

**Nonpoint Source Pollution and Erosion Comparison Tool (N-SPECT)
Technical Guide**

Version 1.0 Release 1, November 2004

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Introduction

This document is the technical guide for the Nonpoint Source Pollution and Erosion Comparison Tool (N-SPECT), developed by the NOAA Coastal Services Center to accompany the Waianae Ecological Characterization. The tool is an extension to ESRI's ArcGIS software package and allows users to examine relationships between land cover, nonpoint source pollution, and erosion. N-SPECT is useful for understanding and predicting the impacts of management decisions on water quality and, potentially, on coral health.

The technical guide is aimed at more advanced users and explains the underlying science and mathematical equations that drive the tool's processing and functionality.

N-SPECT is a very flexible tool and addresses several issues of concern to water quality specialists and coastal managers. Tool capabilities include

- Estimating runoff depth and volume
- Estimating pollutant loads and concentrations
- Identifying areas highly susceptible to erosion by water
- Estimating sediment loads and concentrations
- Assessing the relative impacts of land use changes with scenario analysis

Pollutant concentrations are estimated using coefficients that represent the contribution of each land cover class to the overall pollutant load. These coefficients are derived from local water quality sampling data using a new procedure detailed in the Pollutant Concentration section of this document. Erosion rates and sediment loads are calculated using the Revised Universal Soil Loss Equation (RUSLE) and Modified Universal Soil Loss Equation (MUSLE). Lastly, an overall water quality rating is assigned to the stream network within each watershed or sub-watershed by comparing estimated total pollutant and sediment concentrations to local water quality standards. This water quality rating will help resource managers make informed decisions about water quality and identify areas to target for improvement.

Model Setup

N-SPECT is delivered with data sets specific to the Wai'anae region of Oahu, and very little user interaction is required to run a basic analysis for this area. However, applying the tool in other regions may require the specification of several input data sets:

- Digital elevation model (DEM)
- Land cover grid
- Rainfall grid
- Soils shapefile
- R-factor grid (annual erosion)
- Local pollutant coefficients
- Water quality standards

Many of the grids driving N-SPECT's functionality are derived from the DEM and for this reason, it is perhaps the most important of these data sets. N-SPECT automatically sets the raster analysis environment to the parameters of the DEM file. This is an important step because it ensures that all grids produced have the same cell size, spatial reference, and extent. Otherwise, the cells of input and output grids may or may not overlay properly.

Watershed Delineation

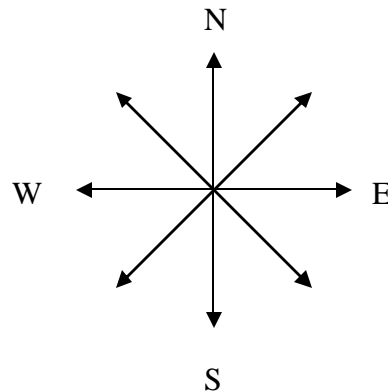
A typical N-SPECT run begins with watershed delineation. N-SPECT removes artificial sinks and other imperfections that are commonly found in raw topography data sets using the FILL command. Next, a flow direction grid is generated from the DEM by calculating the downstream flow path of water leaving each cell. Flow direction is determined by evaluating the relative elevation of the eight cells surrounding the cell in

question. The neighboring cell with the least elevation is identified as the direction of outflow from the current cell. The value of the current cell in the output flow direction grid is assigned based on the value of the cell it flows into, as given in Figure 1 below, where the center cell is being evaluated.

Figure 1: Flow Direction Grid Values

| | | |
|----|----|-----|
| 32 | 64 | 128 |
| 16 | | 1 |
| 8 | 4 | 2 |

Source: Jenson and Domingue, 1988.



For instance, a cell that flows into the cell to its immediate left would have a value of 16 in the resulting flow direction grid. Assuming that the above diagram is oriented in a north-south direction, the values of the output flow direction grid are given below:

- East 1
- Southeast 2
- South 4
- Southwest 8
- West 16
- Northwest 32
- North 64
- Northeast 128

The flow accumulation grid is created based on the flow direction grid and is used to derive a stream network. The values of the cells in a user-specified weight grid are summed according to the hydrologic linkages represented by the flow direction grid. Each cell contains the total value of all upstream cells that flow through it along the flow paths dictated by the flow direction grid (Jenson and Domingue, 1988).

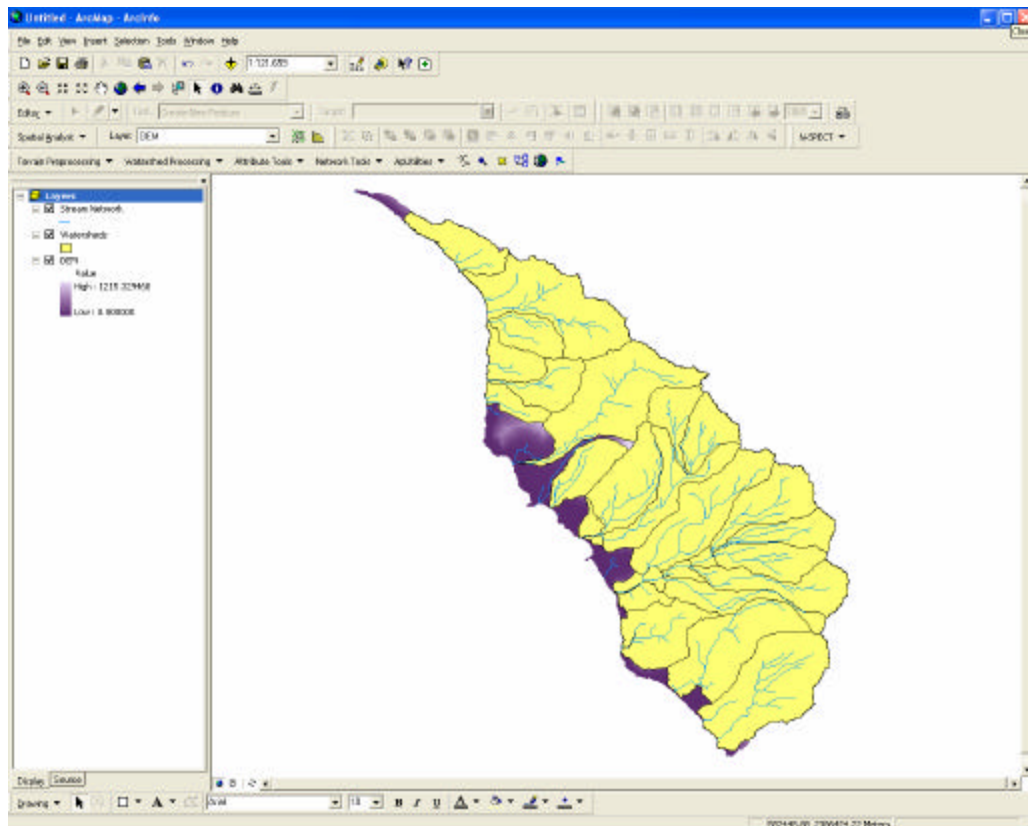
The maximum value from the flow accumulation grid is multiplied by one of the predefined threshold values (0.001, 0.01, 0.1), which correspond to small, medium, and large watershed sizes, respectively. N-SPECT then extracts a stream network by giving all cells in the flow accumulation grid that exceed the defined threshold (0.1%, 1%, 10% of total flow accumulation) a numeric value, and coding all other grid cells as NoData. Therefore, the number of upstream grid cells flowing into a given cell must be greater than the threshold percentage of the total flow accumulation to be classified as part of the stream network.

The STREAMLINK command partitions the larger stream network into links where one or more reaches come together. The WATERSHED command delineates all of the cells that flow directly into each of the individual stream links. The resulting grid is the basis for the watershed polygons that are the primary product of N-SPECT's watershed delineation process. The results of the water quality assessment are reported using these watershed polygons or a user-defined polygon data layer.

Sheet Flow Impacts

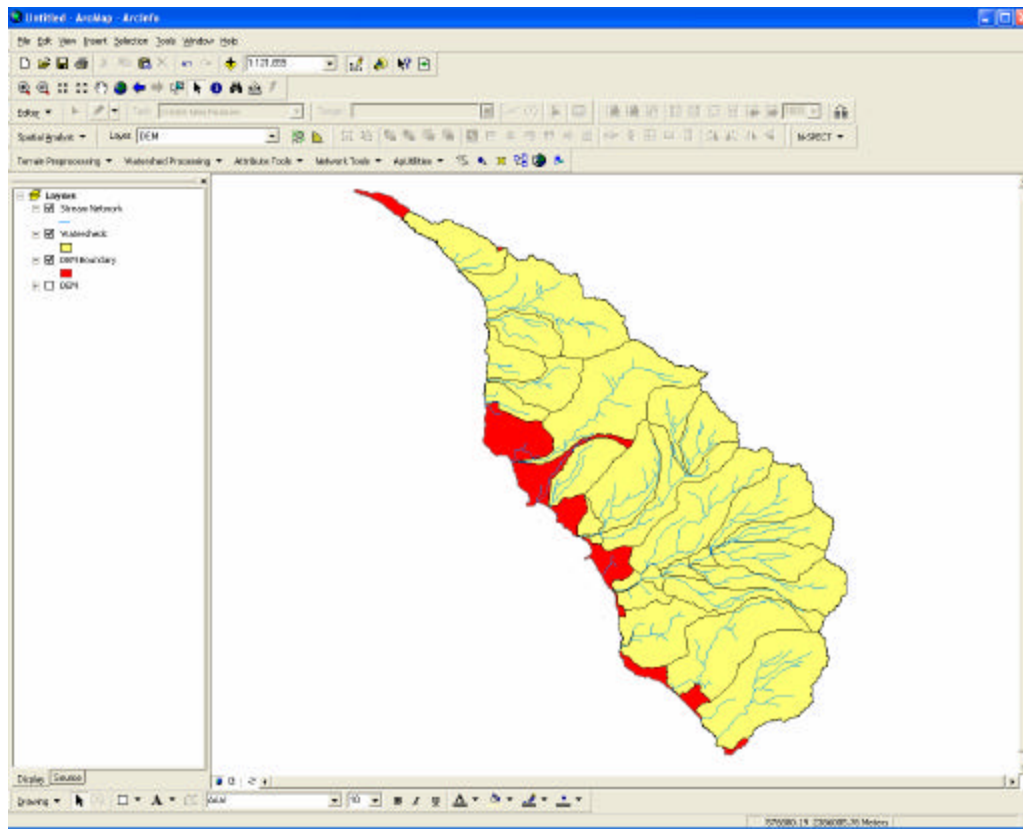
Coastal areas close to the shore typically do not have significant relief and digital elevation models are not precise enough to represent these subtle changes in elevation. This typically results in the omission of significant areas of the study area from the final watershed delineation and prevents the watersheds from reaching the ocean. Figure 2 illustrates the effects of this common problem.

Figure 2: Incomplete Watershed Delineation



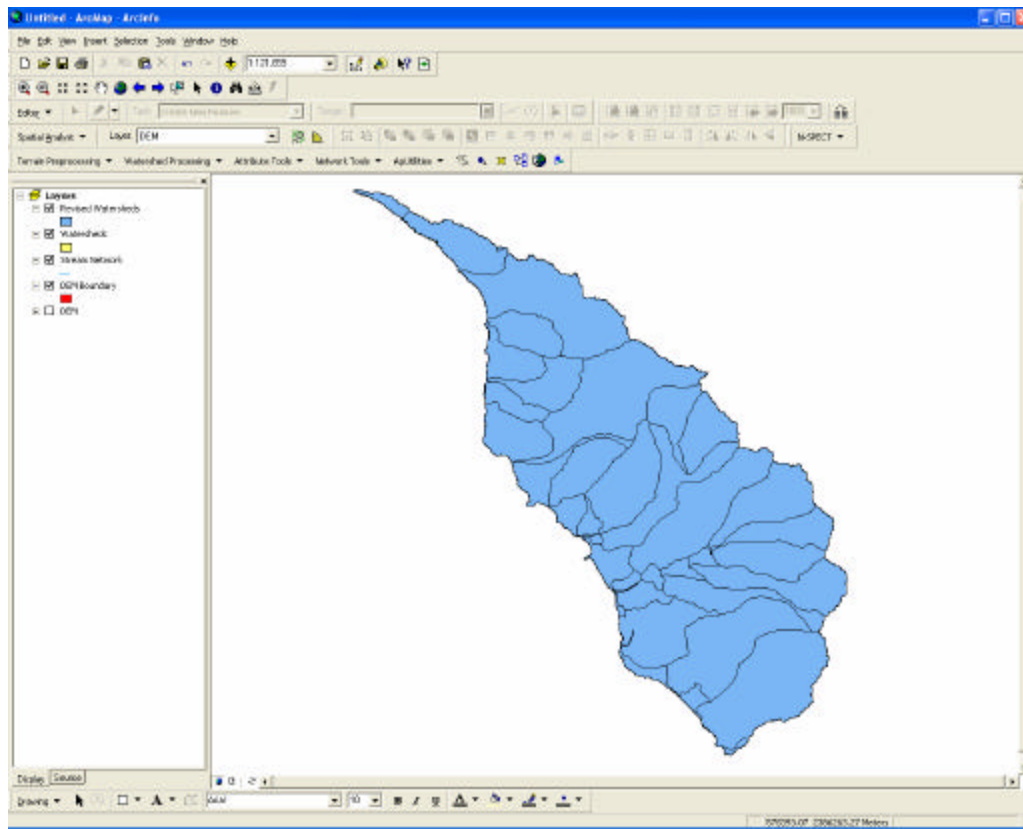
The dark-colored cells near the shore are not connected to the larger stream network. This is because these cells are not connected, via the flow direction grid, to any grid cells identified as part of the larger stream network. Figure 3 shows how N-SPECT mitigates this problem.

Figure 3: Watersheds and DEM Boundary



N-SPECT works around this issue by merging this polygon layer with a shapefile boundary of the entire study area drawn directly from the DEM. N-SPECT assumes that cells of zero elevation indicate sea level when deriving this boundary shapefile.

Figure 4: Revised Watersheds



This figure demonstrates an acceptable solution because the affected watersheds are not attached to the flow network; otherwise, they would already be part of a larger drainage. The result is that the high numbers of small, often one-celled, watersheds along the coast are aggregated into larger, more manageable units, which simplifies the reporting process.

Upstream and Local Effects

N-SPECT allows users to examine both local and upstream contributions to pollutant loads. “Local effects” refers to pollution generated by a single cell or group of cells with no input from upstream sources. Upstream effects include local effects but also incorporate pollutants flowing into the current cell from upstream cells according to the flow direction grid.

Local effects are simple to calculate within a grid environment, but upstream effects present a challenge. In order to accurately estimate upstream pollutant contributions for a given cell, N-SPECT needs to be able to easily determine all of the cells that flow into the current cell.

The BASIN command delineates the major drainage basins within a given DEM. This is accomplished by identifying ridge lines and watershed pour points, and then using the flow direction grid to determine all cells that drain the same area.

