

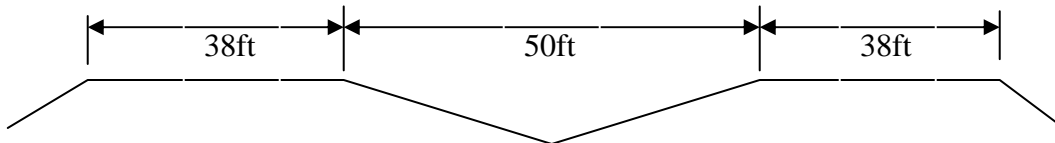
In this example you will learn:

- The design criteria for infiltration ponds.
- A summary of the infiltration design criteria from the HRM.
- How to create a discharge structure using infiltration.
- The differences and definitions of saturated hydraulic conductivity, hydraulic gradient, and infiltration rate.
- How to calculate the infiltration rate from the soil samples.
- Different options for inputting soil data into StormSHED.

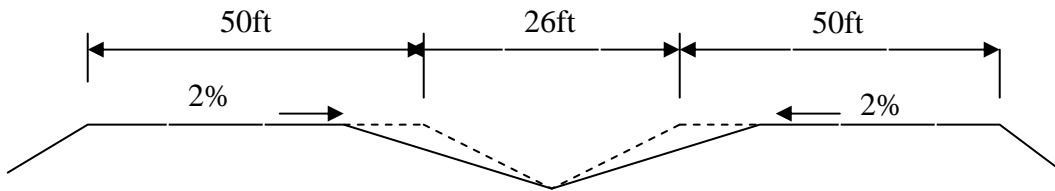
Sample Problem Description

A section of highway near the city of Spokane is to be improved with an additional lane in each direction. Design an infiltration pond (BMP IN.02) using the data below the design criteria summary on the following pages.

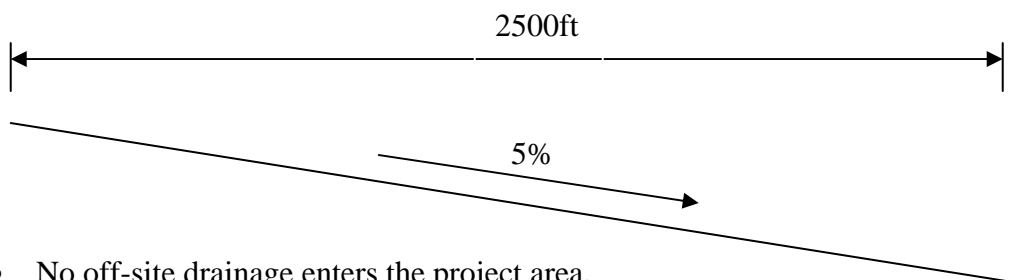
- The existing roadway configuration consists of **two 12-foot lanes** with a **6-foot shoulder** on one side and an **8-foot shoulder** on the other in each direction.
- The north and south bound lanes are separated by a **50-foot grassed median**.



- The proposed project will add **one 12-foot lane in each direction** on the inside into the median, while maintaining the current shoulder widths.
- The pavement is sloped **2%** towards a **“V” shaped median** acting as a conveyance system with **4:1 side slopes**.



- The roadway **profile 2500'** long on a **continous 5%**.



- No off-site drainage enters the project area.
- The median area is grassed with no appreciable amount of brush and the soil in the project vicinity has a NRCS identification as **Spokane**. From the TR55 CN Tables in Appendix 4B in the HRM, Table 4B-1 rates Spokane soils as **Type C**. From Table 4B-3 for EWA, **Meadow cover for type C soils has a CN=71**.
- The **existing** roadway contributes **4.36 acres of impervious** runoff and the **2.87 acres of pervious** runoff.
- The proposed project will contribute **5.74 acres of impervious** surface and **1.49 acres of pervious** runoff.

Design Criteria for IN.02 Infiltration Ponds

Infiltration ponds are intended primarily for flow control; however they can also be used for runoff treatment where infiltration requirements are met. Infiltration ponds are used to collect, temporarily store, and infiltrate stormwater runoff. Infiltration of runoff is the preferred method of flow control. The following is a summary of the requirements for Infiltration Ponds.

Before starting an actual infiltration pond design designers should read section IN.02 of the HRM, the items below are a summary of that section.

- Infiltration ponds are sized using the volume of runoff produced from the 25 year Long Duration or Type 1A storm (Climatic Regions 2 and 3 only).
- The 100 year storm should also be analyzed to verify there is no possibility of property damage downstream of the pond. If it is determined that the 100 year storm could overflow and cause property damage, the pond size should be increased or an emergency overflow spillway should be established.
- Pond depths should be designed for between 2' and 6' with a minimum 1' of freeboard. The slope of the pond bottom must not exceed 3% in any direction.
- Site runoff should be infiltrated to the extent that occurred before the site was developed.
- The detailed approach should be used to determine the hydraulic conductivity and long term infiltration rates should be used to size the infiltration pond. Both are discussed in more detail later in this tutorial or in Chapter 4 of the HRM.
- A geotechnical investigation must be conducted and at least one test pit or test hole should be performed for every 5000sqft of infiltrating bottom surface area.
- Groundwater monitoring wells should be installed to locate the groundwater table and establish its gradient, direction of flow, and seasonal variations. At a minimum 3 wells should be installed per infiltration facility, through at least one wet season
- Drawdown time for the maximum ponded volume is 72 hours, following a storm (once precipitation has ceased).
- Infiltration must be greater than 0.5in/hr to be used as the primary discharge from a pond. If the infiltration rate is less than 0.5in/hr, infiltration can still be used but as a secondary discharge method.
- Follow the guidelines in section 5-3.7.1 from the Highway Runoff Manual, to provide maintenance access to the ponds.

Hydrologic Analysis Methods for Flow Control/Runoff Treatment Facility Design

There are several steps required when conducting a hydrological analysis using a single event hydrograph method such as StormShed to design a flow control or runoff treatment facility. These steps are summarized in **Section 4-4.5 of the HRM** and were used to develop this tutorial. Prior to starting any flow control or runoff treatment facility design, designers should review this section.

Flow Chart of Steps Required to Design an Infiltration Facility

Since we are using infiltration as the method of discharge, we also need to make certain we are following section **4-5 Infiltration Design Criteria** in the HRM. **Figure 4-15** shown below was created as an outline of the steps outline in section 4-5. *The flow chart is not intended as a substitute for reading section 4-5, designers should read the entire section before starting a design.*

(We will use the chart through the tutorial, look for steps in blue font.)

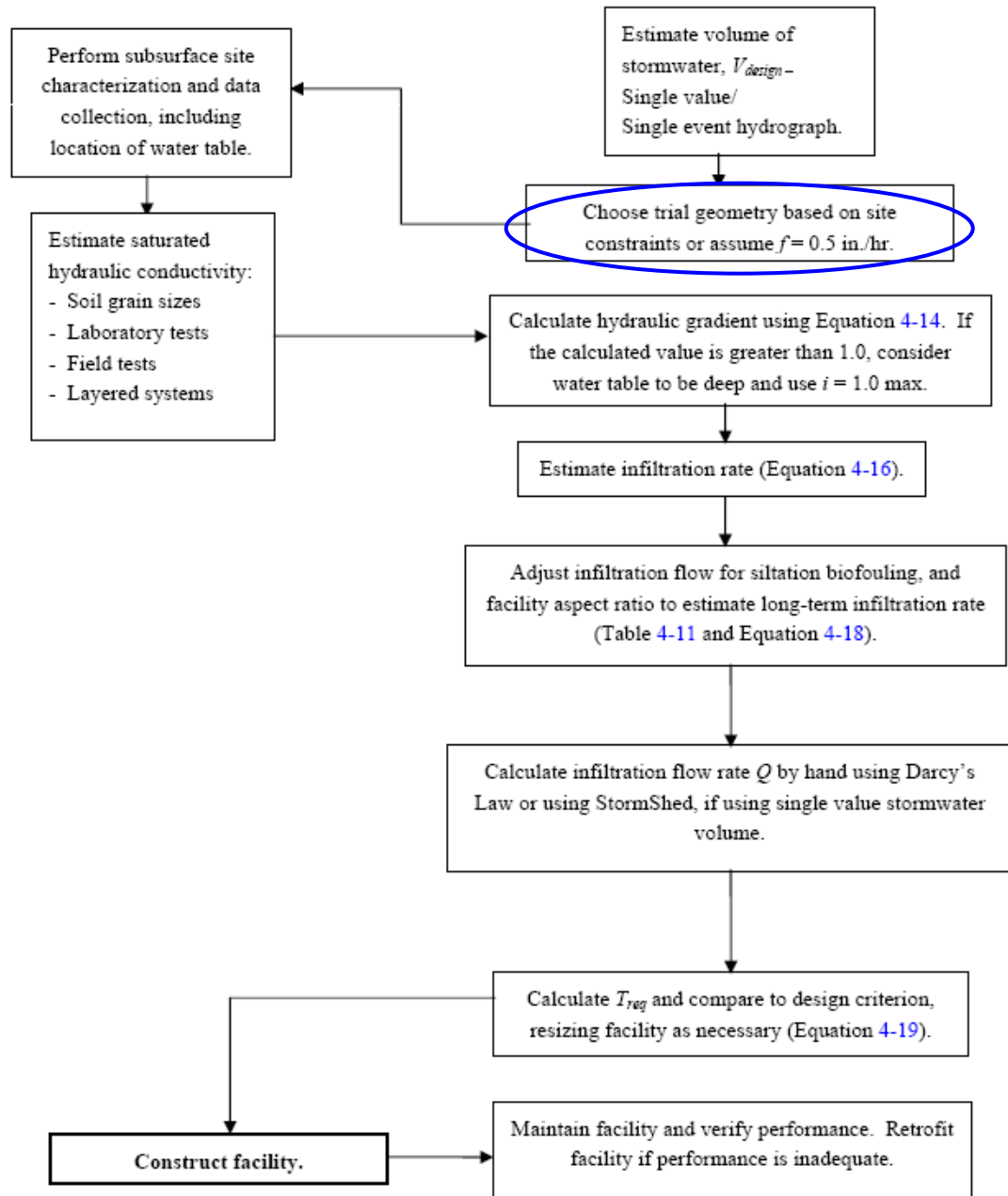
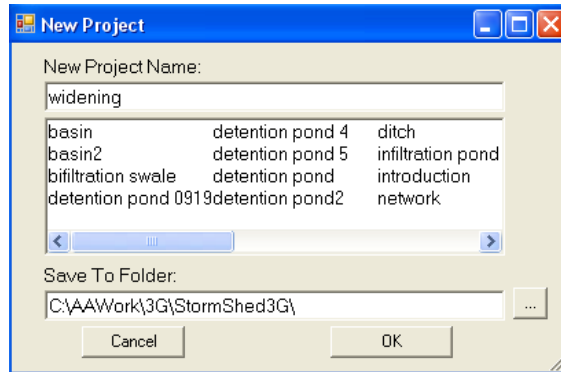


Figure 4-15. Engineering design steps for final design of infiltration facilities using the single hydrograph method (eastern Washington).

