Exercise 9a – Sediment Erosion and Delivery

BASINS/HSPF Application Steps

Study Definition/Modeling Strategy	Timeseries Data Management	Parameter Development/Model Setup	Hydrologic Calibration/ Validation	Water Quality Calibration/ Validation	Scenario Analysis
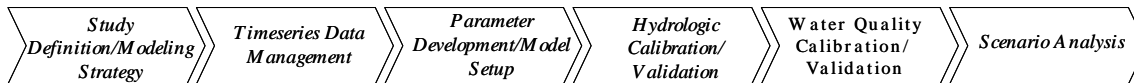
In Exercises 9a and 9b, we will add sediment erosion and transport to the West Branch Patuxent model (using an input file that has been calibrated for hydrology). Exercise 9a focuses on determining sediment loads from both pervious land segments and impervious land segments. Explanations are provided to help you estimate reasonable parameter inputs and to ensure that reasonable sediment loads are calculated. Exercise 9b will explain how to ensure that sediment routing in the stream is appropriate.

Questions addressed in this exercise:
1) How do I add sediment to my calibrated hydrology model?
2) How do I make sure I am getting reasonable sediment load estimates from individual land use segments?
3) Once I know the target loads for each landuse, how do I calibrate sediment erosion in WinHSPF?

A. Introduction to Sediment Modeling

Sediment from the land surface is one of the most common pollutants of waters from urban, agricultural, and forested lands. Sediment is important in water quality modeling because it muddies waters, covers fish eggs, and limits the capacity of reservoirs. It also transports nutrients and toxic chemicals.

Within WinHSPF, the SEDMNT module simulates the production and removal of sediment from a pervious land segment. Sediment can be considered as inorganic, organic, or both; the definition is up to the user.

Removal of sediment by water is simulated as a washoff process with two parts: 1) the detachment/attachment of sediment to and from the soil matrix and 2) the removal/transport of the sediment from a pervious land surface (*HSPF Manual*). These will be further discussed in Section C of this exercise.

B. Adding Sediment to Western Branch Model

QUESTION ANSWERED:
1) How do I add sediment to my calibrated hydrology model?

1.   From the **Start** menu under **Programs**, select **BASINS** and then **WinHSPF**.

2.   From the **File** menu, select **Open**.

3.   Navigate to *c:\basins\modelout\sediment* and **double click** the "*sed.uci*" file.

4.   Click the "Control Cards" button, .

5.   In the "Control Window Selection" box, click DESCRIPTIONS.

6.   Make sure the "Pervious Land" tab is selected. Check the box beside "SEDMNT –
        Production and Removal of Sediment."
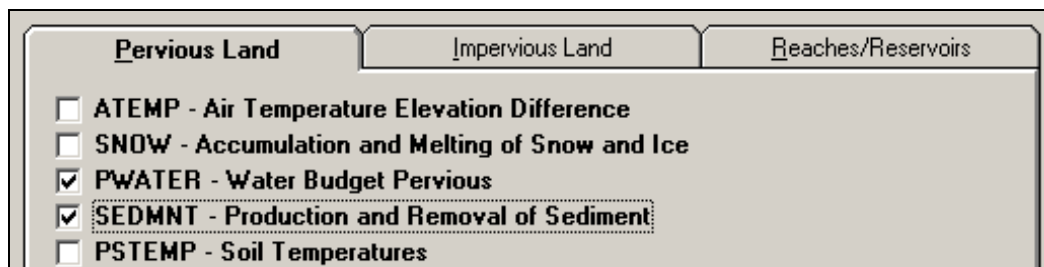
7.   Click the "Impervious Land" tab. Check the box beside "SOLIDS – Accumulation
   and Removal of Solids."
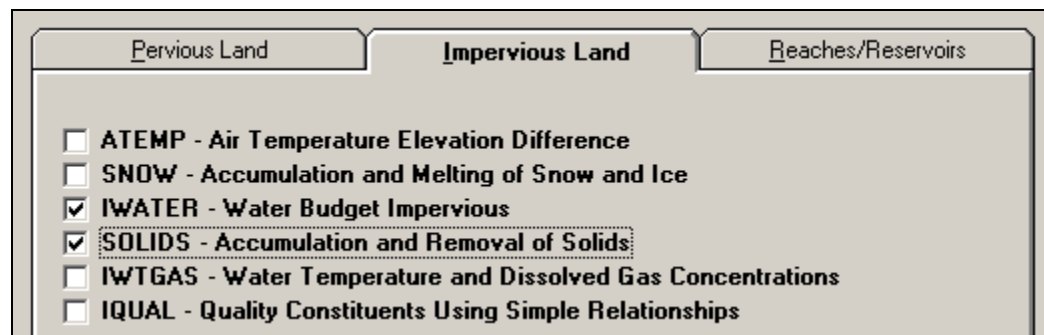
8.   Click the "Reaches/Reservoirs" tab.

9.   Check the box beside ADCALC.

        Note: The ADCALC module is required when modeling water quality constituents.

10.   Check the box beside "SEDTRN – Behavior of Inorganic Sediment."

11.   Click (un-check) the box beside "HTRCH – Heat Exchange and Water Temperature"
        to turn "off" the HTRCH module.

Note: When you selected SEDTRN, HTRCH was automatically turned "on" (checked) because an optional method for calculating sand transport requires water temperature (See *HSPF User's Manual, Version 12*). Since we will not be using this method, we can turn "off" (un-check) HTRCH. We will implement HTRCH in the fecal coliform exercise.

Your screen should look like the following:

12.   Click OK.

13.   When the following messages appear, click OK for each (you will click OK three times).
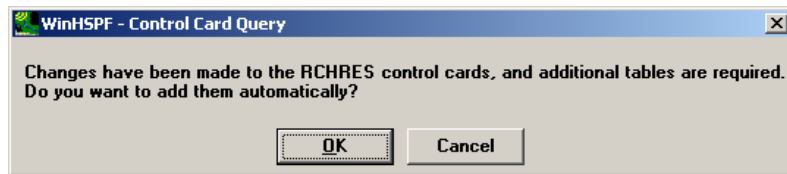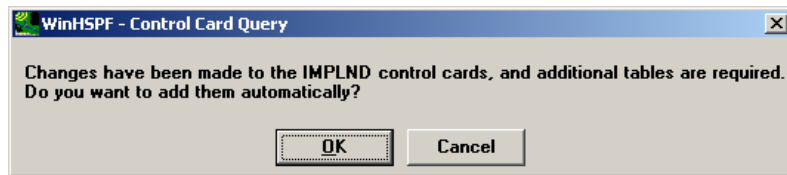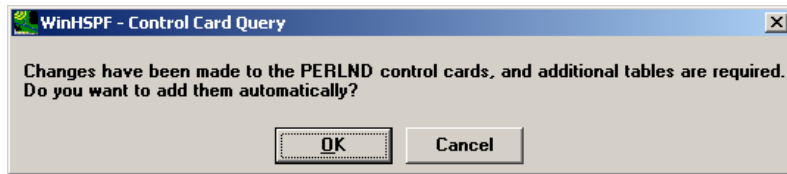
14.   Click the "Input Data Editor" button, .

Next, we will enter the required PERLND, IMPLND and RCHRES input values into the sediment-related tables.

PERLND Inputs

1.   **Double click** PERLND, SEDMNT, and then SED-PARM1 (PERLND → SEDMNT → SED-PARM1).

2.   If the following message box appears, click OK.

> **WinHSPF - Input Data Editor**   ×
>
> Table SED-PARM1 does not exist. Do you want to add it?
>
> [OK]   [Cancel]

The following table will appear: Look at the table and read the explanations below.

