

TRIM.FaTE USER'S GUIDE

MODULE 11: ESTIMATING RUNOFF AND EROSION FRACTIONS FOR SURFACE SOIL¹

1. BACKGROUND

Runoff and erosion are important advective processes that facilitate the transport of pollutants in soil. In a natural system, runoff is the overland transport of water on top of the surface soil, and erosion is the transport of surface soil particles moved via runoff water. Both processes can lead to the movement of chemical pollutants: runoff by the transport of chemicals dissolved in the runoff water, and erosion by the transport of chemicals sorbed to soil particles.

The chemical mass transported via runoff and erosion in TRIM.FaTE originates as mass within a surface soil compartment (i.e., the sending compartment). Advective transport of mass via runoff and erosion is represented by algorithms on links between that surface soil compartment and an adjacent surface soil compartment, surface water compartment, or (if the sending compartment is on the edge of the modeling region) soil advection sink. Consequently, the total chemical mass transported from a single surface soil sending compartment via these processes is apportioned between any receiving compartments.

To calculate advective transport of a chemical due to runoff and erosion in TRIM.FaTE, the user must specify input values for several parameters. If relying on the algorithms currently available in the TRIM.FaTE library, the user must define the total average runoff rate (i.e., volume of runoff water transported per square meter of surface soil per day) and the total average erosion rate (i.e., mass of surface soil particles transported per square meter of surface soil per day) for each surface soil compartment. Examples of regional estimates for these values are presented in McKone et al. (2001). The surface soil area available for runoff and surface soil available for erosion must also both be defined for each compartment to account for impermeable or other surfaces that do not contribute to runoff and/or erosion. The runoff and erosion rate and the surface area available for runoff and erosion are all compartment properties in a TRIM.FaTE scenario (i.e., these properties are set at the compartment level).

In addition, both the fraction of total runoff and fraction of total erosion transported to compartments associated with adjacent volume elements must be defined for each link between a surface soil compartment and the appropriate receiving compartment(s) (i.e., surface soil, surface water, or soil advection sink). These fractions are link properties (i.e., are set at the link level). The determination of these runoff and erosion fractions is the subject of this module.

2. ESTIMATING RUNOFF AND EROSION FRACTIONS

It is the responsibility of the TRIM.FaTE user to estimate runoff and erosion fractions. These parameters are dependent on the site-specific compartment spatial layout being used and the local hydrology; thus, values cannot be readily obtained from the literature. To simplify this

¹Descriptions of library-specific algorithms and properties presented in this module pertain to the July 2005 version of the TRIM.FaTE Public Reference Library.

step, the user may want to take into account local topography and hydrology in designing the parcel layout. Depending on the purpose for the simulation, it may be appropriate to design the parcel boundaries to be consistent with site-specific watershed boundaries to reduce the number of calculations required to assign the fractions of total runoff and total erosion transported between adjacent compartments. The values for these properties are entered as real number inputs into TRIM.FaTE. These runoff and erosion parameters (and their corresponding property names in the TRIM.FaTE library, in parentheses) that are discussed further in this module include:

- **Fraction of total runoff** for each link between a surface soil compartment and all adjacent surface soil and surface water compartments or sinks (*FractionofTotalRunoff*); and
- **Fraction of total erosion** for each link between a surface soil compartment and all adjacent surface soil and surface water compartments or sinks (*FractionofTotalErosion*).

For the purposes of this discussion, the fractions for runoff and for erosion are treated in the same manner; it is assumed that erosion occurs as sediment loads are carried off by surface water during runoff, and thus the two advective processes occur simultaneously in the same direction. TRIM.FaTE can, however, accept different values for these two parameters if the user determines that is appropriate.