Start a new project

To start a new project in StormSHED, we first need to name a new project.

- Open StormShed 3G and select **File>New** from the main toolbar.
- For the project name type **widening** and then select **OK**.

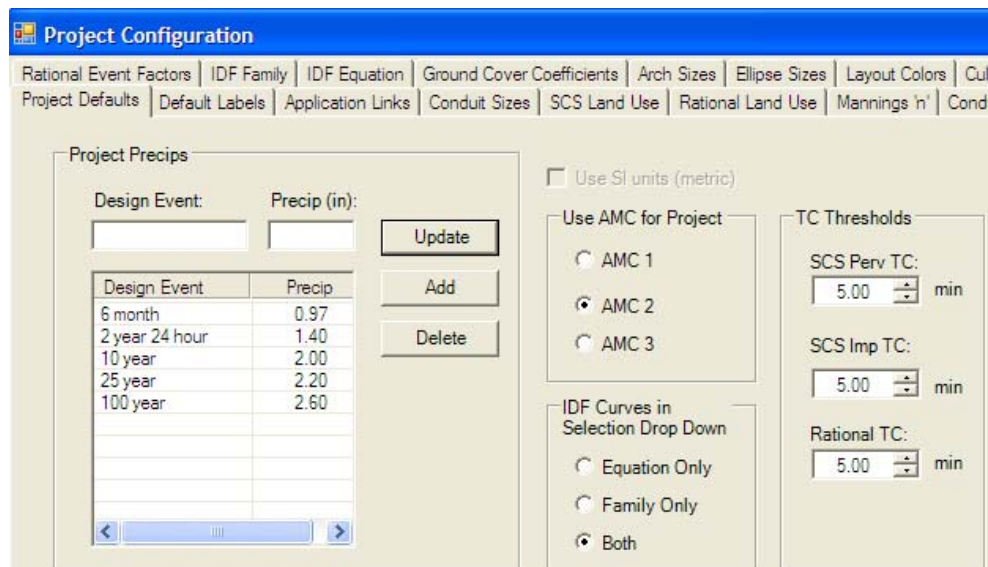


- Press the **I Fully Understand** button after reading the disclaimer.

Project Configuration

Next we will setup the project defaults.

- Select **Data>Config** from the main toolbar and the follow dialog box will open.
- Input the precipitation values and other defaults shown below. The values were determined following the steps outlined in the **Long Duration Storm/Detention Pond Tutorial Section 7**.



- Click on the **OK** button to close the dialog box.

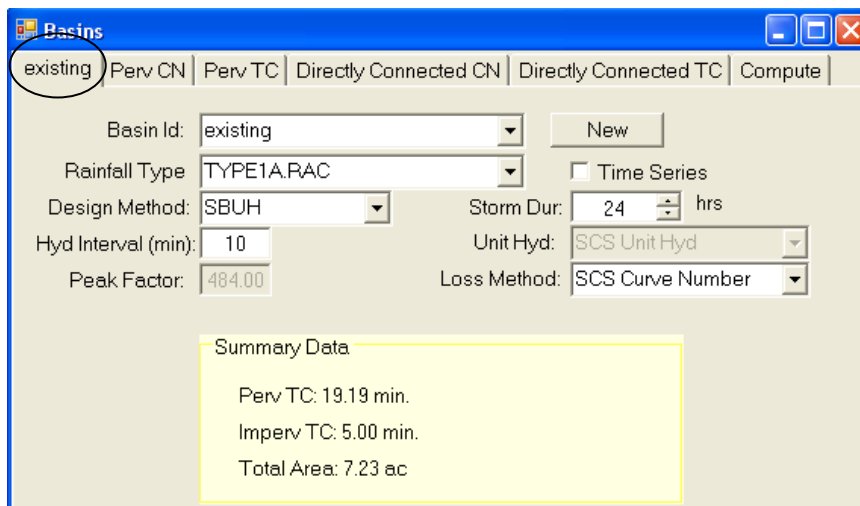
Step 1 - Estimate volume of stormwater V_{design}

Define Basins

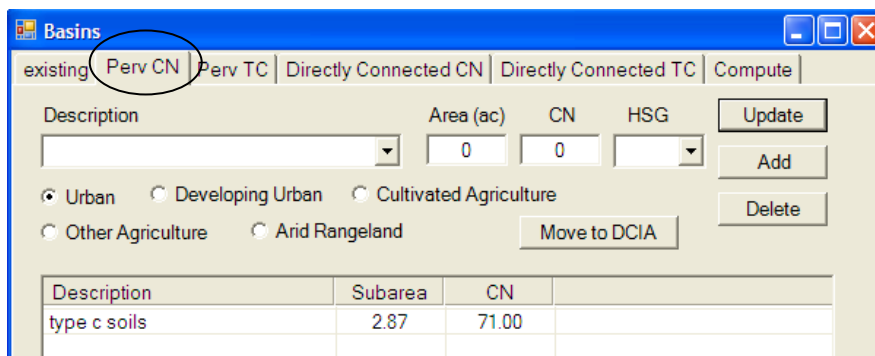
The pond will be designed using the inflow from the **developed** conditions described in our example problem and the release rates from the **existing** basin. Both the developed and existing site runoff conditions must be determined and documented in the Hydraulic Report. We are required to match 100% of the release rates for the 25 and 100 year storm and to match 50% of the release rates for the 2 year storm. This is so the release of runoff from the site will be the same as before construction.

Create Existing Basin

- Double Click on the “**PROTOTYPE**” record under the Basins in the Treeview.
- Click on the **New Basin** button.
- Input **existing** for the new basin name and press the **OK** button.
- Change the “**Rainfall Type**” to **Type 1A**.



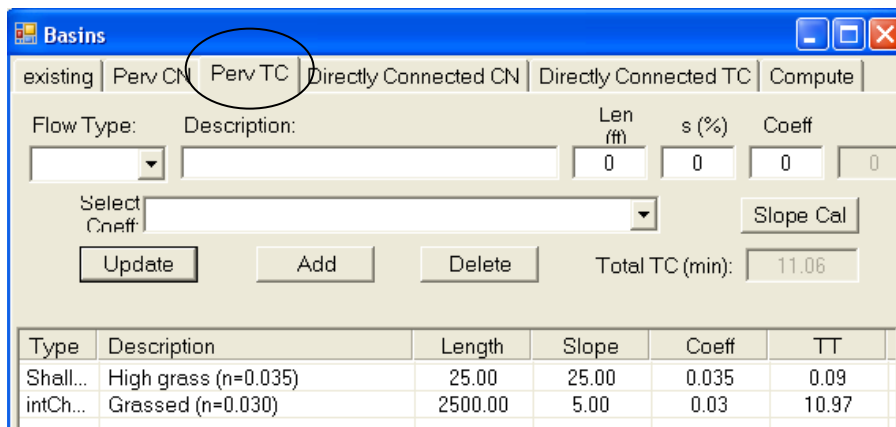
- Click on the “**Perv CN**” tab.
- Click on the on one of the default values in the Description area.
- Modify per Figure below and then click the **Update** button.



- **Delete** the remaining default values with a single LMB click and click on the Delete button until only the single value shown above is left.

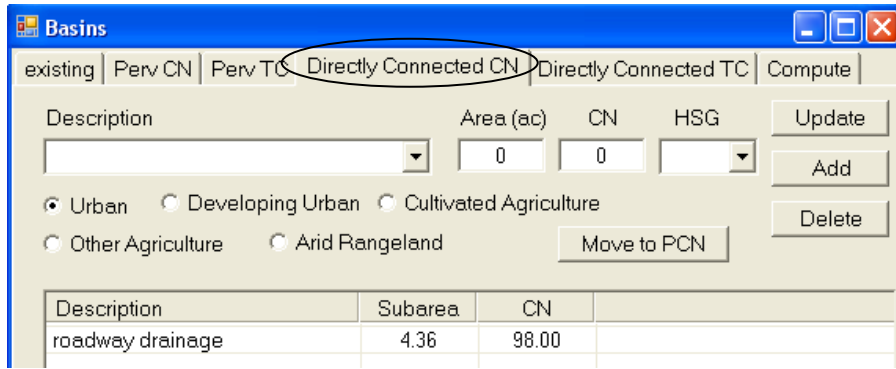
Next we will look at the pervious values that contribute to the time concentration. Both sides of the 50' median shed to the bottom of the ditch at a 4:1 side slope or 25%. Then the runoff travels down the center of the median to the point of analysis. The type of flow on the side slopes was determined to be shallow instead of sheet flow. Sheet flow is for relatively flat slopes with a depth less than 0.1' and in this case the side slope is 25% and flow will likely start to concentrate. For conveyance through the ditch, intermittent channel flow was selected due to the 25% slope and the length of the ditch flow will likely start to accumulate into more of a channel flow.

- Click on the “*Perv TC*” tab.
- Click on one of the defaults in the box below and modify the reflect runoff on the side slopes of the median: **shallow flow 25 feet** in length with a slope of **25%**. For the coefficient, use **High Grass** to depict the median.
- Click on the **Update** button.
- Click on the next default and modify to reflect drainage traveling down the ditch: **intChannel 2500 feet** in length with a slope of **5%**. For the coefficient select grassed.
- Click on the **Update** button.
- Delete the remaining default values by LMB clicking on each and then clicking on the Delete button.