> **Edit PERLND:SED-PARM1**   _ □ ×
>
> ☑ Show Description

OpNum	Description	CRVFG	VSIVFG	SDOPFG
101	Forest Land	0	0	1
102	Urban or Built-up La	0	0	1
103	Agricultural Land	0	0	1
104	Barren Land	0	0	1
105	Wetlands	0	0	1

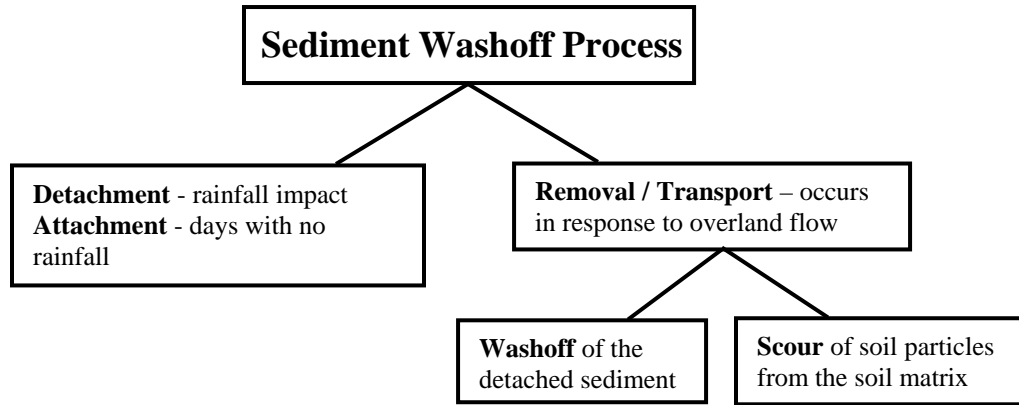*CRVFG – If CRVFG is 1, erosion-related cover may vary monthly.*
SDOPFG - If SDOPFG is 1, removal of sediment from the land surface will be simulated with the algorithm used in the predecessor models ARM and NPS. If it is 0, a different algorithm will be used.

3.   Click in the first cell in the "CRVFG" column. Enter "1" and **double click** the column heading to copy the value for the rest of the cells. This specifies that we will provide monthly values for "COVER." We will do this after we modify the SED-PARM tables.

> **Note:** We want to vary the erosion-related COVER values monthly in order to account for the variability of land cover in different seasons. Leave SDOPFG as 1. This selects a specific sediment removal algorithm.

4.   Click APPLY.

5.   Click OK.

Recall that in WinHSPF, the washoff process involves two parts: 1) the *detachment/ attachment* of sediment to and from the soil matrix, and 2) the *removal/transport* of the sediment from a pervious land surface. Detachment occurs by rainfall impact and attachment occurs on days when there is no rainfall. Removal/transport occurs in response to overland flow, and is modeled using two mechanisms: 1) washoff of the detached sediment and 2) scour of soil particles from the soil matrix (see diagram below) (*HSPF User's Manual, Version 12*).

```
                    ┌─────────────────────────────────┐
                    │    Sediment Washoff Process      │
                    └─────────────────────────────────┘
                        ╱                         ╲
        ┌───────────────────────────┐   ┌──────────────────────────────┐
        │ Detachment - rainfall     │   │ Removal / Transport – occurs  │
        │ impact                    │   │ in response to overland flow  │
        │ Attachment - days with no │   └──────────────────────────────┘
        │ rainfall                  │         ╱              ╲
        └───────────────────────────┘  ┌──────────────┐ ┌──────────────────┐
                                       │ Washoff of   │ │ Scour of soil    │
                                       │ the detached │ │ particles from   │
                                       │ sediment     │ │ the soil matrix  │
                                       └──────────────┘ └──────────────────┘
```

The following section is divided into three parts: *Detachment*, *Attachment*, and *Removal / Transport*.   Explanations are included to help you understand which parameters are associated with each process.

Sediment Detachment Parameters

1.   **Double click** SED-PARM2. The following window will appear. Look at the table and read the explanations provided below the table.
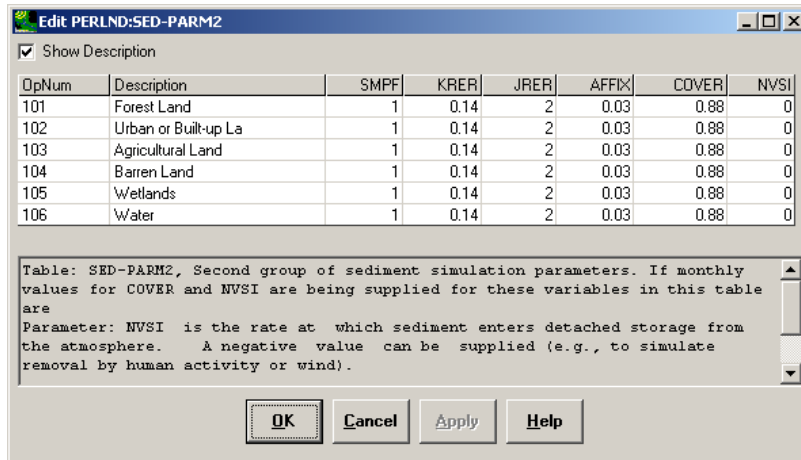
SMPF - A "supporting management practice factor." It is used to simulate the reduction in erosion achieved by use of erosion control practices.
KRER - The coefficient in the soil detachment equation.
JRER- The exponent in the soil detachment equation.
AFFIX - The fraction (first order rate) by which detached sediment storage decreases each day, as a result of soil compaction.
COVER - The fraction of land surface that is shielded from erosion by rainfall (not considering snow cover, which can be handled internally).
NVSI - The rate at which sediment enters detached storage from the atmosphere. A negative value can be supplied (e.g., to simulate removal by human activity or wind).

2.   Click in the first cell in the "KRER" column. Enter "0.325" and **double click** the column heading to copy the values to the rest of the cells.

Note: KRER is generally approximated by the K factor in the USLE, and then can be adjusted in calibration.

Note: We will leave the value of "SMPF" as "1" because there were no erosion control practices implemented in this watershed during the time period we are modeling. If a significant fraction of a land use segment had such erosion control practices, the SMPF value would be estimated given the sediment removal efficiency of the practice. We will leave the value of "JRER" (the exponent for rainfall intensity in the soil detachment equation) as "2.0." JRER is typically set to 2.0 based on evidence that soil splash is proportional to the square of rainfall intensity. Values in the range 2 - 3 have produced reasonable results for many watersheds.

Sediment Attachment Parameters

3.   Change the values in the "AFFIX" column to the following:

Land Use	AFFIX
PERLND 101 (Forest)	0.002
PERLND 102 (Urban)	0.01
PERLND 103 (Agriculture)	0.01
PERLND 104 (Barren Land)	0.008
PERLND 105 (Wetlands)	0.002

Note: AFFIX is a measure of the soil's tendency to undergo compaction. Forest soils are assumed to have more organic matter than other soils, and therefore resist compaction somewhat better. Urban and agricultural soils may have less organic material and are also subject to forces that encourage compaction, such as "traffic", crop growth, and excessive tillage, which tends to break down the soil structure. Typical values are in the range 0.01 – 0.1, tending toward the lower part of the range.

Note: We will leave the values in the "COVER" column as they are. Since we set CVRFG to "1" in the SED-PARM1 table, WinHSPF will use the monthly values for "COVER" in another table and disregard the values in this table.

4.   Change the values in the "NVSI" column to the following:

Land Use	NVSI
PERLND 101 (Forest)	2
PERLND 102 (Urban)	1
PERLND 103 (Agriculture)	2
PERLND 104 (Barren Land)	1
PERLND 105 (Wetlands)	2

Note: It is typical to use NVSI values within the range of 0.0 – 2.0 lbs/ac/day. This

parameter reflects the net amount of sediment deposited to (or removed from) a land segment due to wind, human activity, etc. A negative value indicates removal.

The "SED-PARM2" table should look like the following:

OpNum	Description	SMPF	KRER	JRER	AFFIX	COVER	NVSI
101	Forest Land	1	0.325	2	0.002	0.88	2
102	Urban or Built-up La	1	0.325	2	0.01	0.88	1
103	Agricultural Land	1	0.325	2	0.01	0.88	2
104	Barren Land	1	0.325	2	0.008	0.88	1
105	Wetlands	1	0.325	2	0.002	0.88	2

5.   Click APPLY.

6.   Click OK.

Sediment Removal/Transport Parameters

7.   **Double click** SED-PARM3. The following window will appear. Look at the table and read the parameter explanations below the table.

