

Documentation on Delivery Ratio used for CEAP Cropland Modeling for Various River Basins in the United States

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Chapter Organization

This document describes the delivery ratio procedure used in the CEAP National Assessment for Cropland. The delivery ratio is a factor that compensates for the natural attenuation or loss of sediment and nutrients as they travel in water from the source to the watershed outlet. This document covers the delivery ratio procedure used in Soil and Water Assessment Tool (SWAT) and Agricultural Policy Extender (APEX) models to account for deposition of sediment, nitrogen, phosphorus and atrazine in ditches, floodplains, and tributary stream channels during transit from the edge of the field or HRUs to the 8-digit watershed outlet. The document is arranged as follows: Chapter 1 covers the development of the delivery ratio procedure in APEX and SWAT models and sediment delivery ratio estimated for the Upper Mississippi River basin with several illustrations of the sediment delivery ratio for various types of readers/audience from field level to University researchers. Chapters 2 through 5 further describe the delivery ratio used in other river basins of the United States by the order of completion. References cited in all the Chapters are provided in the Reference Section in Chapter 1.

Delivery Ratio used in CEAP Cropland Modeling in the Upper Mississippi River Basin

Background on Sedimentation and Sediment Delivery Ratio

Problems caused by soil erosion and sedimentation include losses of soil productivity, water quality degradation, and decreased capacity of channels and reservoirs. Sediment may carry pollutants into water systems and cause significant water quality problems. Erosion of soil and sediment yield, and subsequent nutrients and pesticides transported with sediment can be strongly impacted by land management practices, land use and climate changes (Clark et al., 1985). Policy makers need to quantify erosion rates and sediment yields at regional or global levels in order to evaluate and develop environmental and land use management plans (e.g., COST634, 2005; Mausbach and Dedrick, 2004). The historical record of sediment data is sparse. For example, only a few sediment sampling stations exist in the United States and most of the stations have relatively short records (Pannell, 1999). Therefore, reasonable and realistic prediction of sediment yield is important for managing natural resources and protecting the environment.

The methods involving estimating sediment delivery ratios (e.g., Lim et al., 2005; Syvitski et al., 2005; Mutua et al., 2006; Bhattacharai and Dutta, 2007) or calculating sediment transport capacity (e.g., Morgan et al., 1998; Van Rompaey et al., 2001; Vente et al., 2007) are often used to link gross erosion to sediment yield at the watershed outlet. However, not all of the soil that erodes from fields ends up in the watershed outlet. Most of the soil that is eroded gets deposited on the way, although the deposition is temporary. Eroded soil may deposit in low spots, on flatter lands, at the edge of the field and sometimes settles at the bottom of the channel. The delivery ratio is a factor that compensates for the natural attenuation or loss of sediment (and nutrients) as they travel in water from the source to the watershed outlet. The processes of transport of sediment from different sources, deposition and re-entrainment on the way to the mouth of a watershed are difficult to model without detailed topographic and small-scale intensive soils and surface condition data. The sediment delivery ratio (SDR) is used as a logical tool to integrate the factors that affect the production of sediment from the gross erosion occurring in a watershed. Traditionally, the SDR is defined as the ratio of sediment load delivered to the watershed outlet (sediment yield) to gross erosion occurring from sources within the watershed. Types of erosion include sheet, rill, wind, classic gully, ephemeral gully, streambank, streambed, roadbank and ditch, roadbed, con-

struction, landslides, and background or geologic erosion. SDR can be affected by a number of factors including hydrological inputs (rainfall-runoff factors), landscape and watershed characteristics (e.g., land use/land cover, nearness to the main stream, channel density, drainage area, slope, slope length), soil properties (sediment source, texture) and their interactions. The amount of floodplain sedimentation occurring and the presence of hydrologically controlled areas (such as ponds, reservoirs, lakes, wetlands, etc.) also affect the rate of sediment delivery to the watershed mouth and hence the SDR. These complexities make the SDR regionalization mainly empirical. Numerous SDR relationships have been developed based on combinations of these factors (Ouyang and Bartholic, 1997). Sediment delivery ratios have also been developed based on measured rates of sediment accumulations in reservoirs. The types of erosion occurring in a contributing watershed provide information on the relative SDR, when the measured sedimentation rates are also known.

Sediment delivery ratios are used mostly in planning small to medium water resources projects. Historically one of the most important applications was the NRCS flood control program that involved planning, designing, and evaluating flood water retarding structures. Traditionally, delivery ratios have been estimated by comparing sediment yield data with predicted gross erosion. These delivery ratios have been related to watershed characteristics to develop delivery ratio prediction equations for use on ungauged watersheds (Gottschalk and Brune 1950; Maner 1958; Maner 1962; Roehl 1962; Williams and Berndt 1972). However, these analyses depend on the existence of long periods of sediment yield records at the stream gaging stations and; therefore, were limited to a few regions of the United States because of insufficient data. This deficiency was partially overcome by using simulated sediment yields (Williams, 1977) for determining delivery ratios. Long-term average annual sediment yields are divided by gross erosion to calculate delivery ratios. These simulated delivery ratios are related to watershed characteristics to develop equations for predicting delivery ratios for nearby ungauged watersheds.

With the development of the Modified Universal Soil Loss Equation (MUSLE) (Williams 1975a) and sediment routing (Williams, 1975b; Williams, 1978) it became apparent that one of the most important variables in estimating delivery ratios was the peak runoff rate (q_p). The original sediment routing model (Williams 1975b) routed se-

diment from subarea outlets to the watershed outlet as a function of $q_p^{0.56}$, travel time, and median particle size. This concept is used in the Agricultural Policy Environmental eXtender (APEX) model (Williams and Izaurrealde, 2006). Gassman et al. (2009) have provided a comprehensive review of APEX model applications and stated that APEX is one of the few existing models which is capable of simulating flow and pollutant transport routing at the field scale. The APEX model has been chosen as the field-scale modeling tool for the Conservation Effects Assessment Project (CEAP).

The CEAP was initiated to quantify the environmental benefits of conservation practices at the regional/national scale. In CEAP, the edge-of-field effects of the conservation practices implemented on cultivated cropland and land enrolled in the Conservation Reserve Program (CRP) of the watershed were assessed using the field scale model, APEX. The watershed scale model, SWAT (Soil and Water Assessment Tool) was used to simulate the non-cultivated land including pasture, range, urban, forest and wetlands and point sources in the watershed. The results from the APEX model simulations were integrated into the regional water quality model—SWAT (Arnold, et al., 1998; Arnold, et al., 1999; Arnold and Fohrer, 2005)—to assess the off-site effects of conservation practices at regional level (Santhi et al., 2005). Gassman et al., (2007) have provided a comprehensive review of SWAT model applications across United States and other countries and recommended SWAT as one of the widely used watershed models with expanding modeling capabilities.

Databases and model inputs required for SWAT in CEAP is derived from a framework called, HUMUS (Hydrologic Unit Modeling of the United States). In HUMUS/SWAT system, each major river basin in the United States is treated as a watershed and each 8-digit watershed as a subwatershed or subbasin (Figure 1-1). At the 8-digit watershed level, two simulation models, APEX and SWAT, were run independently. The cultivated area estimates were made via a sampling and APEX modeling approach. The simulated results (flow, sediment, nutrients and pesticides) from APEX were aggregated to the 8-digit watershed using the statistical sampling weights derived from the National Resource Inventory (NRI) data. The delivery ratio and upland sediment yields were estimated separately for cultivated land and non-cultivated land uses. The integrated modeling results at the 8-digit watershed outlets were routed downstream through the stream network along with point sources in SWAT for estimating the offsite ef-

fects of conservation practices on water quality at the watershed outlets.

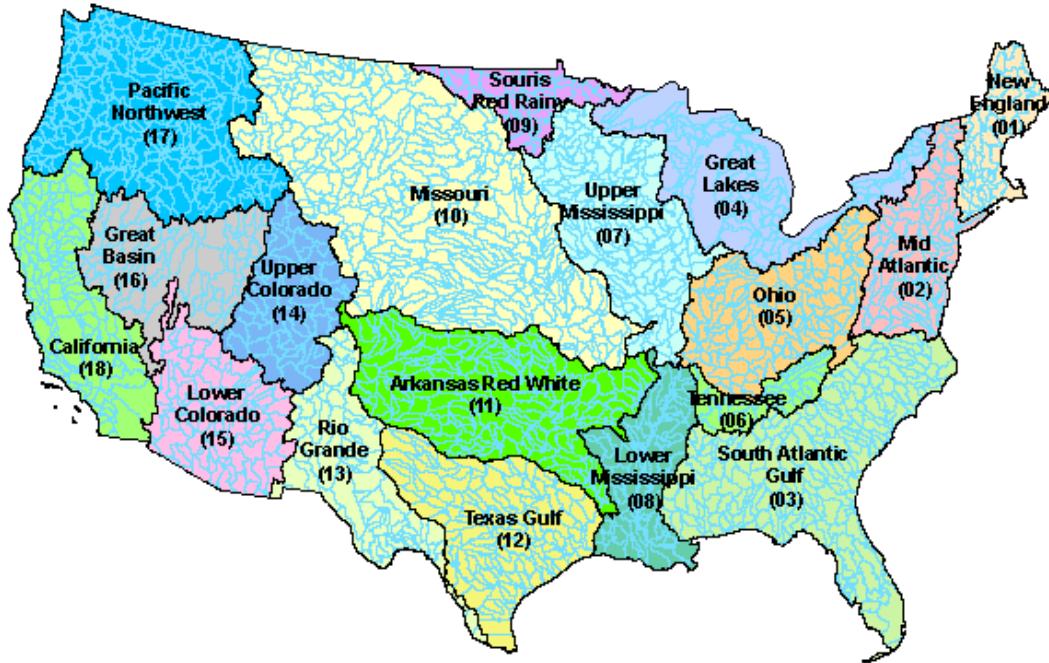
Chapter 1 describes the SDR procedure used in APEX and HUMUS/SWAT models for the CEAP National Assessment in the Upper Mississippi River Basin. This chapter includes a discussion of the following:

1. Development of SDR procedure used for estimating sediment losses (deposition) from edge-of-field to 8-digit watershed outlet in APEX for cultivated cropland and CRP;
2. Development of SDR procedure used for estimating sediment losses (deposition) from non-cultivated crop-land HRUs to 8-digit watershed outlet in SWAT;
3. Application and validation of the SDR procedure in the Upper Mississippi River Basin; and
4. Delivery ratio of sediment bound (organic) and soluble nutrients and pesticides

For CEAP, at the 8-digit watershed level, there are typically 20 plus NRI-CEAP points simulated with APEX. Each APEX simulation represents a fraction of the cultivated areas by statistical weights assigned to each point. There are about 30-40 hydrologic resource units (HRUs) simulated with SWAT. Each HRU represents a particular land use/soil combination, which is a portion of the 8-digit watershed area and does not represent a contiguous land area. Therefore, both the APEX-simulated-cultivated land and SWAT-simulated-HRUs are assumed randomly distributed within the 8-digit watershed.

Both APEX and SWAT compute SDR as a function of the ratio of time of concentration of the field or HRU to the time of concentration of the 8-digit watershed. As previously described, SDRs are typically defined as the ratio of sediment yield to erosion (soil loss). It is to be noted that delivery ratio estimated for the CEAP national assessment is different from the traditionally estimated SDR. In the CEAP national assessment, the SDRs are estimated within each simulation and defined as the ratio of edge-of-field sediment delivered to the 8-digit watershed outlet to the sediment load simulated at APEX sites or SWAT-simulated-HRUs. APEX and SWAT models estimate the sediment yield from the randomly distributed APEX subareas and SWAT HRUs to the outlet of the 8-digit watershed or subbasin.

Figure 1-1. Major River Basins and 8-digit watersheds in the United States



Development of delivery ratio from APEX sites to 8-digit watershed outlets

The APEX modeling setup for CEAP used information from the NRI-CEAP Cropland Survey. The survey was conducted at a subset of NRI sample points which provide statistical samples representing the diversity of soils and other conditions on the landscape. Since each APEX simulation represents a fraction of the cultivated areas within an 8-digit watershed, the actual locations are not known and are assumed to be randomly distributed. Due to this limitation, the development of SDR in this study depends on the efficiency of the algorithm with a modest input parameter requirement. The SDR can be estimated as:

$$SDR = \frac{Y_B}{\sum Y_S} \quad (1)$$

where Y_B is the sediment yield at the basin outlet and Y_S is the sediment yield at the outlet of the APEX sites (or edge-of-field sites). The field surrounding each NRI sample point for modeling purposes, is assumed to be 16 ha, and may be broken into a maximum of four apex subareas, depending on the presence of buffer areas or grassed waterways. Edge-of-field sediment yield (Y) can be estimated using a variation of MUSLE called MUST (MUSLE developed from Theory (Williams 1995):

$$Y = 2.5 \times (Q \times q_p)^\alpha \times K \times C \times P \times LS \times CFRG \quad (2)$$

where Q is the runoff volume (mm), q_p is the peak runoff rate (mm h^{-1}), K , C , P , and LS are the linear USLE factors, $CFRG$ is the coarse fragment factor and α is the runoff and peak runoff rate exponent, which is set as 0.5 in the original MUST equation (Williams 1995). The α can be smaller than 0.5 in developing the delivery ratio. Y_B can be calculated with Eq. 2 by areally weighting the linear USLE factors and Q , and estimating q_p at the basin outlet. Y_S can be estimated for each of the APEX sites using appropriate values of the linear USLE factors, Q , and q_p . The delivery ratio can be estimated by substituting these values into Eq. 1. Since the linear USLE factors and Q cancel, the delivery ratio for each APEX site can be estimated with the equation:

$$SDR_S = \left(\frac{q_{pB}}{q_{pS}} \right)^\alpha \quad (3)$$

where SDR_S is the delivery ratio for the APEX sites, q_{pB} is the peak runoff rate at the basin outlet (mm h^{-1}), and q_{pS} is

the peak runoff rate at the outlet of the APEX sites (mm h⁻¹).

Since the APEX simulation results are passed to SWAT at the basin outlet, q_{pB} is not known when APEX is running. However, the peak runoff rate is a function of runoff volume and watershed time of concentration:

$$q_p = f\left(\frac{Q}{t_c}\right) \quad (4)$$

Substituting the inverse of t_c for q_p (Q cancels) in Eq 3 yields:

$$SDR_S = \left(\frac{t_{cS}}{t_{cB}}\right)^\alpha \quad (5)$$

where t_{cS} is the time of concentration of the APEX site and t_{cB} is the time of concentration of the basin. The times of concentration can be estimated with the Kirpich equation in the metric form:

$$t_c = 0.0663 \times \frac{L^{0.77}}{S^{0.385}} \quad (6)$$

where L is the watershed length along the main stem from the outlet to the most distant point (km) and S is the main stem slope (m/m).

Substituting t_{cS} and t_{cB} calculated from Eq. 6 in Eq. 5 yields:

$$SDR_S = \left(\left(\frac{L_S}{L_B}\right)^{0.77} \times \left(\frac{S_B}{S_S}\right)^{0.385} \right)^\alpha \quad (7)$$

where L_B and S_B are the 8-digit watershed basin channel length (km) and basin channel slope (m/m), respectively; L_S and S_S are the APEX watershed length (km) and slope (m/m), respectively. The α was set to 0.2.

Description of the delivery ratio procedure developed within SWAT

SWAT simulates the sediment yield from the non-cultivated land HRUs using the Modified Universal Soil Loss Equation developed by Williams et al. (1975a and 1975b; Williams et al., 1995):

$$sed = 11.8 \cdot (Q_{surf} \cdot q_{peak} \cdot area_{hru})^{0.56} \cdot K_{USLE} \cdot C_{USLE} \cdot P_{USLE} \cdot LS_{USLE} \cdot CFRG \quad (12)$$

where sed is the sediment load on a given day (metric tons), Q_{surf} is the surface runoff volume (mm), q_{peak} is the peak runoff rate (m³/s), $area_{hru}$ is the area of the HRU (ha), K_{USLE} is the USLE soil erodibility factor, C_{USLE} is the USLE cover and management factor, P_{USLE} is the USLE support practice factor, LS_{USLE} is the USLE topographic

factor and CFRG is the coarse fragment factor (Neitsch et al., 2005). The area of each HRU for various land use classes may vary from a few hundred acres to several thousands of acres within each 8-digit watershed.

After estimating the sediment load for each HRU, a delivery ratio is applied to determine the amount of sediment that reaches the 8-digit watershed (HUC) outlet from each HRU. In SWAT, SDR is estimated as a function of the time of concentration of HRU to the time of concentration of the HUC/8-digit watershed. Time of concentration is related to watershed characteristics such as slope, slope length, landscape characteristics and drainage area:

$$SDR = \left(\frac{t_{c,hru}}{t_{c,sub}}\right)^{dr_exp} \quad (13)$$

where $t_{c,hru}$ is the time of concentration of HRU in hours, $t_{c,sub}$ is the time of concentration of the subbasin (8-digit HUC) in hours, typically more than 24 hours for most of the 8-digit watersheds, and dr_exp is the delivery ratio exponent parameter. Time of concentration of HRU and of 8-digit also varies across the 8-digit watersheds. For the CEAP national assessment, the delivery ratio exponent (dr_exp) was set to 0.5 in SWAT. This parameter is similar to the peak runoff rate exponent (α) used in the MUSLE.

Computation of time of concentration of subbasin/HUC

The time of concentration is calculated by summing the overland flow time (the time it takes for flow from the most remote point in the subbasin to reach the channel) and the channel flow time (the time it takes for flow in the upstream channels to reach the outlet). Total time of concentration is the sum of overland and channel flow times:

$$t_{c,sub} = t_{ov} + t_{ch,sub} \quad (14)$$

where $t_{c,sub}$ is the time of concentration for a subbasin (hr), t_{ov} is the time of concentration for overland flow (hr), and $t_{ch,sub}$ is the time of concentration for channel flow (hr).

Computation of time of concentration of overland flow

Tributary channel characteristics related to the HRU such as average slope length (m), HRU slope steepness (m m⁻¹) and Manning's "n" values representing roughness coefficient for overland flow are used in computing overland flow time of concentration:

$$t_{ov} = \frac{L_{slp}^{0.6} \cdot n^{0.6}}{18 \cdot slp^{0.3}} \quad (15)$$

where L_{slp} is the average subbasin slope length (m), slp is the average slope of HRU in the subbasin ($m m^{-1}$), and n is Manning's roughness coefficient for the overland flow representing characteristics of the land surface with residue cover or tillage operations. Manning's "n" ranges from 0.01 to 0.60.

Computation of time of concentration of channel flow of subbasin

The time of concentration for channel flow of the subbasin is computed as:

$$t_{ch,sub} = \frac{0.62 \cdot L \cdot n^{0.75}}{Sub_area^{0.125} \cdot slp_{ch}^{0.375}} \quad (16)$$

where $t_{ch,sub}$ is the time of concentration for channel flow (hr), L is the channel length from the most distant point to the subbasin/HUC outlet (km) or the longest tributary channel length, n is Manning's roughness coefficient for the channel representing the characteristics of the channel (ranges from 0.025 through 0.100), Sub_area is the subbasin/HUC area (km^2), and slp_{ch} is the average slope of the longest tributary channel ($m m^{-1}$).

Computation of time of concentration of the HRU

The time of concentration of HRU is estimated using the following equation.

$$t_{c, hru} = t_{ov} + t_{ch, hru} \quad (17)$$

Computation of time of concentration of channel flow of HRU

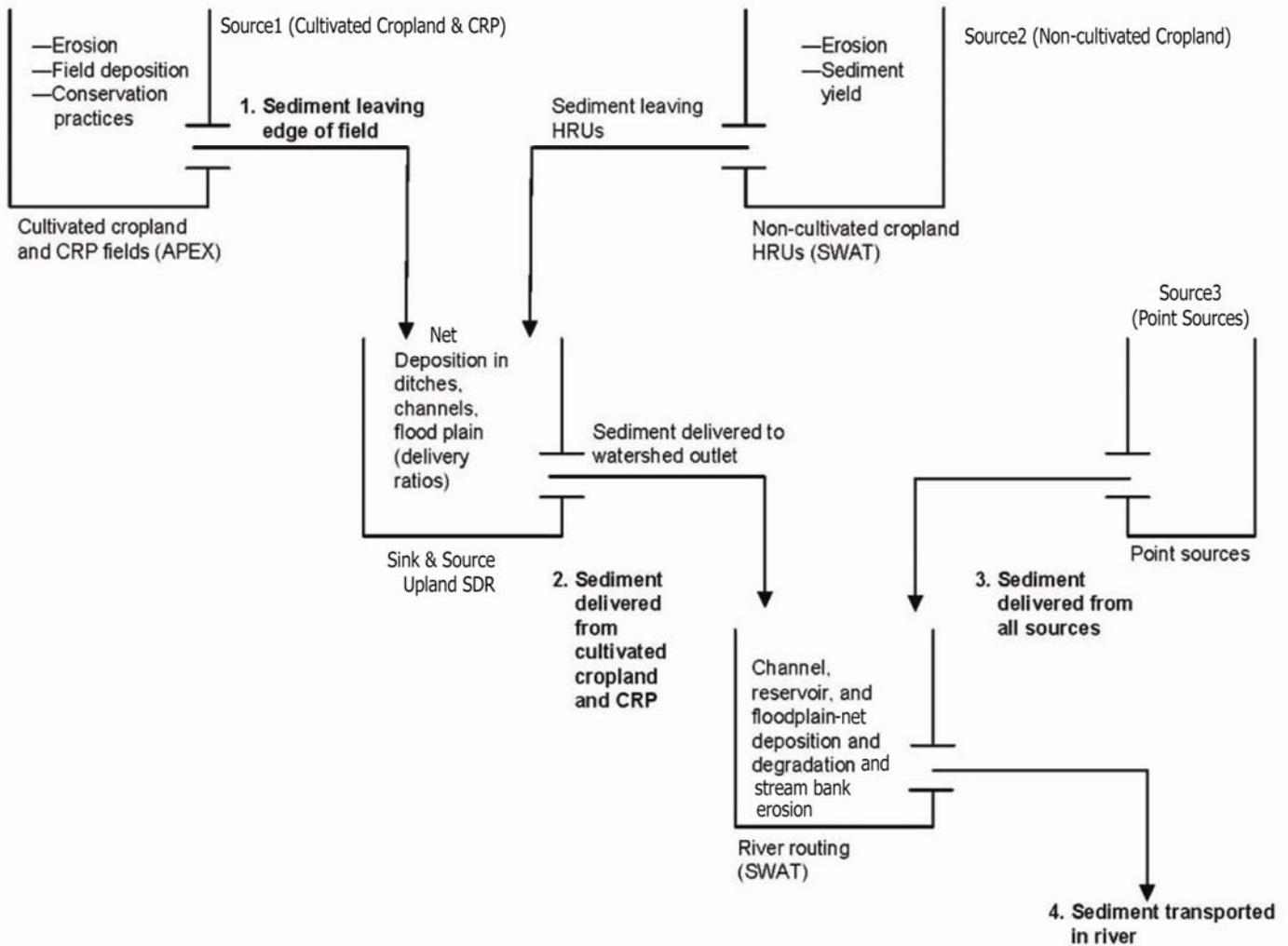
The time of concentration for channel flow of the HRU is computed as:

$$t_{ch,hru} = \frac{0.62 \cdot L * hru_prop \cdot n^{0.75}}{hru_area^{0.125} \cdot slp_{ch}^{0.375}} \quad (18)$$

where, hru_prop is the proportion of the tributary channel length in hru. It is estimated by multiplying the longest tributary channel length by the ratio of hru area to subbasin area, and hru_area is the area of hru.

Equations 15 and 18 are used in computing time of concentration for HRU as shown in Eq. 17. Thus, Eqs. 14 and 17 are used in Eq. 12 to compute the SDR. Figure 1-2. depicts the schematic of sediment sources and delivery as modeled with HUMUS/SWAT for the CEAP Cropland National Assessment.

Figure 1-2. Schematic of sediment sources and delivery as modeled with HUMUS/SWAT and APEX for the CEAP Crop-land National Assessment



Application and validation of sediment routing ratio procedures

The delivery ratio procedures described above have been applied to the CEAP national assessment study in the Upper Mississippi River Basin (UMRB) (Figure 1-3). The UMRB covers about 190,000 square miles, including large parts of Illinois, Iowa, Minnesota, Missouri, and Wisconsin, and small areas of Indiana, Michigan, and South Dakota. The total cultivated cropland and land enrolled in the CRP General Signup is about 52 percent of the total UMRB area. In most basins, the percent of CRP land is generally less. Most of the cultivated land is located in Iowa, Illinois and Wisconsin. A total of 131 8-digit watersheds are in the UMRB. Within each 8-digit watershed, the percent cultivated cropland and CRP area ranges from 0 to 89 percent. A total of 5534 representative cultivated fields (3703 NRI-CEAP cropland points and 1831 CRP points) were setup to run using APEX. The statistical weights associated with each representative field range from 6 to 1,369 thousand acres. Nine out of 131 8-digit watersheds in the UMRB have no CEAP points. These nine 8-digit watersheds have zero or fewer than 3 percentage cultivated cropland. Non-cultivated land is distributed over 4 percent of the UMRB. Within each 8-digit watershed, non-cultivated land uses such as pasture, range, hay, horticulture, forest deciduous, forest mixed, forest evergreen, urban, urban construction, barren land wetland and water are simulated as HRUs in SWAT. A total of 4452 HRUs are simulated in the Upper Mississippi River Basin.

Cultivated cropland and CRP

Each NRI-CEAP point and CRP point is unique; therefore, sediment yield and delivery ratios also vary for each cultivated cropland site simulated in an 8-digit watershed. Examples of inputs and the corresponding estimated delivery ratios are listed in Table 1-1. Examples of delivery ratio distributions at the 8-digit watershed level are shown in Figure 1-4. The mean delivery ratios for each of the 8-digit watershed in the UMRB range from 0.30 to 0.46 (Figure 1-5 and Table 1-2).

Non-cultivated land

Since the runoff, tributary channel characteristics, HRU areas, and HUC area vary, sediment yield and delivery ratio also vary for each non-cultivated HRU simulated in an 8-digit watershed. Example inputs used and corresponding time of concentrations and delivery ratios for non-cultivated land HRUs are shown for three 8-digit watersheds in Central Minnesota, Central Iowa and Eastern Missouri near St. Louis (Table 1-3). Figure 1-6 depicts the

distribution of SDR of non-cultivated land HRUs in those three 8-digit watersheds. Sediment delivery ratio varied from 0.16 to 0.46 depending on the HRU area, slope, slope length, land use characteristics and soil characteristics.

Figure 1-7 depicts the SDR estimated for major non-cultivated landuses such as forest, urban land, pasture, range grass, hay and urban construction HRUs in each 8-digit watershed in the Upper Mississippi River Basin. Since the SWAT HRU areas are more widely varied than the areas used in APEX simulation sites (16 ha), the SDR is also varied for some of the pasture, forest and urban land HRUs. Sediment delivery ratios were less for urban construction HRUs as their areas are relatively smaller. The MUSLE equation used in SWAT accounts for the area and thus, sediment load predicted by MUSLE per area is lower as HRU area increases. Figure 1-8 depicts the distribution of SDRs for pasture, range grasses, forest, urban and urban construction HRUs in the Upper Mississippi River Basin.

Table 1-4. shows the mean SDR, 10th percentile and 90th percentile for the non-cultivated land HRUs in all 8-digit watersheds in the Upper Mississippi River Basin. Spatial variation of mean SDR estimated for non-cultivated land HRUs in 8-digit watersheds in the Upper Mississippi River basin is shown in Figure 1-9. The mean delivery ratio varied from 0.24 to 0.43 across the 8-digit watersheds.

Validation of sediment delivery ratios used in the Upper Mississippi River Basin

Sediment delivery ratio was used in APEX and SWAT models to account for deposition of sediment in ditches, floodplains, and tributary stream channels during transit from the edge of the field to the 8-digit watershed outlet. The SDRs were used to estimate the sediment losses or deposition from each of the cropland APEX simulation sites and non-cropland HRUs to the 8-digit watershed outlets. The mean SDRs were calculated from the SDRs of APEX sites and SWAT HRUs within each 8-digit watershed. The mean SDR varied from 0.24 through 0.43.

Meade et al. (1990) developed relationships for sediment yields in the UMRB as a function of drainage area and land use based on a study conducted before 1950. Based on Meade's relationships, the SDR from the edge-of-fields to the 8-digit watershed outlets is approximately 0.3 to 0.4. Sediment delivery ratios estimated for the upland in the CEAP national assessment study are closer to the delivery ratio range suggested by Meade et al. (1990). This indicates that the sediment modeling from the CEAP national assessment study are reasonable.

Delivery ratio used to compute transport of sediment attached nutrients and pesticides from cropland APEX sites to the 8-digit watershed outlets

Sediment transported nutrients and pesticides are simulated using an enrichment ratio approach:

$$YNP_B = YNP_S \times DR \times ERTO \quad (8)$$

where YNP is the nutrient or pesticide load and ERTO is the enrichment ratio (concentration of nutrient/pesticide in outflow from APEX sites divided by that at the basin outlet). The enrichment ratio is calculated by considering sediment concentration in the equation:

$$ERTO = b_1 \times Y_{SC}^{b_2} \quad (9)$$

where Y_{SC} is the sediment concentration of the outflow from the APEX sites and b_1 and b_2 are parameters that can be determined by considering two points in Eq. 9. For the enrichment ratio to approach 1.0, the sediment concentration must be extremely high. Conversely, for the enrichment ratio to approach 1/SDR, the sediment concentration must be low. The simultaneous solution of Eq. 9 at the boundaries assuming that sediment concentrations range from 5×10^{-4} to 0.1 Mg m^{-3} gives:

$$b_2 = \log(SDR)/2.301 \quad (10)$$

$$b_1 = 1/0.1^{b_2} \quad (11)$$

Thus, the delivery ratios and enrichment ratios are used to transport sediment, nutrients, and pesticides from APEX sites to the basin outlet for input to SWAT.

Delivery ratio used to compute transport of sediment attached nutrients and pesticides from non-cultivated land HRUs to the 8-digit watershed outlets

For non-cultivated land uses simulated within SWAT, organic nitrogen, phosphorus and pesticide transported with sediment are calculated with a loading function developed by McElroy et al. (1976) and modified by Williams and Hann (1978) for application to individual runoff events. The basic concept of the loading function used in SWAT is identical to APEX. The loading function estimates the daily organic N runoff loss from a HRU, based on the concentration of organic N or P in the top soil layer in the field or HRU, the sediment yield, and the enrichment ratio. The enrichment ratio (Menzel, 1980) is the concentration of organic nitrogen, phosphorus and pesticide transported with sediment to the main channel to the concentration in the soil surface layer at the field or HRU.

In addition to the SDR, the enrichment ratio was used to simulate organic nitrogen, organic phosphorus, and sediment-attached pesticide transport in ditches, floodplains, and tributary stream channels during transit from the edge of the field or HRU to the outlet (Menzel, 1980). The enrichment ratio was defined as the organic nitrogen, organic phosphorus, and sediment attached pesticide concentration transported with sediment to the watershed outlet divided by their concentration at the edge-of-field. As sediment is transported from the edge-of-field to the watershed outlet, coarse sediments are deposited first, while more of the fine sediments that hold organic particles remain in suspension enriching the organic concentrations delivered to the watershed outlet.

Thus, the edge of loadings of sediment bound nutrients (organic nitrogen and phosphorus) and pesticides delivered to the 8-digit watershed outlets account for the delivery losses based on the SDR and enrichment ratio simulated within APEX model and SWAT models.

Delivery ratio for soluble nutrients used from cropland and CRP from APEX

Loads simulated by APEX for each survey point were appropriately weighted to develop a single aggregated load for all cultivated cropland within each 8-digit watershed. Sediment and particulate (organic) nutrients forms are subject to delivery ratios appropriate to their relative source locations within the subbasin and distance to the SWAT subbasin outlet. This adjustment is performed within the APEX prior to the inclusion of APEX loads into SWAT. However, soluble nutrient and pesticide loading from APEX is excluded from this delivery ratio adjustment. To reconcile this discrepancy, delivery ratio for soluble constituents were applied to APEX loads within the SWAT model. In this way both soluble and particulate constituents from cultivated cropland are treated with a delivery ratio. In order to fit the existing modeling framework, separate delivery ratios for soluble constituents were needed. Development of delivery ratios for soluble nutrients and pesticides is difficult. In-stream interaction between soluble and particulate fractions are complex and difficult to isolate, thus there are little research data upon which to base appropriate values. Soluble delivery ratios for APEX loads were derived from in-stream soluble nutrient and pesticide delivery as predicted by SWAT. The SWAT model predicts these losses within each river reach using the routines adapted from the QUAL2E model. The average delivery ratios predicted by SWAT for a single reach

segment in the UMRB were 0.97, 0.93 and 0.94 for nitrate, soluble phosphorus and soluble pesticide, respectively. Because they are derived from the SWAT model, soluble loads from non-cultivated areas are already subject to similar reductions. Application of soluble delivery ratios ensures equitable treatment of pollutants between APEX and SWAT. Individual delivery ratios were calculated using equations (12 to 14) as described below. These values typically ranged from 0.80 to 0.98, indicating in general a higher delivery ratio for soluble as compared to particulate (organic) fractions.

Development of delivery ratios for soluble nutrients and pesticides is difficult. There is little existing research upon which to base appropriate values. Instream interaction between soluble and particulate fractions make it difficult to isolate delivery ratios for each fraction from measured data, yet in order to fit the existing modeling framework separate delivery ratios are needed. Due to a lack of measured delivery ratios for soluble fractions in the literature, these data were derived from SWAT predictions. Delivery ratios applied to the monthly soluble loads from the APEX model were derived from SWAT predicted pollutant retention by reach. The SWAT model predicts the loss of soluble nutrient and pesticides within each reach due to instream processes. These predictions can be used to estimate a delivery ratio for soluble fractions for each reach in the model. The average delivery ratios predicted by SWAT for a single reach segment in the UMRB were 0.97, 0.93 and 0.94 for nitrate, soluble phosphorus and soluble pesticide, respectively. Because they are derived from the SWAT model, soluble loads from non-cultivated areas are already subject to similar reductions. To ensure equitable treatment of soluble pollutants between APEX and SWAT, the application of these delivery ratios is needed. Individual delivery ratios were calculated using Eq. 12 through 14 as described below. Delivery ratios used for soluble nutrients and pesticides were greater than 0.9 in most of the basins.

Nitrate Delivery Ratio

The nitrate delivery ratio in the main channel reach, NO₃_DR_RCH, is calculated as follows:

$$\text{NO}_3\text{-DR}_\text{RCH} = \text{NO}_3\text{-OUT}_\text{RCH} / \text{NO}_3\text{-IN}_\text{RCH} \quad (12)$$

where NO₃_IN_RCH is the nitrate transported with water into reach and NO₃_OUT_RCH is the nitrate transported with water out of reach. NO₃_IN_RCH load includes nitrogen loads accumulated from subbasins above that reach).

Soluble Phosphorus Delivery Ratio

$$\text{MINP_DR}_\text{RCH} = \text{MINP_OUT}_\text{RCH} / \text{MINP_IN}_\text{RCH} \quad (13)$$

where, MINP_DR_RCH is the in-stream mineral phosphorus delivery ratio in the main channel reach, MINP_IN_RCH is the mineral phosphorus transported with water into reach, and MINP_OUT_RCH is the mineral phosphorus transported with water out of reach. MINP_IN load includes phosphorus loads accumulated from subbasins above that reach).

Soluble Pesticide Delivery Ratio

$$\text{SOLPST_DR}_\text{RCH} = \text{SOLPST_OUT}_\text{RCH} / \text{SOLPST_IN}_\text{RCH} \quad (14)$$

where, SOLPST_DR_RCH is the instream soluble pesticide delivery ratio in the main channel reach, SOLPST_IN_RCH is the soluble pesticide transported with water into reach, and SOLPST_OUT_RCH is the soluble pesticide transported with water out of reach.

While more than one pesticide may be applied to the HRUs in SWAT, due to the complexity of the pesticide equations only one pesticide is routed through the stream network. Several types of pesticides are applied to cropland and horticultural land in the Upper Mississippi River Basin. For the CEAP national assessment, atrazine was chosen as one of the high priority or high risk pesticides in the Upper Mississippi River Basin. The only source of atrazine load is cultivated cropland; point sources and non-cultivated land had no atrazine contributions. Atrazine is routed through the stream reach during SWAT simulation. A delivery ratio of 0.94 was chosen soluble pesticides for the UMRB.

Summary

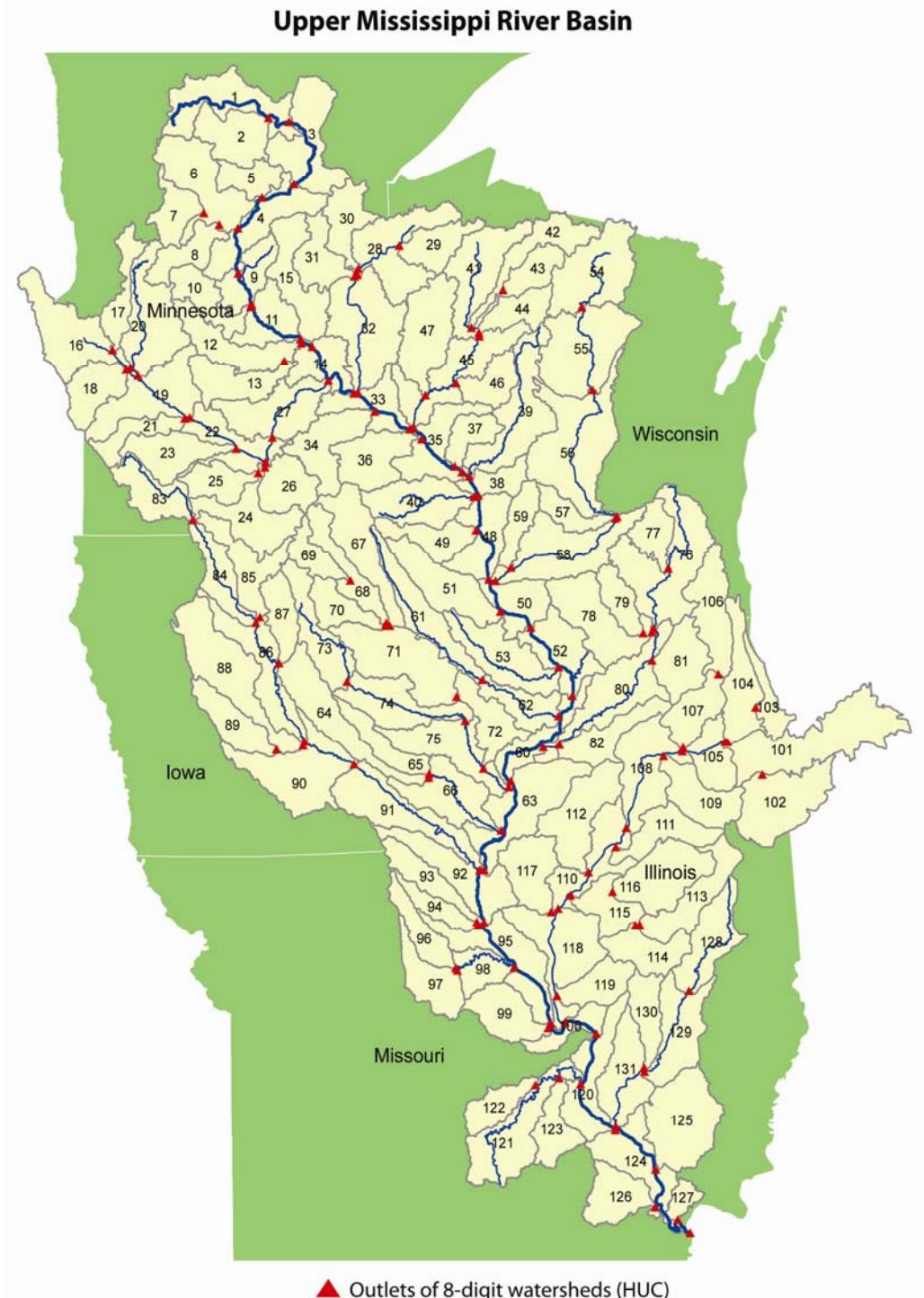
- Sediment delivery ratio is used to account for the sediment losses or deposition in ditches, channels, and floodplain occurring from edge-of-field of the cropland or non-cropland HRU to 8-digit watershed outlets in each river basin.
- Sediment delivery ratio is unique for each cultivated land and CRP survey point and each non-cultivated cropland HRU. Sediment delivery ratio varied as a function of drainage area, HRU of farm-field area, channel slope, slope length, soil, land use and management factors.

Delivery Ratio used in CEAP in the Upper Mississippi River Basin

- Mean SDR (from edge-of-field to 8-digit watershed outlet SDR) varied from 0.3 to 0.5 for cultivated and CRP land simulated within APEX and it varied from 0.21 to 0.45 for non-cultivated land use HRUs simulated within SWAT.
- Edge-of-field loadings of sediment-bound nutrients (organic nitrogen and phosphorus) delivered to the 8-digit watershed outlets account for the delivery losses based on the SDR and enrichment ratio simulated within APEX and SWAT models.
- Soluble nutrient and pesticide delivery ratios were derived from the SWAT instream model and applied to APEX loadings. The application of soluble nutrient and pesticide delivery ratios to APEX loading ensures equitable treatment of the loads generated for cultivated and non-cultivated areas.

Delivery Ratio used in CEAP in the Upper Mississippi River Basin

Figure 1-3 Map of the 8-digit watersheds in the Upper Mississippi River Basin



Delivery Ratio used in CEAP in the Upper Mississippi River Basin

Figure 1-4 Examples of sediment delivery ratio distributions for cultivated cropland (edge-of-field to 8-digit watershed outlet) in the Upper Mississippi River Basin

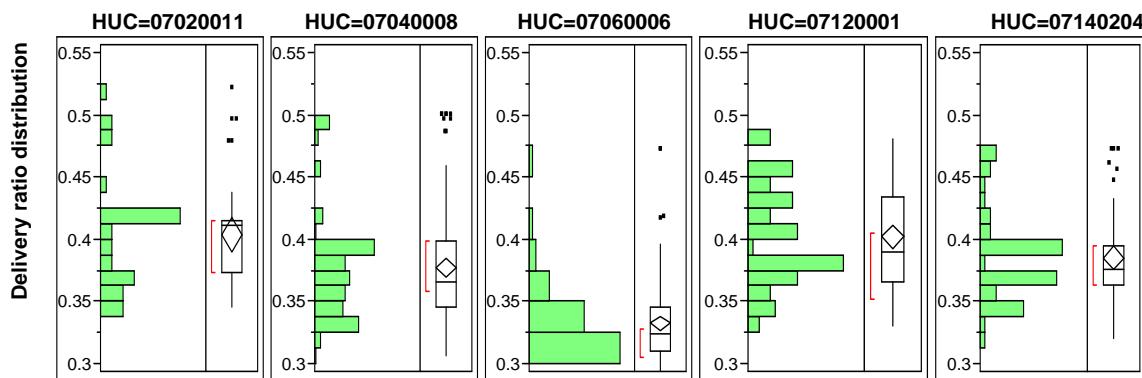
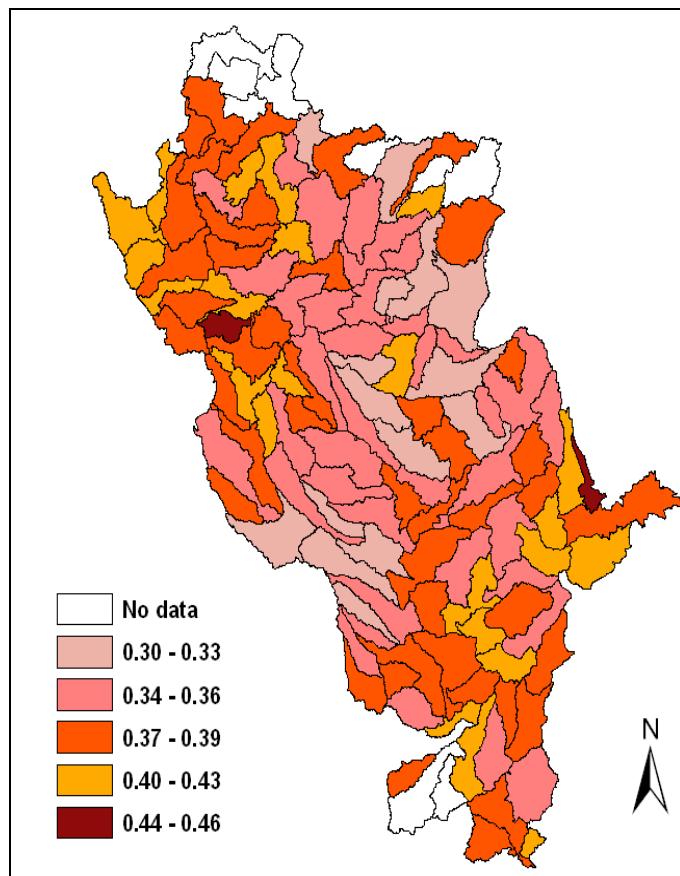


Figure 1-5 Mean sediment delivery ratio (sediment yield at the 8-digit watershed outlet divided by sediment yield at the edge-of-cropland fields) for cultivated cropland in the Upper Mississippi River Basin



Delivery Ratio used in CEAP in the Upper Mississippi River Basin

Table 1-1 Examples of inputs and estimated delivery ratios for cultivated cropland in the Upper Mississippi River Basin

8-digit wa- tershed NO.	SWAT basin channel length L_B (km)	SWAT basin channel slope S_B (m/m)	APEX site watershed length [‡] L_S (km)	APEX site main stem slope S_s (m/m)	Time of conc. of the basin t_{cB} (h)	Time of conc. of the APEX site t_{cW} (h)	Delivery ratio DR_s
07100009	239.9	0.001	0.447	0.051	64.44	0.11	0.28
			0.447	0.016	64.44	0.18	0.31
			0.447	0.002	64.44	0.39	0.36
07020001	92.3	0.003	0.447	0.013	20.23	0.19	0.39
07070006	115.5	0.002	0.447	0.031	28.11	0.14	0.34
07010108	69.5	0.001	0.447	0.017	24.82	0.17	0.37

[‡] Each APEX site is assumed to be a 16 ha of square area.

