management**

**IOPS:** Crop operation schedule. Should choose a grass operation schedule.

**LUNS:** Land use number. This number is from the NRCS land use-hydrologic soil group table.

*Pushpa Tuppad, Chinnasamy Santhi, Raghavan Srinivasan, and Jimmy R. Williams. 2009. Best Management Practice (BMP) Verification using Observed Water Quality Data and Watershed Planning for Implementation of BMPs. Blackland Research and Extension Center report.*

# Green Roofs

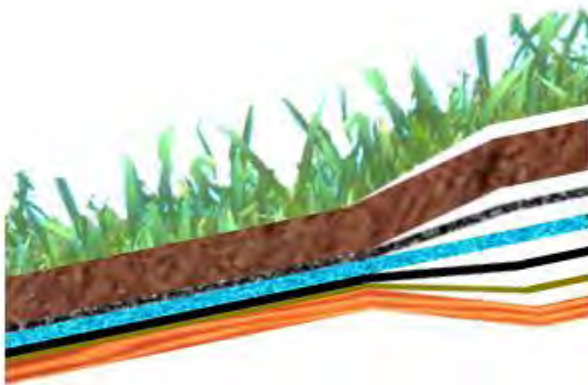
## DESCRIPTION

Green roofs can be effectively used to reduce stormwater runoff from commercial, industrial, and residential buildings. In contrast to traditional asphalt or metal roofing, green roofs absorb, store, and later evapotranspire initial precipitation, thereby acting as a stormwater management system and reducing overall peak flow discharge to a storm sewer system. Green roofs have the potential to reduce discharge of pollutants such as nitrogen and phosphorous due to soil microbial processes and plant uptake. However, initial studies conflict as to the removal efficiency of nutrients, particularly nitrogen, by green roofs. If implemented on a wide scale, green roofs will reduce the volume of stormwater entering local waterways resulting in less in-stream scouring, lower water temperatures and better water quality.

US Environmental Protection Agency Stormwater Menu of BMPs



Photo Courtesy NRCS Urban Conservation Photo Gallery



PLANT LAYER  
SOIL MIX LAYER  
SOIL FILTER FABRIC  
DRAIN MAT  
WATERPROOF MEMBRANE  
SUB MEMBRANE LAYER  
ROOF DECK

Diagram Courtesy of Project Green Roof <http://www.hadj.net/green-roofs/assemblies.html>

## SWAT INPUT

Green roofs can be simulated in SWAT by decreasing **FCIMP** (the fraction of total impervious area) in the Urban Database (urban.dat) to account for reduced runoff from rooftops. Depending upon the location and discharge from green roofs, it may be necessary to also modify **FCIMP** (Fraction of directly connected impervious area.)

# Interceptor Swale/ Rain Garden

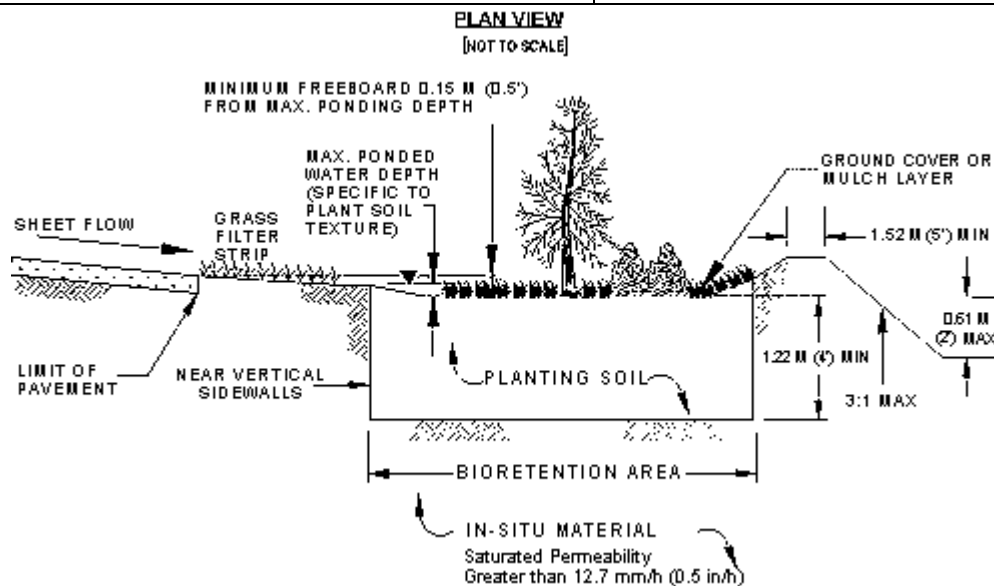
## DESCRIPTION

An interceptor swale or rain garden is an open, vegetated channel that collects and diverts the flow of stormwater to a desired location. Swales are an aesthetically pleasing variation on a drainage ditch and are enhanced with native vegetation and landscape features to slow and filter stormwater. This practice is most typically used in an urban or suburban setting.

Jacobs Carter Burgess, 2008. Collin County, Texas Phase II TPDES Stormwater Management Program.



Stafford County, Virginia  
[co.stafford.va.us/code/Stormwater\\_Management/](http://co.stafford.va.us/code/Stormwater_Management/).



US Department of Transportation Federal Highway Administration [www.fhwa.dot.gov/environment/ultraurb/fig6b.gif](http://www.fhwa.dot.gov/environment/ultraurb/fig6b.gif)

## SWAT INPUT

**APEX INPUT**

To effectively simulate a rain garden, the area will need to be divided into several small subareas. The grass filter strips will need to be separate subareas from the mulched area. A new soil will also need to be created to simulate the bioretention area below the mulched area. A drainage pipe may also be included.

***Grass Filter Strips*****Subarea file – Subarea geometry**

For grass filter strips, the channel dimensions are required; however, the channel is very small—essentially nonexistent. These filter strips will likely be very narrow in flow length and not very wide.

**CHL:** Distance from outlet to most distant point in the subarea (km)

**CHD:** Channel depth (m)

**CHS:** Mainstream channel slope (m/m). The average channel slope is computed by dividing the difference in elevation between the watershed outlet and the most distant point by CHL.

**CHN:** Manning's N for channel. Should be set to 0.2-0.4.

**SLP:** Average upland slope (m/m)

**SPLG:** Average upland slope length (m). This is the distance that sheet flow is the dominant surface runoff flow process. Slope length should be measured to the point that flow begins to concentrate.

**UPN:** Manning's N for upland. Should be set to 0.2-0.4.

**FFPQ:** Fraction of floodplain flow. Range is 0 – 1. This is the fraction of the flow that travels through the filter strip or buffer from the subarea entering the filter strip. If the filter strip could be placed perfectly on a contour, all upstream flow would flow through as sheet flow. However, it is impossible to locate a filter strip on contour in nature. .FFPQ is used to account for uneven topography. For example, if the factor is set to 1.0 all runoff flows through the filter. At 0.25 only 25% flows through the filter and the remainder flows through channels.

**RCHL:** Channel length of routing reach (km). The length between where the channel starts or enters the subarea and leaves the subarea.

**RCHD:** Channel depth of routing reach (m)

**RCBW:** Bottom width of routing reach channel (m)

**RCTW:** Top width of routing reach channel (m)

**RCHS:** Channel slope of routing reach (m/m)

**RCHN:** Channel Manning's N of routing reach. Should be set to 0.2-0.4.

**RCHC:** USLE Crop Management channel factor. If the channel has very good land cover, it should be set to 0.0001.

**RCHK:** USLE Erodibility channel factor. Should be set to 0.3.

**RFPW:** filter strip (reach floodplain) width (m)

**RFPL:** flow length (routing reach length) (km)

**Subarea file – Management**

**IOPS:** Crop operation schedule. A grass crop should be chosen.

**LUNS:** Land use number. This number is from the NRCS land use-hydrologic soil group table.

***Mulched Area with Bioretention Zone***

For the mulched area, the channel dimensions are required, however the channel is very small—essentially nonexistent. Mulching is accomplished by added additional residue to the soil surface.

**Subarea file – Subarea geometry**

**CHL:** Distance from outlet to most distant point in the subarea (km)

**CHD:** Channel depth (m)

**CHS:** Mainstream channel slope (m/m). The average channel slope is computed by dividing the difference in elevation between the watershed outlet and the most distant point by CHL.

**CHN:** Manning's N for channel. Should be set to 0.2-0.4.

**SLP:** Average upland slope (m/m). This area will have almost no slope.

**SPLG:** Average upland slope length (m). This is the distance that sheet flow is the dominant surface runoff flow process. Slope length should be measured to the point that flow begins to concentrate.

**UPN:** Manning's N for upland. Should be set to 0.2-0.4.

**RCHL:** Channel length of routing reach (km). The length between where the channel starts or enters the subarea and leaves the subarea.

**RCHD:** Channel depth of routing reach (m)

**RCBW:** Bottom width of routing reach channel (m)

**RCTW:** Top width of routing reach channel (m)

**RCHS:** Channel slope of routing reach (m/m)

**RCHN:** Channel Manning's N of routing reach. Should be set to 0.2-0.4

**RCHC:** USLE Crop Management channel factor. If the channel has very good land cover, it should be set to 0.0001.

**RCHK:** USLE Erodibility channel factor. Should be set to 0.3.

**RFPW:** filter strip (reach floodplain) width (m)

**RFPL:** flow length (routing reach length) (km)

**Subarea file – Management**

**IOPS:** Crop operation schedule. This may be a mix of trees, shrubs and low-growing plants, which are grown in an intercropped scenario.

**LUNS:** Land use number. This number is from the NRCS land use-hydrologic soil group table.

**Subarea file – Irrigation**

If a drainage system is installed in the rain garden, this should be included in the simulation.

**IDR:** Drainage code. Enter the depth to the drainage system (mm)

**DRT:** Time required for drainage system to end plant stress (days). Artificial drainage systems may be very efficient and quickly reduce water tables or it may take several days for the water level to decline sufficiently to eliminate aeration stress. The variable DRT is used to specify the time needed for the drainage system to eliminate stress.

**Soils Data**

A new soil will need to be created with layers corresponding to the different layers of the bioretention zone. The soil data should be edited for each layer of the soil paying close attention to the following parameters.



