

***APPENDIX E: Using the TMDL USLE Tool to Estimate
Sediment Loads***

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The purpose of this appendix is to present one method of roughly estimating landuse-specific sediment loading rates for the pervious categories represented in this model; forest, urban, agriculture and barren. These estimated loading rates will help ensure that the HSPF results are reasonable and then assist in further refining the HSPF sediment model of the watershed.

The Universal Soil Loss Equation (USLE) is an empirical model that estimates net hillslope erosion. The USLE was developed on Midwestern US cropland to predict average annual soil loss caused by sheet and rill erosion from a hill slope element. It was not created to consider deposition or route sediment from a hill slope element. In relatively large watersheds, most sediment gets deposited within the watershed and only a fraction of the soil that is eroded from hill slopes will reach the stream system or watershed outlet. This fraction or portion of sediment that is available for delivery is referred to as the Sediment Delivery Ratio (SDR). This ratio can be multiplied by the predicted erosion rate to estimate the percent of eroded material that will reach the watershed outlet.

The USLE formula to calculate soil loss is as follows:

$$A = R * L * S * C * P * K$$

Where:

A = annual soil loss in tons per acre per year

R = rainfall erosivity factor

L = slope length factor

S = slope gradient factor

C = cover management factor

P = erosion control practice factor

K = soil erodibility factor

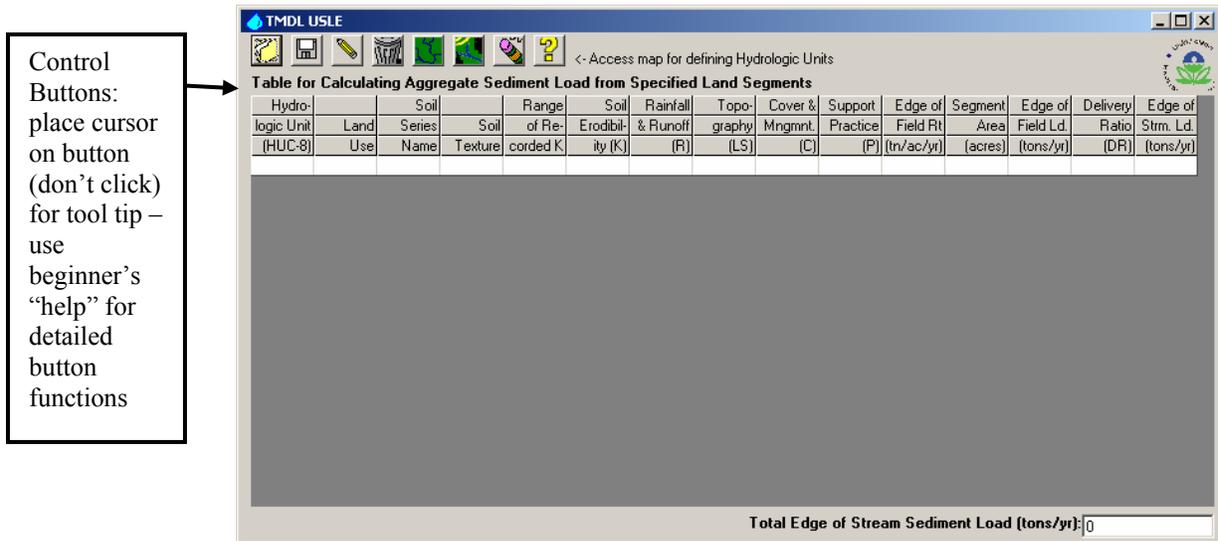
When using the TMDL USLE tool, the primary demand of the user will be to define the land segments that are deemed to be the significant sources of sediment loading to the watershed. For each land segment, the following information will need to be provided by the user:

- **Predominant Soils** - A list of available soil series and their textures is provided for the HUC(s) selected. Knowing the name of the most predominant (or most representative) soil in the land segment will allow the user to select this soil and thus obtain default values for the K-factor.
- **Slope Incline and Slope Length** - These two values, along with susceptibility to rill erosion, are used to generate a LS (or topography factor) value. Landuse coverage and topographic or digital elevation maps are useful for defining these values.
- **Susceptibility to Rill Erosion** - A general knowledge of whether the land use is

highly, moderately, or minimally susceptible to rill erosion is needed in generating a LS (or topography factor) value.