Delivery Ratio used in CEAP in the Upper Mississippi River Basin

Table 1-2 Sediment delivery ratios for cultivated cropland by 8-digit watershed

HUC	Cropland		CRP		Crop + CRP			
	Points	Mean SDR	Points	Mean SDR	Points	Mean SDR	10 th percentile	90 th percentile
7010104	4	0.38			4	0.38	0.34	0.49
7010106	8	0.37	3	0.36	11	0.37	0.34	0.41
7010107	5	0.39	2	0.37	7	0.39	0.37	0.40
7010108	5	0.39	14	0.38	19	0.38	0.36	0.43
7010201	10	0.42	1	0.37	11	0.41	0.36	0.53
7010202	13	0.35	9	0.34	22	0.35	0.32	0.39
7010203	16	0.39	4	0.36	20	0.38	0.34	0.47
7010204	25	0.37	30	0.37	55	0.37	0.33	0.40
7010205	24	0.39	3	0.37	27	0.39	0.34	0.49
7010206	11	0.40			11	0.40	0.37	0.44
7010207	18	0.41			18	0.41	0.36	0.50
7020001	41	0.41	38	0.39	79	0.40	0.37	0.43
7020002	10	0.41	6	0.39	16	0.40	0.35	0.50
7020003	35	0.44	23	0.41	58	0.43	0.37	0.55
7020004	35	0.39	24	0.36	59	0.38	0.33	0.44
7020005	31	0.37	36	0.36	67	0.37	0.32	0.46
7020006	17	0.42	17	0.40	34	0.41	0.37	0.48
7020007	24	0.43	3	0.40	27	0.42	0.36	0.51
7020008	32	0.37	4	0.37	36	0.37	0.33	0.40
7020009	38	0.38	2	0.32	40	0.38	0.32	0.46
7020010	17	0.45	4	0.41	21	0.44	0.39	0.50
7020011	30	0.39	10	0.35	40	0.38	0.33	0.45
7020012	34	0.36	6	0.32	40	0.36	0.31	0.41
7030001	3	0.37			3	0.37	0.33	0.44
7030003	1	0.33			1	0.33	0.33	0.33
7030004	7	0.35			7	0.35	0.32	0.37
7030005	28	0.34	17	0.33	45	0.34	0.30	0.37
7040001	35	0.40	13	0.37	48	0.39	0.35	0.45
7040002	76	0.36	30	0.34	106	0.35	0.31	0.44
7040003	20	0.34	11	0.33	31	0.34	0.31	0.37
7040004	62	0.36	16	0.33	78	0.35	0.31	0.38
7040005	13	0.34	13	0.32	26	0.33	0.31	0.37
7040006	9	0.38	7	0.34	16	0.36	0.34	0.41
7040007	14	0.34	3	0.29	17	0.33	0.28	0.37
7040008	85	0.36	40	0.33	125	0.35	0.31	0.41
7050001	1	0.33			1	0.33	0.33	0.33
7050002	1	0.39			1	0.39	0.39	0.39
7050004	1	0.44	1	0.41	2	0.43	0.41	0.44
7050005	23	0.36	6	0.33	29	0.35	0.31	0.38
7050006	5	0.35	2	0.33	7	0.34	0.31	0.38
7050007	20	0.35	16	0.33	36	0.34	0.30	0.36
7060001	17	0.42	34	0.38	51	0.40	0.37	0.43
7060002	34	0.35	32	0.32	66	0.33	0.31	0.37
7060003	26	0.38	35	0.36	61	0.37	0.35	0.40

Delivery Ratio used in CEAP in the Upper Mississippi River Basin

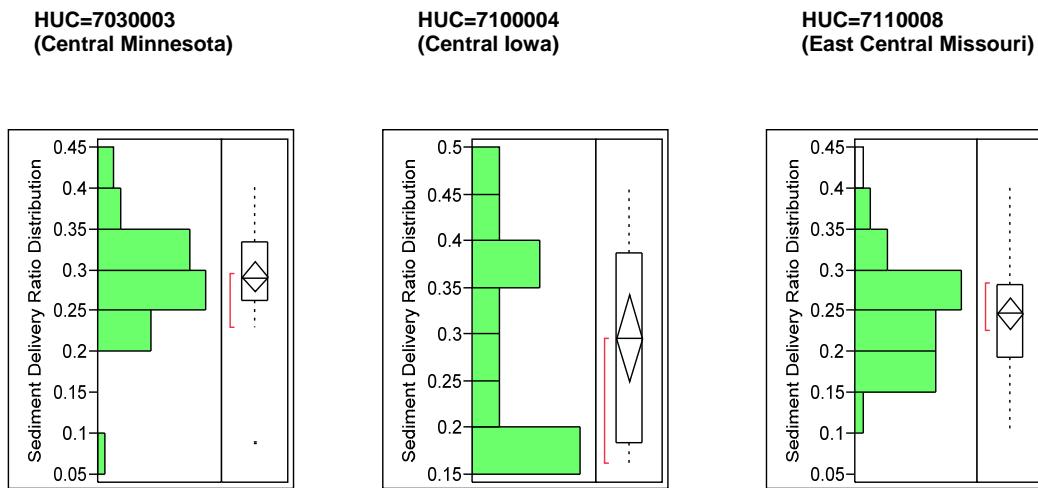
7060004	30	0.33	41	0.30	71	0.31	0.29	0.35
7060005	49	0.41	46	0.36	95	0.38	0.35	0.43
7060006	61	0.32	46	0.29	107	0.31	0.29	0.35
7070002	13	0.37			13	0.37	0.35	0.40
7070003	34	0.34	6	0.29	40	0.33	0.29	0.37
7070004	4	0.37	6	0.33	10	0.35	0.32	0.44
7070005	21	0.34	39	0.31	60	0.32	0.30	0.35
7070006	9	0.36	15	0.34	24	0.34	0.33	0.39
7080101	41	0.39	12	0.36	53	0.39	0.34	0.46
7080102	35	0.36	7	0.33	42	0.36	0.33	0.43
7080103	36	0.37	11	0.32	47	0.35	0.31	0.41
7080104	74	0.39	19	0.35	93	0.38	0.33	0.44
7080105	41	0.35	23	0.32	64	0.34	0.29	0.42
7080106	21	0.34	27	0.32	48	0.33	0.31	0.37
7080107	36	0.37	58	0.31	94	0.33	0.30	0.40
7080201	82	0.36	25	0.35	107	0.36	0.31	0.42
7080202	45	0.39	20	0.38	65	0.39	0.34	0.47
7080203	16	0.40	7	0.39	23	0.40	0.35	0.47
7080204	16	0.39	3	0.35	19	0.38	0.34	0.48
7080205	43	0.34	7	0.30	50	0.34	0.30	0.35
7080206	24	0.40	11	0.35	35	0.39	0.34	0.47
7080207	29	0.36	7	0.34	36	0.36	0.31	0.42
7080208	28	0.36	21	0.32	49	0.35	0.31	0.42
7080209	69	0.36	52	0.32	121	0.34	0.30	0.39
7090001	69	0.36	16	0.32	85	0.35	0.31	0.38
7090002	22	0.40	7	0.37	29	0.39	0.34	0.42
7090003	50	0.34	38	0.31	88	0.33	0.30	0.36
7090004	19	0.37	6	0.33	25	0.36	0.32	0.45
7090005	73	0.36	22	0.32	95	0.35	0.31	0.40
7090006	64	0.39	6	0.36	70	0.39	0.35	0.43
7090007	25	0.38	5	0.35	30	0.38	0.33	0.42
7100001	78	0.39	24	0.37	102	0.39	0.34	0.42
7100002	18	0.39	7	0.36	25	0.38	0.32	0.47
7100003	28	0.40	6	0.39	34	0.40	0.36	0.46
7100004	31	0.39	2	0.39	33	0.39	0.36	0.47
7100005	15	0.41	1	0.37	16	0.41	0.36	0.47
7100006	44	0.34	5	0.31	49	0.34	0.31	0.37
7100007	31	0.39	19	0.33	50	0.37	0.32	0.47
7100008	46	0.34	59	0.31	105	0.32	0.29	0.36
7100009	27	0.32	83	0.30	110	0.30	0.28	0.34
7110001	35	0.35	38	0.32	73	0.34	0.30	0.39
7110002	25	0.35	43	0.32	68	0.33	0.30	0.37
7110003	13	0.38	40	0.34	53	0.35	0.31	0.38
7110004	35	0.40	25	0.37	60	0.39	0.35	0.44
7110005	24	0.35	41	0.33	65	0.34	0.30	0.37
7110006	33	0.39	52	0.36	85	0.37	0.34	0.39

Delivery Ratio used in CEAP in the Upper Mississippi River Basin

7110007	19	0.40	29	0.38	48	0.39	0.36	0.42
7110008	30	0.36	15	0.33	45	0.35	0.32	0.39
7110009	21	0.41	6	0.37	27	0.40	0.35	0.47
7120001	71	0.38	4	0.32	75	0.38	0.33	0.43
7120002	56	0.41	4	0.37	60	0.41	0.35	0.48
7120003	3	0.46			3	0.46	0.40	0.50
7120004	15	0.41	3	0.39	18	0.41	0.37	0.45
7120005	26	0.41	2	0.35	28	0.41	0.35	0.47
7120006	41	0.34	9	0.33	50	0.34	0.30	0.37
7120007	49	0.39	2	0.34	51	0.38	0.34	0.46
7130001	53	0.35	1	0.31	54	0.35	0.32	0.36
7130002	38	0.40	3	0.40	41	0.40	0.36	0.48
7130003	35	0.42	6	0.40	41	0.42	0.37	0.47
7130004	22	0.37	6	0.33	28	0.36	0.32	0.40
7130005	54	0.35	6	0.32	60	0.35	0.30	0.39
7130006	33	0.36	1	0.35	34	0.36	0.32	0.41
7130007	21	0.42	1	0.34	22	0.41	0.36	0.48
7130008	26	0.43	7	0.37	33	0.42	0.34	0.51
7130009	39	0.37	1	0.32	40	0.37	0.33	0.42
7130010	41	0.37	4	0.32	45	0.37	0.32	0.40
7130011	66	0.39	12	0.35	78	0.38	0.34	0.43
7130012	24	0.37	4	0.33	28	0.37	0.32	0.42
7140101	24	0.42	3	0.36	27	0.41	0.36	0.47
7140103	4	0.38			4	0.38	0.36	0.43
7140105	30	0.40	20	0.35	50	0.38	0.34	0.48
7140106	47	0.36	48	0.34	95	0.35	0.31	0.41
7140107	5	0.41	9	0.36	14	0.38	0.34	0.44
7140108	18	0.45	19	0.37	37	0.41	0.36	0.53
7140201	40	0.38	4	0.33	44	0.37	0.33	0.42
7140202	45	0.38	17	0.35	62	0.37	0.33	0.43
7140203	31	0.40	12	0.36	43	0.39	0.35	0.44
7140204	50	0.36	4	0.37	54	0.36	0.32	0.42

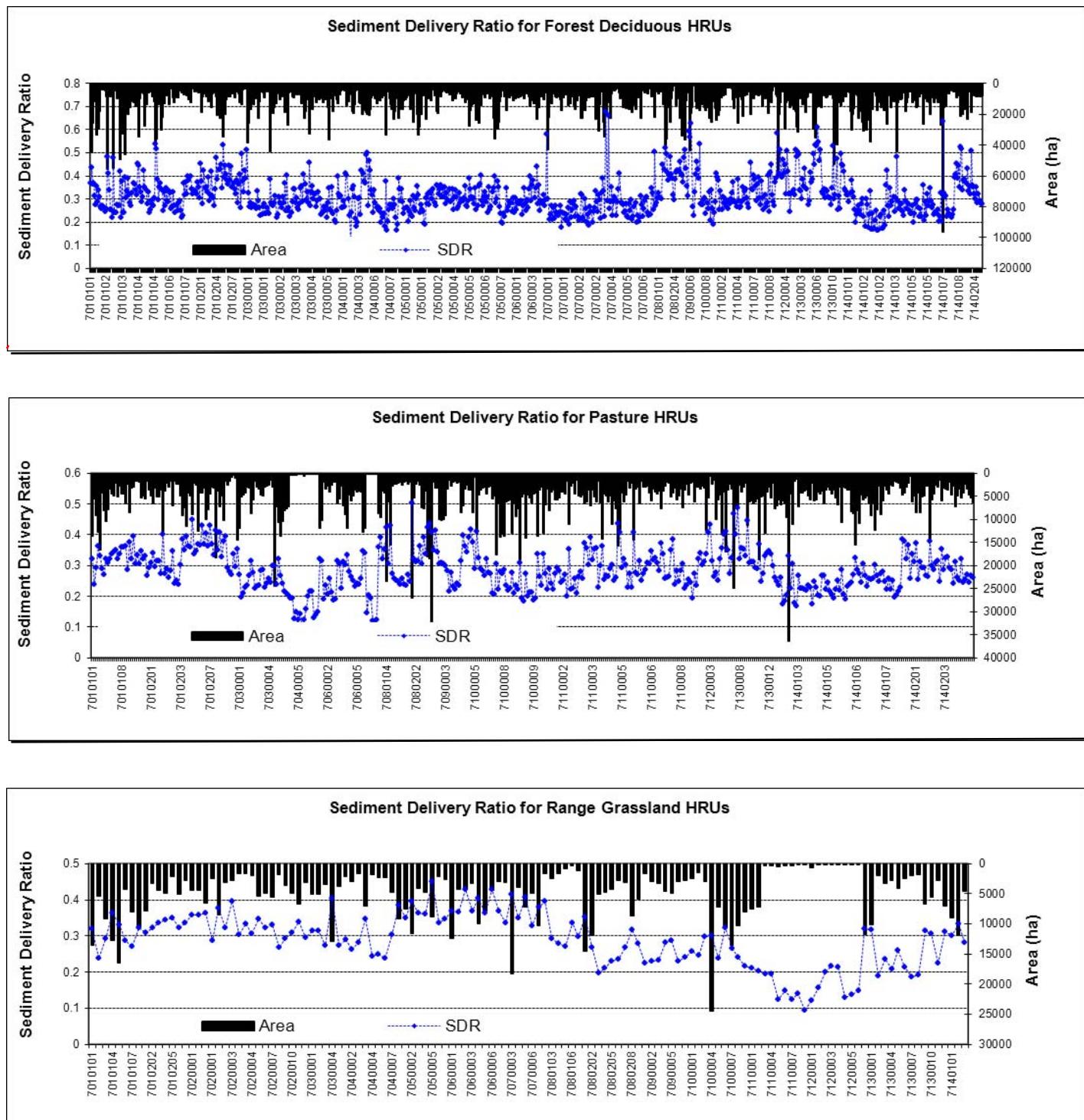
Delivery Ratio used in CEAP in the Upper Mississippi River Basin

Figure 1-6 Examples of sediment delivery ratio distributions for non-cultivated land HRUs for three 8-digit watersheds in the Upper Mississippi River Basin



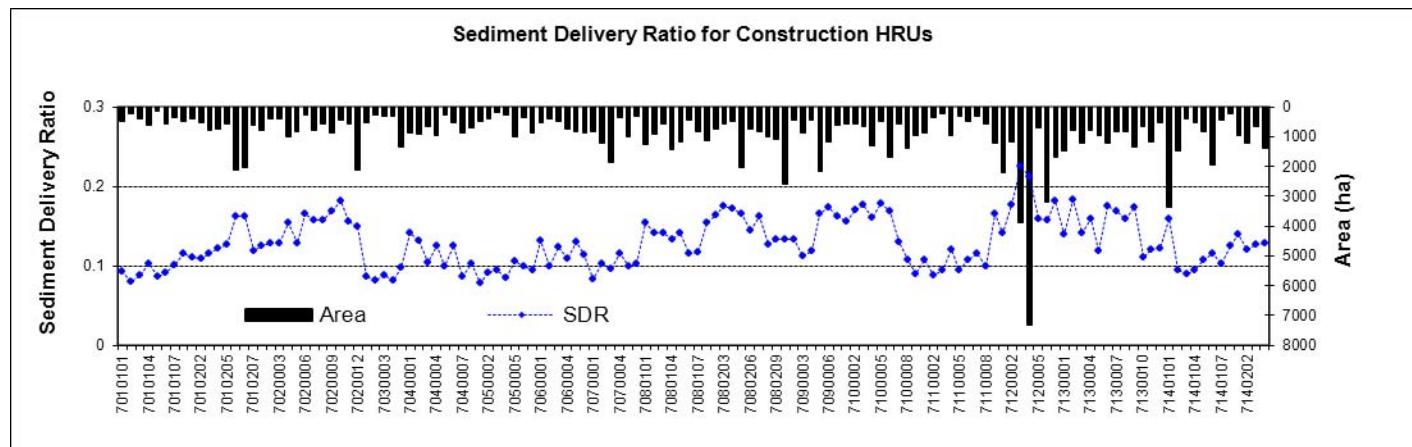
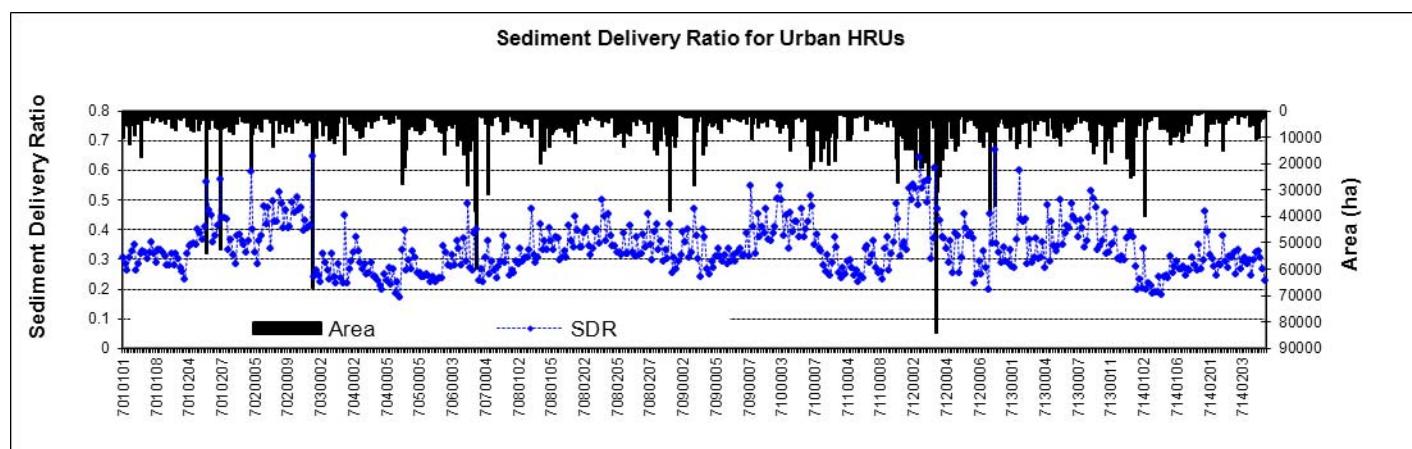
Delivery Ratio used in CEAP in the Upper Mississippi River Basin

Figure 1-7 Sediment delivery ratio estimated for major non-cultivated land HRUs (Forest, Pasture, Range, Urban and Construction) in the Upper Mississippi River Basin



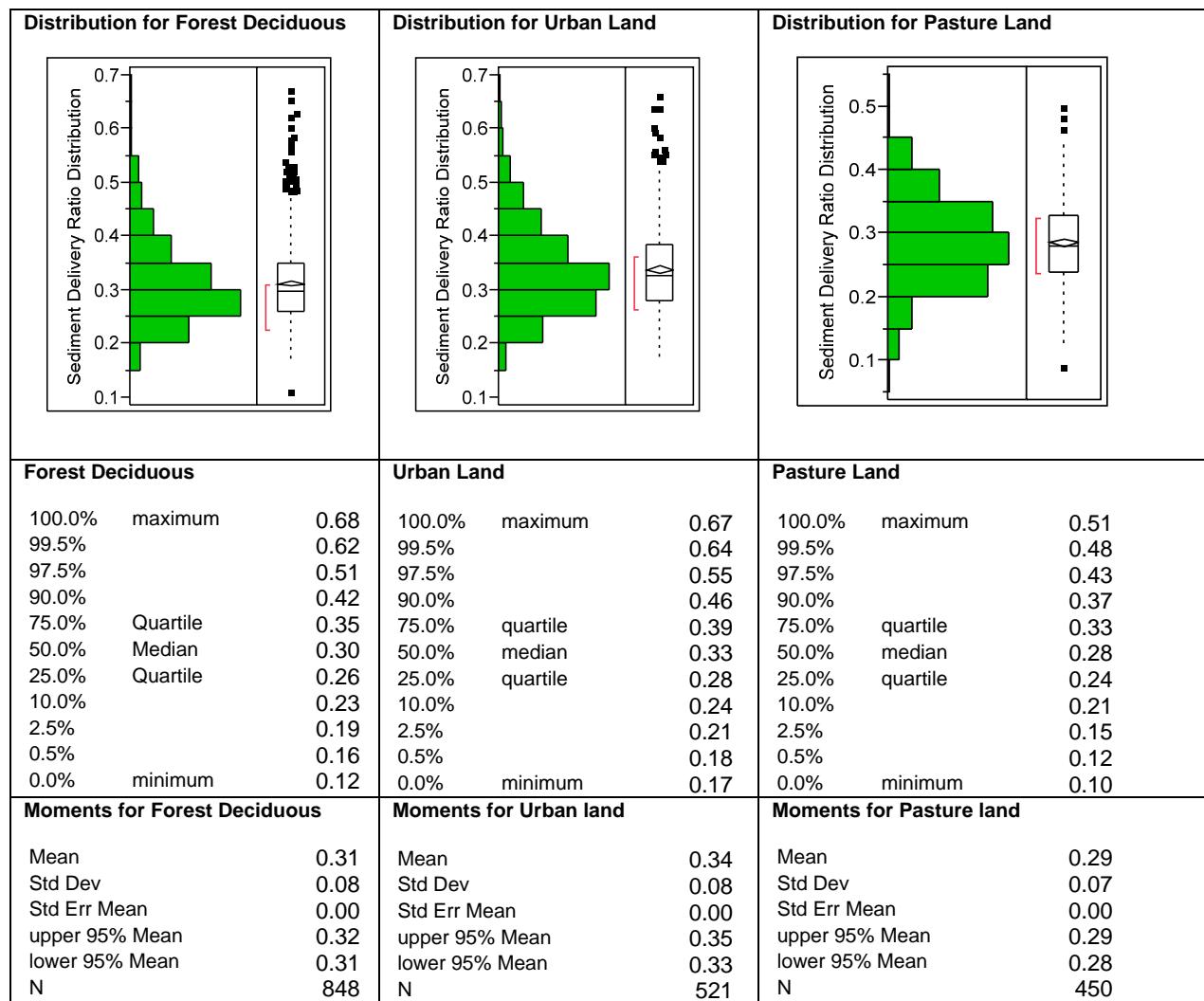
Delivery Ratio used in CEAP in the Upper Mississippi River Basin

Figure 1-7 Sediment delivery ratio estimated for major non-cultivated land HRUs (Forest, Pasture, Range, Urban and Construction) in the Upper Mississippi River Basin (Contd.)



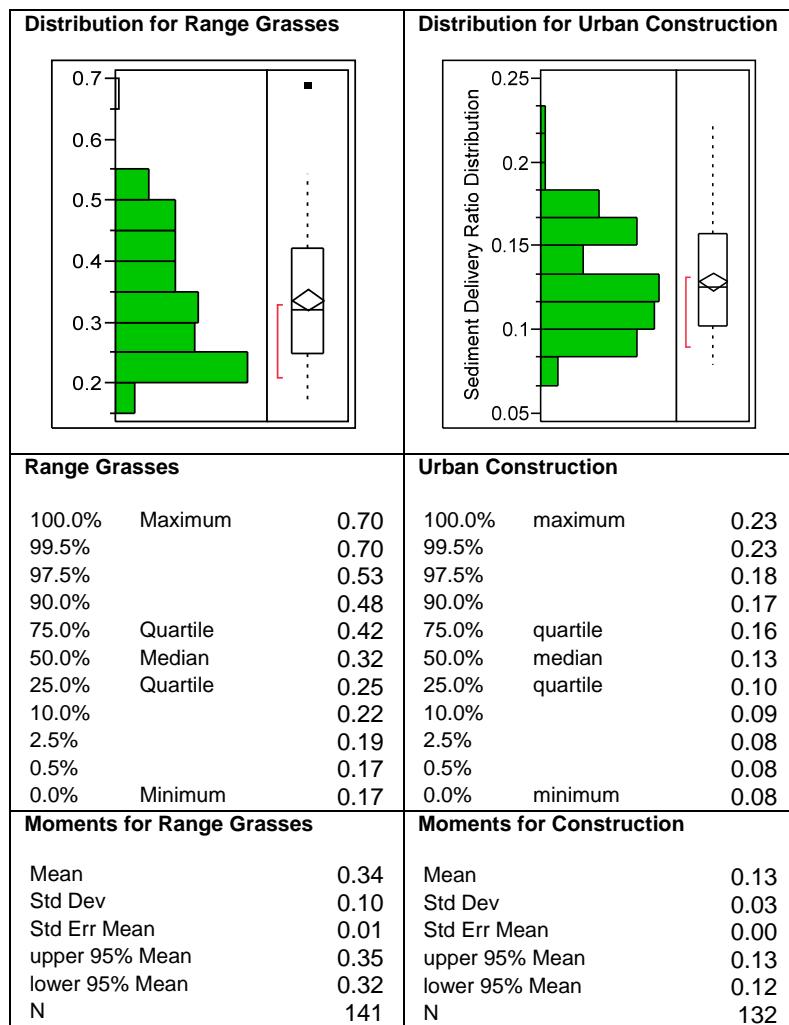
Delivery Ratio used in CEAP in the Upper Mississippi River Basin

Figure 1-8 Distribution of sediment delivery ratio for forest, urban, pasture, range and construction HRUs in the Upper Mississippi River Basin



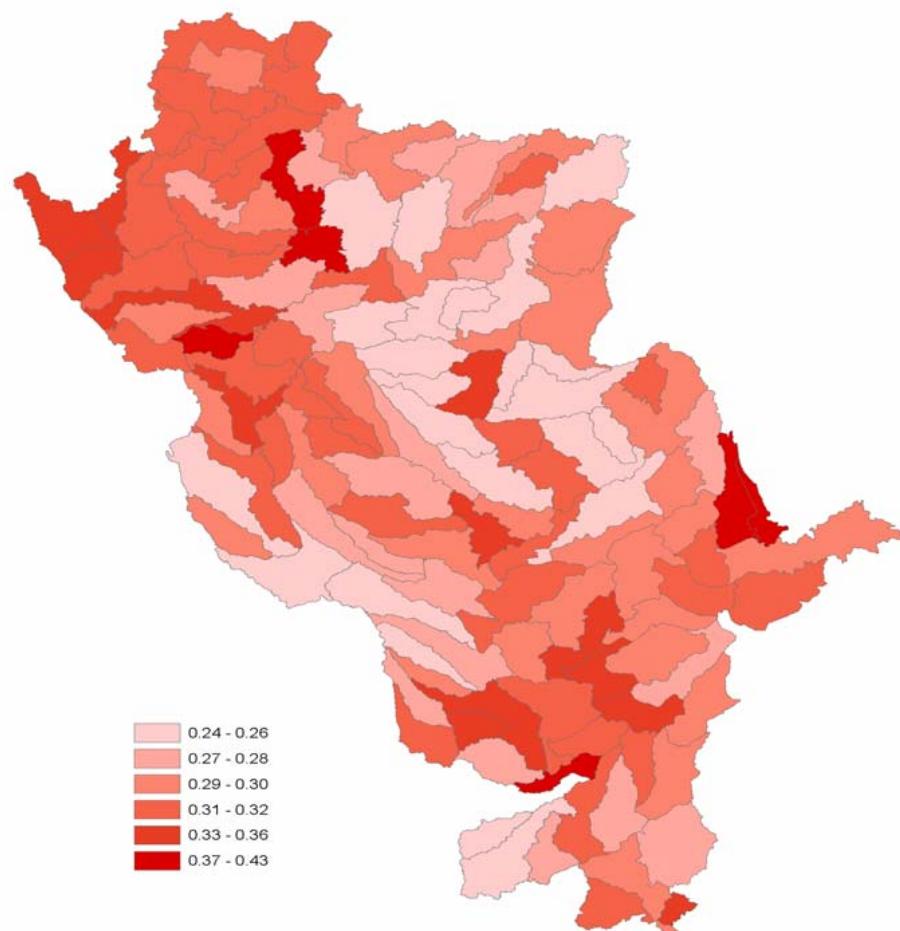
Delivery Ratio used in CEAP in the Upper Mississippi River Basin

Figure 1-8 Distribution of sediment delivery ratio for forest, urban and pasture land HRUs in the Upper Mississippi River Basin Continued.



Delivery Ratio used in CEAP in the Upper Mississippi River Basin

Figure 1-9 Mean sediment delivery ratio computed for non-cultivated land HRUs in the 8-digit watersheds in the Upper Mississippi River Basin



Delivery Ratio used in CEAP in the Upper Mississippi River Basin

Table 1-3 Example inputs, time of concentration and sediment delivery ratio estimated for non-cultivated land HRUs in three 8-digit watersheds in the Upper Mississippi River Basin

HUC	Landuse	Time of conc. of HRU	Time of conc. of sub-basin	Delivery Ratio	Area (ha)	Subbasin Slope Length (km)	Subbasin Channel Slope (%)	HRU Slope %	HRU Slope Length (m)
7030003	Forest Deciduous	3.75	44.84	0.29	8189.06	97.45	0.001	0.006	149.49
7030003	Forest Deciduous	5.36	46.24	0.34	9156.76	97.45	0.001	0.003	291.43
7030003		7.42	46.24	0.40	19020.22	97.45	0.001	0.003	291.43
7030003	Forest Deciduous	5.59	47.55	0.34	4438.21	97.45	0.001	0.002	430.65
7030003	Forest Deciduous	3.64	45.56	0.28	4613.28	97.45	0.001	0.004	220.9
7030003	Forest Deciduous	4.23	45.56	0.31	7154.59	97.45	0.001	0.004	220.9
7030003	Forest Deciduous	3.14	45.13	0.26	4286.86	97.45	0.001	0.005	178.18
7030003	Forest Deciduous	2.86	45.13	0.25	3162.41	97.45	0.001	0.005	178.18
7030003	Pasture	2.48	44.84	0.24	2806.13	97.45	0.001	0.006	149.49
7030003	Forest Deciduous	3.45	44.84	0.28	6871.12	97.45	0.001	0.006	149.49
7030003	Water	3.07	44.84	0.26	5225.95	97.45	0.001	0.006	149.49
7030003	Pasture	3.26	45.56	0.27	3070.57	97.45	0.001	0.004	220.9
7030003	Forest Deciduous	5.47	45.56	0.35	12834.84	97.45	0.001	0.004	220.9
7030003	Range Brush	3.48	46.24	0.28	1314.22	97.45	0.001	0.003	291.43
7030003	Forest Deciduous	5.81	46.24	0.35	11212.00	97.45	0.001	0.003	291.43
7030003	Evergreen Forest	6.25	46.24	0.37	13286.06	97.45	0.001	0.003	291.43
7030003	Non-forested wet-land	4.75	46.24	0.32	6446.94	97.45	0.001	0.003	291.43
7030003	Forest Deciduous	3.76	44.84	0.29	8210.15	97.45	0.001	0.006	149.49
7030003	Horticulture	2.41	45.56	0.23	63.49	97.45	0.001	0.004	220.9
7030003	Legume Hay	4.45	45.56	0.31	8140.74	97.45	0.001	0.004	220.9
7030003	Other Hay	3.31	45.56	0.27	3274.88	97.45	0.001	0.004	220.9
7030003	Pasture	4.56	45.56	0.32	8626.58	97.45	0.001	0.004	220.9
7030003	Pasture with manure	2.43	45.56	0.23	125.58	97.45	0.001	0.004	220.9
7030003	Range Grass	5.39	45.56	0.34	12454.14	97.45	0.001	0.004	220.9
7030003	Forest Deciduous	7.46	45.56	0.41	22695.27	97.45	0.001	0.004	220.9
7030003	Forest Mixed	2.51	45.56	0.24	338.62	97.45	0.001	0.004	220.9
7030003	Urban	4.64	45.56	0.32	8984.70	97.45	0.001	0.004	220.9
7030003	Non-forested wet-land	5.07	45.56	0.33	10980.90	97.45	0.001	0.004	220.9
7030003	Legume Hay with Manure	2.39	45.56	0.23	15.81	97.45	0.001	0.004	220.9
7030003	Other Hay with Manure	2.41	45.56	0.23	52.87	97.45	0.001	0.004	220.9
7030003	Urban Construction	0.34	43.40	0.09	277.87	97.45	0.001	0.15	6.73
7030003	Pasture	3.49	45.13	0.28	5757.54	97.45	0.001	0.005	178.18
7030003	Deciduous Forest	6.05	45.13	0.37	17695.35	97.45	0.001	0.005	178.18
7030003	Non-forested wet-land	3.96	45.13	0.30	7838.74	97.45	0.001	0.005	178.18

Delivery Ratio used in CEAP in the Upper Mississippi River Basin

7030003	Deciduous Forest	4.08	46.24	0.30	3595.33	97.45	0.001	0.003	291.43
7030003	Deciduous Forest	4.95	45.56	0.33	10414.63	97.45	0.001	0.004	220.9
7030003	Barren	2.39	45.56	0.23	13.79	97.45	0.001	0.004	220.9
7030003	Non-forested wet-land	4.20	45.56	0.30	7011.85	97.45	0.001	0.004	220.9
7030003	Deciduous Forest	3.69	46.24	0.28	2065.97	97.45	0.001	0.003	291.43
7100004	Urban	7.68	52.82	0.38	4867.44	97.5	0.001	0.002	430.65
7100004	Barren	8.36	56.49	0.39	344.09	97.5	0.001	0.001	839.55
7100004	Urban	11.31	56.49	0.45	4822.25	97.5	0.001	0.001	839.55
7100004	Deciduous Forest	8.25	49.62	0.41	11641.30	97.5	0.001	0.009	101.16
7100004	Range Grass	7.40	49.74	0.39	9810.96	97.5	0.001	0.008	113.31
7100004	Deciduous Forest	10.54	49.74	0.46	15780.72	97.5	0.001	0.008	113.31
7100004	Evergreen Forest	1.36	49.74	0.17	49.35	97.5	0.001	0.008	113.31
7100004	Urban	5.55	49.74	0.33	6500.42	97.5	0.001	0.008	113.31
7100004	Non-forested wet-land	2.74	49.74	0.24	1893.58	97.5	0.001	0.008	113.31
7100004	Horticulture	1.92	50.11	0.20	251.88	97.5	0.001	0.006	149.49
7100004	Legume Hay	3.77	50.11	0.27	2901.51	97.5	0.001	0.006	149.49
7100004	Other Hay	2.40	50.11	0.22	867.17	97.5	0.001	0.006	149.49
7100004	Pasture	7.05	50.11	0.38	8509.06	97.5	0.001	0.006	149.49
7100004	Pasture with manure	1.71	50.11	0.19	32.91	97.5	0.001	0.006	149.49
7100004	Range Grass	1.68	50.11	0.18	5.93	97.5	0.001	0.006	149.49
7100004	Urban	10.58	50.11	0.46	15124.34	97.5	0.001	0.006	149.49
7100004	Forested Wetland	4.38	50.11	0.30	3882.58	97.5	0.001	0.006	149.49
7100004	Legume Hay with Manure	1.68	50.11	0.18	9.80	97.5	0.001	0.006	149.49
7100004	Other Hay with Manure	1.69	50.11	0.18	15.54	97.5	0.001	0.006	149.49
7100004	Urban Construction	1.26	48.67	0.16	1282.71	97.5	0.001	0.15	6.73
7100004	Water	5.27	49.74	0.33	6020.68	97.5	0.001	0.008	113.31
7100004	Mixed Forest	1.46	49.90	0.17	0.94	97.5	0.001	0.007	128.86
7100004	Urban	7.75	49.90	0.39	10159.64	97.5	0.001	0.007	128.86
7110008	Pasture	3.28	57.89	0.24	8189.06	121.08	0.001	0.006	149.49
7110008	Pasture	4.68	58.18	0.28	9156.76	121.08	0.001	0.005	178.18
7110008	Deciduous Forest	5.43	58.18	0.31	19020.22	121.08	0.001	0.005	178.18
7110008	Pasture	3.52	57.39	0.25	4438.21	121.08	0.001	0.009	101.16
7110008	Deciduous Forest	4.30	57.39	0.27	4613.28	121.08	0.001	0.009	101.16
7110008	Pasture	4.77	59.29	0.28	7154.59	121.08	0.001	0.003	291.43
7110008	Horticulture	2.12	58.18	0.19	4286.86	121.08	0.001	0.005	178.18
7110008	Legume Hay	3.83	58.18	0.26	3162.41	121.08	0.001	0.005	178.18
7110008	Other Hay	7.40	58.18	0.36	2806.13	121.08	0.001	0.005	178.18
7110008	Pasture	5.41	58.18	0.31	6871.12	121.08	0.001	0.005	178.18
7110008	Pasture with Manure	2.10	58.18	0.19	5225.95	121.08	0.001	0.005	178.18
7110008	Deciduous Forest	8.34	58.18	0.38	3070.57	121.08	0.001	0.005	178.18
7110008	Urban	4.25	58.18	0.27	12834.84	121.08	0.001	0.005	178.18

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7110008	Forested Wetland	4.65	58.18	0.28	1314.22	121.08	0.001	0.005	178.18
7110008	Water	2.80	58.18	0.22	11212.00	121.08	0.001	0.005	178.18
7110008	Legume Hay with Manure	1.97	58.18	0.18	13286.06	121.08	0.001	0.005	178.18
7110008	Other Hay with Manure	2.09	58.18	0.19	6446.94	121.08	0.001	0.005	178.18
7110008	Pasture	2.89	57.29	0.23	8210.15	121.08	0.001	0.01	91.4
7110008	Forest Deciduous	5.37	57.29	0.31	63.49	121.08	0.001	0.01	91.4
7110008	Pasture	3.20	58.18	0.23	8140.74	121.08	0.001	0.005	178.18
7110008	Forest Deciduous	3.76	58.18	0.25	3274.88	121.08	0.001	0.005	178.18
7110008	Pasture	3.70	57.68	0.25	8626.58	121.08	0.001	0.007	128.86
7110008	Forest Deciduous	5.88	57.68	0.32	125.58	121.08	0.001	0.007	128.86
7110008	Barren	1.67	57.68	0.17	12454.14	121.08	0.001	0.007	128.86
7110008	Urban	3.72	57.68	0.25	22695.27	121.08	0.001	0.007	128.86
7110008	Pasture	3.49	58.60	0.24	338.62	121.08	0.001	0.004	220.9
7110008	Pasture	2.17	57.39	0.19	8984.70	121.08	0.001	0.009	101.16
7110008	Forest Deciduous	4.06	57.39	0.27	10980.90	121.08	0.001	0.009	101.16
7110008	Forest Deciduous	4.59	57.89	0.28	15.81	121.08	0.001	0.006	149.49
7110008	Pasture	4.37	57.68	0.28	52.87	121.08	0.001	0.007	128.86
7110008	Range Brush	1.62	57.68	0.17	277.87	121.08	0.001	0.007	128.86
7110008	Range Grass	2.87	57.68	0.22	5757.54	121.08	0.001	0.007	128.86
7110008	Forest Deciduous	9.36	57.68	0.40	17695.35	121.08	0.001	0.007	128.86
7110008	Evergreen Forest	1.75	57.68	0.17	7838.74	121.08	0.001	0.007	128.86
7110008	Mixed Forest	1.63	57.68	0.17	3595.33	121.08	0.001	0.007	128.86
7110008	Urban	3.91	57.68	0.26	10414.63	121.08	0.001	0.007	128.86
7110008	Urban Construction	0.57	56.45	0.10	13.79	121.08	0.001	0.15	6.73
7110008	Pasture	3.16	57.89	0.23	7011.85	121.08	0.001	0.006	149.49
7110008	Forest Deciduous	3.54	57.89	0.25	2065.97	121.08	0.001	0.006	149.49
7110008	Urban	3.16	57.89	0.23	8189.06	121.08	0.001	0.006	149.49
7110008	Non-forested Wetland	1.77	57.89	0.18	9156.76	121.08	0.001	0.006	149.49

Table 1-4. Mean and percentiles of sediment delivery ratio (sediment delivered at 8-digit watershed outlet by sediment yield at HRUs) estimated for non-cultivated land HRUs within SWAT for the 8-digit watersheds in the Upper Mississippi River Basin

HUC	Subbasin	Number_of non-cropland HRUs simulated within SWAT	Mean SDR	10 th Percentile SDR	90 th Percentile SDR
7010101	1	41	0.31	0.25	0.38
7010102	2	36	0.28	0.21	0.39
7010103	3	40	0.31	0.24	0.37
7010104	4	42	0.32	0.25	0.39
7010105	5	37	0.30	0.24	0.37
7010106	6	41	0.30	0.23	0.36
7010107	7	48	0.30	0.25	0.36
7010108	8	45	0.32	0.26	0.36
7010201	9	49	0.32	0.28	0.39
7010202	10	39	0.26	0.19	0.34
7010203	11	47	0.29	0.24	0.34
7010204	12	33	0.30	0.23	0.40
7010205	13	33	0.30	0.23	0.41
7010206	14	37	0.36	0.30	0.44
7010207	15	45	0.38	0.33	0.43
7020001	16	30	0.35	0.29	0.45
7020002	17	32	0.33	0.27	0.42
7020003	18	27	0.34	0.28	0.48
7020004	19	24	0.30	0.21	0.46
7020005	20	27	0.30	0.22	0.42
7020006	21	24	0.34	0.27	0.50
7020007	22	26	0.34	0.27	0.52
7020008	23	23	0.29	0.19	0.48
7020009	24	26	0.30	0.23	0.47
7020010	25	25	0.37	0.30	0.49
7020011	26	26	0.30	0.23	0.45
7020012	27	24	0.27	0.18	0.45
7030001	28	48	0.28	0.22	0.35
7030002	29	48	0.26	0.20	0.34
7030003	30	45	0.29	0.23	0.36
7030004	31	49	0.26	0.21	0.33
7030005	32	42	0.26	0.18	0.35
7040001	33	39	0.31	0.25	0.38
7040002	34	30	0.27	0.18	0.40
7040003	35	41	0.25	0.18	0.36
7040004	36	33	0.25	0.17	0.42
7040005	37	33	0.26	0.17	0.39
7040006	38	37	0.29	0.22	0.39
7040007	39	36	0.25	0.14	0.34
7040008	40	31	0.24	0.16	0.40
7050001	41	44	0.26	0.19	0.34
7050002	42	48	0.29	0.23	0.34
7050003	43	49	0.31	0.24	0.36

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7050004	44	44	0.28	0.21	0.33
7050005	45	33	0.28	0.19	0.38
7050006	46	37	0.27	0.19	0.36
7050007	47	39	0.25	0.18	0.37
7060001	48	40	0.34	0.30	0.39
7060002	49	41	0.24	0.17	0.33
7060003	50	34	0.31	0.25	0.39
7060004	51	27	0.24	0.15	0.38
7060005	52	41	0.30	0.25	0.38
7060006	53	23	0.25	0.15	0.49
7070001	54	51	0.26	0.18	0.32
7070002	55	36	0.29	0.22	0.37
7070003	56	28	0.28	0.17	0.42
7070004	57	42	0.26	0.19	0.34
7070005	58	37	0.25	0.17	0.34
7070006	59	40	0.26	0.19	0.34
7080101	60	35	0.30	0.24	0.38
7080102	61	25	0.27	0.17	0.44
7080103	62	24	0.28	0.19	0.46
7080104	63	24	0.31	0.22	0.48
7080105	64	24	0.27	0.16	0.43
7080106	65	30	0.27	0.19	0.39
7080107	66	25	0.28	0.19	0.47
7080201	67	21	0.28	0.17	0.44
7080202	68	23	0.32	0.23	0.42
7080203	69	22	0.32	0.22	0.47
7080204	70	22	0.31	0.21	0.46
7080205	71	24	0.27	0.16	0.40
7080206	72	22	0.35	0.26	0.44
7080207	73	22	0.29	0.18	0.45
7080208	74	19	0.30	0.19	0.48
7080209	75	22	0.29	0.19	0.44
7090001	76	31	0.28	0.20	0.41
7090002	77	36	0.32	0.25	0.40
7090003	78	31	0.24	0.16	0.35
7090004	79	44	0.26	0.19	0.33
7090005	80	33	0.25	0.16	0.37
7090006	81	34	0.29	0.22	0.39
7090007	82	26	0.29	0.21	0.46
7100001	83	24	0.32	0.24	0.49
7100002	84	25	0.29	0.19	0.43
7100003	85	23	0.34	0.26	0.50
7100004	86	26	0.31	0.22	0.44
7100005	87	23	0.32	0.23	0.46
7100006	88	23	0.25	0.15	0.46
7100007	89	29	0.28	0.20	0.40
7100008	90	37	0.26	0.17	0.33
7100009	91	40	0.24	0.15	0.32
7110001	92	35	0.27	0.19	0.39
7110002	93	45	0.26	0.19	0.33

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7110003	94	44	0.28	0.22	0.37
7110004	95	43	0.33	0.30	0.40
7110005	96	41	0.27	0.20	0.35
7110006	97	40	0.31	0.25	0.37
7110007	98	38	0.33	0.27	0.41
7110008	99	46	0.27	0.21	0.34
7110009	100	39	0.36	0.31	0.43
7120001	101	26	0.28	0.20	0.42
7120002	102	22	0.32	0.24	0.53
7120003	103	30	0.43	0.39	0.55
7120004	104	35	0.36	0.32	0.45
7120005	105	25	0.31	0.22	0.45
7120006	106	35	0.27	0.19	0.35
7120007	107	24	0.30	0.22	0.46
7130001	108	24	0.28	0.18	0.45
7130002	109	20	0.31	0.21	0.49
7130003	110	33	0.36	0.29	0.44
7130004	111	25	0.29	0.19	0.43
7130005	112	22	0.28	0.18	0.50
7130006	113	23	0.28	0.18	0.47
7130007	114	23	0.35	0.27	0.47
7130008	115	25	0.33	0.26	0.49
7130009	116	21	0.29	0.19	0.51
7130010	117	30	0.30	0.22	0.36
7130011	118	27	0.32	0.25	0.42
7130012	119	27	0.31	0.21	0.44
7140101	120	46	0.32	0.26	0.39
7140102	121	48	0.24	0.18	0.33
7140103	122	54	0.25	0.19	0.33
7140104	123	48	0.26	0.21	0.32
7140105	124	56	0.29	0.25	0.35
7140106	125	49	0.27	0.22	0.33
7140107	126	51	0.30	0.26	0.35
7140108	127	41	0.34	0.29	0.43
7140201	128	26	0.28	0.20	0.47
7140202	129	38	0.29	0.22	0.38
7140203	130	40	0.30	0.24	0.36
7140204	131	45	0.27	0.21	0.33

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Chapter 2

**Delivery Ratio used in CEAP Cropland
Modeling in the Chesapeake Bay
Watershed**

The APEX model is a field-scale, daily time-step model that simulates weather, farming operations, crop growth and yield, and the movement of water, soil, carbon, nutrients, sediment, and pesticides. The APEX model was used also to simulate the effects of conservation practices at the field scale (Williams and Izaurrealde, 2006; Gassman et al. 2009) in the Chesapeake Bay Watershed. APEX simulates all of the basic biological, chemical, hydrological, and meteorological processes of farming systems and their interactions. Soil erosion is simulated over time, including wind, sheet and rill erosion. The nitrogen, phosphorus, and carbon cycles are simulated, including chemical transformations in the soil that affect their availability for plant growth or for transport from the field.

While the APEX model was used to simulate the cultivated cropland and the SWAT model was used to simulate the non-cultivated cropland in the 8-digit watersheds (sub-basins) of the river basin. SWAT is a physical process model with a daily time step (Arnold and Fohrer 2005; Arnold et al. 1998; Gassman et al. 2007). The hydrologic cycle in the model is divided into two parts. The land phase of the hydrologic cycle, or upland processes, simulates the amount of water, sediment, nutrients, and pesticides delivered from the land to the outlet of each watershed. The routing phase of the hydrologic cycle, or channel processes, simulates the movement of water, sediment, nutrients, and pesticides from the outlet of the upstream watershed through the main channel network to the watershed outlet.

In SWAT, each 8-digit watershed is divided into multiple Hydrologic Response Units (HRUs) that have homogeneous land use, soil and slope. SWAT is used to simulate the fate and transport of water, sediment, nutrients, and pesticides from various non-cropland HRUs as described in Chapter 1.