N-SPECT executes the BASIN command on the DEM and converts the resulting grid to a shapefile. Intersecting this basin shapefile with a user-defined area of interest (polygon shapefile) yields an approximation of the upstream contributing area and the relevant polygons from the basin layer are used to clip the DEM and other input grids. Although this approach is not ideal, it provides a reasonable estimate of contributions from upstream sources.

Resources

Jenson, S.K. and J.O. Domingue. 1988. "Extracting Topographic Structure from Digital Elevation Data for Geographic Information System Analysis." *Photogrammetric Engineering and Remote Sensing*. Vol. 54, No. 11, November 1988, pp. 1593–1600.

Basic Concept: Runoff Estimation

Stormwater runoff and nonpoint source pollution are problematic for several reasons. Reduced capacities for infiltration and storage associated with impervious surfaces lead to larger and more rapid discharges to receiving waters. Downstream flooding, changes in stream morphology (straightening, downcutting, etc.), and erosion are a few of the problems that can result from too much water leaving a site too quickly. Stormwater runoff from developed areas also tends to carry higher pollutant loads than runoff from undisturbed sites. Nutrients such as phosphorus and nitrogen, suspended solids or sediments, hydrocarbons like oil and grease, and metals (zinc, copper, lead) are all commonly found in stormwater runoff from developed sites (Schueler 2000).

N-SPECT allows users to investigate the impacts of land use changes on stormwater runoff and water quality, in general. Although there is no user interface that is directly related to the estimation of runoff, these calculations are the basis of many of the other N-SPECT functions and processes. This section of the technical guide discusses the procedures N-SPECT uses to estimate runoff depth and volume.

SCS Curve Number Method

N-SPECT uses the method presented in the Natural Resources Conservation Service's *Urban Hydrology for Small Watersheds: Technical Release 55* as the basis for its runoff estimates. Retention, initial abstraction, and runoff depth are all derived according to the following equations:

$$Q = (P - I_a)^2 / [(P - I_a) + S]$$

$$I_a = 0.2 * S$$

$$S = (1000 / CN) - 10$$

Where:

Q = runoff (in)

P = rainfall (in)

S = potential maximum retention after runoff begins (in)

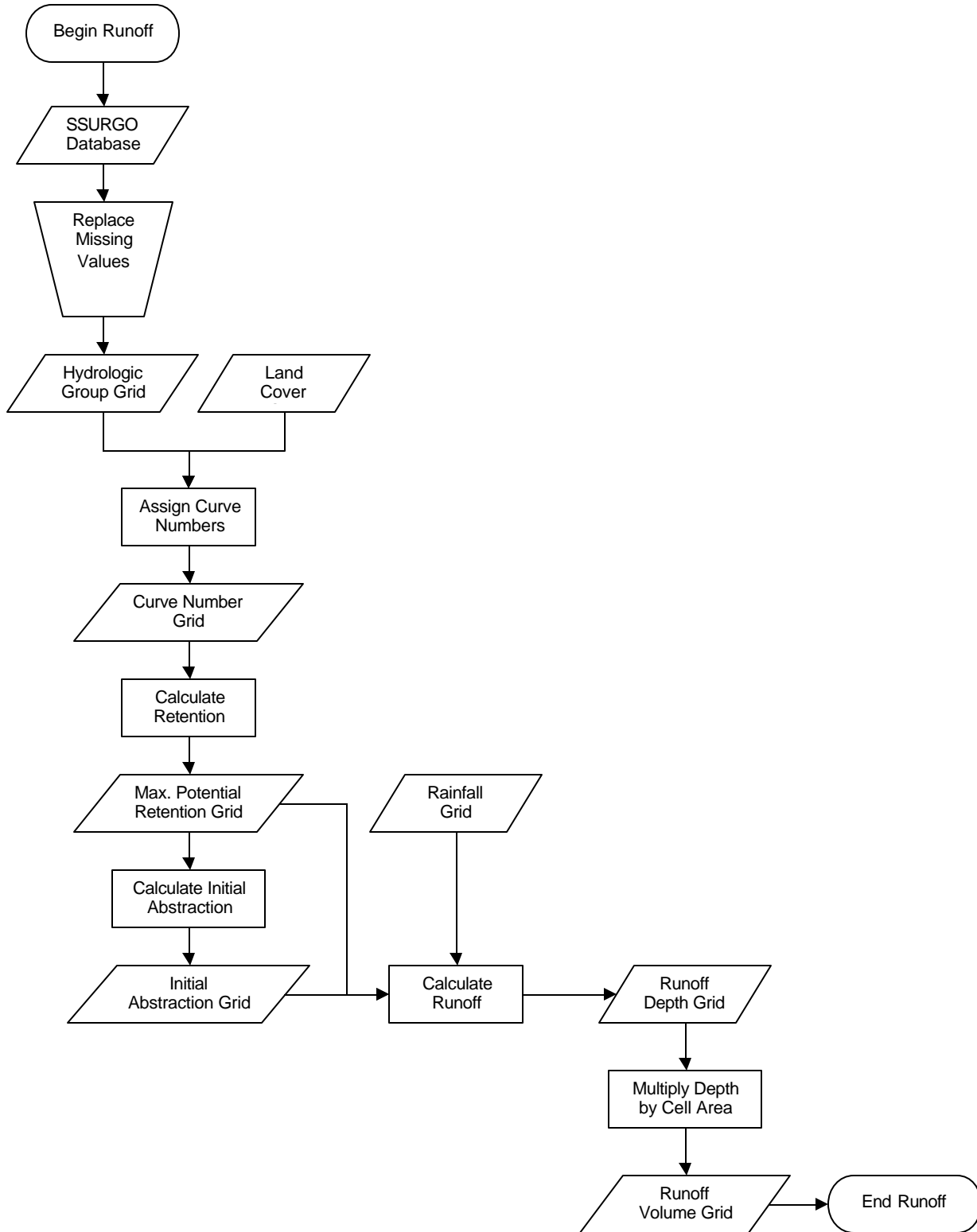
I_a = initial abstraction (in)

CN = runoff curve number

Note: If $(P - I_a) = 0$, then $Q = 0$

If the initial abstraction at a given cell is greater than the rainfall at that cell, N-SPECT sets runoff depth to zero. This prevents the reintroduction of artificial sinks to the runoff analysis. Figure 5 provides a basic overview of the runoff estimation process.

Figure 5: N-SPECT Runoff Process



Calculating Runoff

This section of the technical guide walks through the processing that occurs behind the scenes when N-SPECT estimates runoff depth and volume.

Step 1: Create the Curve Number Grid

Runoff curve numbers were developed by NRCS based on soil properties and represent overall permeability. This number varies from 0 (100 percent rainfall infiltration) to 100 (0 percent infiltration— i.e., pavement) and is used to estimate runoff depth. N-SPECT generates a curve number grid based on the combination of land cover and hydrologic soil group at each cell within a given analysis area (see Table1).

Step 2: Calculate Maximum Potential Retention

Retention represents the ability of the soil to absorb or retain moisture. Precipitation that is absorbed or retained by the soil does not contribute to runoff. N-SPECT calculates retention at each grid cell as shown below:

$$\text{Retention} = (1000 / \text{Curve Number}) - 10$$

Units associated with the abstraction grid are inches.

Step 3: Calculate Initial Abstraction

Abstraction refers to the losses that occur before runoff begins. This can include water stored by surface depressions and water intercepted by vegetation, evaporation, and infiltration. N-SPECT calculates abstraction at each grid cell as shown below:

$$\text{Abstraction} = (0.2 * \text{Retention})$$

Units associated with the abstraction grid are inches.

Step 4: Precipitation Grid

The next step is to either choose a preexisting input precipitation grid or create a new precipitation grid using a geographic information system (GIS). This grid must be in inches, as the Technical Release 55 equation for estimating runoff assumes precipitation inputs are in inches.

Step 5: Calculate Runoff

Event-based runoff depth is estimated according to the following equation taken directly from Technical Release 55:

$$\text{Runoff Depth} = (\text{Rainfall} - \text{Abstraction})^2 / (\text{Rainfall} - \text{Abstraction}) + \text{Retention}$$

N-SPECT checks for instances where abstraction is greater than rainfall and sets runoff to zero. This method is designed for average conditions, does not explicitly account for rainfall intensity or duration, and is less accurate when precipitation is 0.5 inches or less.

Annual runoff depth is estimated based on the following equation, which accounts for the average number of days it rains per year. The estimated abstraction and retention are multiplied by the number of rain days, thus reducing estimated runoff.

$$\text{Runoff Depth} = (\text{Rainfall} - (\text{Abstraction} * \text{Rain Days}))^2 / [(\text{Rainfall} - (\text{Abstraction} * \text{Rain Days})) + (\text{Retention} * \text{Rain Days})]$$

Step 6: Convert Units

The next step in the runoff estimation process is to convert the runoff depth grid to runoff volume and to other units that will be used as inputs to subsequent processing.

Because the Technical Release 55 runoff equation yields the depth (inches) of excess water that runs off the landscape for a given total rainfall depth, this grid must be multiplied by the cell area in order to produce a true runoff volume grid.

The cell area is simply the length times the width of the cell. For example, a grid with 30 x 30 meter cells would have a cell area of 900 square meters. This cell area value can be converted to other units by multiplying it by the appropriate conversion factor.

Input Data Sets

N-SPECT makes use of a variety of data sets, but only a few of these are required for basic analyses. This section of the technical guide provides an overview of the required input data sets.

Rainfall Data

The runoff component of N-SPECT is driven by the precipitation grid. N-SPECT includes several precipitation grids for the Wai'anae region of Oahu as a default, but the tool also allows users to import additional precipitation grids for other regions.

The National Climate Data Center (NCDC) is the primary repository for precipitation data collected by stations in the federal network. Data for individual stations can be accessed on-line by visiting this Web site:

wfn.ncdc.noaa.gov/oa/climate/stationlocator.html

For users working in the United States, the NCDC also maintains links to state climate offices (SCOs), which serve as the point of contact and clearinghouse for state and local climate data.

www.ncdc.noaa.gov/oa/climate/stateclimatologists.html

Additional information on how to access nonfederal precipitation data should be directed to the appropriate state climatologist's office.

Annual Precipitation

The annual type precipitation scenarios for Wai'anae were developed in conjunction with the Hawaii State Climatologist. Historical precipitation records for the island of Oahu are available from the National Climatic Data Center (NCDC). However, the federal precipitation network is fairly sparse and the gaps in coverage must be filled by data from state precipitation gages. Combining data from the state and federal networks yields a spatial coverage representative of microclimate rainfall variations common in Hawaii. Monthly and annual rainfall records for stations on the Wai'anae coast were interpolated as grids based on both federal and state precipitation records.

Event Precipitation

The Hawaii State Climatologist's Office also generated data for the event type precipitation scenarios for Wai'anae. These grids represent short-term rainfall events of varying duration and intensity typical of the study area. Precipitation grids representing frontal, upper-level low, and Kona storm events, the major source of rainfall for the Wai'anae Coast, were derived from the historical meteorological data available from both federal and state sources.

Elevation Data

N-SPECT was developed and tested using U.S. Geological Survey (USGS) 10-meter digital elevation model (DEM) data re-sampled to a 30-meter grid. Although other digital elevation models may be used, USGS 10-meter DEMs are downloadable at no charge from the following GeoCommunity web site:

<http://data.geocomm.com/dem/demdownload.html>

The DEM files each represent one USGS topographic quadrangle and are distributed in SDTS format. The files for Honolulu County were imported to raster using ESRI's ArcToolBox™ and then merged using the ArcInfo grid command MOSAIC. Care must be taken to ensure the grid cells of the DEM and land cover data sets (and all other grid data sets) are aligned to each other. This can be accomplished by setting the "snap to extent" feature to the DEM data set in the ArcGIS™ Spatial Analyst options menu.

The entire runoff and pollutant routing process is based on flow direction and flow accumulation grids derived from the DEM. Although it is possible to use higher resolution DEMs with N-SPECT, these data sets will result in increased processing times.

Land Cover Data

Coastal Change Analysis Program (C-CAP) data sets are produced by the NOAA Coastal Services Center and are considered the default source of land cover data for use with N-SPECT. The tool is distributed with C-CAP land cover data for the Wai'anae region but is designed to also accommodate other land cover data sets for other regions of the world.

For general information on the C-CAP program and land cover data sets, please visit the following Web sites:

www.csc.noaa.gov/crs/lca/ccap.html

www.csc.noaa.gov/crs/lca/tech_cls.html

When applying N-SPECT outside of the Wai'anae region, a few steps are necessary to obtain and prepare the land cover data. To download C-CAP land cover data for a new study area, visit the link below and follow the directions:

www.csc.noaa.gov/crs/lca/data.html

After downloading the data, the next steps are to subset and reproject the data using ERDAS Imagine® or a similar software package. All input data sets must be converted to a common projection; in the case of Wai'anae, this projection was UTM Zone 4 with datum NAD83. Finally, export the image file as a grid.

Open ArcGIS, specify the soils shapefile as the analysis mask (Spatial Analyst/Options) and use the Raster Calculator to create a new land cover grid clipped to soils data. Again, make sure the grid cells of the DEM and land cover data sets (and all other grid data sets) match. This can be accomplished by setting the "snap to extent" feature of the ArcGIS Spatial Analyst options menu to the DEM data set.

Runoff Curve Numbers (CN)

Runoff curve numbers represent the infiltration capacity of the soil and range from 0 to 100, with 0 being no runoff and 100 indicating no infiltration. Curve numbers play an important role in N-SPECT's runoff depth estimation calculations.

N-SPECT includes default curve number values for use with C-CAP land cover data sets. Table 1 shows C-CAP land cover classifications and the corresponding curve number values for each of the four hydrologic soil types. N-SPECT also allows the user to modify these default values or specify entirely

new values. Refer to *Urban Hydrology for Small Watersheds: Technical Release 55* for more information on determining appropriate curve numbers for other land cover classes.

For instances in which a dual hydrologic group is assigned (e.g., A/D, B/D, C/D), the highest curve number of the two components will be used. For instance, B/D areas will be assigned a value of D for that land cover class. Higher curve numbers are given for landscapes with more impervious cover, surface soils with high clay content, or lands with low soil cover.