- **Cover (C) Factor Value** - Although some reference tables for estimating C Factors are provided in the Help, the majority of C Factor values will need to come from outside the program. As mentioned in the help, excellent resources for gathering C Factor values are the regional NRCS offices.

1. From the **Start** menu under **Programs**, select **TMDL USLE**. The TMDL USLE window will open. Your screen should look like the following:



Note: The “Table for Calculating Aggregate Sediment Load from Specified Land Segments” table is located below the control buttons. In this table, there are 15 parameters for which values must be assigned. Some of these values are automatically computed, but the user must provide most of the values. Read through the following general explanations of how to populate these fields. More detail about these inputs is provided in the following sections. For more information about a specific parameter in the TMDL USLE table, click in a

cell in the corresponding column, and click the “Assistance” button, .

- Hydrologic Unit (HUC-8s):** Select segment location using electronic map.
- Land Use:** Select segment land use from pull-down menu or type in custom land use.
- Soil Series Name:** Select soil series from list – list will correspond to HUC selection
- Soil Texture:** Select from list – list will correspond to Soil Series Name selection.
- Range of Recorded K:** Automatically computed - determined by selection of soil series and soil texture.
- Soil Erodibility (K):** Automatically computed – determined by selection of soil series and soil texture.
- Rainfall and Runoff (R):** Interpolate value from electric isoerodent map.
- Topography (LS):** User may estimate using knowledge of values derived for previous local USLE applications or by using estimation aid in on-line ‘help.’
- Cover and Management (C):** User may estimate based on knowledge or use by using estimation aids in on-line ‘help.’

Support Practice (P): User may estimate based on knowledge or use by using estimation aids in on-line ‘help.’

Segment Area (acres): User must provide segment areas from off-line sources.

Edge of Field Loading (tons/yr): Automatically computed when values are provided for all columns to the left of this field.

Delivery Ratio (DR): User may estimate based on knowledge or use by using estimation aids in on-line ‘help.’

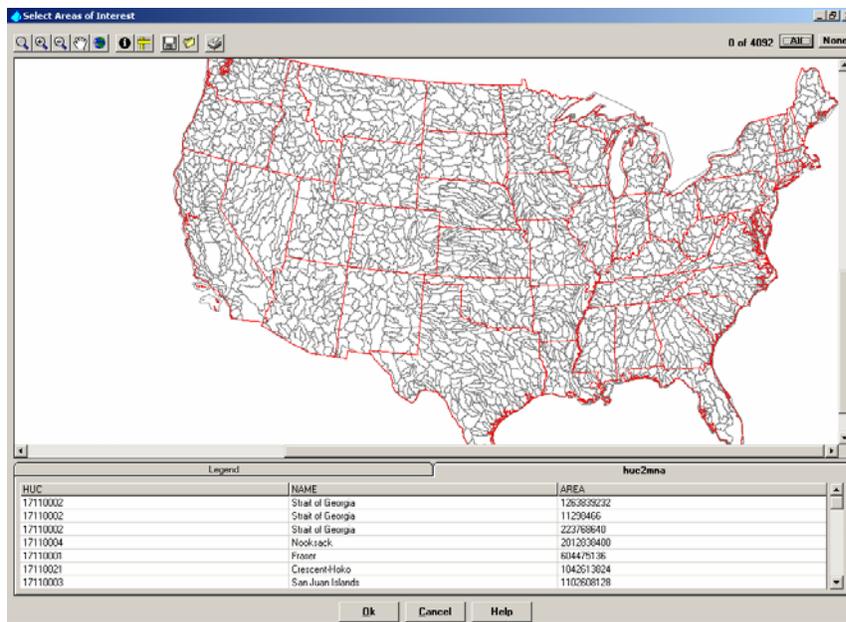
Edge of Stream Loading (tons/yr): Automatically computed when the “Edge of Field Loading” and “Delivery Ratio” fields are populated.