**Z:** Depth of bottom of layer (m)

**BD:** Moist bulk density ( $\text{Mg}/\text{m}^3$  or  $\text{g}/\text{cm}^3$ )

**SAN:** Sand fraction

**SIL:** Silt fraction

**PH:** Soil pH

**ROK:** Coarse fragment fraction

**RSD:** Crop residue (t/ha). This is the amount of biomass in or on the soil surface from a previous crop.

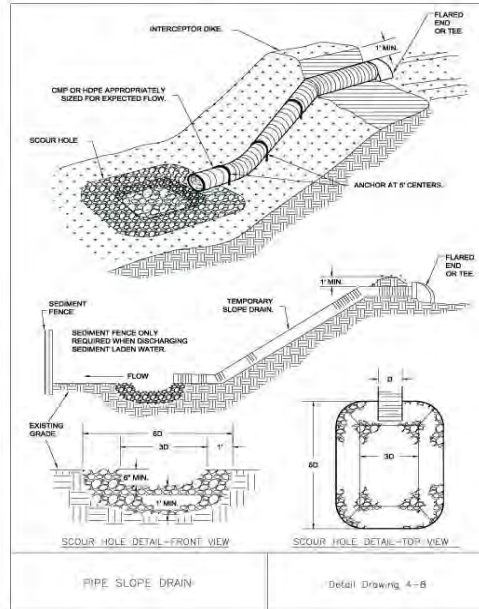
**SATC:** Saturated conductivity (mm/h). Rate at which water passes through the soil layer, when saturated. The saturated hydraulic conductivity relates soil water flow rate (flux density) to the hydraulic gradient and is a measure of the ease of water movement through the soil. The saturated conductivity is the reciprocal of the resistance of the soil matrix to water flow

# Pipe Slope Drain

## DESCRIPTION

A pipe slope drain is a device used to carry concentrated runoff from the top to the bottom of a slope that has already been damaged by erosion or is at high risk for erosion. It may be used to convey runoff from off-site around a disturbed portion of the site. It may also be used to drain saturated slopes that have the potential for soil slides. Pipe slope drains can either be temporary or permanent, dependent on the method of installation and materials used.

Idaho Department of Environmental Quality Stormwater Best Management Practices Catalog 2005



Page 4-55

Clackamas County, Oregon 2000



NRCS Urban Conservation Photo Gallery

## SWAT INPUT

**APEX INPUT**

This could be treated as a tile-drained terrace. Flow from a tile-drained terrace in one subarea can be discharged on any other subarea.

**Subarea file (.sub)— Management**

***ISAO:*** ID of subarea receiving outflow from buried pipe outlet. This value should be entered on the subarea that the pipe is draining. The value entered should be the number of the subarea that the pipe is draining in to.

# Porous Pavement

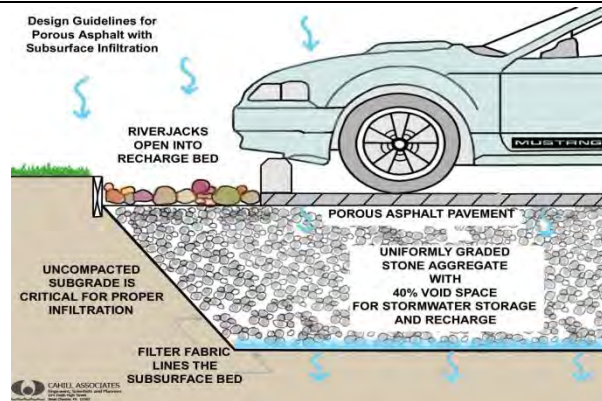
## DESCRIPTION

Porous pavement is a permeable surface that allows the passing of stormwater through an underlying stone reservoir. This is most commonly used as parking area surface and mitigates the flux of stormwater from parking surfaces in a rain event. Pollutants are removed by filtration, sorption, and biological activity in the underlying soil or filter matrix.

Jacobs Carter Burgess, 2008. Collin County, Texas Phase II TPDES Stormwater Management Program



US Department of Transportation Federal Highway Administration  
[international.fhwa.dot.gov/.../images/fig2.jp](http://international.fhwa.dot.gov/.../images/fig2.jp)



Cahill and Associates, Inc. 2004

## SWAT INPUT

**APEX INPUT**

The soil profile description is input by layers to any depth. The volumetric fraction of rock would be the most important input for simulating porous pavement and the underlying stormwater storage and recharge.

**Soils Data**

A new soil will need to be created with layers corresponding to the different layers of the porous pavement zone. The soil data should be edited for each layer of the soil paying close attention to the following parameters.

**Z:** Depth of bottom of layer (m)

**BD:** Moist bulk density ( $\text{Mg/m}^3$  or  $\text{g/cm}^3$ )

**SAN:** Sand fraction

**SIL:** Silt fraction

**PH:** Soil pH

**ROK:** Coarse fragment fraction

**SATC:** Saturated conductivity (mm/h). Rate at which water passes through the soil layer, when saturated. The saturated hydraulic conductivity relates soil water flow rate (flux density) to the hydraulic gradient and is a measure of the ease of water movement through the soil. The saturated conductivity is the reciprocal of the resistance of the soil matrix to water flow.

# Porous Pavement with Grass (Green Parking)

## DESCRIPTION

Turf paving represents a variety of practices incorporating the use of turf grasses with innovative and traditional paving methods. These include:

Modular Paving Blocks and Grids:  
Interlocking grids to provide stability with gaps filled in with grass.

Cast in Place Systems: Monolithic pavement systems with gaps left to be filled in with grasses.

Soil Enhancements: Synthetic mesh elements blended with a sandy growing medium, resulting in a natural turf surface with engineered load-bearing root zone.

*Oak Park Conservancy District Stormwater Best Management Practices. Permeable Pavements (Turf Pavers) SPD-02.4. 2005*



Lake Superior Streams, 2005. *Community Partnerships For Understanding Water Quality and Stormwater Impacts at the Head of the Great Lakes*. University of Minnesota-Duluth, Duluth, MN. <http://lakesuperiorstreams.org>

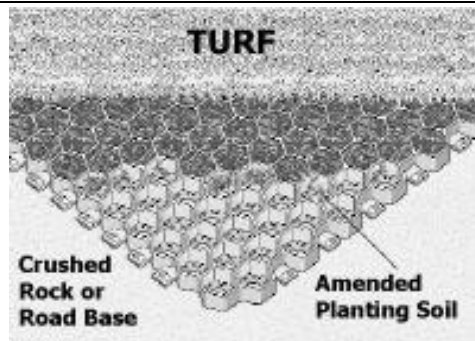


Figure Courtesy Irriland Corporation <http://www.irriland.com/tufftrackgrasspavers.html>

## SWAT INPUT

**APEX INPUT**

The soil profile description is input by layers to any depth. The volumetric fraction of rock would be the most important input for simulating porous pavement and the underlying stormwater storage and recharge.

**Soils Data**

A new soil will need to be created with layers corresponding to the different layers of the porous pavement zone. The soil data should be edited for each layer of the soil paying close attention to the following parameters.

**Z:** Depth of bottom of layer (m)

**BD:** Moist bulk density ( $\text{Mg/m}^3$  or  $\text{g/cm}^3$ )

**SAN:** Sand fraction

**SIL:** Silt fraction

**PH:** Soil pH

**ROK:** Coarse fragment fraction

**SATC:** Saturated conductivity (mm/h). Rate at which water passes through the soil layer, when saturated. The saturated hydraulic conductivity relates soil water flow rate (flux density) to the hydraulic gradient and is a measure of the ease of water movement through the soil. The saturated conductivity is the reciprocal of the resistance of the soil matrix to water flow.

**Subarea file – Management**

**IOPS:** Crop operation schedule. This should be a grass or mix of grasses grown in an intercropped scenario.

**LUNS:** Land use number. This number is from the NRCS land use-hydrologic soil group table.



# Sediment Basin

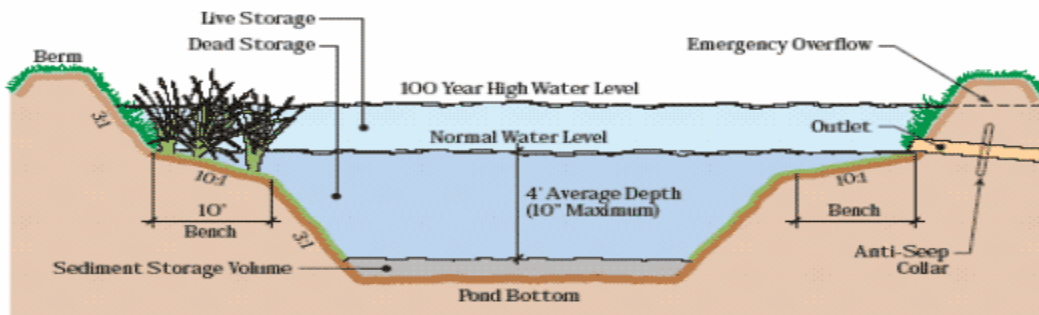
## DESCRIPTION

A basin constructed to collect and store debris or sediment. Sediment basins are installed to preserve the capacity of reservoirs, wetlands, ditches, canals, diversion, waterways, and streams. This practice also prevents undesirable deposition on bottom lands and developed areas. The practice works to trap sediment originating from construction sites or other disturbed areas. Sediment basins also work to reduce or abate pollution by providing basins for deposition and storage of silt, sand, gravel, stone, agricultural waste solids, and other detritus.

USDA-NRCS, 2003. *National Conservation Practice Standards*.  
<http://www.nrcs.usda.gov/technical/standards/nhcp.html>



Photo Courtesy USDA- NRCS Online Photo Gallery



- Bench areas promote growth of emergent vegetation.
- Maximize distance between the outlet and all inlets to prevent short circuiting of flows.

City of Chanhassen, Minnesota 1994. [www.ci.chanhassen.mn.us/serv/cip/swmp/ad.htm](http://www.ci.chanhassen.mn.us/serv/cip/swmp/ad.htm)

## SWAT INPUT

Sedimentation basin can be simulated as a pond in SWAT. The fractional area of a subbasin contributing to sedimentation basins can be used to specify **PND\_FR** (Fraction of subbasin area that drains to ponds). The total surface area of sedimentation basins can be used to define **PND\_PSA** (Surface area of ponds when filled to principle spillway.) **PND\_PVOL** (Volume of water stored in ponds when filled to the principal spillway.) can be calculated by assuming a reasonable average depth of sedimentation basins. **PND\_K** (Hydraulic conductivity through bottom of ponds.) should be somewhat higher than typical values for ponds, as these structures may not be designed to permanently hold water.

**APEX INPUT**

There are two options for simulating sediment basins. Option one is that a reservoir is used for detailed simulations of individual sediment basins. In this case runoff from the upstream subarea(s) is routed through the reservoir. The principle spillway elevation is set to provide adequate sediment storage for the design period. The emergency spillway elevation is set to provide small to moderate flood storage to reduce downstream channel erosion.

The second option is useful in watersheds with fairly large subareas that contain many sediment basins. The user simply specifies the fraction of the subarea that is controlled by ponds and APEX designs the ponds using appropriate criteria.

**Sediment Basin as a Reservoir****Subarea file (.sub)– Reservoir**

**RSEE:** Elevation at emergency spillway (m)

**RSAP:** Total reservoir surface area at emergency spillway elevation (ha)

**RSVE:** Runoff volume from reservoir catchment area at emergency spillway elevation (mm)

**RSEP:** Elevation at principal spillway (m)

**RSAP:** Total reservoir surface area at principal spillway elevation (ha)

**RSVP:** Volume at principal spillway elevation (mm)

**RSV:** Initial reservoir volume (mm)

**RSRR:** Average principal spillway release rate (mm/h)

**RSYS:** Initial sediment concentration in reservoir (ppm). Optional - Default value is 250 ppm.

**RSYN:** Normal sediment concentration in reservoir (ppm) Optional - Default value is 250 ppm.

**RSHC:** Hydraulic conductivity of reservoir bottom (mm/h)

**RSDP:** Time for sediment concentrations to return to normal (days) following a runoff event

**RSBD:** Bulk density of sediment in reservoir ( $t/m^3$ ) Optional - Default value is  $0.8 t/m^3$ .

**Sediment Basin as Fraction of Subarea****Subarea file (.sub)– Reservoir**

**PCOF:** Fraction of the subarea that flows through ponds. This affects only the hydrology that originates in this subarea. Inflow from other subareas is not routed through the ponds in this subarea.