Soils Data

The hydrologic group attribute (*hydgrp*) is used to assign runoff curve numbers when working with new land cover data sets or classes. The soils data used to run N-SPECT is taken from the U.S. Department of Agriculture's (USDA) Natural Resources Conservation Service (NRCS) Soil Survey Geographic (SSURGO) database. This data is available for download from the website:

<http://www.ncgc.nrcs.usda.gov/products/datasets/ssurgo/data/>

A few modifications are necessary before the data can be loaded into N-SPECT. The file *cov.zip* contains soil polygons in ArcInfo coverage format, *out.zip* in ArcInfo interchange format, and *shp.zip* as shapefiles. In addition to the polygon shapefile representing soil units, three tables are needed to obtain the data necessary for running N-SPECT. The *layer* table contains the kfactor values, the *comp* table contains the hydrologic soil group attributes, and the *mapunit* table contains the information needed to link the *comp* and *layer* tables to the shapefile. These tables are joined in sequence using following protocol.

| | From table or layer | To table or layer | Field used for join |
|----|----------------------------|--------------------------|----------------------------|
| 1. | SSURGO polygon shapefile | mapunit | musym |
| 2. | mapunit | comp | muid |
| 3. | comp | layer | muid |

While each soil unit is associated with one unique component, each component may be associated with many layers. This one-to-many relationship must be simplified before the soil features are converted to rasters. There are a couple of methods that can be used to accomplish this. The simplest is to select only the first layer associated with each component. A more complex method is to calculate a weighted average of all layers associated with each component. The *SSURGO Database Data Use Information* publication provides detailed background on the data structure and how to access the tables in a GIS.

Once all the joins have been established, the shapefile can be exported and cleaned to eliminate the unnecessary fields contained in the attribute table. Occasionally (usually when a polygon is over water) there records do not contain kfactor or hydrologic soil group data. In these instances, the user must populate these fields with conservative data. Set the kfactor to 0 and the hydrologic soil group to D, unless prior knowledge indicates that different values are more appropriate. N-SPECT has a tool (in N-SPECT → Advanced Settings → Soils) that allows a user to define a new soils data set. Use the newly created shapefile and select the appropriate fields for kfactor and hydrologic soil group.

Table 1: Mapping C-CAP Land Cover Classes to Curve Numbers

| C-CAP Value | C-CAP Class | TR-55 Cover Type | TR-55 Treatment | TR-55 Condition | Group A | Group B | Group C | Group D |
|-------------|--------------------------------|------------------------------|-----------------|-----------------|---------|---------|---------|---------|
| 2 | High-Intensity Developed | Commercial and Business | | | 89 | 92 | 94 | 95 |
| 3 | Low-Intensity Developed | 1/4 Acre Residential | | | 61 | 75 | 83 | 87 |
| 4 | Cultivated Land | Row Crops | Straight Row | Good | 67 | 78 | 85 | 89 |
| 5 | Grassland | Pasture, Grassland, or Range | | Good | 39 | 61 | 74 | 80 |
| 6 | Deciduous Forest | Woods | | Good | 30 | 55 | 70 | 77 |
| 7 | Evergreen Forest | Woods | | Good | 30 | 55 | 70 | 77 |
| 8 | Mixed Forest | Woods | | Good | 30 | 55 | 70 | 77 |
| 9 | Scrub/Shrub | Brush | | Good | 30 | 48 | 65 | 73 |
| 10 | Palustrine Forested Wetland | | | | 0 | 0 | 0 | 0 |
| 11 | Palustrine Scrub/Shrub Wetland | | | | 0 | 0 | 0 | 0 |
| 12 | Palustrine Emergent Wetland | | | | 0 | 0 | 0 | 0 |
| 13 | Estuarine Forested Wetland | | | | 0 | 0 | 0 | 0 |
| 14 | Estuarine Scrub/Shrub Wetland | | | | 0 | 0 | 0 | 0 |
| 15 | Estuarine Emergent Wetland | | | | 0 | 0 | 0 | 0 |
| 16 | Unconsolidated Shore | | | | 0 | 0 | 0 | 0 |
| 17 | Bare Land | Fallow | Bare soil | | 77 | 86 | 91 | 94 |
| 18 | Water | | | | 0 | 0 | 0 | 0 |
| 19 | Palustrine Aquatic Bed | | | | 0 | 0 | 0 | 0 |
| 20 | Estuarine Aquatic Bed | | | | 0 | 0 | 0 | 0 |

Source: USDA-NRCS, 1986

Output Data Sets

Data sets produced by the runoff calculation process include

- Runoff volume (L)
- *Runoff depth**
- *Runoff curve number**

**Data sets in italics are temporary and are not reported.*

N-SPECT uses each of these data sets as input to subsequent processes like the estimation of sediment concentrations. Runoff volume is also an important input to the pollutant concentration portion of N-SPECT.

Resources

- Renard, K.G., G.R. Foster, G.A. Weesies, D.K. McCool, and D.C. Yoder. 1997. *Predicting Soil Erosion by Water: A Guide to Conservation Planning with Revised Universal Soil Loss Equation (RUSLE)*. United States Department of Agriculture, Agriculture Handbook 703, United States Government Printing Office, Washington D.C.
- Schueler, Thomas R. "Why Stormwater Matters." *The Practice of Watershed Protection*. Eds. Thomas R. Schueler and Heather K. Holland. Ellicott City, MD: Center for Watershed Protection, 2000. pp 365–370.
- USDA-NRCS. 1986. *Urban Hydrology for Small Watersheds. Technical Release 55 (TR-55)*. Second Edition. Washington, D.C.
Available at ftp://ftp.wcc.nrcs.usda.gov/downloads/hydrology_hydraulics/tr55/tr55.pdf

Basic Concept: Pollutant Concentration

Nonpoint source pollution has proven to be a difficult problem to address due to its complex nature. It is not always clear exactly where the most significant pollution sources are located, and it is even more difficult to monitor and enforce relatively small contributions from many widely dispersed sources.

The effects of nonpoint source pollution range from eutrophication and algal blooms to closed beaches and shellfish beds, and can cause human health impacts through the food chain (Arnold and Gibbons, 1996).

N-SPECT estimates pollutant concentrations by using land cover as a proxy. This is accomplished by applying pollutant contribution coefficients (similar to event mean concentrations) to land cover classes and introducing a runoff volume grid.

The pollutant concentration estimation procedure does not explicitly take duration or intensity of rainfall into account.

Pollutant Coefficients Method

Pollutant coefficients for the Wai'anae region were developed based on local water quality sampling data. The basic methodology is documented in this section of the manual and the process can be replicated wherever the necessary supporting data are available.

The coefficient derivation process centers around a FORTRAN program that generates pollutant coefficient values for all land cover classes in a given study area. These coefficients represent the contribution of a particular land cover to the overall pollutant load.

After the required input data have been collected, formatted, and read, the program begins a bootstrapping routine which is used to select unique, random samples from the set of water quality observations and upstream land cover data. The number of samples selected is the number of land cover classifications present in the larger study area, and each water quality observation can only be selected once (no replacement).

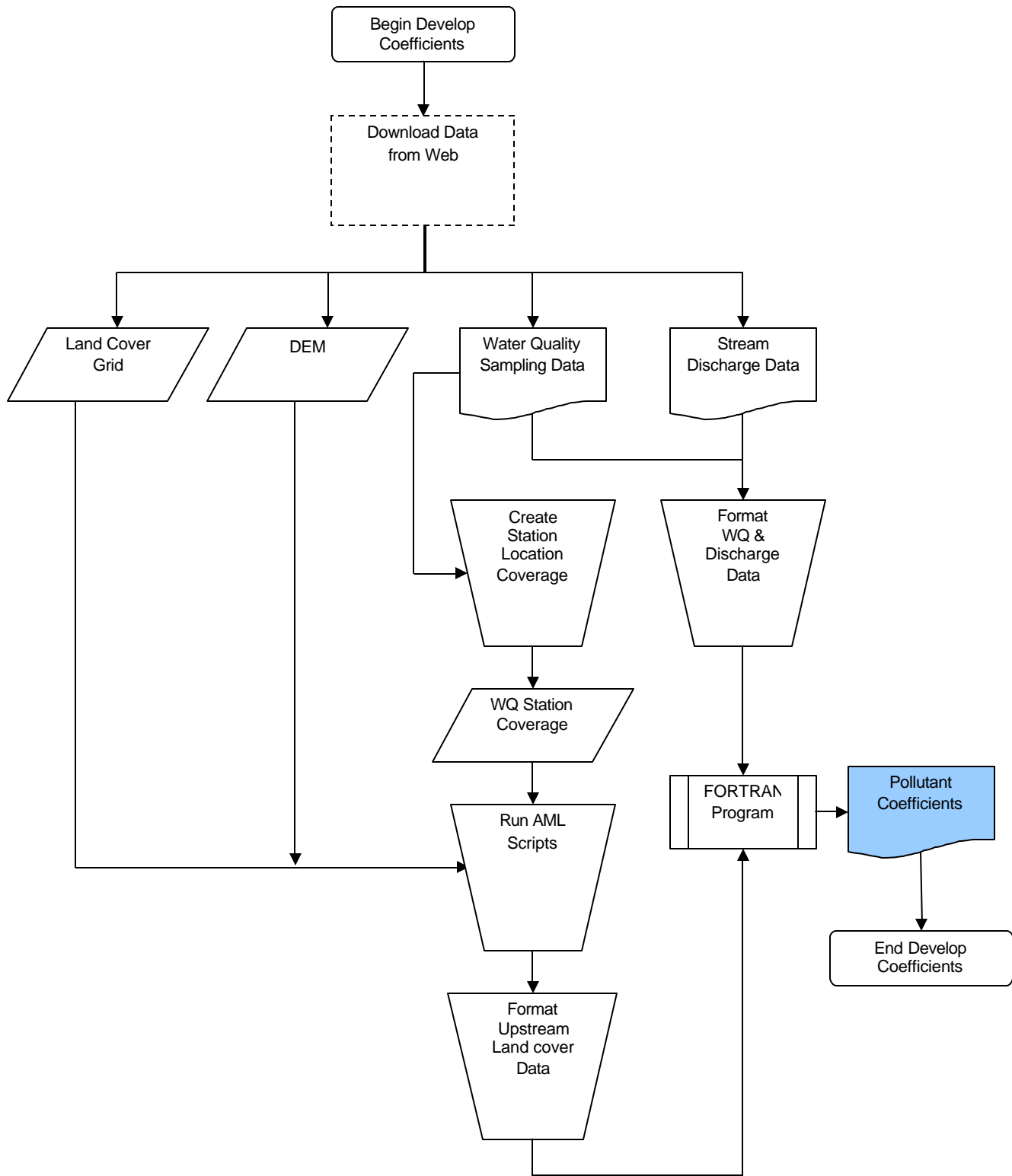
For each selected water quality observation, the program solves multiple regression equations simultaneously to yield a single pollutant coefficient value for each land cover class present within the sampling site's upstream contributing area. The equations take the following form:

$$\text{Observed Pollutant Load} = (C_0 * LC_0) + (C_1 * LC_1) + (C_2 * LC_2) + \dots + (C_N * LC_N)$$

Observed Pollutant Load represents an individual pollutant measurement, LC is the percentage of the total upstream contributing area classified by a given land cover class, and C is the coefficient value associated with this land cover class for this particular pollutant. For each of these equations, the Observed Pollutant Load and LC variables are known and the C variables are unknown. The program dictates that there must be at least one watershed and water quality sample for each land cover class present within the study area in order to find a unique solution.

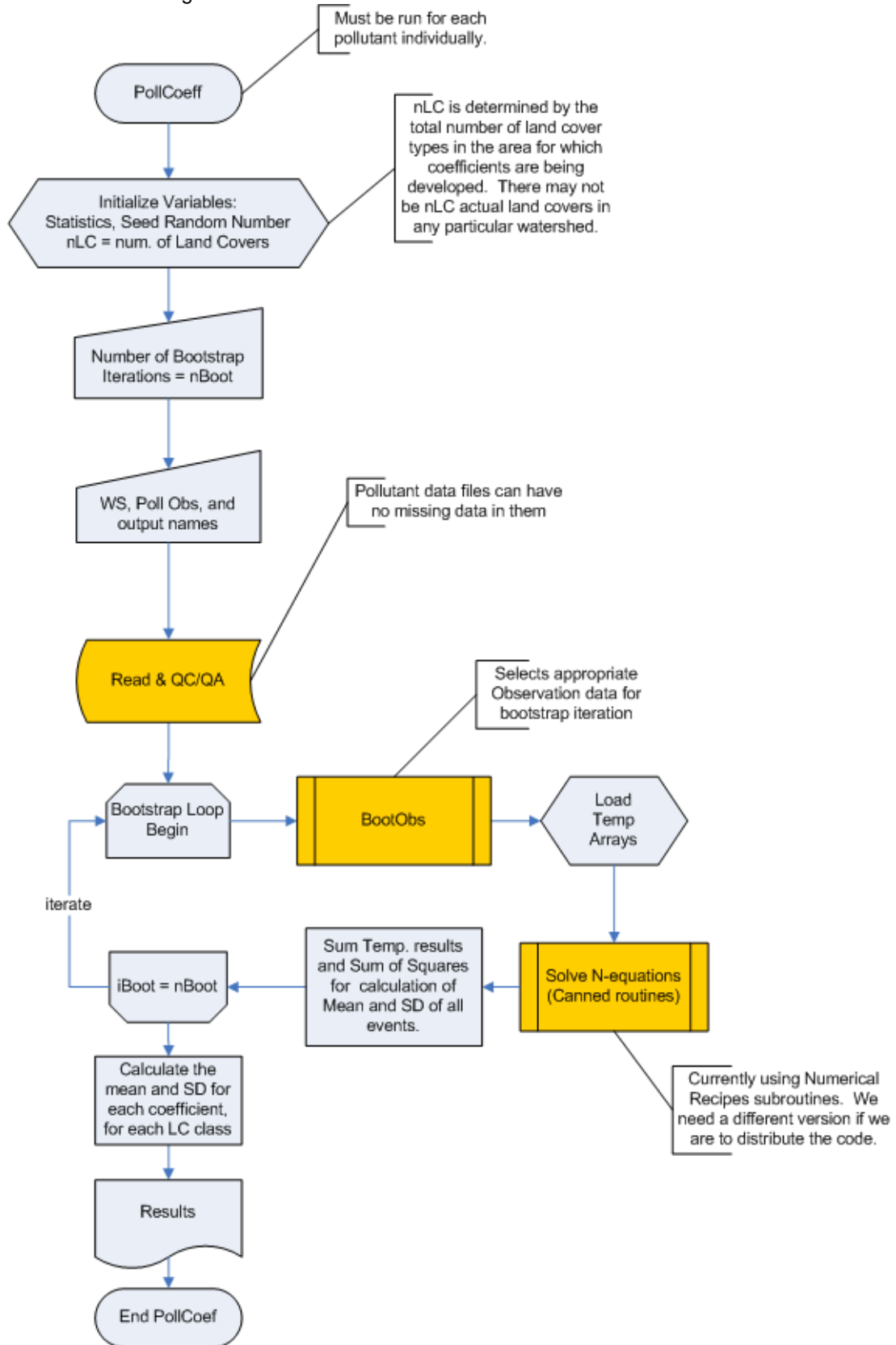
The mean and standard deviation for each coefficient for each land cover class are calculated and reported as part of the program output. N-SPECT uses the pollutant coefficients as input to the larger pollutant estimation process. A more detailed treatment of the steps involved in deriving pollutant coefficients is provided in the subsequent sections of this document.

Figure 6: Pollutant Coefficients Development Process



Note: Shading indicates output data set.