OpNum	Description	KSER	JSER	KGER	JGER
101	Forest Land	0.1	2	0.01	1
102	Urban or Built-up La	0.1	2	0.01	1
103	Agricultural Land	0.1	2	0.01	1
104	Barren Land	0.1	2	0.01	1
105	Wetlands	0.1	2	0.01	1

   KSER - The coefficient in the detached sediment washoff equation.
   JSER - The exponent in the detached sediment washoff equation.
   KGER - The coefficient in the matrix soil scour equation (simulates gully erosion).
   JGER - The exponent in the matrix soil scour equation (simulates gully erosion).

8.   Change the values in the "KSER" column to the following:

Land Use	KSER
PERLND 101 (Forest)	0.2
PERLND 102 (Urban)	0.1
PERLND 103 (Agriculture)	0.9
PERLND 104 (Barren Land)	0.2
PERLND 105 (Wetlands)	0.2

   Note: KSER is the primary sediment erosion calibration parameter. It encompasses the effects of several factors including slope, overland flow length, soil particle size, and roughness. Past applications of HSPF suggest values in the range of 0.1 – 5.0.

   Note: We will leave the values of "JSER" as "2." Past applications of HSPF suggest

values in the range of 1.5 – 2.5. JSER is a possible calibration parameter.

9. Click in the first cell in the "KGER" column. Enter "0" and **double click** the column heading to copy the value to the rest of the cells in the column.

10. Leave the values of "JGER" as "1."

The "SED-PARM3" table should look like the following:

OpNum	Description	KSER	JSER	KGER	JGER
101	Forest Land	0.2	2	0	1
102	Urban or Built-up La	0.1	2	0	1
103	Agricultural Land	0.9	2	0	1
104	Barren Land	0.2	2	0	1
105	Wetlands	0.2	2	0	1

Note: KGER is changed to 0 and JGER is left at 1 because there is little gully erosion occurring in this watershed.

11. Click APPLY.

12. Click OK.

13. **Double click** MON-COVER. Click OK if asked whether to add the table.

14. Add the following monthly values for "COVER," the fraction of the land surface shielded from rainfall by vegetation.

Land Use	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
PERLND 101 (Forest)	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
PERLND 102 (Urban)	0.90	0.90	0.90	0.91	0.93	0.93	0.93	0.93	0.93	0.91	0.90	0.90
PERLND 103 (Agriculture)	0.70	0.70	0.50	0.50	0.60	0.75	0.80	0.93	0.93	0.90	0.80	0.75
PERLND 104 (Barren Land)	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
PERLND 105 (Wetlands)	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97

Note: These values are based on site-specific conditions and the seasonal patterns affecting each landuse type. These values can be adjusted during calibration.

15. Click APPLY.

16. Click OK.

17. **Double click** SED-STOR. Click OK if asked whether to add the table.

Note: The values in this table specify the initial detached sediment storage in tons/acre. Storage provides an important source of sediment for erosion

during the first two months of our simulation.

18.   Enter the following values in the "DETS" column.

Land Use	DETS
PERLND 101 (Forest)	0.1
PERLND 102 (Urban)	0.4
PERLND 103 (Agriculture)	0.5
PERLND 104 (Barren Land)	0.4
PERLND 105 (Wetlands)	0.1

.

          Note: DETS is the initial storage of detached sediment in tons/acre. These values are representative of the conditions at the beginning of the simulation.

19.   Click APPLY.

20.   Click OK.

21.   **Double click** PERLND to contract the list.

IMPLND INPUTS

The parameters in this section are similar to those in the PERLND → SEDMNT section. The largest difference between modeling sediment removal for impervious land segments and modeling sediment removal for pervious land segments is the manner in which sediment accumulation is managed.

1.   **Double click** IMPLND → SOLIDS → SLD-PARM1. Click OK if asked whether to add the table.

2.   Change the value of "SDOPFG" to "1."

          Note: If the value of SDOPFG is 1, removal of sediment from the land surface will be simulated with the algorithm used in the predecessor NPS model. If it is 0, a different algorithm will be used.

3.   Click APPLY.

4.   Click OK.

5.   **Double click** SLD-PARM2. The following window will appear. Read the parameter explanations provided below.
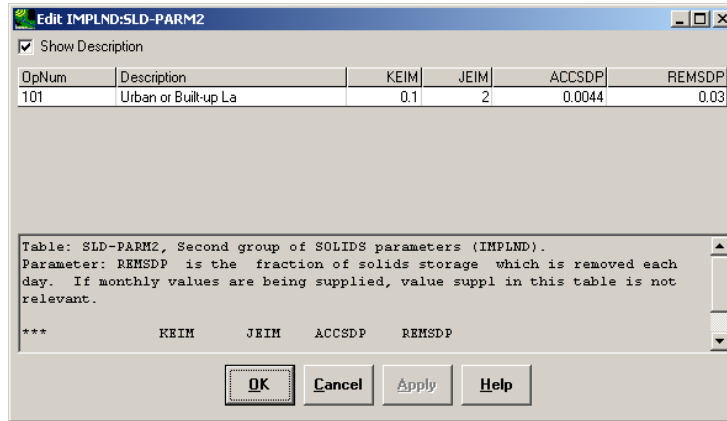
KEIM - The coefficient in the solids washoff equation.
JEIM - The exponent in the solids washoff equation.
ACCSDP - The rate at which solids accumulate on the land surface. If monthly values are being
     supplied, the value supplied in this table is not relevant.
REMSDP - The fraction of solids storage that is removed each day. If monthly values are being
     supplied, the value supplied in this table is not relevant.

Sediment Washoff Parameters

6.   Look at the values for JEIM and KEIM. We will leave them as the defaults. These are potential calibration parameters that you may choose to adjust later.

   Note: JEIM approximates the relationship between runoff intensity and sediment transport capacity; i.e., higher values of JEIM will produce an increased transport capacity. Typically, JEIM values are in the range 1.0-2.5, and previous experience suggests that most often values in the range 1.6-2.0 are appropriate. KEIM is a coefficient that represents the combined effects of slope, overland flow length, particle size, and surface roughness into a single calibration parameter. Previous experience indicates values in the range 0.05-5.0. Since it is a calibration parameter, choose an initial value near the middle of this range (Donigian and Crawford, 1976).

Sediment Accumulation and Removal Parameters

7.   Change the value of "ACCSDP" to "0.0005."

   Note: The units of ACCSDP are tons/acre/day.

   Note: Impervious accumulation rates are generally greater than on pervious areas, and vary in the range 0.5-100 lbs/acre/day (0.00025-0.05 tons/acre/day). For this application, we will use 1 lb/acre/day or 0.0005 tons/acre/day. Generally, if data are not available for the watershed in question, literature values must be used. Usually, such accumulation rates are presented in terms of lbs/day per mile of curb length, and will need to be converted using an estimate of curb length per acre.

8.   Look at REMSDP. We will leave the value as 0.03.

> **Note:** This value should be estimated. It is important to understand that REMSDP (removal of solids) and ACCSDP (accumulation of solids) are correlated and that the values chosen for these parameters must provide for a reasonable amount of sediment available for wash off. In other words, you need to ensure that you do not effectively generate several inches of sediment on the surface, or that the removal rate prevents any buildup of sediment.

The "SLD-PARM2" table should look like the following:

OpNum	Description	KEIM	JEIM	ACCSDP	REMSDP
101	Urban or Built-up La	0.1	2	0.0005	0.03

9.   Click APPLY.

10.   Click OK.

11.   **Double click** SLD-STOR. Click OK if asked whether to add the table.

12.   Change the value of "SLDS" to "0.005." This is the initial storage of solids in tons/acre.

13.   Click APPLY.

14.   Click OK.

15.   **Double click** IMPLND to contract the list.

RCHRES INPUTS

In our sediment model, we have focused on sediment transport through overland flow; however, sediment routing through the reaches is also important. We need to adjust many values in the RCHRES section so that we can accurately simulate sediment transport within and through the channels. We will address this topic briefly in this section, and discuss it in further detail in Exercise 8b.

1.   **Double click** RCHRES → SEDTRN → SANDFG. Click OK if asked whether to add the table.