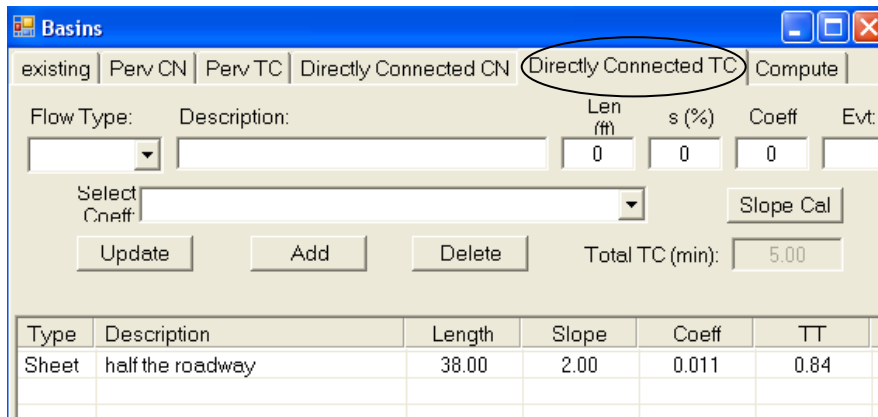


Next we will account for the runoff from the roadway on our project.

- Click on the “*Directly Connected CN*” tab.
- **Modify** per Figure below and then select the **Add** button.



Next we will determine the time of concentration from runoff sheet flowing off the roadway.

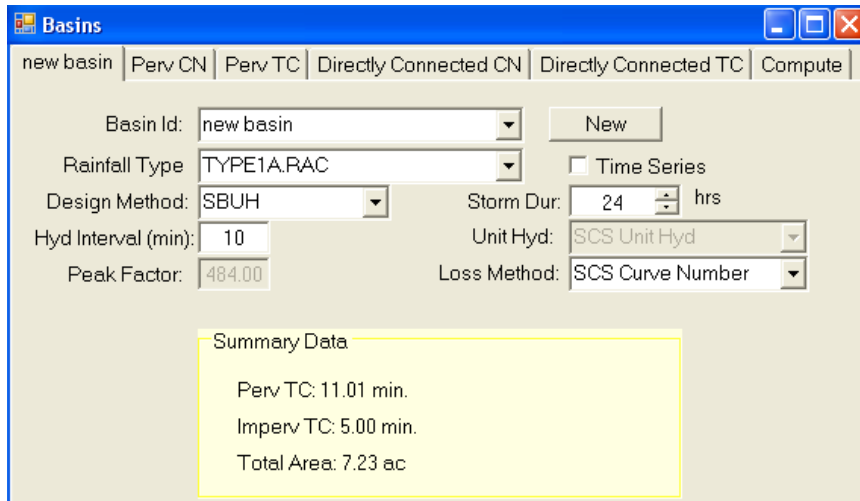


- Click on the “*Directly Connected TC*” tab.
- Select **Sheet flow** for the flow type, type **38 feet** for the length and **2%** for the slope. For the coefficient, select **Smooth surface** to depict the paved road.
- Click on the **ADD** button.

Create Developed Basin

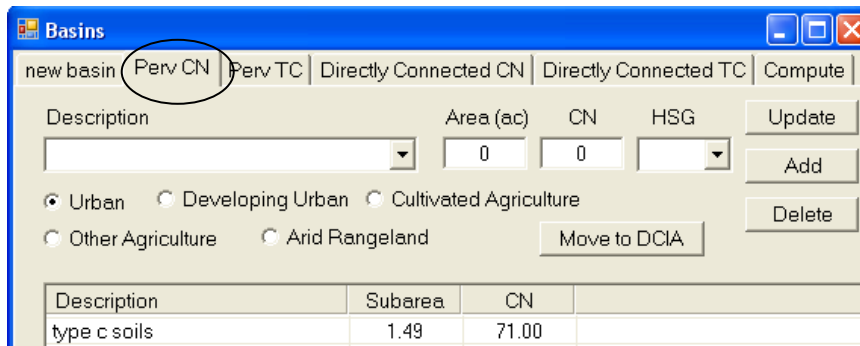
The “**Existing**” basin can now be used as a template for the developed basin.

- Double click on the “Existing” basin under *Basins* in the Tree View.
- Press the **New Basin** button.
- Enter **new basin** for the Basin ID and then select the OK button to close the dialog box.

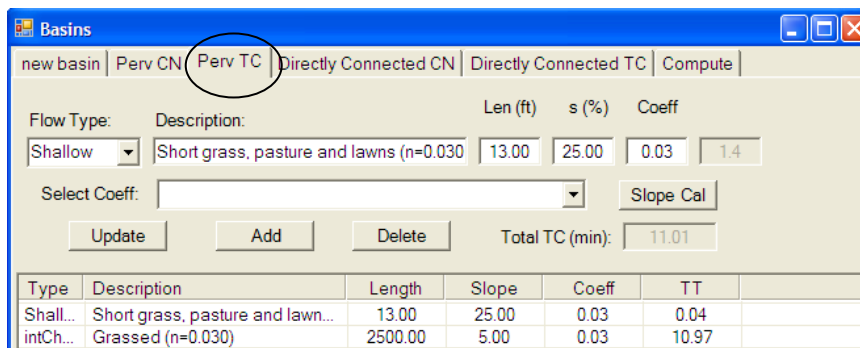


Since we used the existing basin as a template, we do not need to modify any other information on the first tab.

- Click on the “*Perv CN*” tab.
- Modify the *type c soils* area to **1.49** acres and then click the **Update** button



- Click on the “*Perv TC*” tab
- Modify the Shallow flow length to **13ft** and click the **Update** button.



The last step is to modify the Impervious roadway for developed conditions.

- Click on the “*Directly Connected CN*” tab.
- Modify the roadway drainage area to **5.74** acres and then click the **Update** button.

Description	Subarea	CN
roadway drainage	5.74	98.00

- Click on the “*Directly Connected TC*” tab.
- Modify half the roadway Sheet flow to **50ft** and then select the update button.
- Close the basin dialog box.

Type	Description	Length	Slope	Coeff	TT
Sheet	half the roadway	50.00	2.00	0.011	1.05

Step 2 – Choose trial geometry based on site constraints or assume $f=0.5in/hr$

Define the pond

Now that we have defined our basins, we can estimate a ponds size. Next we will define our Trap Pond that represents the infiltration pond.

- Double click on the node “*PROTOTYPE*” record under the Node in the Tree View.
- Click on the **New Node** button and change the “AutoLabel” ID to **Infil**.
- Press the **OK** button to close the “AutoLabel” dialog box.
- For description type “**Infiltration Pond**” and select **Trap Pond** for the Node Type.
- Input **200.00** for the Starting Elevation and **205.00** for the Max Elevation.

The screenshot shows the 'Nodes' dialog box with the 'infiltration pond' tab selected. The 'Node Type' section has 'Trap Pond' selected. The 'Node ID' is 'infiltration pond', 'Description' is 'pond', 'Start EL(ft)' is '200.00', 'Max EL(ft)' is '205.00', 'North (ft)' is '0.00', 'East (ft)' is '0.00', 'Increment for rating curves' is '0.10', and 'Void Ratio (%)' is '100'.

We will skip the *Contrib Drainage Area* tab since we define the runoff contributing to the pond in the *Pond Design* Tab.

Next select the *Trap* tab to define the pond. The site selected for the pond can only accommodate a width of 10 feet bottom width, only the length can be varied.

- Input the information shown below and then select the **OK** button.

The screenshot shows the 'Nodes' dialog box with the 'Trap' tab selected. A diagram of a trapezoidal pond is shown with a bottom width of 10.00 ft and side slopes of 4:1. The dimensions are: Width ss1 (h:1v): 4.00, Width (ft): 10.00, Width ss2 (h:1v): 4.00, Length ss1 (h:1v): 4.00, Length (ft): 300.00, and Length ss2 (h:1v): 4.00.

Define a Discharge Control Structure

Next we will define our discharge control structure, for this tutorial it is infiltration. At this point we have not received any soil testing data for our project, so we will have to assume a trial infiltration rate. Section 4-5 of the HRM suggests using a value of **0.5in/hr** if no data is available; however the materials lab has informed us that from previous projects in the area the rate will not be less than **1.0 in/hr**. Once we receive the soils data from the lab we will repeat the process with the correct infiltration rate. At this point we are just estimating the pond size to make sure we have enough right of way available to construct our pond and determine the number of test holes required.

- Double click on the *PROTOTYPE* record found under the “*Discharge*” node in the Tree View and press the **New Control** button.
- Replace the “AutoLabel” ID with **infiltration** and press **OK**.

- Type “**pond infiltration**” for the description and change the “Start El” to **200** and the Max El. to **205**.
- From the *Select Control Type* pulldown menu, select **Infiltration**.

The screenshot shows the 'Control Structures' dialog box with the 'Infiltration' tab selected. The 'Select Control Type' dropdown is set to 'Infiltration'. The 'Control ID' is 'infiltration'. The 'Description' is 'pond infiltration'. The 'Start El' is 200.00 and the 'Max WS El over Ctrl' is 205.00. The 'Increment' is 0.10. There are buttons for 'New Control' and 'Update Control Elevs'.

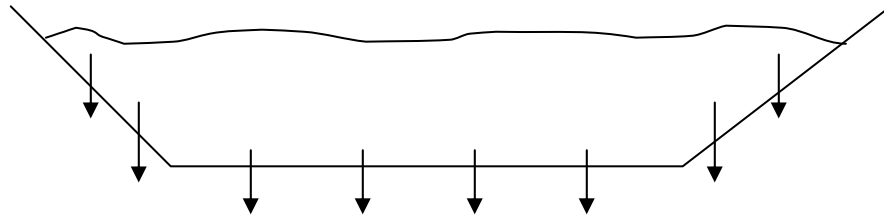
- Click on the 2nd “**Infiltration**” tab to define the infiltration rate.

The screenshot shows the 'Control Structures' dialog box with the 'Infiltration' tab selected. The 'Infiltration rate to be applied to wetted surface area of storage structure (in/hr)' is 1.00. The 'Based on Average Saturated Hydraulic Conductivity of:' is 0 (cm/sec). The 'Infiltration Rate Reduction Factors' section has two unchecked checkboxes: 'High Potential for Biofouling' and 'Avg to High Degree of Long Term Maintenance/Performance Monitoring'. The 'Enter groundwater elevation (ft):' is 0.