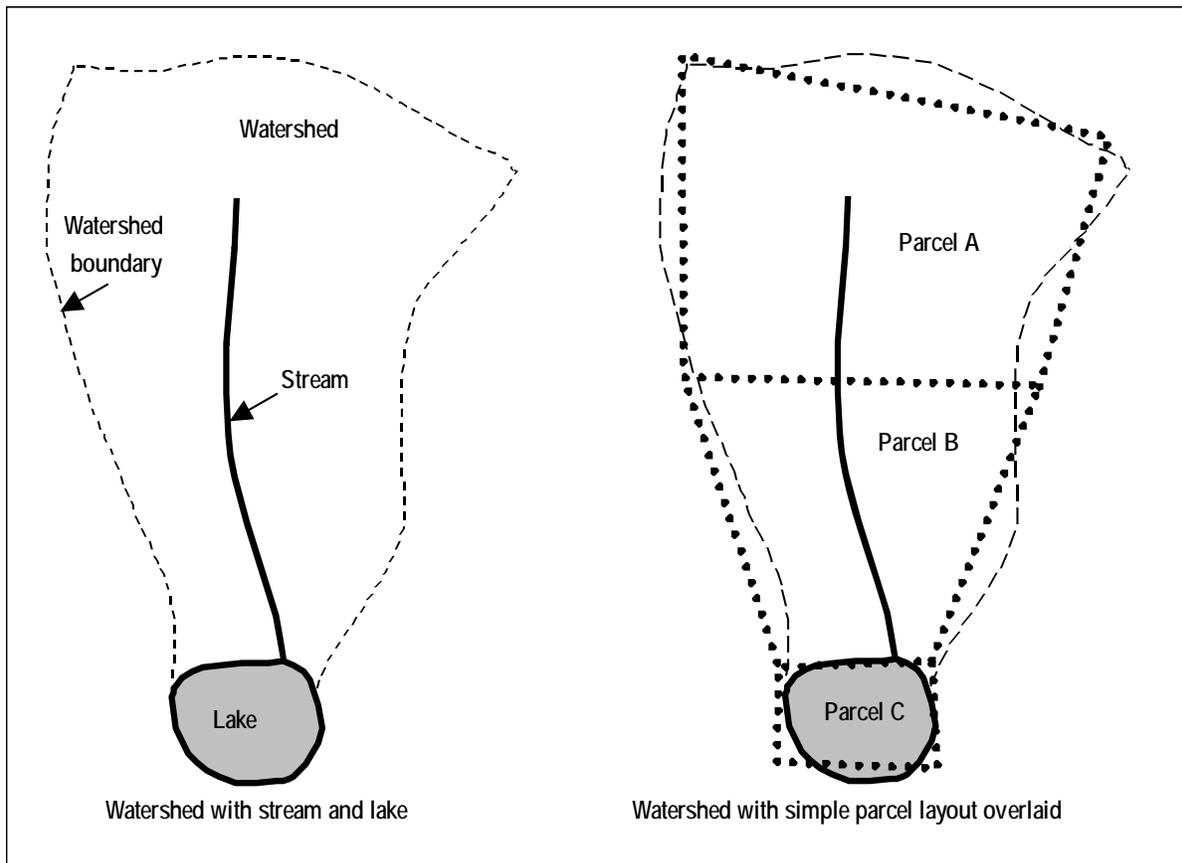
Various methods can be used to estimate runoff and erosion fractions, from simple to complex. All methods require consideration of the surface parcel spatial layout of the modeling region and topographic maps of the area. A relatively straightforward, non-resource-intensive approach would involve professional judgment based on inspection of ridge lines and water body locations in relation to the surface parcel layout. Such an approach may be adequate for some TRIM.FaTE applications; others may require more in-depth methods.

As an example, see Figure 1 for a simple modeling region consisting of a single watershed containing a stream and a lake. The region has been divided into three parcels for TRIM.FaTE modeling, including two surface soil parcels (Parcels A and B) and one surface water parcel (Parcel C). For this example, surface soil compartments named “SS_A” and “SS_B” have been assigned to the volume elements in Parcels A and B, respectively. A surface water compartment named “SW_C” has been assigned to the volume element in Parcel C. Based on the topography of the modeling region, the user estimates that 100 percent of the erosion and runoff leaving SS_A is transported to SS_B, and 100 percent of the erosion and runoff leaving SS_B is transported to SW_C. Therefore, the user could set both the *FractionofTotalRunoff* and *FractionofTotalErosion* link properties as follows:

- For the link between SS_A and SS_B: 1.0.
- For the link between SS_B and SW_C: 1.0.