Figure 7: FORTRAN Program



Deriving Pollutant Coefficients

Pollutant coefficients are the basis of the water quality comparison component of N-SPECT. There are many sets of pollutant coefficients available in the literature, but N-SPECT produces its most accurate results when locally derived values are used. The procedures for deriving local pollutant coefficient values are described below.

Step 1: Get Water Quality Sampling Data

The first step is to identify which USGS stations or other sampling sites are within the study area and determine their geographic location as accurately as possible. These points will eventually be converted to a grid and snapped to the stream network derived from the DEM. Data for the Wai'anae region was drawn from two sources: USGS and the Hawaii Department of Health (DOH). USGS water quality data for Hawaii are available at the following Web site:

<http://nwis.waterdata.usgs.gov/hi/nwis/qwdata>

Similarly, USGS water quality data for the rest of the nation are available at:

<http://nwis.waterdata.usgs.gov/usa/nwis/qwdata>

When collecting water quality sampling data, it is important to make sure the samples are relatively contemporary with the land cover data set. A good rule of thumb is to limit the search to two to three years before and after the date of the land cover data set.

C-CAP land cover data are available for download at:

www.csc.noaa.gov/crs/lca/locate.html

USGS 10-meter digital elevation model (DEM) data sets are available for download at:

<http://data.geocomm.com/dem/demdownload.html>

These DEMs are in SDTS format. After unzipping and untarring the files, use ArcToolBox[®] to import the SDTS format to raster. Depending on the study area, it may be necessary to mosaic several DEM quads together. This can be accomplished using the ArcInfo MOSAIC grid command.

Step 2 : Get Discharge/Precipitation Data

The DOH water quality sampling data did not include simultaneous discharge volume measurements. This issue was mitigated by finding USGS discharge gages inside the upstream contributing area of each of the DOH sample sites. Although measurements from these stations are not ideal, they allow us to determine if the DOH samples were taken during precipitation events or baseflow conditions. Table 4 shows how these data were organized in the spreadsheet.

Streamflow data are available for download at the following Web sites:

<http://waterdata.usgs.gov/hi/nwis/sw>

<http://waterdata.usgs.gov/usa/nwis/sw>

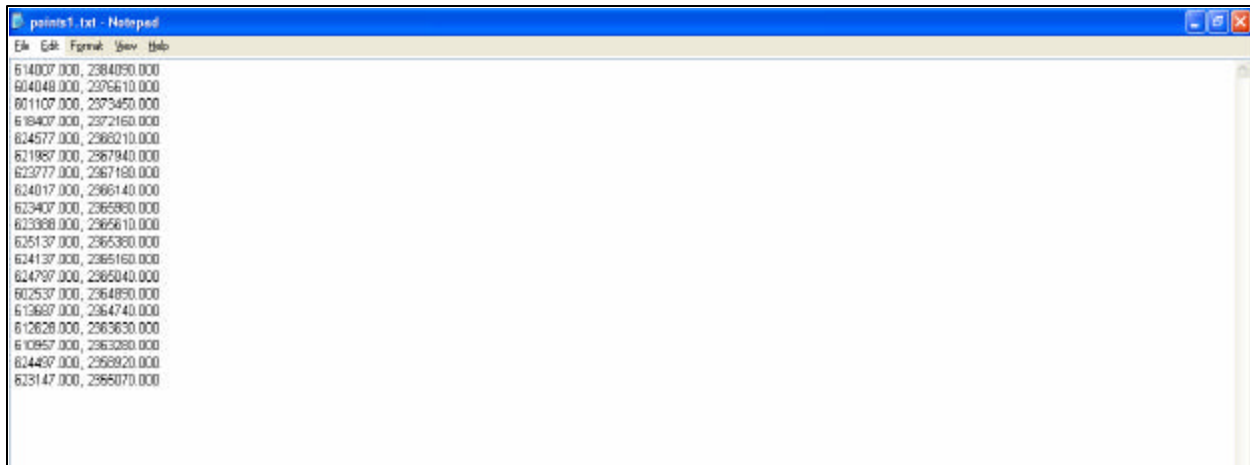
Step 3: Upstream Contributing Area and Land Cover Percentages

Once the geographic location of each USGS station or water quality sampling site has been determined, a coverage must be created that incorporates each of these as points.

First, run the AML script *dem_prep.aml*, which fills sinks in the DEM and creates grids that will be used in the following AMLs (*snap_gages.aml*, *landcover.aml*) to isolate the upstream land uses for a given point on the stream network. A digital elevation model (grid) with filename *dem* is a required input for this AML.

Next, run *snap_gages.aml*, which snaps the monitoring stations to the stream network and converts the resulting grid to a shapefile. After this AML finishes, use ArcToolBox to convert *snapshape.shp* to a coverage called *snappcov*. Use ArcToolBox or ArcInfo to add xy coordinates to the coverage and export the .vat as a .dbf file. Use Notepad to create an input file of xy coordinates based on the contents of the .dbf file.

Figure 8: Sample Input Points File for Land Cover Script



Although there is theoretically no limit to the number of points that can be processed, the AML works best with input point files that have 20 or fewer sets of coordinates. There should be no spaces at the end of a line in the input coordinates file or the script will fail.

Finally, run *landcover.aml*, which isolates the contributing upstream land uses for a given point on the stream network. It will be used to derive pollutant coefficients for N-SPECT based on local water quality sampling data.

Step 4: Format The Data

The water quality and land cover percentages data must be formatted before the FORTRAN program can perform its processing.

Data from the USGS web site are organized by date and time of the sample with multiple pollutant measurements. There is an option to save the data as a file, and specifying an .xls file extension creates an Excel file on your machine. The Excel spreadsheet is likely to contain several rows for many different pollutants. It is necessary to remove data rows for pollutants you are not interested in, which can be accomplished most easily by removing the header rows and sorting the data by the parameter code column.

Tables 2 and 3 show how the water quality data and land cover percentages were arranged in the spreadsheet. These values were later converted to a delimited text file and read directly by the FORTRAN program that solves for the pollutant coefficients.

Table 2: Land Cover Percentages Spreadsheet

| USGS Station | Station Name | Num. of Classes | Name | C-CAP Class | Cell Count | Percent of Contributing Area | Directory | Run # |
|--------------|--|-----------------|--------------------------|-------------|------------|------------------------------|-----------|-------|
| 16275000 | Haiku Str nr Heeia, Oahu, HI | 6 | | | | | usgs1 | 7 |
| | | | High-Intensity Developed | 2 | 462 | 1.81% | | |
| | | | Low-Intensity Developed | 3 | 328 | 1.28% | | |
| | | | Grassland | 5 | 2744 | 10.73% | | |
| | | | Evergreen Forest | 7 | 7056 | 27.60% | | |
| | | | Scrub/Shrub | 9 | 14711 | 57.55% | | |
| | | | Bare Land | 17 | 261 | 1.02% | | |
| | | | | | 25562 | 100.00% | | |
| 16274100 | Kaneohe Str blw Kamehameha Hwy, Oahu, HI | 8 | | | | | usgs1 | 6 |
| | | | High-Intensity Developed | 2 | 7524 | 5.53% | | |
| | | | Low-Intensity Developed | 3 | 19448 | 14.29% | | |
| | | | Cultivated Land | 4 | 1611 | 1.18% | | |
| | | | Grassland | 5 | 16452 | 12.09% | | |
| | | | Evergreen Forest | 7 | 42503 | 31.23% | | |
| | | | Scrub/Shrub | 9 | 47350 | 34.79% | | |
| | | | Bare Land | 17 | 390 | 0.29% | | |
| | | | Water | 18 | 837 | 0.61% | | |
| | | | | | 136115 | 100.00% | | |

The station ID and name columns are self-explanatory. The “number of classes” column refers to the number of different land cover classes accounted for in the delineated upstream contributing area. The name and C-CAP class columns refer to the actual land cover classes present within the upstream contributing area. The cell count and percentage columns show the cell count within each land cover class and what proportion of the overall upstream contributing area it comprises. The directory column specifies in which folder to look for the grids created during the delineation process for each USGS station or water quality sampling site. Finally, the run number refers to the numeric suffix at the end of the corresponding grid and .dbf file for each station. So, the grids and .dbf files for Haiku Stream can be found in the usgs1 folder and would have the numeric suffix 7 (i.e., wshed7, lulc_subset7, outfile7.dbf).

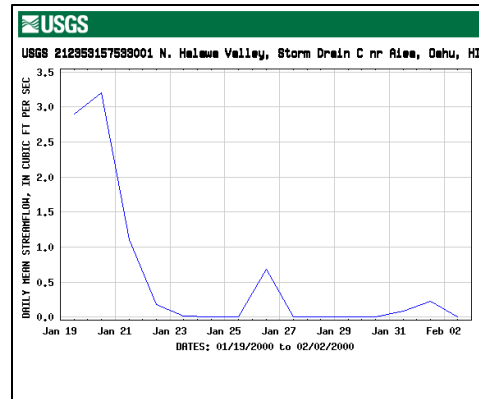
Table 3: Water Quality Data Spreadsheet

| Agency | Station | Date | Time | Nitrogen (milligrams/liter) | Phosphorus (milligrams/liter) | Lead (micrograms/liter) | Zinc (micrograms/liter) | Instantaneous Discharge (cfs) | Instantaneous Discharge (gpm) |
|--------|-----------------|-----------|-------|--------------------------------|----------------------------------|----------------------------|----------------------------|----------------------------------|-------------------------------------|
| USGS | 16213000 | 8/20/2000 | 18:00 | 0.49 | 0.205 | 1 | 1 | 1340 | -9999 |
| USGS | 16240500 | 8/24/1999 | 9:40 | 0.06 | 0.012 | 1 | 1 | 2.4 | -9999 |
| USGS | 16274100 | 8/3/1999 | 11:20 | 0.1 | 0.019 | 1 | 1 | 6.3 | -9999 |
| USGS | 16284200 | 8/19/1999 | 10:10 | 0.11 | 0.032 | 1 | 1 | 4.1 | -9999 |
| USGS | 211700157490101 | 3/21/2000 | 12:00 | 0.31 | 0.066 | 1 | 1 | -9999 | 500 |
| USGS | 211813157494706 | 5/23/2000 | 12:00 | 0.58 | 0.037 | 1.16 | 1 | -9999 | 1750 |
| USGS | 211844157512201 | 2/15/2000 | 12:00 | 0.67 | 0.035 | 1 | 1 | -9999 | 750 |
| USGS | 212044157511701 | 2/22/2000 | 12:00 | 0.67 | 0.052 | 1.19 | 10 | -9999 | 500 |

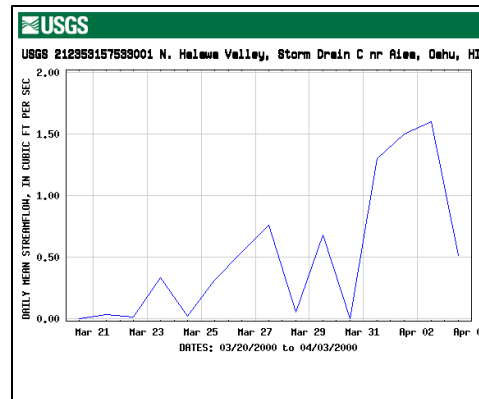
USGS water quality samples are typically accompanied by an instantaneous measurement of discharge volume, but this is not part of the Hawaii DOH sampling process. To work around this, USGS streamflow stations inside the upstream contributing area of the DOH sites were identified and discharge data from the closest stations were used to determine if the water quality sample was taken during a precipitation event or baseflow conditions.

Table 4: Spreadsheet Data

| Agency | Station | Date | Time | Nitrogen (milligrams/liter) | Phosphorus (milligrams/liter) | Lead (micrograms/liter) | Zinc (micrograms/liter) | Instantaneous Discharge (cfs) | Instantaneous Discharge (gpm) |
|--------|-----------------|-----------|------|--------------------------------|----------------------------------|----------------------------|----------------------------|----------------------------------|----------------------------------|
| USGS | 212353157533001 | 1/26/2000 | 9:47 | 0.16 | 0.05 | 1 | 21 | 0.43 | -9999 |



| | | | | | | | | | |
|------|-----------------|-----------|------|------|------|---|----|-----|-------|
| USGS | 212353157533001 | 3/27/2000 | 8:50 | 0.12 | 0.03 | 1 | 20 | 1.6 | -9999 |
|------|-----------------|-----------|------|------|------|---|----|-----|-------|



Estimating Pollutant Concentration

N-SPECT estimates concentrations for four default pollutants (nitrogen, phosphorus, lead, and zinc) as well as additional user-specified pollutants.

The runoff volume grid is converted to liters by multiplying each cell by a conversion factor. Next, the accumulated runoff grid is created from the flow direction grid and the new runoff volume grid. Each cell in the accumulated runoff grid represents the total amount of water that passes through that cell, including contributions from upstream cells.

A pollutant concentration grid is then created from either the default pollutant coefficients or a new set derived from local sampling data where each cell is assigned a value based on its land cover classification. The pollutant coefficient value represents an average concentration (mg/L) for a given land cover classification. When the pollutant concentration grid is multiplied by the runoff volume grid, the result is a new grid that indicates the mass of the pollutant produced by each individual cell. This grid does not take into account upstream contributions.

The pollutant mass grid is accumulated using the flow direction grid, which yields an accumulated pollutant mass grid in which the value of each cell represents the total mass of pollutant that passes through that cell, including contributions from upstream cells.

An accumulated pollutant concentration grid is derived by dividing the accumulated pollutant mass grid by the accumulated runoff grid. However, this grid does not include the pollutant mass and runoff volume generated at the current cell, instead including only the total value of all upstream cells that flow through the current cell. The final pollutant concentration grid is created by adding the pollutant mass grid and accumulated pollutant mass grid, then dividing this quantity by the sum of the runoff volume grid and the accumulated runoff grid.

Input Data Sets

Inputs to the pollutant concentration estimation process include:

- Precipitation grid (in)
- Digital elevation model (m)
- Land cover grid
- Rasterized SSURGO soils data set (hydrologic group attribute)

Rainfall Data

The runoff component of N-SPECT is driven by the precipitation grids. N-SPECT includes several precipitation grids for the Wai'anae region of Oahu as a default, but the tool also allows users to create and import additional precipitation grids for other regions.

The National Climate Data Center (NCDC) is the primary repository for precipitation data collected by stations in the federal network. Data for individual stations can be accessed on-line by visiting this web site:

<http://lwf.ncdc.noaa.gov/oa/climate/stationlocator.html>

For users working in the United States, the NCDC also maintains links to state climate offices (SCOs), which serve as the point of contact and clearinghouse for state and local climate data.

www.ncdc.noaa.gov/oa/climate/stateclimatologists.html

Additional information on how to access nonfederal precipitation data should be directed to the appropriate state climatologist's office.

Annual Precipitation

The annual type precipitation scenarios for Wai'anae were developed in conjunction with the Hawaii State Climatologist. Historical precipitation records for the island of Oahu are available from the National Climatic Data Center (NCDC). However, the federal precipitation network is fairly sparse and the gaps in coverage must be filled by data from precipitation gages. Combining data from the state and federal networks yields a spatial coverage representative of microclimate rainfall variations common in Hawaii. Monthly and annual rainfall records for stations on the Wai'anae coast were interpolated as grids based on both federal and state precipitation records.

