OUT-OF-BANK FLOW DESIGN PROCEDURE

The following procedure may be used to check the out-of-bank velocity using the Grassed Waterway Design program.

Step #1-Waterway Design - Enter the following input:

Capacity Retardance: B or C
Velocity Retardance: C or D (at least one curve lower than capacity retardance
Solve for: D
Capacity: Qmin = drainage curve value or larger
Slope: waterway slope
Side Slope Ratio: desired waterway side slope
Bottom Width: desired
Mod Vee Bottom width:desired

The resultant "Total Depth" is the minimum waterway depth to be built.

Step #2-Velocity Check - Enter the following input:

Capacity Retardance: B or C
Velocity Retardance: C or D (at least one curve lower than capacity retardance)
Solve for: D
Capacity: Q_{10} value
Slope: waterway slope
Side Slope Ratio: desired waterway side slope
Bottom Width: desired
Mod Vee Bottom width:desired

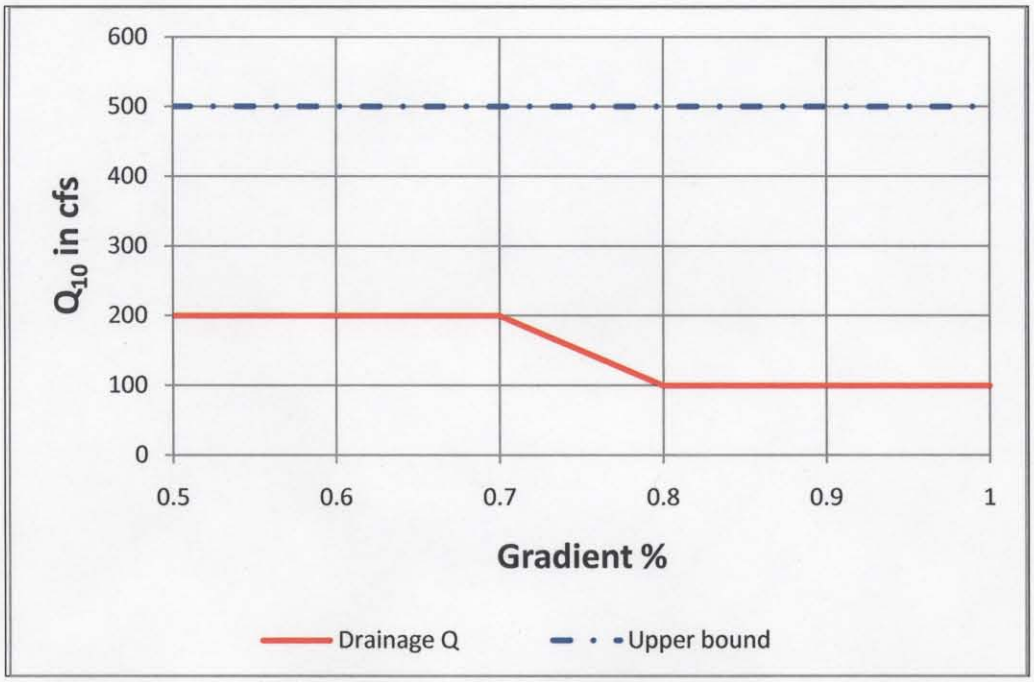
Compare the design "Velocity" to the allowable velocity in the 412 practice standard. If the design velocity is greater than allowable, return to step #1, increase the size of the waterway and repeat steps 1 and 2.

Step #3-Out-of-Bank Velocity Check - Enter the following:

Capacity Retardance: N
Velocity Retardance: N
Solve for: D
Capacity: Q_{10}-Qmin used in step #1
Slope: waterway slope
Side Slope Ratio: land grade perpendicular to the waterway
Bottom Width: Top width of the waterway designed in step #1
Mod Vee Bottom width:0.00
Capacity N-Value: 0.035 (cropland value, bare soil)
Velocity N-Value: 0.035 (cropland value, bare soil)

If the resultant "Velocity" is greater than the allowable velocity for the cropland, increase the design Q in step #1 and repeat steps 1, 2, and 3. For permissible out-of-bank velocities, see Table 2, Waterway Standard 412, "Permissible Velocities for Out of Bank Flow".

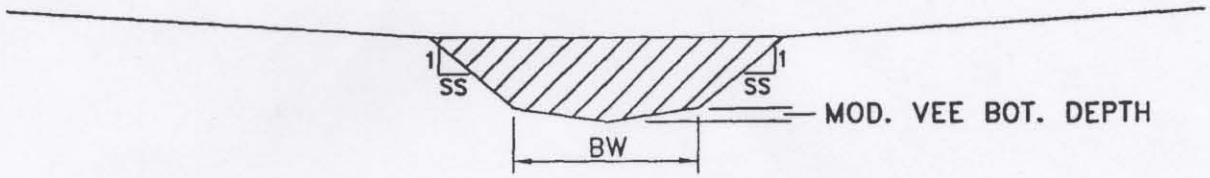
GRASSED WATERWAY
OUT-OF-BANK FLOW -- VELOCITY CHECK PROCEDURE



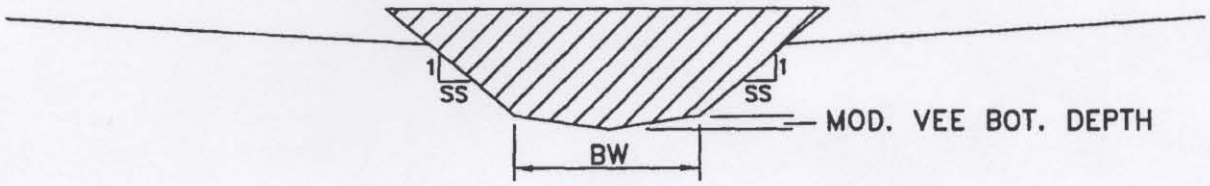
Above the Upper Bound line, use a routing program such as HEC-RAS to determine the out-of-channel velocity.