By setting these link property values to 1.0, all chemical transport via erosion and runoff processes in this simple modeling region have been accounted for.

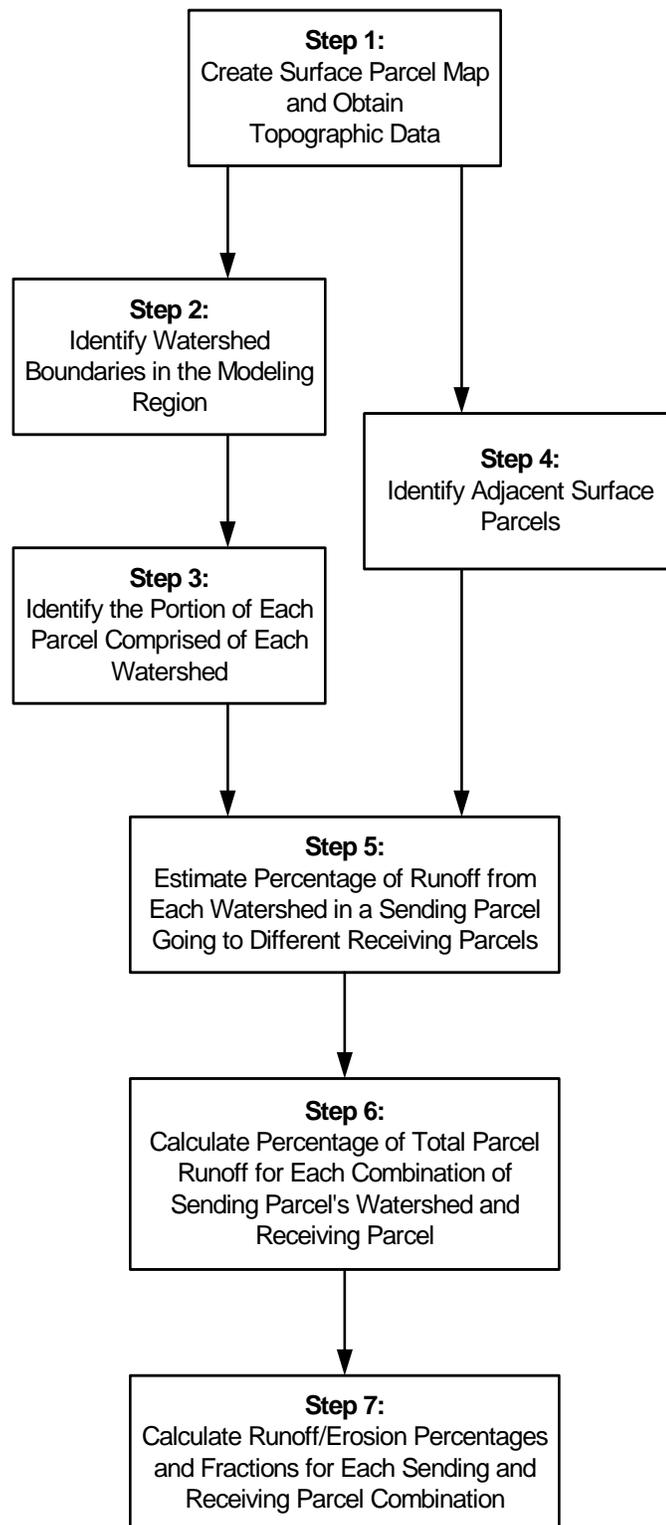
Figure 1
Example Modeling Region with Parcel Layout



A method for estimating values for these parameters in a more complex parcel layout or application is summarized in the flow chart in Figure 2. This method is presented as an example and a reference point for the user; many variants of this approach, both simpler and more complex, are possible. This method uses information on watersheds and surface elevation, together with the spatial layout of the surface parcels, to estimate the percentage of runoff or erosion originating in a surface soil compartment (i.e., the sending compartment) that is sent to each neighboring compartment (i.e., the receiving compartment or sink). A value must be determined for runoff and erosion for the link at each interface involving a surface soil compartment (i.e., between adjacent surface soil compartments, between adjacent surface soil and surface water compartments, and between a surface soil compartment at the edge of the modeling region and the soil advection sink outside of the modeling region) in the spatial layout. Thus, as the spatial layout becomes more complex through the inclusion of additional parcels, additional values for the fraction of total runoff/erosion are needed as model inputs.