Not all of the soil that erodes from a field or HRUs ends up in the watershed outlet. Most of the soil eroded gets deposited on the way although the deposition is temporary. Eroded soil may deposit in low spots, flat lands, at the edge of the field and sometimes settles at the bottom of the channel. Hence, a SDR was used to account for deposition in ditches, floodplains, and tributary stream channels during transit from the edge of the field or HRUs to the 8-digit watershed outlet in the CEAP National Assessment modeling. The SDR used in this study is a function of the ratio of the time of concentration for the HRU (land uses other than cultivated cropland) or field (cultivated cropland) to the time of concentration for the watershed (8-digit HUC).

The time of concentration for the watershed is the time from when a surface water runoff event occurs at the most distant point in the watershed to the time the surface water runoff reaches the outlet of the watershed. It is calculated by summing the overland flow time (the time it takes for flow from the remotest point in the watershed to reach the channel) and the channel flow time (the time it takes for flow in the upstream channels to reach the outlet). The time of concentration for the field is derived from APEX. The time of concentration for the HRU is derived from characteristics of the watershed, the HRU, and the proportion of total acres represented by the HRU. Consequently, each cultivated cropland sample point has a unique delivery ratio within each watershed, as does each HRU. The description of the SDR procedure is provided in Chapter 1.

The APEX model simulates the edge of sediment yield using a variation of MUSLE called MUST (MUSLE developed from Theory) (Williams 1995) as described in Chapter 1. After estimating the sediment load from each APEX simulation site, the delivery ratio is applied to determine the amount of sediment that reaches the 8-digit watershed outlet from each APEX simulation site. The sediment load from APEX simulation sites are aggregated for the 8-digit watershed and integrated into the SWAT model at each 8-digit watershed to estimate the water quality effects of conservation practices. In SWAT, the sediment yield for the non-cropland HRUs are estimated using the MUSLE as described in Chapter 1. After estimating the SDR for each HRU, the SDR is applied to determine the amount of sediment that reaches the 8-digit watershed outlet.

Sediment delivery ratios were estimated to account for sediment losses or deposition occurring from edge-of-field or HRUs to the 8-digit watershed outlet for each APEX simulation site in the cultivated cropland and CRP and non-cropland HRUs in the Chesapeake Bay Watershed (Figure 2-1). The Chesapeake Bay has a drainage area of 43.85 million acres. The cultivated cropland and land enrolled in the CRP General Signup is about 10 percent of the Chesapeake Bay Watershed. A total of 58 8-digit watersheds are in the Chesapeake Bay Watershed (Figure 2-1). Within each 8-digit watershed, the percent of cultivated cropland and CRP area and non-cultivated cropland area varies widely across the entire watershed.

A total of 832 representative cultivated fields (771 NRI-CEAP cropland points and 61 CRP points) were setup to run using APEX. Eight out of 57, 8-digit watersheds in the Chesapeake Bay Watershed have no CEAP points.

These 8-digit watersheds have zero or fewer than 6% percentage cultivated cropland.

Non-cultivated land is distributed over 90 percent of the Chesapeake Bay Watershed. Within each 8-digit watershed, non-cultivated land uses such as pasture, range, hay, horticulture, forest deciduous, forest mixed, forest evergreen, urban, urban construction, barren land wetland and water are simulated as HRUs in SWAT. A total of 2598 HRUs are simulated in SWAT for the Chesapeake Bay Watershed.

Each NRI-CEAP point and CRP point is unique; therefore, sediment yield and delivery ratio also vary for each cultivated cropland site simulated in an 8-digit watershed as well as for HRU. The number of CEAP sample points, and mean, 10th percentile and 90th percentile of the delivery ratios of the APEX simulation sites in the 8-digit watersheds in the Chesapeake Bay are shown in Table 2-1 and Figure 2-1. Table 2-2 shows the number of HRUs and mean, 10th percentile and 90th percentile of the SDRs estimated for the non-cultivated land HRUs in the 8-digit watersheds in the Chesapeake Bay Watershed (Figure 2-1). The mean, 10th and 90th percentile SDRs for the non-cropland HRUs are depicted in Figure 2-2.

In addition to the SDR, an enrichment ratio was used to simulate organic nitrogen, organic phosphorus, and sediment-attached pesticide transport in ditches, floodplains, and tributary stream channels during transit from the edge-of-field to the outlet. The enrichment ratio was defined as the organic nitrogen, organic phosphorus, and sediment attached pesticide concentration from the edge-of-field divided by the concentration at the 8-digit watershed outlet as discussed in Chapter 1. The enrichment ratio is estimated for each APEX simulation site and SWAT HRU and it varies from 0.5 to 1.5 (average=1). As sediment is transported from the edge-of-field to the watershed outlet, coarse sediments are deposited first while more of the fine sediment that hold organic particles remain in suspension, thus enriching the organic concentrations delivered to the watershed outlet.

A separate delivery ratio is used to simulate the transport of nitrate-nitrogen, soluble phosphorus, and soluble pesticides. In general, the proportion of soluble nutrients and pesticides delivered to rivers and streams is higher than the proportion attached to sediments because they are not subject to sediment deposition.

Figure 2-1 Map of the 8-digit watersheds in the Chesapeake Bay Watershed



Table 2-1. Mean and percentiles of sediment delivery ratio (sediment delivered at 8-digit watershed outlet by sediment yield at simulation sites) estimated for cultivated simulation sites within APEX for the 8-digit watersheds in the Chesapeake Bay Watershed

HUC	Cropland		CRP		Crop + CRP			
	Point s	Mean SDR	Point s	Mean SDR	Point s	Mean_S DR	10 th per- centile SDR	90 th per- centile SDR
2050101	3	0.32			3	0.32	0.31	0.35
2050102	4	0.36	2	0.33	6	0.35	0.31	0.44
2050103	1	0.42			1	0.42	0.42	0.42
2050104	4	0.39			4	0.39	0.35	0.44
2050105	4	0.44	3	0.38	7	0.42	0.37	0.53
2050106	4	0.37	6	0.34	10	0.35	0.33	0.38
2050107	7	0.37	7	0.35	14	0.36	0.32	0.44
2050201	1	0.33			1	0.33	0.33	0.33
2050203	1	0.39			1	0.39	0.39	0.39
2050204	3	0.46	1	0.39	4	0.44	0.39	0.54
2050205	2	0.39			2	0.39	0.38	0.40
2050206	15	0.37	2	0.34	17	0.36	0.33	0.41
2050301	21	0.37	2	0.34	23	0.37	0.34	0.41
2050302	3	0.47	1	0.39	4	0.45	0.39	0.56
2050303	3	0.38			3	0.38	0.36	0.40
2050304	9	0.35	2	0.32	11	0.34	0.31	0.42
2050305	38	0.38	2	0.35	38	0.38	0.36	0.41
2050306	92	0.34			94	0.34	0.32	0.38
2060002	57	0.44	9	0.40	66	0.43	0.39	0.50
2060003	24	0.41			24	0.41	0.37	0.50
2060004	2	0.46			2	0.46	0.46	0.46
2060005	53	0.44	3	0.42	56	0.44	0.38	0.50
2060006	20	0.35			20	0.35	0.31	0.42
2060007	12	0.49	1	0.46	13	0.49	0.44	0.58
2060008	57	0.45	1	0.37	58	0.45	0.39	0.49
2060009	30	0.42			30	0.42	0.40	0.48
2060010	23	0.53	1	0.51	24	0.53	0.46	0.58
2070001	4	0.42			4	0.42	0.39	0.49
2070002	1	0.40			1	0.40	0.40	0.40
2070003	1	0.37	1	0.21	2	0.29	0.21	0.37
2070004	36	0.35	1	0.34	37	0.35	0.33	0.37
2070005	9	0.36			9	0.36	0.34	0.40
2070006	3	0.38			3	0.38	0.38	0.39
2070007	6	0.45			6	0.45	0.41	0.55
2070008	15	0.39	4	0.33	19	0.38	0.35	0.48
2070009	38	0.40	1	0.42	39	0.40	0.37	0.42
2070010	4	0.38			4	0.38	0.36	0.41
2070011	25	0.41	2	0.31	27	0.40	0.37	0.44
2080102	21	0.47	1	0.32	22	0.47	0.42	0.54
2080103	7	0.42	1	0.30	8	0.40	0.30	0.47
2080104	25	0.37	3	0.21	28	0.35	0.24	0.40

2080105	16	0.39	1	0.22	17	0.38	0.32	0.41
2080106	8	0.40			8	0.40	0.35	0.48
2080107	3	0.46			3	0.46	0.45	0.49
2080109	17	0.61			17	0.61	0.54	0.71
2080110	13	0.55			13	0.55	0.48	0.63
2080206	15	0.43	2	0.25	17	0.41	0.25	0.53
2080207	2	0.36	1	0.21	3	0.31	0.21	0.38
2080208	9	0.47			9	0.47	0.43	0.54

Figure 2-2. Mean and percentiles of sediment delivery ratio (sediment delivered at 8-digit watershed outlet by sediment yield at simulation sites) estimated for cultivated simulation sites within APEX for the 8-digit watersheds in the Chesapeake Bay Watershed

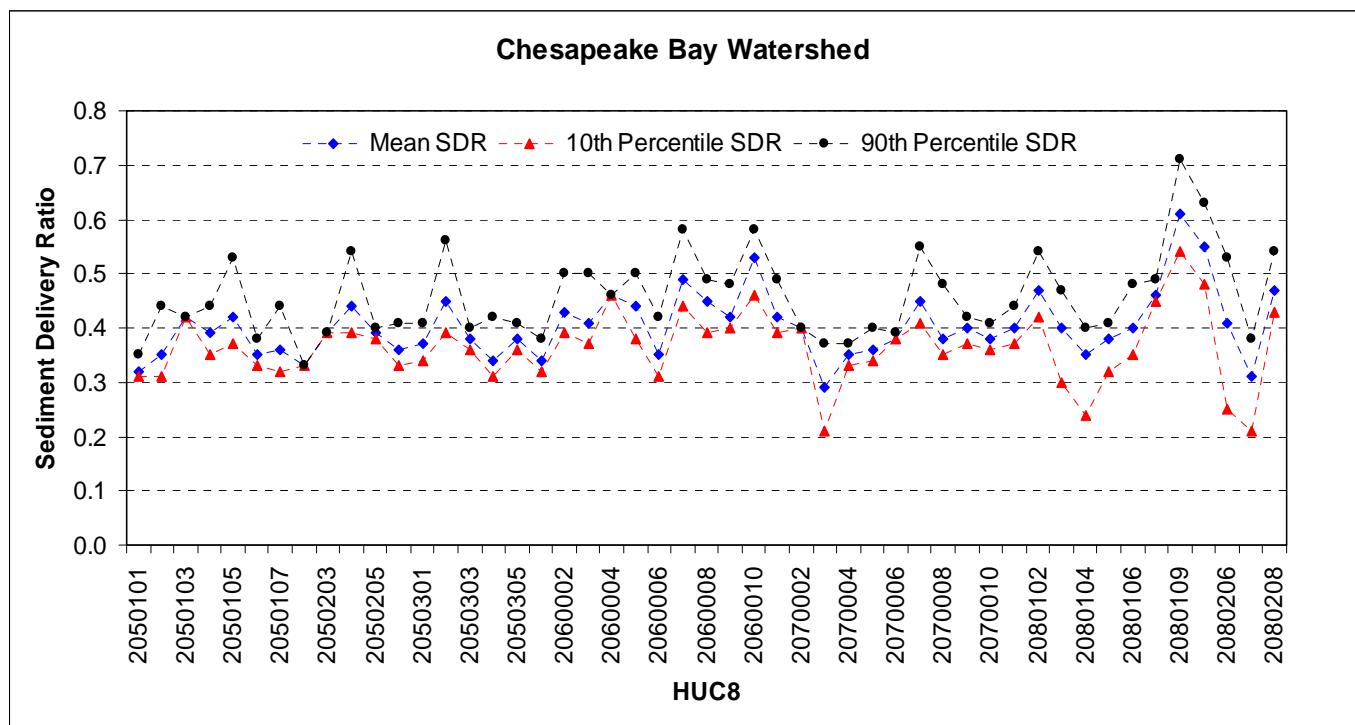
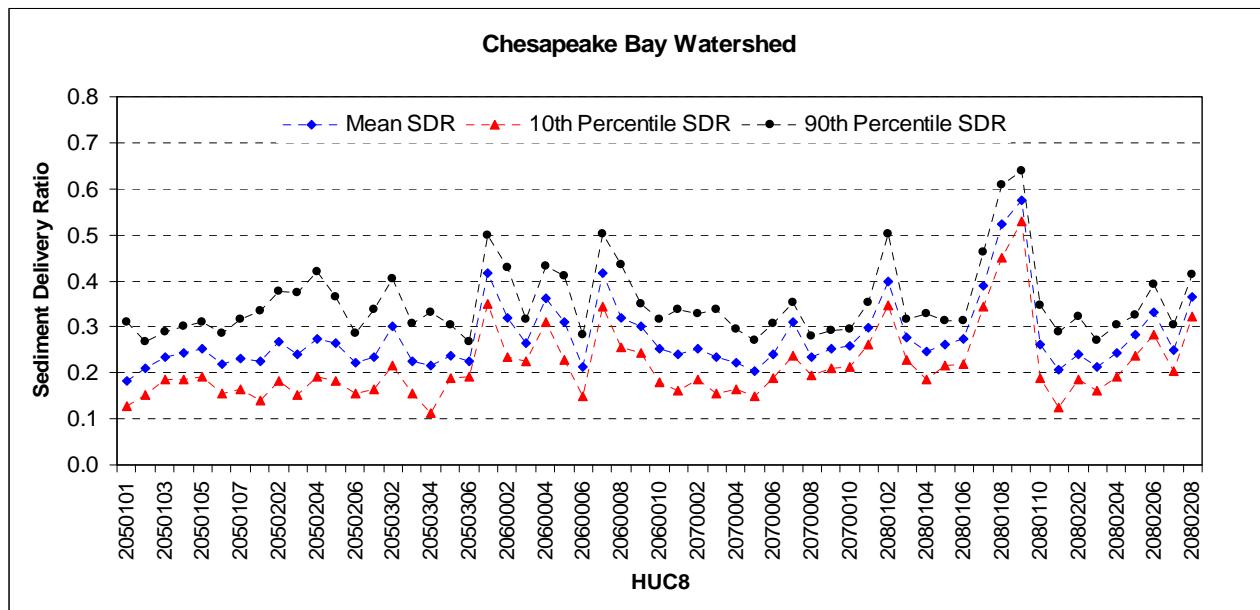


Table 2-3. Mean and percentiles of sediment delivery ratio (sediment delivered at 8-digit watershed outlet by sediment yield at HRUs) estimated for non-cultivated land HRUs within SWAT for the 8-digit watersheds in the Chesapeake Bay Watershed

HUC	Subbasin	Number of non-cropland HRUs simulated within SWAT	Mean SDR	10 th Percentile SDR	90 th Percentile SDR
2050101	1	53	0.18	0.13	0.31
2050102	2	50	0.21	0.15	0.27
2050103	3	54	0.23	0.19	0.29
2050104	4	50	0.24	0.19	0.30
2050105	5	43	0.25	0.19	0.31
2050106	6	49	0.22	0.15	0.29
2050107	7	43	0.23	0.16	0.32
2050201	8	40	0.22	0.14	0.33
2050202	9	31	0.27	0.18	0.38
2050203	10	33	0.24	0.15	0.37
2050204	11	31	0.27	0.19	0.42
2050205	12	34	0.26	0.18	0.36
2050206	13	47	0.22	0.15	0.29
2050301	14	41	0.23	0.17	0.34
2050302	15	27	0.30	0.22	0.40
2050303	16	42	0.22	0.15	0.31
2050304	17	37	0.22	0.11	0.33
2050305	18	51	0.24	0.19	0.30
2050306	19	61	0.22	0.19	0.27
2060001	20	21	0.42	0.35	0.50
2060002	21	36	0.32	0.23	0.43
2060003	22	58	0.26	0.23	0.32
2060004	23	33	0.36	0.31	0.43
2060005	24	38	0.31	0.23	0.41
2060006	25	52	0.21	0.15	0.28
2060007	26	35	0.42	0.34	0.50
2060008	27	33	0.32	0.25	0.43
2060009	28	41	0.30	0.24	0.35
2060010	29	40	0.25	0.18	0.32
2070001	30	38	0.24	0.16	0.34
2070002	31	38	0.25	0.19	0.33
2070003	32	42	0.23	0.16	0.34
2070004	33	58	0.22	0.17	0.30
2070005	34	71	0.20	0.15	0.27
2070006	35	60	0.24	0.19	0.31
2070007	36	34	0.31	0.24	0.35
2070008	37	76	0.24	0.19	0.28
2070009	38	73	0.25	0.21	0.29
2070010	39	61	0.26	0.21	0.29
2070011	40	48	0.30	0.26	0.35
2080102	41	48	0.40	0.35	0.50

2080103	42	61	0.28	0.23	0.32
2080104	43	47	0.25	0.19	0.33
2080105	44	49	0.26	0.22	0.31
2080106	45	56	0.27	0.22	0.31
2080107	46	33	0.39	0.34	0.46
2080108	47	28	0.52	0.45	0.61
2080109	48	26	0.57	0.53	0.64
2080110	49	40	0.26	0.19	0.35
2080201	50	48	0.21	0.13	0.29
2080202	51	47	0.24	0.19	0.32
2080203	52	61	0.21	0.16	0.27
2080204	53	57	0.24	0.19	0.30
2080205	54	50	0.28	0.24	0.32
2080206	55	51	0.33	0.28	0.39
2080207	56	54	0.25	0.20	0.30
2080208	57	39	0.36	0.32	0.41

Figure 2-2. Mean and percentiles of sediment delivery ratio (sediment delivered at 8-digit watershed outlet by sediment yield at HRUs) estimated for non-cultivated land HRUs within SWAT for the 8-digit watersheds in the Chesapeake Bay Watershed



Chapter 3

**Delivery Ratio used in CEAP Cropland
Modeling in the Delaware River Basin**

The APEX model is a field-scale, daily time-step model that simulates weather, farming operations, crop growth and yield, and the movement of water, soil, carbon, nutrients, sediment, and pesticides. The APEX model was used also to simulate the effects of conservation practices at the field scale (Williams and Izaurrealde, 2006; Gassman et al. 2009) in the Delaware River Basin. APEX simulates all of the basic biological, chemical, hydrological, and meteorological processes of farming systems and their interactions. Soil erosion is simulated over time, including wind, sheet and rill erosion. The nitrogen, phosphorus, and carbon cycles are simulated, including chemical transformations in the soil that affect their availability for plant growth or for transport from the field.

While the APEX model was used to simulate the cultivated cropland, the SWAT model was used to simulate the non-cultivated cropland in the 8-digit watersheds of the river basin. SWAT is a physical process model with a daily time step (Arnold and Fohrer 2005; Arnold et al. 1998; Gassman et al. 2007). The hydrologic cycle in the model is divided into two parts. The land phase of the hydrologic cycle, or upland processes, simulates the amount of water, sediment, nutrients, and pesticides delivered from the land to the outlet of each watershed. The routing phase of the hydrologic cycle, or channel processes, simulates the movement of water, sediment, nutrients, and pesticides from the outlet of the upstream watershed through the main channel network to the watershed outlet.

In SWAT, each 8-digit watershed is divided into multiple Hydrologic Response Units (HRUs) that have homogeneous land use, soil, and slope. SWAT is used to simulate the fate and transport of water, sediment, nutrients, and pesticides from various non-cropland HRUs as described in Chapter 1.

Not all of the soil that erodes from a field or HRUs ends up in the watershed outlet. Most of the soil eroded gets deposited on the way although the deposition is temporary. Eroded soil may deposit in lower spots, flatter lands, deposited at the edge of the field and sometimes settles at the bottom of the channel. Hence, a SDR was used to account for deposition in ditches, floodplains, and tributary stream channels during transit from the edge of the field or HRUs to the 8-digit watershed outlet in the CEAP National Assessment modeling. The SDR used in this study is a function of the ratio of the time of concentration for the HRU (land uses other than cultivated cropland) or

field (cultivated cropland) to the time of concentration for the watershed (8-digit HUC). The time of concentration for the watershed is the time from when a surface water runoff event occurs at the most distant point in the watershed to the time the surface water runoff reaches the outlet of the watershed. It is calculated by summing the overland flow time (the time it takes for flow from the remotest point in the watershed to reach the channel) and the channel flow time (the time it takes for flow in the upstream channels to reach the outlet). The time of concentration for the field is derived from APEX. The time of concentration for the HRU is derived from characteristics of the watershed, the HRU, and the proportion of total acres represented by the HRU. Consequently, each cultivated cropland sample point has a unique delivery ratio within each watershed, as does each HRU. The description of the SDR procedure is provided in Chapter 1.

The APEX model simulates the edge of sediment yield using a variation of MUSLE called MUST (MUSLE developed from Theory) (Williams 1995) as described in Chapter 1. After estimating the sediment load from each APEX simulation site, the delivery ratio is applied to determine the amount of sediment that reach the 8-digit watershed outlet from each APEX simulation site. The sediment load from apex simulation sites are aggregated for the 8-digit watershed and integrated into the SWAT model at each 8-digit watershed to estimate the water quality effects of conservation practices. In SWAT, the sediment yield for the non-cropland HRUs are estimated using the MUSLE as described in Chapter 1. After estimating the SDR for each HRU, the SDR is applied to determine the amount of sediment that reach the 8-digit watershed outlet.

Sediment delivery ratios were estimated to account for sediment losses or deposition occurring from edge-of-field or HRUs to the 8-digit watershed outlet for each APEX simulation site in the cultivated cropland and CRP and non-cropland HRUs in the Delaware River Basin (Figure 3-1). The Delaware River Basin has a drainage area of 8.72 million acres. The cultivated cropland and land enrolled in the CRP General Signup is about 13 percent of the Delaware River Basin. A total of 13, 8-digit watersheds are in the Delaware River Basin (Figure 3-1). Within each 8-digit watershed, the percent of cultivated cropland and CRP area and non-cultivated cropland area varies widely across the entire watershed.

Delivery Ratio used in CEAP in the Delaware River Basin

A total of 188 representative cultivated fields (186 NRI-CEAP cropland points and 2 CRP points) were setup to run using APEX. Four out of 14, 8-digit watersheds in the Delaware River Basin have no CEAP points. The non-cultivated land is distributed over 87 percent of the Chesapeake Bay Watershed. Within each 8-digit watershed, non-cultivated land uses such as pasture, range, hay, horticulture, forest deciduous, forest mixed, forest evergreen, urban, urban construction, barren land wetland and water are simulated as HRUs in SWAT. A total of 501 HRUs are simulated in SWAT for the Delaware River Basin.

Each NRI-CEAP point and CRP point is unique; therefore, sediment yield and delivery ratio also vary for each cultivated cropland site simulated in an 8-digit watershed and so as for HRU. The number of CEAP sample points, and mean, 10th percentile and 90th percentile of the delivery ratios of the APEX simulation sites in the 8-digit watersheds in the Chesapeake Bay are shown in Table 3-1 and Figure 3-2. Table 3-2 shows number of HRUs and mean, 10th percentile and 90th percentile of the SDRs estimated for the non-cultivated land HRUs in the 8-digit watersheds in the Chesapeake Bay Watershed (Figure 3-2). The mean, 10th and 90th percentile SDRs for the non-cropland HRUs are plotted in Figure 3-3.

In addition to the SDR, an enrichment ratio was used to simulate organic nitrogen, organic phosphorus, and sediment-attached pesticide transport in ditches, floodplains, and tributary stream channels during transit from the edge of the field to the outlet. The enrichment ratio was defined as the organic nitrogen, organic phosphorus, and sediment attached pesticide concentration from the edge-of-field divided by the concentration at the 8-digit watershed outlet. The enrichment ratio is estimated for each APEX simulation site and SWAT HRUs and it varies from 0.5 to 1.5 (Average 1). As sediment is transported from the edge-of-field to the watershed outlet, coarse sediments are deposited first while more of the fine sediment that hold organic particles remain in suspension, thus enriching the organic concentrations delivered to the watershed outlet.

A separate delivery ratio is used to simulate the transport of nitrate nitrogen, soluble phosphorus, and soluble pesticides. In general, the proportion of soluble nutrients and pesticides delivered to rivers and streams is higher than the proportion attached to sediments because they are not subject to sediment deposition.

Delivery Ratio used in CEAP in the Delaware River Basin

Figure 3-1 Map of the 8-digit watersheds in the Delaware River Basin

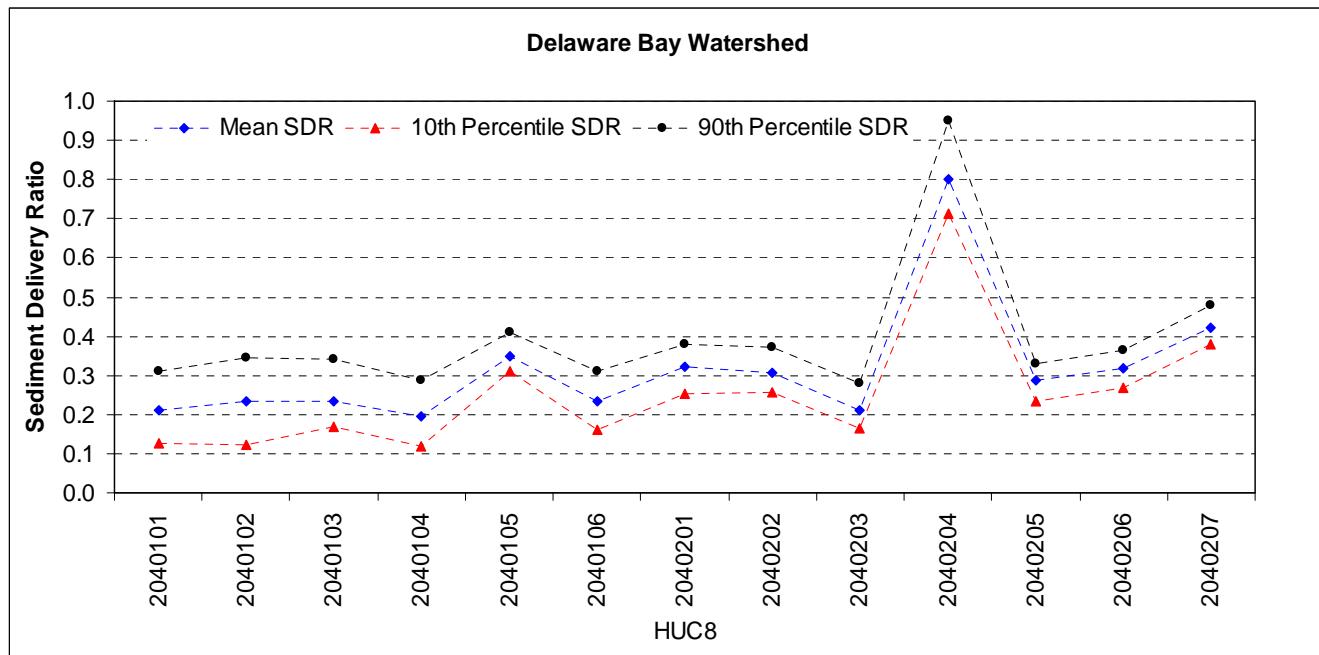


Delivery Ratio used in CEAP in the Delaware River Basin

Table 3-2. Mean and percentiles of sediment delivery ratio (sediment delivered at 8-digit watershed outlet by sediment yield at HRUs) estimated for non-cultivated land HRUs within SWAT for the 8-digit watersheds in the Delaware River Basin

HUC	Subbasin	Number of non-cropland HRUs simulated within SWAT	Mean SDR	10 th Percentile SDR	90 th Percentile SDR
2040101	1	42	0.21	0.13	0.31
2040102	2	32	0.23	0.12	0.34
2040103	3	44	0.24	0.17	0.34
2040104	4	52	0.20	0.12	0.29
2040105	5	43	0.35	0.31	0.41
2040106	6	38	0.23	0.16	0.31
2040201	7	35	0.32	0.25	0.38
2040202	8	44	0.31	0.26	0.37
2040203	9	53	0.21	0.16	0.28
2040204	10	3	0.80	0.71	0.95
2040205	11	42	0.29	0.23	0.33
2040206	12	38	0.32	0.27	0.36
2040207	13	35	0.42	0.38	0.48
2040301	14	51	0.20	0.13	0.27
2040302	15	33	0.22	0.11	0.34

Figure 3-2. Mean and percentiles of sediment delivery ratio (sediment delivered at 8-digit watershed outlet by sediment yield at HRUs) estimated for non-cultivated land HRUs within SWAT for the 8-digit watersheds in the Delaware River Basin



Chapter 4

**Delivery Ratio used in CEAP Cropland
Modeling in the Ohio-Tennessee
River Basin**

The APEX model is a field-scale, daily time-step model that simulates weather, farming operations, crop growth and yield, and the movement of water, soil, carbon, nutrients, sediment, and pesticides. The APEX model was used also to simulate the effects of conservation practices at the field scale (Williams and Izaurrealde, 2006; Gassman et al. 2009) in the Ohio-Tennessee River Basin. APEX simulates all of the basic biological, chemical, hydrological, and meteorological processes of farming systems and their interactions. Soil erosion is simulated over time, including wind erosion, sheet and rill erosion. The nitrogen, phosphorus, and carbon cycles are simulated, including chemical transformations in the soil that affect their availability for plant growth or for transport from the field.

While the APEX model was used to simulate the cultivated cropland, the SWAT model was used to simulate the non-cultivated cropland in the 8-digit watersheds of the river basin. SWAT is a physical process model with a daily time step (Arnold and Fohrer 2005; Arnold et al. 1998; Gassman et al. 2007). The hydrologic cycle in the model is divided into two parts. The land phase of the hydrologic cycle, or upland processes, simulates the amount of water, sediment, nutrients, and pesticides delivered from the land to the outlet of each watershed. The routing phase of the hydrologic cycle, or channel processes, simulates the movement of water, sediment, nutrients, and pesticides from the outlet of the upstream watershed through the main channel network to the watershed outlet.

In SWAT, each 8-digit watershed is divided into multiple Hydrologic Response Units (HRUs) that have homogeneous land use, soil and slope. SWAT is used to simulate the fate and transport of water, sediment, nutrients, and pesticides from various non-cropland HRUs as described in Chapter 1.

Not all of the soil that erodes from a field or HRUs ends up in the watershed outlet. Most of the soil eroded gets deposited on the way although the deposition is temporary. Eroded soil may deposit in lower spots, flatter lands, deposited at the edge of the field and sometimes settles at the bottom of the channel. Hence, a SDR was used to account for deposition in ditches, floodplains, and tributary stream channels during transit from the edge of the field or HRUs to the 8-digit watershed outlet in the CEAP National Assessment modeling. The SDR used in this study is a function of the ratio of the time of concentration for

the HRU (land uses other than cultivated cropland) or field (cultivated cropland) to the time of concentration for the watershed (8-digit HUC). The time of concentration for the watershed is the time from when a surface water runoff event occurs at the most distant point in the watershed to the time the surface water runoff reaches the outlet of the watershed. It is calculated by summing the overland flow time (the time it takes for flow from the remotest point in the watershed to reach the channel) and the channel flow time (the time it takes for flow in the upstream channels to reach the outlet). The time of concentration for the field is derived from APEX. The time of concentration for the HRU is derived from characteristics of the watershed, the HRU, and the proportion of total acres represented by the HRU. Consequently, each cultivated cropland sample point has a unique delivery ratio within each watershed, as does each HRU. The description of the SDR procedure is provided in Chapter 1.

The APEX model simulates the edge of sediment yield using a variation of MUSLE called MUST (MUSLE developed from Theory) (Williams 1995) as described in Chapter 1. After estimating the sediment load from each APEX simulation site, the delivery ratio is applied to determine the amount of sediment that reach the 8-digit watershed outlet from each APEX simulation site. The sediment load from apex simulation sites are aggregated for the 8-digit watershed and integrated into the SWAT model at each 8-digit watershed to estimate the water quality effects of conservation practices. In SWAT, the sediment yield for the non-cropland HRUs are estimated using the MUSLE as described in Chapter 1. After estimating the SDR for each HRU, the SDR is applied to determine the amount of sediment that reach the 8-digit watershed outlet.

The APEX model simulates the edge of sediment yield using a variation of MUSLE called MUST (MUSLE developed from Theory) (Williams 1995) as described in Chapter 1. After estimating the sediment load from each APEX simulation site, the delivery ratio is applied to determine the amount of sediment that reach the 8-digit watershed outlet from each APEX simulation site. The sediment load from apex simulation sites are aggregated for the 8-digit watershed and integrated into the SWAT model at each 8-digit watershed to estimate the water quality effects of conservation practices. In SWAT, the sediment yield for the non-cropland HRUs are estimated using the MUSLE as described in Chapter 1. After estimat-

Delivery Ratio used in CEAP in the Ohio-Tennessee River Basin

ing the SDR for each HRU, the SDR is applied to determine the amount of sediment that reach the 8-digit watershed outlet.

Sediment delivery ratios were estimated to account for sediment losses occurring from edge-of-field or HRUs to the 8-digit watershed outlet for each APEX simulation site in the cultivated cropland and CRP and non-cropland HRUs in the Ohio-Tennessee River Basin (Figure 4-1). The Ohio-Tennessee River Basin has a drainage area of 130.39 million acres. The cultivated cropland and land enrolled in the CRP General Signup is about 21 percent of the Ohio-Tennessee River Basin. A total of 152 8-digit watersheds are in the Ohio-Tennessee River Basin (Figure 4-1). Within each 8-digit watershed, the percent of cultivated cropland and CRP area and non-cultivated cropland area varies widely across the entire basin.

A total of 2465 representative cultivated fields (1989 NRI-CEAP cropland points and 476 CRP points) were setup to run using APEX. Twenty-six out of 120, 8-digit watersheds in the Ohio River basin have no CEAP points. The twenty-six 8-digit watersheds have zero or fewer than 10% percentage cultivated cropland. A total of 218 representative cultivated fields (135 NRI-CEAP cropland points and 83 CRP points) were setup to run using APEX. Eleven out of 32, 8-digit watersheds in the Tennessee River Basin have no CEAP points. The eleven 8-digit watersheds have zero or fewer than 3% percentage cultivated cropland.

Non-cultivated land is distributed over 79 percent of the Ohio-Tennessee River Basin. Within each 8-digit watershed, non-cultivated land uses such as pasture, range, hay, horticulture, forest deciduous, forest mixed, forest evergreen, urban, urban construction, barren land wetland and water are simulated as HRUs in SWAT. A total of 6574 HRUs are simulated in SWAT for the Ohio-Tennessee River Basin.

Each NRI-CEAP point and CRP point is unique; therefore, sediment yield and delivery ratio also vary for each cultivated cropland site simulated in an 8-digit watershed and so as for HRU. The number of CEAP sample points, and mean, 10th percentile and 90th percentile of the delivery ratios of the APEX simulation sites in the 8-digit watersheds in the Ohio-Tennessee River Basin are shown in Table 4-1 and Figure 4-1. Table 4-2. shows number of HRUs and mean, 10th percentile and 90th percentile of the SDRs estimated for the non-cultivated land HRUs in

the 8-digit watersheds in the Ohio-Tennessee River Basin (Figure 4-2). The mean, 10th and 90th percentile SDRs for the non-cropland HRUs are plotted in Figure 4-2.

In addition to SDR, an enrichment ratio was used to simulate organic nitrogen, organic phosphorus, and sediment-attached pesticide transport in ditches, floodplains, and tributary stream channels during transit from the edge of the field to the outlet. The enrichment ratio was defined as the organic nitrogen, organic phosphorus, and sediment attached pesticide concentration from the edge-of-field divided by the concentration at the 8-digit watershed outlet. The enrichment ratio is estimated for each APEX simulation site and SWAT HRUs and it varies from 0.5 to 1.5 (Average 1.0). As sediment is transported from the edge-of-field to the watershed outlet, coarse sediments are deposited first while more of the fine sediment that hold organic particles remain in suspension, thus enriching the organic concentrations delivered to the watershed outlet.

A separate delivery ratio is used to simulate the transport of nitrate nitrogen, soluble phosphorus, and soluble pesticides. In general, the proportion of soluble nutrients and pesticides delivered to rivers and streams is higher than the proportion attached to sediments because they are not subject to sediment deposition.

Delivery Ratio used in CEAP in the Ohio-Tennessee River Basin

Figure 4-1 Map of the 8-digit watersheds in the Ohio-Tennessee River Basin

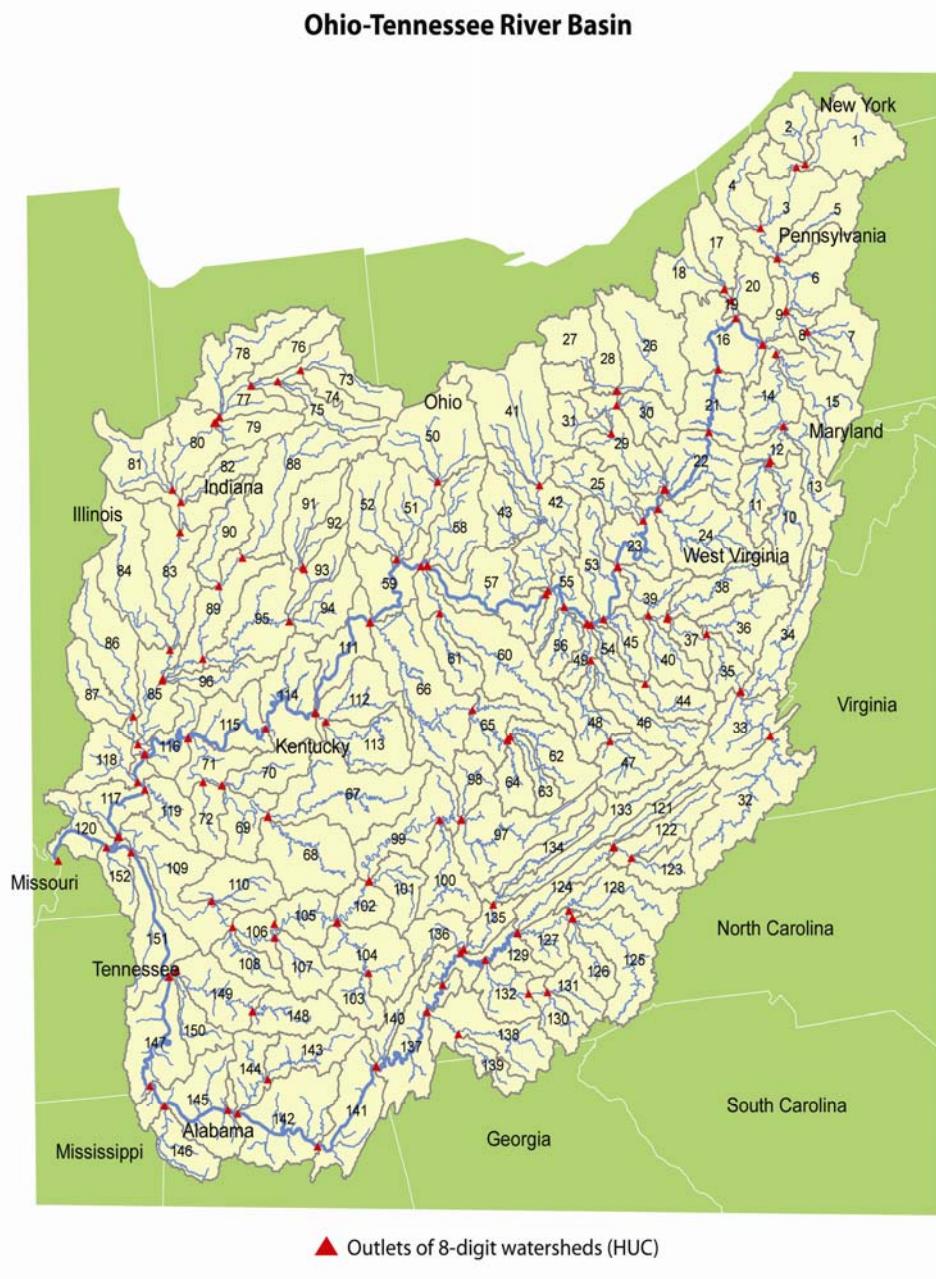


Table 4-1. Mean and percentiles of sediment delivery ratio (sediment delivered at 8-digit watershed outlet by sediment yield at simulation sites) estimated for cultivated simulation sites within APEX for the 8-digit watersheds in the Ohio River Basin

HUC	Cropland		CRP		Crop + CRP			
	Points	Mean SDR	Points	Mean SDR	Points	Mean SDR	10 th percentile SDR	90 th percentile SDR
5010001	1	0.37			1	0.37	0.37	0.37
5010002	3	0.43	1	0.38	4	0.42	0.36	0.50
5010003	3	0.37			3	0.37	0.36	0.38
5010004	10	0.35	1	0.32	11	0.34	0.32	0.41
5010005	2	0.38			2	0.38	0.31	0.45
5010006	15	0.35			15	0.35	0.32	0.38
5010007	5	0.37	1	0.36	6	0.37	0.34	0.40
5010008	2	0.43			2	0.43	0.40	0.46
5010009	2	0.42			2	0.42	0.41	0.42
5020001	1	0.46			1	0.46	0.46	0.46
5020005	2	0.32			2	0.32	0.31	0.32
5020006	10	0.37	1	0.32	11	0.36	0.32	0.48
5030101	5	0.40	2	0.36	7	0.39	0.35	0.52
5030102	15	0.34			15	0.34	0.31	0.38
5030103	23	0.35			23	0.35	0.32	0.39
5030105	6	0.38			6	0.38	0.36	0.41
5030106	1	0.36			1	0.36	0.36	0.36
5030201	2	0.41			2	0.41	0.38	0.44
5030202	1	0.35			1	0.35	0.35	0.35
5030204	10	0.36			10	0.36	0.33	0.38
5040001	30	0.34	2	0.31	32	0.34	0.30	0.37
5040002	16	0.39	7	0.38	23	0.39	0.35	0.43
5040003	21	0.36	2	0.35	23	0.36	0.33	0.39
5040004	11	0.48	2	0.43	13	0.47	0.42	0.54
5040006	7	0.41			7	0.41	0.35	0.50
5050001	1	0.32			1	0.32	0.32	0.32
5050002	1	0.43			1	0.43	0.43	0.43
5050003	1	0.47			1	0.47	0.47	0.47
5050008	1	0.33			1	0.33	0.33	0.33
5060001	76	0.36	14	0.36	90	0.36	0.33	0.40
5060002	22	0.38	5	0.36	27	0.38	0.35	0.39
5060003	26	0.44	8	0.38	34	0.42	0.36	0.54
5080001	78	0.38	10	0.35	88	0.38	0.33	0.45
5080002	43	0.37	2	0.34	45	0.37	0.34	0.41
5080003	54	0.37	14	0.34	68	0.36	0.32	0.43
5090101	3	0.36			3	0.36	0.35	0.37
5090103	1	0.34			1	0.34	0.34	0.34
5090201	44	0.36	10	0.34	54	0.35	0.32	0.41
5090202	65	0.40	7	0.35	72	0.39	0.35	0.45
5090203	24	0.44	1	0.40	25	0.44	0.39	0.51

5100101	8	0.33			8	0.33	0.31	0.39
5100102	4	0.37			4	0.37	0.35	0.39
5100204	2	0.41			2	0.41	0.39	0.42
5100205	17	0.37			17	0.37	0.33	0.47
5110001	25	0.32	15	0.30	40	0.31	0.29	0.34
5110002	21	0.35	5	0.32	26	0.35	0.31	0.40
5110003	11	0.41	6	0.36	17	0.39	0.34	0.50
5110004	13	0.35	9	0.32	22	0.33	0.30	0.37
5110005	26	0.37	2	0.32	28	0.36	0.32	0.40
5110006	26	0.40	14	0.36	40	0.38	0.34	0.42
5120101	30	0.41	11	0.38	41	0.40	0.35	0.47
5120102	5	0.45	7	0.42	12	0.43	0.41	0.49
5120103	20	0.42	2	0.39	22	0.42	0.37	0.49
5120104	16	0.37	8	0.38	24	0.37	0.33	0.44
5120105	12	0.43	2	0.39	14	0.42	0.37	0.51
5120106	39	0.37	10	0.31	49	0.36	0.31	0.42
5120107	16	0.43			16	0.43	0.39	0.49
5120108	67	0.38	8	0.35	75	0.38	0.34	0.44
5120109	38	0.39	2	0.34	40	0.38	0.36	0.43
5120110	11	0.38	1	0.35	12	0.38	0.34	0.44
5120111	60	0.38	9	0.33	69	0.37	0.33	0.43
5120112	87	0.37	9	0.33	96	0.37	0.33	0.42
5120113	70	0.37	5	0.35	75	0.37	0.33	0.43
5120114	68	0.37	32	0.35	100	0.37	0.31	0.42
5120115	38	0.40	47	0.35	85	0.38	0.33	0.44
5120201	61	0.36	2	0.32	63	0.36	0.32	0.41
5120202	44	0.41	4	0.34	48	0.40	0.34	0.49
5120203	29	0.39	4	0.33	33	0.38	0.33	0.43
5120204	30	0.42	1	0.37	31	0.42	0.36	0.46
5120205	9	0.45			9	0.45	0.37	0.52
5120206	26	0.43	1	0.35	27	0.43	0.37	0.52
5120207	33	0.40			33	0.40	0.36	0.45
5120208	26	0.35	22	0.33	48	0.34	0.31	0.38
5120209	18	0.40	4	0.40	22	0.40	0.34	0.47
5130101	1	0.42			1	0.42	0.42	0.42
5130103	10	0.33			10	0.33	0.31	0.41
5130104	1	0.35			1	0.35	0.35	0.35
5130107	8	0.44	1	0.42	9	0.44	0.42	0.48
5130108	1	0.42	1	0.40	2	0.41	0.40	0.42
5130201	3	0.37			3	0.37	0.35	0.38
5130203	2	0.42	1	0.37	3	0.40	0.37	0.42
5130204	2	0.43	2	0.32	4	0.38	0.32	0.47
5130205	19	0.33	22	0.31	41	0.32	0.30	0.35
5130206	43	0.38	3	0.36	46	0.37	0.34	0.45
5140101	20	0.38			20	0.38	0.35	0.44
5140102	14	0.35	1	0.32	15	0.35	0.32	0.37
5140103	11	0.36	1	0.31	12	0.35	0.31	0.42
5140104	26	0.35	15	0.33	41	0.34	0.32	0.38
5140201	26	0.38	1	0.34	27	0.37	0.33	0.44
5140202	50	0.40			50	0.40	0.35	0.46
5140203	21	0.39	25	0.35	46	0.37	0.33	0.40
5140204	28	0.42	33	0.38	61	0.40	0.34	0.49

5140205	17	0.39	11	0.34	28	0.37	0.33	0.46
5140206	36	0.43	27	0.39	63	0.41	0.36	0.51
6010101	2	0.42			2	0.42	0.37	0.46
6010102	1	0.44			1	0.44	0.44	0.44
6010103	1	0.42			1	0.42	0.42	0.42
6010105	2	0.35			2	0.35	0.34	0.35
6010108	1	0.33			1	0.33	0.33	0.33
6010201	1	0.45			1	0.45	0.45	0.45
6010204	3	0.40			3	0.40	0.38	0.43
6010207	1	0.40			1	0.40	0.40	0.40
6020004	1	0.39			1	0.39	0.39	0.39
6030001	11	0.40			11	0.40	0.35	0.45
6030002	23	0.35	3	0.33	26	0.35	0.32	0.41
6030003	9	0.37	2	0.35	11	0.37	0.35	0.44
6030004	6	0.41	1	0.40	7	0.41	0.37	0.50
6030005	16	0.37	8	0.33	24	0.36	0.32	0.45
6030006			1	0.38	1	0.38	0.38	0.38
6040001	14	0.36	17	0.33	31	0.35	0.30	0.36
6040002	5	0.35	3	0.34	8	0.34	0.33	0.37
6040003	2	0.43	4	0.32	6	0.36	0.31	0.43
6040004			1	0.36	1	0.36	0.36	0.36
6040005	13	0.36	22	0.34	35	0.35	0.31	0.38
6040006	23	0.43	21	0.39	44	0.41	0.36	0.46