Specifying Area to Model

To begin with, we need to specify for which watershed we will run the TMDL USLE model.

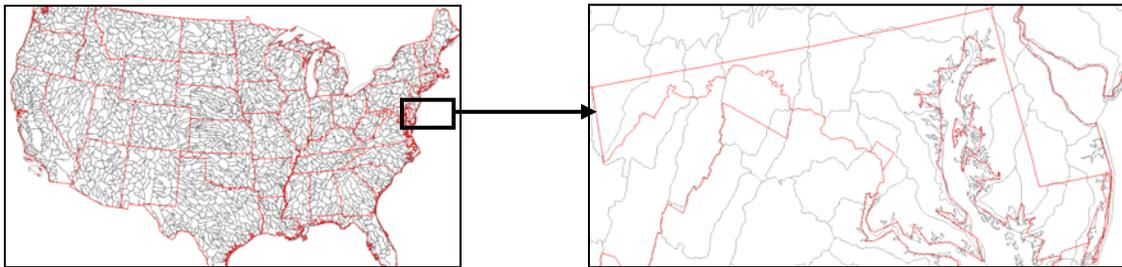
2. Select the cell in the “Hydrologic Unit (HUC-8)” column.

3. Click the “Select HUC-8s From Map” button, . The following window will appear.



Note: From this window, you can select one or more watersheds.

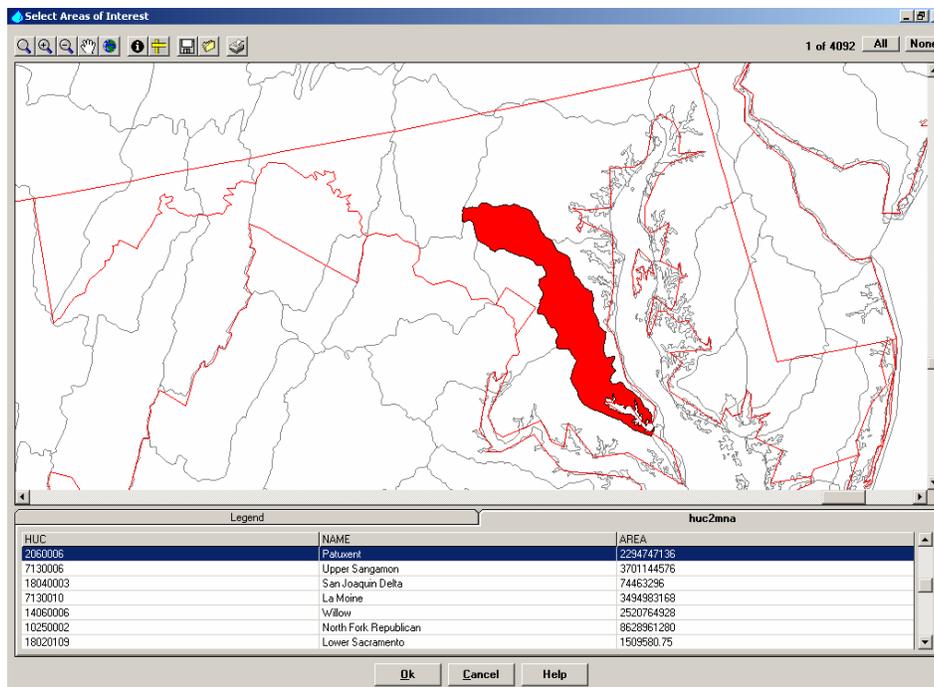
4. Use the “zoom” , “zoom in” , “zoom out” , and “pan”  buttons to zoom to Maryland.



5. Click NONE. This will unselect any watersheds you may have accidentally selected and will also return your cursor to “pointer” mode.

Note: You can also return the cursor to “pointer” mode by clicking whichever button is currently active. For example, if you have been using the “pan” tool, click on the “pan” button again to change the cursor mode back to “pointer.”