# Silt Fence

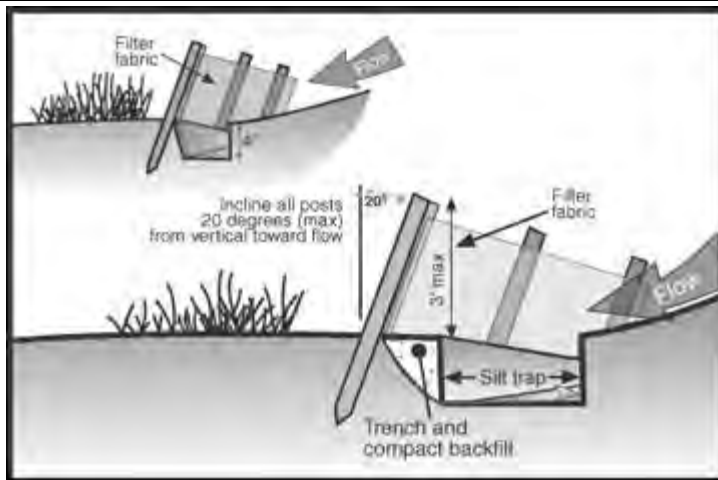
## DESCRIPTION

A sediment fence is a temporary barrier consisting of synthetic fiber that is stretched across and attached to supporting posts. Sediment fences are designed to limit the flow of silt and sediment from construction sites in which the soil is disturbed. Fences are often part of a compliment of best management practices designed for construction sites to work in concert as part of a Storm Water Prevention and Protection Plan as mandated by the Texas Commission on Environmental Quality.

US Army Corps of Engineers. Best Management Practices. <http://www.usace.army.mil/publications/eng-pamphlets/ep1110-1-16/bmp-5.pdf>.



Photo Courtesy of: North Carolina State University  
<http://www.water.ncsu.edu/watershedss/dss/wetland/aqlife/construc.html>



University of Missouri Extension <http://extension.missouri.edu/explore/aquides/aqengin/q01509.htm>

## SWAT INPUT

**APEX INPUT**

A silt fence can be simulated with the reservoir component assuming little or no storage. The principle spillway elevation is set at the base of the fence and the release rate is set to reflect the flow rate through or under the fence. The emergency spillway is set at the top of the dike.

**Subarea file (.sub) – Reservoir**

**RSEE:** Elevation at emergency spillway (m). This is the height to the top of the silt fence.

**RSAE:** Total reservoir surface area at emergency spillway elevation (ha)

**RSVE:** Runoff volume from reservoir catchment area at emergency spillway elevation (mm)

**RSEP:** Elevation at principal spillway (m). This is the height to the base of the silt fence, which will be 0 or very near 0.

**RSAP:** Total reservoir surface area at principal spillway elevation (ha)

**RSVP:** Volume at principal spillway elevation (mm)

**RSV:** Initial reservoir volume (mm). This should be 0 in most cases.

**RSRR:** Average principal spillway release rate (mm/h). This will be the rate at which the water seeps through the silt fence.

**RSYS:** Initial sediment concentration in reservoir (ppm)

**RSYN:** Normal sediment concentration in reservoir (ppm)

**RSHC:** Hydraulic conductivity of reservoir bottom (mm/h)

**RSDP:** Time for sediment concentrations to return to normal (days) following a runoff event

**RSBD:** Bulk density of sediment in reservoir ( $t/m^3$ )

# Stone Outlet Sediment Trap

## DESCRIPTION

A temporary impoundment (reservoir) built to retain sediment and debris on a drainage area less than one acre. The sediment trap, on areas between one and three acres, is formed by building a predetermined reservoir confined by an earthen embankment with a pipe outlet.

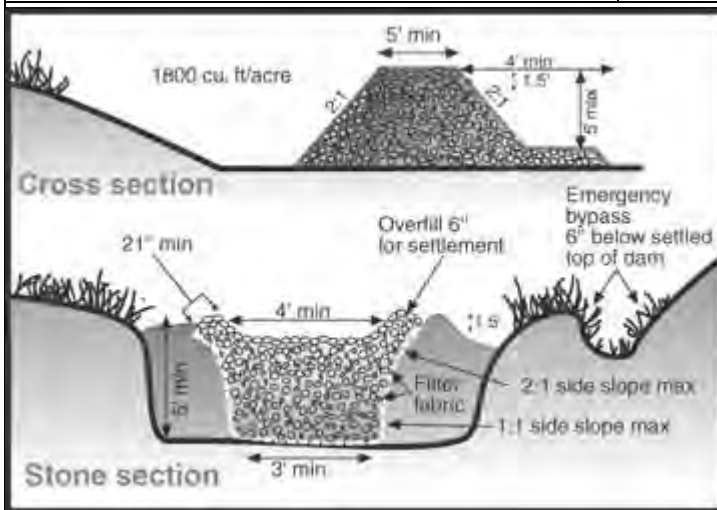
Fairfax County Virginia 2004

<http://www.fairfaxcounty.gov/nvswcd/newsletter/esc.htm>



Fairfax County Virginia 2004.

<http://www.fairfaxcounty.gov/nvswcd/newsletter/esc.htm>



University of Missouri Extension <http://extension.missouri.edu/explore/agguides/agengin/g01509.htm>

## SWAT INPUT

**APEX INPUT**

Another reservoir application with spillways set appropriately.

# Terraces

## DESCRIPTION

An earth embankment, or a combination ridge and channel, constructed across the field slope.

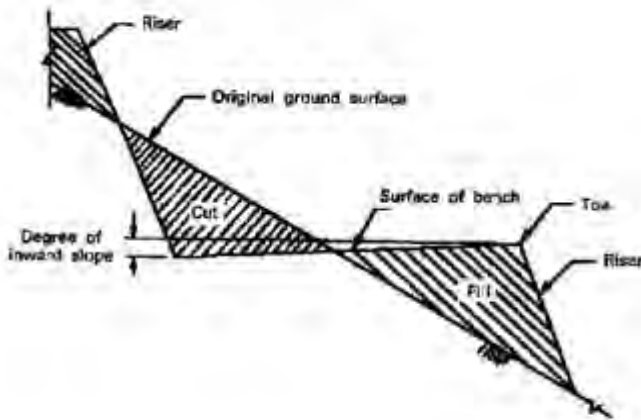
This practice is applied as part of a resource management system designed to reduce erosion by reducing slope length and retaining runoff for moisture conservation.

This practice applies where soil erosion caused by water and excessive slope length is a problem, excess runoff is a problem, and there is a need to conserve water. Terracing requires that the soils and topography are such that terraces can be constructed and reasonably farmed and suitable outlet can be provided.

USDA-NRCS, 2006. *National Conservation Practice Standards*.  
<http://www.nrcs.usda.gov/technical/standards/nhcp.html>



Photo Courtesy of USDA-NRCS Online Photo Gallery



Food & Fertilizer Technology Center of Asian and the Pacific [www.agnet.org/library/pt/2001024/](http://www.agnet.org/library/pt/2001024/)

## SWAT INPUT

The effect of terraces can be simulated by modifying the following SWAT parameters:

**CN2** (Initial SCS runoff curve number for moisture condition II.) should be set using Table 20-1 of the SWAT users manual. In general terraced fields are also farmed on the contour.

**USLE\_P** (USLE practice factor) should be derived from table 20-6 of the SWAT users manual to reflect reduced sediment losses. Terraces outlet type can be reflected in the P value using this table, or a grassed waterway can be simulated. It is however not appropriate to account for outlet effects in both the P factor and as separate grassed waterways.



***SLSUBBSN*** (Average slope length) should be set to the distance between terraces.

## **APEX INPUT**

There are two ways to simulate the effects of terraces in APEX. For detailed field simulations the area between each terrace and the terrace channel are treated as separate subareas and runoff, sediment, nutrients and pesticides are routed down the terrace channel to the outlet. For watershed work with fairly large subareas with many fields containing terraces, it is more convenient to simply change the erosion control practice factor and the runoff curve number.

### **Terrace as separate subarea**

#### **Subarea file – Subarea geometry**

Water must be rerouted away from the natural downstream subarea and to an alternate outlet. The reach channel length will be increased greatly and the reach slope will be lessened to a very minimal slope.

***CHL:*** Distance from outlet to most distant point in the subarea (km)

***CHD:*** Channel depth (m)

***CHS:*** Mainstream channel slope (m/m). The average channel slope is computed by dividing the difference in elevation between the watershed outlet and the most distant point by CHL.

***CHN:*** Manning's N for channel

***SLP:*** Average upland slope (m/m)

***SPLG:*** Average upland slope length (m). This is the distance that sheet flow is the dominant surface runoff flow process. Slope length should be measured to the point that flow begins to concentrate.

***UPN:*** Manning's N for upland. Should be set to 0.2-0.4.

***RCHL:*** Channel length of routing reach (km). The length between where the channel starts or enters the subarea and leaves the subarea.

***RCHD:*** Channel depth of routing reach (m)

***RCBW:*** Bottom width of routing reach channel (m)

***RCTW:*** Top width of routing reach channel (m)

***RCHS:*** Channel slope of routing reach (m/m)

***RCHN:*** Channel Manning's N of routing reach.

***RCHC:*** USLE Crop Management channel factor. This is dependent on land cover. With bare channel conditions, RCHC should be set to 0.1-0.6. If the land cover is very good, it should be set to 0.0001.

***RCHK:*** USLE Erodibility channel factor. This is dependent on soil texture and organic matter content. With rock condition, RCHK should be 0.0001; with loess (silt/mud) condition, it should be 0.30

### **Terrace as part of a large subarea**

The effect of terrace is simulated by modifying the USLE\_P factor and CN2. Also refer to the SWAT INPUT above.

#### **Subarea file (.sub)-General**

***PEC (USLE\_P):*** The erosion control practice factor normally ranges from 0.1 to 0.2 for well-maintained terrace systems with proper waterways. (0.12 used in Tuppad, et al., 2009; 0.2

for parallel terrace in good condition in Bracmort, et al., 2006)

**LUNS:** Land use number. This number is from the NRCS land use-hydrologic soil group table and is used to calculate the runoff curve number.