StormShed 3G supports three different methods for infiltration rate:

1. ***Infiltration rate to be applied to wetted surface area of storage structure (in/hr)*** – This is the primary method used and is simply the input of a constant infiltration rate in inches per hour.
2. ***Based on Average Saturated Hydraulic Conductivity of:*** - The second method is based on the methodology from The 2005 Washington State Department of Ecology Stormwater Management Manual, Volume III, Section 3.3.8. Specifically, the saturated hydraulic conductivity that StormShed3G is expecting is described in step 6, page 3-89 of the volume. *Using this method should provide a liberal result (a slightly smaller pond that required) compared to the iterative method used in the spreadsheet we will go over later in this tutorial.*
3. ***Based on Soil Log/TP*** – The third method is a further implementation of the procedure described in Volume III. It allows users to compute the saturated hydraulic conductivity (K_{sat}) directly from soils logs.

All of the options will consider infiltration on the wetted surface areas of the pond. For example if runoff rises 3' in the pond, the program will consider infiltration not only on the pond of the bottom but also on the pond sides up to 3' where the wetted surface ends.



For this tutorial we will use the first option.

- Select the first radio button and input an infiltration rate of **1.00 in/hr.**
- Select the **Close** button to close the dialog box.

Define the RLPool Node

In order for StormShed to understand that the trap pond and discharge structure created go together we have to create a node that defines this. In past versions of StormShed this Node Type was called an RLPool, in 3G a Detention Pond node type is used instead.

- Double click on the *PROTOTYPE* node record found under the “**Nodes**” node in the Tree View and press the **New Node** button.
- Change the “*Next Auto ID*” to **Pond45** and then press the **OK** button to close the “AutoLabel” dialog box.
- Change the “Node Type” to **Level Pool**.
- Change the description to **define pond and infiltration.**

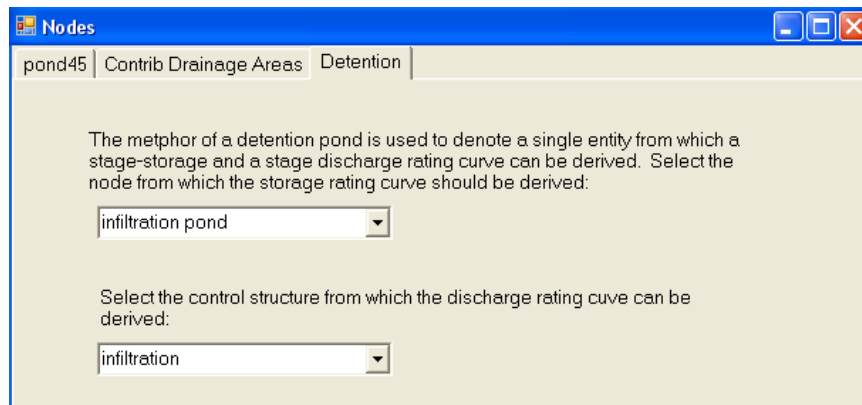
Leave the “*Start EL*” and “*Max EL*” boxes blank, the program automatically input this information once we define the pond and discharge structure on the last tab.

The screenshot shows the 'Nodes' dialog box with the following fields and values:

- Node ID: pond45
- Description: define pond and infiltration
- Start EL(ft): 200
- Max EL(ft): 205
- Node Type: Level Pool (selected)
- Increment for rating curves: 0.10
- Void Ratio (%): 100

- Click on the “**Detention**” tab.
- From the first drop down, select **infiltration pond.** This defines from which node the stage storage routing curve will be defined.

- From the second drop down, select **infiltration**. This defines where the discharge rating curve is defined.
- Select the **OK** button to close the node dialog box.



Determine the Preliminary Pond Size

Now it is time to estimate the pond size using the trial infiltration rate. Remember this pond size will only be used to estimate if there is enough room to construct the pond within the right of way, we will run the final pond analysis after the final soil data has been received from the lab.

- Select **Pond Design** from the Layout View tabs and the screen below will appear.
- From the *Select Detention Pond Node* drop down menu select **Pond45**.
- The Start Stg can be left at **0** or we could input the **200'** pond bottom elevation.
- From the *Design Event* drop down menu are all the events for which we defined a precipitation value. For this example select **25 year**.
- The *Matching Runoff Hyd* is where we define which basins runoff rates we are trying to match. In this case select **existing**.
- Leave the *% of Rate* box at 100%. This says is we are trying to match 100% of the release rate for the existing basin.
- The *Inflow Hyd/Basin* defines the basin that is providing runoff to our pond. For this tutorial select **new basin**
- Stormshed will automatically name the *Out Hyd* based on the Design Event selected, in this case **25 year out**. The Out Hyd. is simply the name of the hydrograph that has been routed through the pond.
- Verify the storm duration is **24 hours**, for certain long duration storms this main not be 24 hours. Consult Appendix 4C of the HRM for more information.
- Select the **Add** button and notice the values input now appear in the **Computational Instructions** box.
- Repeat the process using the **100 year** information shown below.

- Select the **Compute** button and the program will route the inflow hydrograph through the pond and the output is noted in the **Results** box.

Select Detention Pond Node: pond45 Start Stg (ft) 0.00 Update

Design Event: 100 year Matching Runoff Hyd.: existing % of Rate: 100.00 Add

Inflow Hyd/Basin: new basin Out Hyd.: 100 year out Delete Stm Dur (hrs): 24

Computational Instructions:

Design Ev...	Matching Hyd/B...	%	Inflow Hyd/Basin	Outhyd
25 year	existing	100.00	new basin	25 year out
100 year	existing	100.00	new basin	100 year out

Results:

Design Ev...	Match Flow (cfs)	Peak ...	Max Depth (ft)	Detention Vol (cf)	Hrs to Empty (hr)	% Vol
25 year	2.152313	0.285...	3.362211	24918.425975	40.167	99.93
100 year	2.659107	0.324...	3.910577	31971.780857	46.50	99.93

Compute

Routing Table

Size Outlet

Save Chart

Report

Display Peak Elev

Large Volume

Maximum Plot Time: 4290

Results

Using the design criteria outlined at the beginning of this example, we will verify the pond is large enough. Since this pond is being designed for flow control, the following requirements apply:

- 1' of freeboard above the peak level in the pond for the 25 year event is required and from the Max Depth column in the Result section we see we have about 1.6' (5' – 3.36').
- The 100 year storm should be checked for damages and flood control. In this case the 100 year storm does not overtop the pond, so downstream flood damage is not a concern.
- The pond depth shall be designed to between 2' minimum and 6' maximum (including the freeboard). Our pond will not exceed 4' for either the 25 or 100 year events.

A review of the design criteria determines a pond size of 300'x10' exceeds the requirements. At this point we should be able to determine the pond location and verify if we have enough right of way to construct our pond.

Let's assess where we are in the steps to design our infiltration facility.

1. We estimated the volume of stormwater by creating the existing and developed basins for the project.
2. Next we estimated the geometry for the pond and used the best information we had to estimate an infiltration rate.

Step 3 - Now we are ready to assess the suitability of the site for an infiltration pond and request soil testing from the lab at our proposed pond location (see circled area).

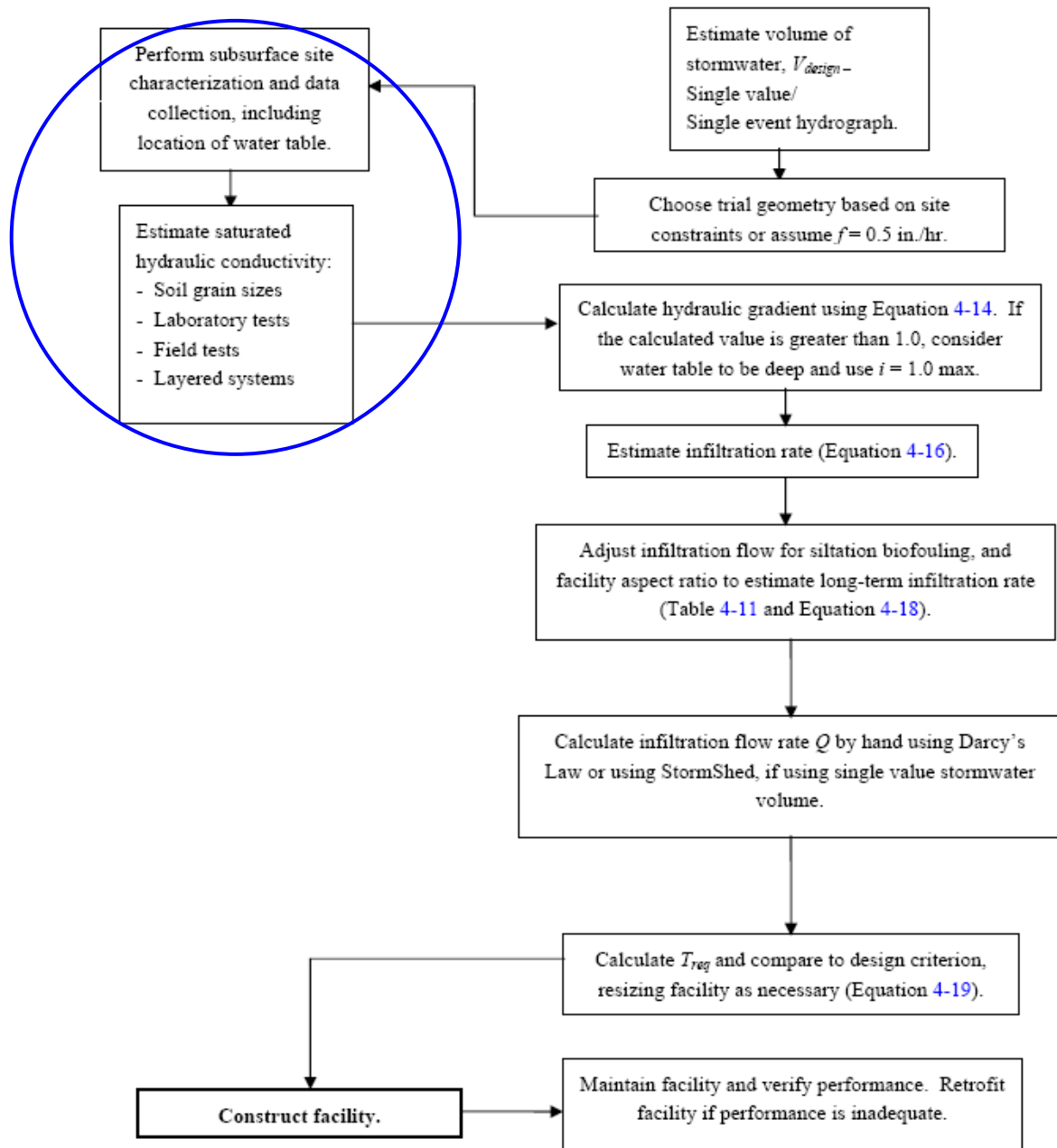


Figure 4-15. Engineering design steps for final design of infiltration facilities using the single hydrograph method (eastern Washington).