Between the two lines, check cropland velocity using the 3-step procedure from the previous page.

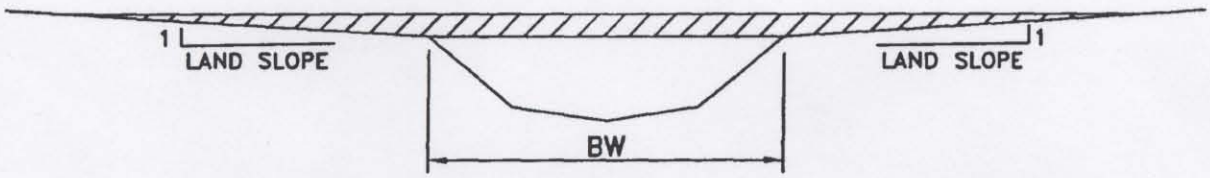
Below the Drainage Q line, use the drainage Q from this MN EFH supplement or a larger design discharge. Step 3 of this procedure is not needed if the discharge is greater than or equal to 20% of Q_{10}. ($Q \geq 0.2Q_{10}$)



STEP #1 – Q min. = Drainage Curve



STEP #2 – Storm Q_{10}



STEP #3 – OUT-OF-BANK

$Q = Q_{10} - Q$ Step #1

DRAINAGE DESIGN DISCHARGES

Drainage Area, acres	Curve 1 (cfs)	Curve 2 (cfs)	Curve 3 (cfs)
10	1	1	1.3
20	2	2	3
40	3	3	5
50	4	4	6
60	5	5	7
80	6	6	9
100	8	8	12
150	10	11	16
200	12	14	21
300	14	18	28
500	19	24	37
700	23	29	45
1000	29	36	56
1500	40	50	75
2000	52	65	95

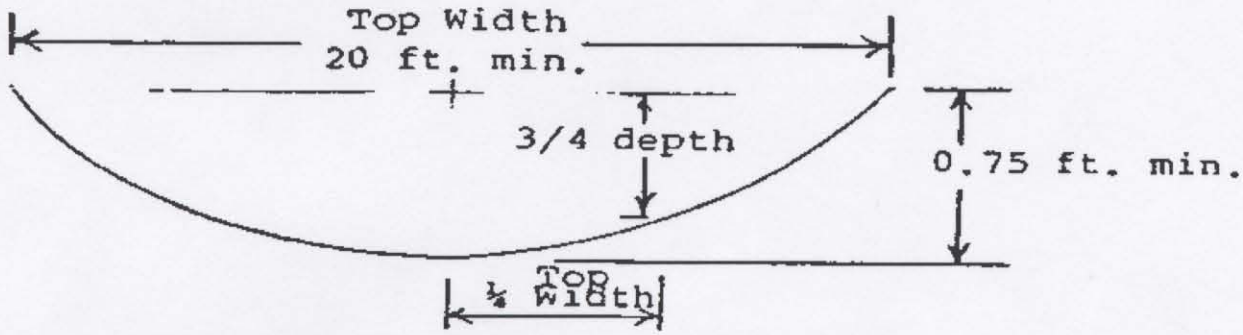
The information is adapted from Drawing No. 3-N-45058 dated 1/3/1957 for the State of Minnesota.

GUIDELINE FOR SMALL GRASS WATERWAYS

Critical Area Planting (CAP) Waterway:

Ephemeral gullies can be treated with the Critical Area Planting (342) standard if it meets the following criteria:

- Drainage area is 7 acres or less.
- Vegetated area begins 250 ft from the top of watershed and is no longer than 500 ft downslope.
- Bottom grade between 3% and 10% (if bottom grade exceeds 10%, drainage area should be 4 acres or less)
- Has a stable outlet. Is not an outlet for a terrace or diversion.
- Shape is parabolic with at least 20 foot top width and 0.75 foot depth.



CAP Waterway

INTRODUCTION Use of Minnesota Waterway Design Charts

The development of the charts for Minnesota for small waterways bears some similarity to the development of the "quickie" charts in Iowa, developed in spring 2011.

Runoff in Minnesota for the 10-year event was assumed to range from 1.4 inches to 2.5 inches using rainfall values of 3.5 to 4.4 inches with an RCN of 76 for B soils and RCN of 82 for C soils. By using runoff, a chart dividing the state into regions is not needed.

Side slopes used are 6:1, 8:1, and 10:1.

The tables were prepared for all four soil erosion categories – easily erodible, erodible, erosion resistant and very erosion resistant. MN soils were grouped into soil erosion categories using the unified soil classification (USC) and plasticity index (PI) (see separate explanation). Instructions were developed for obtaining USC and PI from soil data viewer in Toolkit. Thus no charts of soils are needed and up-to-date soils information is used.

Following Iowa's method, designs for grassed waterways with drainage areas from 0 to 10 acres were based on B-C retardance values for capacity and stability design respectively. Designs for waterways with drainage areas from 11 to 30 acres were based on B-D retardance values for capacity and stability design respectively.

The minimum waterway depth used was 12 inches or 1 foot. The charts were developed using a Shape A bottom (flat). Thus for wide bottom widths, it would be best to run WDT again using a v-bottom appropriate for the width.

Minimum top widths varied depending on the side slope (z) ratio. For a z value of 6, the minimum top width is 30 feet. For a z value of 8, the minimum top width is 32 feet. For a z value of 10, the minimum top width is 34 feet.

The vegetative factor used was 0.87. This is valid for brome grass and brome grass mixtures.

The actual acreage used in the design is the maximum in each grouping. For 0-7 acres, 7 acres was used to develop the chart values. This smallest category was used to coincide with the CAP waterways described in MN standard 412. For 8-10 acres, 10 acres was used to develop the chart values. For 11-20 acres, 20 acres was used to develop the chart values. For 21-30 acres, 30 acres was used to develop the chart values.

EFH2 was used to determine the peak discharge for each scenario. Since these are basically all under 30 acres, the Folmar & Miller adjustment to Tc was not used.