Figure 4-2. Mean and percentiles of sediment delivery ratio (sediment delivered at 8-digit watershed outlet by sediment yield at simulation sites) estimated for cultivated simulation sites within APEX for the 8-digit watersheds in the Ohio River Basin

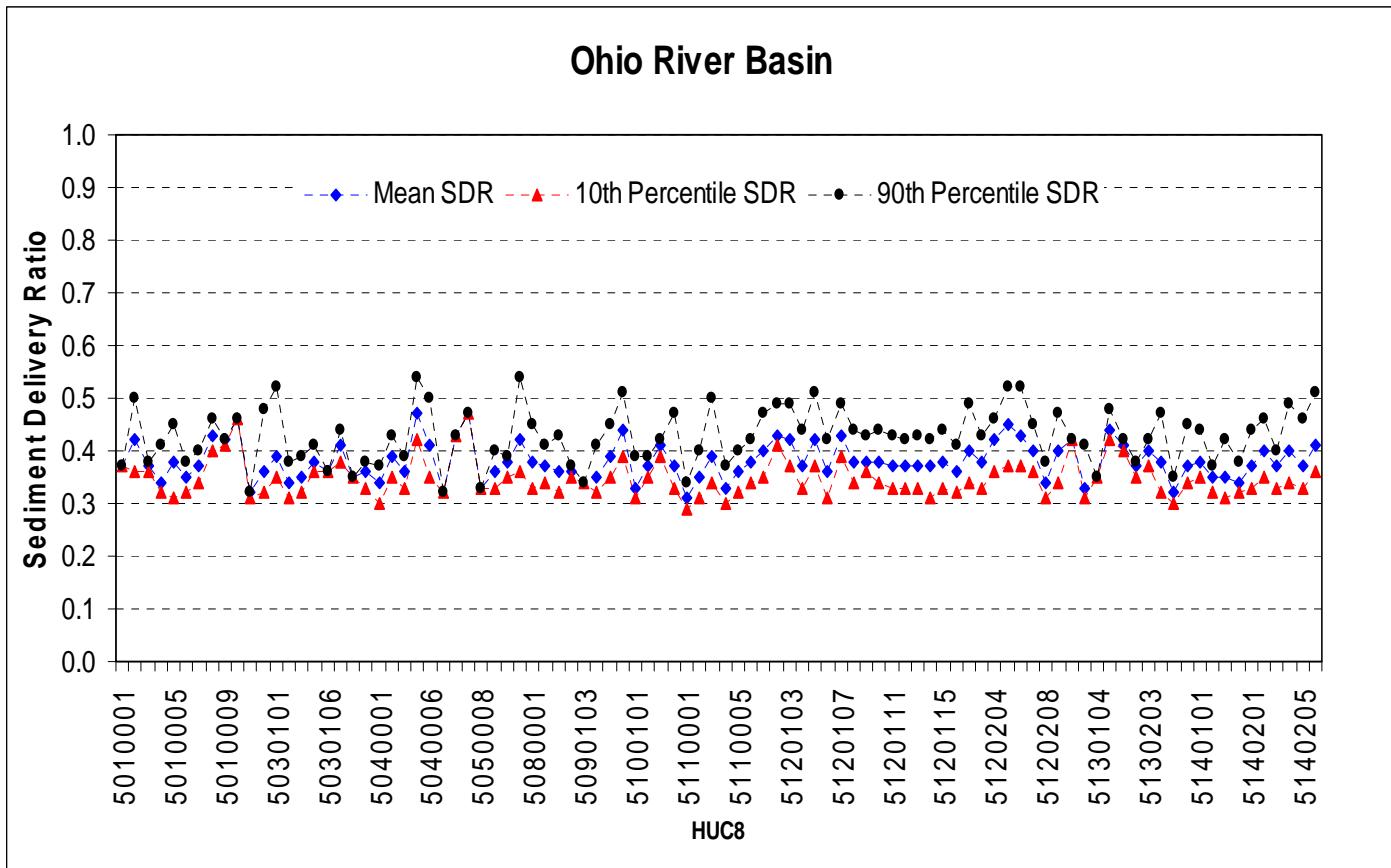


Figure 4-2. Mean and percentiles of sediment delivery ratio (sediment delivered at 8-digit watershed outlet by sediment yield at simulation sites) estimated for cultivated simulation sites within APEX for the 8-digit watersheds in the Tennessee River Basin

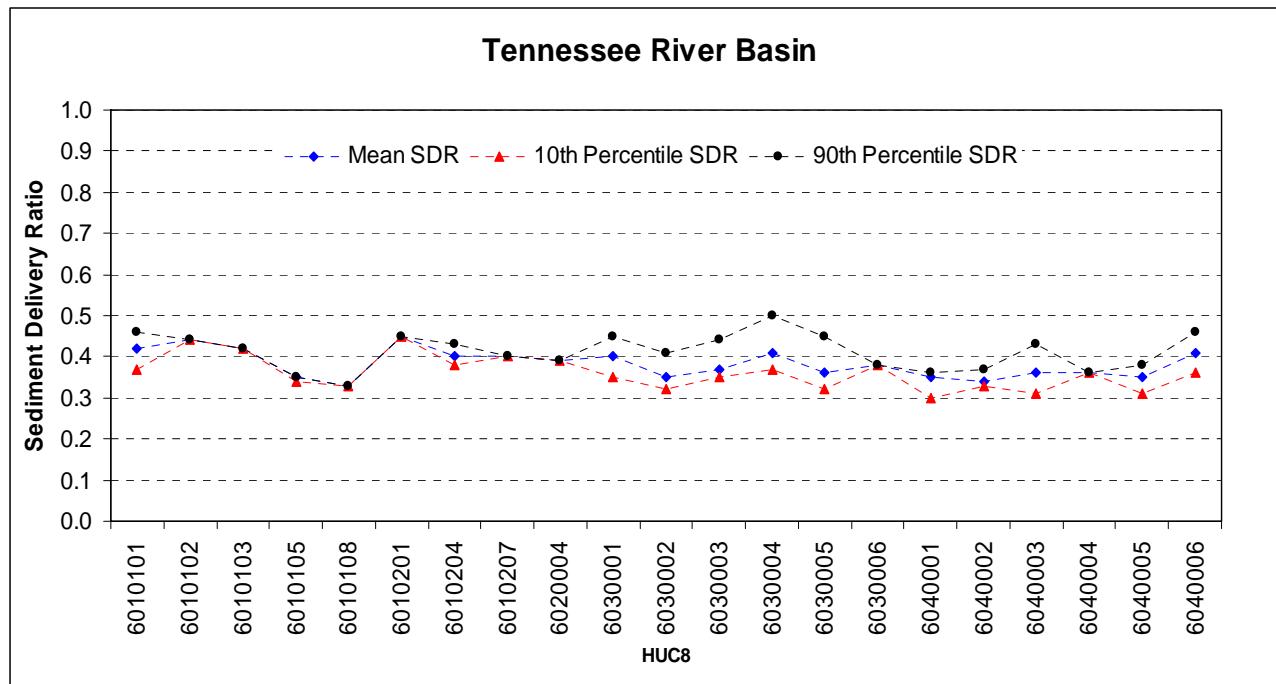


Table 4-2. Mean and percentiles of sediment delivery ratio (sediment delivered at 8-digit watershed outlet by sediment yield at HRUs) estimated for non-cultivated land HRUs within SWAT for the 8-digit watersheds in the Ohio-Tennessee River Basin

HUC	Subbasin	Number of non-cropland HRUs simulated within SWAT	Mean SDR	10 th Percentile SDR	90 th Percentile SDR
5010001	1	44	0.20	0.12	0.28
5010002	2	38	0.25	0.16	0.31
5010003	3	35	0.24	0.15	0.33
5010004	4	41	0.21	0.12	0.27
5010005	5	30	0.23	0.12	0.34
5010006	6	39	0.22	0.14	0.32
5010007	7	41	0.23	0.15	0.33
5010008	8	35	0.28	0.20	0.39
5010009	9	23	0.28	0.19	0.57
5020001	10	40	0.22	0.12	0.30
5020002	11	47	0.21	0.12	0.29
5020003	12	37	0.29	0.21	0.41
5020004	13	41	0.22	0.12	0.29
5020005	14	49	0.20	0.12	0.30
5020006	15	48	0.20	0.12	0.30
5030101	16	44	0.24	0.16	0.33
5030102	17	30	0.22	0.11	0.35
5030103	18	39	0.22	0.13	0.31
5030104	19	18	0.42	0.35	0.69
5030105	20	27	0.25	0.16	0.43
5030106	21	53	0.23	0.16	0.29
5030201	22	54	0.20	0.12	0.26
5030202	23	51	0.22	0.14	0.27
5030203	24	64	0.19	0.12	0.24
5030204	25	47	0.21	0.14	0.28
5040001	26	52	0.20	0.13	0.27
5040002	27	30	0.25	0.16	0.42
5040003	28	27	0.24	0.13	0.39
5040004	29	53	0.34	0.29	0.39
5040005	30	43	0.24	0.17	0.31
5040006	31	43	0.24	0.16	0.31
5050001	32	77	0.17	0.13	0.22
5050002	33	60	0.23	0.16	0.28
5050003	34	51	0.19	0.10	0.26
5050004	35	41	0.25	0.18	0.37
5050005	36	41	0.23	0.15	0.31
5050006	37	30	0.26	0.16	0.42
5050007	38	47	0.23	0.15	0.30
5050008	39	46	0.21	0.12	0.29
5050009	40	33	0.26	0.17	0.37
5060001	41	30	0.23	0.13	0.40
5060002	42	45	0.22	0.15	0.28

5060003	43	28	0.28	0.18	0.37
5070101	44	35	0.24	0.13	0.32
5070102	45	33	0.25	0.16	0.36
5070201	46	51	0.20	0.10	0.26
5070202	47	45	0.25	0.18	0.33
5070203	48	38	0.23	0.14	0.31
5070204	49	31	0.23	0.13	0.41
5080001	50	24	0.25	0.14	0.42
5080002	51	40	0.23	0.15	0.32
5080003	52	32	0.23	0.13	0.36
5090101	53	54	0.20	0.12	0.26
5090102	54	32	0.24	0.15	0.39
5090103	55	46	0.21	0.12	0.29
5090104	56	44	0.23	0.15	0.33
5090201	57	56	0.20	0.13	0.26
5090202	58	35	0.24	0.15	0.32
5090203	59	50	0.26	0.21	0.32
5100101	60	68	0.17	0.11	0.24
5100102	61	62	0.21	0.15	0.26
5100201	62	38	0.22	0.12	0.31
5100202	63	27	0.27	0.19	0.44
5100203	64	35	0.25	0.16	0.36
5100204	65	46	0.23	0.15	0.29
5100205	66	82	0.19	0.15	0.24
5110001	67	65	0.18	0.11	0.24
5110002	68	67	0.19	0.13	0.24
5110003	69	47	0.23	0.16	0.32
5110004	70	44	0.21	0.13	0.31
5110005	71	34	0.23	0.13	0.33
5110006	72	35	0.24	0.14	0.33
5120101	73	25	0.26	0.15	0.36
5120102	74	17	0.31	0.21	0.67
5120103	75	23	0.26	0.15	0.41
5120104	76	19	0.25	0.13	0.60
5120105	77	24	0.26	0.15	0.41
5120106	78	23	0.25	0.11	0.41
5120107	79	21	0.29	0.18	0.49
5120108	80	23	0.25	0.13	0.43
5120109	81	25	0.25	0.13	0.39
5120110	82	22	0.23	0.12	0.40
5120111	83	31	0.24	0.14	0.33
5120112	84	24	0.25	0.13	0.42
5120113	85	23	0.25	0.13	0.40
5120114	86	33	0.22	0.11	0.35
5120115	87	29	0.24	0.14	0.40
5120201	88	30	0.22	0.10	0.37
5120202	89	30	0.26	0.16	0.38
5120203	90	27	0.23	0.12	0.38
5120204	91	26	0.25	0.14	0.38
5120205	92	21	0.32	0.22	0.51
5120206	93	33	0.25	0.16	0.38
5120207	94	37	0.24	0.16	0.35

5120208	95	47	0.21	0.13	0.29
5120209	96	30	0.25	0.16	0.37
5130101	97	61	0.23	0.18	0.28
5130102	98	49	0.22	0.15	0.29
5130103	99	57	0.19	0.13	0.26
5130104	100	51	0.21	0.14	0.30
5130105	101	42	0.23	0.15	0.30
5130106	102	41	0.23	0.14	0.32
5130107	103	51	0.27	0.22	0.32
5130108	104	54	0.24	0.19	0.30
5130201	105	65	0.20	0.15	0.26
5130202	106	37	0.23	0.15	0.34
5130203	107	64	0.22	0.17	0.28
5130204	108	54	0.20	0.13	0.28
5130205	109	49	0.19	0.11	0.28
5130206	110	50	0.22	0.14	0.27
5140101	111	47	0.22	0.14	0.30
5140102	112	63	0.21	0.15	0.26
5140103	113	54	0.20	0.12	0.27
5140104	114	59	0.20	0.14	0.25
5140201	115	41	0.22	0.13	0.30
5140202	116	27	0.26	0.15	0.40
5140203	117	44	0.23	0.15	0.30
5140204	118	34	0.25	0.16	0.35
5140205	119	34	0.23	0.13	0.34
5140206	120	47	0.25	0.19	0.31
6010101	121	42	0.21	0.12	0.32
6010102	122	59	0.24	0.20	0.29
6010103	123	48	0.25	0.20	0.33
6010104	124	53	0.19	0.13	0.27
6010105	125	63	0.20	0.14	0.23
6010106	126	40	0.23	0.15	0.34
6010107	127	53	0.28	0.25	0.32
6010108	128	56	0.20	0.13	0.27
6010201	129	57	0.26	0.21	0.31
6010202	130	36	0.27	0.19	0.35
6010203	131	35	0.27	0.19	0.37
6010204	132	49	0.26	0.21	0.31
6010205	133	56	0.18	0.09	0.25
6010206	134	45	0.23	0.14	0.30
6010207	135	48	0.26	0.19	0.33
6010208	136	50	0.23	0.17	0.32
6020001	137	55	0.21	0.16	0.28
6020002	138	57	0.21	0.16	0.27
6020003	139	38	0.24	0.15	0.36
6020004	140	43	0.20	0.11	0.30
6030001	141	58	0.21	0.16	0.29
6030002	142	63	0.19	0.15	0.27
6030003	143	68	0.20	0.15	0.26
6030004	144	75	0.22	0.17	0.26
6030005	145	65	0.21	0.17	0.27
6030006	146	47	0.23	0.17	0.31

6040001	147	62	0.20	0.15	0.28
6040002	148	63	0.20	0.16	0.26
6040003	149	56	0.21	0.15	0.27
6040004	150	44	0.27	0.21	0.33
6040005	151	46	0.22	0.14	0.31
6040006	152	38	0.28	0.21	0.36

Figure 4-2. Mean and percentiles of sediment delivery ratio (sediment delivered at 8-digit watershed outlet by sediment yield at HRUs) estimated for non-cultivated land HRUs within SWAT for the 8-digit watersheds in the Ohio River Basin

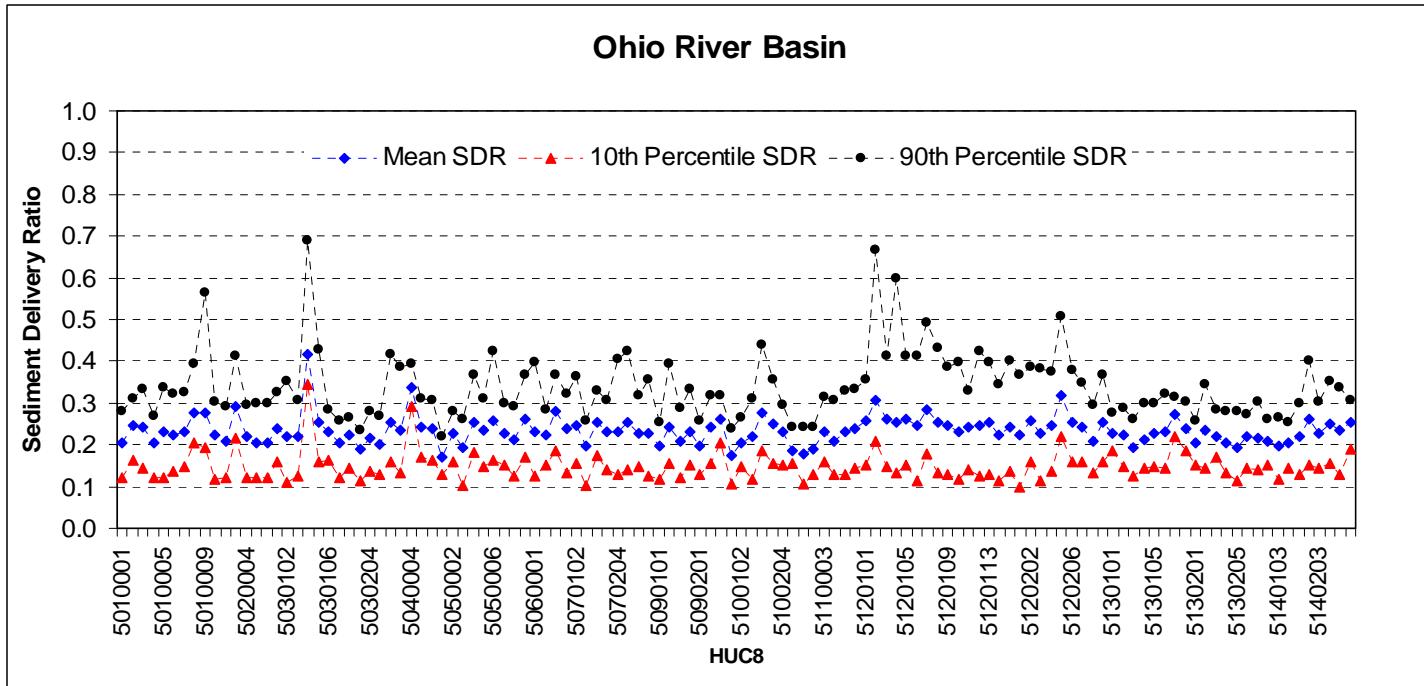
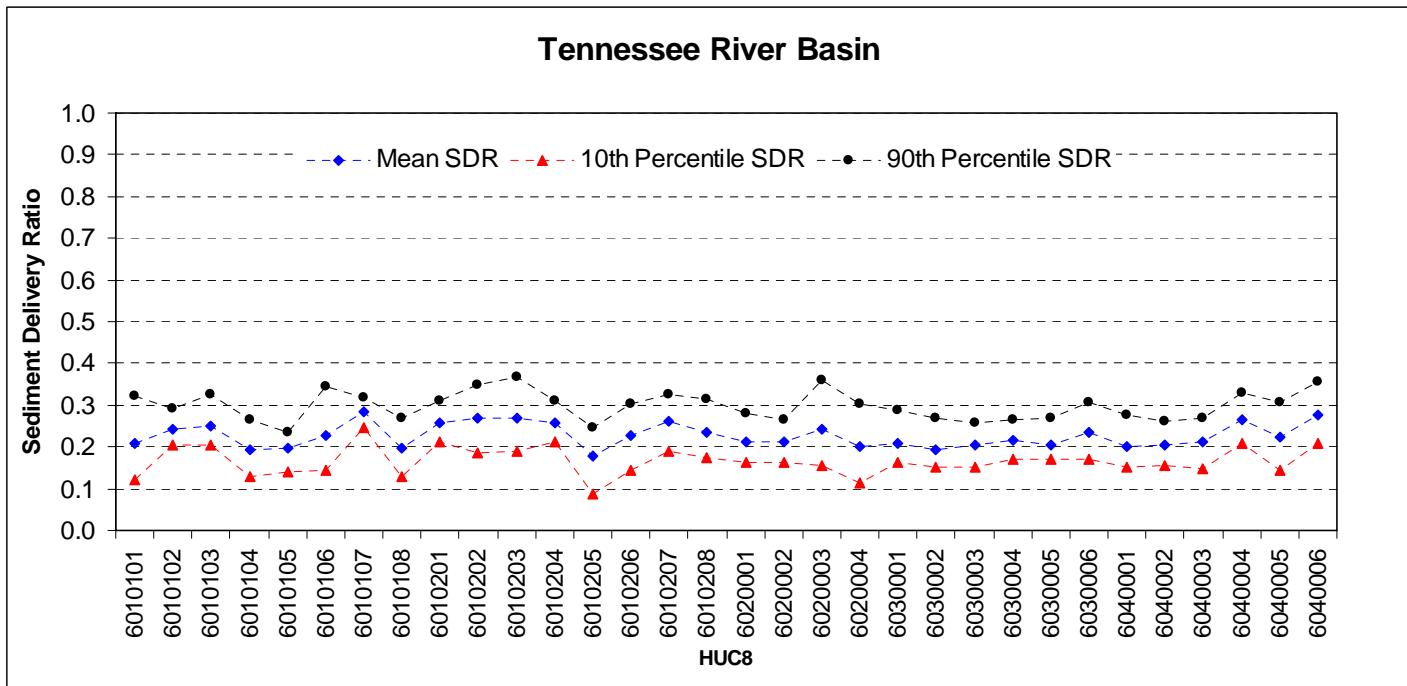


Figure 4-3. Mean and percentiles of sediment delivery ratio (sediment delivered at 8-digit watershed outlet by sediment yield at HRUs) estimated for non-cultivated land HRUs within SWAT for the 8-digit watersheds in the Tennessee River Basin



Chapter 5

**Delivery Ratio used in CEAP Cropland
Modeling in the Great Lakes Basin**

Delivery Ratio used in CEAP in the Great Lakes Basin

The APEX model is a field-scale, daily time-step model that simulates weather, farming operations, crop growth and yield, and the movement of water, soil, carbon, nutrients, sediment, and pesticides. The APEX model was used also to simulate the effects of conservation practices at the field scale (Williams and Izaurrealde, 2006; Gassman et al. 2009) in the Great Lakes Basin. APEX simulates all of the basic biological, chemical, hydrological, and meteorological processes of farming systems and their interactions. Soil erosion is simulated over time, including wind erosion, sheet and rill erosion. The nitrogen, phosphorus, and carbon cycles are simulated, including chemical transformations in the soil that affect their availability for plant growth or for transport from the field.

While the APEX model was used to simulate the cultivated cropland, the SWAT model was used to simulate the non-cultivated cropland in the 8-digit watersheds of the river basin. SWAT is a physical process model with a daily time step (Arnold and Fohrer 2005; Arnold et al. 1998; Gassman et al. 2007). The hydrologic cycle in the model is divided into two parts. The land phase of the hydrologic cycle, or upland processes, simulates the amount of water, sediment, nutrients, and pesticides delivered from the land to the outlet of each watershed. The routing phase of the hydrologic cycle, or channel processes, simulates the movement of water, sediment, nutrients, and pesticides from the outlet of the upstream watershed through the main channel network to the watershed outlet.

In SWAT, each 8-digit watershed is divided into multiple Hydrologic Response Units (HRUs) that have homogeneous land use, soil, and slope. SWAT is used to simulate the fate and transport of water, sediment, nutrients, and pesticides from various non-cropland HRUs as described in Chapter 1.

Not all of the soil that erodes from a field or HRUs ends up in the watershed outlet. Most of the soil eroded gets deposited on the way although the deposition is temporary. Eroded soil may deposit in lower spots, flatter lands, deposited at the edge of the field and sometimes settles at the bottom of the channel. Hence, a SDR was used to account for deposition in ditches, floodplains, and tributary stream channels during transit from the edge of the field or HRUs to the 8-digit watershed outlet in the CEAP National Assessment modeling. The SDR used in this study is a function of the ratio of the time of concentration for the HRU (land uses other than cultivated cropland) or field (cultivated cropland) to the time of concentration for the watershed (8-digit HUC). The time of concentration for the watershed is the time from when a surface water runoff event occurs at the most distant point in the watershed to

the time the surface water runoff reaches the outlet of the watershed. It is calculated by summing the overland flow time (the time it takes for flow from the remotest point in the watershed to reach the channel) and the channel flow time (the time it takes for flow in the upstream channels to reach the outlet). The time of concentration for the field is derived from APEX. The time of concentration for the HRU is derived from characteristics of the watershed, the HRU, and the proportion of total acres represented by the HRU. Consequently, each cultivated cropland sample point has a unique delivery ratio within each watershed, as does each HRU. The description of the sediment delivery ratio procedure is provided in Chapter 1.

The APEX model simulates the edge of sediment yield using a variation of MUSLE called MUST (MUSLE developed from Theory) (Williams 1995) as described in Chapter 1. After estimating the sediment load from each APEX simulation site, the delivery ratio is applied to determine the amount of sediment that reach the 8-digit watershed outlet from each APEX simulation site. The sediment load from apex simulation sites are aggregated for the 8-digit watershed and integrated into the SWAT model at each 8-digit watershed to estimate the water quality effects of conservation practices. In SWAT, the sediment yield for the non-cropland HRUs are estimated using the MUSLE as described in Chapter 1. After estimating the SDR for each HRU, the SDR is applied to determine the amount of sediment that reach the 8-digit watershed outlet.

Sediment delivery ratios were estimated to account for sediment losses or deposition occurring from edge-of-field or HRUs to the 8-digit watershed outlet for each APEX simulation site in the cultivated cropland and CRP and non-cropland HRUs in the Great Lakes Basin (Figure 5-1). The Great Lakes Basin has a drainage area of 111.58 million acres. The cultivated cropland and land enrolled in the CRP General Signup is about 16 percent of the Great Lakes Basin. A total of 111, 8-digit watersheds are in the Great Lakes Basin including the five lakes (Figure 5-1). Within each 8-digit watershed, the percent of cultivated cropland and CRP area and non-cultivated cropland area varies widely across the entire basin.

A total of 1843 representative cultivated fields (1418 NRI-CEAP cropland points and 425 CRP points) were setup to run using APEX. Thirty-six out of 111, 8-digit watersheds in the Great Lakes have no CEAP points; the thirty-six 8-digit watersheds have zero or fewer than 7% percentage cultivated.

Non-cultivated land is distributed over 84 percent of the Great Lakes Basin. Within each 8-digit watershed, non-

cultivated land uses such as pasture, range, hay, horticulture, forest deciduous, forest mixed, forest evergreen, urban, urban construction, barren land wetland and water are simulated as HRUs in SWAT. A total of 3900 HRUs are simulated in SWAT for the Great Lakes Basin.

Each NRI-CEAP point and CRP point is unique; therefore, sediment yield and delivery ratio also vary for each cultivated cropland site simulated in an 8-digit watershed and so as for HRU. The number of CEAP sample points, and mean, 10th percentile and 90th percentile of the delivery ratios of the APEX simulation sites in the 8-digit watersheds in the Great Lakes Basin are shown in Table 5-1 and Figure 5-1). Table 5-2. shows number of HRUs and mean, 10th percentile and 90th percentile of the SDRs estimated for the non-cultivated land HRUs in the 8-digit watersheds in the Great Lakes Basin (Figure 5-1). The mean, 10th and 90th percentile SDRs for the non-cropland HRUs are plotted in Figure 5-2.

In addition to SDR, an enrichment ratio was used to simulate organic nitrogen, organic phosphorus, and sediment-attached pesticide transport in ditches, floodplains, and tributary stream channels during transit from the edge of the field to the outlet. The enrichment ratio was defined as the organic nitrogen, organic phosphorus, and sediment attached pesticide concentration from the edge-of-field divided by the concentration at the 8-digit watershed outlet. The enrichment ratio is estimated for each APEX simulation site and SWAT HRUs and it varies from 0.5 to 1.5 (Average 1.0). As sediment is transported from the edge-of-field to the watershed outlet, coarse sediments are deposited first while more of the fine sediment that hold organic particles remain in suspension, thus enriching the organic concentrations delivered to the watershed outlet.

A separate delivery ratio is used to simulate the transport of nitrate nitrogen, soluble phosphorus, and soluble pesticides. In general, the proportion of soluble nutrients and pesticides delivered to rivers and streams is higher than the proportion attached to sediments because they are not subject to sediment deposition.

Delivery Ratio used in CEAP in the Great Lakes Basin

Figure 5-1 Map of the 8-digit watersheds in the Great Lakes Basin



Delivery Ratio used in CEAP in the Great Lakes Basin

Table 5-1. Mean and percentiles of sediment delivery ratio (sediment delivered at 8-digit watershed outlet by sediment yield at simulation sites) estimated for cultivated simulation sites within APEX for the 8-digit watersheds in the Great Lakes Basin

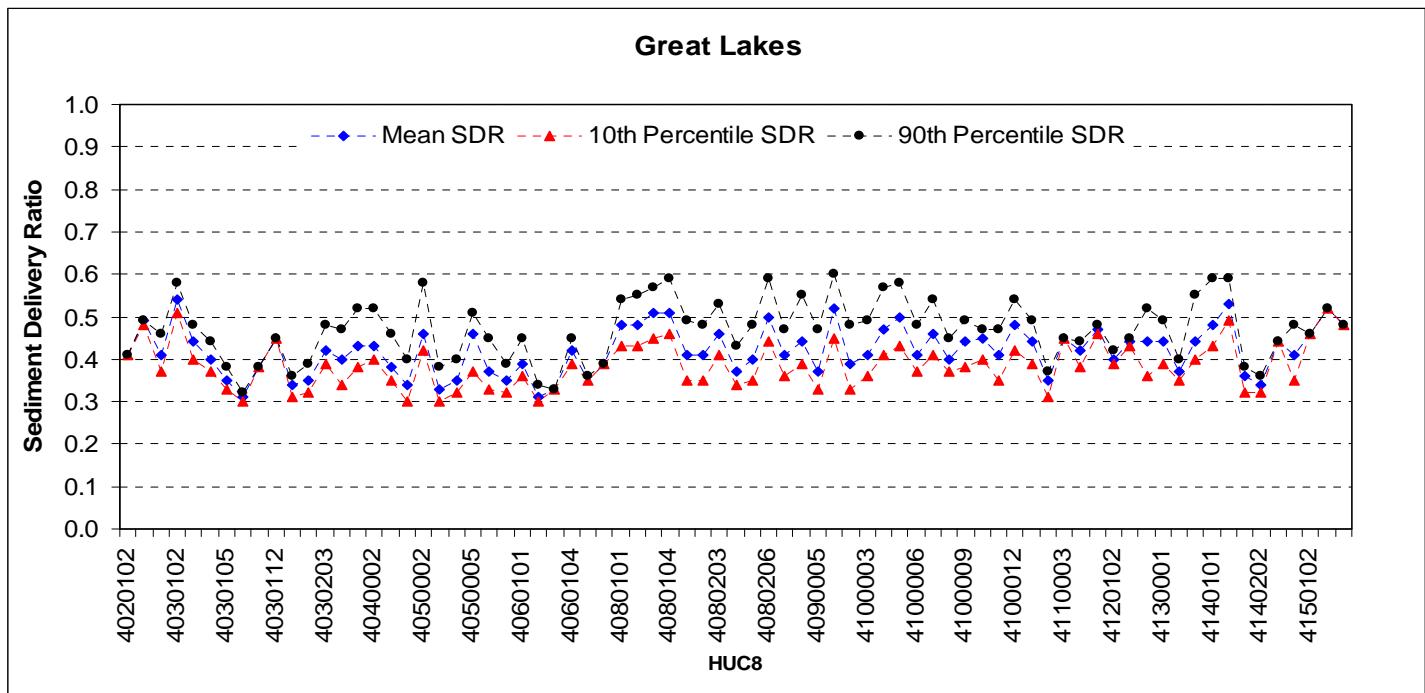
HUC	Cropland		CRP		Crop + CRP			
	Points	Mean SDR	Points	Mean SDR	Point s	Mean SDR	10 th percentile SDR	90 th percentile SDR
4020102	1	0.41			1	0.41	0.41	0.41
4020103			2	0.49	2	0.49	0.48	0.49
4030101	54	0.41	12	0.39	66	0.41	0.37	0.46
4030102	26	0.55	17	0.54	43	0.54	0.51	0.58
4030103	8	0.44	3	0.43	11	0.44	0.40	0.48
4030104	5	0.40	8	0.39	13	0.40	0.37	0.44
4030105	5	0.35			5	0.35	0.33	0.38
4030108	2	0.31			2	0.31	0.30	0.32
4030109	1	0.38			1	0.38	0.38	0.38
4030112	1	0.45			1	0.45	0.45	0.45
4030201	25	0.34	15	0.33	40	0.34	0.31	0.36
4030202	29	0.36	25	0.34	54	0.35	0.32	0.39
4030203	8	0.41	6	0.43	14	0.42	0.39	0.48
4030204	6	0.40	3	0.39	9	0.40	0.34	0.47
4040001	21	0.44	3	0.39	24	0.43	0.38	0.52
4040002	12	0.44	3	0.41	15	0.43	0.40	0.52
4040003	23	0.39	5	0.37	28	0.38	0.35	0.46
4050001	200	0.34	48	0.32	248	0.34	0.30	0.40
4050002	11	0.46			11	0.46	0.42	0.58
4050003	57	0.33	4	0.32	61	0.33	0.30	0.38
4050004	31	0.36	1	0.31	32	0.35	0.32	0.40
4050005	13	0.46	3	0.45	16	0.46	0.37	0.51
4050006	17	0.38	5	0.35	22	0.37	0.33	0.45
4050007	9	0.36	4	0.34	13	0.35	0.32	0.39
4060101	12	0.39			12	0.39	0.36	0.45
4060102	6	0.32	2	0.30	8	0.31	0.30	0.34
4060103	1	0.33			1	0.33	0.33	0.33
4060104	4	0.42			4	0.42	0.39	0.45
4060105	1	0.35	1	0.36	2	0.35	0.35	0.36
4070006	2	0.39			2	0.39	0.39	0.39
4080101	2	0.49	1	0.46	3	0.48	0.43	0.54
4080102	10	0.48	1	0.44	11	0.48	0.43	0.55
4080103	25	0.51	5	0.48	30	0.51	0.45	0.57
4080104	14	0.51	5	0.53	19	0.51	0.46	0.59
4080201	5	0.41	1	0.39	6	0.41	0.35	0.49
4080202	14	0.43	4	0.37	18	0.41	0.35	0.48
4080203	17	0.45	3	0.49	20	0.46	0.41	0.53
4080204	16	0.37	2	0.37	18	0.37	0.34	0.43
4080205	13	0.41	4	0.38	17	0.40	0.35	0.48
4080206	7	0.50			7	0.50	0.44	0.59
4090001	27	0.40	3	0.45	30	0.41	0.36	0.47

Delivery Ratio used in CEAP in the Great Lakes Basin

4090003	6	0.44			6	0.44	0.39	0.55
4090005	19	0.37			19	0.37	0.33	0.47
4100001	29	0.52			29	0.52	0.45	0.60
4100002	62	0.40	21	0.35	83	0.39	0.33	0.48
4100003	80	0.42	95	0.40	175	0.41	0.36	0.49
4100004	30	0.48	2	0.43	32	0.47	0.41	0.57
4100005	15	0.51	8	0.49	23	0.50	0.43	0.58
4100006	41	0.42	35	0.39	76	0.41	0.37	0.48
4100007	66	0.47	12	0.42	78	0.46	0.41	0.54
4100008	29	0.41	2	0.36	31	0.40	0.37	0.45
4100009	31	0.44	1	0.39	32	0.44	0.38	0.49
4100010	22	0.45	2	0.47	24	0.45	0.40	0.47
4100011	48	0.41	12	0.43	60	0.41	0.35	0.47
4100012	39	0.48	15	0.47	54	0.48	0.42	0.54
4110001	26	0.44	5	0.42	31	0.44	0.39	0.49
4110002	3	0.35			3	0.35	0.31	0.37
4110003	1	0.45			1	0.45	0.45	0.45
4110004	3	0.41	1	0.44	4	0.42	0.38	0.44
4120101	2	0.47			2	0.47	0.46	0.48
4120102	3	0.40	1	0.42	4	0.40	0.39	0.42
4120103	1	0.45	1	0.43	2	0.44	0.43	0.45
4120104	9	0.44	2	0.42	11	0.44	0.36	0.52
4130001	14	0.45	4	0.43	18	0.44	0.39	0.49
4130002	6	0.37	1	0.36	7	0.37	0.35	0.40
4130003	18	0.44	1	0.41	19	0.44	0.40	0.55
4140101	9	0.49	2	0.46	11	0.48	0.43	0.59
4140102	4	0.53			4	0.53	0.49	0.59
4140201	49	0.36	2	0.34	51	0.36	0.32	0.38
4140202	4	0.34	1	0.32	5	0.34	0.32	0.36
4140203	1	0.44			1	0.44	0.44	0.44
4150101	4	0.41			4	0.41	0.35	0.48
4150102	1	0.46			1	0.46	0.46	0.46
4150302	1	0.52			1	0.52	0.52	0.52
4150303	1	0.48			1	0.48	0.48	0.48

Delivery Ratio used in CEAP in the Great Lakes Basin

Figure 5-2. Mean and percentiles of sediment delivery ratio (sediment delivered at 8-digit watershed outlet by sediment yield at simulation sites) estimated for cultivated simulation sites within APEX for the 8-digit watersheds in the Great Lakes Basin



Delivery Ratio used in CEAP in the Great Lakes Basin

Table 5-2. Mean and percentiles of sediment delivery ratio (ratio of sediment delivered at 8-digit watershed outlet by sediment yield at HRUs) estimated for non-cultivated land HRUs within SWAT for the 8-digit watersheds in the Great Lakes Basin

HUC	Subbasin	Number of non-cropland HRUs simulated within SWAT	Mean SDR	10 th Percentile SDR	90 th Percentile SDR
4010101	1	49	0.34	0.28	0.39
4010102	2	37	0.49	0.44	0.52
4010201	3	41	0.24	0.18	0.29
4010202	4	30	0.25	0.16	0.32
4010301	5	46	0.34	0.29	0.39
4010302	6	47	0.28	0.22	0.34
4020101	7	39	0.33	0.25	0.38
4020102	8	48	0.27	0.20	0.31
4020103	9	32	0.39	0.33	0.49
4020104	10	39	0.26	0.17	0.33
4020105	11	42	0.31	0.25	0.36
4020201	12	44	0.41	0.34	0.45
4020202	13	36	0.26	0.18	0.35
4020203	14	32	0.38	0.33	0.44
4020300	15	4	0.51	0.26	0.79
4030101	16	37	0.29	0.22	0.38
4030102	17	41	0.48	0.44	0.52
4030103	18	33	0.33	0.27	0.43
4030104	19	38	0.30	0.23	0.36
4030105	20	41	0.24	0.16	0.33
4030106	21	46	0.25	0.17	0.32
4030107	22	44	0.27	0.21	0.33
4030108	23	43	0.23	0.15	0.30
4030109	24	37	0.30	0.24	0.37
4030110	25	47	0.24	0.18	0.32
4030111	26	39	0.33	0.27	0.38
4030112	27	32	0.34	0.27	0.45
4030201	28	26	0.25	0.12	0.35
4030202	29	26	0.25	0.13	0.35
4030203	30	29	0.28	0.20	0.43
4030204	31	27	0.27	0.16	0.41
4040001	32	37	0.32	0.25	0.39
4040002	33	26	0.32	0.25	0.51
4040003	34	34	0.27	0.19	0.33
4050001	35	26	0.25	0.14	0.45
4050002	36	36	0.34	0.28	0.42
4050003	37	38	0.23	0.15	0.32
4050004	38	44	0.22	0.15	0.29
4050005	39	35	0.28	0.21	0.37
4050006	40	36	0.25	0.16	0.32
4050007	41	41	0.23	0.16	0.31
4060101	42	31	0.28	0.19	0.37

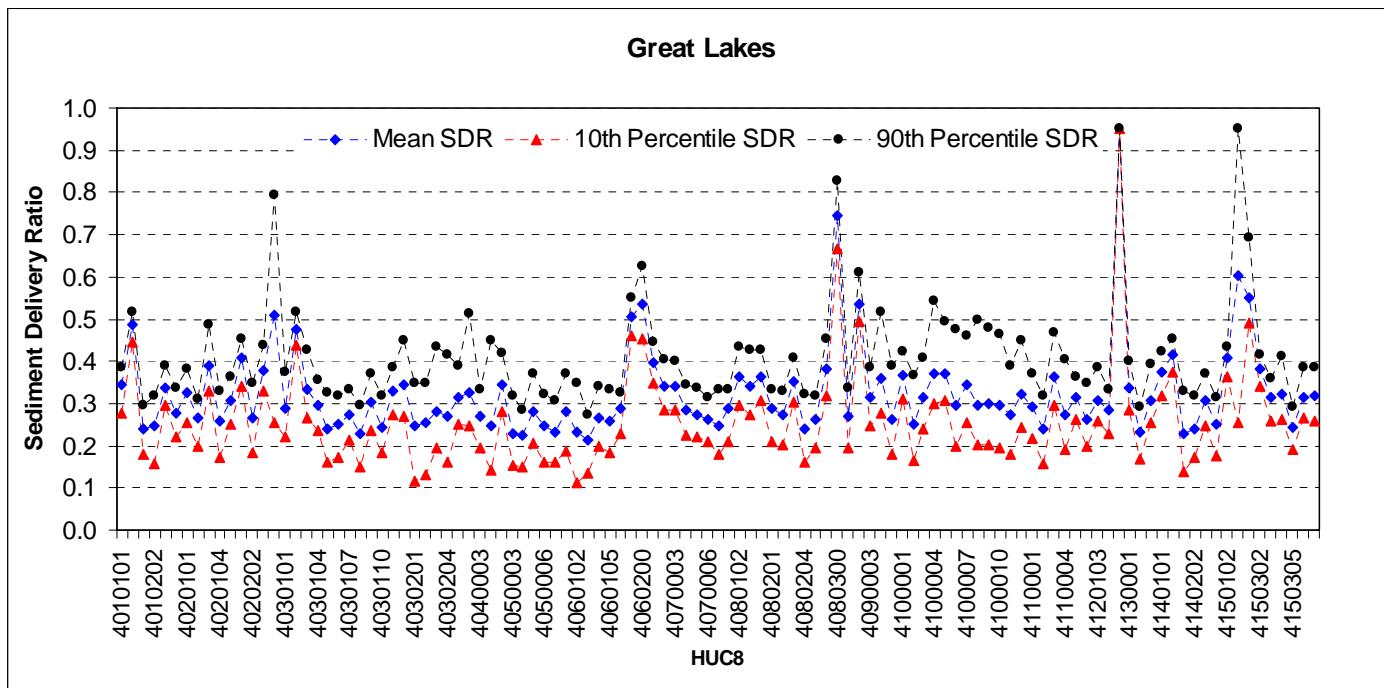
Delivery Ratio used in CEAP in the Great Lakes Basin

4060102	43	31	0.23	0.11	0.35
4060103	44	48	0.21	0.13	0.27
4060104	45	37	0.27	0.20	0.34
4060105	46	38	0.26	0.18	0.33
4060106	47	48	0.29	0.23	0.33
4060107	48	38	0.51	0.46	0.55
4060200	49	5	0.54	0.45	0.63
4070001	50	36	0.40	0.35	0.45
4070002	51	34	0.34	0.29	0.41
4070003	52	39	0.34	0.29	0.40
4070004	53	38	0.28	0.22	0.35
4070005	54	46	0.28	0.22	0.34
4070006	55	45	0.26	0.21	0.31
4070007	56	42	0.25	0.18	0.33
4080101	57	43	0.29	0.21	0.33
4080102	58	32	0.37	0.29	0.43
4080103	59	30	0.34	0.27	0.43
4080104	60	35	0.36	0.31	0.43
4080201	61	40	0.29	0.21	0.33
4080202	62	40	0.28	0.20	0.33
4080203	63	38	0.35	0.30	0.41
4080204	64	43	0.24	0.16	0.32
4080205	65	42	0.26	0.20	0.32
4080206	66	19	0.38	0.32	0.45
4080300	67	2	0.75	0.67	0.83
4090001	68	38	0.27	0.19	0.34
4090002	69	26	0.54	0.49	0.61
4090003	70	36	0.31	0.25	0.38
4090004	71	26	0.36	0.28	0.52
4090005	72	35	0.26	0.18	0.39
4100001	73	36	0.37	0.31	0.42
4100002	74	32	0.25	0.17	0.37
4100003	75	30	0.31	0.24	0.41
4100004	76	22	0.37	0.30	0.54
4100005	77	21	0.37	0.31	0.50
4100006	78	24	0.29	0.20	0.47
4100007	79	25	0.34	0.26	0.46
4100008	80	20	0.30	0.20	0.50
4100009	81	23	0.30	0.20	0.48
4100010	82	23	0.30	0.19	0.47
4100011	83	25	0.27	0.18	0.39
4100012	84	25	0.32	0.24	0.45
4110001	85	38	0.29	0.22	0.37
4110002	86	33	0.24	0.16	0.32
4110003	87	28	0.36	0.29	0.47
4110004	88	33	0.27	0.19	0.40
4120101	89	45	0.31	0.26	0.36
4120102	90	42	0.26	0.20	0.35
4120103	91	45	0.31	0.26	0.39
4120104	92	52	0.28	0.23	0.33
4120200	93	1	0.95	0.95	0.95

Delivery Ratio used in CEAP in the Great Lakes Basin

4130001	94	43	0.34	0.28	0.40
4130002	95	49	0.23	0.17	0.29
4130003	96	39	0.31	0.26	0.39
4140101	97	44	0.37	0.32	0.42
4140102	98	46	0.41	0.38	0.45
4140201	99	36	0.23	0.14	0.33
4140202	100	42	0.24	0.17	0.32
4140203	101	39	0.31	0.25	0.37
4150101	102	42	0.25	0.18	0.31
4150102	103	55	0.41	0.36	0.44
4150200	104	2	0.60	0.26	0.95
4150301	105	17	0.55	0.49	0.69
4150302	106	36	0.38	0.34	0.41
4150303	107	44	0.31	0.26	0.36
4150304	108	31	0.32	0.26	0.41
4150305	109	41	0.24	0.19	0.29
4150306	110	45	0.31	0.26	0.39
4150307	111	40	0.32	0.26	0.39

Figure 5-3. Mean and percentiles of sediment delivery ratio (sediment delivered at 8-digit watershed outlet by sediment yield at HRUs) estimated for non-cultivated land HRUs within SWAT for the 8-digit watersheds in the Great Lakes Basin



Chapter 6

**Delivery Ratio used in CEAP Cropland
Modeling in the Missouri River Basin**

The APEX model is a field-scale, daily time-step model that simulates weather, farming operations, crop growth and yield, and the movement of water, soil, carbon, nutrients, sediment, and pesticides. The APEX model was used also to simulate the effects of conservation practices at the field scale (Williams and Izaurrealde, 2006; Gassman et al. 2009) in the Missouri River Basin. APEX simulates all of the basic biological, chemical, hydrological, and meteorological processes of farming systems and their interactions. Soil erosion is simulated over time, including wind erosion, sheet and rill erosion. The nitrogen, phosphorus, and carbon cycles are simulated, including chemical transformations in the soil that affect their availability for plant growth or for transport from the field.