Soil Suitability Criteria

Next we need to determine if the site is suitable for an infiltration pond. Section 4-5.1 **Soil Suitability Criteria** (SSC) of the HRM provides a list of 8 applicable soil criteria that must be met before constructing an infiltration BMP. If any of the 8 can not be met, appropriate mitigation must be implemented or a different BMP will need to be selected. The following table contains a brief summary of the requirements:

#	Title	Notes
SSC-1	Setback Requirements	Provides setback requirements from infiltration facilities to: building foundations, drinking water wells, and property lines for example.
SSC-2	Seepage Analysis and Control	Consider what adverse effects could be caused by seepage zones near building foundations, roads, parking lots, or sloping sites.
SSC-3	Groundwater Protection Areas	Any infiltrated stormwater that could cause a violation of the Ecology Ground Water Quality Standard, is not acceptable. This SSC applies to sites at aquifers and wellhead protection zones.
SSC-4	Depth to Bedrock, Water Table, or Impermeable Layer	The base of all infiltration basins or trench systems must be greater than 5' above the seasonal high water mark, bedrock, or other low-permeability layer.
SSC-5	Soil Infiltration Rate	Describes the difference between short and long term infiltration rates: Short-term rates are less than 2.4 in/hr and are only used to determine if the treatment criterion is met. Does not consider biofouling or siltation. Long-term rates should be used to size facilities and takes into account the long term affects of biofouling and siltation.
SSC-6	Drawdown Time	Flow control/runoff treatment facilities in EWA be designed to completely drain ponded runoff within 72 hours.
SSC-7	Soil Physical and Chemical Suitability for Treatment	Describes physical and chemical characteristics that are required for removing target pollutants.
SSC-8	Cold Climate Impacts of Roadway Deicers	Consider the impact of deicers on potable water wells and groundwater quality.

Contact the Lab

Before requesting data from the lab, we need to determine how many test holes are required at the proposed pond location. As noted in the design criteria 1 test hole is required for every 5000sqft of pond bottom. Since our pond is only 3000sqft, we are only required to have one test hole.

Back ground data on infiltration

Lets review a few key terms before proceeding:

Infiltration Rate – is a measure of how fast water can move through soil and is based on the saturated hydraulic conductivity and the hydraulic gradient.

Hydraulic Gradient – the slope of a potential head relative to a fixed datum.

Saturated Hydraulic Conductivity – the ease with which water can move through the void spaces and is dependant on the permeability of the soil.

The infiltration rate is the computed from the hydraulic gradient and saturated hydraulic conductivity. There are two ways to determine the saturated hydraulic conductivity: using the **detailed approach** or the **Guelph Permeameter**. Which method to use is dependant on whether infiltration occurs at the surface or below the surface (subsurface).

The surface infiltration BMP design is based on different criteria than the subsurface infiltration BMP design. For example, natural dispersion and VFS are designed to intercept sheet flow and are considered surface infiltration and are designed based on the surface infiltration rate. For **surface infiltration BMP's use the Guelph Permeameter**. Infiltration ponds use **subsurface infiltration and should use the detailed method** to determine the saturated hydraulic conductivity.

Determining the Saturated Hydraulic Conductivity using the Detailed Method

The data from the lab has been received; see Laboratory Summary on the next page. Notice there is no Saturated Hydraulic Conductivity, Hydraulic Gradient, or Infiltration Rate. All these values will need to be calculated as described below.

Hand Calculations

Two samples were taken at the same hole one at 14' and then one at 17'. For each depth a K_{sat} will be determined and then averaged.

1. Determine the saturated hydraulic conductivity using equation 4-12 in the HRM:

$$\log_{10}(K_{sat}) = -1.57 + 1.90D_{10} + 0.015D_{60} - 0.013D_{90} - 2.08f_{fines}$$

Where:

D_{10}, D_{60}, D_{90} = grain sizes in mm for which 10%, 60%, and 90% percent of the sample is more fine

f_{fines} = grain size in mm for the fraction of the soil (by weight) that passes the number 200 sieve

K_{sat} = saturated hydraulic conductivity in cm/s

Given the lab summary, input D_{10}, D_{60}, D_{90} and the percent fines as shown below for the 14' depth. Since the lab did not print the exact value for D_{90} it will need to be determined using the graph as shown on the following page. For this example it is found to be 0.85 for the test at 14' depth.

$$\log_{10}(K_{sat}) = -1.57 + 1.90(0.096) + 0.015(0.386) - 0.013(0.85) - 2.08(0.071)$$

$$\log_{10}(K_{sat}) = -1.54$$

For those who have not used logarithm in a while, the equation above is equivalent to the following:

$$10^{-1.54} = K_{sat}$$

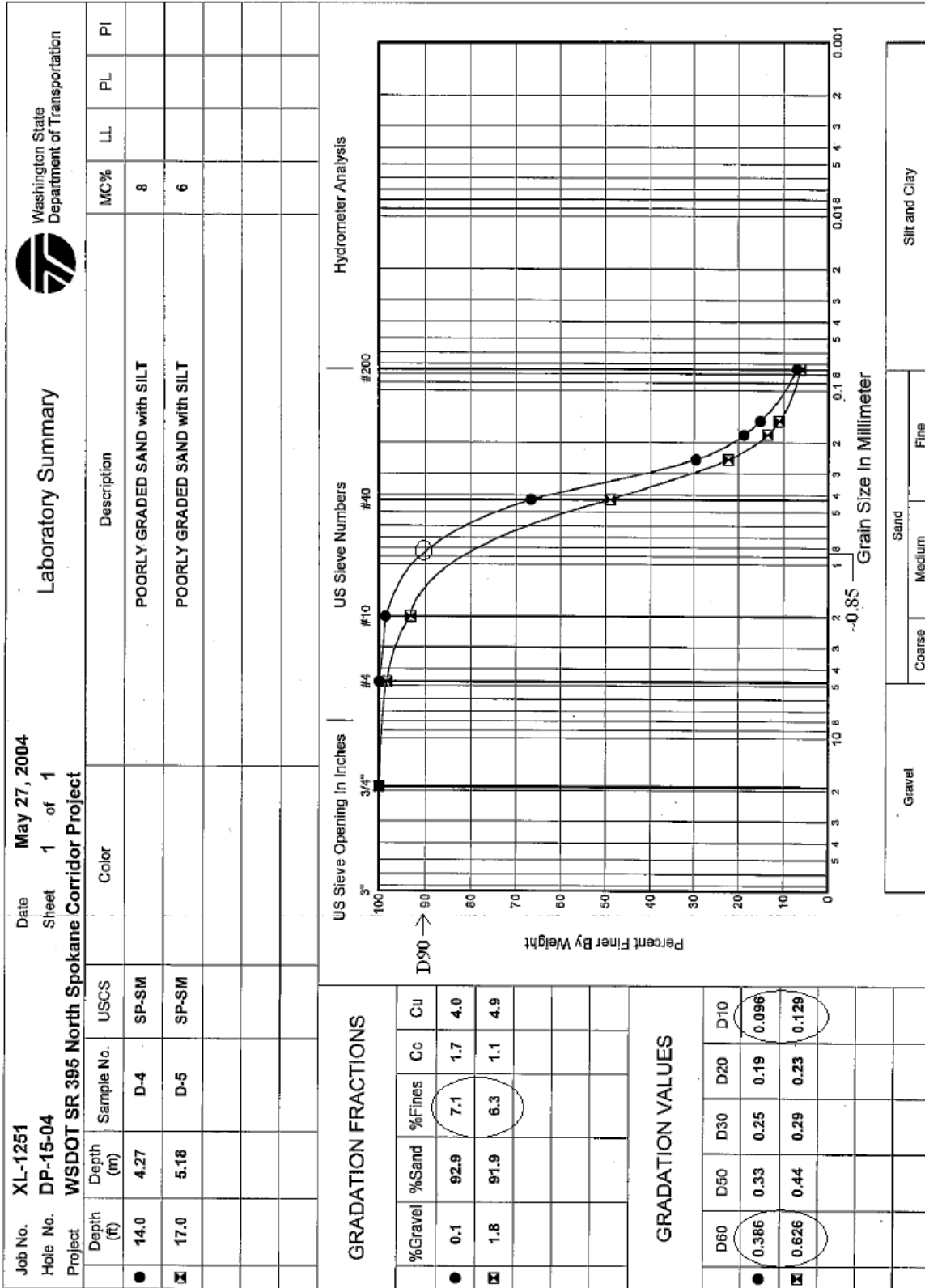
$$K_{sat} = 0.029 \frac{\text{cm}}{\text{s}}$$

Next convert K_{sat} to inches per hour:

$$K_{sat} = 0.029 \frac{\text{cm}}{\text{s}} \times \frac{0.394 \text{ in.}}{\text{cm}} \times \frac{60 \text{ sec.}}{\text{min.}} \times \frac{60 \text{ min.}}{\text{hr}} = 40.86 \frac{\text{in.}}{\text{hr}}$$

Repeat the process above for the 17' sample.

$$K_{sat} = 0.034 \frac{\text{cm}}{\text{s}} \text{ or } 48.5 \frac{\text{in.}}{\text{hr}}$$



2. Determine the effective average saturated hydraulic conductivity:

Since there are multiple saturated hydraulic conductivities for one test hole, the average saturated hydraulic conductivity ($K_{equiv.}$) will need to be calculated.

$$K_{equiv.} = \frac{d}{\sum \frac{d_i}{K_i}} \tag{4-13}$$

Where:

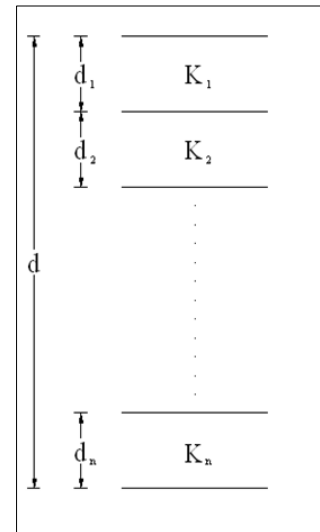
$K_{equiv.}$ = average saturated hydraulic conductivity

d = total depth of soil column

d_i = the thickness of layer “i”

K_i = saturated hydraulic conductivity of layer “i”

$$K_{equiv.} = \frac{17}{\sum \left(\frac{14}{40.86} + \frac{3}{48.5} \right)} = 42.0 \frac{\text{in}}{\text{hr}}$$



Referencing the boxes on the flow chart, from calculate the hydraulic gradient to adjust the infiltration rate, will be calculated on a spreadsheet created to make determining the infiltration rate easier. The following steps will review the process and go over the equations without actually calculating a value.