A shape was used where the watershed length is about 1.5 times the watershed width. The length was used in EFH2 to calculate Tc. Assumptions used:

Range	DA used	Area	Watershed width	Watershed length
0-7 acres	7	304,920 sq ft	451	677
8-10 acres	10	435,600 sq ft	539	808
11-20 acres	20	871,200 sq ft	762	1143
21-30 acres	30	1,306,800 sq ft	933	1400

Many runs of the Engineering Field Tools (EFT) Waterway Design Tool (WDT) software were completed to develop the charts. The software does not allow for a fixed bottom width so the tables are given with depth and top width for each soil erodibility class. The user will need to back calculate to a bottom width if that is desired for design and construction, or WDT can be run looking at options.

Steps to Use the Design Charts

1. Select the site up to 30 acres in drainage area.
2. Determine the dominant soil(s) the waterway will be constructed in. Note the depth of the surface layer to know whether the waterway is likely to be constructed deeper than the surface layer or not.
3. Use the Soil Lookup Instructions to determine which of the four soil classes is to be used for the site.

Decision Tree

If the soil textural class is	**And the reference PI is**	**the erodibility class is**
CL	Any value	Erosion resistant (ER)
CH	Any value	Very erosion resistant (VER)
CL-ML	PI < = 16	Erodible (E)
CL-ML	PI > 16	Erosion resistant (ER)
ML	PI < 5	Easily erodible (EE)
ML	5 <= PI < 19	Erodible (E)
ML	PI >= 19	Erosion resistant (ER)
MH (elastic silts)	PI <= 15	Erodible (E)
MH (elastic silts)	PI > 15	Erosion resistant (ER)
SC, SC-SM, SM	PI < 5	Easily Erodible (EE)
SC, SC-SM, SM	PI > =5	Erodible (E)
SP, SP-SM, PT, organics	Any value (typically PI < 5)	Easily erodible (EE)

4. Determine the drainage area for the project. Measure or estimate the slope of the waterway course.
5. Determine the 10 year, 24 hour rainfall amount and calculate the runoff curve number (RCN) and peak discharge (Q) using EFH2 software. Note the runoff amount calculated in EFH2.
6. Choose a side slope ratio, 6:1, 8:1, or 10:1.
7. Use the charts to determine the required size of the waterway, or execute EFT-WDT to look at options. The charts are the more conservative option.