An illustrative example following the methodical method summarized in Figure 2 is presented in Appendix A of this module.

Figure 2
Illustrative Stepwise Approach to Estimating Runoff and Erosion Fractions



3. REFERENCES

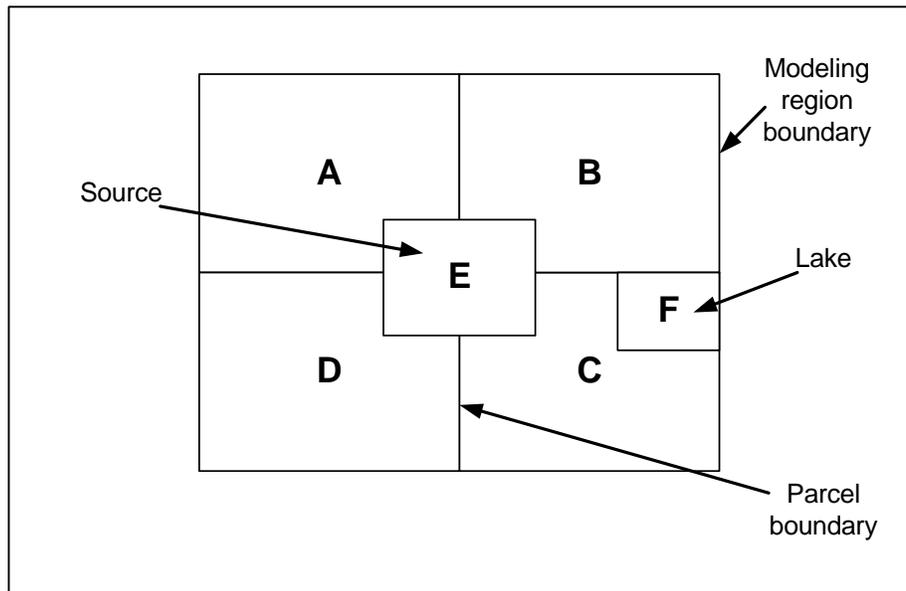
McKone, T.E., A.B. Bodnar, and E.G. Hertwich. 2001. Development and evaluation of State-specific landscape data sets for multimedia source-to-dose models. University of California at Berkeley. Supported by U.S. Environmental Protection Agency (Sustainable Technology Division, National Risk Management Research Laboratory and National Exposure Research Laboratory) and Environmental Defense Fund. July. LBNL-43722.

APPENDIX A
ILLUSTRATIVE STEPWISE APPROACH TO ESTIMATING EROSION AND
RUNOFF FRACTIONS: AN EXAMPLE

A.1 Step 1: Create a Surface Parcel Map and Obtain Topographic Maps

Before attempting to estimate runoff erosion fractions, the final surface parcel layout map for the modeling region should be completed. This map generally will be in a GIS format. As an example, Figure A-1 represents a simple parcel layout which depicts the source parcel (E), a surface water parcel (F), and four surface soil parcels (A, B, C, and D). Note that the parcel layout used in this example has been constructed for demonstrative purposes only and should not necessarily be considered a “reasonable” parcel layout (for example, it may be appropriate to position parcel boundaries closer to the actual watershed boundaries at the site). The user will also need a detailed topographic map for the site, such as the 7.5 minute series maps published by the U.S. Geological Survey (USGS) (available for purchase directly from USGS at http://mcmweb.er.usgs.gov/topomaps/ordering_maps.html).