3. Calculate the hydraulic gradient

The equation to calculate the hydraulic gradient is as follows:

$$gradient = i \approx \frac{D_{wt} + D_{pond}}{138.62((0.5 * K_{equiv})^{0.1})} CF_{size} \tag{4-14}$$

Where:

i = steady state hydraulic gradient

D_{wt} = depth from the base of facility to the water table in feet

D_{pond} = depth of water in the facility in feet

K_{equiv} = the average saturated conductivity in feet/day
(0.5 converts K_{equiv} from inch/hour to feet/day)

CF_{size} = the correction for pond size

The correction factor was developed for ponds with bottom areas between 0.6 and 6 acres in size. For small ponds, less than 2/3 acre, the correction factor is equal to 1. For large ponds, greater than 6 acres, use a CF of 0.2.

$$CF_{size} = 0.73(A_{pond})^{-0.76} \tag{4-15}$$

Where:

A_{pond} = the area of the pond bottom

Obviously the value of the hydraulic gradient will change depending on the height of water in the pond. Rather than calculate this value for each height in the pond, a spreadsheet was developed to make this step easier.

4. Estimate the infiltration rate.

Next we will estimate the short term infiltration rate that is the rate that we would expect to get after immediately constructing the pond. The infiltration rate is calculated using Darcy's law:

$$f = 0.5K_{equiv}(i) \quad (4-16)$$

Where:

- f = infiltration rate of the infiltration facility
- K_{equiv} = average saturated hydraulic conductivity (ft/day)
- i = hydraulic gradient
- 0.5 = converts ft/day to in/hr

For runoff treatment facilities, the short term infiltration rate has to be 2.4in/hr or less.

5. Adjust the infiltration rate to account for long term use due to long-term maintenance/performance monitoring or potential for biofouling.

The infiltration rate is adjusted to account for any reductions in rate that are expected resulting from lack of long term maintenance, performance monitoring and or the potential for biofouling. The two factors to consider when determining an adjustment value are: what is the potential for biofouling and what degree of maintenance is expected at the pond site

It should be assumed that an average to high degree of maintenance would be performed on these facilities. A low degree of maintenance should only be considered when there is no other option (i.e. access problems).

Next we consider the potential for biofouling. An example of a situation with a high potential for biofouling is a pond located in a shady area where moss and litterfall from adjacent vegetation could build up on the pond bottom.

Finally use Table 4-11 below to determine the $CF_{silt/bio}$ for the site. Since the pond is located in an area with no shade and good maintenance access we will assume the biofouling to be low and the maintenance/monitoring to be average to high yielding a $CF_{silt/bio}$ reduction factor of 0.9.

Table 4-11 Infiltration rate reduction factors to account for biofouling and siltation effects for ponds (Massman 2003)

Potential for Biofouling	Degree of Long-Term Maintenance/Performance Monitoring	Infiltration Rate Reduction Factor, $CF_{silt/bio}$
Low	Average to High	0.9
Low	Low	0.6
High	Average to High	0.5
High	Low	0.2

Next we will calculate the correction factor:

$$CF_{aspect} = 0.02A_r + 0.98 \tag{4-17}$$

Where:

- CF_{aspect} = the aspect ratio correction factor
- A_r = the aspect ratio for the pond (length/width)

The final infiltration rate is calculated as follows:

$$f = (0.5K_{equiv})(i)(CF_{aspect})(CF_{silt/bio})$$

Calculate the infiltration flow rate Q

Spreadsheet

Given the K_{equiv} and $CF_{silt/bio}$ determined above and the size of the pond estimated in StormShed, the values can now be input into the gray areas on the spreadsheet to determine stage storage discharge relationship. It should be noted that the size of the pond and the infiltration rates are dependant. It will be an iterative process between the spreadsheet and StormShed to determine the final pond size and infiltration rates.

Infiltration Ponds

Length of Pond Bottom (ft)
Area of Bottom of Pond (acres)
Pond Side Slopes (3:1 typical)

300
0.07
4

Width of Pond Bottom (ft)

Depth of Pond, D_{pond} <small>Varies 1' to 6'</small> (ft)	Depth to Water Table, D_{wt} <small>Determined by Lab Tests</small> (ft)	Hydraulic Conductivity, K_{equiv} <small>Determined by Lab Tests</small> (in/hr)	Area of Pond Bottom, A_{pond} <small>Determined by designer</small> (Acres)	Hydraulic Gradient, i <small>Equation 4-14</small>	CF_{size} <small>Equation 4-15 (1.0 max value)</small>	Infiltration Rate, f <small>Equation 4-16</small> (in/hr)	Length of Pond (ft)	Width of Pond (ft)	CF_{aspect} <small>Equation 4-17 (1.4 max value)</small>	$CF_{silt/bio}$ <small>See Table 4-9</small>	Adjusted Infiltration Rate, f_{corr} <small>Equation 4-18</small> (in/hr)	Infiltration <small>converts in/hr to cfs</small> (cfs)	Pond Volume <small>Calculated (or from CA/CE)</small> (ft ³)
0													
1	9	42	0.07	0.05	1.00	1.95	308	18	1.32	0.9	2.31	0.301	4272
2	9	42	0.13	0.05	1.00	2.14	316	26	1.22	0.9	2.36	0.452	11152
3	9	42	0.19	0.06	1.00	2.33	324	34	1.17	0.9	2.46	0.632	20768
4	9	42	0.25	0.06	1.00	2.53	332	42	1.14	0.9	2.59	0.841	33248
5	9	42	0.32	0.06	1.00	2.72	340	50	1.12	0.9	2.74	1.082	48720

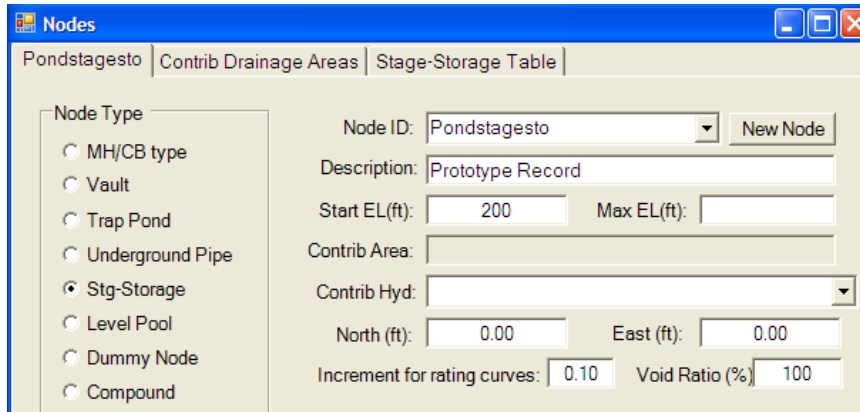
Size the facility

Define a Stage Storage Node

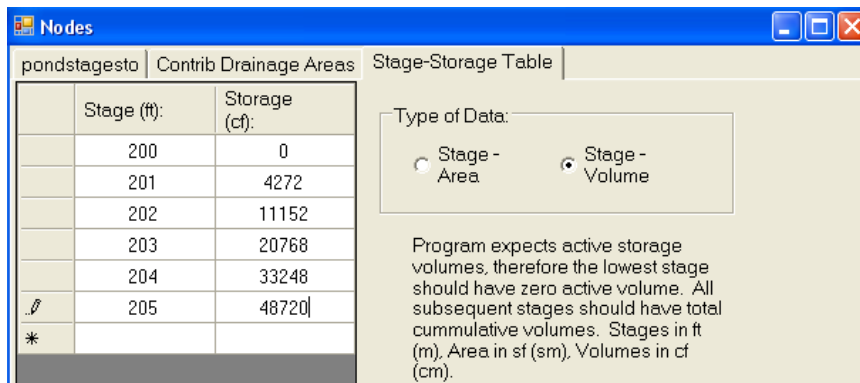
The first step in the iterative process of determining the pond size is to create a stage storage node using the pond volumes at different depths from the spreadsheet.

- Double click on the “**PROTOTYPE**” record under Nodes in the Tree View.

- Click on the **New Node** button.
- Change the “AutoLabel” ID to **Pondstagesto**.
- Press the **OK** button to close the “AutoLabel” dialog box.
- The Start El is the bottom pond elevation at **200ft**. The Max El. can be left blank, StormShed, will automatically input this value after the stage storage rating curve has been created.
- For *Descrip* input **stage storage pond**.



- Select the ***Stage-Storage Table*** tab.
- Input the **stage and volume** calculated on the spreadsheet and shown below.
- Select the **OK** button to close the dialog box.



Define a Control Structure

Next we will create a discharge structure that uses stage discharge so we can input the infiltration rate at different stages.

- Double click on the *PROTOTYPE* record found under the “***Discharge***” node in the Tree View.
- Press the **New Control** button.
- Replace the “AutoLabel” ID with **InfilStgDisc**.
- Press **OK** to close the “AutoLabel” dialog box.

- From the *Select Control Type* pull down menu, select **Stage-Discharge**.
- Change the “*Outlet Elev*” to **200**.
- Change the “*Max Elev*” to **205**.

The screenshot shows the 'Control Structures' dialog box with the 'Stage-Discharge Table' tab selected. The 'Select Control Type' dropdown is set to 'Stage-Discharge'. The 'Control ID' is 'infilstgdisc'. The 'Description' is 'pond infiltration'. The 'Start El' is 200.00 and the 'Max WS El over Ctrl' is 205.00. The 'Increment' is 0.10. There are 'New Control' and 'Update Control Elevs' buttons.