While the APEX model was used for simulate the cultivated cropland and the SWAT model was used to simulate the non-cultivated cropland in the 8-digit watersheds of the river basin. SWAT is a physical process model with a daily time step (Arnold and Fohrer 2005; Arnold et al. 1998; Gassman et al. 2007). The hydrologic cycle in the model is divided into two parts. The land phase of the hydrologic cycle, or upland processes, simulates the amount of water, sediment, nutrients, and pesticides delivered from the land to the outlet of each watershed. The routing phase of the hydrologic cycle, or channel processes, simulates the movement of water, sediment, nutrients, and pesticides from the outlet of the upstream watershed through the main channel network to the watershed outlet.

In SWAT, each 8-digit watershed is divided into multiple Hydrologic Response Units (HRUs) that have homogeneous land use, soil, and slope. SWAT is used to simulate the fate and transport of water, sediment, nutrients, and pesticides from various non-cropland HRUs as described in Chapter 1.

Not all of the soil that erodes from a field or HRUs ends up in the watershed outlet. Most of the soil eroded gets deposited on the way although the deposition is temporary. Eroded soil may deposit in lower spots, flatter lands, deposited at the edge of the field and sometimes settles at the bottom of the channel. Hence, a SDR was used to account for deposition in ditches, floodplains, and tributary stream channels during transit from the edge of the field or HRUs to the 8-digit watershed outlet in the CEAP National Assessment modeling. The SDR used in this study is a function of the ratio of the time of concentration for the HRU (land uses other than cultivated cropland) or

field (cultivated cropland) to the time of concentration for the watershed (8-digit HUC). The time of concentration for the watershed is the time from when a surface water runoff event occurs at the most distant point in the watershed to the time the surface water runoff reaches the outlet of the watershed. It is calculated by summing the overland flow time (the time it takes for flow from the remotest point in the watershed to reach the channel) and the channel flow time (the time it takes for flow in the upstream channels to reach the outlet). The time of concentration for the field is derived from APEX. The time of concentration for the HRU is derived from characteristics of the watershed, the HRU, and the proportion of total acres represented by the HRU. Consequently, each cultivated cropland sample point has a unique delivery ratio within each watershed, as does each HRU. The description of the sediment delivery ratio procedure is provided in Chapter 1.

The APEX model simulates the edge of sediment yield using a variation of MUSLE called MUST (MUSLE developed from Theory) (Williams 1995) as described in Chapter 1. After estimating the sediment load from each APEX simulation site, the delivery ratio is applied to determine the amount of sediment that reach the 8-digit watershed outlet from each APEX simulation site. The sediment load from apex simulation sites are aggregated for the 8-digit watershed and integrated into the SWAT model at each 8-digit watershed to estimate the water quality effects of conservation practices. In SWAT, the sediment yield for the non-cropland HRUs are estimated using the MUSLE as described in Chapter 1. After estimating the SDR for each HRU, the SDR is applied to determine the amount of sediment that reaches the 8-digit watershed outlet.

Sediment delivery ratios were estimated to account for sediment losses or deposition occurring from edge-of-field or HRUs to the 8-digit watershed outlet for each APEX simulation site in the cultivated cropland and CRP and non-cropland HRUs in the Missouri River Basin (Figure 6-1). The Missouri River Basin has a drainage area of 327 million acres. The cultivated cropland and land enrolled in the CRP General Signup is about 29 percent of the Missouri River Basin. A total of 310, 8-digit watersheds are in the Missouri River Basin (Figure 6-1). Within each 8-digit watershed, the percent of cultivated cropland and CRP area and non-cultivated cropland area varies widely across the entire basin.

A total of 8186 representative cultivated fields (3916 NRI-CEAP cropland points and 4270 CRP points) were setup to run using APEX. Fifty-four out of 310, 8-digit watersheds in the Missouri have no CEAP points; the fifty-four 8-digit watersheds have zero or fewer than 7% percentage cultivated.

Non-cultivated land is distributed over 71 percent of the Missouri River Basin. Within each 8-digit watershed, non-cultivated land uses such as pasture, range, hay, horticulture, forest deciduous, forest mixed, forest evergreen, urban, urban construction, barren land wetland and water are simulated as HRUs in SWAT. A total of 11,716 HRUs are simulated in SWAT for the Missouri River Basin.

Each NRI-CEAP point and CRP point is unique; therefore, sediment yield and delivery ratio also vary for each cultivated cropland site simulated in an 8-digit watershed and so as for HRU. The number of CEAP sample points, and mean, 10th percentile and 90th percentile of the delivery ratios of the APEX simulation sites in the 8-digit watersheds in the Missouri River Basin are shown in Table 6-1 and Figure 6-2. Table 6-2 shows number of HRUs and mean, 10th percentile and 90th percentile of the SDRs estimated for the non-cultivated land HRUs in the 8-digit watersheds in the Missouri River Basin (Figure 6-1). The mean, 10th and 90th percentile SDRs for the non-cropland HRUs are plotted in Figure 6-3.

In addition to SDR, an enrichment ratio was used to simulate organic nitrogen, organic phosphorus, and sediment-attached pesticide transport in ditches, floodplains, and tributary stream channels during transit from the edge of the field to the outlet. The enrichment ratio was defined as the organic nitrogen, organic phosphorus, and sediment attached pesticide concentration from the edge-of-field divided by the concentration at the 8-digit watershed outlet. The enrichment ratio is estimated for each APEX simulation site and SWAT HRUs and it varies from 0.5 to 1.5 (Average 1.0). As sediment is transported from the edge-of-field to the watershed outlet, coarse sediments are deposited first while more of the fine sediment that hold organic particles remain in suspension, thus enriching the organic concentrations delivered to the watershed outlet.

A separate delivery ratio is used to simulate the transport of nitrate nitrogen, soluble phosphorus, and soluble pesticides. In general, the proportion of soluble nutrients and pesticides delivered to rivers and streams is higher than the proportion attached to sediments because they are not subject to sediment deposition.

Delivery Ratio used in CEAP in the Missouri River Basin

Figure 6-1. Map of the 8-digit watersheds in the Missouri River Basin .

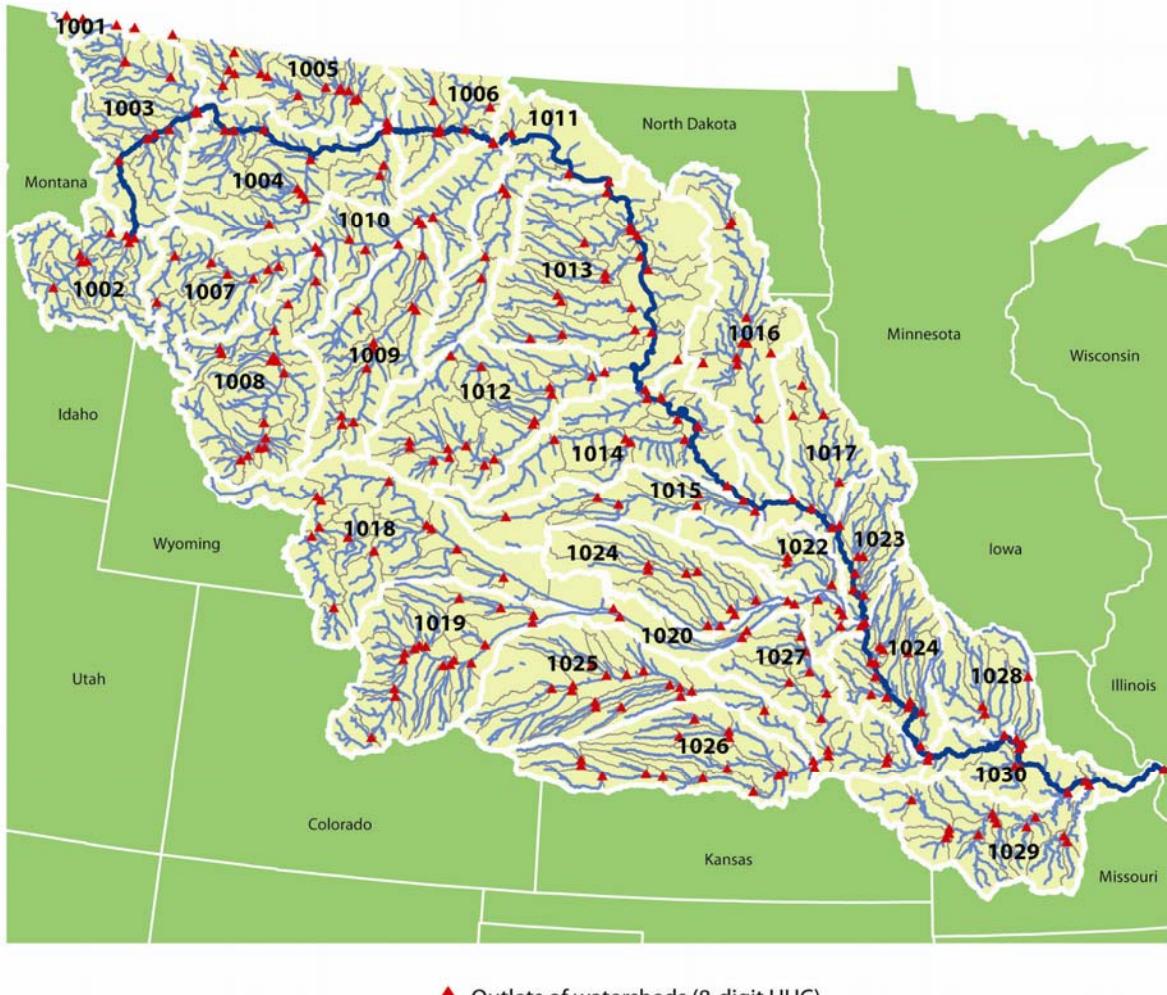


Table 6-1. Mean and percentiles of sediment delivery ratio (sediment delivered at 8-digit watershed outlet by sediment yield at simulation sites) estimated for cultivated simulation sites within APEX for the 8-digit watersheds in the Missouri River Basin.

HUC	Cropland		CRP		Crop + CRP			
	Points	Mean SDR	Points	Mean SDR	Points	Mean SDR	10 th percentile	90 th percentile
10020003	1	0.44			1	0.44	0.44	0.44
10020005	1	0.48	10	0.36	11	0.37	0.34	0.46
10020006	1	0.43			1	0.43	0.43	0.43
10020008	5	0.41	1	0.43	6	0.41	0.38	0.43
10030101	11	0.36	9	0.38	20	0.37	0.34	0.40
10030102	13	0.48	9	0.47	22	0.48	0.45	0.52
10030103	2	0.39			2	0.39	0.39	0.40
10030104	6	0.43	9	0.39	15	0.40	0.35	0.48
10030105			1	0.43	1	0.43	0.43	0.43
10030201	1	0.45	2	0.35	3	0.39	0.35	0.45
10030202	8	0.44	4	0.37	12	0.42	0.36	0.52
10030203	23	0.35	41	0.35	64	0.35	0.32	0.38
10030204	7	0.42	23	0.36	30	0.38	0.34	0.43
10030205	14	0.39	16	0.40	30	0.39	0.37	0.44
10040101	2	0.48	8	0.46	10	0.46	0.41	0.53
10040102			13	0.42	13	0.42	0.39	0.45
10040103	22	0.39	10	0.38	32	0.39	0.36	0.40
10040104	3	0.37	2	0.35	5	0.36	0.35	0.39
10040105	4	0.40	7	0.37	11	0.38	0.36	0.41
10040106	4	0.37	14	0.37	18	0.37	0.36	0.39
10040201	6	0.37	16	0.37	22	0.37	0.34	0.39
10040202			8	0.35	8	0.35	0.33	0.38
10040203	1	0.46	5	0.41	6	0.42	0.39	0.46
10040204	3	0.39	1	0.35	4	0.38	0.35	0.40
10040205	3	0.40	1	0.44	4	0.41	0.38	0.44
10050001	1	0.48			1	0.48	0.48	0.48
10050002	5	0.40	15	0.42	20	0.42	0.38	0.46
10050004	7	0.42	13	0.41	20	0.41	0.37	0.45
10050005	5	0.43	7	0.43	12	0.43	0.40	0.46
10050006	8	0.46	20	0.47	28	0.47	0.44	0.49
10050008	1	0.44	2	0.46	3	0.46	0.44	0.46
10050009	1	0.46	3	0.48	4	0.47	0.45	0.51

Delivery Ratio used in CEAP in the Missouri River Basin

10050010	8	0.38	7	0.36	15	0.37	0.32	0.40
10050011	1	0.38	2	0.39	3	0.39	0.36	0.42
10050012	12	0.41	11	0.37	23	0.40	0.35	0.47
10050013			5	0.38	5	0.38	0.38	0.39
10050014			11	0.37	11	0.37	0.35	0.39
10050015			4	0.39	4	0.39	0.37	0.40
10050016	2	0.41	5	0.39	7	0.40	0.37	0.45
10060001	21	0.39	22	0.37	43	0.38	0.34	0.47
10060002	13	0.35	34	0.35	47	0.35	0.33	0.37
10060003	20	0.39	23	0.39	43	0.39	0.36	0.43
10060004	10	0.39	10	0.39	20	0.39	0.37	0.42
10060005	15	0.42	4	0.41	19	0.42	0.39	0.48
10060006	27	0.33	67	0.33	94	0.33	0.31	0.36
10060007	8	0.43	38	0.41	46	0.41	0.38	0.44
10070003	3	0.46	4	0.34	7	0.39	0.33	0.49
10070004	10	0.41	9	0.41	19	0.41	0.37	0.45
10070006	3	0.40	2	0.35	5	0.38	0.34	0.43
10070007	12	0.40	10	0.36	22	0.38	0.35	0.41
10070008	2	0.44			2	0.44	0.43	0.44
10080007	13	0.42			13	0.42	0.39	0.43
10080008	1	0.43			1	0.43	0.43	0.43
10080009	4	0.46			4	0.46	0.44	0.47
10080011	1	0.59			1	0.59	0.59	0.59
10080014	6	0.45			6	0.45	0.43	0.46
10080015	5	0.41	4	0.39	9	0.40	0.37	0.43
10080016	1	0.39	3	0.37	4	0.37	0.35	0.39
10090202	4	0.34	4	0.20	8	0.27	0.19	0.36
10090208	1	0.38			1	0.38	0.38	0.38
10090209			3	0.34	3	0.34	0.32	0.37
10090210	1	0.39	7	0.37	8	0.38	0.35	0.41
10100001	5	0.36	5	0.34	10	0.35	0.32	0.41
10100002	1	0.47			1	0.47	0.47	0.47
10100004	33	0.33	23	0.31	56	0.32	0.30	0.35
10100005	4	0.36	12	0.37	16	0.37	0.35	0.41
10110101	47	0.35	70	0.34	117	0.34	0.31	0.38
10110102	12	0.35	19	0.35	31	0.35	0.32	0.39
10110201	3	0.36	11	0.34	14	0.34	0.32	0.36
10110202	1	0.36			1	0.36	0.36	0.36
10110203	9	0.33	19	0.32	28	0.32	0.31	0.35
10110204	18	0.37	16	0.35	34	0.36	0.34	0.38
10110205	3	0.34	7	0.32	10	0.32	0.30	0.35
10120106	1	0.43			1	0.43	0.43	0.43

Delivery Ratio used in CEAP in the Missouri River Basin

10120107	1	0.43			1	0.43	0.43	0.43
10120108			2	0.42	2	0.42	0.41	0.44
10120109	1	0.45			1	0.45	0.45	0.45
10120110	1	0.41			1	0.41	0.41	0.41
10120111	1	0.41	1	0.39	2	0.40	0.39	0.41
10120112	1	0.49			1	0.49	0.49	0.49
10120113	1	0.37	3	0.33	4	0.34	0.32	0.37
10120201	1	0.33	2	0.19	3	0.24	0.18	0.33
10120202	3	0.34	1	0.35	4	0.34	0.33	0.35
10130101	21	0.34	23	0.35	44	0.35	0.32	0.38
10130102	17	0.35	36	0.34	53	0.34	0.32	0.37
10130103	14	0.33	92	0.32	106	0.32	0.30	0.35
10130104	9	0.44	28	0.44	37	0.44	0.41	0.48
10130105	23	0.35	20	0.34	43	0.34	0.31	0.36
10130106	22	0.37	51	0.36	73	0.36	0.34	0.39
10130201	21	0.33	23	0.33	44	0.33	0.31	0.36
10130202	11	0.34	55	0.33	66	0.33	0.32	0.35
10130203	6	0.35	13	0.33	19	0.34	0.32	0.37
10130204	17	0.33	32	0.32	49	0.32	0.30	0.35
10130205	11	0.33	52	0.32	63	0.32	0.30	0.34
10130206			6	0.36	6	0.36	0.35	0.38
10130301	9	0.36	22	0.36	31	0.36	0.34	0.39
10130302	2	0.35	3	0.34	5	0.34	0.34	0.35
10130303	4	0.34	4	0.34	8	0.34	0.32	0.36
10130306	4	0.31	6	0.33	10	0.32	0.31	0.34
10140101	56	0.33	18	0.32	74	0.33	0.30	0.35
10140102	8	0.34	17	0.33	25	0.33	0.31	0.34
10140103	9	0.38	15	0.38	24	0.38	0.34	0.41
10140104	4	0.43	13	0.39	17	0.40	0.38	0.45
10140105	11	0.40	6	0.40	17	0.40	0.37	0.43
10140201	3	0.34	5	0.33	8	0.34	0.32	0.36
10140202			1	0.32	1	0.32	0.32	0.32
10140203	4	0.34	4	0.32	8	0.33	0.31	0.37
10140204	14	0.37	11	0.37	25	0.37	0.35	0.42
10150001	9	0.36	3	0.33	12	0.35	0.32	0.38
10150002			3	0.36	3	0.36	0.35	0.38
10150003	14	0.33	22	0.32	36	0.33	0.30	0.35
10150004	5	0.34	5	0.34	10	0.34	0.30	0.40
10150006	3	0.34	3	0.35	6	0.35	0.33	0.37
10150007	15	0.39	6	0.36	21	0.38	0.33	0.42
10160001	28	0.36	52	0.37	80	0.37	0.34	0.38
10160002	6	0.36	28	0.35	34	0.35	0.32	0.38

Delivery Ratio used in CEAP in the Missouri River Basin

10160003	48	0.37	88	0.37	136	0.37	0.33	0.40
10160004	13	0.39	43	0.39	56	0.39	0.37	0.41
10160005	9	0.43	5	0.44	14	0.43	0.39	0.48
10160006	44	0.39	43	0.38	87	0.38	0.34	0.42
10160007	9	0.48	10	0.48	19	0.48	0.44	0.59
10160008	16	0.37	13	0.36	29	0.37	0.35	0.38
10160009	14	0.37	4	0.39	18	0.37	0.33	0.41
10160010	8	0.40	42	0.39	50	0.39	0.37	0.43
10160011	72	0.38	32	0.37	104	0.38	0.35	0.41
10170101	83	0.36	79	0.33	162	0.34	0.31	0.38
10170102	87	0.34	15	0.33	102	0.34	0.31	0.37
10170103	9	0.42	2	0.42	11	0.42	0.39	0.46
10170201	19	0.37	24	0.35	43	0.36	0.33	0.38
10170202	34	0.40	35	0.39	69	0.40	0.37	0.44
10170203	100	0.33	21	0.33	121	0.33	0.30	0.35
10170204	82	0.37	5	0.33	87	0.37	0.34	0.43
10180008			3	0.22	3	0.22	0.21	0.23
10180009	25	0.40	50	0.29	75	0.33	0.22	0.42
10180011	1	0.41	6	0.24	7	0.27	0.23	0.41
10180012	5	0.38	30	0.27	35	0.28	0.23	0.39
10180013	9	0.41	31	0.40	40	0.41	0.38	0.46
10180014	4	0.39	1	0.33	5	0.38	0.33	0.41
10190003	24	0.38	6	0.39	30	0.38	0.35	0.42
10190005	1	0.48			1	0.48	0.48	0.48
10190007	4	0.44	3	0.39	7	0.42	0.39	0.44
10190008			5	0.48	5	0.48	0.44	0.51
10190009	3	0.41	5	0.40	8	0.40	0.37	0.43
10190010	6	0.42	4	0.43	10	0.42	0.41	0.43
10190011	16	0.38	25	0.37	41	0.37	0.35	0.40
10190012	34	0.39	25	0.37	59	0.38	0.35	0.44
10190013	10	0.40	20	0.39	30	0.40	0.36	0.42
10190014	3	0.43	1	0.41	4	0.42	0.41	0.45
10190015	14	0.40	35	0.26	49	0.30	0.23	0.42
10190016	17	0.40	44	0.32	61	0.34	0.24	0.42
10190017	5	0.44	55	0.41	60	0.42	0.30	0.47
10190018	17	0.39	3	0.38	20	0.39	0.35	0.44
10200101	27	0.38	2	0.31	29	0.37	0.32	0.41
10200102	6	0.43			6	0.43	0.36	0.44
10200103	35	0.41	4	0.34	39	0.40	0.34	0.44
10200201	15	0.38	9	0.32	24	0.36	0.31	0.44
10200202	19	0.44	4	0.42	23	0.43	0.39	0.50
10200203	41	0.37	18	0.35	59	0.37	0.34	0.40

Delivery Ratio used in CEAP in the Missouri River Basin

10210002			1	0.34	1	0.34	0.34	0.34
10210003	14	0.34	4	0.32	18	0.34	0.30	0.41
10210004	5	0.33	2	0.32	7	0.33	0.28	0.37
10210005	2	0.37	1	0.33	3	0.36	0.33	0.37
10210006	2	0.30			2	0.30	0.28	0.32
10210007	12	0.39	3	0.33	15	0.38	0.32	0.44
10210008			3	0.37	3	0.37	0.36	0.39
10210009	19	0.34	18	0.32	37	0.33	0.30	0.40
10210010	11	0.35	12	0.32	23	0.33	0.29	0.39
10220001	12	0.32	18	0.31	30	0.31	0.29	0.34
10220002	13	0.40	4	0.36	17	0.39	0.35	0.47
10220003	46	0.35	10	0.32	56	0.34	0.31	0.37
10220004	32	0.34	11	0.32	43	0.33	0.30	0.36
10230001	62	0.35	41	0.30	103	0.33	0.29	0.39
10230002	31	0.39	1	0.37	32	0.39	0.32	0.47
10230003	52	0.35	14	0.31	66	0.34	0.29	0.43
10230004	15	0.40	8	0.34	23	0.38	0.32	0.47
10230005	11	0.34	5	0.32	16	0.33	0.31	0.36
10230006	33	0.37	7	0.33	40	0.37	0.32	0.46
10230007	26	0.35	7	0.31	33	0.35	0.31	0.41
10240001	24	0.36	4	0.33	28	0.36	0.32	0.40
10240002	37	0.32	8	0.30	45	0.32	0.30	0.36
10240003	29	0.36	17	0.33	46	0.35	0.31	0.39
10240004	3	0.52	6	0.44	9	0.46	0.43	0.54
10240005	58	0.37	36	0.34	94	0.36	0.31	0.44
10240006	29	0.37	23	0.34	52	0.36	0.33	0.39
10240007	15	0.37	44	0.34	59	0.35	0.33	0.38
10240008	34	0.37	45	0.34	79	0.35	0.33	0.38
10240009	14	0.34	17	0.32	31	0.33	0.31	0.37
10240010	30	0.35	41	0.33	71	0.34	0.32	0.38
10240011	46	0.38	16	0.32	62	0.36	0.31	0.45
10240012	38	0.36	52	0.33	90	0.34	0.32	0.38
10240013	23	0.34	26	0.31	49	0.33	0.30	0.36
10250001	16	0.37	18	0.36	34	0.37	0.35	0.39
10250002	38	0.39	40	0.40	78	0.39	0.36	0.43
10250003	25	0.37	58	0.36	83	0.36	0.33	0.38
10250004	26	0.38	10	0.37	36	0.38	0.34	0.40
10250005	33	0.38	9	0.36	42	0.38	0.35	0.42
10250006	44	0.38	16	0.36	60	0.37	0.34	0.39
10250007	5	0.37	3	0.38	8	0.37	0.36	0.39
10250008	3	0.38	4	0.36	7	0.37	0.34	0.40
10250009	15	0.39	6	0.34	21	0.37	0.33	0.42

Delivery Ratio used in CEAP in the Missouri River Basin

10250010	9	0.39	8	0.36	17	0.38	0.33	0.41
10250011	10	0.37	4	0.35	14	0.37	0.32	0.41
10250012	6	0.40			6	0.40	0.36	0.43
10250013	9	0.42	3	0.42	12	0.42	0.39	0.46
10250014	7	0.38	2	0.32	9	0.37	0.31	0.41
10250015	14	0.34			14	0.34	0.32	0.37
10250016	39	0.35	20	0.33	59	0.34	0.31	0.38
10250017	31	0.35	19	0.32	50	0.34	0.31	0.36
10260001	5	0.40	25	0.39	30	0.40	0.37	0.42
10260002	3	0.41	4	0.40	7	0.40	0.38	0.46
10260003	11	0.42	10	0.39	21	0.40	0.37	0.46
10260004	17	0.38	13	0.36	30	0.37	0.34	0.40
10260005	5	0.39	2	0.37	7	0.38	0.36	0.41
10260006	17	0.37	26	0.35	43	0.36	0.33	0.38
10260007	5	0.36	3	0.35	8	0.36	0.35	0.38
10260008	16	0.40	41	0.37	57	0.38	0.36	0.40
10260009	15	0.32	18	0.30	33	0.31	0.29	0.33
10260010	10	0.36	26	0.33	36	0.34	0.32	0.37
10260011	11	0.36	18	0.33	29	0.34	0.31	0.37
10260012	17	0.37	9	0.36	26	0.37	0.34	0.40
10260013	8	0.37	15	0.33	23	0.34	0.32	0.37
10260014	5	0.39	4	0.37	9	0.38	0.35	0.41
10260015	17	0.35	16	0.33	33	0.34	0.31	0.37
10270101			1	0.39	1	0.39	0.39	0.39
10270102	19	0.37	30	0.33	49	0.35	0.32	0.40
10270103	42	0.37	39	0.34	81	0.36	0.33	0.38
10270104	50	0.36	11	0.33	61	0.35	0.32	0.41
10270201	33	0.39	1	0.34	34	0.39	0.34	0.43
10270202	25	0.40	18	0.36	43	0.38	0.35	0.42
10270203	41	0.38	1	0.32	42	0.38	0.33	0.42
10270204	18	0.37	2	0.33	20	0.37	0.33	0.41
10270205	24	0.40	31	0.37	55	0.38	0.36	0.41
10270206	61	0.36	2	0.35	63	0.36	0.31	0.40
10270207	22	0.36	18	0.34	40	0.35	0.32	0.37
10280101	56	0.32	245	0.30	301	0.31	0.29	0.35
10280102	26	0.35	154	0.30	180	0.30	0.28	0.34
10280103	31	0.35	153	0.31	184	0.32	0.30	0.36
10280201	22	0.36	56	0.32	78	0.33	0.31	0.37
10280202	14	0.37	38	0.33	52	0.34	0.30	0.38
10280203	8	0.36	12	0.33	20	0.34	0.31	0.38
10290101	20	0.35	15	0.33	35	0.34	0.32	0.36
10290102	20	0.38	32	0.37	52	0.37	0.35	0.41

Delivery Ratio used in CEAP in the Missouri River Basin

10290103	8	0.39	9	0.37	17	0.38	0.37	0.40
10290104	15	0.40	24	0.38	39	0.39	0.37	0.42
10290105	9	0.39	11	0.37	20	0.38	0.36	0.42
10290106	5	0.36	5	0.36	10	0.36	0.35	0.39
10290108	25	0.35	24	0.34	49	0.34	0.33	0.37
10290109	2	0.37			2	0.37	0.36	0.37
10290111	1	0.36			1	0.36	0.36	0.36
10290201	1	0.36			1	0.36	0.36	0.36
10290203	1	0.35			1	0.35	0.35	0.35
10300101	54	0.34	36	0.30	90	0.32	0.30	0.40
10300102	32	0.37	36	0.33	68	0.35	0.31	0.40
10300103	22	0.38	6	0.36	28	0.38	0.35	0.42
10300104	33	0.36	12	0.34	45	0.35	0.33	0.42
10300200	18	0.34	15	0.31	33	0.33	0.30	0.41

Delivery Ratio used in CEAP in the Missouri River Basin

Figure 6-2. Mean and percentiles of sediment delivery ratio (sediment delivered at 8-digit watershed outlet by sediment yield at simulation sites) estimated for cultivated simulation sites within APEX for the 8-digit watersheds in the Missouri River Basin.

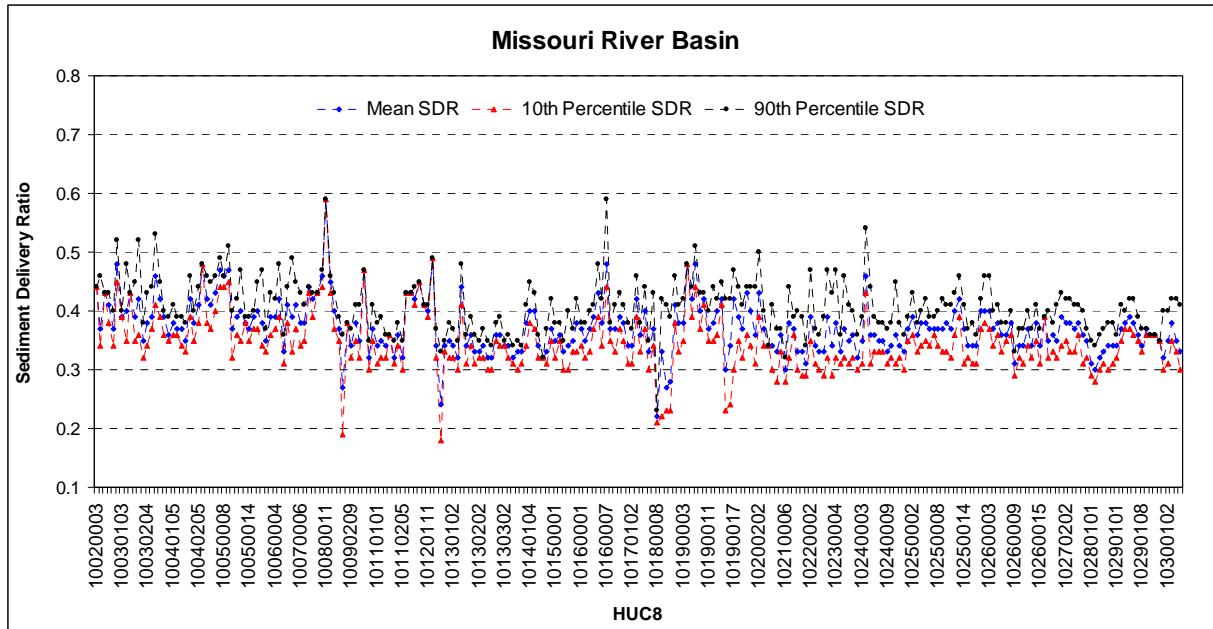


Table 6-2. Mean and percentiles of sediment delivery ratio (ratio of sediment delivered at 8-digit watershed outlet by sediment yield at HRUs) estimated for non-cultivated land HRUs within SWAT for the 8-digit watersheds in the Missouri River Basin.

HUC	Subbasin	Number_of non-cropland HRUs simulated within SWAT	Mean SDR	10 th Percentile SDR	90 th Percentile SDR
10010001	1	23	0.45	0.40	0.53
10010002	2	41	0.32	0.28	0.37
10020001	3	54	0.21	0.14	0.27
10020002	4	56	0.22	0.16	0.28
10020003	5	58	0.23	0.17	0.28
10020004	6	53	0.20	0.12	0.28
10020005	7	52	0.29	0.23	0.34
10020006	8	47	0.24	0.17	0.32
10020007	9	41	0.20	0.12	0.32
10020008	10	55	0.21	0.14	0.26
10030101	11	35	0.22	0.12	0.33
10030102	12	36	0.33	0.26	0.40
10030103	13	50	0.22	0.15	0.31
10030104	14	41	0.25	0.18	0.32
10030105	15	45	0.26	0.18	0.34
10030201	16	43	0.29	0.23	0.37
10030202	17	39	0.27	0.21	0.35
10030203	18	25	0.22	0.12	0.43
10030204	19	34	0.26	0.16	0.37
10030205	20	27	0.25	0.15	0.41
10040101	21	37	0.32	0.27	0.39
10040102	22	34	0.27	0.19	0.36
10040103	23	32	0.25	0.17	0.34
10040104	24	34	0.24	0.13	0.35
10040105	25	39	0.25	0.17	0.32
10040106	26	35	0.25	0.16	0.37
10040201	27	36	0.23	0.14	0.33
10040202	28	52	0.22	0.15	0.29
10040203	29	38	0.26	0.18	0.36
10040204	30	46	0.24	0.16	0.33
10040205	31	44	0.26	0.19	0.35
10050001	32	37	0.30	0.24	0.40
10050002	33	25	0.27	0.15	0.40
10050003	34	8	0.53	0.42	0.86
10050004	35	38	0.29	0.22	0.36
10050005	36	29	0.29	0.20	0.41
10050006	37	20	0.32	0.21	0.52
10050007	38	23	0.35	0.25	0.53
10050008	39	27	0.31	0.22	0.43

Delivery Ratio used in CEAP in the Missouri River Basin

10050009	40	35	0.32	0.24	0.43
10050010	41	28	0.24	0.14	0.41
10050011	42	24	0.27	0.17	0.48
10050012	43	38	0.26	0.17	0.35
10050013	44	25	0.29	0.21	0.43
10050014	45	41	0.23	0.14	0.34
10050015	46	33	0.26	0.17	0.38
10050016	47	26	0.27	0.18	0.47
10060001	48	37	0.24	0.14	0.32
10060002	49	38	0.23	0.14	0.30
10060003	50	23	0.27	0.18	0.45
10060004	51	30	0.25	0.16	0.35
10060005	52	31	0.29	0.20	0.40
10060006	53	21	0.23	0.11	0.46
10060007	54	20	0.30	0.21	0.49
10070001	55	53	0.25	0.18	0.29
10070002	56	37	0.26	0.18	0.36
10070003	57	49	0.27	0.21	0.33
10070004	58	39	0.25	0.18	0.32
10070005	59	52	0.25	0.19	0.31
10070006	60	51	0.22	0.16	0.27
10070007	61	42	0.24	0.16	0.31
10070008	62	44	0.27	0.21	0.35
10080001	63	50	0.28	0.20	0.37
10080002	64	41	0.35	0.24	0.49
10080003	65	42	0.30	0.25	0.39
10080004	66	36	0.29	0.19	0.46
10080005	67	44	0.31	0.24	0.44
10080006	68	45	0.24	0.19	0.31
10080007	69	49	0.24	0.16	0.30
10080008	70	59	0.22	0.15	0.29
10080009	71	55	0.23	0.16	0.28
10080010	72	53	0.33	0.28	0.41
10080011	73	36	0.27	0.21	0.42
10080012	74	51	0.24	0.18	0.31
10080013	75	56	0.23	0.18	0.30
10080014	76	55	0.26	0.20	0.33
10080015	77	51	0.23	0.15	0.31
10080016	78	54	0.24	0.16	0.31
10090101	79	43	0.25	0.17	0.32
10090102	80	35	0.22	0.13	0.41
10090201	81	46	0.30	0.23	0.37
10090202	82	53	0.21	0.13	0.27
10090203	83	46	0.23	0.15	0.32
10090204	84	34	0.27	0.19	0.36
10090205	85	38	0.26	0.17	0.36
10090206	86	52	0.25	0.17	0.32
10090207	87	55	0.22	0.15	0.27

Delivery Ratio used in CEAP in the Missouri River Basin

10090208	88	54	0.22	0.14	0.28
10090209	89	56	0.21	0.14	0.26
10090210	90	47	0.23	0.15	0.30
10100001	91	34	0.23	0.12	0.34
10100002	92	34	0.25	0.16	0.34
10100003	93	48	0.22	0.14	0.29
10100004	94	30	0.22	0.10	0.35
10100005	95	50	0.23	0.15	0.29
10110101	96	28	0.24	0.15	0.40
10110102	97	29	0.24	0.14	0.39
10110201	98	42	0.21	0.12	0.30
10110202	99	51	0.22	0.14	0.29
10110203	100	46	0.20	0.11	0.27
10110204	101	33	0.23	0.14	0.36
10110205	102	42	0.20	0.10	0.28
10120101	103	38	0.27	0.19	0.36
10120102	104	24	0.28	0.19	0.47
10120103	105	47	0.24	0.16	0.29
10120104	106	43	0.30	0.23	0.35
10120105	107	35	0.27	0.19	0.39
10120106	108	46	0.28	0.20	0.35
10120107	109	53	0.24	0.18	0.30
10120108	110	34	0.29	0.21	0.38
10120109	111	48	0.24	0.16	0.31
10120110	112	27	0.26	0.17	0.46
10120111	113	41	0.24	0.14	0.29
10120112	114	41	0.25	0.17	0.34
10120113	115	44	0.22	0.13	0.31
10120201	116	47	0.21	0.11	0.30
10120202	117	55	0.20	0.13	0.26
10120203	118	48	0.31	0.26	0.37
10130101	119	29	0.25	0.16	0.36
10130102	120	41	0.22	0.14	0.34
10130103	121	24	0.21	0.12	0.36
10130104	122	33	0.33	0.26	0.41
10130105	123	45	0.21	0.13	0.30
10130106	124	27	0.25	0.17	0.38
10130201	125	44	0.21	0.12	0.30
10130202	126	32	0.22	0.12	0.35
10130203	127	45	0.21	0.13	0.28
10130204	128	35	0.21	0.11	0.34
10130205	129	38	0.21	0.11	0.33
10130206	130	32	0.25	0.17	0.40
10130301	131	37	0.22	0.13	0.34
10130302	132	53	0.21	0.14	0.29
10130303	133	52	0.21	0.13	0.30
10130304	134	37	0.23	0.16	0.36
10130305	135	47	0.26	0.20	0.33

Delivery Ratio used in CEAP in the Missouri River Basin

10130306	136	52	0.20	0.12	0.28
10140101	137	33	0.22	0.12	0.36
10140102	138	57	0.20	0.13	0.26
10140103	139	32	0.24	0.15	0.46
10140104	140	31	0.27	0.19	0.41
10140105	141	43	0.26	0.19	0.30
10140201	142	48	0.21	0.13	0.29
10140202	143	46	0.21	0.12	0.28
10140203	144	41	0.21	0.13	0.32
10140204	145	44	0.23	0.15	0.29
10150001	146	29	0.22	0.14	0.42
10150002	147	36	0.23	0.15	0.37
10150003	148	36	0.21	0.12	0.34
10150004	149	43	0.21	0.13	0.32
10150005	150	27	0.26	0.18	0.44
10150006	151	39	0.22	0.13	0.34
10150007	152	41	0.24	0.16	0.32
10160001	153	29	0.25	0.16	0.40
10160002	154	35	0.23	0.14	0.35
10160003	155	29	0.26	0.17	0.43
10160004	156	51	0.25	0.20	0.32
10160005	157	31	0.27	0.20	0.38
10160006	158	39	0.25	0.18	0.34
10160007	159	30	0.38	0.33	0.56
10160008	160	45	0.24	0.17	0.33
10160009	161	43	0.24	0.17	0.35
10160010	162	29	0.29	0.22	0.42
10160011	163	39	0.25	0.17	0.36
10170101	164	30	0.24	0.15	0.41
10170102	165	29	0.22	0.12	0.43
10170103	166	24	0.30	0.22	0.52
10170201	167	26	0.24	0.15	0.50
10170202	168	32	0.28	0.20	0.37
10170203	169	25	0.21	0.12	0.51
10170204	170	25	0.22	0.13	0.46
10180001	171	46	0.25	0.17	0.32
10180002	172	53	0.21	0.13	0.27
10180003	173	44	0.27	0.19	0.36
10180004	174	46	0.30	0.24	0.35
10180005	175	36	0.28	0.20	0.38
10180006	176	54	0.20	0.12	0.29
10180007	177	47	0.23	0.17	0.31
10180008	178	53	0.21	0.14	0.28
10180009	179	33	0.26	0.19	0.39
10180010	180	44	0.23	0.17	0.32
10180011	181	48	0.25	0.20	0.30
10180012	182	39	0.24	0.16	0.34
10180013	183	38	0.25	0.18	0.40

Delivery Ratio used in CEAP in the Missouri River Basin

10180014	184	32	0.23	0.15	0.44
10190001	185	47	0.24	0.15	0.32
10190002	186	52	0.24	0.16	0.30
10190003	187	42	0.24	0.16	0.32
10190004	188	39	0.28	0.22	0.37
10190005	189	40	0.31	0.27	0.38
10190006	190	39	0.28	0.22	0.36
10190007	191	41	0.25	0.17	0.31
10190008	192	29	0.32	0.24	0.42
10190009	193	40	0.25	0.18	0.34
10190010	194	31	0.28	0.21	0.44
10190011	195	39	0.23	0.15	0.34
10190012	196	28	0.24	0.16	0.44
10190013	197	30	0.25	0.16	0.44
10190014	198	31	0.25	0.18	0.44
10190015	199	29	0.25	0.18	0.45
10190016	200	31	0.25	0.17	0.42
10190017	201	26	0.31	0.23	0.49
10190018	202	28	0.24	0.15	0.43
10200101	203	31	0.23	0.13	0.41
10200102	204	29	0.25	0.16	0.45
10200103	205	27	0.25	0.15	0.42
10200201	206	27	0.24	0.13	0.39
10200202	207	31	0.30	0.22	0.41
10200203	208	30	0.25	0.16	0.38
10210001	209	24	0.19	0.11	0.47
10210002	210	24	0.20	0.14	0.45
10210003	211	41	0.21	0.12	0.35
10210004	212	37	0.20	0.11	0.35
10210005	213	24	0.24	0.16	0.55
10210006	214	32	0.20	0.11	0.40
10210007	215	40	0.23	0.14	0.35
10210008	216	28	0.22	0.13	0.44
10210009	217	30	0.22	0.12	0.38
10210010	218	33	0.21	0.12	0.38
10220001	219	35	0.22	0.11	0.35
10220002	220	27	0.26	0.17	0.42
10220003	221	21	0.23	0.12	0.55
10220004	222	20	0.20	0.11	0.59
10230001	223	24	0.22	0.11	0.40
10230002	224	27	0.23	0.11	0.39
10230003	225	21	0.22	0.09	0.50
10230004	226	23	0.24	0.14	0.47
10230005	227	24	0.24	0.11	0.41
10230006	228	31	0.24	0.15	0.36
10230007	229	24	0.24	0.13	0.46
10240001	230	33	0.23	0.14	0.37
10240002	231	24	0.20	0.10	0.49

Delivery Ratio used in CEAP in the Missouri River Basin

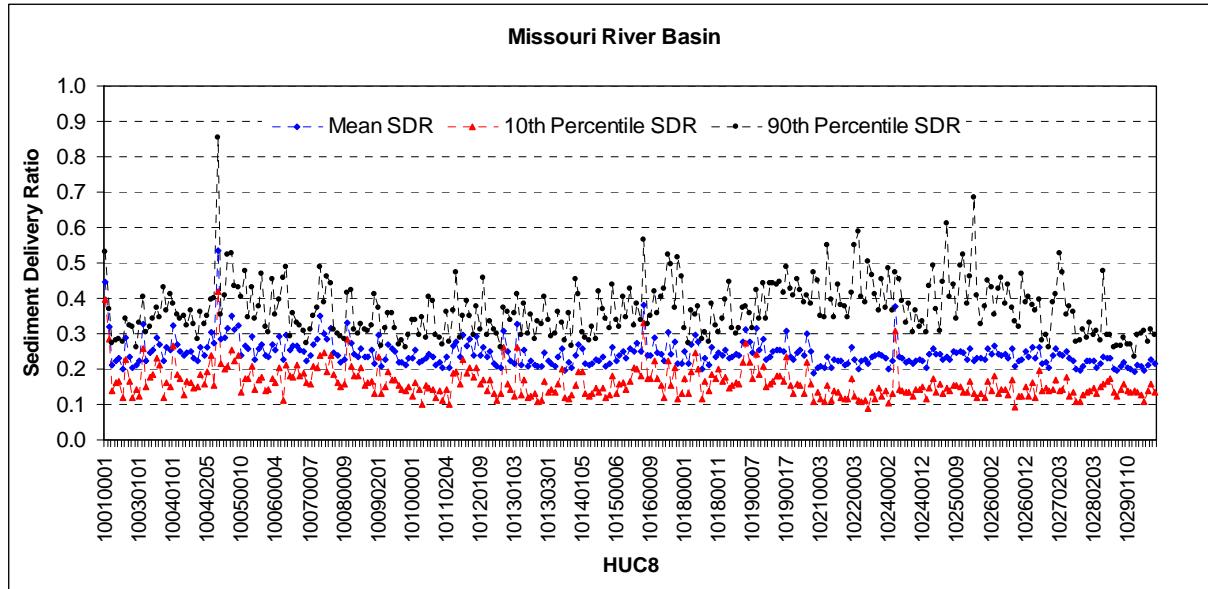
10240003	232	29	0.22	0.13	0.37
10240004	233	30	0.38	0.31	0.47
10240005	234	27	0.23	0.14	0.46
10240006	235	32	0.23	0.14	0.39
10240007	236	41	0.22	0.13	0.33
10240008	237	34	0.22	0.13	0.38
10240009	238	40	0.21	0.13	0.30
10240010	239	37	0.22	0.14	0.37
10240011	240	42	0.23	0.14	0.32
10240012	241	44	0.22	0.15	0.34
10240013	242	44	0.21	0.12	0.30
10250001	243	23	0.24	0.15	0.43
10250002	244	26	0.26	0.18	0.49
10250003	245	27	0.24	0.13	0.37
10250004	246	35	0.24	0.16	0.31
10250005	247	27	0.23	0.13	0.45
10250006	248	19	0.24	0.15	0.61
10250007	249	21	0.23	0.14	0.40
10250008	250	28	0.25	0.16	0.44
10250009	251	36	0.25	0.16	0.34
10250010	252	23	0.25	0.15	0.49
10250011	253	20	0.25	0.14	0.52
10250012	254	23	0.23	0.13	0.38
10250013	255	20	0.26	0.17	0.46
10250014	256	19	0.22	0.13	0.68
10250015	257	25	0.23	0.12	0.41
10250016	258	34	0.23	0.13	0.33
10250017	259	32	0.23	0.12	0.38
10260001	260	27	0.26	0.16	0.45
10260002	261	25	0.24	0.14	0.43
10260003	262	34	0.27	0.18	0.36
10260004	263	23	0.24	0.13	0.43
10260005	264	25	0.24	0.14	0.46
10260006	265	30	0.24	0.14	0.38
10260007	266	26	0.23	0.13	0.44
10260008	267	33	0.26	0.17	0.37
10260009	268	31	0.21	0.09	0.33
10260010	269	37	0.22	0.12	0.32
10260011	270	27	0.23	0.13	0.47
10260012	271	30	0.25	0.15	0.39
10260013	272	28	0.24	0.12	0.40
10260014	273	28	0.26	0.16	0.38
10260015	274	29	0.23	0.12	0.37
10270101	275	35	0.26	0.20	0.40
10270102	276	48	0.22	0.14	0.28
10270103	277	48	0.22	0.14	0.30
10270104	278	60	0.20	0.14	0.26
10270201	279	22	0.24	0.14	0.39

Delivery Ratio used in CEAP in the Missouri River Basin

10270202	280	28	0.26	0.17	0.41
10270203	281	22	0.24	0.14	0.53
10270204	282	24	0.24	0.14	0.47
10270205	283	37	0.25	0.18	0.35
10270206	284	28	0.23	0.12	0.38
10270207	285	37	0.22	0.13	0.36
10280101	286	41	0.20	0.11	0.28
10280102	287	42	0.20	0.11	0.28
10280103	288	48	0.21	0.13	0.31
10280201	289	43	0.22	0.13	0.29
10280202	290	42	0.22	0.14	0.33
10280203	291	46	0.22	0.14	0.30
10290101	292	52	0.20	0.13	0.31
10290102	293	58	0.22	0.15	0.28
10290103	294	27	0.24	0.16	0.48
10290104	295	57	0.23	0.16	0.30
10290105	296	55	0.23	0.17	0.30
10290106	297	67	0.20	0.13	0.26
10290107	298	62	0.20	0.12	0.27
10290108	299	59	0.21	0.14	0.26
10290109	300	54	0.22	0.16	0.29
10290110	301	60	0.21	0.14	0.27
10290111	302	63	0.20	0.13	0.27
10290201	303	63	0.19	0.14	0.24
10290202	304	49	0.21	0.14	0.30
10290203	305	46	0.21	0.13	0.30
10300101	306	46	0.20	0.11	0.31
10300102	307	55	0.21	0.14	0.28
10300103	308	48	0.23	0.16	0.31
10300104	309	48	0.22	0.13	0.30
10300200	310	48	0.20	0.11	0.29

Delivery Ratio used in CEAP in the Missouri River Basin

Figure 6-3. Mean and percentiles of sediment delivery ratio (sediment delivered at 8-digit watershed outlet by sediment yield at HRUs) estimated for non-cultivated land HRUs within SWAT for the 8-digit watersheds in the Missouri River Basin.