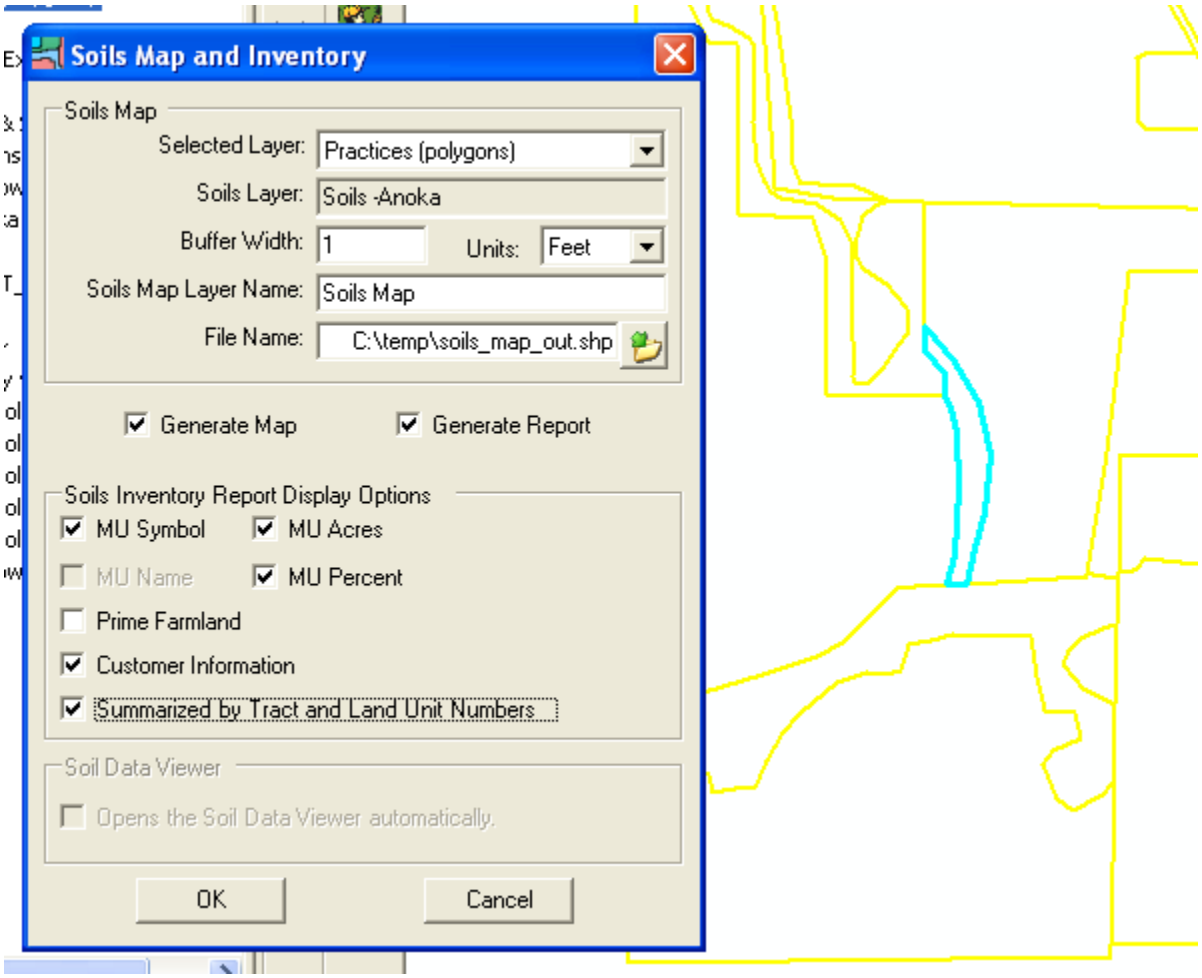
650.0703 Design process

SOIL LOOKUP INSTRUCTIONS

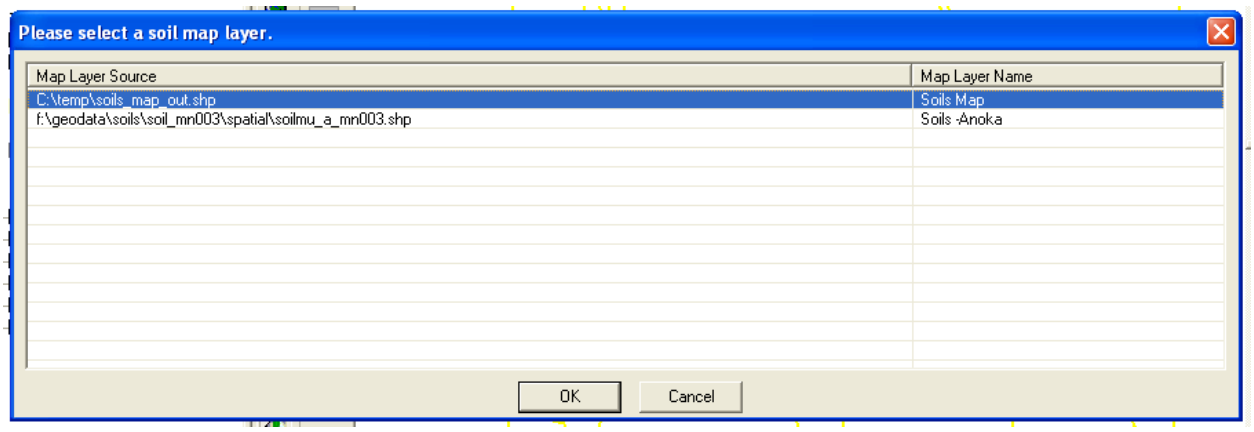
This is instructions for a procedure in Toolkit to obtain unified soil classification and plasticity index to use the decision matrix for design of a grassed waterway within the WDT module of Engineering Field Tools (EFT).

Within Toolkit, load the conservation plan and practices. Select the site where the waterway will be built and highlight the polygon. Click the soils button; this will clip the soils to just the area where the waterway will be constructed.

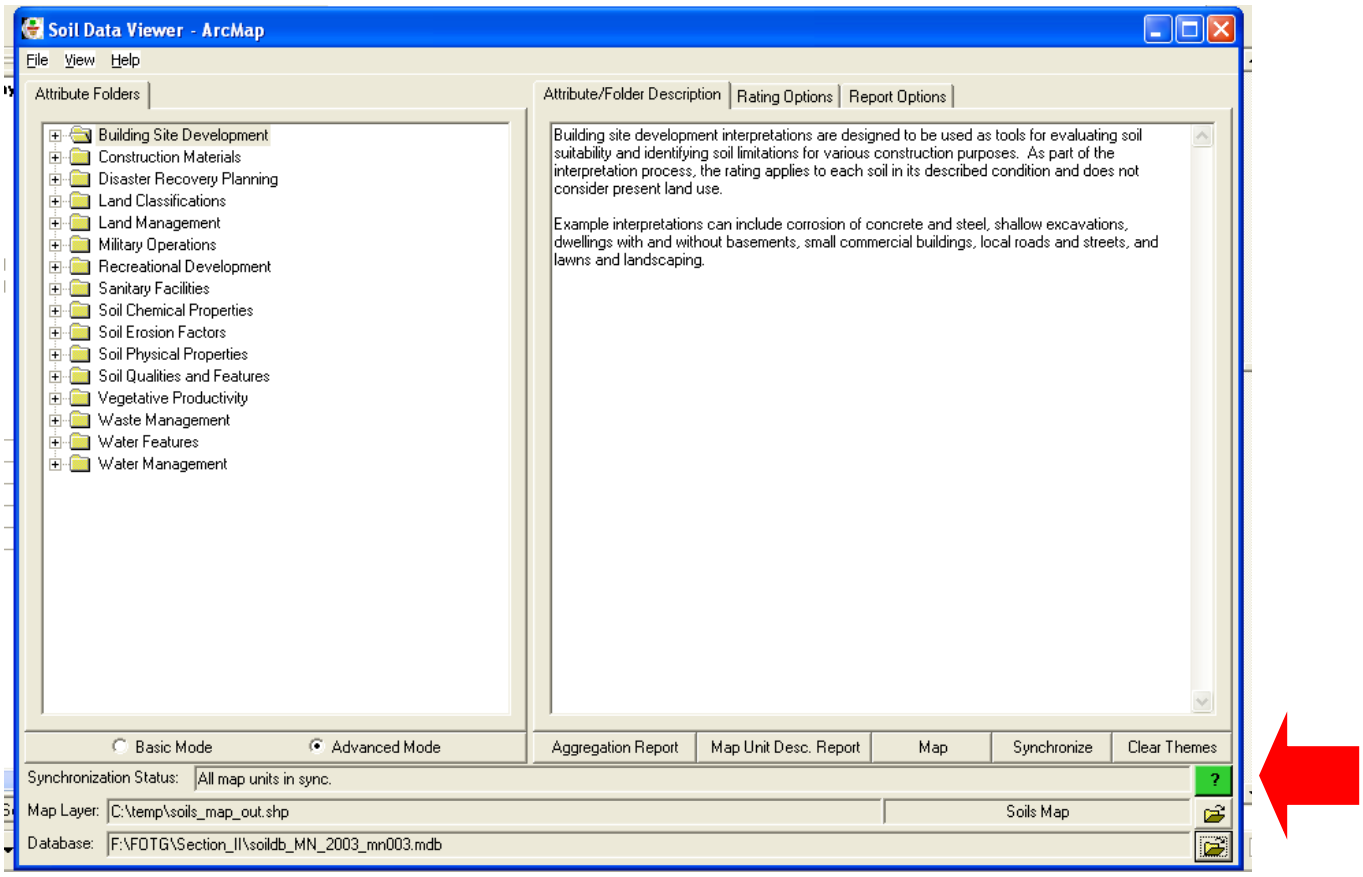
Choose soils map and inventory and generate the report. See below.