Event Precipitation

The Hawaii State Climatologist's Office also generated data for the event type precipitation scenarios for Wai'anae. These grids represent short-term rainfall events of varying duration and intensity typical of the study area. Precipitation grids representing frontal, upper-level low, and Kona storm events, the major source of rainfall for the Wai'anae coast, were derived from the historical meteorological data available from both federal and state sources.

Elevation Data

Any digital elevation model can be used to drive N-SPECT as long as it's units are in meters and share the same projection as the rest of the input data. N-SPECT was developed and tested using USGS 10-meter digital elevation model (DEM) data re-sampled to a 30-meter grid. USGS 10-meter digital elevation models are available for download at the following web site at no charge:

<http://data.geocomm.com/dem/demdownload.html>

The DEM files each represent one USGS topographic quadrangle and are distributed in SDTS format. The files for Honolulu County were imported to raster using ESRI's ArcToolBox™ and merged using the ArcInfo grid command MOSAIC. Care must be taken to ensure the grid cells of the DEM and land cover data sets (and all other grid data sets) match. This can be accomplished by setting the "snap to extent" feature of the ArcGIS™ Spatial Analyst options menu to the DEM data set.

The entire runoff and pollutant routing process is based on flow direction and flow accumulation grids derived from the DEM. Although it is possible to use higher resolution DEMs with N-SPECT, these data sets will result in increased processing times.

Land Cover Data

Coastal Change Analysis Program (C-CAP) data sets are produced by the NOAA Coastal Services Center and are considered the default source of land cover data for use with N-SPECT. The tool is distributed with C-CAP land cover data for the Wai'anae region but is designed to also accommodate other land cover data sets for other regions of the world.

For general information on the C-CAP program and land cover data sets, please visit the following Web sites:

www.csc.noaa.gov/crs/lca/ccap.html

www.csc.noaa.gov/crs/lca/tech_cls.html

When applying N-SPECT outside of the Wai'anae region, a few steps are necessary to obtain and prepare the land cover data. To download C-CAP land cover data for a new study area, visit the link below and follow the directions:

www.csc.noaa.gov/crs/lca/data.html

After downloading the data, the next steps are to subset and reproject the data using ERDAS Imagine® or a similar software package. All input data sets must be converted to a common projection; in the case of Wai'anae, this projection was UTM Zone 4 with datum NAD83. Finally, export the image file as a grid.

Open ArcGIS, specify the soils shapefile as the analysis mask (Spatial Analyst/Options), and use the Raster Calculator to create a new land cover grid clipped to soils data. Again, make sure the grid cells of the DEM and land cover data sets (and all other grid data sets) match. This can be accomplished by setting the “snap to extent” feature of the ArcGIS Spatial Analyst options menu to the DEM data set.

Soils Data Layer

The soils data used to run N-SPECT is taken from the USDA Natural Resources Conservation Service Soil Survey Geographic (SSURGO) database. Although this data is available for download on the web, a few modifications are necessary before it can be loaded into N-SPECT.

The hydrologic group (hydgrp) is an attribute found in the *comp* table of the SSURGO database and is assigned based on soil infiltration rates. These are grouped into four categories, A through D, based on decreasing infiltration (A = high infiltration, D = very slow infiltration).

Table 5: Hydrologic Soil Group Definitions

| Hydrologic Soil Group | Soil Group Characteristics |
|------------------------------|---|
| A | Soils having high infiltration rates, even when thoroughly wetted and consisting chiefly of deep, well- to excessively-drained sands or gravels. These soils have a high rate of water transmission. |
| B | Soils having moderate infiltration rates when thoroughly wetted and consisting chiefly of moderately deep to deep, and moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission. |
| C | Soils having slow infiltration rates when thoroughly wetted and consisting chiefly of soils with a layer that impedes downward movement of water, or soils with moderately fine to fine texture. These soils have a slow rate of water transmission. |
| D | Soils having very slow infiltration rates when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very slow rate of water transmission. |

Occasionally, there are polygons without a value defined. This implies one of two scenarios: (1) the area covered by the polygon represents water, or (2) this area has highly disturbed soils and the actual soil type can no longer be determined (as in urbanized areas).

Areas covered by water were recoded as hydrologic group D. All other polygons without values were considered disturbed soils and were coded as hydrologic group D. In some cases, Appendix A of the NRCS publication *Urban Hydrology for Small Watersheds: Technical Release 55* can be used to populate this value based on the soil series name. Another option is to assign a hydrologic group based on the defined soil texture as follows:

Table 6: Hydrologic Soil Group and Soil Texture

| Hydrologic Soil Group | Soil Texture |
|-----------------------|---|
| A | Sand, loamy sand, or sandy loam |
| B | Silt loam or loam |
| C | Sandy clay loam |
| D | Clay loam, silty clay loam, sandy clay, silty clay, or clay |

Another potential wrinkle is that some polygons may have a compound hydrologic group specified (e.g., A/D, C/D). In these cases, the right-most soil group is assigned for that polygon (A/D becomes D).

After all of the polygons have been assigned a single hydrologic soil group, convert them to a numeric classification scheme. Polygons coded as A become 1, B becomes 2, C becomes 3, and D becomes 4. This numeric attribute should be specified as the source of the hydrologic soil group when creating new soils grids in N-SPECT.

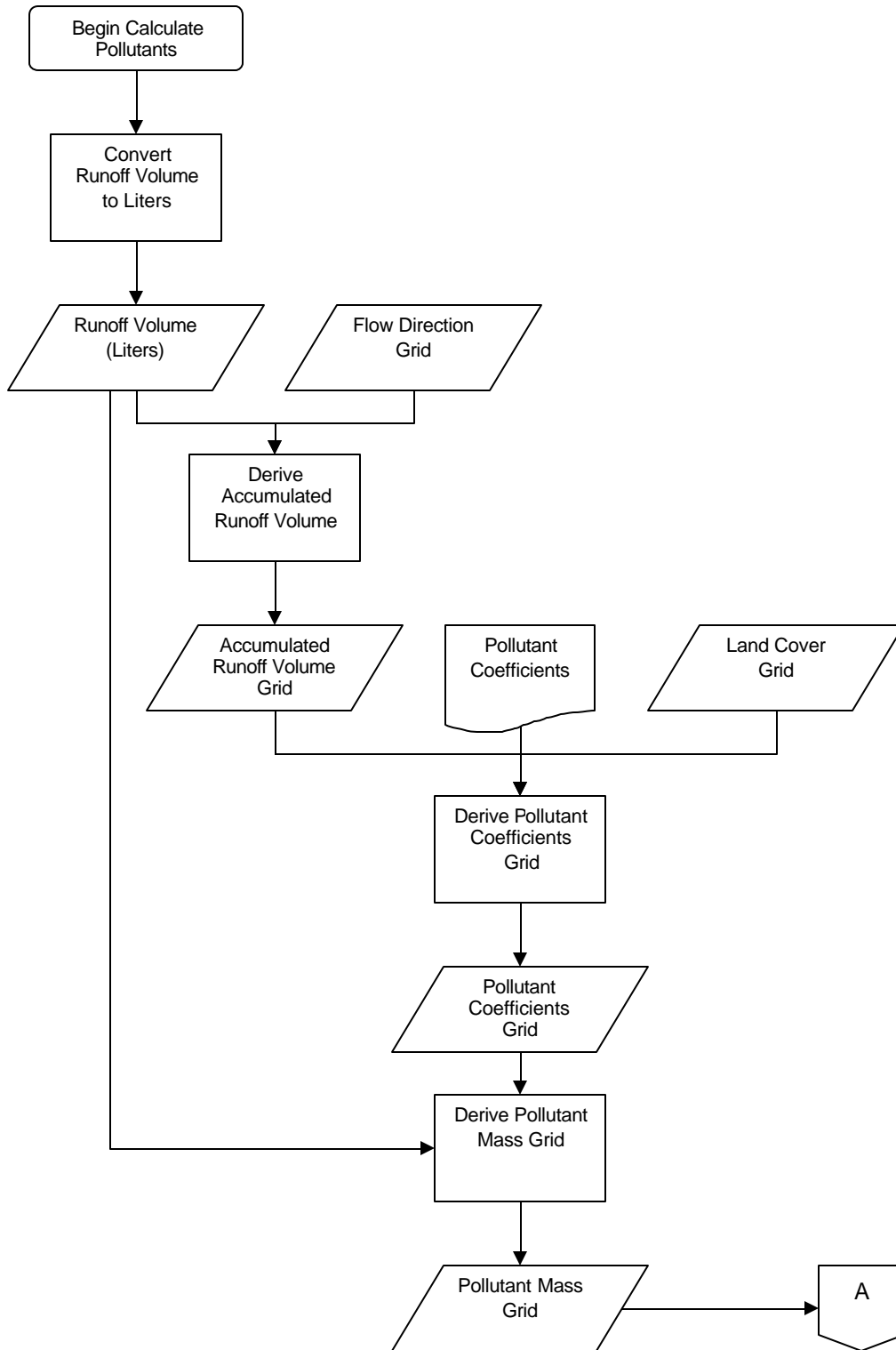
Output Data Sets

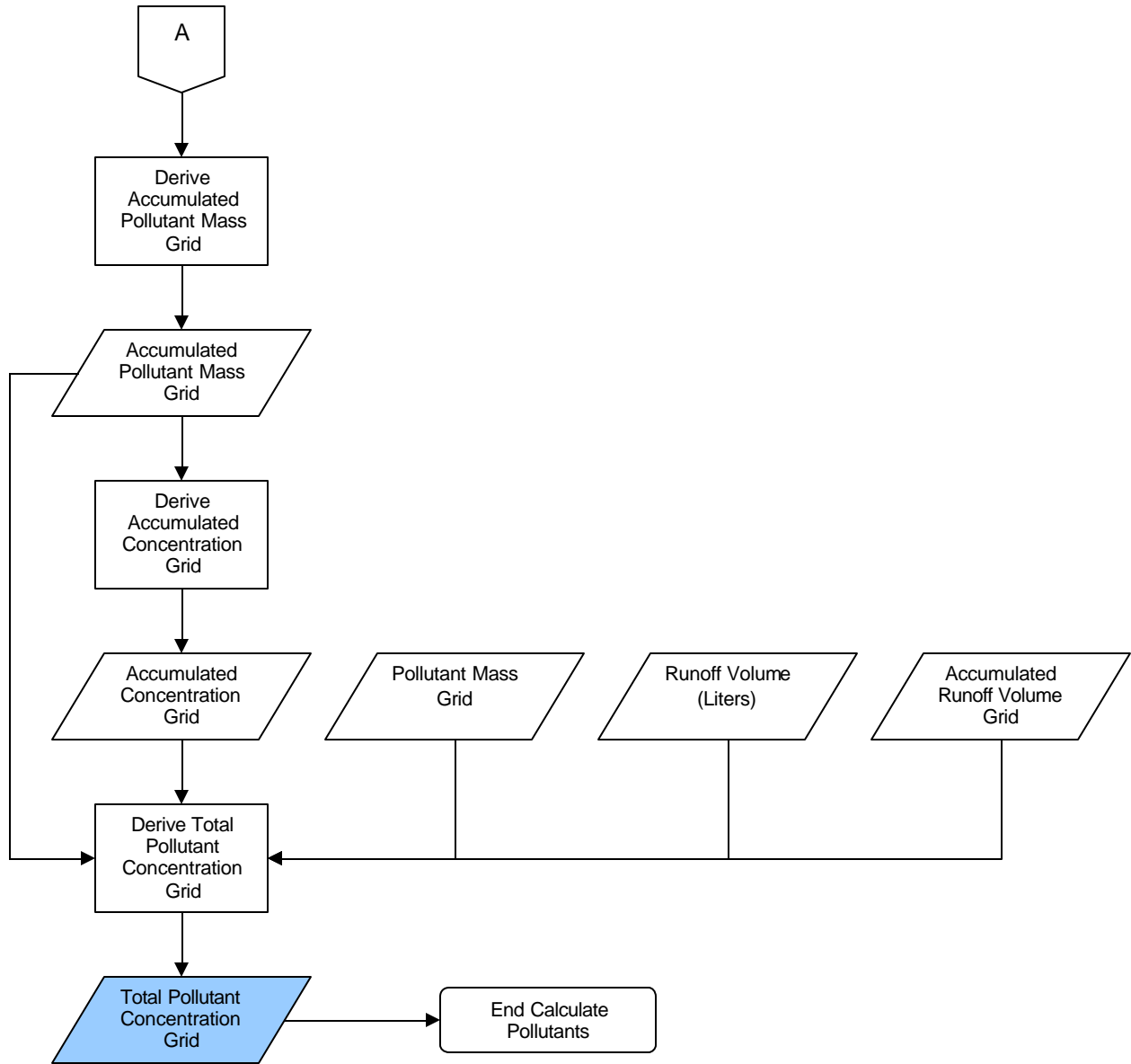
N-SPECT produces a concentration grid for each pollutant specified in the initial analysis setup. If the Local Effects Only option is unchecked, the resulting grid represents the expected pollutant concentration value if a sample were taken at a given cell location. If the “Local Effects Only” option is checked, the resulting grid represents the ratio of pollutant to runoff produced at each individual cell with no input from upstream cells.

- Accumulated Pollutant (kg)
- Pollutant Concentration (mg/L)
- Comparison to Pollutant Standard (exceeds standard or below standard)

The pollutant concentration grids are used as inputs to the water quality assessment and reporting component of N-SPECT.

Figure 9: Pollutant Concentration Estimation Process





Note: Shading indicates output data set.

Resources

- Adamus, Christine L. and Martinus Bergman. 1995. "Estimating Nonpoint Source Pollution Loads with a GIS Screening Model." *Water Resources Bulletin*. 31(4): 647–655.
- Arnold, C.L., and C.J. Gibbons. 1996. "Impervious Surface Coverage: The Emergence of a Key Environmental Indicator." *Journal of the American Planning Association*. 62(2): 243–258.
- CH2M HILL. 2000. *Technical Memorandum 1, Urban Stormwater Pollution Assessment*. Prepared for North Carolina Department of Environment and Natural Resources, Division of Water Quality, August, 2000.
- USDA-NRCS. 1986. *Urban Hydrology for Small Watersheds. Technical Release 55 (TR-55)*. Second Edition. Washington, D.C.
Available at ftp://ftp.wcc.nrcs.usda.gov/downloads/hydrology_hydraulics/tr55/tr55.pdf
- US EPA. 1983. *Final Report of the Nationwide Urban Runoff Program*. U.S. Environmental Protection Agency (US EPA), Water Planning Division, Washington, DC.

Basic Concept: Sediment Concentration

Erosion and sedimentation are significant problems in the Wai'anae region and suspended sediments are one of the most serious and widespread nonpoint source pollution issues in the nation. This section of the technical guide documents the equations and processes N-SPECT uses to estimate suspended sediment concentrations.