- Click on the “*Stage-Discharge Table*” tab.
- Input the values from the spreadsheet as shown below. *Note that values need to be in CFS, the infiltration rate has been converted to CFS on the spread sheet in the second to last column.*

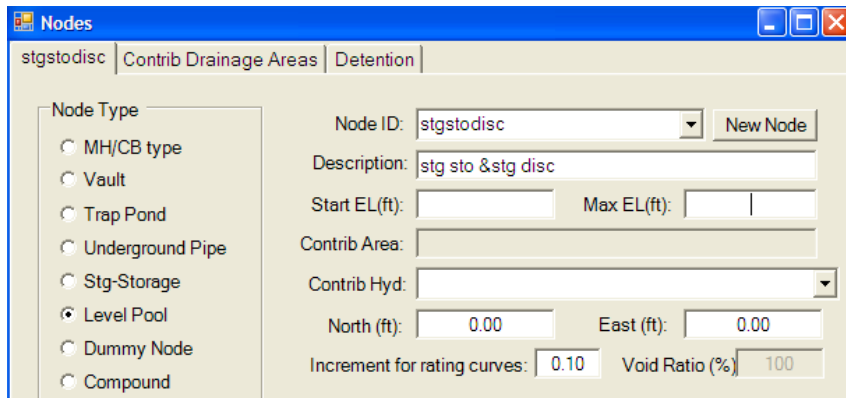
The screenshot shows the 'Control Structures' dialog box with the 'Stage-Discharge Table' tab selected. The table contains the following data:

Stage	YVal
200	0
201	0.323
202	0.485
203	0.677
204	0.902
205	1.16

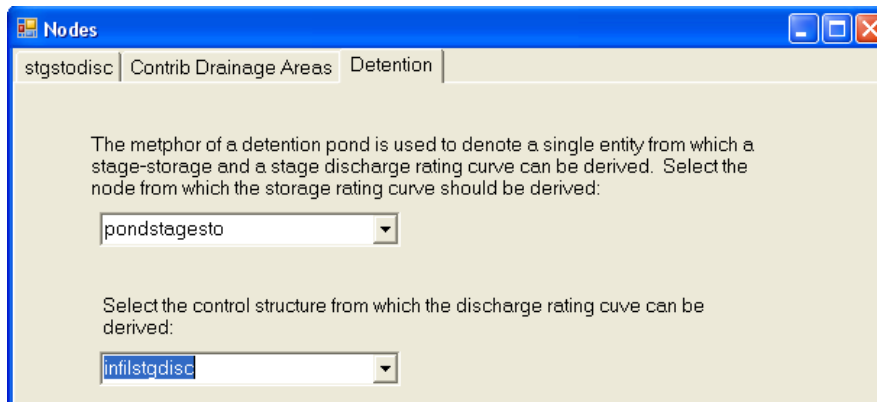
Below the table is a note: "Stage/Discharge Rating Curve. Note: Program expects active discharges rates, therefore, the lowest stage should have zero discharge. All subsequent stages should have increasing rates."

Define the Detention Pond Node

- Double click on the *PROTOTYPE* node record found under the “*Nodes*” node in the Tree View.
- Press the **New Node** button.
- Change the “Next Auto ID” to **StgStoDisc**.
- Press the **OK** button to close the “AutoLabel” dialog box.
- Change the “Node Type” to **Level Pool**.
- Input **Stg Sto & Stg Disc** for the *Description*.
- Leave the “*Start El*” and “*Max El*” blank, StormSHED will automatically update these boxes once the pond and discharge structures are defined.



- Click on the “*Detention*” tab.
- For the first drop down menu, select **pondstagesto**. This defines from which node the stage storage routing curve will be defined.
- From the second drop down select **infilstgdisc**. This defines where the discharge rating curve is defined.
- Select the **OK** button to close the node dialog box.



Sizing the Infiltration Facility

- Select the *Pond Design* tab from the Tree View.
- Select **Stgstdisc** from the “**Select Detention Pond Node**” drop down menu.
- Fill out the pond design dialog box as shown below.
- Press the **Compute** button.

The screenshot shows the 'Pond Design' dialog box in a software application. The interface includes a sidebar with tabs for 'Pond Design', 'History View', 'Layout View', 'Hydrographs', and 'Plots'. The main area contains several input fields and buttons:

- Select Detention Pond Node:** A dropdown menu set to 'stgstdisc'.
- Start Stg (ft):** A text box with '0.00' and an 'Update' button.
- Design Event:** A dropdown menu set to '100 year'.
- Matching Runoff Hyd:** A dropdown menu set to 'existing'.
- % of Rate:** A spinner box set to '100.00'.
- Add** and **Delete** buttons.
- Inflow Hyd/Basin:** A dropdown menu set to 'new basin'.
- Out Hyd:** A dropdown menu set to '100 year out'.
- Stm Dur (hrs):** A spinner box set to '24'.

Below these fields are two tables:

Computational Instructions:

Design Ev...	Matching Hyd/B...	%	Inflow Hyd/Basin	Outhyd
25 year	existing	100.00	new basin	25 year out
100 year	existing	100.00	new basin	100 year out

Results:

Design Ev...	Match Flow (cfs)	Peak ...	Max Depth (ft)	Detention Vol (cf)	Hrs to Empty (hr)	% Vol
25 year	2.152299	0.544...	2.310894	14141.561353	15.667	99.71
100 year	2.659044	0.623...	2.721597	18090.873737	17.833	99.76

Additional controls on the right include a 'Compute' button, checkboxes for 'Routing Table', 'Size Outlet', 'Save Chart', 'Report', 'Display Peak Elev', and 'Large Volume', and a 'Maximum Plot Time' spinner set to '2570'.

Results

Calculate the Treq or the time required to infiltrate the design stormwater volume

Using the design criteria outlined at the beginning of this tutorial and the SSC, we will verify the pond is large enough. Since this pond is being designed for flow control, the following requirements apply:

- Infiltrate the 25 year storm in 72 hours (starting after precipitation has ceased). In the column titled Hrs to Empty in the Results box, notice it will take just over 12 hours to infiltrate the design stormwater volume, well within the required time.
- 1' of freeboard above the peak level in the pond for the 25 year event is required and from the Max Depth column in the Result section we see we have about 2.69' (5' – 2.31').
- The 100 year storm should be checked for damages and flood control. In this case the 100 year storm does not overtop the pond, so downstream flood damage is not a concern.
- The pond depth shall be designed to between 2' minimum and 6' maximum (including the freeboard). Our pond is within this requirement for both the 25 and 100 year events.

A review of the design criteria determines a pond size of 300'x10' exceeds the requirements. At this point we could accept the design or repeat the process using a smaller geometry.

Repeat the process with a smaller (150'x10') pond

Infiltration Ponds													
Length of Pond Bottom (ft)		150		Width of Pond Bottom (ft)		10							
Area of Bottom of Pond (acres)		0.03											
Pond Side Slopes (3:1 typical)		4											
Depth of Pond, D _{pond}	Depth to Water Table, D _{wt}	Hydraulic Conductivity, K _{equiv}	Area of Pond Bottom, A _{pond}	Hydraulic Gradient, i	CF _{size}	Infiltration Rate, f	Length of Pond	Width of Pond	CF _{esspt}	CF _{stlbb0}	Adjusted Infiltration Rate, f _{adj}	Infiltration	Pond Volume
Varies 1' to 6'	Determined by Lab Tests	Determined by Lab Tests	Determined by designer	Equation 4-14	Equation 4-15 (1.0 max value)	Equation 4-16			Equation 4-17 (1.4 max value)	See Table 4-9	Equation 4-18	converts in/hr to cfs	Calculated (or from CA(CE))
(ft)	(ft)	(in/hr)	(Acres)			(in/hr)	(ft)	(ft)			(in/hr)	(cfs)	(ft*3)
0													
1	9	42	0.03	0.05	1.00	1.95	150	18	1.16	0.9	2.02	0.135	2172
2	9	42	0.07	0.05	1.00	2.14	166	26	1.11	0.9	2.13	0.215	5752
3	9	42	0.10	0.06	1.00	2.33	174	34	1.08	0.9	2.27	0.314	10868
4	9	42	0.14	0.06	1.00	2.53	182	42	1.07	0.9	2.43	0.433	17648
5	9	42	0.18	0.06	1.00	2.72	190	50	1.06	0.9	2.59	0.573	26220

Nodes

pondstagesto | Contrib Drainage Areas | Stage-Storage Table

Stage (ft):	Storage (cf):
200	0
201	2172
202	5752
203	10868
204	17648
205	26220

Type of Data:
 Stage - Area
 Stage - Volume

Program expects active storage volumes, therefore the lowest stage should have zero active volume. All subsequent stages should have total cumulative volumes. Stages in ft (m), Area in sf (sm), Volumes in cf (cm).

17648

Control Structures

infilstgdisc | Stage-Discharge Table

Stage	YVal
200	0
201	0.135
202	0.215
203	0.314
204	0.433
205	0.573

Stage/Discharge Rating Curve

Note: Program expects active discharges rates, therefore, the lowest stage should have zero discharge. All subsequent stages should have increasing rates.

Computational Instructions:

Design Ev...	Matching Hyd/B...	%	Inflow Hyd/Basin	Outhyd
25 year	existing	100.00	new basin	25 year out
100 year	existing	100.00	new basin	100 year out

Results:

Design Ev...	Match Flow (cfs)	Peak ...	Max Depth (ft)	Detention Vol (cf)	Hrs to Empty (hr)	% Vol
25 year	2.152299	0.435...	4.017552	17780.90554	25.833	99.64
100 year	2.659044	0.518...	4.609242	22261.181054	28.50	99.70

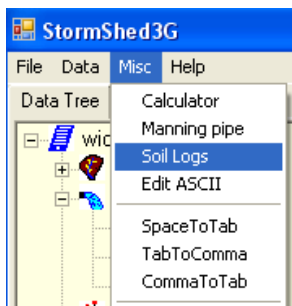
Results

Again review the time to infiltrate, freeboard, 100 year elevation, and pond depth. For the 150'x10' pond size all four of these are within the required values and the smaller pond size is acceptable.

Another Option for the spreadsheet

StormShed has a simple option to compute the infiltration using the iterative method in the spreadsheet.