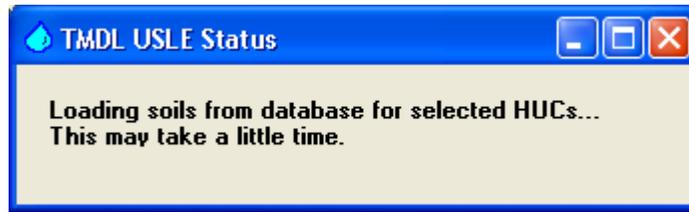
6. Click in the Western Patuxent watershed boundary (HUC # 02060006) to select it. Your screen should look similar to the following.



Note: The top record in the table below the map will be highlighted (blue). This indicates that you have selected the watershed corresponding to the HUC 02060006 (Patuxent).

7. Click OK to return to the main TMDL USLE screen.

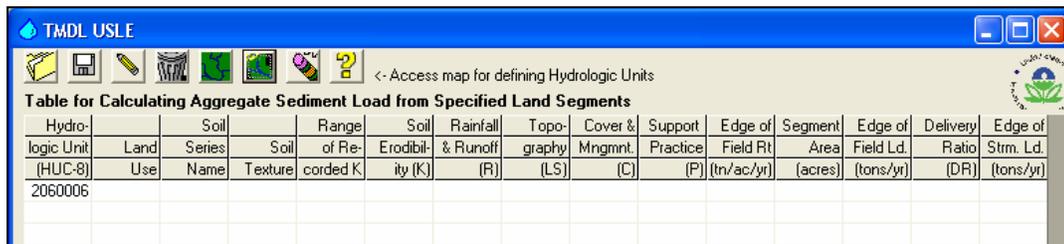
Note: A window will appear that informs you that the soils database for this cataloging unit is being loaded.



Define Aggregated Land Segments

The next step is to define the aggregated land segments. Ideally, you should determine each unique combination of land uses, soils, and cropping practices for which aggregated sediment load estimates will be performed in the watershed. In order to save time, we will calculate loads for each landuse on a basin wide scale. It would be more accurate to calculate loads by landuse within each subbasin. Our watershed has three land uses for which the USLE TMDL tool is applicable. Refer to the TMDL USLE User’s Manual for information detailing the landuses to which this tool applies. It is important to understand that the approaches shown below are not all inclusive. There are many ways to approximate these inputs. You need to check with your local NRCS to assist in regional parameters.

8. Click the “Add New Land Segment” button, . A new, blank record will appear in the table. Continue adding records by clicking the “Add New Land Segment” button until there are three blank records in the table (you will click the button a total of two times). The number “2060006” will be in the first cell of the first record. Your screen should look like the following:



9. In the “Land Use” column, create records for each land use in the Western Branch Patuxent watershed by double clicking inside the cell and selecting a pre-defined land use. The land uses for which we need to create records are as follows: Forest, Urban, Agriculture, and Barren.

Your table should look like the following:

Hydro-logic Unit (HUC-8)	Land Use	Soil Series Name	Soil Texture	Range of Re-corded K	Soil Erodibility (K)	Rainfall (R)	Topography (LS)	Cover & Mngmnt (C)	Support Practice (P)	Edge of Field Rt (tn/ac/yr)	Segment Area (acres)	Edge of Field Ld. (tons/yr)	Delivery Ratio (DR)	Edge of Strm. Ld. (tons/yr)
2060006	Forest													
	Urban Areas													
	Agriculture													
	Barren													

Populating USLE Input Requirements

- 10. Double click in the “Soil Series Name” column next to “Forest.” A drop down list should appear.
- 11. Choose the “Beltsville” option. Notice that once the “Soil Series Name” is selected that the “Range of Recorded K” and “Soil Erodibility” fields will be automatically populated.