> **Note:** The value of SANDFG indicates which method will be used for sand load simulation; a value of "1" specifies Toffaleti method, a value of "2" specifies the Colby method, and 3 specifies the power function method.

2.   We will leave the value of SANDFG as 3 since we want to use the power function for simulation. Click CANCEL.

3.   **Double click** SED-GENPARM. Read the following explanations:

    BEDWID - The width of the cross-section over which HSPF will assume bed sediment is deposited regardless of stage, top-width, etc. It is used to estimate the depth of bed sediment.
    BEDWRN - The bed depth which, if exceeded (e.g., through deposition) will cause a warning message to be printed.
    POR - The porosity of the bed (void volume/total volume). It is used to estimate bed depth.

4.   Click in the first cell in the "BEDWID" column. Enter "30" and **double click** the column heading to copy the value to the rest of the cells.

    Note: BEDWID is the approximate width of the channel (in feet) that sediment will be deposited to. For a rectangular channel it is the width of the channel. For a trapezoidal channel it is the width of the base.

5.   Change each value of "BEDWRN" to "6." This specifies that if our simulation results in more than six feet of bed being scoured, a warning will be shown.

    Note: Leave the value of "POR" at "0.5."

6.   Click APPLY.

7.   Click OK.

8.   **Double click** SAND-PM. Read the explanations below.

    D - The effective diameter of the transported sand particles. Note that the transport formulae do not actually use D (they use DB50, supplied in Table-type HYDR-PARM2). D is included here for consistency with the input data supplied for cohesive sediment.
    W - The fall velocity of transported sand particles in still water.
    RHO - The density of the sand particles.
    KSAND - The coefficient in the sand load power function formula.
    EXPSND - The exponent in the sand load power function formula.

9.   Change all values of "D" to "0.005."

10.   Change all values of "W" to "0.02."

11.   Change all values of "RHO" to "2.5."

    Note: The D, W, and RHO values can be obtained (or calculated) from texts on sedimentation/hydrology or from particle size analysis of sediments in your watershed.

Note: Leave the value of KSAND as 0.1.

12.   Change each value of "EXPSND" to "2."

        Note: KSAND and EXPSND are calibration parameters. Suggested starting values
                are ≈0.1 for KSAND and ≈2.0 for EXPSND.

        The "SAND-PM" table should look like the following:

OpNum	Description	D	W	RHO	KSAND	EXPSND
1	Western Branch Patux	0.005	0.02	2.5	0.1	2
2	Southwest Branch Wes	0.005	0.02	2.5	0.1	2
3	South Collington Bra	0.005	0.02	2.5	0.1	2
4	South Reach, Western	0.005	0.02	2.5	0.1	2
5	Western Branch Patux	0.005	0.02	2.5	0.1	2
6	North Collington Bra	0.005	0.02	2.5	0.1	2

13.   Click APPLY.

14.   Click OK.

15.   Double click SILT-CLAY-PM. Read the explanations provided below.

        D - The effective diameter of the particles.
        W - The fall velocity of the particles in still water.
        RHO - The density of the particles.
        *TAUCD - The critical bed shear stress for deposition. Above this stress, there will be no deposition; as
            the stress drops below this value to zero, deposition will gradually increase to the value implied by
            the fall velocity in still water.*
        *TAUCS -T he critical bed shear stress for scour. Below this value, there will be no scour; above it,
            scour will steadily increase. In general TAUCD should be less than or equal to TAUCS.*
        M - The erodibility coefficient of the sediment.

        Note: Initial values of the TAUCS and TAUCD parameters should be estimated by
                examining graphs of the simulated shear stress (timeseries name = TAU). For
                each reach, you should assign a value below the maximum of the curve for
                TAUCS and a value above the minimum of the curve for TAUCD. This
                process will be discussed in detail in Exercise 8b.

        Note: M is a calibration parameter.

16.   Make sure that "1" appears in the "Occurrence" box. Change the values of "D" to
        "0.0004" (remember to **double click** the column heading to copy down the values).

17.   Click in the first cell in the "W" column. Change all values of "W" to "0.0003."

18.   Change all values in the "RHO" column to "2.2."

19.   Leave the default values for "TAUCD" and "TAUCS. We will address these
        parameters in the following exercise.

20.   Change each value of "M" to "0.01."

        The "SILT-CLAY-PM" (Occurrence 1) table should look like the following:

OpNum	Description	D	W	RHO	TAUCD	TAUCS	M
1	Western Branch Patux	0.0004	0.0003	2.2	0.1	0.3	0.01
2	Southwest Branch Wes	0.0004	0.0003	2.2	0.1	0.3	0.01
3	South Collington Bra	0.0004	0.0003	2.2	0.1	0.3	0.01
4	South Reach, Western	0.0004	0.0003	2.2	0.1	0.3	0.01
5	Western Branch Patux	0.0004	0.0003	2.2	0.1	0.3	0.01
6	North Collington Bra	0.0004	0.0003	2.2	0.1	0.3	0.01

21.   Click APPLY.

22.   In the "Occurrence" box, select "2."

23.   Change all values in the "D" column to "0.0001."

24.   Change all values in the "W" column to "0.00001."

25.   Change all values in the "RHO" column to "2."

26.   Leave the default values for "TAUCD" and "TAUCS.

27.   Change each value in the "M" column to "0.01."

        The "SILT-CLAY-PM" (Occurrence 2) table should look like the following:

OpNum	Description	D	W	RHO	TAUCD	TAUCS	M
1	Western Branch Patux	0.0001	0.00001	2	0.1	0.3	0.01
2	Southwest Branch Wes	0.0001	0.00001	2	0.1	0.3	0.01
3	South Collington Bra	0.0001	0.00001	2	0.1	0.3	0.01
4	South Reach, Western	0.0001	0.00001	2	0.1	0.3	0.01
5	Western Branch Patux	0.0001	0.00001	2	0.1	0.3	0.01
6	North Collington Bra	0.0001	0.00001	2	0.1	0.3	0.01

28.   Click APPLY.

29.   Click OK

Next, we will specify the water column's initial concentrations (mg/L) of suspended
sediment for sand, silt, and clay.

30.   **Double click** SSED-INIT. Click OK if asked whether to add the table. Read the

explanations below.

SSED1 - The initial concentration (in suspension) of sand.
SSED2 - The initial concentration (in suspension) of silt.
SSED3 - The initial concentration (in suspension) of clay.

31. Change each value of "SSED1" to "5."

32. Change each value of "SSED2" to "25."

33. Change each value of "SSED3" to "25."

34. Click APPLY.

35. Click OK.

36. **Double click** BED-INIT. Click OK if asked whether to add the table. Read the explanations below.

BEDDEP - The initial total depth (thickness) of the bed.
SANDFR - The initial fraction (by weight) of sand in the bed material.
SILTFR - The initial fraction (by weight) of silt in the bed material.
CLAYFR - The initial fraction (by weight) of clay in the bed material.

Note: The sum of the three fractions must be 1.00
(SANDFR + SILTFR + CLAYFR = 1.0)

37. Change each value of "BDDEP" to "2."

38. Change each value of "SANDFR" to "0.8."

39. Change each value of "SILTFR" to "0.1."

40. Change each value of "CLAYFR" to "0.1."

41. Click APPLY.

42. Click OK.

43. Click Close.

A. Determining Sediment Loads for Land Use Segments

QUESTION ANSWERED:

2) How do I make sure I am getting reasonable sediment load estimates from individual land use segment?