Figure A-1
Simple Parcel Layout



NOTE ABOUT TERMINOLOGY: PARCELS AND COMPARTMENTS

To estimate runoff/erosion fractions, the user needs a two-dimensional representation of the ground-level compartment layout (i.e., a map comprised of the horizontal aspects of surface soil and surface water compartments). Because the locations of these compartments in TRIM.FaTE are defined by the surface parcel layout, it is convenient to use this parcel layout as a base “map” for estimating the runoff/erosion fractions. For convenience, the following discussion uses this terminology in referring to “sending parcels” (representing the sending surface soil compartments) and “receiving parcels” (representing the three types of receiving compartments). However, the user should be aware that in TRIM.FaTE these mass transport processes occur between linked compartments (not parcels), and the fractions that the user calculates are actually properties of the links between these compartments.

A.2 Step 2: Identify Watershed Boundaries in the Modeling Region

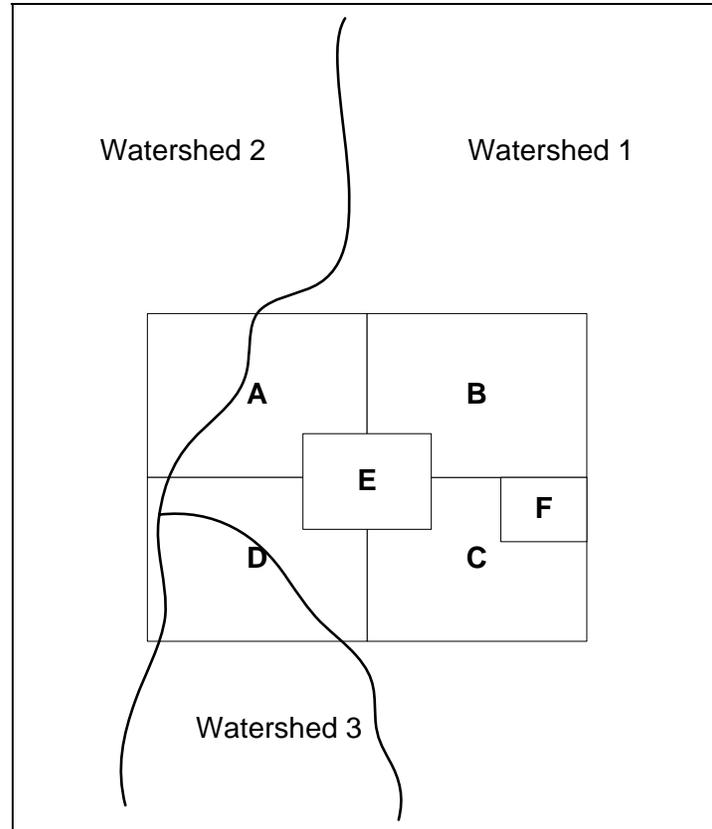
For the second step of the process, the user identifies watersheds within the modeling region and defines the watershed boundaries on the parcel layout map. Maps of watershed boundaries can be found on the Internet on the USGS Water Resources web page entitled “Hydrologic Unit Maps,” which is located at <http://water.usgs.gov/GIS/huc.html>. The USGS defines a watershed as “a geographic area representing part or all of a surface drainage basin, a combination of drainage basins, or a distinct hydrologic feature.” These watersheds are the smallest hydrologic units defined by USGS at this time. It is the responsibility of the user to ensure that the scale and size selected to define the watersheds within a modeling region is appropriate for a given TRIM.FaTE application. For convenience in the subsequent steps, the user should assign each watershed an identifying number or name.

After the watersheds have been identified, the user can create a transparent map overlay showing the watershed boundaries and surface soil and surface water parcel boundaries, scaled to the topographic map so that the two can be directly compared. This process can be performed using GIS tools by scaling and aligning the watershed and parcel map data with the hard copy of the topographic map available to the user. Note that this step also can be done entirely with GIS overlays consisting of a watershed map superimposed on a topographic elevation map; however, in some cases the resolution of the topographic map may be insufficient. The simplified example parcel layout introduced above with watershed boundaries overlaid is presented in Figure A-2. Parcel A includes both watersheds 1 and 2, and Parcel B is entirely contained in watershed 1. The topographic data for this area are not displayed in Figure A-2 for simplicity.