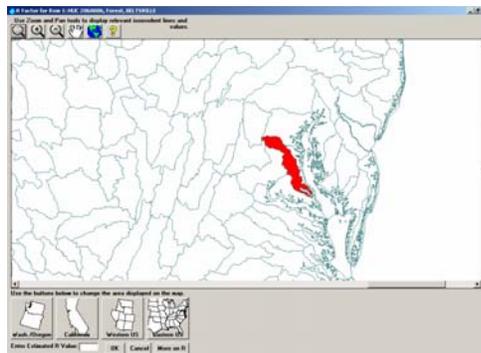
Note: If a representative “Soil Texture” was chosen, the “Range of Recorded K” would be much smaller. You may want to calculate “K” values using area weighted averages for each landuse within each model segment.

- 12. Repeat steps 10 -11 for each landuse.

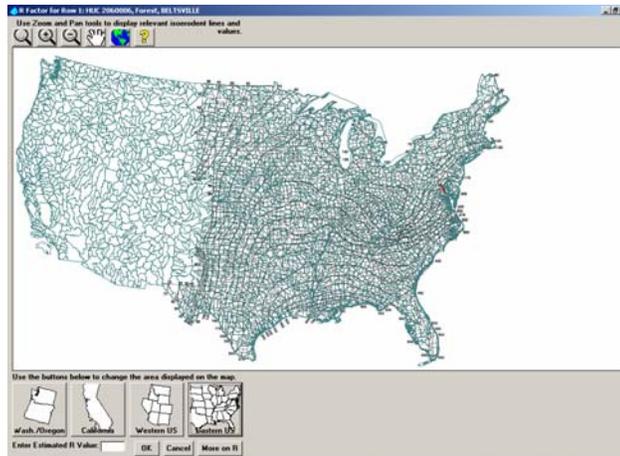
The next step is to estimate the Erosivity Factor (R).

- 13. Click in the first cell in the “Rainfall and Runoff (R)” column.

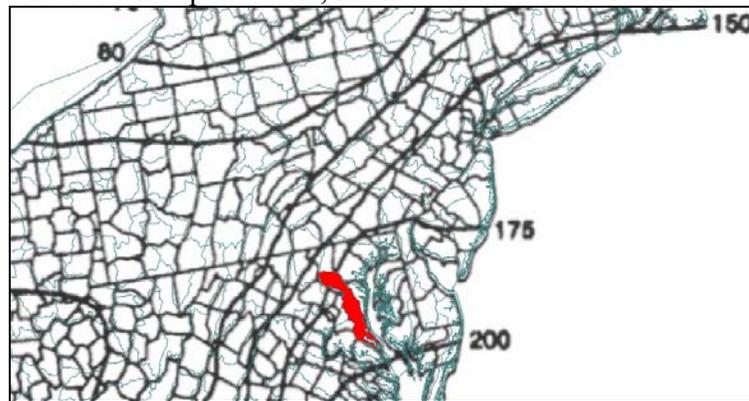
- 14. Click the “Assistance” button, . A map showing isoerodent regions will appear.



- 15. Click the “Eastern US” button, . Your screen will look similar to the following:



16. Using the “zoom” and “pan” tools, zoom to the Western Patuxent Watershed.



Look at the map. Notice that approximately 1/6 of the Western Patuxent watershed lies in the ‘R = 150’ region, and that the rest (5/6) lies within the ‘R = 175’ region. To determine an approximate R-value for the entire watershed, we will use a weighted average:

$$R = \frac{1(150) + 5(175)}{6}$$

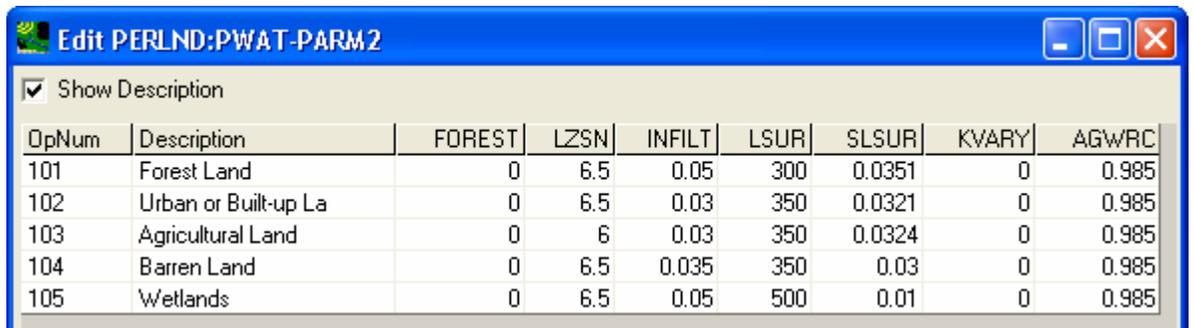
$$R \approx 170$$

17. In the “Enter Estimated R Value” box, type “170” and click OK to return to the main TMDL USLE window. The first cell in the “Rainfall and Runoff (R)” column will be populated with “170.”
18. Enter “170” in the remaining cells in the “Rainfall and Runoff (R)” column. Your table should look like the following:

Hydro-logic Unit (HUC-8)	Land Use	Soil Series Name	Soil Texture	Range of Re-ordered K	Soil Erodibility (K)	Rainfall Runoff (R)	Topography (LS)	Cover & Management (C)	Support Practice (P)	Edge of Field Rt (√ac/yr)	Segment Area (acres)	Edge of Field Ld. (tons/yr)	Delivery Ratio (DR)	Edge of Field Ld. (tons/yr)
2060006	Forest	BELTSVILLE		5- 0.49	0.31	170								
	Urban Areas	BELTSVILLE		5- 0.49	0.31	170								
	Agriculture	BELTSVILLE		5- 0.49	0.31	170								
	Barren	BELTSVILLE		5- 0.49	0.31	170								

We will now determine values for the Topography Factor (LS). The LS factor is estimated using the length and slope of the overland flow plane. Various approaches are used to estimate this factor. The local NRCS or SCS will have typical LS ranges used for the area by soil type. For this example, we will use the same values for slope and length that we used in the WinHSPF model. To find these values, open either *hyd_out.uci* or *sed.uci* in WinHSPF

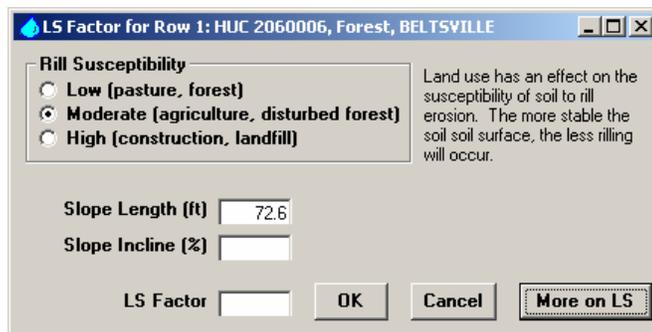
and click the “Input Data Editor” button, . **Double click** PERLND→ PWATER → PWAT – PARM2. The following window will appear:



OpNum	Description	FOREST	LZSN	INFILT	LSUR	SLSUR	KVARY	AGWRC
101	Forest Land	0	6.5	0.05	300	0.0351	0	0.985
102	Urban or Built-up La	0	6.5	0.03	350	0.0321	0	0.985
103	Agricultural Land	0	6	0.03	350	0.0324	0	0.985
104	Barren Land	0	6.5	0.035	350	0.03	0	0.985
105	Wetlands	0	6.5	0.05	500	0.01	0	0.985

Note: Recall that “LSUR” is the length of the assumed overland flow plane and that “SLSUR” is the slope of the assumed overland flow plane. We will use these values to calculate the values for LS.

- Click in the cell that corresponds to “Forest” and “Topography (LS)” and then click on the “Assistance” button, . The following window will appear:



LS Factor for Row 1: HUC 2060006, Forest, BELTSVILLE

Rill Susceptibility

Low (pasture, forest)
 Moderate (agriculture, disturbed forest)
 High (construction, landfill)

Land use has an effect on the susceptibility of soil to rill erosion. The more stable the soil surface, the less rilling will occur.