1.   Click the "Output Manager" button, ⊞.

2.   Click the button beside "Other."
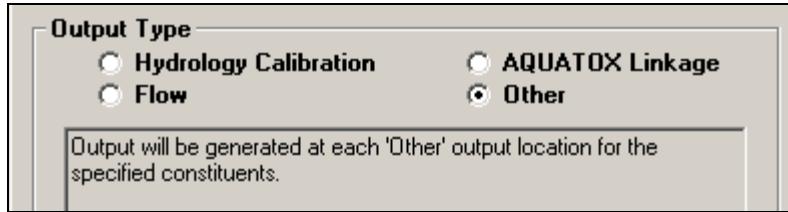
3.   Click ADD.

4.   In the "Operation" window, select "PERLND 101 (Forest Land)."

5.   In the "Group/Member" window, select "SEDMNT:SOSED." Your screen should look like the following:
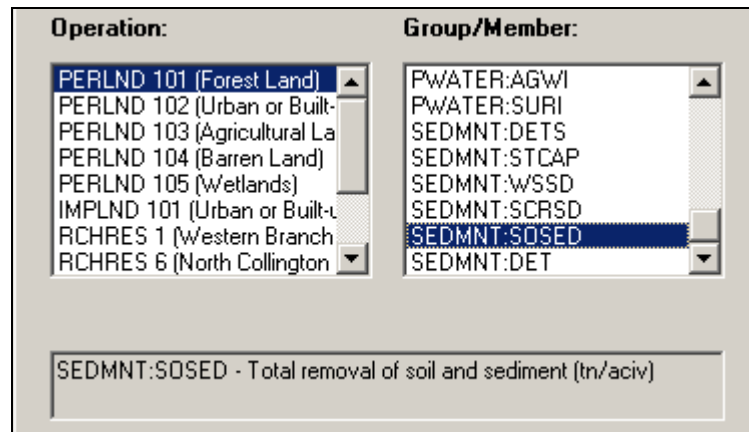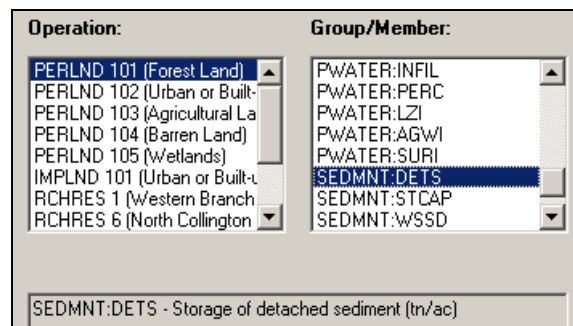

6.   Click OK.

7.   Repeat steps 3-6 for PERLND 102 (Urban or Built-Up Land), PERLND 103 (Agricultural Land), PERLND 104 (Barren Land), and PERLND 105 (Wetlands).

8.   Click ADD.

9.   In the "Operation" box, select "IMPLND 101 (Urban or Built-Up Land)."

10.   In the 'Group/Member:" box, select "SOLIDS:SOSLD." Your screen should look like the following:
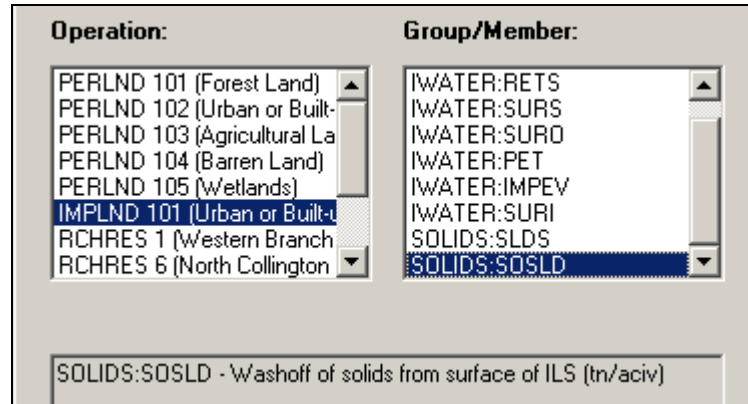
11.   Click OK. Your screen should look like the following:
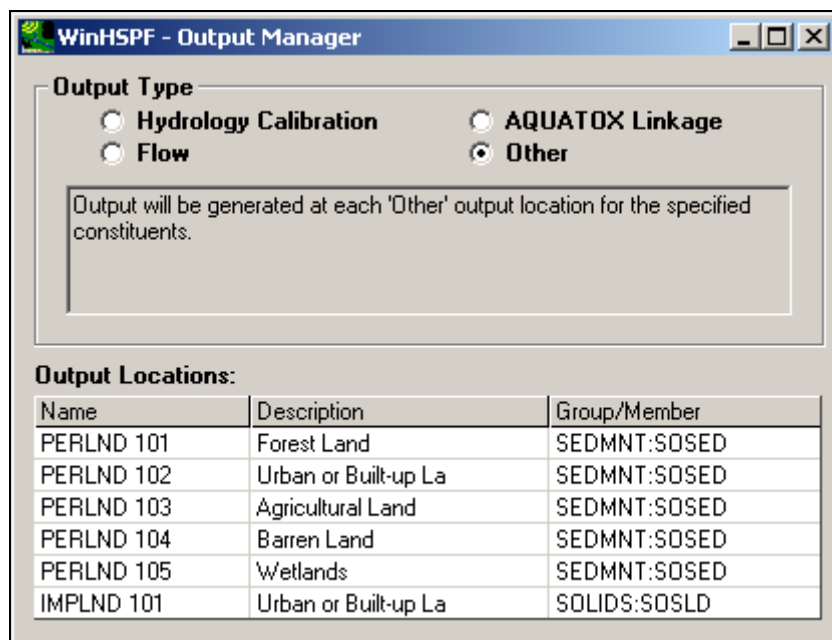
12.   Following Steps 3 - 6, add "SEDMNT:DETS" for all five pervious land segments (PERLNDs 101-105).

13.   For "IMPLND 101," add "SOLIDS:SLDS."
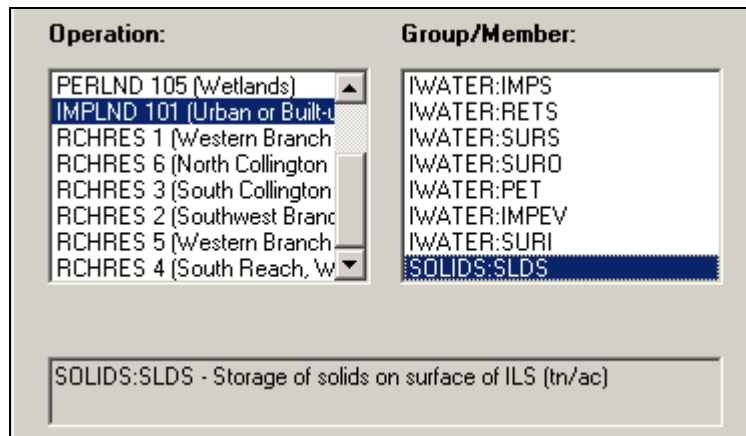
14.   Click OK. The "Output Manager" table should look like the following:

15.   Click CLOSE to exit the Output Manager.

16.   Click the "Input Data Editor" button, .

17.   **Double click** EXT TARGETS. Notice that each of the time series you specified in
        the Output Manager is listed in this table.

VolName	VolId	Group	MemName	MemSub1	MemSub2	MultFact	Tran	VolName	VolId	MemName	Qflag	TSystem	AggrStr	AmdStr
PERLND	101	SEDMNT	SOSED	1	1	1	AVER	WDM1	1001	SOSED	1	ENGL	AGGR	REPL
PERLND	101	SEDMNT	DETS	1	1	1	AVER	WDM1	1007	DETS	1	ENGL	AGGR	REPL
PERLND	102	SEDMNT	SOSED	1	1	1	AVER	WDM1	1002	SOSED	1	ENGL	AGGR	REPL
PERLND	102	SEDMNT	DETS	1	1	1	AVER	WDM1	1008	DETS	1	ENGL	AGGR	REPL
PERLND	103	SEDMNT	SOSED	1	1	1	AVER	WDM1	1003	SOSED	1	ENGL	AGGR	REPL
PERLND	103	SEDMNT	DETS	1	1	1	AVER	WDM1	1009	DETS	1	ENGL	AGGR	REPL
PERLND	104	SEDMNT	SOSED	1	1	1	AVER	WDM1	1004	SOSED	1	ENGL	AGGR	REPL
PERLND	104	SEDMNT	DETS	1	1	1	AVER	WDM1	1010	DETS	1	ENGL	AGGR	REPL
PERLND	105	SEDMNT	SOSED	1	1	1	AVER	WDM1	1005	SOSED	1	ENGL	AGGR	REPL
PERLND	105	SEDMNT	DETS	1	1	1	AVER	WDM1	1011	DETS	1	ENGL	AGGR	REPL
IMPLND	101	SOLIDS	SOSLD	1	1	1	AVER	WDM1	1006	SOSLD	1	ENGL	AGGR	REPL
IMPLND	101	SOLIDS	SLDS	1	1	1	AVER	WDM1	1012	SLDS	1	ENGL	AGGR	REPL

18.   For each PERLND SOSED record and for each IMPLND SOSLD record, change the value in the column "Tran" to "SUM" by **Double clicking** on each cell until a pull-down menu appears and selecting "SUM."