*Bracmort, K. S., M. Arabi, J. R. Frankenberger, B. A. Engel, and J. G. Arnold. 2006. Modeling long-term water quality impact of structural BMPs. Trans. ASABE 49(2): 367–374.*

*Pushpa Tuppad, Chinnasamy Santhi, Raghavan Srinivasan, and Jimmy R. Williams. 2009. Best Management Practice (BMP) Verification using Observed Water Quality Data and Watershed Planning for Implementation of BMPs. Blackland Research and Extension Center report.*

# Triangular Sediment Dike

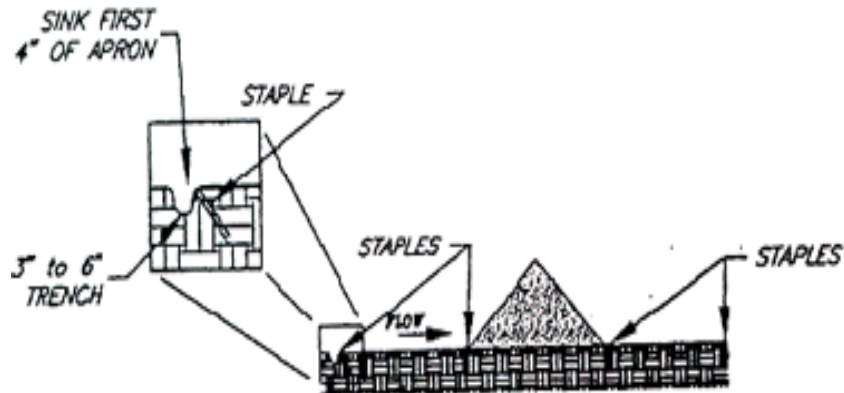
## DESCRIPTION

The purpose of a triangular sediment filter dike is to intercept and detain water-borne sediment from unprotected areas of limited extent. The triangular sediment filter dike is used where there is no concentration of water in a channel or other drainage way above the barrier and the contributing drainage area is less than one acre. This measure is effective on paved areas where installation of silt fence is not possible or where vehicle access must be maintained. The advantage of these controls is the ease with which they can be moved to allow vehicle traffic and then reinstalled to maintain sediment.

US Army Corps of Engineers  
<http://www.swg.usace.army.mil/reg/construction/bmps.asp>



Photo Courtesy of City of Moline, Illinois  
[www.moline.il.us/.../images/BMPimage8.gif](http://www.moline.il.us/.../images/BMPimage8.gif)



Washington State University <http://lakewhatcom.wsu.edu/display.asp?ID=104>

## SWAT INPUT

**APEX INPUT**

A triangular sediment dike can be simulated with the reservoir component assuming little or no storage. The principle spillway elevation is set at the base of the dike and the release rate is set to reflect the flow rate through the dike. The emergency spillway is set at the top of the dike.

**Subarea file (.sub) – Reservoir**

**RSEE:** Elevation at emergency spillway (m). This is the height to the top of the dike.

**RSAE:** Total reservoir surface area at emergency spillway elevation (ha)

**RSVE:** Runoff volume from reservoir catchment area at emergency spillway elevation (mm)

**RSEP:** Elevation at principal spillway (m). This is the height to the base of the dike.

**RSAP:** Total reservoir surface area at principal spillway elevation (ha)

**RSVP:** Volume at principal spillway elevation (mm)

**RSV:** Initial reservoir volume (mm). This should be 0 in most cases.

**RSRR:** Average principal spillway release rate (mm/h). This will be the rate at which the water seeps through the dike.

**RSYS:** Initial sediment concentration in reservoir (ppm)

**RSYN:** Normal sediment concentration in reservoir (ppm)

**RSHC:** Hydraulic conductivity of reservoir bottom (mm/h)

**RSDP:** Time for sediment concentrations to return to normal (days) following a runoff event

**RSBD:** Bulk density of sediment in reservoir ( $t/m^3$ )

# Wetland Creation

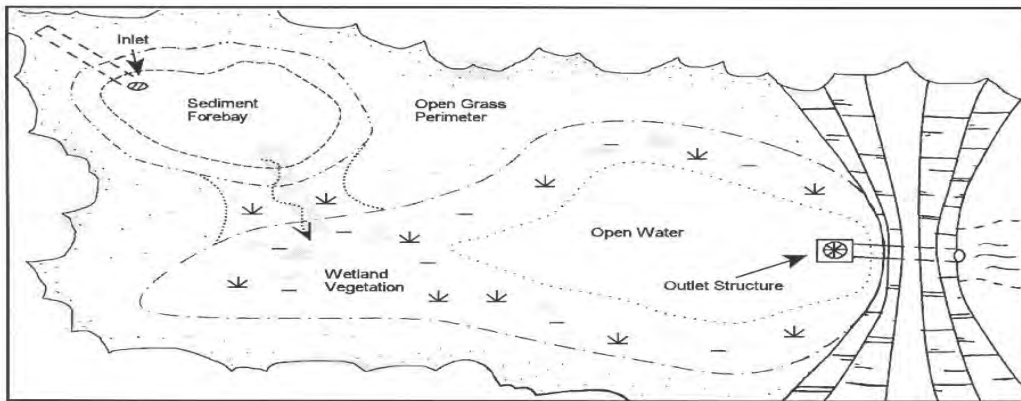
## DESCRIPTION

Constructed wetlands provide a sediment retention and nutrient removal system that uses natural chemical, physical, and biological processes involving wetland vegetation, soils, and their associated microbial populations to improve water quality. Constructed wetlands are designed to use water quality improvement processes occurring in natural wetlands, including high primary productivity, low flow conditions, and oxygen treatment to anaerobic sediments. Nutrient retention in wetlands systems occurs via sorption, precipitation, and incorporation.

Hawkins, J. Constructed Treatment Wetlands. Phosphorus Best Management Practices. USDA-NRCS. SERA17  
<http://sera17.ext.vt.edu>



Photo Courtesy of:  
[www.fxbrowne.com/html/FXB%20Wetland%20CS/fxbi\\_constructed%20wetland\\_CS.htm](http://www.fxbrowne.com/html/FXB%20Wetland%20CS/fxbi_constructed%20wetland_CS.htm)



Jin-Yong Choi & Bernard A. Engel, 1146 ABE, Purdue University, West Lafayette, IN, 47907-114  
[http://www.ecn.purdue.edu/runoff/ubmp0/constructed\\_wetland\\_systems.htm](http://www.ecn.purdue.edu/runoff/ubmp0/constructed_wetland_systems.htm)

## SWAT CALIBRATION

- A.** Wetlands located on the stream network of the watershed are modeled as reservoirs.
- A.1) Reservoirs are impoundments located on the main channel network of the watershed. Reservoirs receive loadings from all upstream subbasins. The reservoir input file (.res) contains input data to simulate water and sediment processes while the lake water quality file (.lwq) contains input data to simulate nutrient and pesticide cycling in the water body. For more information, please read chapter 29 (SWAT Input Data: \*.res) and chapter 30 (SWAT Input Data: \*.lwq). The input parameters should be adjusted based on the wetland specifications.
- B.** Wetlands are impoundments located within the subbasin area. These impoundments receive loadings only from the land area in the subbasin.

**IPND1 (\*.pnd):** Beginning month of mid-year nutrient settling "season". The model allows the user to define two settling rates for each nutrient and the time of the year during which each settling rate is used. A variation in settling rates is allowed so that impact of temperature and other seasonal factors may be accounted for in the modeling of nutrient settling. To use only one settling rate for the entire year, both variables for the nutrient may be set to the same value. Setting all variables to zero will cause the model to ignore settling of nutrients in the water body.

**IPND1 (\*.pnd):** Ending month of mid-year nutrient settling "season".

**WET\_FR (\*.pnd):** Fraction of subbasin area that drains into wetlands. The value for WET\_FR should be between 0.0 and 1.0.

**WET\_NSA (\*.pnd):** Surface area of wetlands at normal water level (ha). For SWAT to calculate the wetland surface area each day the surface area at two different water volumes, normal and maximum, must be defined. If users do not have information for the two water storage volumes, they may enter information for only one and allow SWAT to set values for the other based on the known surface area/volume.

**WET\_NVOL (\*.pnd):** Volume of water stored in wetlands when filled to normal water level (104 m<sup>3</sup> H<sub>2</sub>O).

**WET\_MXSA (\*.pnd):** Surface area of wetlands at maximum water level (ha).

**WET\_MXVOL (\*.pnd):** Volume of water stored in wetlands when filled to maximum water level (104 m<sup>3</sup> H<sub>2</sub>O).

**WET\_VOL (\*.pnd):** Initial volume of water in wetlands (104 m<sup>3</sup> H<sub>2</sub>O). It was recommended using a 1-year equilibration period for the model where the watershed simulation is set to start 1 year prior to the period of interest. This allows the model to get the water cycling properly before any comparisons between measured and simulated data are made. When an equilibration period is incorporated, the value for WET\_VOL is not going to impact model results if the pond is small. However, if the wetland is large a reasonably accurate value needs to be input for this value.

**WET\_SED:** Initial sediment concentration in wetland water (mg/L). It was recommended using a 1-year equilibration period for the model where the watershed simulation is set to start 1 year prior to the period of interest. This allows the model to get the water cycling properly before any comparisons between measured and simulated data are made. When an equilibration period is incorporated, the value for WET\_SED is not going to impact model results.

**WET\_NSED (\*.pnd):** Equilibrium sediment concentration in wetland water (mg/L). The amount of suspended solid settling that occurs in the water body on a given day is calculated as a function of concentration. Settling occurs only when the sediment concentration in the water body exceeds the equilibrium sediment concentration specified by the user.

**WET\_K (\*.pnd):** Hydraulic conductivity through bottom of wetland (mm/hr). If seepage occurs in the water body, the hydraulic conductivity must be set to a value other than 0.

**PSETLW1 (\*.pnd):** Phosphorus settling rate in wetland for months IPND1 through IPND2 (m/year). The apparent settling velocity is most commonly reported in units of m/year and this is how the values are input to the model. For natural lakes, measured phosphorus settling velocities most frequently fall in the range of 5 to 20 m/year although values less than 1 m/year to over 200 m/year have been reported (Chapra, 1997). Panuska and Robertson (1999) noted that the range in apparent settling velocity values for man-made reservoirs tends to be significantly greater than for natural lakes. Higgins and Kim (1981) reported phosphorus apparent settling velocity values from -90 to 269 m/year for 18 reservoirs in Tennessee with a median value of 42.2 m/year. For 27 Midwestern reservoirs, Walker and Kihner (1978)

reported phosphorus apparent settling velocities ranging from -1 to 125 m/year with an average value of 12.7 m/year. A negative settling rate indicates that the reservoir sediments are a source of N or P; a positive settling rate indicates that the reservoir sediments are a sink for N or P.

**PSETLW2 (\*.pnd):** Phosphorus settling rate in wetlands for months other than IPND1-IPND2 (m/year). See explanation for PSETLW1, IPND1 and IPND2 for more information about this variable.

**NSETLW1 (\*.pnd):** Nitrogen settling rate in wetlands for months IPND1 through IPND2 (m/year). See explanation for PSETLW1, IPND1 and IPND2 for more information about this variable.

**NSETLW2 (\*.pnd):** Nitrogen settling rate in wetlands for months other than IPND1-IPND2 (m/year). See explanation for PSETLW1, IPND1 and IPND2 for more information about this variable.