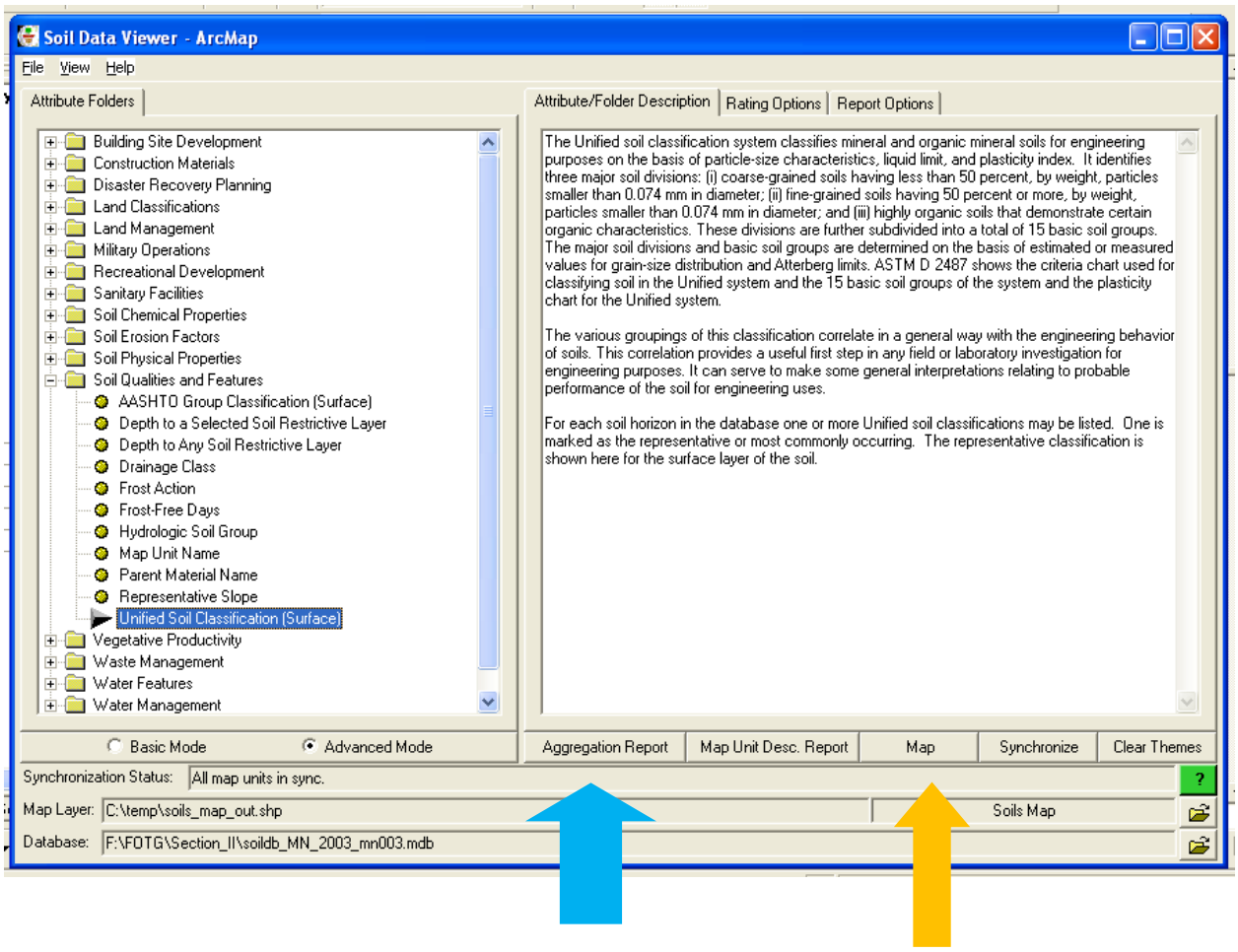
Next, click the Soil data Viewer icon. You will need to synchronize the soil tabular data with the spatial layer. If the box on the right side is red, you will need to browse to your county soils mdb file in F:\FOTG\Section_II folder. You can either point to the whole county soil spatial layer or clip your CLU to limit the soil list.