> **Note**: Remember that the model is running on an hourly time step, but we generally look at the daily output. The user, therefore, needs to specify how they want to view the hourly output in a daily format. For example, you may be interested in writing out the daily maximum ("MAX" transformation) or daily minimum ("MIN" transformation). You may also be interested in writing out the daily average ("AVE" transformation) or the daily sum ("SUM" transformation).
>
> In this case, the "SUM" transformation is applied to the SOSED or SOSLD output time series so that the model output will be written out as the sum of the sediment loading per day for each PERLND or IMPLND. We chose the "SUM" transformation because we want to determine the total daily load (or sum) instead of the average daily load. In the case of DETS, we are interested in understanding the average daily storage of detached sediment, so we will leave the transformation as "AVER" or average. The possible transform functions are defined as follows (Bicknell, et al., 2000): *AVER (average), DIV (divide), INTP (interpolate), LAST, MAX (maximum), MIN (minimum), SAME,* and *SUM.*

Your screen should look like the following:

| VolName	VolId	Group	MemName	MemSub1	MemSub2	MultFact	Tran	VolName	VolId	MemName	Qflag	TSystem	AggrStr	AmdStr
PERLND	101	SEDMNT	SOSED	1	1	1	SUM	WDM1	1001	SOSED	1	ENGL	AGGR	REPL
PERLND	101	SEDMNT	DETS	1	1	1	AVER	WDM1	1007	DETS	1	ENGL	AGGR	REPL
PERLND	102	SEDMNT	SOSED	1	1	1	SUM	WDM1	1002	SOSED	1	ENGL	AGGR	REPL
PERLND	102	SEDMNT	DETS	1	1	1	AVER	WDM1	1008	DETS	1	ENGL	AGGR	REPL
PERLND	103	SEDMNT	SOSED	1	1	1	SUM	WDM1	1003	SOSED	1	ENGL	AGGR	REPL
PERLND	103	SEDMNT	DETS	1	1	1	AVER	WDM1	1009	DETS	1	ENGL	AGGR	REPL
PERLND	104	SEDMNT	SOSED	1	1	1	SUM	WDM1	1004	SOSED	1	ENGL	AGGR	REPL
PERLND	104	SEDMNT	DETS	1	1	1	AVER	WDM1	1010	DETS	1	ENGL	AGGR	REPL
PERLND	105	SEDMNT	SOSED	1	1	1	SUM	WDM1	1005	SOSED	1	ENGL	AGGR	REPL
PERLND	105	SEDMNT	DETS	1	1	1	AVER	WDM1	1011	DETS	1	ENGL	AGGR	REPL
IMPLND	101	SOLIDS	SOSLD	1	1	1	SUM	WDM1	1006	SOSLD	1	ENGL	AGGR	REPL
IMPLND	101	SOLIDS	SLDS	1	1	1	AVER	WDM1	1012	SLDS	1	ENGL	AGGR	REPL

19.   Click APPLY.

20.   Click OK to exit the external targets table.

21.   Click CLOSE to exit the Input Data Editor.

22.   Click ▤↓ (Run HSPF).

23.   Click SAVE/RUN. The following window will appear, indicating that HSPF is
        executing.
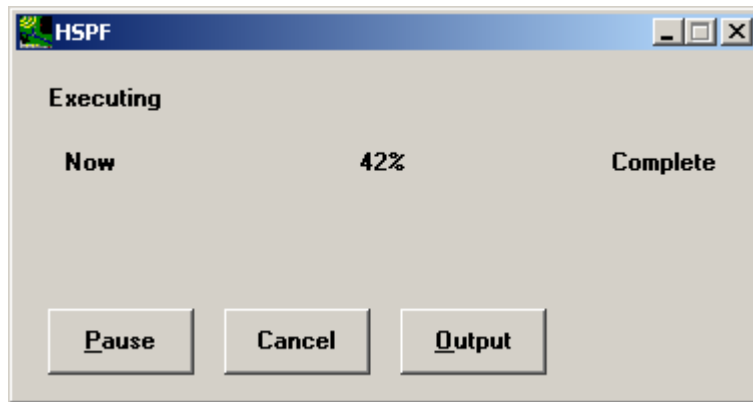
24.   Click the "View Output through GENSCN" button, ▦.

25.   Click the "HSPF Output" tab.

26.   Check the box beside "*c:\BASINS\modelout\sediment.wdm*" and click OK. The
        GenScn window will open.

27.   In the "Scenarios" frame, select "Sed."

28.   In the "Constituents" frame, select "SOSED" and "SOSLD."

29.   Click ➕ (Add to Time Series List). The following 6 time series should appear in
        the Time Series list.

30.   In the "Dates" frame, select "Sum/Div" from the "TStep, Units" menu.

31.   Two new boxes will appear above the "Sum/Div" box. Leave the left box as "1" and select "Year" in the right box.

31.   In the "Dates" frame, change the current "Start" date to "1/1/1986."

32.   In the "Dates" frame, change the current "End" date to "12/31/1988." The "Dates" frame should look like the following:

33.   In the "Time Series" frame, select all six "Sed" time series by holding the SHIFT key while you click each series (they will turn blue when selected).

34.   Click the "Generate Graphs" button, .

35.   Make sure "Standard" is checked and click GENERATE. Your plot should look similar to the following:

Analysis Plot for YEARLY SUMMED SED
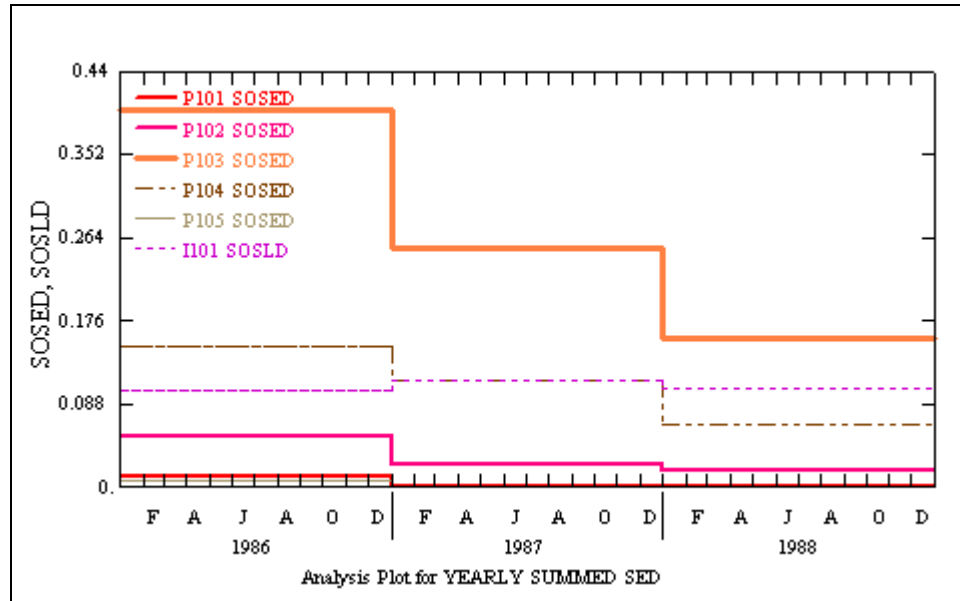
> **Note:** Notice that the highest loads (tons/acre/yr) are coming from P103 (agriculture land) and that other high loads are coming from P104 (barren land) and I101 (Impervious land).