**CHLAW (\*.pnd):** Chlorophyll *a* production coefficient for wetlands. The user-defined coefficient, Chlaco, is included to allow the user to adjust the predicted chlorophyll *a* concentration for limitations of nutrients other than phosphorus. When Chlaco is set to 1.00, no adjustments are made (the original equation is used). For most water bodies, the original equation will be adequate.

The default value for CHLAW is 1.00, which uses the original equation. Therefore, this value should only be adjusted if there are limitations of nutrients other than phosphorus in the wetland.

**SECCIW (\*.pnd):** Water clarity coefficient for wetlands. The clarity of the wetland is expressed by the secchi-disk depth (m), which is calculated as a function of chlorophyll *a*. The user-defined coefficient, SDco, is included to allow the user to adjust the predicted secchi-disk depth for impacts of suspended sediment and other particulate matter on water clarity that are ignored by the original equation. When SDco is set to 1.00, no adjustments are made (the original equation is used). For most water bodies, the original equation will be adequate. The default value for SECCIW is 1.00, which uses the original equation.

**WET\_NO3 (\*.pnd):** Initial concentration of NO<sub>3</sub>-N in wetland (mg N/L). It was recommended using a 1-year equilibration period for the model where the watershed simulation is set to start 1 year prior to the period of interest. This allows the model to get the water cycling properly before any comparisons between measured and simulated data are made. When an equilibration period is incorporated, the value for WET\_NO3 is not going to be important.

**WET\_SOLP (\*.pnd):** Initial concentration of soluble P in wetland (mg P/L).

**WET\_ORGN (\*.pnd):** Initial concentration of organic N in wetland (mg N/L).

**WET\_ORGP (\*.pnd):** Initial concentration of organic P in wetland (mg P/L).

R. Srinivasan. Unpublished SWAT Calibration Instructions for Best Management Practices.



**APEX INPUT**

A wetland is simulated with a very shallow reservoir located in the floodplain. The principle spillway elevation is set to the desired depth of the wetland and the emergency spillway elevation is set slightly higher. For example, the principle spillway might be set to give an average depth of 1 meter and the emergency spillway would be set at 1.1 meter. Vegetative growth would be simulated in the wetland.

To model a wetland in detail, the wetland area should be designated as a separate subarea.

**Subarea file – Reservoir**

***RSEE:*** Elevation at emergency spillway (m)

***RSAE:*** Total reservoir surface area at emergency spillway elevation (ha)

***RSVE:*** Runoff volume from reservoir catchment area at emergency spillway elevation (mm)

***RSEP:*** Elevation at principal spillway (m)

***RSAP:*** Total reservoir surface area at principal spillway elevation (ha)

***RSVP:*** Volume at principal spillway elevation (mm)

***RSV:*** Initial reservoir volume (mm)

***RSRR:*** Average principal spillway release rate (mm/h)

***RSYS:*** Initial sediment concentration in reservoir (ppm)

***RSYN:*** Normal sediment concentration in reservoir (ppm)

***RSHC:*** Hydraulic conductivity of reservoir bottom (mm/h)

***RSDP:*** Time for sediment concentrations to return to normal (days) following a runoff event

***RSBD:*** Bulk density of sediment in reservoir (t/m<sup>3</sup>)

**Subarea file – Management**

***IOPS:*** Crop operation schedule. This should be a crop capable of growing in high aeration stress conditions (i.e. rice). This crop should have a critical aeration factor (CAF) of 1 in order to grow in waterlogged conditions. CAF can be found in the crop parameters.

***LUNS:*** Land use number. This number is from the NRCS land use-hydrologic soil group table.

# Cropland Conversion to Pasture

## DESCRIPTION

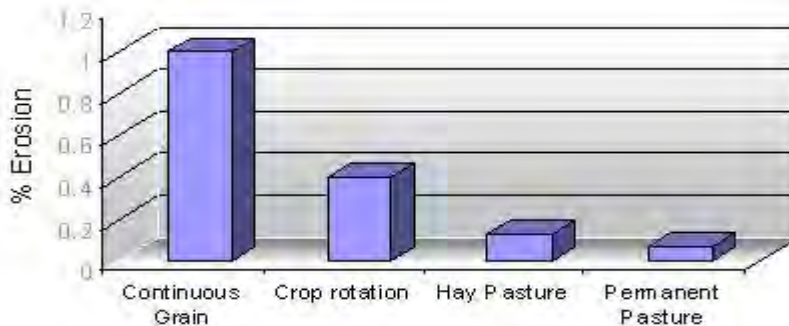
Enrollment in the Conservation Reserve Program requires the conversion of lands used for crop production to be planted for livestock forage. Range and pasture planting require the establishment of adapted perennial vegetation (preferably native). Grass, forbs, legumes, shrubs, and trees work to restore a plant community similar to historically natural conditions yet sensitive to the nutritional needs of livestock and native species.

USDA-NRCS, 2003. *National Conservation Practice Standards*.

<http://www.nrcs.usda.gov/technical/standards/nhcp.html>



Photo Courtesy USDA-NRCS Online Photo Gallery



Ontario Ministry of Agriculture and Food, Robert P. Stone and Neil Moore, [Fact Sheet 95-089](#)

## SWAT INPUT

The enrollment of land in CRP should be represented by changing the management of the HRU to reflect grassland conditions. Multiple model parameters are affected. CRP should generally be unmanaged native grasses, which may be grazed or cut for hay under certain conditions. CRP may also be managed as brushy rangeland as opposed to native grasses. The specific parameter modification necessary to simulate the enrolment of land in CRP vary significantly and should be based on local conditions.

**APEX INPUT**

Mixed stands of grasses, legumes, shrubs, or trees may be planted and their growth simulated by APEX. Normally, the grass/legume mixtures are shredded or mowed annually.

**Subarea file – Management**

***IOPS:*** Crop operation schedule. If a grass and /or legume crop operation is chosen, a mowing or shredding operation should be included in the schedule at least once per year.

***LUNS:*** Land use number. This number is from the NRCS land use-hydrologic soil group table.

# Incorporate Manure with Tillage

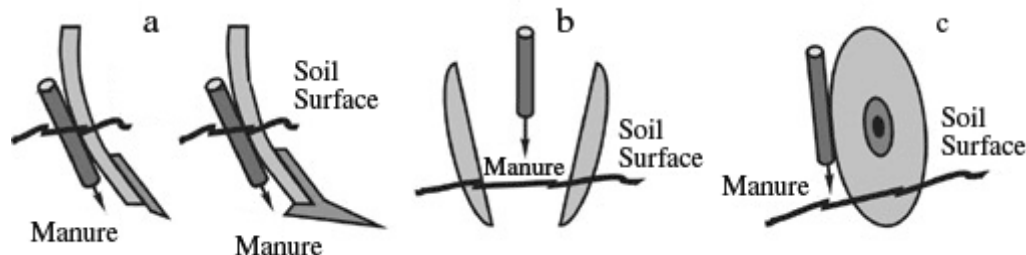
## DESCRIPTION

Land application of animal manure is an efficient utilization alternative because of usually lower costs compared to treatment and the nutrient benefits derived by crops from the manure. Manure nutrients help build and maintain soil fertility. Manure can also improve soil tilth, increase water-holding capacity, lessen wind and water erosion, improve aeration, and promote beneficial organisms. There are two principal objectives in applying animal manure to land: 1) ensuring maximum utilization of the manure nutrients by crops and 2) minimizing water pollution hazards.

Best Management Practices: Land Application of Animal Manure  
AGF-208-95 Ohio State University Extension  
Department of Horticulture and Crop Science



Iowa State University Extension 2004  
<http://www.extension.iastate.edu/pages/communications/epc/Fall02/york.html>



Typical soil-engaging components used for simultaneous application and incorporation of manure: a) chisel and sweep injectors; b) disk-type applicator; and c) coulter-type applicator

University of Nebraska-Lincoln 2006. <http://www.ianrpubs.unl.edu/epublic/pages/publicationD.jsp?publicationId=40>

## SWAT INPUT

**MONTH (\*.mgt):** Month operation takes place. Should be the same for tillage and manure application.

**DAY (\*.mgt):** Day operation takes place. Should be the same for tillage and manure application.

**MGT\_OP (\*.mgt):** Operation code. MGT\_OP = 3 for fertilizer operation.

**FERT\_ID (\*.mgt):** Type of fertilizer/manure applied (code from fert.dat)

**FRT\_Surface (\*.mgt):** Fraction of fertilizer applied to top 10 mm of soil. The remaining fraction is applied to the first soil layer (defined in the HRU .sol file) below 10 mm. If FRT\_SURFACE is set to 0, the model applies 20% of the fertilizer to the top 10 mm and the remainder to the first soil layer.

**FRT\_KG (\*.mgt):** Amount of fertilizer applied to HRU (kg/ha)

R. Srinivasan. Unpublished SWAT Calibration Instructions for Best Management Practices.

**APEX INPUT**

This is a routine APEX application. Any type of manure can be applied and there are a variety of tillage implements available in the tillage file.

**Operation Schedule file (.opc)****Manure application: Add a manure application operation**

***JX4 (Operation):*** Select a fertilizer operation used to apply the manure.

***JX7 (Type fertilizer applied):*** Select the manure to be applied.

***OPV1 (Application amount):*** Enter the amount of manure applied (kg/ha).

***MONTH:*** Month operation takes place. Should be the same for tillage and manure application.

***DAY:*** Day operation takes place. Should be the same for tillage and manure application.

**Tillage Operation: Add a tillage operation**

***JX4 (Operation):*** Select a tillage operation used to incorporate the manure

***MONTH:*** Month operation takes place. Should be the same for tillage and manure application.

***DAY:*** Day operation takes place. Should be the same for tillage and manure application.

# No-Till

## (Residue and tillage management no-till/ strip till/ direct seed)

### DESCRIPTION

No-till agriculture involves the amount, orientation and distribution of crop and other plant residue on the soil surface year round while limiting soil-disturbing activities to only those necessary to place nutrients, condition residue and plant crops.

No-till reduces sheet and rill and wind erosion. The practice works to improve soil organic matter content, reduce CO<sub>2</sub> losses from the soil, reduce soil particulate emissions, increase plant-available moisture, and provide food and escape cover for wildlife.