Chapter 7

Delivery Ratio used in CEAP Cropland
Modeling in the Arkansas-White-Red River
Basin

The APEX model is a field-scale, daily time-step model that simulates weather, farming operations, crop growth and yield, and the movement of water, soil, carbon, nutrients, sediment, and pesticides. The APEX model was used also to simulate the effects of conservation practices at the field scale (Williams and Izaurrealde, 2006; Gassman et al. 2009) in the Arkansas White Red River Basin. APEX simulates all of the basic biological, chemical, hydrological, and meteorological processes of farming systems and their interactions. Soil erosion is simulated over time, including wind erosion, sheet and rill erosion. The nitrogen, phosphorus, and carbon cycles are simulated, including chemical transformations in the soil that affect their availability for plant growth or for transport from the field.

While the APEX model was used for simulate the cultivated cropland and the SWAT model was used to simulate the non-cultivated cropland in the 8-digit watersheds of the river basin. SWAT is a physical process model with a daily time step (Arnold and Fohrer 2005; Arnold et al. 1998; Gassman et al. 2007). The hydrologic cycle in the model is divided into two parts. The land phase of the hydrologic cycle, or upland processes, simulates the amount of water, sediment, nutrients, and pesticides delivered from the land to the outlet of each watershed. The routing phase of the hydrologic cycle, or channel processes, simulates the movement of water, sediment, nutrients, and pesticides from the outlet of the upstream watershed through the main channel network to the watershed outlet.

In SWAT, each 8-digit watershed is divided into multiple Hydrologic Response Units (HRUs) that have homogeneous land use, soil, and slope. SWAT is used to simulate the fate and transport of water, sediment, nutrients, and pesticides from various non-cropland HRUs as described in Chapter 1.

Not all of the soil that erodes from a field or HRUs ends up in the watershed outlet. Most of the soil eroded gets deposited on the way although the deposition is temporary. Eroded soil may deposit in lower spots, flatter lands, deposited at the edge of the field and sometimes settles at the bottom of the channel. Hence, a SDR was used to account for deposition in ditches, floodplains, and tributary stream channels during transit from the edge of the field or HRUs to the 8-digit watershed outlet in the CEAP National Assessment modeling. The SDR used in this

study is a function of the ratio of the time of concentration for the HRU (land uses other than cultivated cropland) or field (cultivated cropland) to the time of concentration for the watershed (8-digit HUC). The time of concentration for the watershed is the time from when a surface water runoff event occurs at the most distant point in the watershed to the time the surface water runoff reaches the outlet of the watershed. It is calculated by summing the overland flow time (the time it takes for flow from the remotest point in the watershed to reach the channel) and the channel flow time (the time it takes for flow in the upstream channels to reach the outlet). The time of concentration for the field is derived from APEX. The time of concentration for the HRU is derived from characteristics of the watershed, the HRU, and the proportion of total acres represented by the HRU. Consequently, each cultivated cropland sample point has a unique delivery ratio within each watershed, as does each HRU. The description of the sediment delivery ratio procedure is provided in Chapter 1.

The APEX model simulates the edge of sediment yield using a variation of MUSLE called MUST (MUSLE developed from Theory) (Williams, 1995) as described in Chapter 1. After estimating the sediment load from each APEX simulation site, the delivery ratio is applied to determine the amount of sediment that reaches the 8-digit watershed outlet from each APEX simulation site. The sediment load from apex simulation sites are aggregated for the 8-digit watershed and integrated into the SWAT model at each 8-digit watershed to estimate the water quality effects of conservation practices. In SWAT, the sediment yield for the non-cropland HRUs are estimated using the MUSLE as described in Chapter 1. After estimating the SDR for each HRU, the SDR is applied to determine the amount of sediment that reaches the 8-digit watershed outlet.

Sediment delivery ratios were estimated to account for sediment losses or deposition occurring from edge-of-field or HRUs to the 8-digit watershed outlet for each APEX simulation site in the cultivated cropland and CRP and non-cropland HRUs in the Arkansas-White-Red River Basin (Figure 7-1). The Arkansas-White-Red River Basin has a drainage area of 159 million acres. The cultivated cropland and land enrolled in the CRP General Signup is about 22% of the Arkansas-White-Red River Basin. A total of 173, 8-digit watersheds are in the Arkansas-White-Red River Basin (Figure 7-1). Within each 8-digit

watershed, the percent of cultivated cropland and CRP area and non-cultivated cropland area varies widely across the entire basin.

A total of 3155 representative cultivated fields (1280 NRI-CEAP cropland points and 1875 CRP points) were setup to run using APEX. Thirty-six out of 173, 8-digit watersheds in the Arkansas-White-Red River Basin have no CEAP points; the thirty-six 8-digit watersheds have 0.01% to 6.2% of land cultivated.

Non-cultivated land is distributed over 78% of the Arkansas-White-Red River Basin. Within each 8-digit watershed, non-cultivated land uses such as pasture, range, hay, horticulture, forest deciduous, forest mixed, forest evergreen, urban, urban construction, barren land wetland and water are simulated as HRUs in SWAT. A total of 6,968 HRUs are simulated in SWAT for the Arkansas-White-Red River Basin.

Each NRI-CEAP point and CRP point is unique; therefore, sediment yield and delivery ratio also vary for each cultivated cropland site simulated in an 8-digit watershed and so as for HRU. The number of CEAP sample points, and mean, 10th percentile and 90th percentile of the delivery ratios of the APEX simulation sites in the 8-digit watersheds in the Arkansas-White-Red River Basin are shown in Table 7-1 and Figure 7-2. Table 7-2 shows number of HRUs and mean, 10th percentile and 90th percentile of the SDRs estimated for the non-cultivated land HRUs in the 8-digit watersheds in the Arkansas-White-Red River Basin. The mean, 10th and 90th percentile SDRs for the non-cropland HRUs are plotted in Figure 7-3.

In addition to SDR, an enrichment ratio was used to simulate organic nitrogen, organic phosphorus, and sediment-attached pesticide transport in ditches, floodplains, and tributary stream channels during transit from the edge of the field to the outlet. The enrichment ratio was defined as the organic nitrogen, organic phosphorus, and sediment attached pesticide concentration from the edge-of-field divided by the concentration at the 8-digit watershed outlet. The enrichment ratio is estimated for each APEX simulation site and SWAT HRUs and it varies from 0.5 to 1.5 (Average 1.0). As sediment is transported from the edge-of-field to the watershed outlet, coarse sediments are deposited first while more of the fine sediment that hold organic particles remain in suspension,

thus enriching the organic concentrations delivered to the watershed outlet.

A separate delivery ratio is used to simulate the transport of nitrate nitrogen, soluble phosphorus, and soluble pesticides. In general, the proportion of soluble nutrients and pesticides delivered to rivers and streams is higher than the proportion attached to sediments because they are not subject to sediment deposition.

Delivery Ratio used in CEAP in the Arkansas White Red River Basin

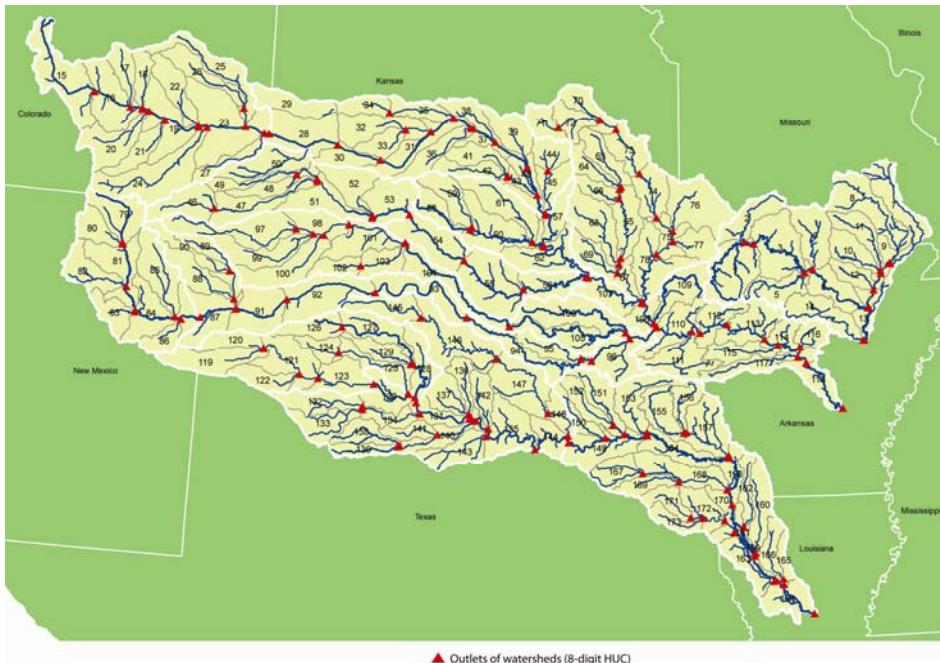


Figure 8-1. Map of the 8-digit watersheds in the Arkansas-White-Red River Basin

Table 7-1. Mean and percentiles of sediment delivery ratio (sediment delivered at 8-digit watershed outlet by sediment yield at simulation sites) estimated for cultivated simulation sites within APEX for the 8-digit watersheds in the Arkansas-White-Red River Basin.

HUC	Cropland		CRP		Crop + CRP			
	Points	Mean_ SDR	Points	Mean_ SDR	Points	Mean_ SDR	10 th percentile	90 th percentile
11010004	3	0.37			3	0.37	0.37	0.39
11010007	19	0.37			19	0.37	0.32	0.42
11010008	5	0.39			5	0.39	0.38	0.41
11010009	7	0.50	1	0.40	8	0.49	0.40	0.56
11010013	11	0.42	2	0.39	13	0.42	0.39	0.47
11010014	1	0.43	4	0.37	5	0.39	0.36	0.43
11020002	1	0.40			1	0.40	0.40	0.40
11020005	7	0.44	36	0.40	43	0.41	0.38	0.44
11020006			1	0.42	1	0.42	0.42	0.42
11020008	1	0.43	16	0.43	17	0.43	0.38	0.49
11020009	15	0.41	49	0.40	64	0.40	0.38	0.43
11020010			1	0.40	1	0.40	0.40	0.40
11020011	4	0.39	12	0.38	16	0.38	0.35	0.40
11020012	8	0.37	18	0.37	26	0.37	0.35	0.39
11020013	2	0.37	11	0.38	13	0.38	0.36	0.42
11030001	16	0.40	69	0.39	85	0.39	0.36	0.44
11030002	11	0.40	36	0.40	47	0.40	0.37	0.43
11030003	8	0.38	5	0.36	13	0.37	0.34	0.43
11030004	27	0.38	41	0.36	68	0.37	0.33	0.42
11030005	18	0.39	49	0.36	67	0.37	0.34	0.40
11030006	10	0.41	12	0.39	22	0.40	0.37	0.42
11030007	12	0.41	18	0.41	30	0.41	0.36	0.49
11030008	9	0.37	9	0.35	18	0.36	0.34	0.39
11030009	29	0.36	40	0.34	69	0.35	0.31	0.38
11030010	11	0.45	10	0.44	21	0.45	0.39	0.50
11030011	17	0.36	9	0.38	26	0.37	0.35	0.39
11030012	21	0.39	3	0.40	24	0.39	0.35	0.43
11030013	12	0.40	3	0.42	15	0.40	0.37	0.45
11030014	23	0.36	57	0.36	80	0.36	0.34	0.39
11030015	16	0.37	48	0.35	64	0.35	0.33	0.38
11030016	9	0.41			9	0.41	0.38	0.46
11030017	4	0.40			4	0.40	0.39	0.42
11030018	5	0.36			5	0.36	0.35	0.38
11040001			3	0.41	3	0.41	0.41	0.42
11040002	11	0.37	25	0.37	36	0.37	0.34	0.40
11040003	10	0.42	48	0.41	58	0.41	0.38	0.46
11040004	8	0.40	24	0.40	32	0.40	0.38	0.41
11040005	17	0.38	54	0.37	71	0.37	0.35	0.38
11040006	26	0.38	73	0.37	99	0.37	0.34	0.40
11040007	23	0.39	32	0.36	55	0.37	0.33	0.41
11040008	25	0.40	48	0.38	73	0.39	0.37	0.41
11050001	27	0.34	6	0.34	33	0.34	0.32	0.36

Delivery Ratio used in CEAP in the Arkansas White Red River Basin

11050002	41	0.35	1	0.34	42	0.35	0.33	0.36
11050003	3	0.37			3	0.37	0.36	0.40
11060001	1	0.35			1	0.35	0.35	0.35
11060002	5	0.39	23	0.37	28	0.38	0.35	0.40
11060003	12	0.40	18	0.37	30	0.38	0.35	0.43
11060004	21	0.36	13	0.32	34	0.34	0.31	0.37
11060005	32	0.35	15	0.33	47	0.34	0.32	0.36
11060006	14	0.36			14	0.36	0.32	0.42
11070101	1	0.33	8	0.34	9	0.34	0.33	0.35
11070102	4	0.41	2	0.37	6	0.39	0.36	0.42
11070103	10	0.37	2	0.35	12	0.36	0.35	0.39
11070104	5	0.41	1	0.38	6	0.40	0.38	0.44
11070105	2	0.40			2	0.40	0.37	0.42
11070106	6	0.37	5	0.33	11	0.35	0.31	0.41
11070201	11	0.40	4	0.36	15	0.39	0.35	0.46
11070202	9	0.41	7	0.39	16	0.40	0.37	0.44
11070203	2	0.37	1	0.37	3	0.37	0.36	0.38
11070204	21	0.40	4	0.37	25	0.39	0.37	0.46
11070205	17	0.39	2	0.37	19	0.39	0.36	0.43
11070206			1	0.43	1	0.43	0.43	0.43
11070207	30	0.36	23	0.35	53	0.36	0.33	0.38
11070208	1	0.41			1	0.41	0.41	0.41
11070209	3	0.36			3	0.36	0.33	0.41
11080006	2	0.40	17	0.38	19	0.38	0.36	0.40
11080007	1	0.41	13	0.39	14	0.39	0.38	0.41
11080008	1	0.44			1	0.44	0.44	0.44
11090101	1	0.41	9	0.32	10	0.33	0.25	0.41
11090102	2	0.44	3	0.40	5	0.42	0.38	0.48
11090103	5	0.41	12	0.34	17	0.36	0.26	0.43
11090104	10	0.41	8	0.39	18	0.40	0.36	0.44
11090105	7	0.43	9	0.27	16	0.34	0.24	0.47
11090106	7	0.40	10	0.26	17	0.32	0.22	0.42
11090201	21	0.33	11	0.31	32	0.33	0.30	0.35
11090202	6	0.34	2	0.31	8	0.33	0.31	0.37
11100101	18	0.39	56	0.37	74	0.38	0.25	0.43
11100102	17	0.43	29	0.42	46	0.43	0.39	0.48
11100103	16	0.39	39	0.26	55	0.30	0.22	0.40
11100104	32	0.40	13	0.24	45	0.35	0.23	0.42
11100201	17	0.37	19	0.28	36	0.33	0.22	0.41
11100202	10	0.45	12	0.27	22	0.36	0.23	0.47
11100203	9	0.39	21	0.32	30	0.34	0.23	0.39
11100301	20	0.32	11	0.30	31	0.32	0.29	0.35
11100302	1	0.38			1	0.38	0.38	0.38
11100303	1	0.34	1	0.32	2	0.33	0.32	0.34
1110102	1	0.44	2	0.46	3	0.46	0.44	0.48
1110103	1	0.40			1	0.40	0.40	0.40
1110104	1	0.47			1	0.47	0.47	0.47
11110201	3	0.43			3	0.43	0.42	0.44
11110202	3	0.42	1	0.36	4	0.41	0.36	0.47
11110203	4	0.48	2	0.45	6	0.47	0.41	0.48
11110205	1	0.46	3	0.43	4	0.44	0.42	0.46

Delivery Ratio used in CEAP in the Arkansas White Red River Basin

11110206			2	0.36	2	0.36	0.35	0.37
11110207	2	0.39	1	0.39	3	0.39	0.39	0.39
11120101	19	0.40	92	0.31	111	0.32	0.24	0.40
11120102	8	0.41	44	0.27	52	0.29	0.23	0.40
11120103	9	0.42	39	0.34	48	0.36	0.24	0.46
11120104	17	0.43	43	0.35	60	0.37	0.27	0.46
11120105	14	0.41	37	0.25	51	0.29	0.22	0.41
11120201	7	0.44	7	0.34	14	0.39	0.26	0.46
11120202	11	0.37	48	0.31	59	0.32	0.20	0.37
11120301	10	0.42	21	0.35	31	0.37	0.27	0.44
11120302	12	0.37	31	0.28	43	0.30	0.19	0.37
11120303	15	0.36	10	0.36	25	0.36	0.33	0.39
11120304	13	0.42	24	0.33	37	0.36	0.24	0.43
11130101	25	0.38	22	0.30	47	0.34	0.22	0.39
11130102	12	0.40	1	0.26	13	0.39	0.30	0.46
11130103	14	0.41	37	0.30	51	0.33	0.23	0.45
11130104	6	0.44	23	0.27	29	0.31	0.24	0.44
11130105	6	0.37	6	0.21	12	0.29	0.21	0.38
11130201	4	0.37	5	0.27	9	0.32	0.18	0.42
11130202	12	0.38	1	0.44	13	0.39	0.36	0.45
11130203	16	0.38	9	0.37	25	0.37	0.35	0.41
11130204	3	0.41	11	0.24	14	0.28	0.21	0.43
11130205			1	0.25	1	0.25	0.25	0.25
11130206	6	0.40			6	0.40	0.39	0.43
11130207	5	0.39	3	0.22	8	0.33	0.22	0.40
11130208	2	0.37	2	0.39	4	0.38	0.34	0.41
11130209	7	0.37			7	0.37	0.35	0.39
11130210	3	0.39	1	0.37	4	0.39	0.37	0.42
11130301	6	0.38	14	0.25	20	0.29	0.21	0.41
11130302	27	0.34	2	0.32	29	0.33	0.31	0.39
11130303	2	0.36			2	0.36	0.36	0.36
11130304			3	0.39	3	0.39	0.39	0.40
11140101	4	0.38	1	0.19	5	0.34	0.19	0.39
11140102			4	0.36	4	0.36	0.35	0.37
11140104	1	0.44			1	0.44	0.44	0.44
11140106	2	0.39	9	0.39	11	0.39	0.35	0.43
11140109			1	0.36	1	0.36	0.36	0.36
11140201	5	0.44			5	0.44	0.44	0.44
11140202			1	0.44	1	0.44	0.44	0.44
11140206	2	0.43	2	0.48	4	0.46	0.42	0.50
11140207	2	0.39			2	0.39	0.38	0.40
11140301	10	0.38	5	0.22	15	0.32	0.21	0.42
11140302	1	0.38	3	0.24	4	0.28	0.22	0.38
11140304	2	0.43	3	0.44	5	0.43	0.41	0.45

Table 7-2. Mean and percentiles of sediment delivery ratio (sediment delivered at 8-digit watershed outlet by sediment yield at HRUs) estimated for non-cultivated land HRUs within SWAT for the 8-digit watersheds in the Arkansas-White-Red River Basin

HUC	Subbasin	Number of non-cropland HRUs simulated within SWAT	Mean SDR	10 th Percentile SDR	90 th Percentile SDR
11010001	1	51	0.18	0.08	0.28
11010002	2	65	0.18	0.11	0.26
11010003	3	61	0.17	0.09	0.25
11010004	4	52	0.18	0.08	0.26
11010005	5	48	0.19	0.11	0.26
11010006	6	65	0.19	0.12	0.26
11010007	7	41	0.21	0.13	0.33
11010008	8	50	0.20	0.10	0.29
11010009	9	38	0.33	0.22	0.57
11010010	10	52	0.20	0.13	0.30
11010011	11	55	0.19	0.11	0.29
11010012	12	60	0.20	0.13	0.27
11010013	13	34	0.29	0.10	0.45
11010014	14	52	0.19	0.12	0.28
11020001	15	40	0.19	0.07	0.30
11020002	16	49	0.20	0.11	0.27
11020003	17	33	0.21	0.06	0.36
11020004	18	25	0.26	0.14	0.45
11020005	19	25	0.27	0.18	0.39
11020006	20	34	0.22	0.10	0.33
11020007	21	22	0.24	0.12	0.51
11020008	22	24	0.27	0.15	0.46
11020009	23	28	0.26	0.17	0.43
11020010	24	46	0.19	0.08	0.29
11020011	25	33	0.24	0.13	0.36
11020012	26	23	0.24	0.14	0.48
11020013	27	26	0.23	0.13	0.40
11030001	28	23	0.26	0.16	0.46
11030002	29	21	0.25	0.16	0.54
11030003	30	18	0.24	0.17	0.53
11030004	31	25	0.26	0.16	0.44
11030005	32	24	0.24	0.14	0.49
11030006	33	22	0.27	0.18	0.50
11030007	34	25	0.27	0.19	0.41
11030008	35	27	0.25	0.15	0.37
11030009	36	23	0.26	0.15	0.54
11030010	37	22	0.39	0.30	0.55
11030011	38	28	0.25	0.15	0.37
11030012	39	27	0.27	0.17	0.40
11030013	40	33	0.31	0.23	0.41
11030014	41	24	0.26	0.17	0.52

Delivery Ratio used in CEAP in the Arkansas White Red River Basin

11030015	42	25	0.25	0.15	0.44
11030016	43	24	0.31	0.21	0.47
11030017	44	34	0.32	0.25	0.39
11030018	45	34	0.25	0.14	0.37
11040001	46	54	0.20	0.13	0.27
11040002	47	32	0.22	0.13	0.39
11040003	48	21	0.26	0.17	0.42
11040004	49	25	0.25	0.16	0.40
11040005	50	22	0.22	0.13	0.42
11040006	51	24	0.23	0.15	0.47
11040007	52	23	0.23	0.15	0.46
11040008	53	29	0.25	0.16	0.44
11050001	54	46	0.21	0.13	0.30
11050002	55	41	0.22	0.12	0.30
11050003	56	51	0.20	0.11	0.28
11060001	57	37	0.21	0.12	0.33
11060002	58	34	0.24	0.16	0.36
11060003	59	32	0.23	0.14	0.42
11060004	60	28	0.24	0.14	0.42
11060005	61	30	0.23	0.14	0.37
11060006	62	44	0.21	0.11	0.30
11070101	63	48	0.21	0.13	0.31
11070102	64	41	0.23	0.15	0.34
11070103	65	58	0.21	0.15	0.28
11070104	66	48	0.24	0.16	0.31
11070105	67	54	0.24	0.20	0.31
11070106	68	52	0.19	0.12	0.30
11070107	69	50	0.20	0.13	0.27
11070201	70	47	0.24	0.19	0.32
11070202	71	35	0.27	0.20	0.39
11070203	72	32	0.23	0.15	0.44
11070204	73	65	0.23	0.18	0.30
11070205	74	69	0.23	0.18	0.29
11070206	75	60	0.28	0.21	0.36
11070207	76	61	0.20	0.13	0.29
11070208	77	43	0.21	0.15	0.36
11070209	78	75	0.18	0.13	0.26
11080001	79	39	0.22	0.10	0.32
11080002	80	23	0.21	0.08	0.50
11080003	81	38	0.23	0.12	0.33
11080004	82	37	0.21	0.07	0.34
11080005	83	27	0.24	0.14	0.43
11080006	84	35	0.21	0.09	0.37
11080007	85	32	0.23	0.13	0.37
11080008	86	20	0.27	0.15	0.44
11090101	87	43	0.23	0.16	0.29
11090102	88	21	0.25	0.12	0.48
11090103	89	23	0.28	0.16	0.48

Delivery Ratio used in CEAP in the Arkansas White Red River Basin

11090104	90	15	0.27	0.13	0.63
11090105	91	36	0.23	0.13	0.32
11090106	92	42	0.21	0.11	0.29
11090201	93	20	0.23	0.10	0.51
11090202	94	42	0.20	0.10	0.30
11090203	95	46	0.21	0.12	0.32
11090204	96	46	0.22	0.12	0.33
11100101	97	27	0.24	0.12	0.37
11100102	98	24	0.29	0.17	0.44
11100103	99	19	0.25	0.12	0.52
11100104	100	21	0.27	0.13	0.46
11100201	101	40	0.22	0.12	0.31
11100202	102	22	0.29	0.15	0.44
11100203	103	36	0.27	0.19	0.37
11100301	104	39	0.20	0.12	0.36
11100302	105	63	0.19	0.12	0.25
11100303	106	49	0.19	0.11	0.26
11110101	107	71	0.23	0.17	0.29
11110102	108	71	0.27	0.19	0.32
11110103	109	82	0.17	0.11	0.23
11110104	110	64	0.24	0.19	0.31
11110105	111	64	0.16	0.08	0.25
11110201	112	66	0.21	0.14	0.29
11110202	113	68	0.19	0.13	0.27
11110203	114	78	0.25	0.20	0.32
11110204	115	69	0.17	0.11	0.25
11110205	116	73	0.22	0.18	0.27
11110206	117	60	0.16	0.08	0.26
11110207	118	46	0.29	0.20	0.37
11120101	119	22	0.26	0.15	0.48
11120102	120	17	0.27	0.16	0.58
11120103	121	30	0.24	0.14	0.36
11120104	122	20	0.27	0.13	0.54
11120105	123	32	0.25	0.16	0.37
11120201	124	25	0.27	0.18	0.37
11120202	125	21	0.25	0.13	0.48
11120301	126	21	0.26	0.14	0.53
11120302	127	33	0.23	0.12	0.35
11120303	128	28	0.24	0.13	0.38
11120304	129	28	0.25	0.15	0.41
11130101	130	25	0.28	0.17	0.42
11130102	131	25	0.27	0.16	0.38
11130103	132	30	0.24	0.15	0.36
11130104	133	33	0.24	0.15	0.35
11130105	134	17	0.26	0.13	0.59
11130201	135	47	0.21	0.12	0.30
11130202	136	36	0.23	0.13	0.35
11130203	137	34	0.24	0.15	0.36

Delivery Ratio used in CEAP in the Arkansas White Red River Basin

11130204	138	22	0.27	0.16	0.41
11130205	139	20	0.25	0.13	0.43
11130206	140	44	0.26	0.20	0.35
11130207	141	35	0.23	0.15	0.36
11130208	142	34	0.24	0.15	0.36
11130209	143	42	0.23	0.15	0.33
11130210	144	56	0.23	0.16	0.29
11130301	145	37	0.22	0.12	0.32
11130302	146	32	0.21	0.10	0.33
11130303	147	46	0.20	0.11	0.30
11130304	148	50	0.24	0.18	0.31
11140101	149	55	0.24	0.19	0.29
11140102	150	40	0.23	0.17	0.34
11140103	151	58	0.21	0.15	0.27
11140104	152	60	0.21	0.15	0.27
11140105	153	56	0.18	0.10	0.24
11140106	154	61	0.24	0.18	0.30
11140107	155	54	0.21	0.15	0.28
11140108	156	54	0.19	0.13	0.28
11140109	157	55	0.24	0.16	0.32
11140201	158	58	0.26	0.18	0.33
11140202	159	37	0.40	0.35	0.47
11140203	160	44	0.23	0.15	0.30
11140204	161	49	0.48	0.37	0.62
11140205	162	49	0.24	0.16	0.33
11140206	163	54	0.33	0.24	0.47
11140207	164	47	0.27	0.20	0.38
11140208	165	27	0.23	0.15	0.40
11140209	166	43	0.23	0.14	0.32
11140301	167	50	0.24	0.17	0.32
11140302	168	50	0.27	0.21	0.34
11140303	169	68	0.22	0.17	0.29
11140304	170	62	0.26	0.20	0.31
11140305	171	64	0.21	0.16	0.27
11140306	172	50	0.24	0.16	0.32
11140307	173	42	0.21	0.14	0.35

Figure 7-2. Mean and percentiles of sediment delivery ratio (sediment delivered at 8-digit watershed outlet by sediment yield at simulation sites) estimated for cultivated simulation sites within APEX for the 8-digit watersheds in the Arkansas-White-Red River Basin

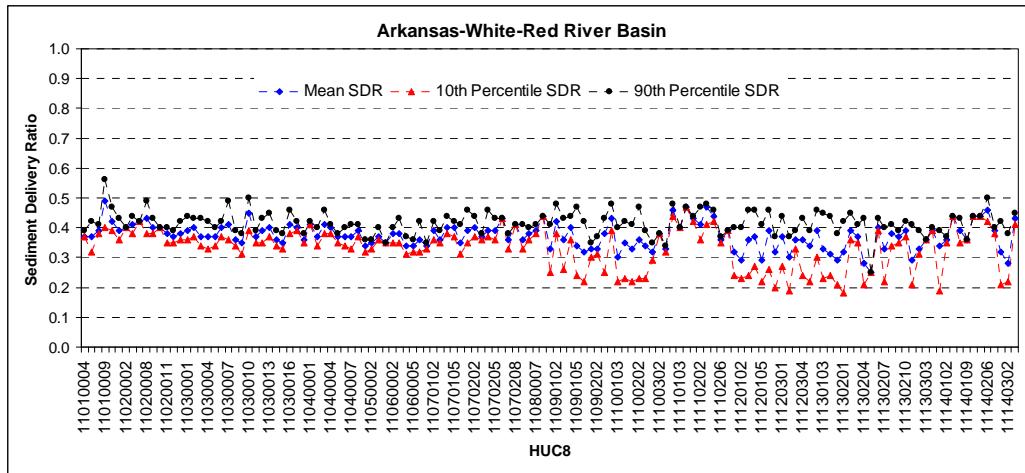
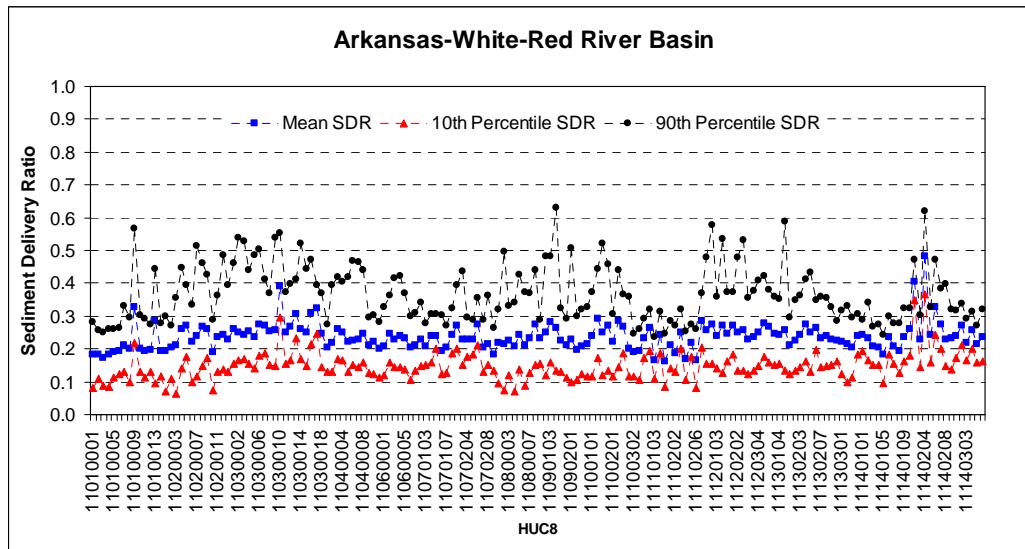


Figure 7-3. Mean and percentiles of sediment delivery ratio (sediment delivered at 8-digit watershed outlet by sediment yield at HRUs) estimated for non-cultivated land HRUs within SWAT for the 8-digit watersheds in the Arkansas-White-Red River Basin



Chapter 8

**Delivery Ratio used in CEAP Cropland
Modeling in the Lower Mississippi River
Basin**

The APEX model is a field-scale, daily time-step model that simulates weather, farming operations, crop growth and yield, and the movement of water, soil, carbon, nutrients, sediment, and pesticides. The APEX model was used also to simulate the effects of conservation practices at the field scale (Williams and Izaurralde, 2006; Gassman et al. 2009) in the Lower Mississippi River Basin. APEX simulates all of the basic biological, chemical, hydrological, and meteorological processes of farming systems and their interactions. Soil erosion is simulated over time, including wind erosion, sheet and rill erosion. The nitrogen, phosphorus, and carbon cycles are simulated, including chemical transformations in the soil that affect their availability for plant growth or for transport from the field.

While the APEX model was used for simulate the cultivated cropland and the SWAT model was used to simulate the non-cultivated cropland in the 8-digit watersheds of the river basin. SWAT is a physical process model with a daily time step (Arnold and Fohrer 2005; Arnold et al. 1998; Gassman et al. 2007). The hydrologic cycle in the model is divided into two parts. The land phase of the hydrologic cycle, or upland processes, simulates the amount of water, sediment, nutrients, and pesticides delivered from the land to the outlet of each watershed. The routing phase of the hydrologic cycle, or channel processes, simulates the movement of water, sediment, nutrients, and pesticides from the outlet of the upstream watershed through the main channel network to the watershed outlet.

In SWAT, each 8-digit watershed is divided into multiple Hydrologic Response Units (HRUs) that have homogeneous land use, soil, and slope. SWAT is used to simulate the fate and transport of water, sediment, nutrients, and pesticides from various non-cropland HRUs as described in Chapter 1.

Not all of the soil that erodes from a field or HRUs ends up in the watershed outlet. Most of the soil eroded gets deposited on the way although the deposition is temporary. Eroded soil may deposit in lower spots, flatter lands, deposited at the edge of the field and sometimes settles at the bottom of the channel. Hence, a SDR was used to account for deposition in ditches, floodplains, and tributary

stream channels during transit from the edge of the field or HRUs to the 8-digit watershed outlet in the CEAP National Assessment modeling. The SDR used in this study is a function of the ratio of the time of concentration for the HRU (land uses other than cultivated cropland) or field (cultivated cropland) to the time of concentration for the watershed (8-digit HUC). The time of concentration for the watershed is the time from when a surface water runoff event occurs at the most distant point in the watershed to the time the surface water runoff reaches the outlet of the watershed. It is calculated by summing the overland flow time (the time it takes for flow from the remotest point in the watershed to reach the channel) and the channel flow time (the time it takes for flow in the upstream channels to reach the outlet). The time of concentration for the field is derived from APEX. The time of concentration for the HRU is derived from characteristics of the watershed, the HRU, and the proportion of total acres represented by the HRU. Consequently, each cultivated cropland sample point has a unique delivery ratio within each watershed, as does each HRU. The description of the sediment delivery ratio procedure is provided in Chapter 1.

The APEX model simulates the edge of sediment yield using a variation of MUSLE called MUST (MUSLE developed from Theory) (Williams, 1995) as described in Chapter 1. After estimating the sediment load from each APEX simulation site, the delivery ratio is applied to determine the amount of sediment that reaches the 8-digit watershed outlet from each APEX simulation site. The sediment load from apex simulation sites are aggregated for the 8-digit watershed and integrated into the SWAT model at each 8-digit watershed to estimate the water quality effects of conservation practices. In SWAT, the sediment yield for the non-cropland HRUs are estimated using the MUSLE as described in Chapter 1. After estimating the SDR for each HRU, the SDR is applied to determine the amount of sediment that reaches the 8-digit watershed outlet.

Sediment delivery ratios were estimated to account for sediment losses or deposition occurring from edge-of-field or HRUs to the 8-digit watershed outlet for each APEX simulation site in the cultivated cropland and CRP and non-cropland HRUs in the

Lower Mississippi River Basin (Figure 8-1). The Lower Mississippi River Basin has a drainage area of 67 million acres. The cultivated cropland and land enrolled in the CRP General Signup is about 30% of the Lower Mississippi River Basin. A total of 82, 8-digit watersheds are in the Lower Mississippi River Basin (Figure 8-1). Within each 8-digit watershed, the percent of cultivated cropland and CRP area and non-cultivated cropland area varies widely across the entire basin.

A total of 2299 representative cultivated fields (1735 NRI-CEAP cropland points and 564 CRP points) were setup to run using APEX. Fifteen out of 82, 8-digit watersheds in the Lower Mississippi River Basin have no CEAP points; the fifteen 8-digit watersheds have zero or fewer than 6.3% of land cultivated (except for HUC 08030208, which has 31.4% of land cultivated).

Non-cultivated land is distributed over 70% of the River Basin. Within each 8-digit watershed, non-cultivated land uses such as pasture, range, hay, horticulture, forest deciduous, forest mixed, forest evergreen, urban, urban construction, barren land wetland and water are simulated as HRUs in SWAT. A total of 2,979 HRUs are simulated in SWAT for the Lower Mississippi River Basin.

Each NRI-CEAP point and CRP point is unique; therefore, sediment yield and delivery ratio also vary for each cultivated cropland site simulated in an 8-digit watershed and so as for HRU. The number of CEAP sample points, and mean, 10th percentile and 90th percentile of the delivery ratios of the APEX simulation sites in the 8-digit watersheds in the Lower Mississippi River Basin are shown in Table 8-1 and Figure 8-2. Table 8-2 shows number of HRUs and mean, 10th percentile and 90th percentile of the SDRs estimated for the non-cultivated land HRUs in the 8-digit watersheds in the Lower Mississippi River Basin. The mean, 10th and 90th percentile SDRs for the non-cropland HRUs are plotted in Figure 8-3.

In addition to SDR, an enrichment ratio was used to simulate organic nitrogen, organic phosphorus, and sediment-attached pesticide transport in ditches, floodplains, and tributary stream channels during transit from the edge of the field to the outlet. The

enrichment ratio was defined as the organic nitrogen, organic phosphorus, and sediment attached pesticide concentration from the edge-of-field divided by the concentration at the 8-digit watershed outlet. The enrichment ratio is estimated for each APEX simulation site and SWAT HRUs and it varies from 0.5 to 1.5 (Average 1.0). As sediment is transported from the edge-of-field to the watershed outlet, coarse sediments are deposited first while more of the fine sediment that hold organic particles remain in suspension, thus enriching the organic concentrations delivered to the watershed outlet.

A separate delivery ratio is used to simulate the transport of nitrate nitrogen, soluble phosphorus, and soluble pesticides. In general, the proportion of soluble nutrients and pesticides delivered to rivers and streams is higher than the proportion attached to sediments because they are not subject to sediment deposition.

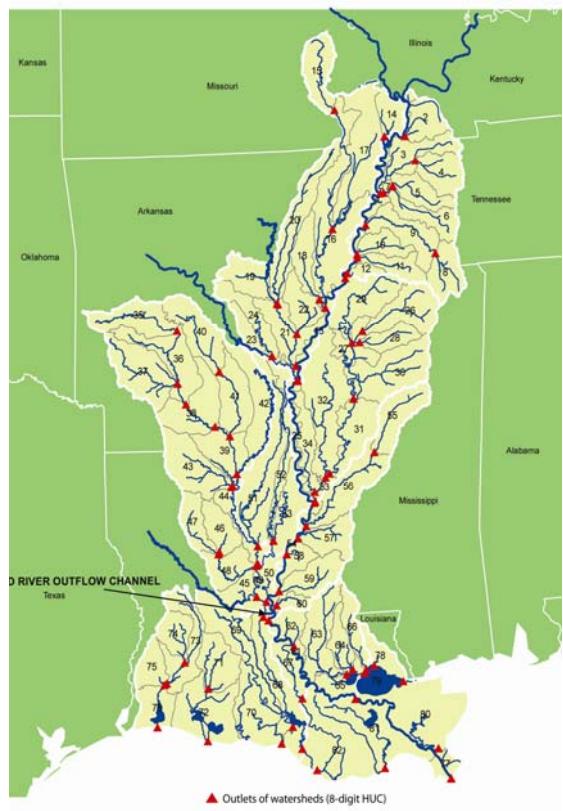


Figure 8-1. Map of the 8-digit watersheds in the Lower Mississippi River Basin

Table 8-1. Mean and percentiles of sediment delivery ratio (sediment delivered at 8-digit watershed outlet by sediment yield at simulation sites) estimated for cultivated simulation sites within APEX for the 8-digit watersheds in the Lower Mississippi River Basin

HUC	Cropland		CRP		Crop + CRP			
	Points	Mean_S DR	Points	Mean_S DR	Points	Mean_S DR	10 th percentile	90 th percentile
8010100	65	0.49	8	0.46	73	0.49	0.44	0.54
8010201	94	0.40	50	0.38	144	0.39	0.35	0.44
8010202	94	0.39	27	0.34	121	0.38	0.33	0.42
8010203	52	0.38	15	0.35	67	0.37	0.34	0.40
8010204	32	0.36	12	0.34	44	0.35	0.31	0.38
8010205	32	0.36	6	0.33	38	0.36	0.32	0.42
8010206	8	0.52			8	0.52	0.44	0.53
8010207	16	0.41	22	0.37	38	0.38	0.35	0.41
8010208	66	0.35	38	0.34	104	0.35	0.31	0.38
8010209	27	0.37	4	0.37	31	0.37	0.33	0.40
8010210	8	0.37	16	0.35	24	0.36	0.32	0.41
8010211	6	0.42			6	0.42	0.38	0.44
8020100	3	0.48			3	0.48	0.47	0.51
8020201	19	0.45			19	0.45	0.41	0.49
8020203	119	0.40	7	0.36	126	0.39	0.34	0.44
8020204	83	0.40	5	0.31	88	0.40	0.35	0.42
8020205	42	0.40	4	0.38	46	0.40	0.36	0.44
8020301	10	0.42	9	0.38	19	0.40	0.33	0.45
8020302	65	0.39	3	0.36	68	0.38	0.35	0.42
8020303	40	0.41	6	0.40	46	0.41	0.38	0.43
8020304	61	0.42			61	0.42	0.39	0.46
8020401	11	0.52	1	0.51	12	0.52	0.48	0.58
8020402	18	0.42			18	0.42	0.39	0.45
8030100	3	0.51	1	0.50	4	0.51	0.48	0.54
8030201	8	0.39	32	0.36	40	0.36	0.31	0.42
8030202	61	0.46	20	0.43	81	0.45	0.41	0.49
8030203	4	0.38	8	0.38	12	0.38	0.33	0.44
8030204	66	0.40	30	0.36	96	0.38	0.33	0.42
8030205	28	0.38	30	0.37	58	0.38	0.32	0.42
8030206	32	0.41	8	0.38	40	0.40	0.37	0.44
8030207	114	0.36	14	0.37	128	0.36	0.34	0.38
8030209	27	0.47	4	0.44	31	0.47	0.43	0.51
8040102	1	0.37			1	0.37	0.37	0.37
8040103	2	0.39	1	0.35	3	0.37	0.35	0.41
8040202	1	0.39			1	0.39	0.39	0.39
8040205	12	0.45			12	0.45	0.42	0.51
8040207	2	0.55	1	0.55	3	0.55	0.55	0.55
8040301	9	0.51	1	0.46	10	0.51	0.46	0.53
8040305	2	0.53	1	0.66	3	0.57	0.51	0.66
8040306	13	0.49	1	0.55	14	0.50	0.44	0.55
8050001	57	0.38	19	0.36	76	0.37	0.35	0.41
8050002	27	0.49	11	0.49	38	0.49	0.45	0.53
8050003	36	0.42	13	0.41	49	0.42	0.37	0.46
8060100	2	0.44	1	0.41	3	0.43	0.41	0.47
8060201	7	0.38	37	0.35	44	0.35	0.32	0.37

8060202	10	0.34	51	0.32	61	0.33	0.30	0.35
8060203	1	0.39	7	0.35	8	0.36	0.34	0.39
8060204	1	0.44	5	0.41	6	0.41	0.38	0.46
8060205	1	0.43	3	0.34	4	0.36	0.30	0.43
8060206			3	0.43	3	0.43	0.39	0.46
8070100	2	0.52			2	0.52	0.51	0.54
8070201			7	0.39	7	0.39	0.34	0.42
8070202			9	0.34	9	0.34	0.33	0.37
8070203			3	0.35	3	0.35	0.33	0.36
8070204	3	0.52			3	0.52	0.47	0.54
8070300	10	0.41			10	0.41	0.39	0.47
8080101	12	0.43			12	0.43	0.40	0.47
8080102	42	0.43	2	0.34	44	0.42	0.39	0.45
8080103	24	0.47			24	0.47	0.42	0.49
8080201	40	0.44	2	0.42	42	0.44	0.41	0.47
8080202	61	0.44			61	0.44	0.39	0.47
8080203	16	0.40	1	0.36	17	0.39	0.37	0.43
8080204			4	0.39	4	0.39	0.37	0.42
8080205	4	0.46	1	0.40	5	0.45	0.40	0.48
8080206	6	0.46			6	0.46	0.41	0.47
8090301	14	0.50			14	0.50	0.46	0.52
8090302	3	0.49			3	0.49	0.49	0.49

Table 8-2. Mean and percentiles of sediment delivery ratio (sediment delivered at 8-digit watershed outlet by sediment yield at HRUs) estimated for non-cultivated land HRUs within SWAT for the 8-digit watersheds in the Lower Mississippi River Basin

HUC	Subbasin	Number_of non-cropland HRUs simulated within SWAT	Mean SDR	10 th Percentile SDR	90 th Percentile SDR
8010100	1	36	0.42	0.33	0.50
8010201	2	33	0.29	0.21	0.39
8010202	3	29	0.28	0.18	0.39
8010203	4	41	0.26	0.19	0.33
8010204	5	34	0.24	0.15	0.38
8010205	6	40	0.23	0.14	0.31
8010206	7	24	0.45	0.39	0.56
8010207	8	43	0.27	0.20	0.32
8010208	9	32	0.25	0.16	0.38
8010209	10	38	0.27	0.19	0.37
8010210	11	48	0.24	0.16	0.33
8010211	12	29	0.32	0.24	0.39
8020100	13	17	0.43	0.35	0.65
8020201	14	31	0.30	0.19	0.41
8020202	15	51	0.25	0.18	0.32
8020203	16	29	0.26	0.17	0.46
8020204	17	28	0.23	0.12	0.44