36.   Close the graph.

37.   Make sure that all time series are still selected (blue) and click the "List Time Series Values" button [111 222]. The following table will appear:

Scenario	SED	SED	SED	SED	SED	SED
Location	P101	P102	P103	P104	P105	I101
Constituent	SOSED	SOSED	SOSED	SOSED	SOSED	SOSLD
1986	0.0111	0.0528	0.400	0.148	0.00711	0.102
1987	0.00036	0.0240	0.254	0.112	0.000160	0.112
1988	0.00040	0.0180	0.157	0.0668	0.000139	0.104

Look at the yearly values of sediment load (tons/acre/year) for individual land use segments.

C. Developing Calibration Targets with the USLE TMDL Tool

QUESTION ANSWERED:
3) Once I know the target loads for each landuse, how do I calibrate sediment erosion in WinHSPF?

Appendix E discusses using and populating the USLE TMDL Tool. We used this tool to help us estimate sediment loads from pervious land segments for the Western Branch of the Patuxent. The following loads will be the target values for our model.

> **Note:** "Target loads" are the values we would like our model to produce. We will adjust various parameters in an effort to make our calculated loads resemble those in the table below. Keep in mind that these are merely initial targets and there are large amounts of uncertainty associated with them.

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 (P101)	0.29	0.046
Urban Areas (P102)	4.03	0.64
Agriculture (P103)	9.96	1.59
Barren (P104)	7.43	1.19

> **Note:** The "Edge of Field" load is the estimated loading for an acre of its corresponding land use segment *at the location of the land segment*. The "Edge of Stream" load takes into account transport, and is an estimate of the actual (adjusted) loading into the stream. We will compare our model results with the "Edge of Stream" loads.

The long-term average rainfall for this subwatershed is approximately 40 inches per year. Of the years simulated, 1987 best represents the average conditions with 38 inches of precipitation. We will therefore compare the estimated sediment loads from 1987 with the loads calculated by the USLE tool. The estimated loads for years with more (or less) precipitation will likely be higher (or lower) than years with average precipitation.

## D. Sediment Erosion Calibration in HSPF (PERLND/IMPLD)

Compare the USLE tool target loads to the loads estimated by our model:

Land Use	USLE tool Edge of Stream Load (tons/ac/yr)	WinHSPF (tons/ac/yr)
Forest (P101)	0.046	0.0004
Urban Areas (P102)	0.64	0.0240
Agriculture (P103)	1.59	0.2540
Barren (P104)	1.19	0.1120

Notice that we are underestimating loads from all pervious land segments. We will adjust the value of KSER (a key sediment calibration parameter) in an effort to increase loads from the pervious land segments.

1.   Click the "Input Data Editor" button, 🖩.

2.   **Double click** PERLND → SEDMNT → SED-PARM3.

3.   Change the values in the "KSER" column to "5."

4.   Click APPLY.

5.   Click OK.

6.   Click CLOSE.

7.   Click ▤↓ (Run HSPF).

8.   Click the "View Output through GENSCN" button, ▮▮.

9.   In the "Scenarios" frame, select "Sed."

10.   In the "Constituents" frame, select "SOSED" and "SOSLD."

11.   Click ➕ (Add to Time-Series List). The following six time series will appear in
        the "Time Series" list.

12.   In the "Dates" frame, select "Sum/Div" from the "TStep, Units" menu.

13.   Two new boxes will appear above the "Sum/Div" box. Leave the left box as "1" and
        select "Year" in the right box.

14.   In the "Dates" frame, change the current "Start" date to "1986/1/1."

15.   In the "Dates" frame, change the current "End" date to "1988/12/31."

16.   In the "Time Series" frame, select all six "Sed" time series by holding the SHIFT key while you click each series (they will turn blue when selected).

17.   Click the "List Time Series Tool," [111/222]. The following table will appear:

Scenario	SED	SED	SED	SED	SED	SED
Location	P101	P102	P103	P104	P105	I101
Constituent	SOSED	SOSED	SOSED	SOSED	SOSED	SOSLD
1986	0.276	0.226	0.483	0.955	0.178	0.102
1987	0.0091	0.279	0.688	1.23	0.0040	0.112
1988	0.0100	0.209	0.499	0.902	0.0035	0.104

Compare these load estimates (for 1987) with the loads calculated by the TMDL USLE tool:

Land Use	USLE tool Edge of Stream Load (tons/ac/yr)	WinHSPF (tons/ac/yr)
Forest (P101)	0.046	0.0091
Urban Areas (P102)	0.64	0.279
Agriculture (P103)	1.59	0.688
Barren (P104)	1.19	1.23

We have now increased the loads as much as we can by maximizing KSER within the expected range. By doing this, we have maximized the amount of sediment transport from each landuse. Many of the loads from various landuses, however, are still too low. In addition to looking at sediment loads from land use segments, it is important to plot SLDS and DETS (sediment availability on pervious segments and impervious segments, respectively) to determine the amount of fines (sediment material) available for washoff from various land use segments during the simulation period. If there aren't sufficient simulated fines available, our model will be unable to accurately simulate washoff. In other words, there has to be something to wash off in order to wash it off. In the following steps, we will plot "DETS" and "SOSED" for agriculture land (PERLND 103) to determine whether we are accurately simulating the fines for the agriculture land segment.

18.   In the "Constituents" frame, select "DETS" and "SOSED."

19.   Click the "Add to Time Series List" button, [+]. Six new DETS time series will appear in the "Time Series" frame.

20.   In the "Dates" frame, change the current "Start" date to "1987/1/1."

21.   Change the current "End" date to "1987/12/31."

22.   In the "Dates" frame, make sure the "TStep, Units" is "Native."

> **Note:** We will look at the loadings for 1987 because its precipitation is most similar
>   to the long-term yearly average.

23.   Hold down the CTRL key while you select the P103 "DETS" and "SOSED" time
       series.

24.   Click ▮▮▮ (Generate Graphs).
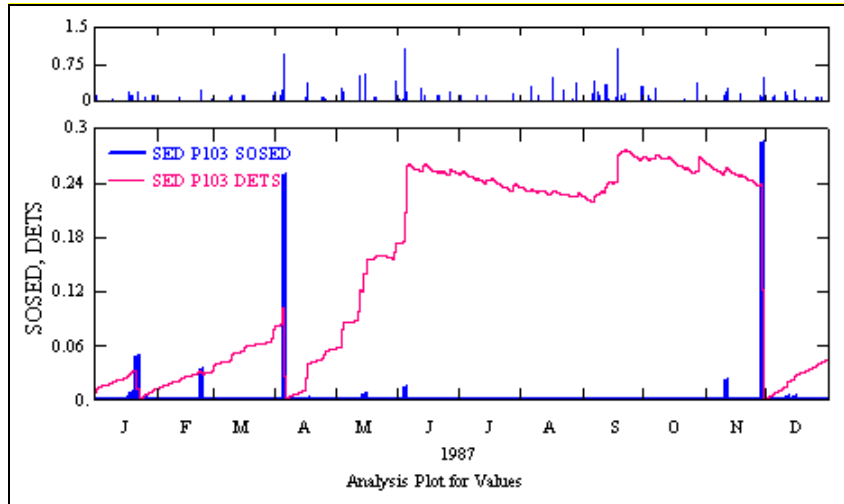
> **Note:** You may want to plot precipitation on the auxiliary axis as shown here. You
>   can do this by adding precipitation (Scenario = Observed, Constituent =
>   HPRECIP) to the "Time series" list and then plotting HPRECIP (DSN 105)
>   with the SOSED and DETS time series. In practice, you should look at this
>   plot for each land use segment; however, for simplification purposes, we will
>   focus this discussion on the pervious agriculture land segment.

Plots similar to the one above can be used to determine whether the simulated washoff
process is "storage-limited"(DETS is often zero or drops to zero during the early part of
storms) or "transport-limited" (DETS is almost never zero). This information will help you
decide whether to adjust the parameters that affect storage (KRER and JRER) or parameters
that affect erosion (KSER and JSER). A plot with SOSLD and SLDS will provide similar
information for impervious land segments.