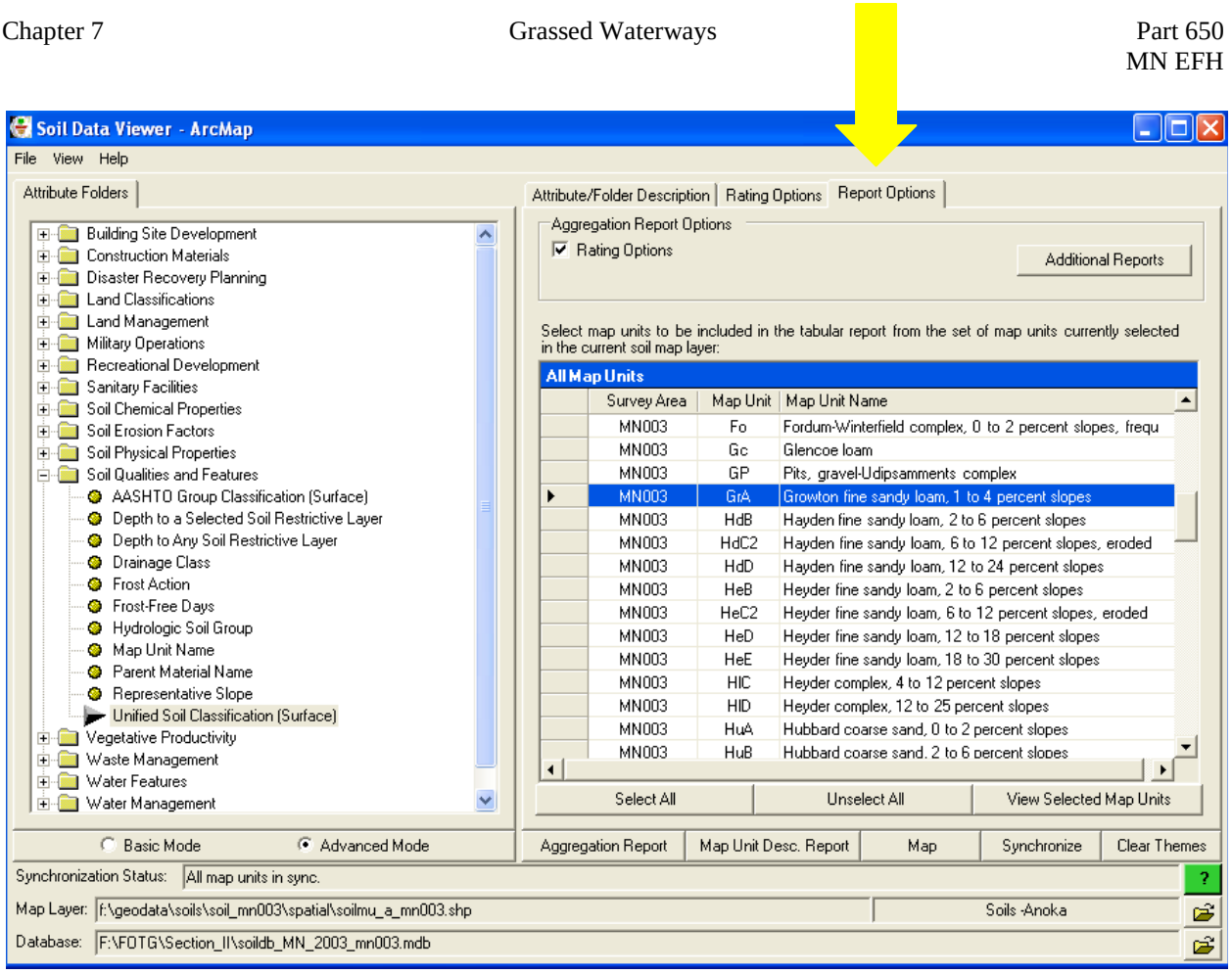
When you are synchronized and ready, the button on the lower right side turns green. See below.



From the list of soils information available, first choose Soil Qualities and Features and expand the list by clicking on the "+" symbol. From that drop down list, choose Unified Soil Classification.

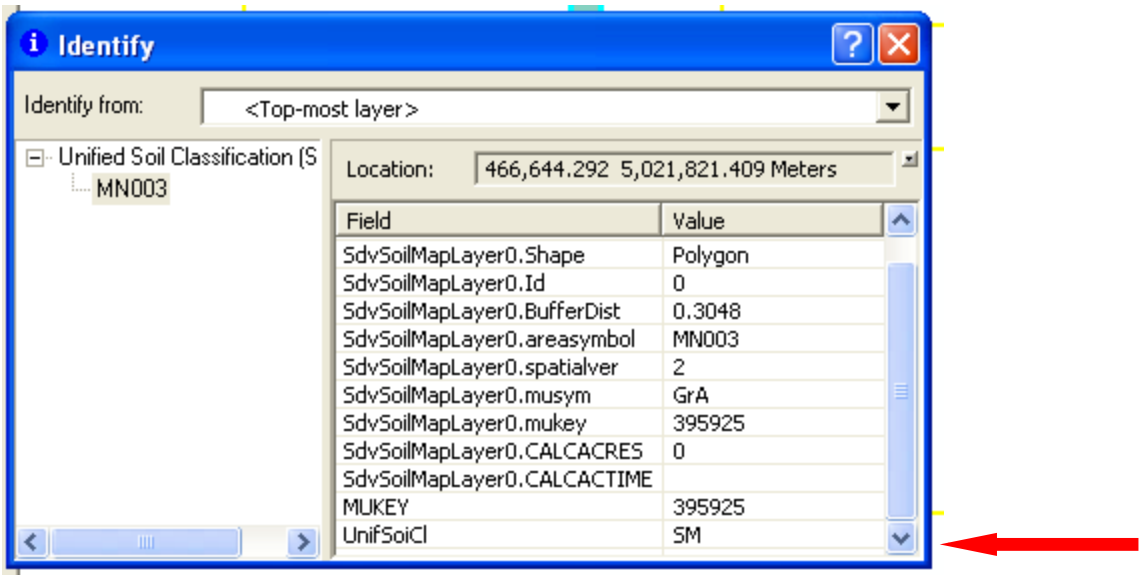


The data can be displayed as an aggregation report for selected soils, or as a map.



Under the Report Options tab, choose the soil or soils that for which the unified soil classification is desired. These will be the only ones shown in the report.

Choose the aggregation report (blue arrow above). The report will show the unified soil classification rating for the soils chosen. The soil classification can also be found using the “map” choice in the screen above (orange arrow) and then using the “identify” key to point to a soil, using the attribute table for the result as shown below.



Choose the appropriate soil classification and use it with the decision tree. If the decision tree indicates that the plasticity index needs to be used also, proceed with the steps below to obtain the plasticity index for the same soil.