8020205	18	33	0.26	0.17	0.38
8020301	19	35	0.29	0.20	0.38
8020302	20	25	0.26	0.13	0.43
8020303	21	29	0.29	0.21	0.41
8020304	22	28	0.29	0.17	0.44
8020401	23	17	0.48	0.40	0.61
8020402	24	28	0.31	0.21	0.40
8030100	25	22	0.46	0.38	0.59
8030201	26	32	0.25	0.16	0.39
8030202	27	28	0.37	0.24	0.54
8030203	28	44	0.25	0.17	0.33
8030204	29	28	0.27	0.16	0.40
8030205	30	36	0.25	0.16	0.34
8030206	31	33	0.28	0.18	0.40
8030207	32	29	0.25	0.15	0.44
8030208	33	28	0.46	0.38	0.59
8030209	34	30	0.40	0.34	0.48
8040101	35	56	0.23	0.16	0.29
8040102	36	41	0.26	0.19	0.33
8040103	37	56	0.24	0.19	0.31
8040201	38	41	0.27	0.21	0.35
8040202	39	43	0.35	0.29	0.41
8040203	40	48	0.24	0.18	0.29
8040204	41	46	0.25	0.18	0.33
8040205	42	41	0.32	0.26	0.37
8040206	43	43	0.24	0.16	0.32
8040207	44	35	0.41	0.33	0.49
8040301	45	33	0.41	0.34	0.52
8040302	46	41	0.27	0.19	0.37
8040303	47	43	0.25	0.18	0.33
8040304	48	43	0.29	0.22	0.37
8040305	49	14	0.61	0.51	0.76
8040306	50	26	0.41	0.30	0.59
8050001	51	25	0.27	0.16	0.42
8050002	52	24	0.40	0.33	0.54
8050003	53	27	0.30	0.22	0.46
8060100	54	20	0.36	0.26	0.54
8060201	55	39	0.24	0.17	0.33
8060202	56	43	0.23	0.16	0.32
8060203	57	51	0.25	0.19	0.32
8060204	58	40	0.34	0.27	0.41
8060205	59	45	0.24	0.16	0.31
8060206	60	43	0.32	0.27	0.38
8070100	61	18	0.47	0.39	0.62
8070201	62	57	0.28	0.23	0.34
8070202	63	55	0.25	0.20	0.31
8070203	64	56	0.25	0.18	0.32
8070204	65	41	0.51	0.41	0.61
8070205	66	56	0.26	0.21	0.32

8070300	67	33	0.33	0.24	0.43
8080101	68	39	0.35	0.26	0.45
8080102	69	44	0.29	0.22	0.35
8080103	70	37	0.36	0.29	0.45
8080201	71	44	0.33	0.28	0.38
8080202	72	34	0.37	0.27	0.49
8080203	73	50	0.26	0.19	0.32
8080204	74	51	0.28	0.21	0.34
8080205	75	40	0.30	0.23	0.41
8080206	76	50	0.40	0.33	0.48
8090100	77	18	0.59	0.51	0.66
8090201	78	40	0.34	0.27	0.40
8090202	79	11	0.64	0.49	0.90
8090203	80	28	0.58	0.52	0.64
8090301	81	40	0.54	0.44	0.62
8090302	82	42	0.48	0.43	0.54

Figure 8-2. Mean and percentiles of sediment delivery ratio (sediment delivered at 8-digit watershed outlet by sediment yield at simulation sites) estimated for cultivated simulation sites within APEX for the 8-digit watersheds in the Lower Mississippi River Basin

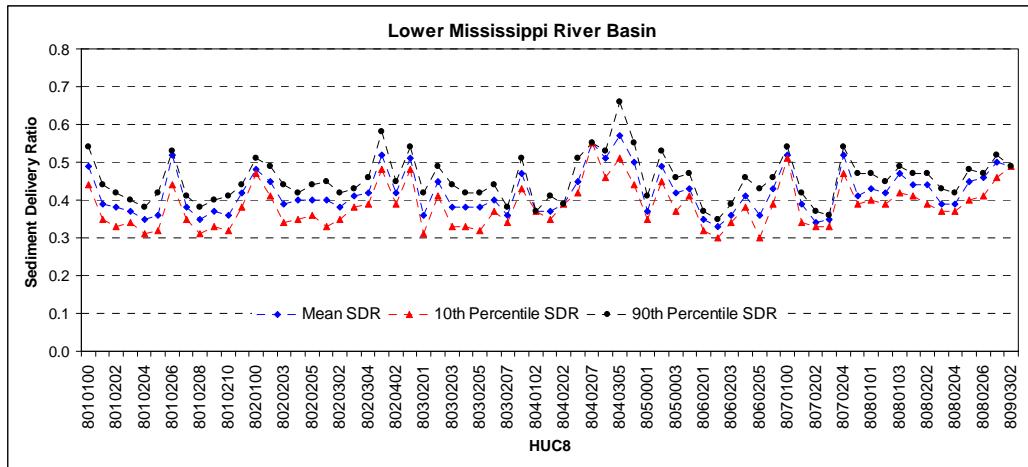
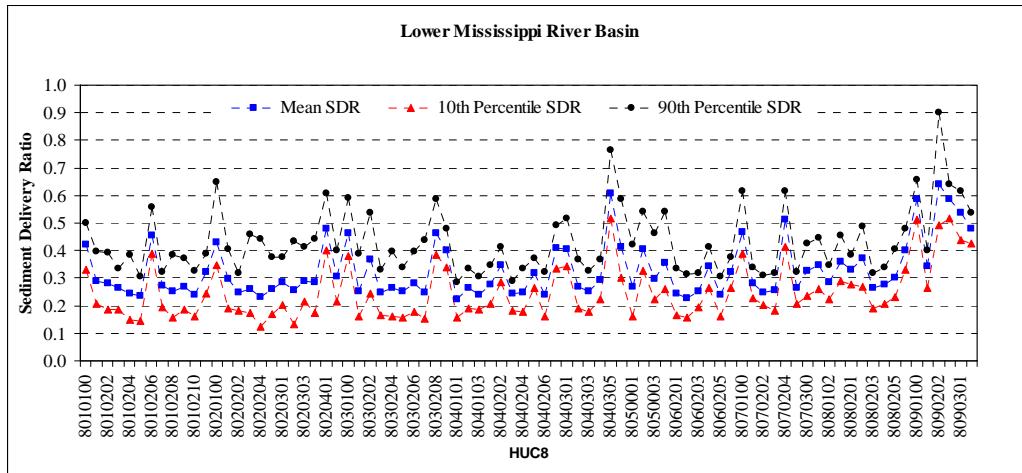


Figure 8-3. Mean and percentiles of sediment delivery ratio (sediment delivered at 8-digit watershed outlet by sediment yield at HRUs) estimated for non-cultivated land HRUs within SWAT for the 8-digit watersheds in the Lower Mississippi River Basin



Chapter 9

Delivery Ratio used in CEAP Cropland
Modeling in the Texas Gulf Basin

The APEX model is a field-scale, daily time-step model that simulates weather, farming operations, crop growth and yield, and the movement of water, soil, carbon, nutrients, sediment, and pesticides. The APEX model was used also to simulate the effects of conservation practices at the field scale (Williams and Izaurralde, 2006; Gassman et al. 2009) in the Texas Gulf Basin. APEX simulates all of the basic biological, chemical, hydrological, and meteorological processes of farming systems and their interactions. Soil erosion is simulated over time, including wind erosion, sheet and rill erosion. The nitrogen, phosphorus, and carbon cycles are simulated, including chemical transformations in the soil that affect their availability for plant growth or for transport from the field.

While the APEX model was used for simulate the cultivated cropland and the SWAT model was used to simulate the non-cultivated cropland in the 8-digit watersheds of the river basin. SWAT is a physical process model with a daily time step (Arnold and Fohrer 2005; Arnold et al. 1998; Gassman et al. 2007). The hydrologic cycle in the model is divided into two parts. The land phase of the hydrologic cycle, or upland processes, simulates the amount of water, sediment, nutrients, and pesticides delivered from the land to the outlet of each watershed. The routing phase of the hydrologic cycle, or channel processes, simulates the movement of water, sediment, nutrients, and pesticides from the outlet of the upstream watershed through the main channel network to the watershed outlet.

In SWAT, each 8-digit watershed is divided into multiple Hydrologic Response Units (HRUs) that have homogeneous land use, soil, and slope. SWAT is used to simulate the fate and transport of water, sediment, nutrients, and pesticides from various non-cropland HRUs as described in Chapter 1.

Not all of the soil that erodes from a field or HRUs ends up in the watershed outlet. Most of the soil eroded gets deposited on the way although the deposition is temporary. Eroded soil may deposit in lower spots, flatter lands, deposited at the edge of the field and sometimes settles at the bottom of the channel. Hence, a SDR was used to account for deposition in ditches, floodplains, and tributary stream

channels during transit from the edge of the field or HRUs to the 8-digit watershed outlet in the CEAP National Assessment modeling. The SDR used in this study is a function of the ratio of the time of concentration for the HRU (land uses other than cultivated cropland) or field (cultivated cropland) to the time of concentration for the watershed (8-digit HUC). The time of concentration for the watershed is the time from when a surface water runoff event occurs at the most distant point in the watershed to the time the surface water runoff reaches the outlet of the watershed. It is calculated by summing the overland flow time (the time it takes for flow from the remotest point in the watershed to reach the channel) and the channel flow time (the time it takes for flow in the upstream channels to reach the outlet). The time of concentration for the field is derived from APEX. The time of concentration for the HRU is derived from characteristics of the watershed, the HRU, and the proportion of total acres represented by the HRU. Consequently, each cultivated cropland sample point has a unique delivery ratio within each watershed, as does each HRU. The description of the sediment delivery ratio procedure is provided in Chapter 1.

The APEX model simulates the edge of sediment yield using a variation of MUSLE called MUST ([MUSLE developed from Theory](#)) (Williams, 1995) as described in Chapter 1. After estimating the sediment load from each APEX simulation site, the delivery ratio is applied to determine the amount of sediment that reach the 8-digit watershed outlet from each APEX simulation site. The sediment load from apex simulation sites are aggregated for the 8-digit watershed and integrated into the SWAT model at each 8-digit watershed to estimate the water quality effects of conservation practices. In SWAT, the sediment yield for the non-cropland HRUs are estimated using the MUSLE as described in Chapter 1. After estimating the SDR for each HRU, the SDR is applied to determine the amount of sediment that reaches the 8-digit watershed outlet.

Sediment delivery ratios were estimated to account for sediment losses or deposition occurring from edge-of-field or HRUs to the 8-digit watershed outlet for each APEX simulation site in the cultivated cropland and CRP and non-cropland HRUs in the Texas Gulf Basin (Figure 9-1). The Texas Gulf Basin has a drainage area

of 116 million acres. The cultivated cropland and land enrolled in the CRP General Signup is about 15% of the Texas Gulf Basin. A total of 122, 8-digit watersheds are in the Texas Gulf Basin (Figure 9-1). Within each 8-digit watershed, the percent of cultivated cropland and CRP area and non-cultivated cropland area varies widely across the entire basin.

A total of 1573 representative cultivated fields (693 NRI-CEAP cropland points and 880 CRP points) were setup to run using APEX. Twenty-eight out of 112, 8-digit watersheds in the Texas Gulf Basin have no CEAP points; the twenty-eight 8-digit watersheds have zero or fewer than 15% of land cultivated.

Non-cultivated land is distributed over 85% of the Texas Gulf Basin. Within each 8-digit watershed, non-cultivated land uses such as pasture, range, hay, horticulture, forest deciduous, forest mixed, forest evergreen, urban, urban construction, barren land wetland and water are simulated as HRUs in SWAT. A total of 5,104 HRUs are simulated in SWAT for the Texas Gulf Basin.

Each NRI-CEAP point and CRP point is unique; therefore, sediment yield and delivery ratio also vary for each cultivated cropland site simulated in an 8-digit watershed and so as for HRU. The number of CEAP sample points, and mean, 10th percentile and 90th percentile of the delivery ratios of the APEX simulation sites in the 8-digit watersheds in the Texas Gulf River Basin are shown in Table 9-1 and Figure 9-2. Table 9-2 shows number of HRUs and mean, 10th percentile and 90th percentile of the SDRs estimated for the non-cultivated land HRUs in the 8-digit watersheds in the Texas Gulf Basin. The mean, 10th and 90th percentile SDRs for the non-cropland HRUs are plotted in Figure 9-3.

In addition to SDR, an enrichment ratio was used to simulate organic nitrogen, organic phosphorus, and sediment-attached pesticide transport in ditches, floodplains, and tributary stream channels during transit from the edge of the field to the outlet. The enrichment ratio was defined as the organic nitrogen, organic phosphorus, and sediment attached pesticide concentration from the edge-of-field divided by the concentration at the 8-digit watershed outlet. The enrichment ratio is estimated for each APEX

simulation site and SWAT HRUs and it varies from 0.5 to 1.5 (Average 1.0). As sediment is transported from the edge-of-field to the watershed outlet, coarse sediments are deposited first while more of the fine sediment that hold organic particles remain in suspension, thus enriching the organic concentrations delivered to the watershed outlet.

A separate delivery ratio is used to simulate the transport of nitrate nitrogen, soluble phosphorus, and soluble pesticides. In general, the proportion of soluble nutrients and pesticides delivered to rivers and streams is higher than the proportion attached to sediments because they are not subject to sediment deposition.

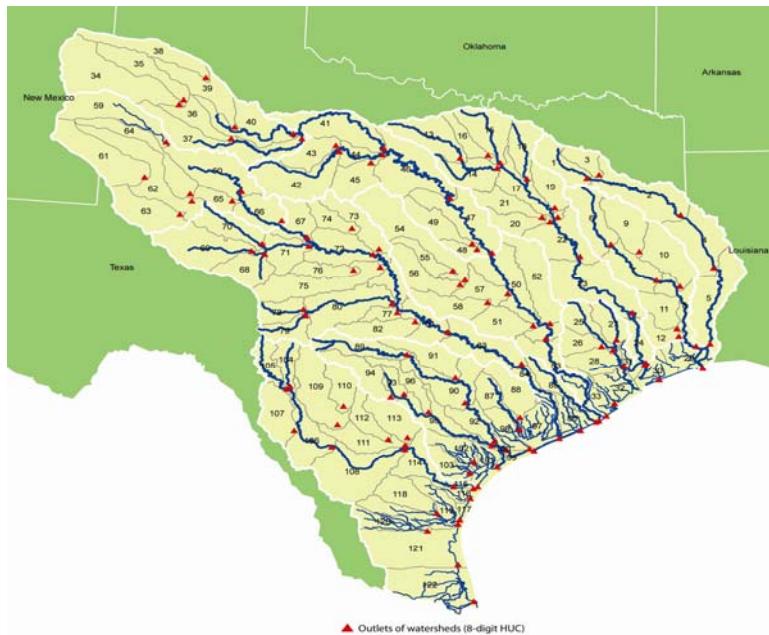


Figure 9-1. Map of the 8-digit watersheds in the Texas Gulf Basin

Table 9-1. Mean and percentiles of sediment delivery ratio (sediment delivered at 8-digit watershed outlet by sediment yield at simulation sites) estimated for cultivated simulation sites within APEX for the 8-digit watersheds in the Texas Gulf Basin

HUC	Cropland		CRP		Crop + CRP			
	Points	Mean_S DR	Points	Mean_S DR	Points	Mean_S DR	10 th percentile	90 th percentile
12010001	5	0.37			5	0.37	0.36	0.38
12010003	1	0.38			1	0.38	0.38	0.38
12020002			1	0.34	1	0.34	0.34	0.34
12020007	1	0.45			1	0.45	0.45	0.45
12030101	3	0.34			3	0.34	0.33	0.36
12030102	5	0.38			5	0.38	0.36	0.39
12030103	4	0.36			4	0.36	0.35	0.38
12030104	3	0.38			3	0.38	0.38	0.38
12030105	3	0.36			3	0.36	0.35	0.38
12030106	11	0.38	1	0.22	12	0.36	0.26	0.40
12030108	6	0.40	2	0.24	8	0.36	0.23	0.43
12030109	6	0.38			6	0.38	0.34	0.44
12030202	1	0.43			1	0.43	0.43	0.43
12030203	1	0.46			1	0.46	0.46	0.46
12040104	1	0.42			1	0.42	0.42	0.42
12040201	6	0.50			6	0.50	0.44	0.53
12040202	11	0.46			11	0.46	0.41	0.49
12040203	2	0.49			2	0.49	0.49	0.49
12040204	3	0.51			3	0.51	0.51	0.51
12040205	2	0.50			2	0.50	0.49	0.52
12050001	50	0.38	224	0.34	274	0.35	0.22	0.42
12050002	39	0.38	54	0.28	93	0.32	0.20	0.41
12050003	23	0.49	4	0.32	27	0.47	0.31	0.54
12050004	42	0.39	45	0.24	87	0.31	0.22	0.41
12050005	32	0.35	41	0.30	73	0.32	0.21	0.37
12050006	30	0.41	49	0.25	79	0.31	0.22	0.43
12050007	17	0.40	36	0.22	53	0.27	0.20	0.41
12060101	26	0.36	4	0.20	30	0.33	0.21	0.38
12060102	16	0.35	21	0.19	37	0.26	0.18	0.37
12060103	20	0.40	13	0.25	33	0.34	0.24	0.42
12060104	2	0.43			2	0.43	0.43	0.43
12060105	2	0.44			2	0.44	0.41	0.47
12060201	4	0.33			4	0.33	0.32	0.34
12060202	9	0.36	3	0.21	12	0.32	0.20	0.38
12060203	2	0.45	1	0.45	3	0.45	0.45	0.45
12060204	3	0.34			3	0.34	0.33	0.36
12070101	10	0.41	3	0.24	13	0.37	0.22	0.47
12070104	3	0.43			3	0.43	0.40	0.44
12070201	6	0.33	1	0.17	7	0.30	0.17	0.35
12070203	1	0.38			1	0.38	0.38	0.38
12070204	3	0.39			3	0.39	0.38	0.41
12070205	2	0.42			2	0.42	0.39	0.45
12080001	19	0.41	75	0.29	94	0.31	0.24	0.41
12080002	21	0.35	49	0.21	70	0.25	0.20	0.36
12080003	10	0.38	40	0.31	50	0.32	0.21	0.43
12080004	28	0.34	75	0.22	103	0.25	0.18	0.34
12080005	6	0.41	9	0.26	15	0.32	0.25	0.43
12080006	24	0.42	57	0.28	81	0.32	0.25	0.43

12080007	5	0.43	6	0.27	11	0.35	0.26	0.45
12080008	4	0.39	8	0.25	12	0.30	0.23	0.40
12090101	10	0.42	17	0.26	27	0.32	0.25	0.43
12090102	2	0.47			2	0.47	0.44	0.50
12090103	5	0.37	3	0.24	8	0.32	0.22	0.39
12090104	2	0.44			2	0.44	0.43	0.44
12090105	10	0.43	4	0.25	14	0.38	0.24	0.46
12090106	8	0.37	1	0.22	9	0.36	0.22	0.46
12090107	4	0.41	1	0.41	5	0.41	0.39	0.43
12090108	4	0.40	2	0.26	6	0.35	0.26	0.41
12090109	1	0.37			1	0.37	0.37	0.37
12090110	1	0.41	1	0.23	2	0.32	0.23	0.41
12090201	1	0.42			1	0.42	0.42	0.42
12090206	1	0.35			1	0.35	0.35	0.35
12090301	3	0.34			3	0.34	0.34	0.34
12090302	1	0.49			1	0.49	0.49	0.49
12090401	5	0.43			5	0.43	0.39	0.46
12090402	1	0.49			1	0.49	0.49	0.49
12100102	4	0.43			4	0.43	0.39	0.47
12100201	1	0.34			1	0.34	0.34	0.34
12100202	2	0.39			2	0.39	0.39	0.39
12100203	2	0.36			2	0.36	0.36	0.36
12100204	1	0.43			1	0.43	0.43	0.43
12100301	1	0.44			1	0.44	0.44	0.44
12100302	3	0.40			3	0.40	0.37	0.41
12100303	2	0.36			2	0.36	0.36	0.36
12100304	6	0.38			6	0.38	0.36	0.40
12100401	5	0.45			5	0.45	0.39	0.46
12100402	5	0.47			5	0.47	0.41	0.49
12100405			1	0.51	1	0.51	0.51	0.51
12100407	8	0.44			8	0.44	0.40	0.48
12110103			1	0.24	1	0.24	0.24	0.24
12110105			3	0.20	3	0.20	0.20	0.21
12110106	5	0.41	1	0.32	6	0.40	0.32	0.45
12110107	1	0.43			1	0.43	0.43	0.43
12110108	1	0.35			1	0.35	0.35	0.35
12110109	2	0.39			2	0.39	0.37	0.41
12110110	1	0.36			1	0.36	0.36	0.36
12110111	4	0.40	1	0.25	5	0.37	0.25	0.42
12110201	1	0.52			1	0.52	0.52	0.52
12110202	1	0.50			1	0.50	0.50	0.50
12110204	2	0.40	1	0.24	3	0.35	0.24	0.41
12110205	12	0.40	12	0.28	24	0.34	0.21	0.43
12110206			6	0.25	6	0.25	0.24	0.26
12110207	1	0.36	2	0.23	3	0.27	0.22	0.36
12110208	29	0.45	1	0.43	30	0.45	0.39	0.47

Table 9-2. Mean and percentiles of sediment delivery ratio (sediment delivered at 8-digit watershed outlet by sediment yield at HRUs) estimated for non-cultivated land HRUs within SWAT for the 8-digit watersheds in the Texas Gulf Basin

HUC	Subbasin	Number_of non-cropland HRUs simulated within SWAT	Mean SDR	10 th Percentile SDR	90 th Percentile SDR
12010001	1	69	0.26	0.22	0.33
12010002	2	43	0.24	0.17	0.35
12010003	3	70	0.28	0.23	0.32
12010004	4	44	0.25	0.19	0.31
12010005	5	45	0.28	0.23	0.34
12020001	6	54	0.24	0.19	0.34
12020002	7	51	0.27	0.21	0.35
12020003	8	49	0.30	0.26	0.38
12020004	9	64	0.26	0.21	0.31
12020005	10	52	0.25	0.19	0.33
12020006	11	55	0.29	0.23	0.36
12020007	12	50	0.34	0.31	0.40
12030101	13	47	0.25	0.18	0.33
12030102	14	57	0.27	0.23	0.33
12030103	15	47	0.27	0.21	0.36
12030104	16	50	0.26	0.21	0.33
12030105	17	57	0.25	0.20	0.31
12030106	18	54	0.28	0.23	0.33
12030107	19	70	0.29	0.24	0.34
12030108	20	50	0.29	0.24	0.35
12030109	21	53	0.25	0.20	0.33
12030201	22	49	0.26	0.20	0.37
12030202	23	45	0.24	0.17	0.35
12030203	24	48	0.34	0.28	0.39
12040101	25	54	0.27	0.21	0.33
12040102	26	48	0.31	0.27	0.37
12040103	27	57	0.28	0.22	0.35
12040104	28	42	0.34	0.28	0.44
12040201	29	46	0.47	0.42	0.55
12040202	30	44	0.40	0.34	0.50
12040203	31	28	0.40	0.34	0.54
12040204	32	47	0.42	0.39	0.47
12040205	33	40	0.43	0.39	0.50
12050001	34	21	0.30	0.21	0.48
12050002	35	17	0.30	0.20	0.59
12050003	36	19	0.40	0.32	0.60
12050004	37	36	0.29	0.22	0.38
12050005	38	19	0.26	0.15	0.43
12050006	39	23	0.30	0.20	0.42
12050007	40	38	0.27	0.21	0.36
12060101	41	35	0.24	0.16	0.34

12060102	42	45	0.24	0.18	0.31
12060103	43	34	0.29	0.21	0.38
12060104	44	24	0.36	0.29	0.48
12060105	45	41	0.33	0.28	0.40
12060201	46	48	0.22	0.15	0.28
12060202	47	49	0.26	0.21	0.32
12060203	48	29	0.36	0.31	0.42
12060204	49	41	0.25	0.17	0.32
12070101	50	48	0.30	0.25	0.36
12070102	51	53	0.27	0.22	0.34
12070103	52	49	0.24	0.18	0.32
12070104	53	50	0.28	0.21	0.34
12070201	54	48	0.22	0.15	0.30
12070202	55	40	0.27	0.21	0.34
12070203	56	51	0.26	0.21	0.34
12070204	57	45	0.29	0.23	0.36
12070205	58	51	0.27	0.22	0.33
12080001	59	18	0.34	0.24	0.52
12080002	60	34	0.26	0.18	0.38
12080003	61	24	0.31	0.23	0.47
12080004	62	22	0.27	0.16	0.44
12080005	63	20	0.36	0.29	0.61
12080006	64	17	0.38	0.29	0.53
12080007	65	22	0.35	0.28	0.53
12080008	66	39	0.29	0.24	0.36
12090101	67	34	0.32	0.25	0.43
12090102	68	27	0.33	0.27	0.56
12090103	69	31	0.27	0.18	0.41
12090104	70	35	0.28	0.22	0.42
12090105	71	33	0.32	0.27	0.41
12090106	72	46	0.25	0.19	0.33
12090107	73	45	0.33	0.29	0.39
12090108	74	32	0.31	0.25	0.46
12090109	75	43	0.24	0.17	0.34
12090110	76	26	0.29	0.22	0.50
12090201	77	41	0.29	0.24	0.36
12090202	78	29	0.32	0.25	0.43
12090203	79	24	0.31	0.24	0.50
12090204	80	41	0.25	0.17	0.33
12090205	81	48	0.30	0.26	0.34
12090206	82	47	0.25	0.18	0.31
12090301	83	54	0.24	0.18	0.31
12090302	84	45	0.35	0.30	0.39
12090401	85	37	0.33	0.28	0.41
12090402	86	43	0.38	0.33	0.43
12100101	87	54	0.27	0.21	0.33
12100102	88	42	0.28	0.20	0.35
12100201	89	47	0.24	0.17	0.34
12100202	90	62	0.28	0.23	0.32

12100203	91	60	0.25	0.20	0.30
12100204	92	74	0.27	0.23	0.32
12100301	93	35	0.38	0.34	0.46
12100302	94	48	0.26	0.22	0.34
12100303	95	53	0.24	0.18	0.29
12100304	96	39	0.28	0.22	0.38
12100401	97	40	0.35	0.29	0.40
12100402	98	36	0.36	0.29	0.43
12100403	99	18	0.52	0.46	0.71
12100404	100	21	0.53	0.47	0.66
12100405	101	35	0.42	0.38	0.48
12100406	102	59	0.29	0.24	0.34
12100407	103	37	0.32	0.26	0.40
12110101	104	43	0.30	0.23	0.40
12110102	105	20	0.32	0.22	0.46
12110103	106	49	0.30	0.25	0.36
12110104	107	49	0.30	0.26	0.37
12110105	108	50	0.25	0.19	0.34
12110106	109	50	0.28	0.24	0.34
12110107	110	36	0.33	0.27	0.41
12110108	111	49	0.26	0.21	0.34
12110109	112	40	0.27	0.21	0.39
12110110	113	47	0.27	0.22	0.35
12110111	114	47	0.26	0.20	0.32
12110201	115	21	0.51	0.45	0.63
12110202	116	24	0.40	0.34	0.55
12110203	117	33	0.57	0.51	0.62
12110204	118	49	0.28	0.21	0.36
12110205	119	39	0.30	0.23	0.40
12110206	120	42	0.31	0.26	0.37
12110207	121	31	0.27	0.21	0.41
12110208	122	35	0.35	0.28	0.42

Figure 9-2. Mean and percentiles of sediment delivery ratio (sediment delivered at 8-digit watershed outlet by sediment yield at simulation sites) estimated for cultivated simulation sites within APEX for the 8-digit watersheds in the Texas Gulf Basin

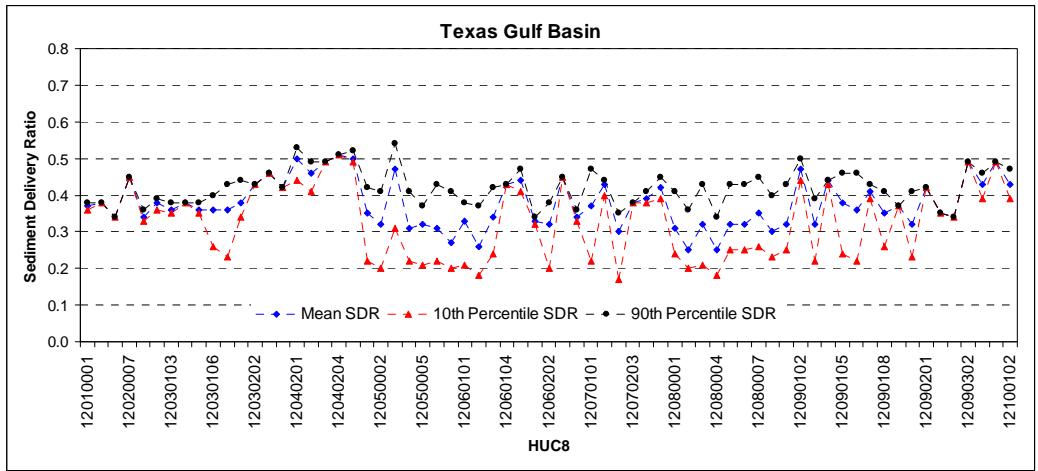
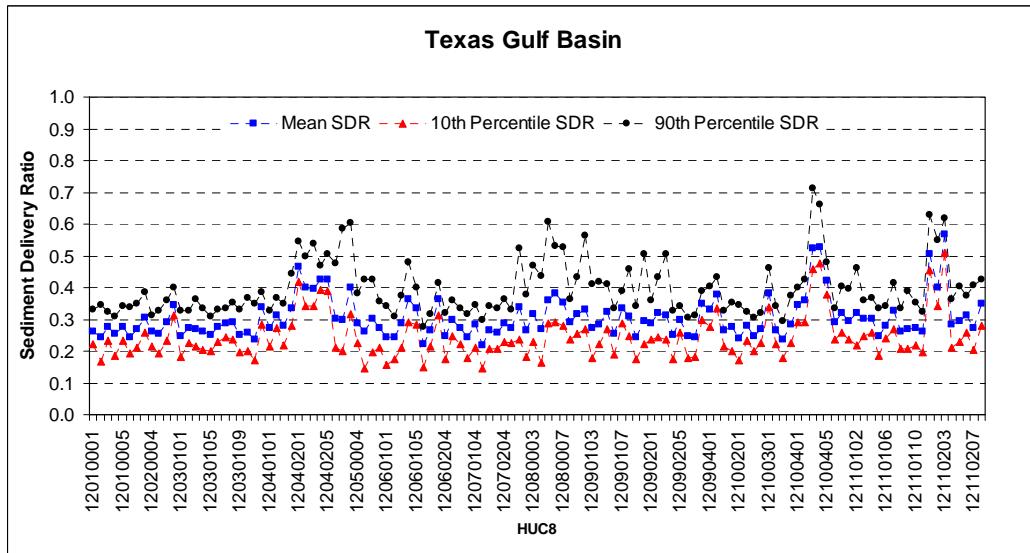


Figure 9-3. Mean and percentiles of sediment delivery ratio (sediment delivered at 8-digit watershed outlet by sediment yield at HRUs) estimated for non-cultivated land HRUs within SWAT for the 8-digit watersheds in the Texas Gulf Basin



Chapter 10

Delivery Ratio used in CEAP Cropland
Modeling in the South Atlantic Gulf Basin

The APEX model is a field-scale, daily time-step model that simulates weather, farming operations, crop growth and yield, and the movement of water, soil, carbon, nutrients, sediment, and pesticides. The APEX model was used also to simulate the effects of conservation practices at the field scale (Williams and Izaurralde, 2006; Gassman et al. 2009) in the South Atlantic Gulf Basin. APEX simulates all of the basic biological, chemical, hydrological, and meteorological processes of farming systems and their interactions. Soil erosion is simulated over time, including wind erosion, sheet and rill erosion. The nitrogen, phosphorus, and carbon cycles are simulated, including chemical transformations in the soil that affect their availability for plant growth or for transport from the field.

While the APEX model was used for simulate the cultivated cropland and the SWAT model was used to simulate the non-cultivated cropland in the 8-digit watersheds of the river basin. SWAT is a physical process model with a daily time step (Arnold and Fohrer 2005; Arnold et al. 1998; Gassman et al. 2007). The hydrologic cycle in the model is divided into two parts. The land phase of the hydrologic cycle, or upland processes, simulates the amount of water, sediment, nutrients, and pesticides delivered from the land to the outlet of each watershed. The routing phase of the hydrologic cycle, or channel processes, simulates the movement of water, sediment, nutrients, and pesticides from the outlet of the upstream watershed through the main channel network to the watershed outlet.

In SWAT, each 8-digit watershed is divided into multiple Hydrologic Response Units (HRUs) that have homogeneous land use, soil, and slope. SWAT is used to simulate the fate and transport of water, sediment, nutrients, and pesticides from various non-cropland HRUs as described in Chapter 1.

Not all of the soil that erodes from a field or HRUs ends up in the watershed outlet. Most of the soil eroded gets deposited on the way although the deposition is temporary. Eroded soil may deposit in lower spots, flatter lands, deposited at the edge

of the field and sometimes settles at the bottom of the channel. Hence, a SDR was used to account for deposition in ditches, floodplains, and tributary stream channels during transit from the edge of the field or HRUs to the 8-digit watershed outlet in the CEAP National Assessment modeling. The SDR used in this study is a function of the ratio of the time of concentration for the HRU (land uses other than cultivated cropland) or field (cultivated cropland) to the time of concentration for the watershed (8-digit HUC). The time of concentration for the watershed is the time from when a surface water runoff event occurs at the most distant point in the watershed to the time the surface water runoff reaches the outlet of the watershed. It is calculated by summing the overland flow time (the time it takes for flow from the remotest point in the watershed to reach the channel) and the channel flow time (the time it takes for flow in the upstream channels to reach the outlet). The time of concentration for the field is derived from APEX. The time of concentration for the HRU is derived from characteristics of the watershed, the HRU, and the proportion of total acres represented by the HRU. Consequently, each cultivated cropland sample point has a unique delivery ratio within each watershed, as does each HRU. The description of the sediment delivery ratio procedure is provided in Chapter 1.

The APEX model simulates the edge of sediment yield using a variation of MUSLE called MUST (MUSLE developed from Theory) (Williams, 1995) as described in Chapter 1. After estimating the sediment load from each APEX simulation site, the delivery ratio is applied to determine the amount of sediment that reach the 8-digit watershed outlet from each APEX simulation site. The sediment load from apex simulation sites are aggregated for the 8-digit watershed and integrated into the SWAT model at each 8-digit watershed to estimate the water quality effects of conservation practices. In SWAT, the sediment yield for the non-cropland HRUs are estimated using the MUSLE as described in Chapter 1. After estimating the SDR for each HRU, the SDR is applied to determine the amount of sediment that reaches the 8-digit watershed outlet.

Sediment delivery ratios were estimated to account for sediment losses or deposition occurring from edge-of-field or HRUs to the 8-digit watershed outlet for each APEX simulation site in the cultivated cropland and CRP and non-cropland HRUs in the South Atlantic Gulf Basin (Figure 10-1). The South Atlantic Basin has a drainage area of 176 million acres. The cultivated cropland and land enrolled in the CRP General Signup is about 8.9% of the South Atlantic Gulf Basin. A total of 197, 8-digit watersheds are in the South Atlantic Gulf Basin (Figure 10-1). Within each 8-digit watershed, the percent of cultivated cropland and CRP area and non-cultivated cropland area varies widely across the entire basin.

A total of 1505 representative cultivated fields (968 NRI-CEAP cropland points and 537 CRP points) were setup to run using APEX. Forty-seven out of 197, 8-digit watersheds in the South Atlantic Basin have no CEAP points; the forty-seven 8-digit watersheds have zero or fewer than 16.8% of land cultivated.

Non-cultivated land is distributed over 91% of the South Atlantic Gulf Basin. Within each 8-digit watershed, non-cultivated land uses such as pasture, range, hay, horticulture, forest deciduous, forest mixed, forest evergreen, urban, urban construction, barren land wetland and water are simulated as HRUs in SWAT. A total of 9,040 HRUs are simulated in SWAT for the South Atlantic Gulf Basin.

Each NRI-CEAP point and CRP point is unique; therefore, sediment yield and delivery ratio also vary for each cultivated cropland site simulated in an 8-digit watershed and so as for HRU. The

number of CEAP sample points, and mean, 10th percentile and 90th percentile of the delivery ratios of the APEX simulation sites in the 8-digit watersheds in the South Atlantic Gulf River Basin are shown in Table 10-1 and Figure 10-2. Table 10-2 shows number of HRUs and mean, 10th percentile and 90th percentile of the SDRs estimated for the non-cultivated land HRUs in the 8-digit watersheds in the South Atlantic Basin. The mean, 10th and 90th percentile SDRs for the non-cropland HRUs are plotted in Figure 10-3.

In addition to SDR, an enrichment ratio was used to simulate organic nitrogen, organic phosphorus, and sediment-attached pesticide transport in ditches, floodplains, and tributary stream channels during transit from the edge of the field to the outlet. The enrichment ratio was defined as the organic nitrogen, organic phosphorus, and sediment attached pesticide concentration from the edge-of-field divided by the concentration at the 8-digit watershed outlet. The enrichment ratio is estimated for each APEX simulation site and SWAT HRUs and it varies from 0.5 to 1.5 (Average 1.0). As sediment is transported from the edge-of-field to the watershed outlet, coarse sediments are deposited first while more of the fine sediment that hold organic particles remain in suspension, thus enriching the organic concentrations delivered to the watershed outlet.

A separate delivery ratio is used to simulate the transport of nitrate nitrogen, soluble phosphorus, and soluble pesticides. In general, the proportion of soluble nutrients and pesticides delivered to rivers and streams is higher than the proportion attached to sediments because they are not subject to sediment deposition.

Delivery Ratio used in CEAP in the South Atlantic Gulf Basin

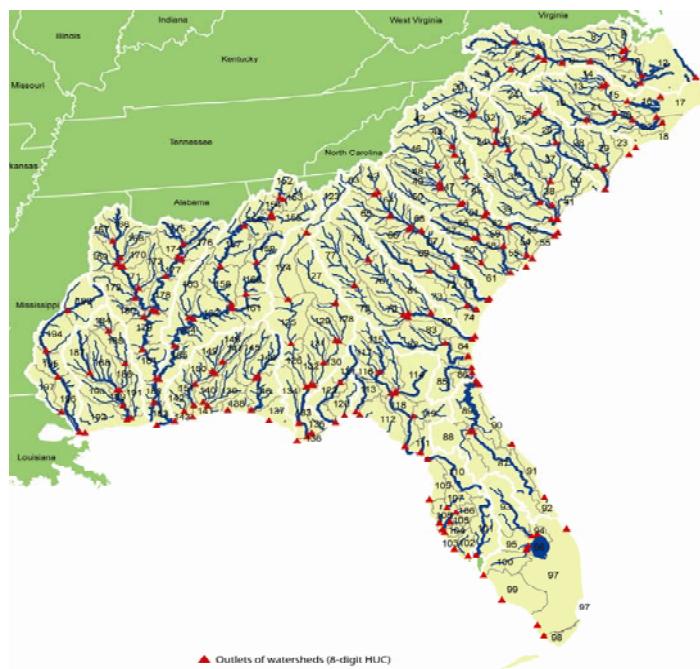


Figure 10-1. Map of the 8-digit watersheds in the South Atlantic Gulf Basin

Table 10-1. Mean and percentiles of sediment delivery ratio (sediment delivered at 8-digit watershed outlet by sediment yield at simulation sites) estimated for cultivated simulation sites within APEX for the 8-digit watersheds in the South Atlantic Gulf Basin

HUC	Cropland		CRP		Crop + CRP			
	Points	Mean_S DR	Points	Mean_S DR	Points	Mean_S DR	10 th percentile	90 th percentile
3010101	3	0.38	1	0.22	4	0.34	0.22	0.41
3010102	2	0.40			2	0.40	0.36	0.45
3010103	4	0.36			4	0.36	0.34	0.38
3010104	5	0.36			5	0.36	0.34	0.37
3010105	3	0.35			3	0.35	0.34	0.35
3010106	1	0.35	2	0.37	3	0.36	0.35	0.37
3010107	13	0.44			13	0.44	0.39	0.49
3010201	20	0.34			20	0.34	0.33	0.36
3010202	29	0.39	1	0.25	30	0.39	0.35	0.46
3010203	28	0.42	1	0.43	29	0.42	0.39	0.49
3010204	36	0.38	3	0.25	39	0.37	0.34	0.41
3010205	71	0.44			71	0.44	0.39	0.47
3020101	5	0.36	1	0.34	6	0.36	0.33	0.38
3020102	10	0.40	1	0.36	11	0.39	0.36	0.41
3020103	21	0.41			21	0.41	0.37	0.46
3020104	9	0.47			9	0.47	0.43	0.54
3020105	5	0.51	1	0.52	6	0.51	0.49	0.52
3020106	3	0.44			3	0.44	0.41	0.45
3020201	18	0.35	4	0.31	22	0.34	0.31	0.40
3020202	14	0.43			14	0.43	0.39	0.50
3020203	20	0.40	4	0.34	24	0.39	0.34	0.44
3020204	8	0.41			8	0.41	0.37	0.45
3030001	2	0.43			2	0.43	0.37	0.48
3030002	8	0.36			8	0.36	0.35	0.37
3030003	1	0.37			1	0.37	0.37	0.37
3030004	17	0.38	1	0.41	18	0.38	0.34	0.45
3030005	6	0.45	1	0.39	7	0.44	0.39	0.49
3030006	16	0.37			16	0.37	0.34	0.39
3030007	6	0.39			6	0.39	0.37	0.42
3040101	11	0.37			11	0.37	0.32	0.47
3040102	2	0.41	1	0.41	3	0.41	0.40	0.41
3040103	1	0.39			1	0.39	0.39	0.39
3040104	4	0.40	2	0.37	6	0.39	0.36	0.47
3040105	16	0.35	5	0.33	21	0.34	0.31	0.36
3040201	31	0.36	14	0.33	45	0.35	0.31	0.40
3040202	13	0.42	6	0.38	19	0.41	0.34	0.47
3040203	34	0.39	1	0.38	35	0.39	0.35	0.46
3040204	44	0.41	2	0.38	46	0.40	0.35	0.46
3040205	22	0.40	13	0.36	35	0.38	0.34	0.42
3040206	13	0.38	3	0.36	16	0.38	0.35	0.44
3040207	1	0.52			1	0.52	0.52	0.52
3050101	1	0.37			1	0.37	0.37	0.37
3050102			1	0.39	1	0.39	0.39	0.39
3050103	1	0.33	1	0.35	2	0.34	0.33	0.35

Delivery Ratio used in CEAP in the South Atlantic Gulf Basin

3050104	1	0.35	1	0.33	2	0.34	0.33	0.35
3050105	5	0.38	5	0.37	10	0.37	0.36	0.40
3050108	1	0.36			1	0.36	0.36	0.36
3050109	5	0.33	6	0.32	11	0.32	0.31	0.36
3050110	4	0.38	1	0.37	5	0.38	0.35	0.43
3050111	2	0.39	5	0.37	7	0.37	0.36	0.41
3050112			2	0.37	2	0.37	0.37	0.37
3050201	1	0.45			1	0.45	0.45	0.45
3050202	1	0.46			1	0.46	0.46	0.46
3050203	2	0.35	7	0.35	9	0.35	0.34	0.37
3050204	9	0.40	5	0.36	14	0.38	0.35	0.48
3050205	1	0.45			1	0.45	0.45	0.45
3050206	12	0.40	2	0.35	14	0.39	0.35	0.42
3050207	16	0.38	9	0.37	25	0.38	0.34	0.41
3050208	11	0.39	2	0.39	13	0.39	0.36	0.44
3060101			1	0.40	1	0.40	0.40	0.40
3060102	2	0.40	1	0.37	3	0.39	0.37	0.40
3060103			3	0.36	3	0.36	0.34	0.37
3060106	1	0.34	6	0.37	7	0.37	0.33	0.39
3060107			1	0.39	1	0.39	0.39	0.39
3060108			1	0.32	1	0.32	0.32	0.32
3060109			1	0.35	1	0.35	0.35	0.35
3060201	6	0.34	2	0.32	8	0.34	0.32	0.36
3060202	6	0.37	1	0.33	7	0.37	0.33	0.38
3060203	12	0.35			12	0.35	0.34	0.41
3070101	2	0.32			2	0.32	0.32	0.32
3070102	1	0.34			1	0.34	0.34	0.34
3070103	1	0.31	2	0.34	3	0.33	0.31	0.35
3070104	18	0.35	11	0.32	29	0.34	0.31	0.41
3070105	3	0.35	3	0.34	6	0.35	0.33	0.36
3070106	5	0.39	1	0.35	6	0.39	0.35	0.45
3070107	4	0.35	2	0.32	6	0.34	0.32	0.37
3070201	6	0.37	5	0.35	11	0.36	0.33	0.41
3070202	8	0.39			8	0.39	0.36	0.43
3080102	1	0.35			1	0.35	0.35	0.35
3080103	1	0.47			1	0.47	0.47	0.47
3090204	1	0.38			1	0.38	0.38	0.38
3090205	2	0.40			2	0.40	0.39	0.41
3110103			3	0.38	3	0.38	0.35	0.40
3110202	13	0.33	3	0.32	16	0.33	0.31	0.34
3110203	14	0.37	2	0.34	16	0.36	0.34	0.43
3110204	8	0.35	2	0.35	10	0.35	0.33	0.36
3110205	2	0.37			2	0.37	0.36	0.38
3120001	1	0.35			1	0.35	0.35	0.35
3120002	8	0.37	2	0.36	10	0.37	0.36	0.39
3120003			1	0.34	1	0.34	0.34	0.34
3130002	1	0.32			1	0.32	0.32	0.32
3130003			2	0.33	2	0.33	0.31	0.36
3130004	16	0.36	8	0.34	24	0.35	0.33	0.37
3130005	3	0.32			3	0.32	0.32	0.32
3130006	15	0.34	4	0.33	19	0.34	0.33	0.36