A.3 Step 3: Identify the Portion of Each Parcel Comprised of Each Watershed

The user then identifies and measures the watershed areas located either wholly or partly within each surface soil parcel. The percentage of the parcel’s surface area covered by each watershed can be calculated using GIS software. It is recommended that the user create a table (e.g., in a spreadsheet program) to keep track of the surface soil parcels (i.e., sending parcels), the watershed number (or name), and the percentage of the parcel that is covered by each watershed. This table will help the user to perform calculations described in subsequent

**Figure A-2
Parcel Layout with Watersheds Overlaid**



steps. Table A-1 below provides an example of how the table might be arranged for the sample watersheds defined above. This table includes sample data for estimating runoff/erosion for two parcels, A and B, that are located in an area with two watersheds, 1 and 2 (see Figure A-2). Note that the example depicted in Figure A-2 includes more than two parcels; estimates and calculations are shown for only Parcels A and B. Based on the map in Figure A-2 and as illustrated in Table A-1, Parcel A contains portions of both watersheds; Watershed 1 covers 60 percent of Parcel A, and Watershed 2 covers the remaining 40 percent of Parcel A. Watershed 1 covers 100 percent of Parcel B.

Table A-1
Sending Surface Soil Parcels, Watersheds, and Watershed Percentages

[Step 3]	[Step 3]	[Step 3]
Sending Parcel (corresponds to a surface soil compartment)	Watershed	Percent of Parcel Covered by Watershed
A	1	60
A	2	40
B	1	100
C	etc.	etc.

A.4 Step 4: Identify Adjacent Surface Parcels

For each surface soil parcel (i.e., the *sending* compartment on the link for runoff/erosion; listed in the first column of Table A-1), the user determines all neighboring parcels (i.e., potential *receiving* compartments, either surface soil or surface water) based on the existence of a shared border. The edge of the modeling region should also be considered because runoff/erosion can transport mass out of the modeling region and into one or more soil advection sinks (recall that these sinks are established by TRIM.FaTE during the spatial set-up for a simulation). Insert the information on receiving parcels in a column of the table started in Step 3. Note that if a parcel includes more than one watershed this information should be repeated in the table for each watershed for that parcel.

Based on the example in Figure A-1, Parcel A shares a border with Parcels B, D, and E and also forms part of the outer boundary of the modeling region (see Table A-2). This information is presented for Parcel A/Watershed 1 and Parcel A/Watershed 2. Parcel B shares a border with Parcels A, C, E, and F and also forms part of the outer boundary of the modeling region. This information is presented for Parcel B/Watershed 1.

Table A-2
Table with Receiving Parcels Added

[Step 3]	[Step 3]	[Step 3]	[Step 4]
Sending Parcel	Watershed	Percent of Parcel Covered by Watershed	Receiving Parcel
A	1	60	B D E out to sink
A	2	40	B D E out to sink
B	1	100	A C E F out to sink
C	etc.	etc.	etc.

A.5 Step 5: Estimate Percentage of Runoff from Each Watershed in a Sending Parcel Going to Different Receiving Parcels

Using the topographic map overlaid with the parcel/watershed layout, the user then estimates, for each sending parcel, the percentage of runoff from each watershed area in the parcel that goes to each bordering parcel. For each sending parcel, the user should estimate the percentage of each watershed's surface area that drains into each neighboring parcel (i.e., the receiving parcels). These estimates should be based on the elevation data and stream locations shown on the topographic map. Drainage should be assumed to be downhill (i.e., perpendicular to lines of elevation, in the direction of decreasing elevation), and it should be assumed that water will not cross watershed boundaries. It is suggested that percentage estimates be made in 5 or 10 percent increments, as it is difficult to accurately discern drainage in smaller increments using this method. The sum of the percentages must equal 100 percent for each different watershed area in each sending parcel (i.e., all of the runoff must be accounted for). It is suggested that the runoff fraction estimates be determined independently by more than one person to minimize error in map interpretation and as a check on subjective judgments in assigning runoff percentages.