Decision Tree

If the soil textural class is	And the reference PI is	the erodibility class is
CL	Any value	Erosion resistant (ER)
CH	Any value	Very erosion resistant (VER)
CL-ML	PI < = 16	Erodible (E)
CL-ML	PI > 16	Erosion resistant (ER)
ML	PI < 5	Easily erodible (EE)
ML	5 <= PI < 19	Erodible (E)
ML	PI >= 19	Erosion resistant (ER)
MH (elastic silts)	PI <= 15	Erodible (E)
MH (elastic silts)	PI > 15	Erosion resistant (ER)
SC, SC-SM, SM	PI < 5	Easily Erodible (EE)
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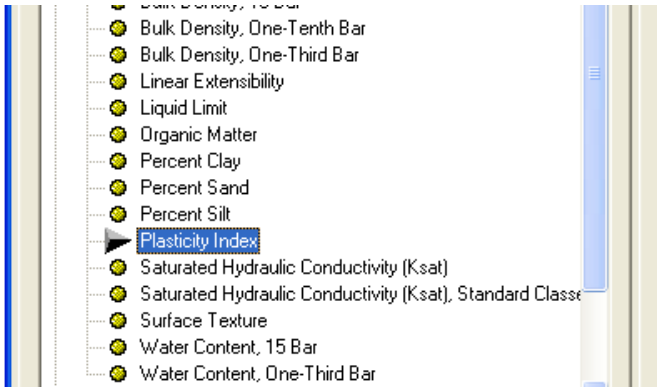
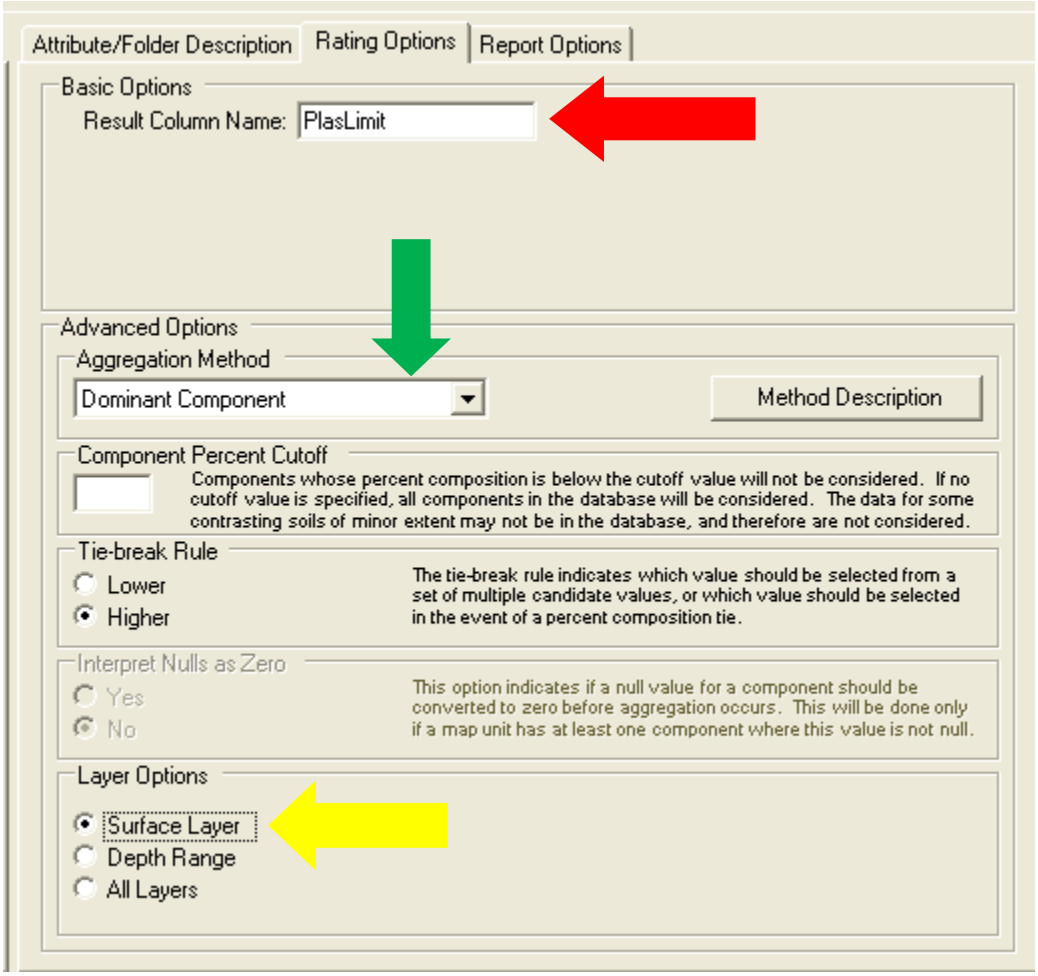
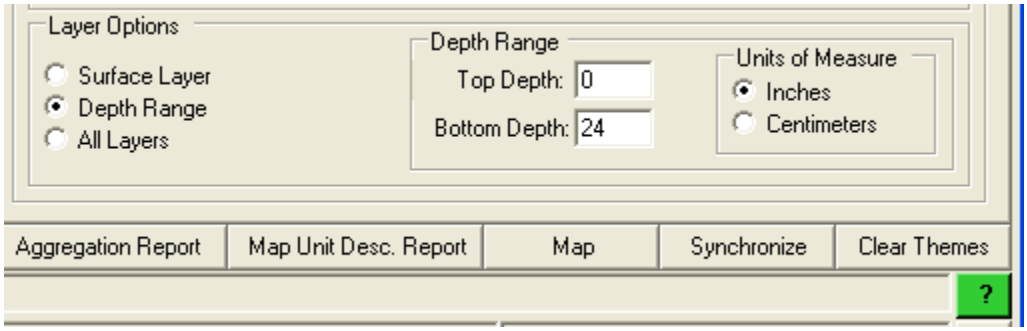
SP, SP-SM, PT, organics	Any value (typically PI < 5)	Easily erodible (EE)



Going back to the list of soil attribute folders, select “Soil Physical Properties” and click the “+” sign to open it. On that list, choose Plasticity Index. On the screen to the right of the list, verify that the options are the ones you desire.



At the red arrow, the box should display “PlasLimit”. At the green arrow, the box should display “Dominant Component”. For the yellow arrow, a choice will need to be made based on the site and soil. If the surface layer is thicker than the anticipated depth of the waterway, the user can just select “surface layer”. If the soil’s surface layer is less thick than the planned depth of the waterway, it will be better to use depth range and specify the depth of soil to be considered (often 12-24 inches – be sure the units are inches and not centimeters!).