The Universal Soil Loss Equation

The Universal Soil Loss Equation (USLE) was developed in the late 1970s, based on empirical research, as a tool for soil conservation. Originally intended for use on croplands, subsequent changes to the USLE expanded its applicability to additional land cover types (RUSLE) and individual storm events (MUSLE).

Annual Erosion

The current standard for estimating annual erosion is the Revised Universal Soil Loss Equation (RUSLE), a variant of the original USLE. The Revised Universal Soil Loss Equation is:

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

Where:

A = average annual soil loss

R = rainfall/runoff erosivity factor

K = soil erodibility factor

L = slope length factor

S = slope steepness factor

C = cover management factor

P = supporting practices factor

R Factor Grid: The rainfall/runoff erosivity factor was estimated from the R factor map for Oahu given in the NRCS Field Office Technical Guide. A line shapefile approximation of the printed map was generated via "heads-up" digitizing. The units are feet * tonfeet * inch/acre * hour * year.

K Factor Grid: The soil erodibility factor was taken directly from the SSURGO data set. Polygons without a K factor value (urban soils) were assumed to carry a K value of 0.30. The units are ton * acre * hour/acres * tonfeet * feet * inch.

LS Factor Grid: LS calculations are based on the RUSLE research of Renard et al. (1997). The LS factor will be generated using an ArcGIS version of an AML script written by Bob Hickey at Central Washington University. Slope length is calculated by deriving the downslope angle for each cell in degrees. Next, a grid showing relative change in downslope angle is created. Areas where downslope angle exceeds 5 percent and the relative change in downslope angle exceeds 50 percent are flagged as breaks in the cumulative slope. Areas where downslope angle is less than or equal to 5 percent and the relative change in downslope angle exceeds 70 percent are also flagged as breaks in the cumulative slope.

A modified flow direction grid is created where the slope break points are recoded as zeros and all other cells retain their original flow direction values. A weight grid is created where each output cell receives a value of 1 (times the cell size) if water flows through it in a cardinal direction, and 1.4142 (times the cell size) if water flows through it in a diagonal direction (Pythagorean Theorem). The FLOWLENGTH command is then used to sum these values along the flow paths until one of the break points, a ridge, or a pour point is encountered. This yields the estimate of slope length *lamda* used to calculate the L factor in the equation on page 105 of Renard et al. (1997).

$$L = (\textit{lamda} / 72.6)^m$$

The slope-length exponent *m* is derived based on Table 4-5 in Renard et al. (1997).

Table 7: Slope-Length Exponent Derivation

| Downslope Angle Is... | | M Value |
|-------------------------------|--------------------|---------|
| Less than or equal to 0.1 | | 0.01 |
| Greater than 0.1 | and less than 0.2 | 0.02 |
| Greater than or equal to 0.2 | and less than 0.4 | 0.04 |
| Greater than or equal to 0.4 | and less than 0.85 | 0.08 |
| Greater than or equal to 0.85 | and less than 1.4 | 0.14 |
| Greater than or equal to 1.4 | and less than 2.0 | 0.18 |
| Greater than or equal to 2.0 | and less than 2.6 | 0.22 |
| Greater than or equal to 2.6 | and less than 3.1 | 0.25 |
| Greater than or equal to 3.1 | and less than 3.7 | 0.28 |
| Greater than or equal to 3.7 | and less than 5.2 | 0.32 |
| Greater than or equal to 5.2 | and less than 6.3 | 0.35 |
| Greater than or equal to 6.3 | and less than 7.4 | 0.37 |
| Greater than or equal to 7.4 | and less than 8.6 | 0.40 |
| Greater than or equal to 8.6 | and less than 10.3 | 0.41 |
| Greater than or equal to 10.3 | and less than 12.9 | 0.44 |
| Greater than or equal to 12.9 | and less than 15.7 | 0.47 |
| Greater than or equal to 15.7 | and less than 20.0 | 0.49 |
| Greater than or equal to 20.0 | and less than 25.8 | 0.52 |
| Greater than or equal to 25.8 | and less than 31.5 | 0.54 |
| Greater than or equal to 31.5 | and less than 37.2 | 0.55 |
| Greater than 37.2 | | 0.56 |

The S factor is calculated using the following equations (Renard, 1997):

$$\text{Where slope} < 9\% \quad S = 10.8 * (\sin \theta) + 0.03$$

$$\text{Where slope} > 9\% \quad S = 16.8 * (\sin \theta) - 0.50$$

The LS factor units are feet.

C Factor Grid: Default cover management factor values are drawn from the table below:

Table 8: Default C Factor Values

| Old C-CAP Value | C-CAP Class | C Factor |
|-----------------|--------------------------------|----------|
| N/A | Developed, Open Space | 0.013 |
| N/A | Medium-Intensity Developed | 0.015 |
| 2 | High-Intensity Developed | 0.000 |
| 3 | Low-Intensity Developed | 0.030 |
| 4 | Cultivated Land | 0.240 |
| 5 | Grassland | 0.050 |
| 6 | Deciduous Forest | 0.009 |
| 7 | Evergreen Forest | 0.004 |
| 8 | Mixed Forest | 0.007 |
| 9 | Scrub/Shrub | 0.014 |
| 10 | Palustrine Forested Wetland | 0.003 |
| 11 | Palustrine Scrub/Shrub Wetland | 0.000 |
| 12 | Palustrine Emergent Wetland | 0.000 |
| 13 | Estuarine Forested Wetland | 0.003 |
| 14 | Estuarine Scrub/Shrub Wetland | 0.000 |
| 15 | Estuarine Emergent Wetland | 0.000 |
| 16 | Unconsolidated Shore | 0.500 |
| 17 | Bare Land | 0.700 |
| 18 | Water | 0.000 |
| 19 | Palustrine Aquatic Bed | 0.000 |
| 20 | Estuarine Aquatic Bed | 0.000 |

C Factor values are unitless.

P Factor Grid: The supporting practices factor is not included in this version of N-SPECT but may be incorporated in future releases as data availability permits.

The annual soil loss grid will be generated by multiplying the R factor, C factor, K factor, and LS factor grids.

Sediment Delivery Ratio

RUSLE produces an estimate of gross erosion, but does not indicate how much eroded soil is actually transported by streams.

$$\text{SDR} = 1.366 * 10^{-11} * (\text{DA})^{-0.0998} * (\text{ZL})^{0.3629} * (\text{CN})^{5.444} \quad (\text{Williams, 1977})$$

Where:

DA = drainage area (km²)
ZL = the relief-length ratio (m/km)
CN = SCS curve number

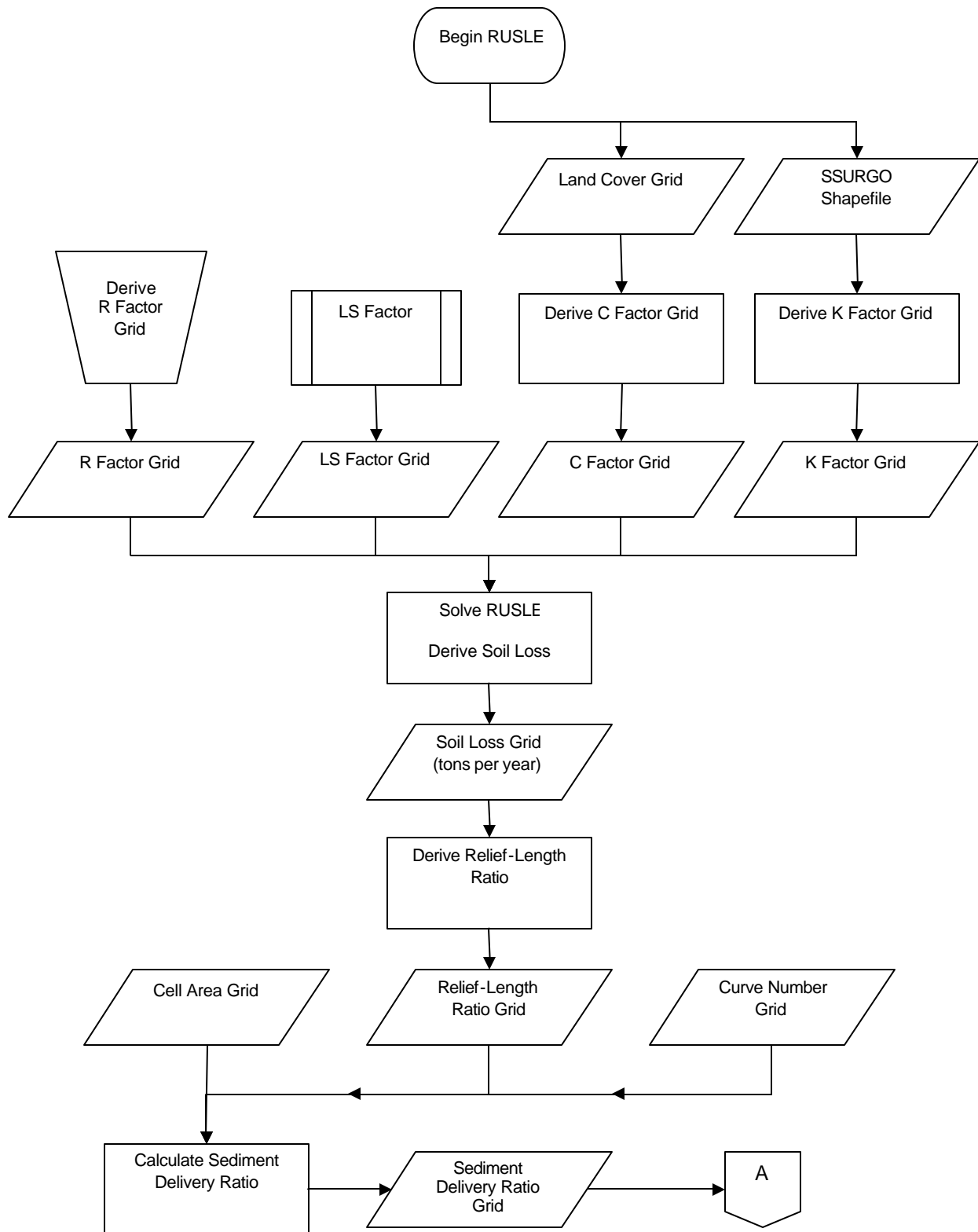
Drainage Area (DA): The sediment delivery ratio is applied at the cell level rather than at the watershed or catchment level. The drainage area parameter represents the area of each individual grid cell.

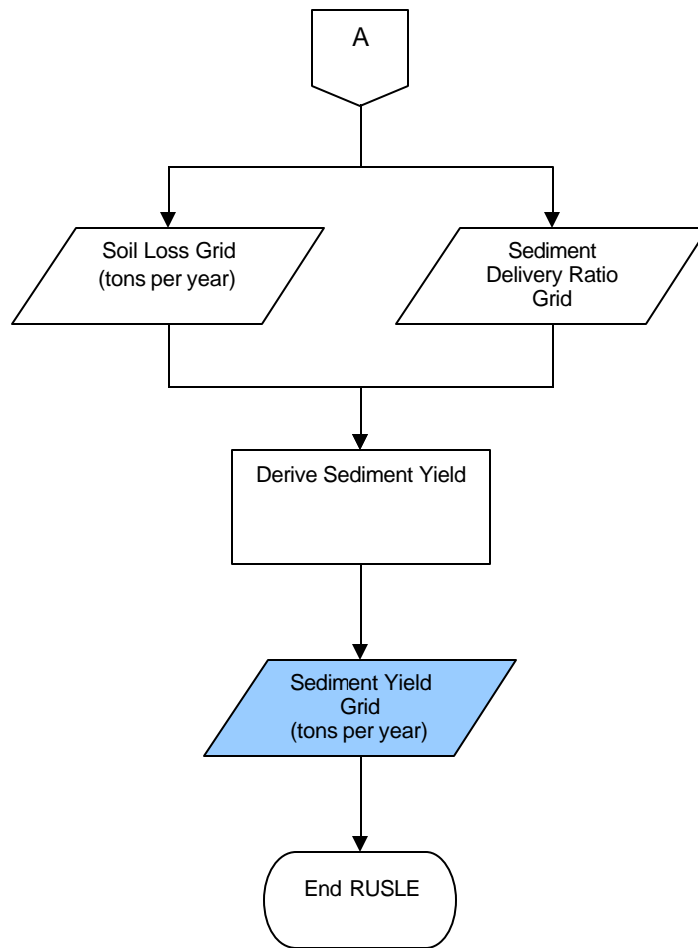
Relief-Length Ratio (ZL): This ratio is calculated based on the DEM and flow direction grid. The elevation change along the downslope flow path is calculated from the DEM and divided by the distance from the center of the current cell to the center of the next cell along the flow path.

Curve number (CN): The runoff curve number grid is derived from the land cover grid and SSURGO shapefile.

Multiplying the resulting sediment delivery ratio grid by the annual soil loss grid from the previous step will produce a true annual sediment yield grid.