USDA-NRCS, 2003. *National Conservation Practice Standards*.  
<http://www.nrcs.usda.gov/technical/standards/nhcp.html>



Photo Courtesy USDA-NRCS Online Photo Gallery

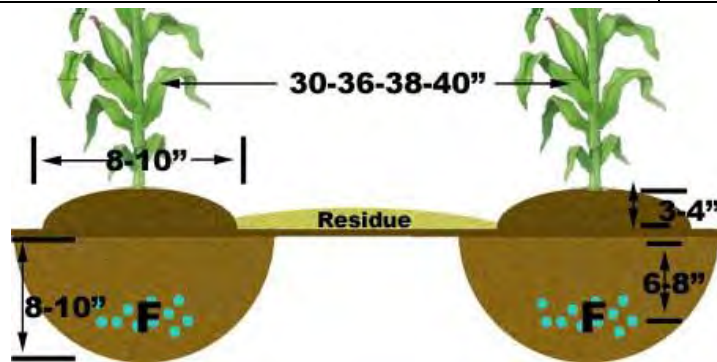


Diagram Courtesy of Farm Industry News [http://farmindustrynews.commag/farming\\_striptill\\_teamwork/](http://farmindustrynews.commag/farming_striptill_teamwork/)

**SWAT INPUT**

**MONTH (\*.mgt):** Month operation takes place

**DAY (\*.mgt):** Day operation takes place

**MGT\_OP (\*.mgt):** Management operation number. MGT\_OP = 6 for tillage operation.

**TILL\_ID (\*.mgt):** Tillage implement code from tillage database. ZEROTILL

**CNOP (\*.mgt):** SCS runoff curve number for moisture condition II. The curve number may be updated in plant, tillage, and harvest/ kill operations. If CNOP is never defined for these operations, the value set for CN2 will be used throughout the simulation. If CNOP is defined for an operation, the value for CN2 is used until the time of the operation containing the first CNOP value. From that point on, the model only uses operation CNOP values to define the curve number for moisture condition II. Values for CN2 and CNOP should be entered for pervious conditions. In HRUs with urban areas, the model will adjust the curve number to reflect the impact of the impervious areas. Studies by Rawls et al. (1980), Rawls and Richardson (1983), and Chung et al. (1999) showed that curve numbers needed to be reduced to reflect the impacts of conservation tillage or no-till (e.g. reduce by 3 points).

([http://gis.esri.com/library/userconf/proc01/\\_professional/papers/pap919/p919.htm](http://gis.esri.com/library/userconf/proc01/_professional/papers/pap919/p919.htm))

**ITNUM (till.dat):** Tillage number. ITNUM is the numeric code used in the management file to identify the tillage practice to be modeled.

**EFFMIX (till.dat):** Mixing efficiency of tillage operation. The mixing efficiency specifies the fraction of materials (residue, nutrients, and pesticides) on the soil surface, which are mixed uniformly throughout the soil depth specified by DEPTIL. The remaining fraction of residue and nutrients is left in the original location (soil surface or layer). Mixing efficiency for generic No-till mixing is 0.05

**DEPTIL (till.dat):** Depth of mixing caused by the tillage operation (mm). Mixing depth for generic No-till is 25mm.

R. Srinivasan. Unpublished SWAT Calibration Instructions for Best Management Practices.

**APEX INPUT**

APEX has been used in a variety of no-till practices throughout the U.S. in the CEAP project as well as many other applications. Normally, no-till only requires the planting and harvesting dates and any fertilizer, irrigation, and pesticide applications. The residue management, erosion control, etc. are handled implicitly by APEX.

**Subarea file – Management**

**IOPS:** Crop operation schedule. Must include a planting and harvesting operation. This is done in the operation schedule editor.

**LUNS:** Land use number. This number is from the NRCS land use-hydrologic soil group table.



# Pet Waste Management

## DESCRIPTION

Pet waste is a common source of pathogens in urban waterways resulting from pet owners who neglect to pick up the waste produced by their pets. The practice of pet waste management can be accomplished by means of public education programs in the form of signage and public service announcements. Public accommodation is likely to assist in the implementation of the practice though the provision of bags and disposal areas at popular pet usage sites such as dog parks and trailheads. Lastly, many jurisdictions have adopted ordinances to require pet owners to clean up pet waste in public areas.



Photo Courtesy of US Fish and Wildlife Service  
[www.fs.fed.us/r5/tbmu/recreation/dogs/](http://www.fs.fed.us/r5/tbmu/recreation/dogs/)

Jacobs Carter Burgess, 2008. Collin County, Texas Phase II TPDES Stormwater Management Program

**Until they can take care of their own business, it's your business.**

Let's keep Bend dog-friendly. Be a responsible dog owner and pick up after your canine friend. For your convenience, Bend Park and Recreation is providing dog clean-up stations in parks. But don't just rely on those. It's always a good idea to carry bags with you whenever you take your dog, just in case of you know what. And don't forget to leash your dog responsibly. Especially if there are children or other animals around. So unless you've got your dog thoroughly toilet trained—don't forget, clean up after your pet. Find out how to get involved by contacting Softpaws, a local volunteer group advocating responsible dog ownership, at [www.softpawsK9.org](http://www.softpawsK9.org)

**De-Poop-Da-Park**  
Dog Waste Clean-Up Campaign

Brought to you by Softpaws and Ruff Wear. Together promoting responsible dog ownership.

Adopt a Pet Business (Texas) | Read Pet Express | Bend Park and Recreation | Bend Park and Recreation | Bend Park and Recreation | Bend Park and Recreation | Bend Park and Recreation | Bend Park and Recreation

City of Bend Oregon Parks and Recreation Department [http://www.epa.gov/nps/toolbox/print/OR\\_dogposterweb\\_low.gif](http://www.epa.gov/nps/toolbox/print/OR_dogposterweb_low.gif)

## SWAT INPUT

SWAT can account for pet waste through the inclusion of a continuous fertilizer operation (MGT\_OP = 14) in the management file for urban areas. The following parameters are required:

**MONTH** and **DAY** should be set to the start of the active pet season.

**FERT\_DAYS** (Duration or length of period (days) the continuous fertilizer operation takes place in the HRU.) should be set to the number of days during the active pet season.

An additional entry in the Fertilizer Database (fert.dat) file is needed to specify the nutrient and bacteria content of pet waste. This entry should be specified using **CFRT\_ID** (Fertilizer/manure identification number from fertilizer database).

### **APEX INPUT**

This can be simulated similar to a herd of animals with removal of manure to a stock pile.

#### **Operation file (.opc)**

A grass operation schedule with an auto mow operation can be used given these are the correct conditions of the dog park. A manure-scraping operation must also be included in the operation schedule.

#### **Control file (cont.dat)**

**MSCP:** Manure-scraping interval in days. This should be set to 1 so that manure is scraped every day to simulate the pet owners removing the pet waste.

#### **Herd file (herd.dat)**

**IDON:** In this case only one owner will have ownership over all of the animals despite the fact that there are actually numerous owners with one to a few animals each. For these purposes all of the dogs (pets) will be treated as one herd and be owned by one owner.

**NCOW:** The number of dogs (pets) that use the park on a daily basis.

**IDMU:** Select the type of manure produced by the pets. If new manure must be added to accurately describe the manure being produced, this must be done in the Fertilizer section (see information below).

**FFED:** This is the average amount of time each animal spends per day in the park.

**GZRT:** Set this to 0 since the pets will not actually be grazing or harvesting any of the grass in the park.

**DUMP:** This is the amount of manure produced by one animal on a daily basis (kg/day).

**VURN:** This is the amount of urine produced by one animal on a daily basis (liters/day).

#### **Subarea file (.sub) – Management**

**IOPS:** Choose the operation schedule that includes the manure-scraping operation as well as auto mow operation if applicable.

**II:** Enter the herd number associated with pets.

**IMW:** Minimum interval between auto mow operations. This refers to the minimum length of time set between mowings when the Auto Mow function is used in the operation schedule (days). The crop will be mowed at this interval given the crop height is greater than the cutting height set on the mower used in the operation.

#### **Fertilizer file (fert.dat)**

**FN:** Fraction of nitrogen in mineral form

**FP:** Fraction of phosphorus in mineral form

**FNO:** Organic nitrogen fraction. This applies to organic fertilizers such as manures. This number must be obtained from an analysis test of the product. The amount is reported as a fraction.

**FNP:** Organic phosphorus fraction. This applies to organic fertilizers such as manures. This number must be obtained from an analysis test of the product. The amount is reported as a fraction.

**FNH3:** Fraction of nitrogen in the ammonia-N form

**FOC:** Organic carbon fraction of manure. Organic carbon = organic matter/1.72

**FSLT:** Amount of salt in fertilizer

# Rainwater Harvesting

## DESCRIPTION

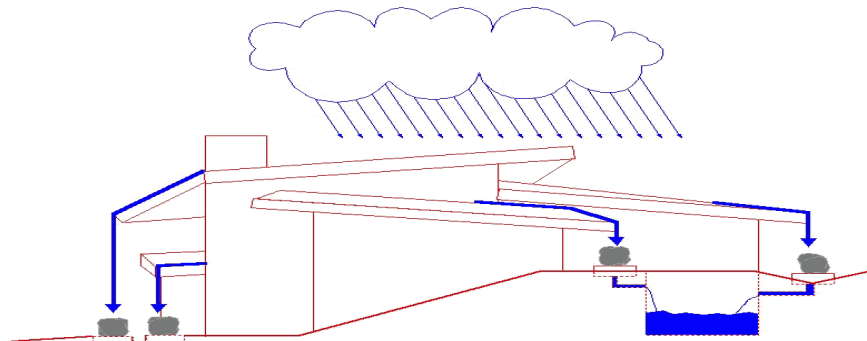
Rainwater Harvesting is the capture, diversion, and storage of rainwater for the purposes of irrigation, domestic use, and stormwater reduction.

Systems can be fabricated from 55-gallon barrels that collect fallen rain or purposefully manufactured cisterns involving the routing of gutters from rooftops. Collected stormwater can then be used to irrigate lawns, landscaping, and building foundations. More elaborate systems involve underground storage tanks and routing of the water for indoor uses.

Texas AgriLife Extension, Texas Water Resources Education.



Texas AgriLife Extension, Texas Water Resources Education.



University of Oregon Rainwater Harvesting <http://www.uoregon.edu/~hof/S01hvestingrain/intro.html>

## SWAT INPUT

**APEX INPUT**

Rainwater harvesting can be simulated as a reservoir with little or no evaporation or seepage loss.

**Subarea file (.sub) – Management**

**IOPS:** An impervious cropping system should be used (Impervious area with no crop).

**LUNS:** The land use number should be set to 35 (Impervious)

**Subarea file (.sub) – Reservoir**

**RSEE:** Elevation at emergency spillway (m). The emergency and principal spillway elevations should be equal unless overflow is allowed. In this case the emergency spillway elevation would be slightly greater than the principal spillway elevation.

**RSAP:** Total reservoir surface area at emergency spillway elevation (ha). To eliminate evaporation, reservoir surface area should be set to 0.

**RSVP:** Runoff volume from reservoir catchment area at emergency spillway elevation (mm). This should be set to 0 unless overflow is allowed.

**RSEP:** Elevation at principal spillway (m). The emergency and principal spillway elevations should be equal unless overflow is allowed. In this case the emergency spillway elevation would be slightly greater than the principal spillway elevation.

**RSAP:** Total reservoir surface area at principal spillway elevation (ha). To eliminate evaporation, reservoir surface area should be set to 0.

**RSVP:** Volume at principal spillway elevation (mm)

**RSV:** Initial reservoir volume (mm)

**RSRR:** Average principal spillway release rate (mm/h). This should be set to 0.

**RSYS:** Initial sediment concentration in reservoir (ppm). This should be a very low number.

**RSYN:** Normal sediment concentration in reservoir (ppm)

**RSHC:** Hydraulic conductivity of reservoir bottom (mm/h). This should be set to 0 in order to eliminate seepage.

**RSDP:** Time for sediment concentrations to return to normal (days) following a runoff event

**RSBD:** Bulk density of sediment in reservoir (t/m<sup>3</sup>)

# Resource Efficient Landscaping

## Ornamentals

**DESCRIPTION**

The addition of resource efficient landscaping for urban and suburban landscapes provides a multifaceted management practice to reduce stormwater pollution through the reduction of necessary fertilization, pesticide application, and irrigation. Additionally, the soil preparation required to correctly install a resource efficient landscape allows for the further infiltration and retention of rainfall preventing stormwater flow and accumulation.