Delivery Ratio used in CEAP in the South Atlantic Gulf Basin

3130007	7	0.35	1	0.36	8	0.35	0.33	0.38
3130008	8	0.37	3	0.37	11	0.37	0.35	0.39
3130009	10	0.38	2	0.34	12	0.37	0.34	0.46
3130010	12	0.38			12	0.38	0.36	0.39
3130012	5	0.35	8	0.33	13	0.34	0.32	0.37
3140103	3	0.35	10	0.33	13	0.33	0.32	0.36
3140104	1	0.36			1	0.36	0.36	0.36
3140201	16	0.36	16	0.34	32	0.35	0.33	0.38
3140202	5	0.32	12	0.32	17	0.32	0.31	0.35
3140203	4	0.35	19	0.35	23	0.35	0.34	0.36
3140301	2	0.38			2	0.38	0.38	0.38
3140302	2	0.35	1	0.35	3	0.35	0.34	0.36
3140303			1	0.36	1	0.36	0.36	0.36
3140304			1	0.37	1	0.37	0.37	0.37
3140305	4	0.36			4	0.36	0.35	0.36
3150101	2	0.49			2	0.49	0.45	0.52
3150103	1	0.43			1	0.43	0.43	0.43
3150104			1	0.36	1	0.36	0.36	0.36
3150105	8	0.43			8	0.43	0.35	0.52
3150106	7	0.34	1	0.30	8	0.33	0.30	0.40
3150107			3	0.37	3	0.37	0.37	0.37
3150110			1	0.35	1	0.35	0.35	0.35
3150201			8	0.32	8	0.32	0.30	0.34
3150202			3	0.32	3	0.32	0.31	0.33
3150203			22	0.35	22	0.35	0.33	0.37
3150204	2	0.41			2	0.41	0.40	0.41
3160101	8	0.39	8	0.37	16	0.38	0.35	0.41
3160102	10	0.41	5	0.38	15	0.40	0.37	0.44
3160103	3	0.36	4	0.38	7	0.37	0.36	0.40
3160104	6	0.42	33	0.39	39	0.39	0.35	0.44
3160105	3	0.44	4	0.43	7	0.43	0.41	0.45
3160106	11	0.40	26	0.39	37	0.39	0.37	0.42
3160108	3	0.44	40	0.36	43	0.36	0.32	0.40
3160109	1	0.42			1	0.42	0.42	0.42
3160111	1	0.32	4	0.32	5	0.32	0.32	0.33
3160112			3	0.41	3	0.41	0.41	0.41
3160113			8	0.36	8	0.36	0.32	0.44
3160201			2	0.38	2	0.38	0.37	0.39
3160202			6	0.39	6	0.39	0.36	0.40
3160203			1	0.33	1	0.33	0.33	0.33
3160205	4	0.40			4	0.40	0.38	0.41
3170001			1	0.37	1	0.37	0.37	0.37
3170002			2	0.34	2	0.34	0.34	0.34
3170003			1	0.39	1	0.39	0.39	0.39
3170004	2	0.35	19	0.33	21	0.33	0.31	0.38
3170005			4	0.33	4	0.33	0.31	0.36
3170006	3	0.42	4	0.38	7	0.40	0.35	0.44
3170007			7	0.35	7	0.35	0.33	0.38
3170008			2	0.37	2	0.37	0.37	0.37
3170009			3	0.35	3	0.35	0.34	0.36
3180001			22	0.35	22	0.35	0.32	0.39

3180002	2	0.37	8	0.35	10	0.35	0.32	0.38
3180003	1	0.41	5	0.37	6	0.38	0.35	0.41
3180004			7	0.35	7	0.35	0.32	0.39
3180005	1	0.33	12	0.33	13	0.33	0.30	0.35

Table 10-2. Mean and percentiles of sediment delivery ratio (sediment delivered at 8-digit watershed outlet by sediment yield at HRUs) estimated for non-cultivated land HRUs within SWAT for the 8-digit watersheds in the South Atlantic Gulf Basin

HUC	Subbasin	Number_of non-cropland HRUs simulated within SWAT	Mean SDR	10 th Percentile SDR	90 th Percentile SDR
3010101	1	63	0.21	0.15	0.26
3010102	2	54	0.23	0.16	0.29
3010103	3	53	0.23	0.17	0.27
3010104	4	56	0.23	0.17	0.29
3010105	5	58	0.22	0.15	0.28
3010106	6	45	0.23	0.17	0.33
3010107	7	42	0.28	0.21	0.37
3010201	8	50	0.22	0.13	0.27
3010202	9	50	0.26	0.20	0.32
3010203	10	39	0.29	0.22	0.37
3010204	11	47	0.24	0.18	0.30
3010205	12	44	0.32	0.23	0.39
3020101	13	50	0.23	0.18	0.31
3020102	14	49	0.26	0.19	0.33
3020103	15	44	0.26	0.18	0.33
3020104	16	38	0.39	0.32	0.47
3020105	17	37	0.40	0.31	0.49
3020106	18	45	0.36	0.33	0.41
3020201	19	40	0.22	0.14	0.33
3020202	20	39	0.29	0.22	0.39
3020203	21	56	0.23	0.17	0.30
3020204	22	44	0.29	0.24	0.39
3030001	23	43	0.28	0.23	0.37
3030002	24	67	0.22	0.18	0.28
3030003	25	71	0.20	0.14	0.26
3030004	26	42	0.25	0.18	0.35
3030005	27	44	0.33	0.27	0.42
3030006	28	41	0.25	0.17	0.34
3030007	29	41	0.24	0.16	0.32
3040101	30	56	0.21	0.16	0.27
3040102	31	86	0.27	0.23	0.32
3040103	32	73	0.25	0.20	0.30
3040104	33	54	0.25	0.20	0.33
3040105	34	77	0.21	0.16	0.25
3040201	35	35	0.23	0.13	0.34

Delivery Ratio used in CEAP in the South Atlantic Gulf Basin

3040202	36	45	0.25	0.17	0.32
3040203	37	37	0.25	0.17	0.33
3040204	38	43	0.25	0.17	0.33
3040205	39	39	0.26	0.19	0.34
3040206	40	43	0.24	0.16	0.32
3040207	41	48	0.37	0.34	0.43
3050101	42	60	0.21	0.15	0.27
3050102	43	75	0.24	0.20	0.29
3050103	44	57	0.22	0.16	0.30
3050104	45	49	0.22	0.14	0.29
3050105	46	51	0.25	0.19	0.28
3050106	47	51	0.25	0.19	0.29
3050107	48	61	0.24	0.18	0.29
3050108	49	63	0.23	0.17	0.28
3050109	50	39	0.22	0.13	0.31
3050110	51	57	0.23	0.17	0.29
3050111	52	45	0.26	0.19	0.31
3050112	53	37	0.25	0.16	0.33
3050201	54	48	0.27	0.21	0.35
3050202	55	42	0.29	0.22	0.37
3050203	56	47	0.24	0.17	0.30
3050204	57	53	0.23	0.18	0.27
3050205	58	46	0.30	0.26	0.37
3050206	59	35	0.26	0.20	0.37
3050207	60	40	0.25	0.17	0.30
3050208	61	44	0.26	0.19	0.33
3060101	62	66	0.25	0.21	0.29
3060102	63	50	0.23	0.17	0.31
3060103	64	52	0.22	0.15	0.30
3060104	65	69	0.20	0.15	0.26
3060105	66	60	0.21	0.15	0.26
3060106	67	36	0.22	0.12	0.34
3060107	68	55	0.23	0.16	0.29
3060108	69	52	0.20	0.12	0.28
3060109	70	49	0.24	0.16	0.31
3060201	71	31	0.24	0.14	0.40
3060202	72	39	0.25	0.16	0.35
3060203	73	47	0.23	0.15	0.30
3060204	74	51	0.33	0.29	0.37
3070101	75	35	0.20	0.12	0.41
3070102	76	30	0.23	0.12	0.36
3070103	77	38	0.20	0.12	0.34
3070104	78	29	0.23	0.12	0.37
3070105	79	46	0.22	0.14	0.30
3070106	80	44	0.25	0.17	0.33
3070107	81	30	0.23	0.13	0.41
3070201	82	36	0.25	0.16	0.34
3070202	83	49	0.25	0.19	0.30

Delivery Ratio used in CEAP in the South Atlantic Gulf Basin

3070203	84	44	0.38	0.34	0.45
3070204	85	50	0.23	0.17	0.30
3070205	86	37	0.32	0.28	0.40
3080101	87	54	0.23	0.17	0.29
3080102	88	54	0.24	0.18	0.31
3080103	89	50	0.28	0.24	0.33
3080201	90	35	0.44	0.40	0.52
3080202	91	25	0.46	0.41	0.57
3080203	92	27	0.47	0.37	0.57
3090101	93	59	0.22	0.17	0.29
3090102	94	21	0.42	0.36	0.58
3090103	95	30	0.30	0.23	0.44
3090201	96	1	0.95	0.95	0.95
3090202	97	39	0.34	0.29	0.42
3090203	98	2	0.79	0.75	0.83
3090204	99	36	0.34	0.30	0.43
3090205	100	40	0.34	0.26	0.41
3100101	101	55	0.23	0.18	0.29
3100102	102	38	0.34	0.29	0.40
3100201	103	35	0.37	0.31	0.45
3100202	104	38	0.30	0.23	0.38
3100203	105	29	0.31	0.23	0.43
3100204	106	44	0.30	0.25	0.35
3100205	107	39	0.31	0.25	0.39
3100206	108	41	0.35	0.30	0.44
3100207	109	46	0.30	0.23	0.35
3100208	110	47	0.24	0.16	0.30
3110101	111	43	0.32	0.24	0.43
3110102	112	48	0.35	0.31	0.42
3110103	113	39	0.26	0.19	0.38
3110201	114	42	0.22	0.14	0.35
3110202	115	33	0.22	0.11	0.34
3110203	116	32	0.24	0.14	0.40
3110204	117	39	0.23	0.14	0.32
3110205	118	36	0.28	0.20	0.37
3110206	119	51	0.24	0.17	0.29
3120001	120	40	0.26	0.17	0.35
3120002	121	33	0.27	0.19	0.36
3120003	122	34	0.24	0.15	0.36
3130001	123	56	0.22	0.16	0.28
3130002	124	45	0.21	0.13	0.28
3130003	125	42	0.22	0.13	0.29
3130004	126	36	0.24	0.16	0.32
3130005	127	50	0.21	0.13	0.27
3130006	128	30	0.24	0.14	0.38
3130007	129	37	0.24	0.16	0.35
3130008	130	43	0.25	0.18	0.32
3130009	131	38	0.25	0.18	0.34

Delivery Ratio used in CEAP in the South Atlantic Gulf Basin

3130010	132	38	0.26	0.17	0.34
3130011	133	40	0.26	0.17	0.37
3130012	134	54	0.22	0.15	0.28
3130013	135	35	0.31	0.25	0.45
3130014	136	1	0.95	0.95	0.95
3140101	137	52	0.28	0.20	0.33
3140102	138	47	0.28	0.22	0.34
3140103	139	43	0.22	0.14	0.31
3140104	140	43	0.25	0.18	0.33
3140105	141	41	0.43	0.40	0.49
3140106	142	47	0.24	0.17	0.30
3140107	143	42	0.43	0.39	0.49
3140201	144	31	0.24	0.16	0.44
3140202	145	39	0.21	0.13	0.36
3140203	146	53	0.23	0.18	0.27
3140301	147	53	0.23	0.17	0.29
3140302	148	58	0.22	0.16	0.26
3140303	149	41	0.23	0.16	0.33
3140304	150	51	0.24	0.18	0.30
3140305	151	41	0.23	0.14	0.30
3150101	152	67	0.26	0.21	0.33
3150102	153	59	0.27	0.22	0.34
3150103	154	71	0.22	0.16	0.28
3150104	155	58	0.23	0.17	0.29
3150105	156	53	0.24	0.17	0.32
3150106	157	49	0.20	0.10	0.28
3150107	158	45	0.24	0.17	0.33
3150108	159	67	0.21	0.14	0.27
3150109	160	52	0.23	0.16	0.31
3150110	161	59	0.23	0.16	0.29
3150201	162	30	0.24	0.15	0.41
3150202	163	45	0.20	0.11	0.28
3150203	164	29	0.25	0.16	0.41
3150204	165	52	0.24	0.17	0.29
3160101	166	33	0.26	0.19	0.42
3160102	167	49	0.24	0.19	0.35
3160103	168	50	0.22	0.15	0.29
3160104	169	53	0.23	0.17	0.33
3160105	170	44	0.27	0.20	0.35
3160106	171	39	0.26	0.18	0.34
3160107	172	52	0.21	0.13	0.26
3160108	173	50	0.22	0.15	0.28
3160109	174	54	0.24	0.19	0.31
3160110	175	56	0.22	0.16	0.30
3160111	176	55	0.20	0.13	0.29
3160112	177	48	0.27	0.21	0.31
3160113	178	48	0.23	0.17	0.31
3160201	179	31	0.26	0.17	0.40

Delivery Ratio used in CEAP in the South Atlantic Gulf Basin

3160202	180	50	0.24	0.18	0.29
3160203	181	40	0.24	0.17	0.35
3160204	182	44	0.25	0.17	0.33
3160205	183	48	0.27	0.21	0.32
3170001	184	58	0.25	0.20	0.30
3170002	185	50	0.22	0.15	0.28
3170003	186	44	0.27	0.20	0.37
3170004	187	52	0.22	0.15	0.32
3170005	188	42	0.22	0.13	0.31
3170006	189	51	0.29	0.23	0.35
3170007	190	51	0.22	0.15	0.29
3170008	191	54	0.21	0.14	0.28
3170009	192	52	0.25	0.18	0.31
3180001	193	46	0.23	0.17	0.37
3180002	194	42	0.23	0.16	0.33
3180003	195	64	0.23	0.19	0.31
3180004	196	60	0.23	0.17	0.30
3180005	197	59	0.20	0.14	0.29

Figure 10-2. Mean and percentiles of sediment delivery ratio (sediment delivered at 8-digit watershed outlet by sediment yield at simulation sites) estimated for cultivated simulation sites within APEX for the 8-digit watersheds in the South Atlantic Gulf Basin

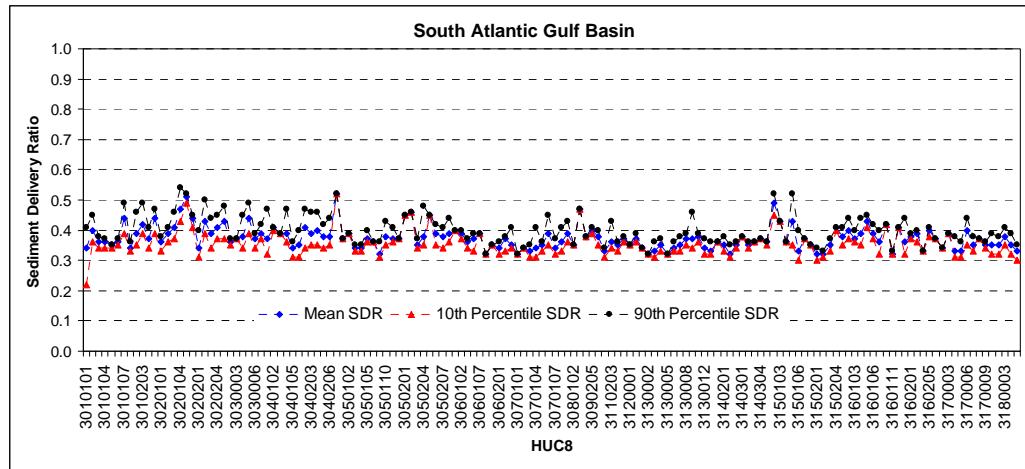
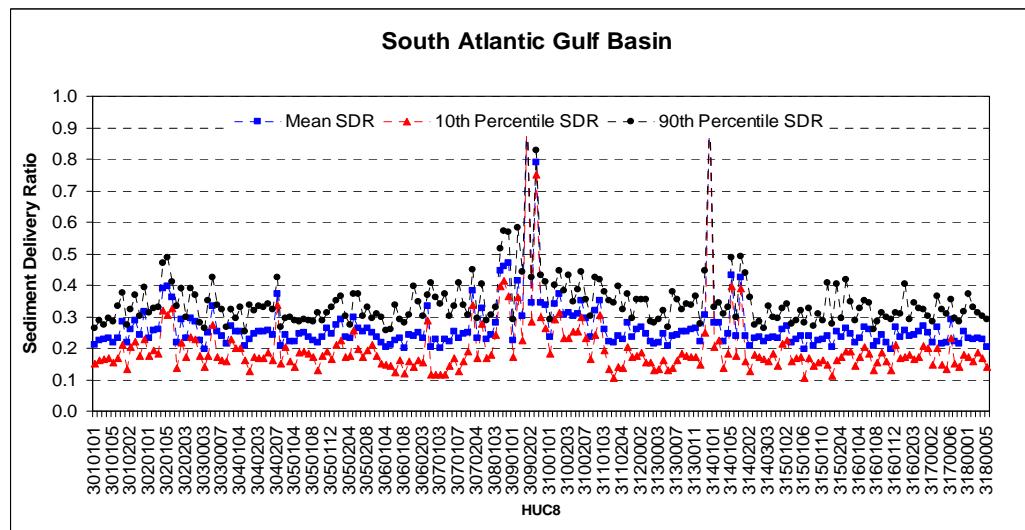


Figure 10-3. Mean and percentiles of sediment delivery ratio (sediment delivered at 8-digit watershed outlet by sediment yield at HRUs) estimated for non-cultivated land HRUs within SWAT for the 8-digit watersheds in the South Atlantic Gulf Basin



Delivery Ratio used in CEAP in the South Atlantic Gulf Basin

Chapter 11

**Delivery Ratio used in CEAP Cropland
Modeling in the Pacific Northwest River
Basin**

The APEX model is a field-scale, daily time-step model that simulates weather, farming operations, crop growth and yield, and the movement of water, soil, carbon, nutrients, sediment, and pesticides. The APEX model was used also to simulate the effects of conservation practices at the field scale (Williams and Izaurrealde, 2006; Gassman et al. 2009) in the Pacific Northwest River Basin. APEX simulates all of the basic biological, chemical, hydrological, and meteorological processes of farming systems and their interactions. Soil erosion is simulated over time, including wind erosion, sheet and rill erosion. The nitrogen, phosphorus, and carbon cycles are simulated, including chemical transformations in the soil that affect their availability for plant growth or for transport from the field.

While the APEX model was used for simulating the cultivated cropland and the SWAT model was used to simulate the non-cultivated cropland in the 8-digit watersheds of the river basin. SWAT is a physical process model with a daily time step (Arnold and Fohrer 2005; Arnold et al. 1998; Gassman et al. 2007). In SWAT, each 8-digit watershed is divided into multiple Hydrologic Response Units (HRUs) that have homogeneous land use, soil, and slope. SWAT is used to simulate the fate and transport of water, sediment, nutrients, and pesticides from various non-cropland HRUs as described in Chapter 1. The hydrologic cycle in the model is divided into two parts. The land phase of the hydrologic cycle, or upland processes, simulates the amount of water, sediment, nutrients, and pesticides delivered from the non-cropland HRUs to the outlet of each watershed. The routing phase of the hydrologic cycle, or channel processes, simulates the movement of water, sediment, nutrients, and pesticides from the outlet of the upstream watershed through the main channel network to the watershed outlet.

Not all of the soil that erodes from a field or HRUs ends up in the watershed outlet. Most of the soil eroded gets deposited on the way although the deposition is temporary. Eroded soil may deposit in lower spots, flatter lands, deposited at the edge of the field and sometimes settles at the bottom of the channel. Hence, a SDR was used to account for deposition in ditches, floodplains, and tributary stream channels during transit from the edge of the field or HRUs to the 8-digit watershed outlet in the CEAP National Assessment modeling. The SDR used in this study is a function of the ratio of the time of concentration for the HRU (land uses other than cultivated cropland) or

field (cultivated cropland) to the time of concentration for the watershed (8-digit HUC). The time of concentration for the watershed is the time from when a surface water runoff event occurs at the most distant point in the watershed to the time the surface water runoff reaches the outlet of the watershed. It is calculated by summing the overland flow time (the time it takes for flow from the remotest point in the watershed to reach the channel) and the channel flow time (the time it takes for flow in the upstream channels to reach the outlet). The time of concentration for the field is derived from APEX. The time of concentration for the HRU is derived from characteristics of the watershed, the HRU, and the proportion of total acres represented by the HRU. Consequently, each cultivated cropland sample point has a unique delivery ratio within each watershed, as does each HRU. The description of the sediment delivery ratio procedure is provided in Chapter 1.

The APEX model simulates the edge of sediment yield using a variation of MUSLE called MUST (MUSLE developed from Theory) (Williams, 1995) as described in Chapter 1. After estimating the sediment load from each APEX simulation site, the delivery ratio is applied to determine the amount of sediment that reaches the 8-digit watershed outlet from each APEX simulation site. The sediment load from apex simulation sites are aggregated for the 8-digit watershed and integrated into the SWAT model at each 8-digit watershed to estimate the water quality effects of conservation practices. In SWAT, the sediment yield for the non-cropland HRUs are estimated using the MUSLE as described in Chapter 1. After estimating the SDR for each HRU, the SDR is applied to determine the amount of sediment that reaches the 8-digit watershed outlet.

Sediment delivery ratios were estimated to account for sediment losses or deposition occurring from edge-of-field or HRUs to the 8-digit watershed outlet for each APEX simulation site in the cultivated cropland and CRP and non-cropland HRUs in the Pacific Northwest River Basin (Figure 11-1). The Pacific Northwest River Basin has a drainage area of 327 million acres. The cultivated cropland and land enrolled in the CRP General Signup is about 29 percent of the Pacific Northwest River Basin. A total of 218, 8-digit watersheds are in the Pacific Northwest River Basin (Figure 11-1). Within each 8-digit watershed, the percent of cultivated cropland and CRP area and non-cultivated cropland area varies widely across the entire

basin. A total of 1748 representative cultivated fields (922 NRI-CEAP cropland points and 826 CRP points) were setup to run using APEX. One hundred and twenty-four out of 218, 8-digit watersheds in the Pacific Northwest have no CEAP points; the 124 8-digit watersheds have zero or fewer than 10% percentage cultivated cropland, except 2 of them having 14% and 19% cultivated cropland, respectively. Non-cultivated land is distributed over 91.5 percent of the Pacific Northwest River Basin. Within each 8-digit watershed, non-cultivated land uses such as pasture, range, hay, horticulture, forest deciduous, forest mixed, forest evergreen, urban, urban construction, barren land wetland and water are simulated as HRUs in SWAT. A total of 9,143 HRUs are simulated in SWAT for the Pacific Northwest River Basin.

Each NRI-CEAP point and CRP point is unique; therefore, sediment yield and delivery ratio also vary for each cultivated cropland site simulated in an 8-digit watershed and so as for HRU. The number of CEAP sample points, and mean, 10th percentile and 90th percentile of the delivery ratios of the APEX simulation sites in the 8-digit watersheds in the Pacific Northwest River Basin are shown in Table 11-1 and Figure 11-2. Table 11-2 shows number of HRUs and mean, 10th percentile and 90th percentile of the SDRs estimated for the non-cultivated land HRUs in the 8-digit watersheds in the Pacific Northwest River Basin (Figure 11-1). The mean, 10th and 90th percentile

SDRs for the non-cropland HRUs are plotted in Figure 11-3.

In addition to SDR, an enrichment ratio was used to simulate organic nitrogen, organic phosphorus, and sediment-attached pesticide transport in ditches, floodplains, and tributary stream channels during transit from the edge of the field to the outlet. The enrichment ratio was defined as the organic nitrogen, organic phosphorus, and sediment attached pesticide concentration from the edge-of-field divided by the concentration at the 8-digit watershed outlet. The enrichment ratio is estimated for each APEX simulation site and SWAT HRUs and it varies from 0.5 to 1.5 (Average 1.0). As sediment is transported from the edge-of-field to the watershed outlet, coarse sediments are deposited first while more of the fine sediment that hold organic particles remain in suspension, thus enriching the organic concentrations delivered to the watershed outlet.

A separate delivery ratio is used to simulate the transport of nitrate nitrogen, soluble phosphorus, and soluble pesticides. In general, the proportion of soluble nutrients and pesticides delivered to rivers and streams is higher than the proportion attached to sediments because they are not subject to sediment deposition.

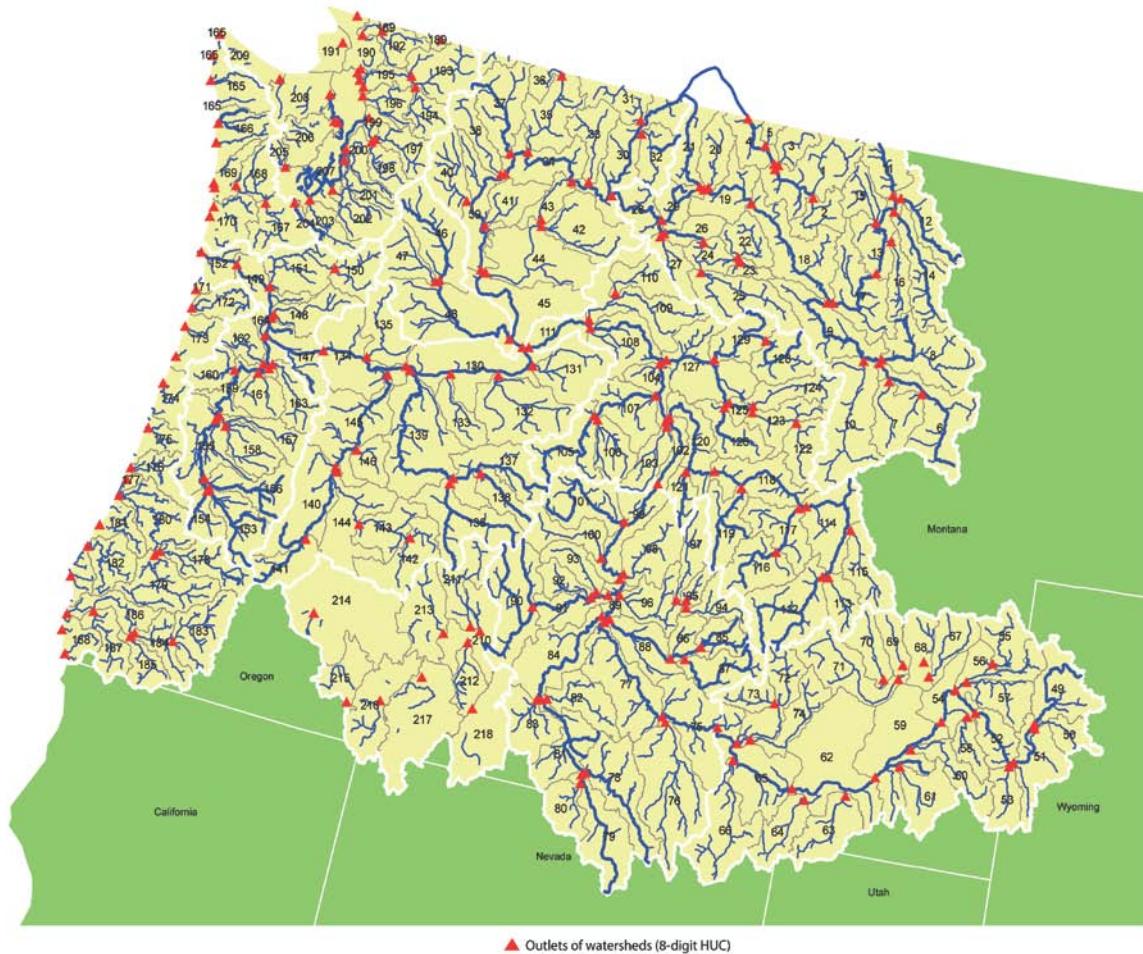


Figure 11-1. Map of the 8-digit watersheds in the Pacific North West River Basin

Table 11-1. Mean and percentiles of sediment delivery ratio (sediment delivered at 8-digit watershed outlet by sediment yield at simulation sites) estimated for cultivated simulation sites within APEX for the 8-digit watersheds in the Pacific Northwest River Basin.

HUC	Cropland		CRP		Crop + CRP			
	Points	Mean_S DR	Points	Mean_S DR	Points	Mean_S DR	10 th percentile	90 th percentile
17010104	5	0.53	2	0.38	7	0.49	0.37	0.60
17010203	3	0.38			3	0.38	0.38	0.38
17010204	1	0.50			1	0.50	0.50	0.50
17010208	8	0.45			8	0.45	0.41	0.50
17010210	3	0.44			3	0.44	0.43	0.45
17010212	1	0.36			1	0.36	0.36	0.36
17010303	1	0.47	3	0.35	4	0.38	0.35	0.47
17010304	1	0.35			1	0.35	0.35	0.35
17010305	5	0.44			5	0.44	0.38	0.47
17010306	16	0.43	8	0.27	24	0.38	0.21	0.48
17010307	3	0.44	7	0.24	10	0.30	0.22	0.50
17020001	3	0.52	1	0.24	4	0.45	0.24	0.65
17020003	1	0.50			1	0.50	0.50	0.50
17020004			1	0.21	1	0.21	0.21	0.21
17020005	3	0.41	18	0.26	21	0.29	0.24	0.41
17020006	3	0.43			3	0.43	0.40	0.46
17020010	3	0.40	10	0.25	13	0.29	0.23	0.41
17020012	6	0.39	21	0.26	27	0.29	0.24	0.41
17020013	26	0.35	12	0.27	38	0.32	0.26	0.37
17020014	5	0.39	1	0.25	6	0.37	0.25	0.41
17020015	26	0.38	34	0.24	60	0.30	0.21	0.39
17020016	35	0.41	36	0.24	71	0.32	0.21	0.43
17030001	3	0.41			3	0.41	0.40	0.41
17030003	8	0.39	11	0.21	19	0.29	0.19	0.41
17040104	2	0.42	13	0.40	15	0.40	0.33	0.46
17040105	1	0.38			1	0.38	0.38	0.38
17040201	39	0.41	11	0.36	50	0.40	0.35	0.46
17040202	2	0.40			2	0.40	0.39	0.40
17040203	9	0.48	12	0.45	21	0.46	0.42	0.50
17040204	36	0.49	33	0.44	69	0.46	0.43	0.58
17040205			8	0.41	8	0.41	0.39	0.42
17040206	25	0.41	45	0.36	70	0.38	0.34	0.44
17040207	1	0.42	3	0.37	4	0.38	0.36	0.42
17040208	11	0.39	78	0.37	89	0.37	0.34	0.41
17040209	51	0.38	45	0.33	96	0.36	0.32	0.39
17040210	9	0.39	12	0.40	21	0.40	0.36	0.47
17040211	8	0.45			8	0.45	0.41	0.48

Delivery Ratio used in CEAP in the Pacific Northwest River Basin

17040212	38	0.43	1	0.42	39	0.43	0.40	0.44
17040213	1	0.42	2	0.40	3	0.41	0.40	0.42
17040215	1	0.60			1	0.60	0.60	0.60
17040218	1	0.47			1	0.47	0.47	0.47
17040219	5	0.45			5	0.45	0.43	0.48
17040220	4	0.43	6	0.42	10	0.43	0.40	0.44
17040221	5	0.47	2	0.44	7	0.46	0.44	0.50
17050101	5	0.39	1	0.39	6	0.39	0.35	0.44
17050103	9	0.39			9	0.39	0.35	0.44
17050114	29	0.43			29	0.43	0.39	0.53
17050115	14	0.53			14	0.53	0.45	0.60
17050117	1	0.47			1	0.47	0.47	0.47
17050122	18	0.45			18	0.45	0.41	0.52
17050124	5	0.43	4	0.39	9	0.41	0.38	0.47
17050201	1	0.55	1	0.28	2	0.41	0.28	0.55
17050203	1	0.44			1	0.44	0.44	0.44
17060103	7	0.50	14	0.34	21	0.39	0.31	0.51
17060104	6	0.43	3	0.38	9	0.41	0.38	0.45
17060105			2	0.41	2	0.41	0.40	0.43
17060106	1	0.47			1	0.47	0.47	0.47
17060107	39	0.41	76	0.23	115	0.29	0.22	0.41
17060108	25	0.36	10	0.24	35	0.32	0.19	0.41
17060109	13	0.36	11	0.22	24	0.30	0.19	0.40
17060110	4	0.37	39	0.22	43	0.23	0.19	0.32
17060209	1	0.40			1	0.40	0.40	0.40
17060305	4	0.43			4	0.43	0.40	0.52
17060306	24	0.40	16	0.35	40	0.38	0.32	0.42
17070101	20	0.41	26	0.28	46	0.34	0.24	0.44
17070102	33	0.42	51	0.21	84	0.29	0.19	0.44
17070103	23	0.37	28	0.30	51	0.33	0.28	0.38
17070104	19	0.40	27	0.29	46	0.34	0.28	0.42
17070105	21	0.44	3	0.39	24	0.44	0.39	0.53
17070106	3	0.42	5	0.26	8	0.32	0.25	0.43
17070204	37	0.36	50	0.30	87	0.33	0.28	0.39
17070306	10	0.37	17	0.33	27	0.35	0.29	0.43
17070307	1	0.47	3	0.30	4	0.34	0.28	0.47
17080001	1	0.65			1	0.65	0.65	0.65
17090003	41	0.41			41	0.41	0.38	0.46
17090005	3	0.46			3	0.46	0.44	0.47
17090006	5	0.48			5	0.48	0.47	0.49
17090007	14	0.46			14	0.46	0.42	0.49
17090008	23	0.45			23	0.45	0.40	0.52
17090009	3	0.53			3	0.53	0.47	0.62
17090010	10	0.45			10	0.45	0.40	0.56
17090012	3	0.52			3	0.52	0.50	0.55
17100303			2	0.32	2	0.32	0.30	0.34

17100308	1	0.51			1	0.51	0.51	0.51
17100309	1	0.49			1	0.49	0.49	0.49
17110001	1	0.68			1	0.68	0.68	0.68
17110002	1	0.54			1	0.54	0.54	0.54
17110004	7	0.58			7	0.58	0.52	0.62
17110007	3	0.60			3	0.60	0.60	0.60
17110009	1	0.50			1	0.50	0.50	0.50
17110011	1	0.48			1	0.48	0.48	0.48
17110014	1	0.48			1	0.48	0.48	0.48
17110019	10	0.48			10	0.48	0.41	0.57
17120002			1	0.34	1	0.34	0.34	0.34

Figure 11-2. Mean and percentiles of sediment delivery ratio (sediment delivered at 8-digit watershed outlet by sediment yield at simulation sites) estimated for cultivated simulation sites within APEX for the 8-digit watersheds in the Pacific Northwest River Basin

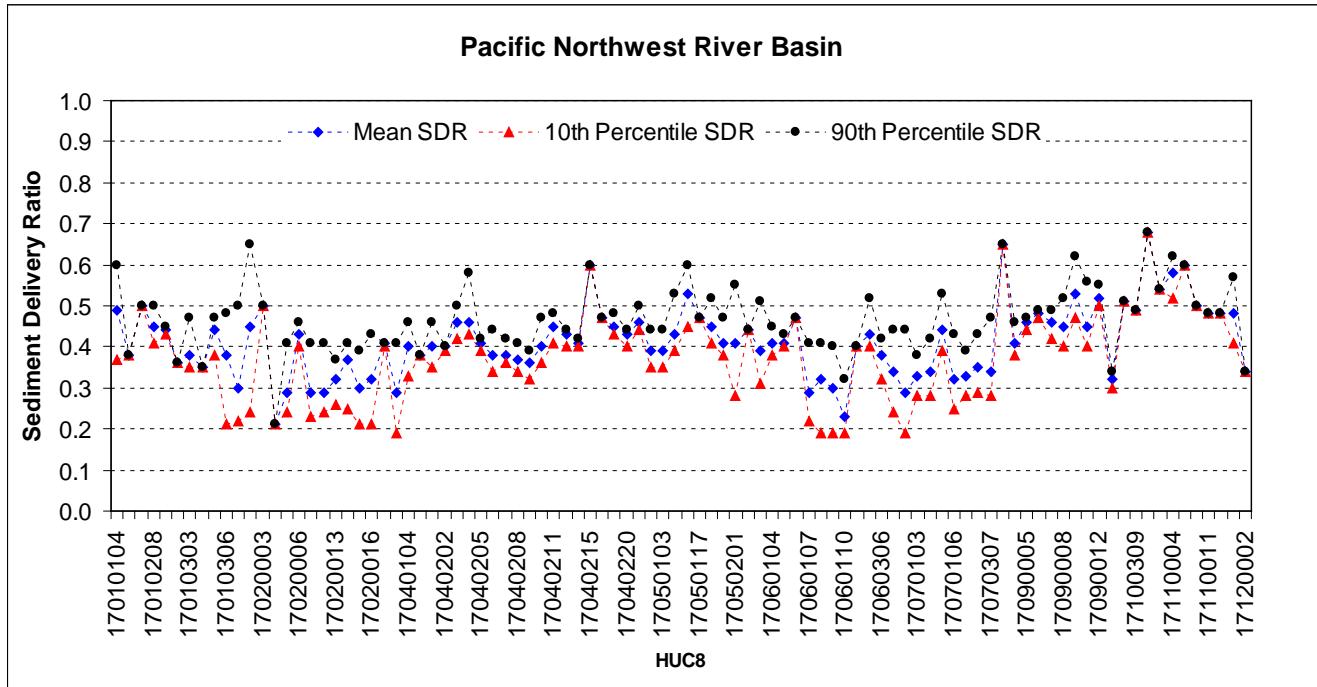


Table 11-2. Mean and percentiles of sediment delivery ratio (sediment delivered at 8-digit watershed outlet by sediment yield at HRUs) estimated for non-cultivated land HRUs within SWAT for the 8-digit watersheds in the Pacific Northwest River Basin

HUC	Subbasin	Number_of non-cropland HRUs simulated within SWAT	Mean SDR	10 th Percentile SDR	90 th Percentile SDR
17010101	1	55	0.206	0.133	0.265
17010102	2	43	0.216	0.125	0.322
17010103	3	28	0.224	0.107	0.397
17010104	4	35	0.234	0.134	0.348
17010105	5	24	0.256	0.150	0.543
17010201	6	47	0.187	0.078	0.317
17010202	7	50	0.199	0.109	0.291
17010203	8	55	0.179	0.087	0.272
17010204	9	58	0.173	0.092	0.239
17010205	10	53	0.175	0.083	0.225
17010206	11	40	0.208	0.104	0.325
17010207	12	42	0.191	0.078	0.300
17010208	13	42	0.220	0.110	0.330
17010209	14	48	0.173	0.073	0.284
17010210	15	42	0.209	0.107	0.313
17010211	16	33	0.217	0.101	0.354
17010212	17	53	0.179	0.080	0.231
17010213	18	59	0.166	0.074	0.251
17010214	19	45	0.224	0.137	0.312
17010215	20	43	0.199	0.099	0.309
17010216	21	46	0.190	0.090	0.292
17010301	22	31	0.209	0.095	0.353
17010302	23	27	0.244	0.130	0.462
17010303	24	38	0.237	0.137	0.333
17010304	25	55	0.179	0.085	0.246
17010305	26	25	0.227	0.104	0.485
17010306	27	31	0.245	0.139	0.392
17010307	28	37	0.211	0.098	0.324
17010308	29	37	0.245	0.152	0.351
17020001	30	47	0.240	0.168	0.330
17020002	31	39	0.258	0.172	0.359
17020003	32	39	0.205	0.100	0.310
17020004	33	49	0.205	0.118	0.276
17020005	34	44	0.210	0.104	0.290
17020006	35	51	0.210	0.132	0.281
17020007	36	37	0.261	0.174	0.371
17020008	37	51	0.188	0.096	0.286
17020009	38	51	0.191	0.094	0.277

Delivery Ratio used in CEAP in the Pacific Northwest River Basin

17020010	39	42	0.219	0.110	0.286
17020011	40	47	0.198	0.111	0.279
17020012	41	29	0.216	0.083	0.381
17020013	42	26	0.207	0.080	0.394
17020014	43	26	0.204	0.090	0.501
17020015	44	24	0.218	0.079	0.465
17020016	45	26	0.221	0.101	0.446
17030001	46	50	0.195	0.106	0.281
17030002	47	44	0.202	0.102	0.317
17030003	48	43	0.191	0.083	0.322
17040101	49	52	0.184	0.085	0.265
17040102	50	40	0.214	0.108	0.326
17040103	51	53	0.191	0.103	0.264
17040104	52	45	0.193	0.085	0.282
17040105	53	47	0.204	0.104	0.278
17040201	54	22	0.241	0.101	0.420
17040202	55	44	0.198	0.099	0.270
17040203	56	34	0.248	0.158	0.341
17040204	57	33	0.244	0.138	0.361
17040205	58	38	0.223	0.122	0.316
17040206	59	30	0.227	0.103	0.360
17040207	60	41	0.206	0.096	0.300
17040208	61	33	0.208	0.082	0.340
17040209	62	25	0.210	0.085	0.434
17040210	63	39	0.199	0.093	0.303
17040211	64	35	0.217	0.099	0.311
17040212	65	34	0.225	0.114	0.314
17040213	66	56	0.193	0.114	0.253
17040214	67	34	0.222	0.122	0.335
17040215	68	32	0.244	0.149	0.366
17040216	69	35	0.231	0.124	0.347
17040217	70	48	0.201	0.099	0.301
17040218	71	43	0.185	0.066	0.263
17040219	72	46	0.214	0.144	0.265
17040220	73	40	0.209	0.108	0.284
17040221	74	35	0.244	0.157	0.384
17050101	75	45	0.207	0.111	0.290
17050102	76	52	0.215	0.176	0.277
17050103	77	50	0.210	0.164	0.271
17050104	78	55	0.206	0.119	0.277
17050105	79	56	0.188	0.088	0.272
17050106	80	27	0.234	0.106	0.386
17050107	81	46	0.228	0.126	0.291
17050108	82	41	0.220	0.123	0.307
17050109	83	41	0.229	0.127	0.332
17050110	84	49	0.198	0.115	0.294
17050111	85	43	0.218	0.121	0.327

Delivery Ratio used in CEAP in the Pacific Northwest River Basin

17050112	86	38	0.233	0.133	0.376
17050113	87	54	0.184	0.092	0.270
17050114	88	46	0.213	0.120	0.287
17050115	89	21	0.360	0.268	0.554
17050116	90	53	0.190	0.099	0.264
17050117	91	37	0.230	0.134	0.342
17050118	92	28	0.297	0.197	0.429
17050119	93	31	0.246	0.115	0.390
17050120	94	51	0.201	0.112	0.270
17050121	95	28	0.247	0.134	0.466
17050122	96	50	0.224	0.170	0.300
17050123	97	45	0.195	0.097	0.285
17050124	98	50	0.202	0.108	0.265
17050201	99	50	0.229	0.143	0.282
17050202	100	42	0.206	0.096	0.287
17050203	101	39	0.219	0.118	0.319
17060101	102	36	0.233	0.120	0.376
17060102	103	43	0.209	0.107	0.288
17060103	104	35	0.264	0.156	0.353
17060104	105	47	0.203	0.099	0.264
17060105	106	33	0.234	0.114	0.320
17060106	107	50	0.208	0.126	0.291
17060107	108	28	0.243	0.107	0.355
17060108	109	20	0.244	0.098	0.540
17060109	110	19	0.257	0.091	0.411
17060110	111	22	0.233	0.093	0.491
17060201	112	54	0.177	0.085	0.235
17060202	113	49	0.208	0.118	0.317
17060203	114	59	0.209	0.138	0.274
17060204	115	60	0.189	0.100	0.253
17060205	116	53	0.200	0.118	0.272
17060206	117	55	0.192	0.102	0.262
17060207	118	54	0.181	0.097	0.288
17060208	119	52	0.183	0.090	0.295
17060209	120	54	0.180	0.084	0.272
17060210	121	46	0.214	0.126	0.309
17060301	122	34	0.223	0.105	0.317
17060302	123	31	0.249	0.140	0.330
17060303	124	38	0.205	0.088	0.295
17060304	125	20	0.326	0.199	0.631
17060305	126	33	0.220	0.098	0.330
17060306	127	31	0.239	0.126	0.351
17060307	128	49	0.192	0.086	0.243
17060308	129	49	0.197	0.103	0.273
17070101	130	30	0.240	0.119	0.376
17070102	131	24	0.249	0.112	0.430
17070103	132	36	0.213	0.096	0.327

Delivery Ratio used in CEAP in the Pacific Northwest River Basin

17070104	133	28	0.239	0.104	0.363
17070105	134	41	0.231	0.144	0.330
17070106	135	40	0.213	0.112	0.319
17070201	136	53	0.194	0.102	0.264
17070202	137	55	0.185	0.097	0.265
17070203	138	38	0.211	0.107	0.349
17070204	139	54	0.180	0.076	0.243
17070301	140	47	0.224	0.143	0.305
17070302	141	29	0.208	0.101	0.320
17070303	142	41	0.197	0.105	0.267
17070304	143	46	0.202	0.108	0.294
17070305	144	32	0.195	0.097	0.299
17070306	145	52	0.186	0.087	0.263
17070307	146	29	0.253	0.128	0.434
17080001	147	46	0.276	0.212	0.326
17080002	148	47	0.204	0.121	0.276
17080003	149	45	0.239	0.171	0.305
17080004	150	42	0.219	0.129	0.329
17080005	151	45	0.213	0.143	0.304
17080006	152	49	0.235	0.169	0.301
17090001	153	51	0.193	0.111	0.288
17090002	154	44	0.206	0.119	0.298
17090003	155	56	0.184	0.118	0.254
17090004	156	44	0.199	0.114	0.298
17090005	157	40	0.210	0.133	0.339
17090006	158	53	0.205	0.133	0.270
17090007	159	49	0.242	0.183	0.324
17090008	160	47	0.209	0.125	0.319
17090009	161	49	0.240	0.177	0.344
17090010	162	50	0.215	0.132	0.308
17090011	163	45	0.196	0.106	0.316
17090012	164	42	0.262	0.196	0.351
17100101	165	44	0.215	0.128	0.313
17100102	166	50	0.213	0.118	0.293
17100103	167	45	0.204	0.119	0.306
17100104	168	45	0.230	0.156	0.307
17100105	169	38	0.283	0.212	0.389
17100106	170	42	0.205	0.101	0.302
17100201	171	19	0.338	0.227	0.545
17100202	172	55	0.179	0.094	0.268
17100203	173	53	0.210	0.138	0.294
17100204	174	52	0.212	0.143	0.297
17100205	175	44	0.211	0.123	0.316
17100206	176	50	0.183	0.090	0.271
17100207	177	33	0.273	0.165	0.410
17100301	178	45	0.195	0.105	0.287
17100302	179	52	0.185	0.100	0.271

Delivery Ratio used in CEAP in the Pacific Northwest River Basin

17100303	180	49	0.182	0.089	0.270
17100304	181	51	0.208	0.121	0.312
17100305	182	52	0.207	0.138	0.275
17100307	183	48	0.199	0.113	0.282
17100308	184	55	0.216	0.149	0.280
17100309	185	46	0.203	0.115	0.325
17100310	186	39	0.206	0.111	0.339
17100311	187	46	0.193	0.098	0.292
17100312	188	45	0.206	0.116	0.326
17110001	189	29	0.385	0.317	0.547
17110002	190	50	0.239	0.182	0.310
17110003	191	1	0.950	0.950	0.950
17110004	192	45	0.235	0.174	0.338
17110005	193	49	0.211	0.127	0.292
17110006	194	38	0.214	0.113	0.393
17110007	195	45	0.257	0.186	0.352
17110008	196	42	0.220	0.135	0.348
17110009	197	41	0.218	0.135	0.362
17110010	198	46	0.217	0.154	0.312
17110011	199	39	0.229	0.149	0.348
17110012	200	42	0.239	0.150	0.356
17110013	201	43	0.218	0.134	0.316
17110014	202	46	0.233	0.175	0.309
17110015	203	47	0.236	0.181	0.300
17110016	204	28	0.355	0.272	0.532
17110017	205	33	0.240	0.142	0.459
17110018	206	41	0.257	0.168	0.354
17110019	207	53	0.228	0.173	0.289
17110020	208	43	0.247	0.181	0.336
17110021	209	36	0.246	0.162	0.485
17120001	210	40	0.256	0.160	0.348
17120002	211	58	0.190	0.110	0.254
17120003	212	36	0.225	0.118	0.341
17120004	213	50	0.197	0.110	0.294
17120005	214	52	0.179	0.075	0.278
17120006	215	41	0.195	0.080	0.301
17120007	216	45	0.193	0.088	0.311
17120008	217	44	0.181	0.080	0.315
17120009	218	44	0.177	0.067	0.315

Figure 11-3. Mean and percentiles of sediment delivery ratio (sediment delivered at 8-digit watershed outlet by sediment yield at HRUs) estimated for non-cultivated land HRUs within SWAT for the 8-digit watersheds in the Pacific Northwest River Basin