Slope Length (ft)

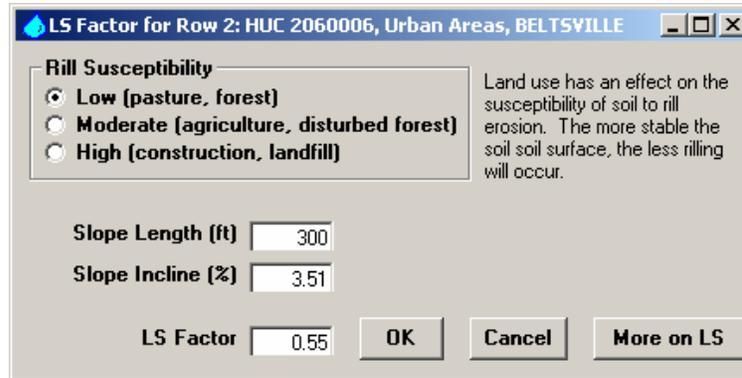
Slope Incline (%)

LS Factor

OK Cancel More on LS

- In the “Rill Susceptibility” box, be sure the “Low (pasture, forest)” option is selected.
- In the “Slope Length (ft)” box, enter “300.” This value was taken from the WinHSPF, “Edit PERLND:PWAT-PARM2” table, shown above.

22. In the “Slope Incline” box, enter “3.51.” The “LS Factor” box will now be populated.



23. Click OK to transfer the value to the main TMDL USLE table. Your screen should look like the following:

Hydrologic Unit (HUC-8)	Land Use	Soil Series	Soil Texture	Range of R-corded K	Soil Erodibility (K)	Rainfall & Runoff (R)	Topography (LS)
2060006	Forest	BELTSVILLE		0.15- 0.49	0.31	170	0.55
	Urban Areas	BELTSVILLE		0.15- 0.49	0.31	170	
	Agriculture	BELTSVILLE		0.15- 0.49	0.31	170	
	Barren	BELTSVILLE		0.15- 0.49	0.31	170	

Follow steps 19-22 in this section to calculate the LS factor for each land use. Use the information in the table below.

Land Use	Slope Length	Slope Incline	Rill Susceptibility
Forest	300	3.51	Low
Urban Areas	350	3.21	Low
Agriculture	350	3.24	Moderate
Barren	350	3	Moderate

Next, we will provide values for the “Cover and Management Factor (C).” This factor is highly variable within the literature. You can click on the “Assistance” button, , to read more about this parameter and receive guidance regarding appropriate values. Other suggested values are as follows:

- Open, Residential, and Commercial: $C \approx 0.15$
- Forest: $C \approx 0.01$
- Agriculture / Other: $C \approx 0.30$
- Barren $C \approx 0.30$

24. In the “Cover and Management” column, enter the following values:

Land Use	Cover and Management Factor
Forest	0.01
Urban Areas	0.15
Agriculture	0.30
Barren	0.30

We will now specify values for the “Support Practice Factor (P).”

25. For all land use categories, enter “1” as the “Support Practice Factor (P).”

Note: All “Support Practice Factors (P)” were assigned to 1 because, as discussed before, we are assuming that are for the time period we are simulating that there are no BMPs implemented.

Note: Notice that the “Edge of Field Rt” field is automatically populated.

The next step is to assign areas for each land use.

26. Enter the following values in the “Segment Area” column.

Land Use	Area
Forest	17320
Urban Areas	13414
Agriculture	21402
Barren	1420

Note: We obtained the area values from WinHSPF. In the WinHSPF interface, click on each reach segment until they are all selected. With the “Land Surface” tab active, select a land use category. The corresponding area will appear in the auxiliary table below the watershed schematic.

Note: Notice that the “Edge of Field Ld.” field is automatically populated.

27. Click in the first cell in the “Delivery Ratio (DR)” column. Click the “Assistance” button, .

Note: The Delivery Ratio (DR) will be used to estimate the fraction of gross sediment erosion occurring in a land segment that reaches the channel (RCHRES).