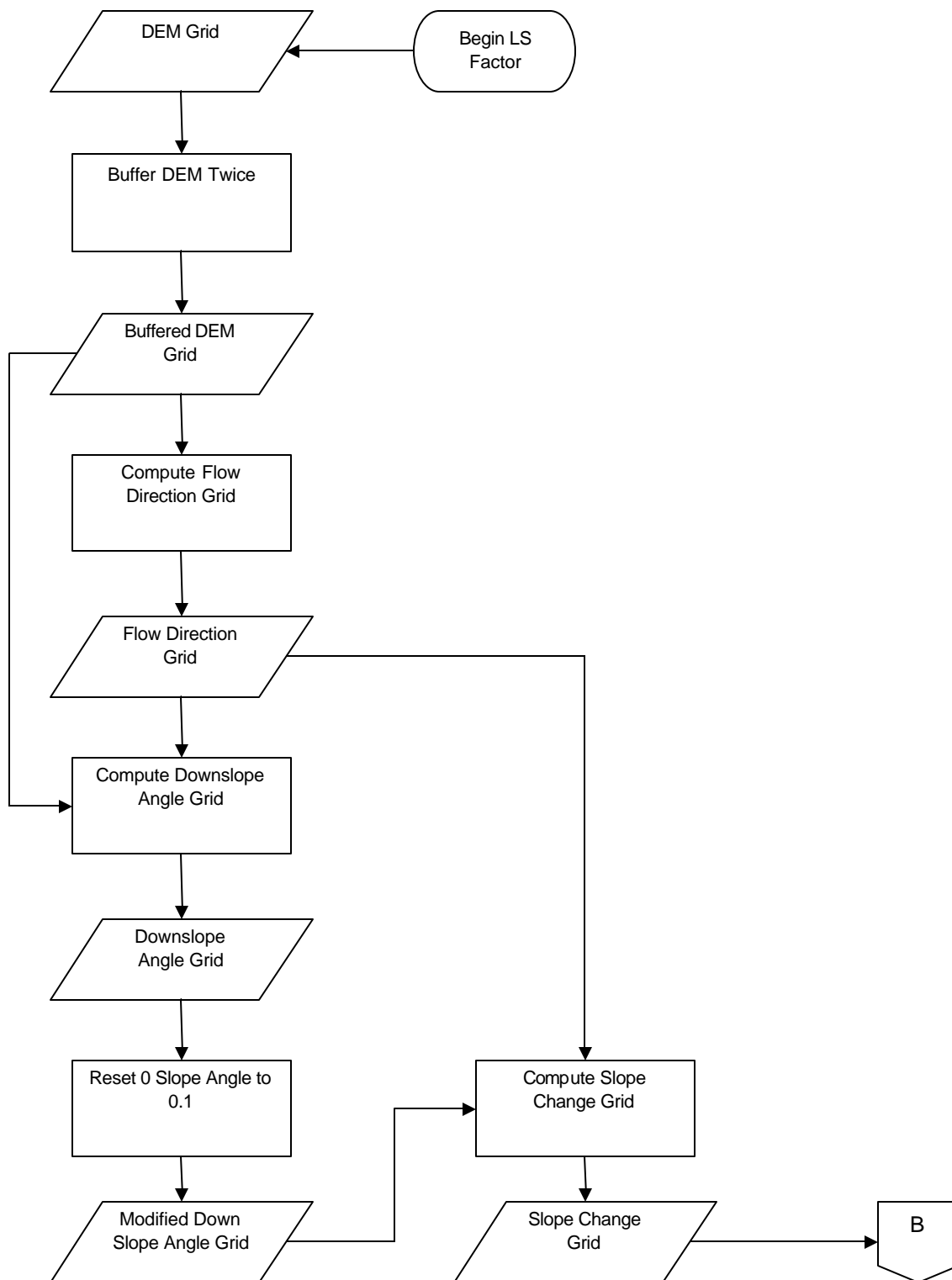
Figure 10: Solving RUSLE

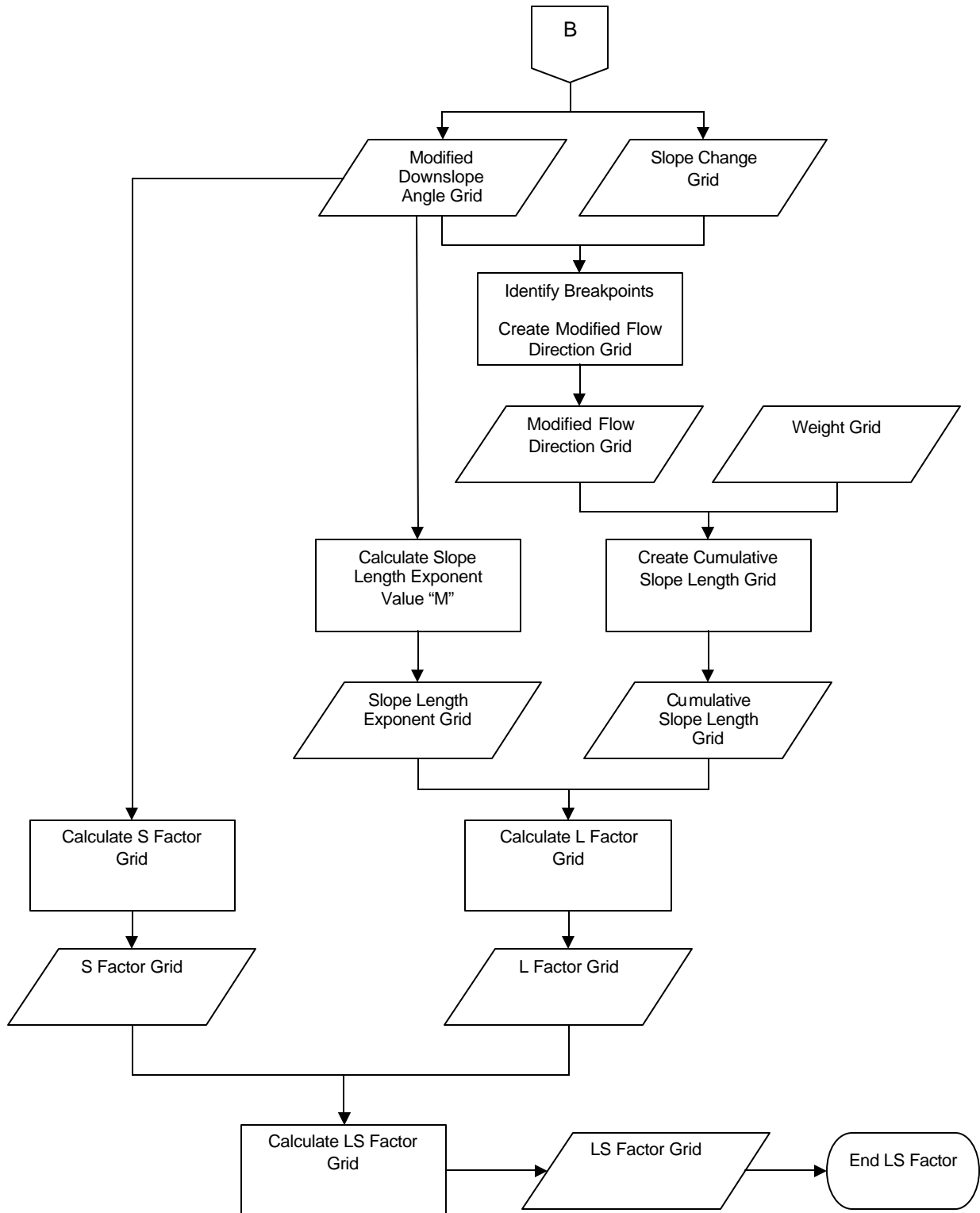




Note: Shading indicates output data set.

Figure 11: Calculate LS Factor





Event-Driven Erosion

In many cases, the effects of a single storm event on erosion and sediment yield are of primary interest. The Modified Universal Soil Loss Equation (MUSLE), given below, is appropriate for use under these circumstances:

$$S = 95 * (Q * q_p)^{0.56} * K * C * P * LS$$

Where

S = sediment yield from an individual storm (tons)
 Q = storm runoff volume (acre-feet)
 q_p = peak runoff rate (cubic feet per second)
 K = soil erodibility factor
 C = cover management factor
 P = supporting practices factor
 L = slope length factor
 S = slope steepness factor

Runoff Volume: Runoff is calculated according to the procedure outlined in the runoff section of this document. A conversion factor is applied to the existing runoff data set to produce a grid with units of acre-feet.

Peak Runoff: This value represents the maximum volume of flow attained at a given point in a stream during a runoff event. N-SPECT incorporates the NRCS Graphical Peak Discharge method to estimate q_p (USDA-NRCS, 1986).

This version of MUSLE is considered the standard version of the equation and is most appropriate for most areas of the United States mainland. However, variations of the standard equation have been developed, and N-SPECT incorporates an Oahu-specific version of MUSLE as its default for the initial release.

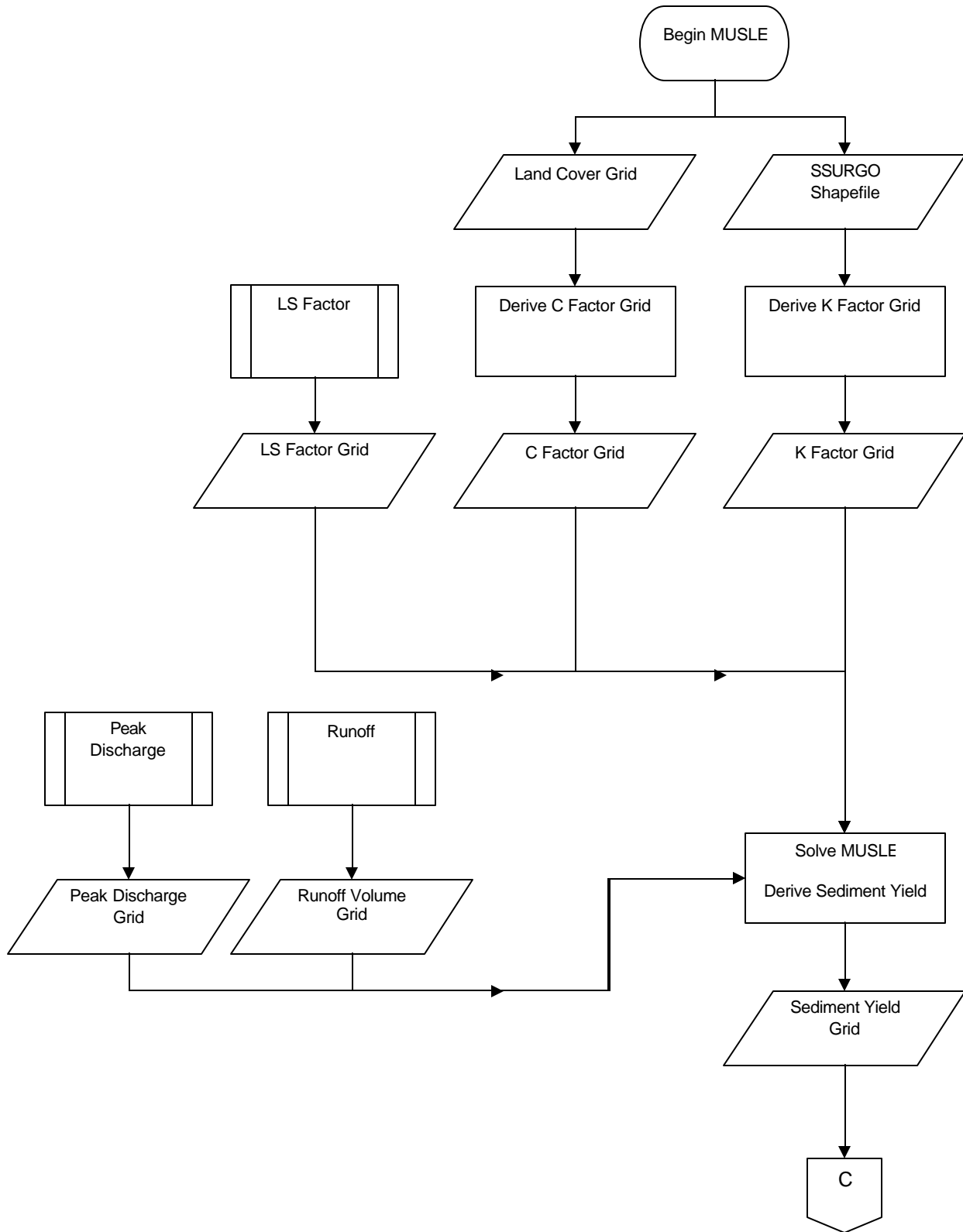
$$S = 18.943 * (Q * qp)^{0.877} * K * C * P * LS$$

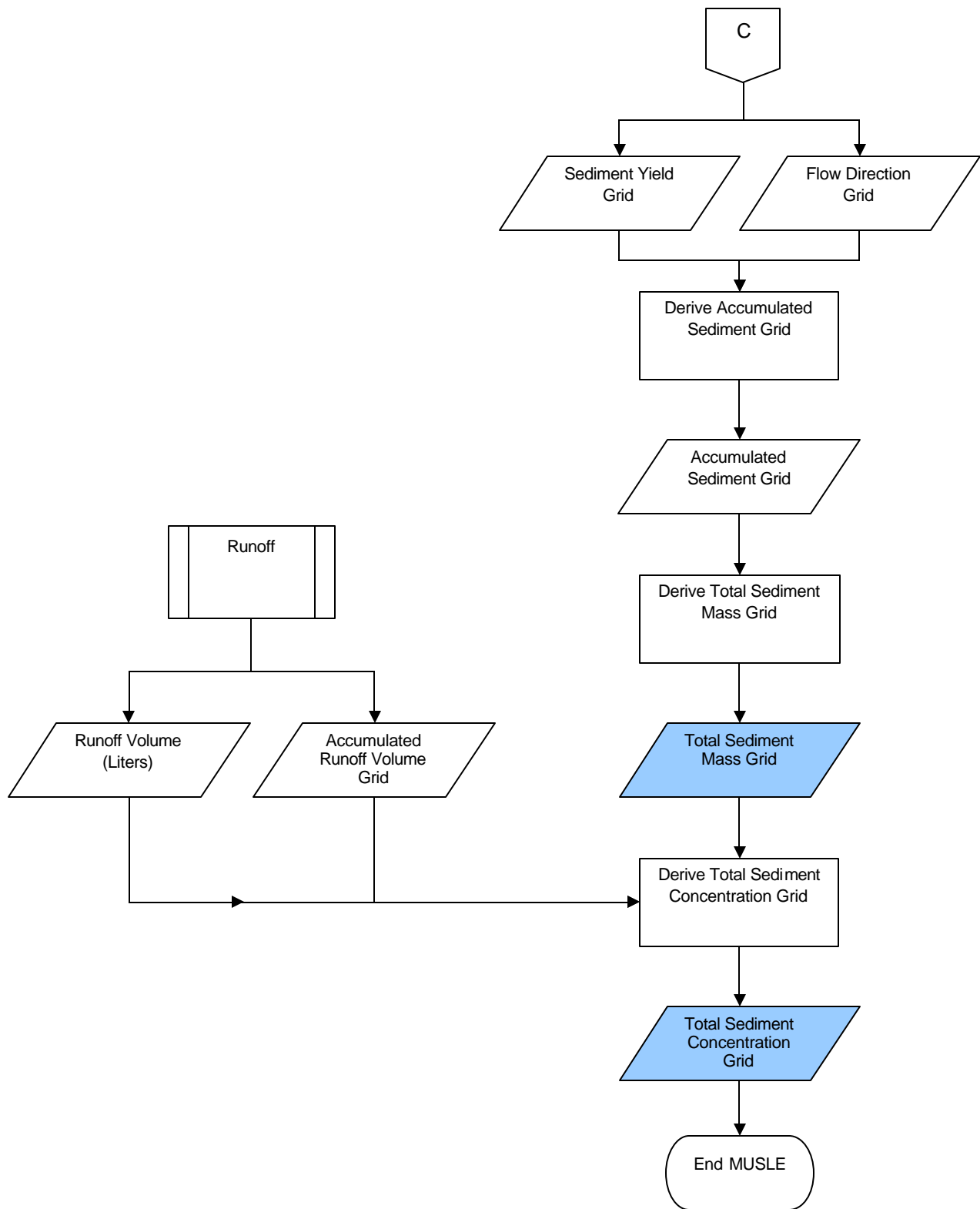
Where

S = sediment yield from an individual storm (tons)
 Q = storm runoff volume (acre-feet)
 q_p = peak runoff rate (cubic feet per second)
 K = soil erodibility factor
 C = cover management factor
 P = supporting practices factor
 L = slope length factor
 S = slope steepness factor

N-SPECT includes an interface menu where the user may change the value of the constant and exponent to better reflect local conditions.