For the portion of Parcel A covered by Watershed 1 in the example, the user has estimated that 50 percent of the total runoff is transported to Parcel B, 25 percent to Parcel D, and 25 percent to Parcel E. These estimates have been entered in the last column in Table A-3. This process is repeated for all of the watersheds in each surface soil parcel.

If these calculations were performed by more than one person for a given TRIM.FaTE scenario, the user should compare the percentage estimates from each person to identify and reconcile discrepancies.

**Table A-3
Table with Addition of Percent of Watershed Runoff Estimates**

[Step 3]	[Step 3]	[Step 3]	[Step 4]	[Step 5]
Sending Parcel	Watershed	Percent of Parcel Covered by Watershed	Receiving Parcel	Percent of Watershed Runoff
A	1	60	B	50
			D	25
			E	25
			out	0
A	2	40	B	0
			D	10
			E	0
			out	90
B	1	100	A	0
			C	20
			E	0
			F	70
			out	10
C	etc.	etc.	etc.	etc.

A.6 Step 6: Calculate the Percentage Total Parcel Runoff for Each Combination of Sending Parcel’s Watershed and Receiving Parcel

The user calculates the percentage of each sending parcel’s runoff going to each receiving parcel from the different watersheds (or portions of watersheds) within each sending surface soil parcel. This is done by multiplying the value in the percent of parcel covered column by the value in the percent of watershed runoff column and dividing by 100. Table A-4 presents the updated table for the example case, with the last column showing values for percent total runoff for Parcels A and B.

**Table A-4
Addition of Percent Total Parcel Runoff to Table**

[Step 3]	[Step 3]	[Step 3]	[Step 4]	[Step 5]	[Step 6]
Sending Parcel	Watershed	Percent of Parcel Covered by Watershed	Receiving Parcel	Percent of Watershed Runoff	Percent of Total Parcel Runoff (percent parcel covered x percent of watershed runoff)/100
A	1	60	B	50	30
			D	25	15
			E	25	15
			out	0	0
A	2	40	B	0	0
			D	10	4
			E	0	0
			out	90	36
B	1	100	A	0	0
			C	20	20
			E	0	0
			F	70	70
			out	10	10
C	etc.	etc.	etc.	etc.	etc.

A.7 Step 7: Calculate Runoff/Erosion Percentages and Fractions for Each Sending and Receiving Parcel Combination

In this step, the user combines the parcel-specific combinations to obtain the runoff/erosion fractions to be entered into the TRIM.FaTE scenario. For each combination of sending parcel-receiving parcel (e.g., A→B, A→D, A→E, A→out for sending Parcel A), sum the adjusted percent of total runoff values for all contributing watersheds. For the example shown here, the fraction for A→B for Watershed 1 should be combined with the fraction for A→B for Watershed 2 (i.e., 30 percent plus 0 percent, using the values included in Table A-4). These sums are percentages that are converted into the runoff/erosion fractions that will be entered as the link property inputs in the TRIM.FaTE scenario (see Module 8, Links and Algorithms, for more information about link properties). Table A-5 presents the runoff/erosion percentages and fractions for each parcel combination in Table A-1 for Parcels A and B.

Table A-5
Runoff/Erosion Fractions for Example Case

Parcel Combination	Percentage of Total Runoff/Erosion	Fraction of Total Runoff/Erosion
A → B	30%	0.30
A → D	19%	0.19
A → E	15%	0.15
A → out	36%	0.36
B → A	0%	0.00
B → C	20%	0.20
B → E	0%	0.00
B → F	70%	0.70
B → out	10%	0.10
C →	etc.	etc.

As a quality assurance check, the user should also calculate the sum of the runoff/erosion percentages for each sending parcel. Because all runoff must be accounted for, this value should equal 100 percent (note that some rounding may affect sums). For the sending Parcel A in the example shown, (30 percent + 19 percent + 15 percent + 36 percent) equals 100 percent.

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