Examine the plot above. The thin line shows the amount of fines available for washoff.
Notice that the washoff process for this land segment is generally storage-limited during the
wettest times of the year when there is high erosion potential (in other words, there is not
enough sediment on the land to wash off). In this situation, you would consider increasing
KRER and JRER and then readjusting KSER to meet the target loads.

Other important steps in calibrating overland sediment loads include the following:

a. Plot the surface runoff (SURO) from the pervious land segments. It is critical that the hydrology parameter values produce sufficient surface runoff; if they don't, there will be little washoff from pervious land segments. This is especially important if you have determined that the sediment loads are transport limited.
b. Determine the relative sediment contribution of each land use segment by examining the total sediment loading (SOSED + SOSLD) to the stream from each land use, and then comparing the loading to those from other segments.
c. Consider manipulating the production of DETS (primarily on agricultural land) to represent soil disturbances caused by activities such as plowing. You can do this by implementing "Special Actions" to increment or update the DETS variable for the appropriate pervious land segments.

25.   If you have time, adjust some of the key sediment calibration parameters (shown below) and examine their impacts on loading. When you are done, close the plots and tables in GenScn and close WinHSPF.

References:

Bicknell, B.R., Imhoff, J.C., Kittle, J.L., Jr., Donigian, A.S., Jr. and Johanson, R.C., 2001. Hydrological Simulation Program -- FORTRAN, User's manual for Release 12. U.S. Environmental Protection Agency, EPA/600/R-97/080, Environmental Research Laboratory, Athens, GA.

Donigian, A.S., Jr., and N.H. Crawford. 1976. Modeling Nonpoint Pollution from the Land Surface. Environmental Research Laboratory, Athens, GA. EPA 600/3-76-083. 280 p.

Pertinent Parameters for Pervious and Impervious Areas

Fines Availability ⟷ **Sediment Washoff**

Pervious Areas
    SEDMNT   COVER   KSER*
                                    KRER*   JSER
                                    AFFIX/NVSI   KGER*
                                    JRER   JGER

Impervious Areas
    (SOLIDS)   ACCSDP*   KEIM
                                    REMSDP   JEIM

    * Primary calibration parameters

Guidelines for Adjustment:

If **DETS, SLDS** is   **SEDIMENT WASHOFF** is

Increasing	Too Low	Increase Washoff
Increasing	Too High	Decrease Fines
Decreasing	Too Low	Increase Fines
Decreasing	Too High	Decrease Washoff

(with **and** between columns 1 and 2, **then** between columns 2 and 3)

SEDIMENT INPUTS

MODULE
  TABLE
    PARAMETER

PERVIOUS LAND

SEDMNT *Module that* simulates the production and removal of sediment from a pervious land segment.

SED-PARM1 (Sediment Simulation Flags)
  CRVFG: If this is 1, erosion-related cover may vary monthly.
  VSIVFG: If this is 1, the rate of net vertical sediment input may vary monthly.
  SDOPFG: If this is 1, removal of sediment from the land surface will be simulated with the algorithm used in the ARM and NPS models. If it is 0, a new algorithm will be used.
SED-PARM2 (Sediment Simulation Inputs)
  SMPF: This is a "supporting management practice factor." It is used to simulate the reduction in erosion achieved by use of erosion control practices.
  KRER: This is the coefficient in the soil detachment equation.
  JRER: This is the exponent in the soil detachment equation.
  AFFIX: This is the fraction by which detached sediment storage decreases each day, as a result of soil compaction.
  COVER: This is the fraction of land surface which is shielded from erosion by rainfall (not considering snow cover, which can be handled by simulation).
  NVSI: This is the rate at which sediment enters detached storage from the atmosphere. A negative value can be supplied (e.g., to simulate removal by human activity or wind).

SED-PARM3 (Sediment Simulation Inputs)
  KSER: This is the coefficient in the detached sediment washoff equation.
  JSER: This is the exponent in the detached sediment washoff equation.
  KGER: This is the coefficient in the matrix soil scour equation (simulates gully erosion, etc.).
  JGER: This is the exponent in the matrix soil scour equation (simulates gully erosion, etc.).

SED-STOR (Sediment Initial Conditions)
  DETS: This is the initial storage of detached sediment.

IMPERVIOUS LAND

SOLIDS *Module that simulates the accumulation and removal of solids by runoff and other means from the impervious land segment*

SLD-PARM1 (Sediment Simulation Flags)
  VASDFG: value of 1 means vary the accumulation rate of solids monthly; 0 means use annual value.
  VRSDFG: value of 1 means vary the unit removal rate of solids monthly; 0 means use annual value.
  SDOPFG: If this is 1, removal of sediment from the land surface will be simulated with the algorithm used in the NPS model. If it is 0, the new algorithm will be used.

SLD-PARM2 (Sediment Simulation Input)
  KEIM: This is the coefficient in the solids washoff equation.

> ***JEIM:*** *This is the exponent in the solids washoff equation.*
> ***ACCSDP:*** *This is the rate at which solids are placed on the land surface. If monthly values are being supplied, value suppl in this table is not relevant.*
> ***REMSDP:*** *This is the fraction of solids storage which is removed each day. If monthly values are being supplied, value suppl in this table is not relevant.*

SLD-STOR (Sediment Initial Conditions)
> ***SLDS:*** *This is the initial storage of solids.*

REACHES AND RESERVOIRS

SEDTRN *Module that simulates the transport, deposition, and scour of inorganic sediment in free-flowing reaches and mixed reservoirs.*

SANDFG (Sandload Method Flag)
> ***SANDFG:*** *This indicates the method that will be used for sandload simulation; 1 means Toffaleti method, 2 means Colby method, and 3 means the "old" HSPF input power function method.*

SED-GENPARM (General Sediment Inputs)
> ***BEDWID:*** *This is the width of the cross-section over which HSPF will assume bed sediment is deposited regardless of stage, top-width, etc. It is used to estimate the depth of bed sediment.*
> ***BEDWRN:*** *This is the bed depth which, if exceeded (eg, through deposition) will cause a warning message to be printed.*
> ***POR:*** *This is the porosity of the bed (volume voids/total volume). It is used to estimate bed depth.*

SAND-PM (Sand Parameters)
> ***D:*** *This is the effective diameter of the transported sand particles. Note that the transport formulae do not actually use D (they use DB50, supplied in Table-type HYDR-PARM2). D is included here for consistency with the input data supplie for cohesive sediment.*
> ***W:*** *This is the fall velocity of transported sand particles in still water.*
> ***RHO:*** *This is the density of the sand particles.*
> ***KSAND:*** *This is the coefficient in the "old" HSPF sandload input power function formula.*
> ***EXPSND:*** *This is the exponent in the "old" HSPF sandload input power function formula.*

SILT-CLAY-PM (Silt and Clay Inputs)
> ***D:*** *This is the effective diameter of the particles.*
> ***W:*** *This is the fall velocity of the particles in still water.*
> ***RHO:*** *This is the density of the particles.*
> ***TAUCD:*** *This is the critical bed shear stress for deposition. Above this stress, there will be no deposition, as the stress drops below this value to zero, deposition will gradually increase to the value implied by the fall velocity in still water.*
> ***TAUCS:*** *This is the critical bed shear stress for scour. Below this value, there will be no scour; above it, scour will steadily increase. In general TAUCD should be less than or equal to TAUCS.*
> ***M:*** *This is the erodibility coefficient of the sediment.*

SSED-INIT (Initial Suspended Sediment Concentrations)
> ***SSED1:*** *The initial concentration (in suspension) of sand.*
> ***SSED2:*** *The initial concentration (in suspension) of silt.*
> ***SSED3:*** *The initial concentration (in suspension) of clay.*

BED-INIT (Initial Fractions of Bed Sediment)

        BEDDEP: *This is the initial total depth (thickness) of the bed.*

        SANDFR: *The initial fraction (by weight) of sand in the bed material. The sum of the three fractions must be 1.00.*

        SILTFR: *The initial fraction (by weight) of silt in the bed material. The sum of the three fractions must be 1.00.*

        CLAYFR: *The initial fraction (by weight) of clay in the bed material. The sum of the three fractions must be 1.00.*