Texas Smartscape Informational Handout 2007.

- |                          |                         |                         |
|--------------------------|-------------------------|-------------------------|
| Birds of Paradise        | Japanese Black Pine     | Roughleafed Dogwood     |
| Buckeye, Mexican         | Juniper, Blue Point     | Texas Persimmon         |
| Buckeye, Red             | Juniper, Wichita Blue   | Vitex                   |
| Buckeye, Texas           | Little Gem Magnolia     | Wax Myrtle              |
| Carolina Buckthorn       | Mesquite                | Winter/Bush Honeysuckle |
| Crepe Myrtle (tree form) | Mexican Plum            | Yaupon Holly            |
| Desert Willow            | Ornamental Pear         |                         |
| Eastern Red Cedar        | Pomegranate             |                         |
| Eve`s Necklace           | Possumhaw Holly         |                         |
| Hawthorne                | Redbud                  |                         |
| Hollywood Juniper        | Rose of Sharon (Althea) |                         |

Texas Smartscape Informational Handout 2007.

**SWAT INPUT**

**APEX INPUT**

APEX simulates plant water and nutrient use realistically. Thus, it could be used to evaluate various plants in terms of water and nutrient requirements and the environmental impacts. Also, fuel required in mowing and CO<sub>2</sub> emissions from mowers can be evaluated.

**Soils Data**

If the soil is amended or changed in any way, these new characteristics should be changed in the Soils editor. The soil data should be edited for each layer of the soil paying close attention to the following parameters.

**Z:** Depth of bottom of layer (m)

**BD:** Moist bulk density (Mg/m<sup>3</sup> or g/cm<sup>3</sup>)

**SAN:** Sand fraction

**SIL:** Silt fraction

**PH:** Soil pH

**ROK:** Coarse fragment fraction

**RSD:** Crop residue (t/ha). This is the amount of biomass in or on the soil surface from a previous crop.

**SATC:** Saturated conductivity (mm/h). Rate at which water passes through the soil layer, when saturated. The saturated hydraulic conductivity relates soil water flow rate (flux density) to the hydraulic gradient and is a measure of the ease of water movement through the soil. The saturated conductivity is the reciprocal of the resistance of the soil matrix to water flow.



# Resource Efficient Landscaping Trees

## DESCRIPTION

The addition of resource efficient landscaping for urban and suburban landscapes provides a multifaceted management practice to reduce stormwater pollution through the reduction of necessary fertilization, pesticide application, and irrigation. Additionally, the soil preparation required to correctly install a resource efficient landscape allows for the further infiltration and retention of rainfall preventing stormwater flow and accumulation.



Texas Pecan Tree

Texas AgriLife Research 1994

[plantpathology.tamu.edu/Textlab/Nuts/pecan.htm](http://plantpathology.tamu.edu/Textlab/Nuts/pecan.htm)

### Texas Resource Efficient Shade Trees

Afghan (or Eldarica) Pine  
American Elm  
Arizona Cypress  
Bald Cypress  
Bigelow Oak  
Bur Oak  
Caddo Maple  
Cedar Elm  
Chinquapin Oak  
Durrand Oak  
Lacebark Elm

Lacey Oak  
Live Oak  
Pecan  
Shumard Oak  
Southern Live Oak  
Southern Magnolia  
Texas Ash  
Texas Red Oak  
Western Soapberry

Texas Smartscape Informational Handout 2007.

## SWAT INPUT

**APEX INPUT**

APEX simulates plant water and nutrient use realistically. Thus, it could be used to evaluate various plants in terms of water and nutrient requirements and the environmental impacts. Also, fuel required in mowing and CO<sub>2</sub> emissions from mowers can be evaluated.

**Soils Data**

If the soil is amended or changed in any way, these new characteristics should be changed in the Soils editor. The soil data should be edited for each layer of the soil paying close attention to the following parameters.

**Z:** Depth of bottom of layer (m)

**BD:** Moist bulk density (Mg/m<sup>3</sup> or g/cm<sup>3</sup>)

**SAN:** Sand fraction

**SIL:** Silt fraction

**PH:** Soil pH

**ROK:** Coarse fragment fraction

**RSD:** Crop residue (t/ha) This is the amount of biomass in or on the soil surface from a previous crop.

**SATC:** Saturated conductivity (mm/h). Rate at which water passes through the soil layer, when saturated. The saturated hydraulic conductivity relates soil water flow rate (flux density) to the hydraulic gradient and is a measure of the ease of water movement through the soil. The saturated conductivity is the reciprocal of the resistance of the soil matrix to water flow.

# Resource Efficient Landscaping

## Turfgrass

### DESCRIPTION

The addition of resource efficient landscaping for urban and suburban landscapes provides a multifaceted management practice to reduce stormwater pollution through the reduction of necessary fertilization, pesticide application, and irrigation. Additionally, the soil preparation required to correctly install a resource efficient landscape allows for the further infiltration and retention of rainfall preventing stormwater flow and accumulation.



*Palisades Zoysiagrass*

Texas AgriLife Urban Solutions Center

<http://dallas.tamu.edu/grasses-palisades-zoysiagrass.aspx>

### Resource Efficient Turfgrasses for Texas:

Buffalograss  
Common Bermuda  
Palisades Zoysiagrass

Texas Smartscape. <http://www.txsmartscape.com>

### **SWAT INPUT**

**APEX INPUT**

APEX simulates plant water and nutrient use realistically. Thus, it could be used to evaluate various plants in terms of water and nutrient requirements and the environmental impacts. Also, fuel required in mowing and CO<sub>2</sub> emissions from mowers can be evaluated.

**Soils Data**

If the soil is amended or changed in any way, these new characteristics should be changed in the Soils editor. The soil data should be edited for each layer of the soil paying close attention to the following parameters.

**Z:** Depth of bottom of layer (m)

**BD:** Moist bulk density (Mg/m<sup>3</sup> or g/cm<sup>3</sup>)

**SAN:** Sand fraction

**SIL:** Silt fraction

**PH:** Soil pH

**ROK:** Coarse fragment fraction

**RSD:** Crop residue (t/ha). This is the amount of biomass in or on the soil surface from a previous crop.

**SATC:** Saturated conductivity (mm/h). Rate at which water passes through the soil layer, when saturated. The saturated hydraulic conductivity relates soil water flow rate (flux density) to the hydraulic gradient and is a measure of the ease of water movement through the soil. The saturated conductivity is the reciprocal of the resistance of the soil matrix to water flow.

# Vegetation

## DESCRIPTION

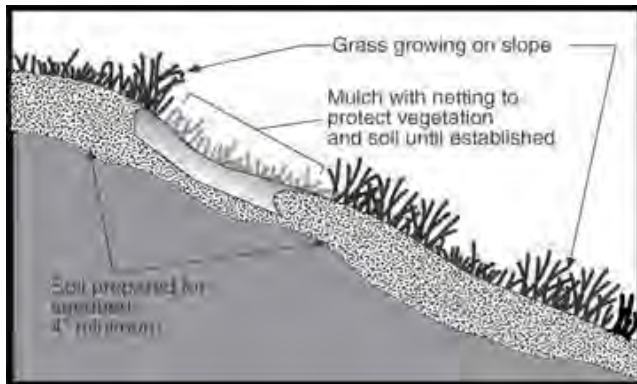
Vegetation is used to control soil loss in areas of disturbed soil by seeding, planting, or sodding areas of concern. The roots of vegetation, such as grass, bind soil particles together to resist erosion. Vegetation helps absorb the impact of raindrops to prevent detachment of soil particles. Vegetation can flatten and, like shingles on a roof, allow the runoff to flow above the soil. Stiff, standing vegetation can slow runoff (which may allow larger particles to settle out) and act as a filter to remove soil particles from flowing water.

University of Missouri Extension

<http://extension.missouri.edu/explore/agguides/agengin/g01509.htm>



United States Army Environmental and Natural Resource Division  
<http://www.jackson.army.mil/enrd/emb/soilerosion.htm>



University of Missouri Extension <http://extension.missouri.edu/explore/agguides/agengin/g01509.htm>

## SWAT INPUT

Existing disturbed or bare areas should be simulated as bare by removing all Plant Operations (MGT\_OP = 1) from the Management (.mgt) file. The establishment of vegetation in these area can be simulating by the addition of a Plant (MGT\_OP = 1) and any other appropriate operations for the newly established vegetation.

Areas that are partially bare may be simulated by specifying a Plant Operation with a reduced value of **BIO\_TARG** (Biomass (dry weight) target). This value should reflect the maximum biomass on the partially bare area during the growing season.

**APEX INPUT**

APEX simulates about 100 crops including annuals, perennials, legumes, shrubs, and trees and their interactions with soil, water and the atmosphere. New crops can be added given the crop parameters are available. The necessary crop parameters can be viewed through the crop editor. Once a crop has been created, an operation schedule (including at least planting) must be created for this crop in the operation schedule editor in order for it to be available for simulation in a subarea.

# Channel Protection

## DESCRIPTION

Measure(s) used to stabilize the bed or bottom of a channel.

This practice may be applied as part of a conservation management system to support one or more of the following:

- Maintain or alter channel bed elevation or gradient.
- Modify sediment transport or deposition.
- Manage surface water and ground water levels in floodplains, riparian areas, and wetlands.



Photo Courtesy of USDA-NRCS Photo Gallery.

USDA-NRCS, 2006. *National Conservation Practice Standards*.

<http://www.nrcs.usda.gov/technical/standards/nhcp.html>

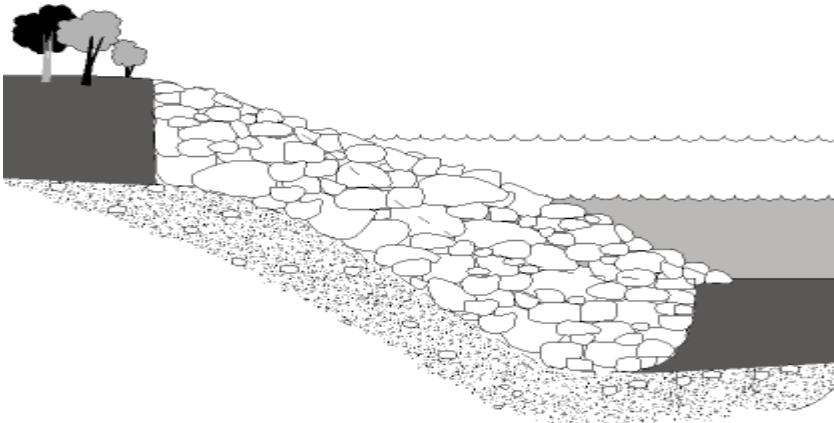


Diagram Courtesy of Ohio Department of Natural Resources

[http://www.dnr.state.oh.us/pubs/fs\\_st/streamfs/tabid/4178/Default.aspx](http://www.dnr.state.oh.us/pubs/fs_st/streamfs/tabid/4178/Default.aspx)

## **SWAT INPUT**

Approach:

Channel protection should be implemented by altering the channel characteristics to reflect increased resistance to erosive forces and slower channel velocities. If the dimensions of the channel are modified during the implementation of this practice, the following variables should be updated:

**CH\_W(2) (\*.rte):** Average width of main channel at top of bank (m)

**CH\_S(2) (\*.rte):** Average Slope of main channel along the channel length (m/m)

***CH\_L(2) (\*.rte)***: Length of main channel (km)

Increased vegetative cover of channel banks or the stabilization using riprap can be simulated by increasing ***CH\_N(2)*** (Manning's "n" value for the main channel.) to account for increased resistance to water flowing in channels. ***CH\_EROD*** (channel erodibility factor) and ***CH\_COV*** (Channel cover factor) should also be reduced to account for increased resistance of the channel to erosion. ***SPCON*** (linear parameter for calculating sediment re-entrained in channel sediment routing) may also be increased.