28. Review the three methods available for estimating Delivery Ratio. We will be using the method discussed in the lecture and described by the following equation (USDA-NRCS, 1983):

$$DR = 0.417762 * A^{-0.134958} - 0.127097$$

where:

DR = Delivery ratio and $DR \leq 1.0$

A = Watershed area in square miles

**Average Subbasin Area = 8948.53 acres
~ 14 mi²**

which means that the delivery ratio is 0.16.

29. Enter “0.16” in the “DR” column for each landuse. Your screen should look like the following:

Hydro-logic Unit (HUC-8)	Land Use	Soil Series Name	Soil Texture	Range of Re-sorted K	Soil Erodibility (K)	Rainfall (R)	Topography (LS)	Cover & Management (C)	Support Practice (P)	Edge of Field Rt (n/ac/yr)	Area (acres)	Edge of Field Ld (tons/yr)	Delivery Ratio (DR)	Edge of Stream Ld (tons/yr)
2060006	Forest	BELTSVILLE		5- 0.49	0.31	170	0.55	0.01	1	0.29	17320	5023	0.16	804
	Urban Areas	BELTSVILLE		5- 0.49	0.31	170	0.51	0.15	1	4.03	13414	54058	0.16	8649
	Agriculture	BELTSVILLE		5- 0.49	0.31	170	0.63	0.3	1	9.96	21402	213164	0.16	34106
	Barren	BELTSVILLE		5- 0.49	0.31	170	0.47	0.3	1	7.43	1420	10551	0.16	1688

Total Edge of Stream Sediment Load (tons/yr): 45247

Note: The following describes how the area was calculated using information available within BASINS or WinHSPF. Note that the accuracy of the calculations is dependent on the resolution of the data used to approximate the inputs (i.e., hydrography coverage, DEM).

Area = In BASINS, make sure the *Subbasins* theme is “on” and “active.”

Click the “Open Theme Table” button, . A table will appear with a field labeled “Area.” This field shows the area of each subbasin. Use the values in this column to calculate the **average** subbasin area (average = (area of subbasin 1 + area of subbasin 2 + + area of

subbasin n/n). These values are in hectares, so you will need to convert them to square miles.

30. Click the “Save Table” button, .

31. Navigate to `c:\basins\modelout\` and type “Sed_West.” Click SAVE.

Note: To retrieve this information during another session, click the Load Saved

Table  button and select the file to which you previously saved the information.

32. To create a report of the results and store it in a file, click the “Write Report” button, .

Note: Keep in mind that these are only initial targets and not necessarily achievable by the HSPF model and might require additional adjustment, depending on numerous factors including the obvious uncertainty in the USLE method and your selection of input parameters.

**Initial Land Use Specific Sediment Target
Loadings from USLE TMDL Tool**

Land Use	Edge of Field Load (tons/ac/yr)	Edge of Stream Load (tons/ac/yr)
Forest	0.29	0.046
Urban Areas	4.03	0.64
Agriculture	9.96	1.59
Barren	7.43	1.19
Wetlands	0	0

Note: The long-term average rainfall for this area is approximately 40 inches per year. Of the years simulated, 1997 best represents the average conditions with 38 inches of precipitation. Therefore, sediment loads from 1997 should be used in the comparison to the loads calculated using the TMDL USLE tool. Loads during years with more (or less) precipitation will likely result in much higher (or lower) sediment loads than those with average precipitation. The average simulated sediment load over the entire simulation period should be similar to the targets (especially if it extends over 5 years).

Remember that there is much uncertainty in these target rates, and you may only get within a factor of 2 to 5, (i.e. you may simulate lower rates in most cases) and still have a reasonable calibration based on instream concentrations. You need not go to extraordinary lengths to match the target values, especially if the instream data indicate otherwise.

References:

USDA-NRCS. 1983. Sediment sources, yields, and delivery ratios. Chapter 6 in *National Engineering Handbook*, Section 3, Sedimentation. U.S. Department Agriculture, Natural Resources Conservation Service formerly Soil Conservation Service (SCS), 6.2-6.19. U.S. Government Printing Office. Washington, D.C.