If Depth Range is selected, the additional boxes above appear in the lower right corner. By choosing “aggregation report” near the bottom of the screen, a report will display like the one shown below.

Note in the heading of the report below with the blue border that the depth range was specified as 0 to 24 inches. The report with the pink border has a depth range of 0-12". Note that the values are not the same for the two depth ranges. Use this plasticity index information in the decision tree on page 5 to determine the soil erodibility class for designing the grassed waterway.

Plasticity Index

Layer Option: Depth Range 0 to 24 Inches
Units of Measure: percent
Aggregation Method: Dominant Component
Tie-break Rule: Higher
Interpret Nulls as Zero: No

Anoka County, Minnesota
Survey Area Version and Date: 8 - 12/14/2009

Map symbol	Map unit name	Rating
GrA	Growton fine sandy loam, 1 to 4 percent slopes	4.9
HeB	Heyder fine sandy loam, 2 to 6 percent slopes	4.1
HeD	Heyder fine sandy loam, 12 to 18 percent slopes	4.1

Plasticity Index

Layer Option: Depth Range 0 to 12 Inches
Units of Measure: percent
Aggregation Method: Dominant Component
Tie-break Rule: Higher
Interpret Nulls as Zero: No

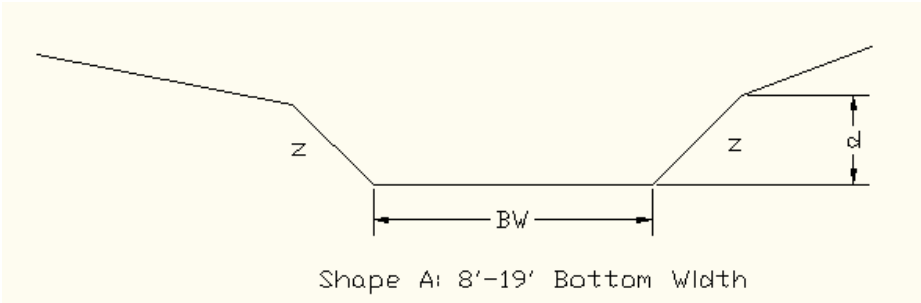
Anoka County, Minnesota
Survey Area Version and Date: 8 - 12/14/2009

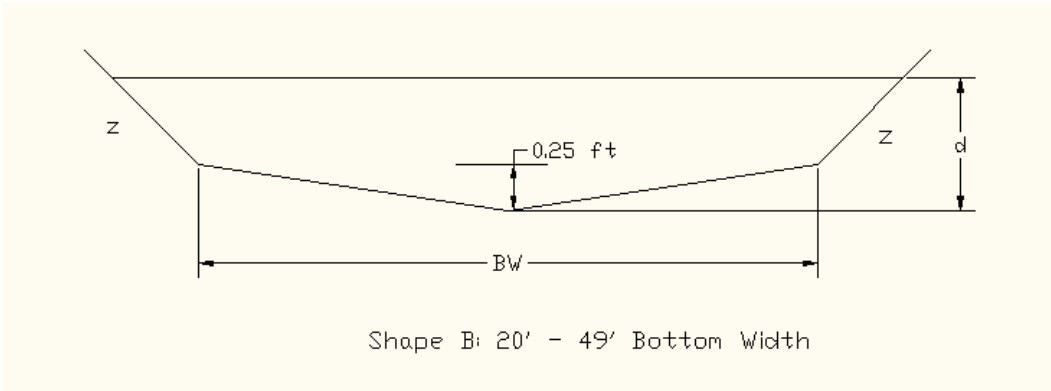
Map symbol	Map unit name	Rating
GrA	Growton fine sandy loam, 1 to 4 percent slopes	2.8
HeB	Heyder fine sandy loam, 2 to 6 percent slopes	4.0
HeD	Heyder fine sandy loam, 12 to 18 percent slopes	4.0

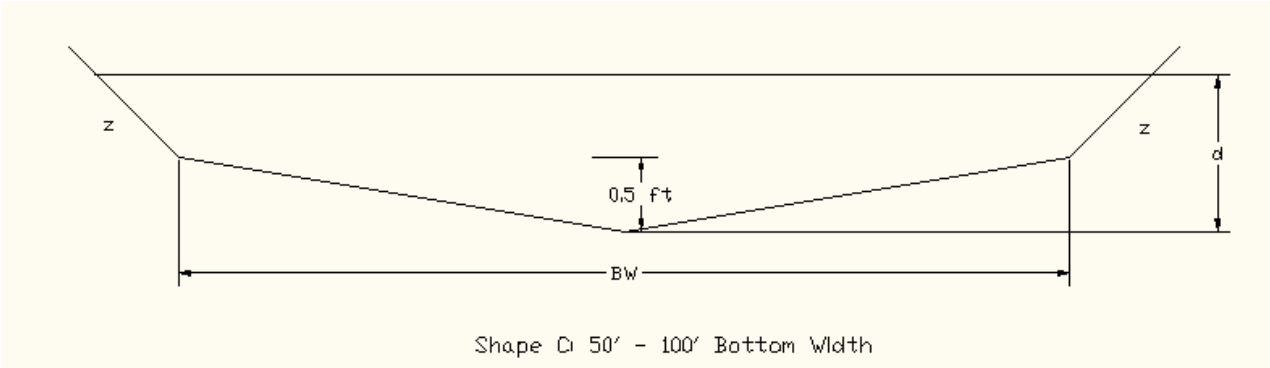
650.0703 Design process

GRASSED WATERWAY SHAPES FOR MINNESOTA

Depending on the bottom width of the waterway, the cross-section should have the shape shown below to encourage flow to concentrate in the center of the channel, and not meander across a flat bottom in patterns that may develop into rills.







BW = Bottom width of the channel in feet
D = depth of water fowing in the waterway, in feet
Z = side slope ratio, often 6:1, 8:1, or 10:1

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