Model parameters such as ***CH\_EROD*** and ***CH\_COV*** may be zero by default. Appropriate values should be included in any pre-implementation scenarios.

R. Srinivasan. Unpublished SWAT Calibration Instructions for Best Management Practices.

### **APEX INPUT**

Channel protection could call for changes in **Manning's n and channel geometry**, but would certainly require changes in the channel erodibility factor.



# Riparian Forest Buffer

## DESCRIPTION

An area of predominantly trees and/or shrubs located adjacent to and up-gradient from watercourses or water bodies. Reduces excess amounts of sediment, organic material, nutrients, and pesticides in surface runoff and reduces excess nutrients and other chemicals in shallow ground water flow. Also reduces pesticide drift entering the water body.

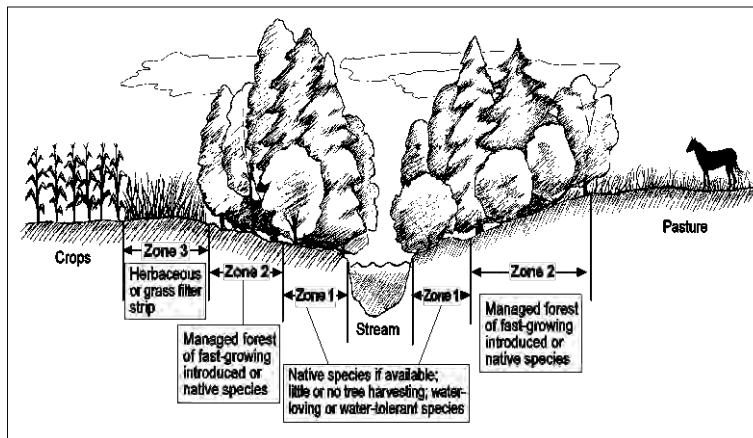
Riparian forest buffers are applied on areas adjacent to permanent or intermittent streams, lakes, ponds, and wetlands.

USDA-NRCS, 2003. *National Conservation Practice Standards.*

<http://www.nrcs.usda.gov/technical/standards/nhcp.html>



Photo Courtesy of USDA-NRCS Online Photo Gallery.



Riparian Forest Buffer: USDA-NRCS Conservation Practice Job Sheet#391. USDA-NRCS 2003.

**SWAT INPUT**

***RIP\_HRUFIL(\*.sub)***: Name of riparian zone HRU general input data file (.hru). Not operational-future feature.

***RIP\_MGTFILE(\*.sub)***: Name of riparian zone HRU land use management data file (.mgt). Not operational-future feature.

***RIP\_SOLFILE(\*.sub)***: Name of riparian zone HRU soil data file (.sol). Not operational-future feature.

***RIP\_CHMFILE(\*.sub)***: Name of riparian zone HRU soil chemical data file (.chm). Not operational-future feature.

***RIP\_GWFILE(sub)***: Name of riparian zone HRU groundwater data file (.gw). Not operational-future feature.

***RIP\_FR(\*.hru)***: Fraction of HRU area that drains into riparian area.

R. Srinivasan. Unpublished SWAT Calibration Instructions for Best Management Practices.

**APEX INPUT**

Floodplains may be split into separate subareas so buffer composition is flexible. Both local subarea runoff and floodplain flow is filtered. The buffer can be planted to various types of trees available in APEX. An operation schedule file (.OPC) file can be created to simulate the operation carried out on the buffer.

# Mulching

## DESCRIPTION

Mulching is the application of plant residues or other suitable materials produced off site, to the land surface. Mulching as a best management practice works to:

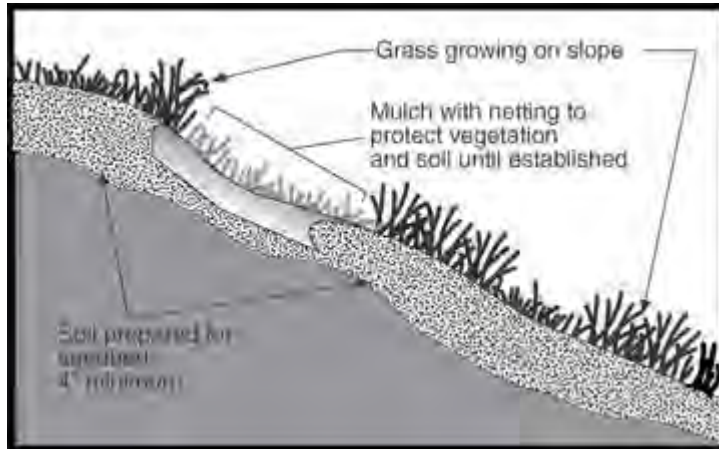
Natural mulch, such as straw and wood chips, and artificial mulch, such as geotextile (fabric) rollout blankets, are effective in absorbing raindrop impact to reduce soil detachment and are effective as soon as they are applied. Mulch is normally used in combination with seeding to provide ground cover during the establishment period for a temporary or permanent vegetative cover.

USDA-NRCS, 2006. *National Conservation Practice Standards*.  
<http://www.nrcs.usda.gov/technical/standards/nhcp.html>

University of Missouri Extension  
<http://extension.missouri.edu/explore/agguides/agengin/q01509.htm>



Photo Courtesy of the California Department of Transportation. 2006



University of Missouri Extension <http://extension.missouri.edu/explore/agguides/agengin/q01509.htm>

**SWAT INPUT****APEX INPUT**

A new fertilizer must be created to simulate the mulch.

**Fertilizer file (fert.dat)**

**FN:** Mulch should be low in nitrogen content.

**FP:** Mulch should be low in phosphorus content.

**FNO:** Mulch should be low in nitrogen content.

**FNP:** Mulch should be low in phosphorus content.

**FNH3:** Mulch should be low in ammonia nitrogen content.

**FOC:** Mulch should have a high organic carbon fraction. Organic carbon = organic matter/1.72

**Operation Schedule file (.opc)****Mulch application: Add a mulch application operation**

**JX4 (Operation):** Since mulch is considered a fertilizer, select a fertilizer operation used to apply the mulch. It should be a surface applied operation type.

**JX7 (Type fertilizer applied):** Select the mulch to be applied.

**OPV1 (Application amount):** Enter the amount of mulch applied (kg/ha).

**MONTH:** Month operation takes place.

**DAY:** Day operation takes place.

# Stream Restoration

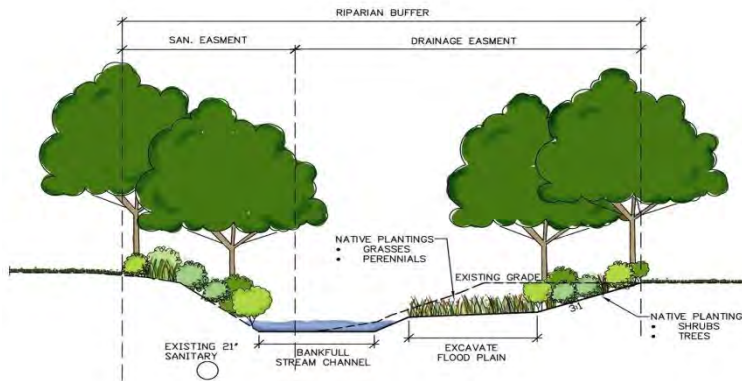
## DESCRIPTION

Stream restoration is a concept that encompasses a variety of constructed practices to mitigate and prevent the erosion and sedimentation of channel areas. These include the planting of stream banks with native vegetation, installation of rocks (rip rap), planting spikes or rods, and reconstructing channels to slow flow. The appropriate structural and vegetative measures are dictated by site specific conditions. Stream restoration is targeted to prevent the loss of land or land uses adjacent to streams and maintain the flow capacity of streams and constructed channels while reducing off-site or downstream effects of sediment resulting from stream bank erosion.



Photo Courtesy USDA- NRCS Online Photo Gallery

Wilson, B. Streambank and Shoreline Protection. Phosphorus Best Management Practices. Minimizing Agricultural Losses from Agriculture. SERA-17. USDA-NRCS.



Lake County Ohio. Kellogg Creek Restoration. 2008  
<http://www2.lakecountyohio.org/smd/projects.htm>

## SWAT INPUT

**APEX INPUT:**

The geometry of the restored channel must be input along with changes in vegetation or other cover. **Manning's N must be changed** to reflect the new roughness of the channel and the channel erodibility factor usually needs reducing to reflect a more stable channel.

If the restored stream is to be modeled in detail, it should be designated as a separate subarea. Both options are detailed below

**Restored Stream as part of a subarea****Subarea file – Subarea geometry**

**RCHD:** Channel depth of routing reach (m)

**RCBW:** Bottom width of routing reach channel (m)

**RCTW:** Top width of routing reach channel (m)

**RCHS:** Channel slope of routing reach (m/m)

**RCHN:** Channel Manning's N of routing reach. Should be set to reflect the new roughness of the channel.

**RCHC:** USLE Crop Management channel factor. If the channel has very good land cover, it should be set to 0.0001.

**RCHK:** USLE Erodibility channel factor. Should be reduced to reflect a more stable channel.

Using the above method the user will not be able to designate a separate crop to be grown on the stream. Crop will be identical to the crop designated for subarea.

**Restored Stream as a separate subarea****Subarea file – Subarea geometry**

**RCHD:** Channel depth of routing reach (m)

**RCBW:** Bottom width of routing reach channel (m)

**RCTW:** Top width of routing reach channel (m)

**RCHS:** Channel slope of routing reach (m/m)

**RCHN:** Channel Manning's N of routing reach. Should be set to reflect the new roughness of the channel.

**RCHC:** USLE Crop Management channel factor. If the channel has very good land cover, it should be set to 0.0001.

**RCHK:** USLE Erodibility channel factor. Should be reduced to reflect a more stable channel.

**Subarea file – Management**

**IOPS:** Crop operation schedule. Should choose a grass operation schedule.

**LUNS:** Land use number. This number is from the NRCS land use-hydrologic soil group table.