- From the main toolbar, select **Misc>Soil Logs**.



- Input the soil data from the laboratory report and as shown below.

Soil Log or Test Pit ID: example Starting Elevation: 205

Description:

	thickness (ft)	d10 (mm)	d60 (mm)	d90 (mm)	finer (%/100)	depthToLayer (ft)
▶	14	0.096	0.386	0.85	0.071	0
	3	0.129	0.626	1.15	0.063	14

Before moving on, we will review some of the terms as noted in the SoilColumnForm.

Thickness (ft) – The thickness is the depth of the layer from either the ground elevation or the last layer. For this example, the thickness would be 14’ for the first sample and 17’-14’=3’ for the second sample.

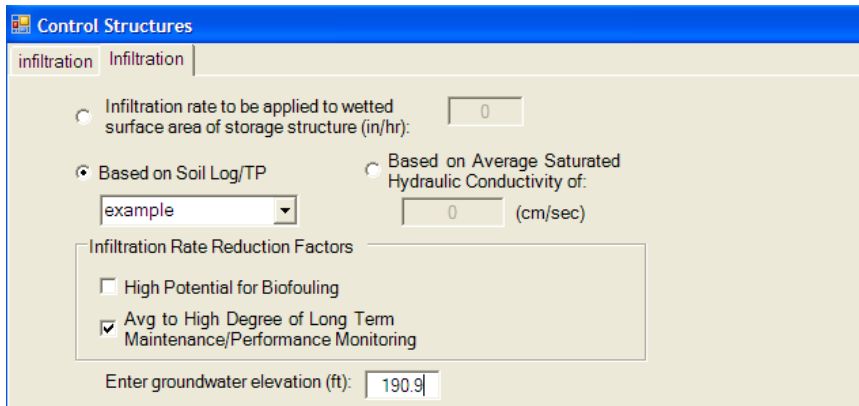
d10/d60/d90/fines – all of these values can be found on the data from the lab.

depthToLayer (ft) – this described the starting place for digging a sample, think of it as where your feet would be if you were starting to dig. For the first sample we start at the ground level or 0’. For the next sample, we start at 14’ to dig a thickness of 3’ to a depth of 17’.

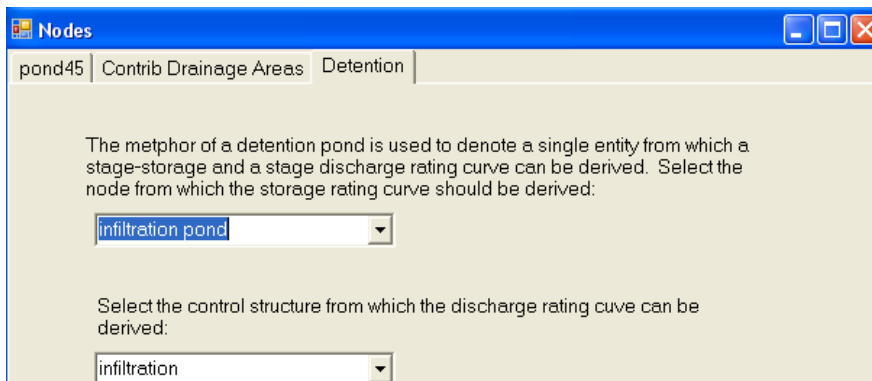
- Select the Update button to accept the Soil Log and close the dialog box.

Next, we will modify the control structure to reference the soil log example.

- In the Tree View, double click on the **Discharge Structure Infiltration**.
- Select the second tab and select the **Based on Soil Log/TP** radio button.
- Input the data shown below in the **Control Structures** and select **Close**.



- Next open the detention pond node called **pond45**, select the detention tab, and change the pond to **infiltration pond** as shown below.
- (Open the **infiltration pond** node and verify the trap pond dimensions are set to 300’x10’).



- Select the **Pond Design** tab in the **Layout View** and input the data shown below.

Computational Instructions:

Design Ev...	Matching Hyd/B...	%	Inflow Hyd/Basin	Outhyd
25 year	existing	100.00	new basin	25 year out
100 year	existing	100.00	new basin	100 year out

Results:

Design Ev...	Match Flow (cfs)	Peak ...	Max Depth (ft)	Detention Vol (cf)	Hrs to Empty (hr)	% Vol
25 year	2.152299	0.504...	2.348156	14161.309467	9.833	99.95
100 year	2.659044	0.582...	2.779956	18383.377088	12.333	99.96

Pond Design Results using Soil Column Form

Next, we will compare the Pond Design Results using the **Soil Column Form** to the spreadsheet (see below Pond Design box for spreadsheet data). Notice the values using the **Soil Column Form** are in general *slightly larger* than the spreadsheet data, that is because the spreadsheet considered infiltration through the sides of the pond as well as the pond bottom and the Soil Column data assumed infiltration only in the pond bottom.

Computational Instructions:

Design Ev...	Matching Hyd/B...	%	Inflow Hyd/Basin	Outhyd
25 year	existing	100.00	new basin	25 year out
100 year	existing	100.00	new basin	100 year out

Results:

Design Ev...	Match Flow (cfs)	Peak ...	Max Depth (ft)	Detention Vol (cf)	Hrs to Empty (hr)	% Vol
25 year	2.152299	0.544...	2.310894	14141.561353	15.667	99.71
100 year	2.659044	0.623...	2.721597	18090.873737	17.833	99.76

Pond Design Results using Spreadsheet

- Repeat the process for a 150'x10' trap pond and compare the Pond Design Data to the Spreadsheet data as shown below.

Select Detention Pond Node: pond45 Start Stg (ft) 200.00 Update

Design Event: Matching Runoff Hyd: % of Rate 100.00 Add

Inflow Hyd/Basin: Out Hyd: Stm Dur (hrs): 24 Delete

Computational Instructions:

Design Ev...	Matching Hyd/B...	%	Inflow Hyd/Basin	Outhyd
25 year	existing	100.00	new basin	25 year out
100 year	existing	100.00	new basin	100 year out

Results:

Design Ev...	Match Flow (cfs)	Peak ...	Max Depth (ft)	Detention Vol (cf)	Hrs to Empty (hr)	% Vol
25 year	2.152299	0.430...	4.011771	17696.369534	21.00	99.96
100 year	2.659044	0.507...	4.580288	22348.411519	24.00	99.97

Pond Design Results using Soil Column Form

Again, the results from the Soil Column Form are generally larger than the results from the spreadsheet.

Select Detention Pond Node: stgstodisc Start Stg (ft) 200.00 Update

Design Event: Matching Runoff Hyd: % of Rate 100.00 Add

Inflow Hyd/Basin: Out Hyd: Stm Dur (hrs): 24 Delete

Computational Instructions:

Design Ev...	Matching Hyd/B...	%	Inflow Hyd/Basin	Outhyd
25 year	existing	100.00	new basin	25 year out
100 year	existing	100.00	new basin	100 year out

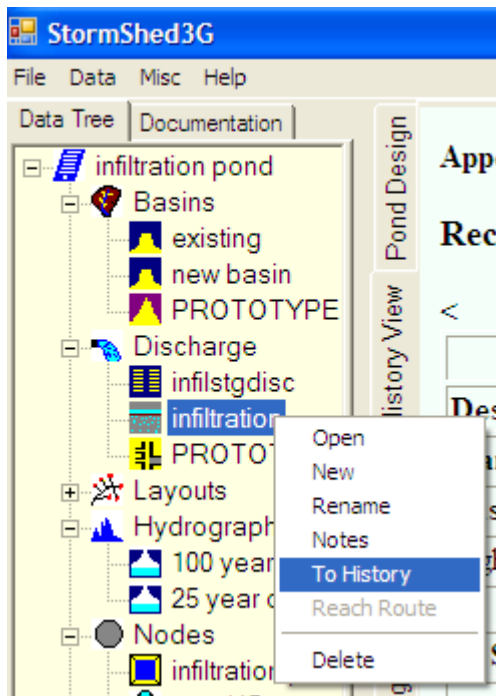
Results:

Design Ev...	Match Flow (cfs)	Peak ...	Max Depth (ft)	Detention Vol (cf)	Hrs to Empty (hr)	% Vol
25 year	2.152299	0.435...	4.015671	17782.330995	25.833	99.64
100 year	2.659044	0.510...	4.556784	22420.749404	28.833	99.71

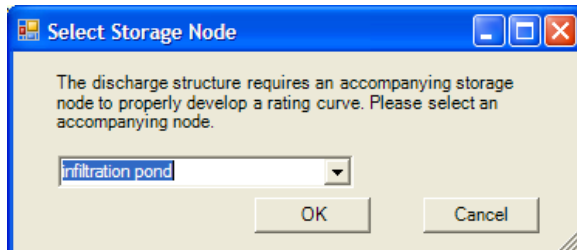
Pond Design Results using Spreadsheet

To save time, designers can use the *Soil Column Form* to determine infiltration rates. Remember the values will be slightly conservative and on projects where space is limited designers should use the spreadsheet for a more precise answer.

- To see the infiltration and hydraulic conductivity rates calculated using the *Soil Column Form, LMB* click on the discharge *infiltration* structure in the tree view and then *RMB* click and select *To History*.



- In order to generate a rating curve, StormSHED will prompt the user to select a corresponding storage node. For this example select *infiltration pond* as shown below.



Appended on: Wednesday, May 21, 2008 10:44:59 AM

Record Id: infiltration

Infiltration			
Descrip:	pond infiltration	Increment	1.00 ft
Start EL	200.00 ft	Max EL	205.00 ft
Based on Soil Log/Test Pit	example	Ground Water El (ft)	191.00
High Potential for Biofouling	Low Degree of Long Term Maintenance Performance Monitoring		

Stg (ft)	Elev (ft)	Infil Rate (in/hr)	Discharge (cfs)	Stg (ft)	Elev (ft)	Infil Rate (in/hr)	Discharge (cfs)
0.00	200.00	1.9661	0.00	3.00	203.00	2.2167	0.3105
1.00	201.00	1.9722	0.1317	4.00	204.00	2.3666	0.4291
2.00	202.00	2.0795	0.2119	5.00	205.00	2.5231	0.5692
Based on Computed Ksat						0.0288 cm/sec	

Note: To control the stage increment data is reported in the *History View*, open the **Control Structure Dialog** box and change the Increment to **1.0** for data at each elevation in increments of 1.0’.