Figure 12: Solve MUSLE





Calculating Peak Runoff

First, calculate time of concentration (minutes) using the SCS Lag Method:

$$T_c = L / 0.6 \quad (\text{Kent, 1972})$$

$$L = W^{0.8} * [(1000 / \text{CN}) - 9]^{0.7} / 1900 * S^{0.5}$$

Where:

L = lag in hours

W = watershed length (feet) (the longest flow path in the watershed)

S = average watershed slope (%)

CN = SCS curve number for the basin

Watershed Length: This measure is calculated at each cell from the digital elevation model (length of one cell side).

Watershed Slope: This is calculated at each cell from the digital elevation model (rise over run times 100).

Curve Number: The curve number grid is created in a previous process.

Then, use T_c to calculate q_u with this equation:

$$\log(q_u) = C_0 + C_1 \log(T_c) + C_2 [\log(T_c)]^2 \quad (\text{TR-55})$$

Where:

q_u = unit peak discharge (csm/in)

T_c = time of concentration (hr)

The C constants will be populated using the la/P ratio at each cell. For instance, if the la/P ratio is less than or equal to 0.10, then $C_0 = 2.30550$, $C_1 = -0.51429$, and $C_2 = -0.11750$.

Table 9: Coefficient Values for Rainfall Type I

| la/P | C₀ | C₁ | C₂ |
|-------------|----------------------|----------------------|----------------------|
| 0.10 | 2.30550 | -0.51429 | -0.11750 |
| 0.20 | 2.23537 | -0.50387 | -0.08929 |
| 0.25 | 2.18219 | -0.48488 | -0.06589 |
| 0.30 | 2.10624 | -0.45695 | -0.02835 |
| 0.35 | 2.00303 | -0.40769 | 0.01983 |
| 0.40 | 1.87733 | -0.32274 | 0.05754 |
| 0.45 | 1.76312 | -0.15644 | 0.00453 |
| 0.50 | 1.67889 | -0.06930 | 0.00000 |

To solve for q_u , raise 10 to the $\log(q_u)$ power.

Finally, calculate peak discharge:

$$q_p = q_u * A_m * Q * F_p \quad (\text{TR-55})$$

Where:

q_p = peak discharge (ft³/s)
 q_u = unit peak discharge (csm/in)
 A_m = drainage area (mi²)
 Q = runoff (in)
 F_p = pond and wetland factor

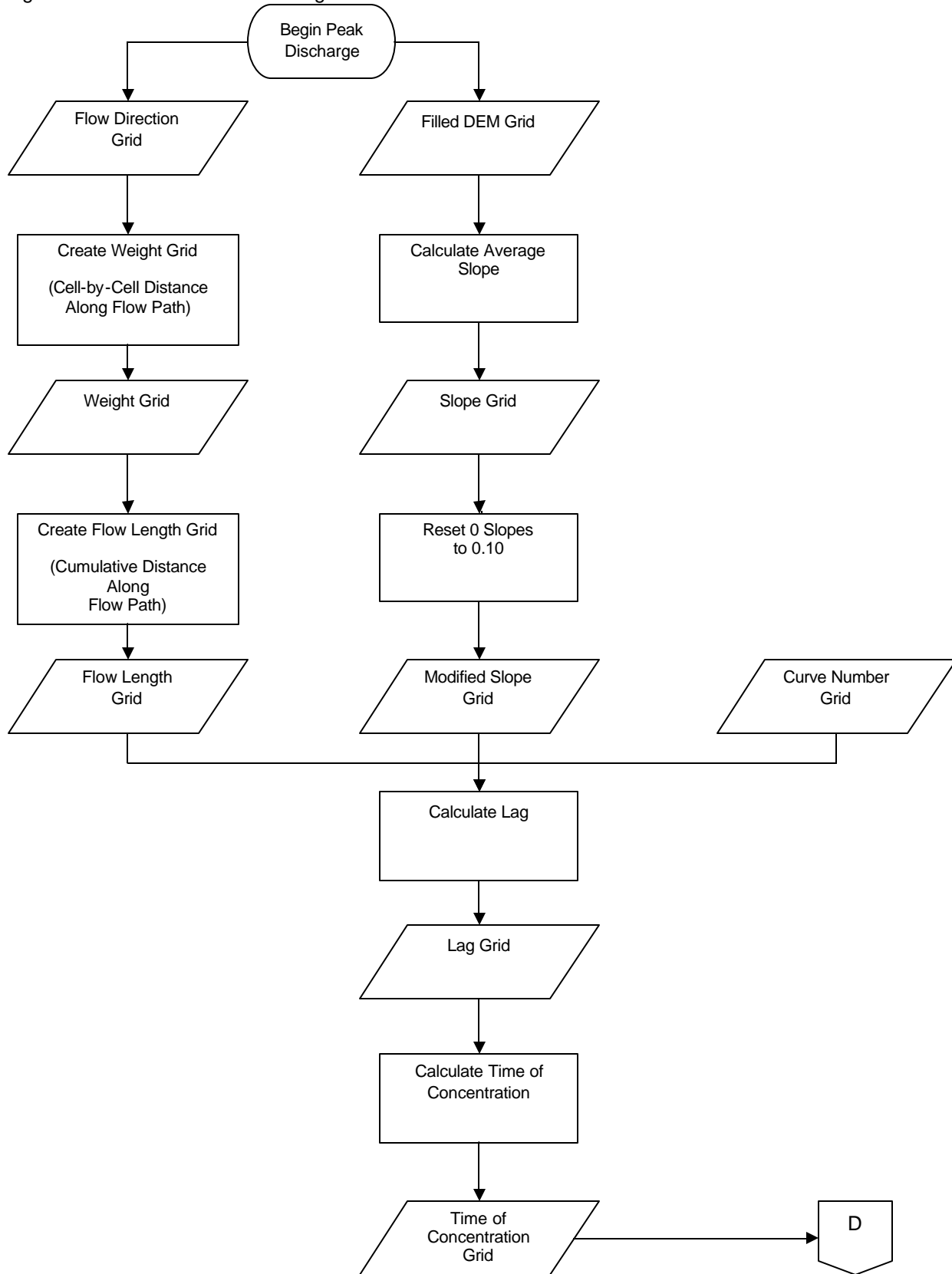
Drainage Area: This is the area of each cell in mi².

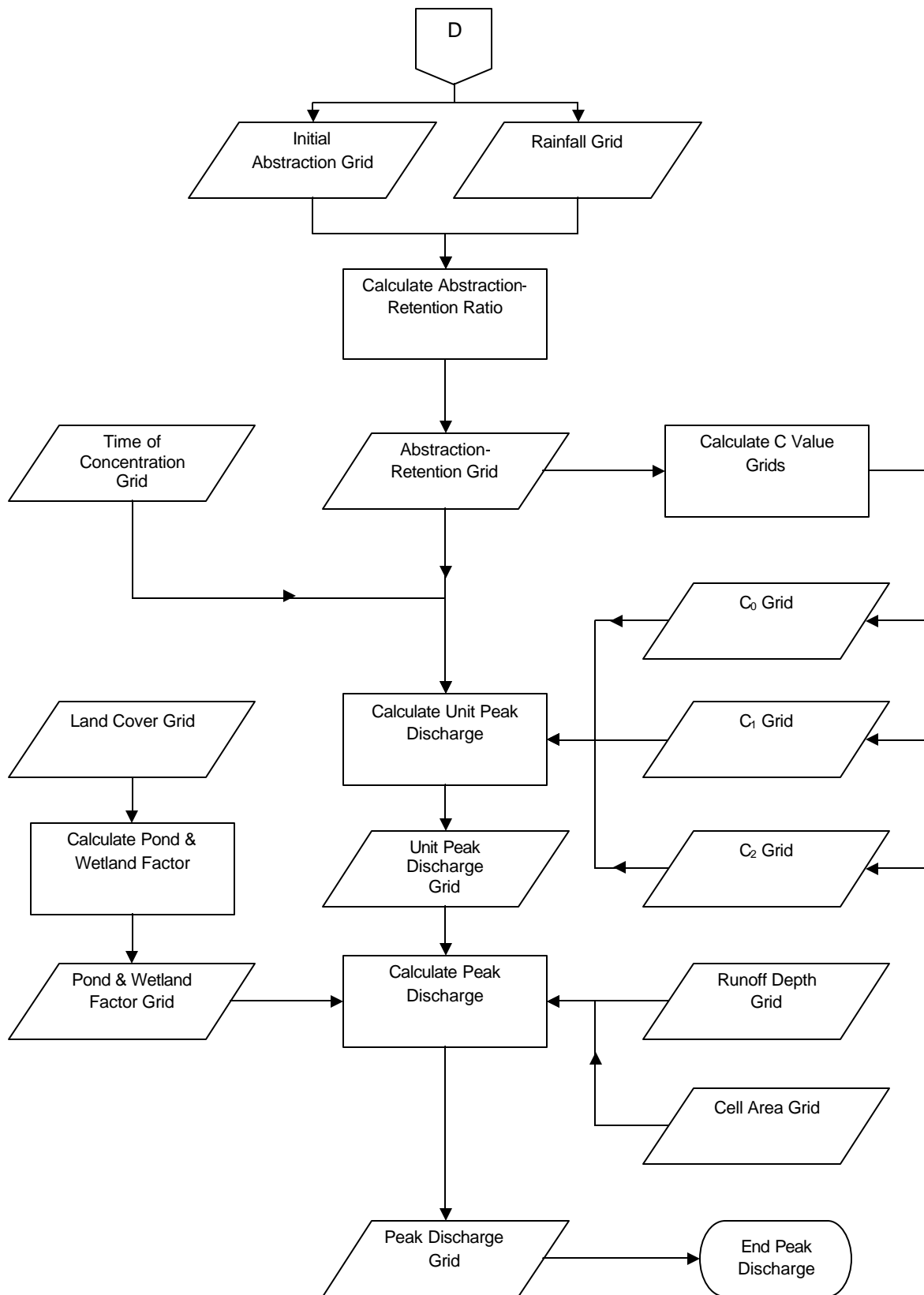
Runoff Depth: This number is the runoff depth grid produced above.

Pond and Wetland Factor: If there is water or wetlands at the cell, F_p will be 0; otherwise, F_p is 1.

The storm event sediment yield grid is generated by multiplying the C factor, K factor, and LS factor grids by $[95 * (Q * q_p)^{0.56}]$.

Figure 13: Calculate Peak Discharge





Input Data Sets

Input data sets used to estimate annual sediment yields using RUSLE include:

- Digital elevation model
- Land cover grid
- Rasterized SSURGO soils data set
- Rainfall grid
- R factor grid

R Factor Grid

N-SPECT uses the Revised Universal Soil Loss Equation (RUSLE) to estimate annual rates of erosion. The R factor is one of the parameters that must be specified but unfortunately does not exist as a data layer for Hawaii. This issue was mitigated by creating a shapefile approximation from a hardcopy version of the R factor map created by the Hawaii State NRCS Office in 1995. View this map at:

http://efotg.nrcs.usda.gov/references/public/HI/R_Oahu_110702.pdf

R factor maps for other regions can typically be found in the NRCS Electronic Field Office Technical Guide or by contacting the local NRCS office. Find your local office at the link below:

www.nrcs.usda.gov/technical/efotg/

Section I of the technical guide has a subheading called Erosion Prediction, which is where the R factor map is likely to be found.

The first step to producing the R factor data set was to create a line shapefile that approximates, as closely as possible, the features of the R factor map. Each of the line features was attributed according to the values given on the hardcopy map. Then, a one-mile buffer was placed along the outside of the Oahu boundary shapefile. This buffer was created to ensure full coverage of the entire island once the interpolation process is completed. The geoprocessing wizard was used to union the buffer shapefile and the R factor shapefile. The line features were converted to points using an ArcView 3.x script (*pline2pt.ave*). ArcToolBox[®] was used to convert the point shapefile to a coverage, then clean and build the coverage. Using ArcGIS[®] and the Spatial Analyst extension, a grid surface based on the point coverage was interpolated. For our purposes, the kriging method was used with the R factor attribute specified as the Z value field. These steps are summarized below:

- Approximate the R Factor Map
- Buffer the Area of Interest
- Union and Convert Lines to Points
- Convert to Coverage
- Interpolate a Grid Surface

Input data sets for estimating event-driven sediment yields using MUSLE include:

- Digital elevation model
- Land cover grid
- Rasterized SSURGO soils (kfactor)
- Rainfall grid

The procedures for obtaining and preparing each of the above data sets for use with N-SPECT is detailed in the runoff section of this document.

Output Data Sets

N-SPECT produces two primary output data sets for both annual and event-driven scenarios:

- Accumulated sediment (kg)
- Sediment concentration (kg/L)

Each cell of the accumulated runoff grid represents the total value of all upstream cells, which flow into the current cell along the paths delineated in the flow direction grid.

The sediment concentration grid provides an estimate of the suspended sediment concentration at each cell. The inclusion of sediment contributions from upstream cells depends on whether the Local Effects Only check box was enabled in the Run Analysis menu.

Resources

- Conaway, Gary, and Neville Curtis Jr. n.d. Calibration of the Modified Universal Soil Loss Equation. Portland, OR: West National Technical Center.
- Kent, Kenneth M. 1972. "Chapter 15: Travel Time, Time of Concentration, and Lag." In *National Engineering Handbook, Section 4*. Available at:
ftp://ftp.wcc.nrcs.usda.gov/downloads/hydrology_hydraulics/neh630/630ch15.pdf
- Renard, K.G., G.R. Foster, G.A. Weesies, D.K. McCool, and D.C. Yoder. 1997. *Predicting Soil Erosion by Water: A Guide to Conservation Planning with Revised Universal Soil Loss Equation (RUSLE)*. United States Department of Agriculture, Agriculture Handbook 703, United States Government Printing Office, Washington D.C.
- USDA-NRCS. 1986. *Urban Hydrology for Small Watersheds*. Technical Release 55 (TR-55). Second Edition. Washington, D.C.
Available at: ftp://ftp.wcc.nrcs.usda.gov/downloads/hydrology_hydraulics/tr55/tr55.pdf
- Van Remortel, R.D., M.E. Hamilton, and R.J. Hickey. 2001. "Estimating the LS Factor for RUSLE through Iterative Slope Length Processing of Digital Elevation Data within ArcInfo Grid." *Cartography*. Vol. 30, No. 1. Pp 27–35.
- Williams, J.R. 1977. Sediment Delivery Ratios Determined With Sediment and Runoff Models. In *Erosion and Solid Matter Transport in Inland Waters*. pp 168-179. IAHS-AISH pub No. 122.
- Wischmeier, W.H. and D.D. Smith. 1978. *Predicting Rainfall Erosion Losses—A Guide to Conservation Planning*. Agriculture Handbook No. 537. U.S. Department of Agriculture, Washington, DC.

Basic Concept: Assessment and Reporting

N-SPECT allows users to estimate pollutant concentrations and the effects of erosion, but the reporting component of the tool is equally important. This section of the technical guide explains how the reporting scheme is organized and how to interpret the output. A brief discussion of scenario analysis with N-SPECT is also provided.

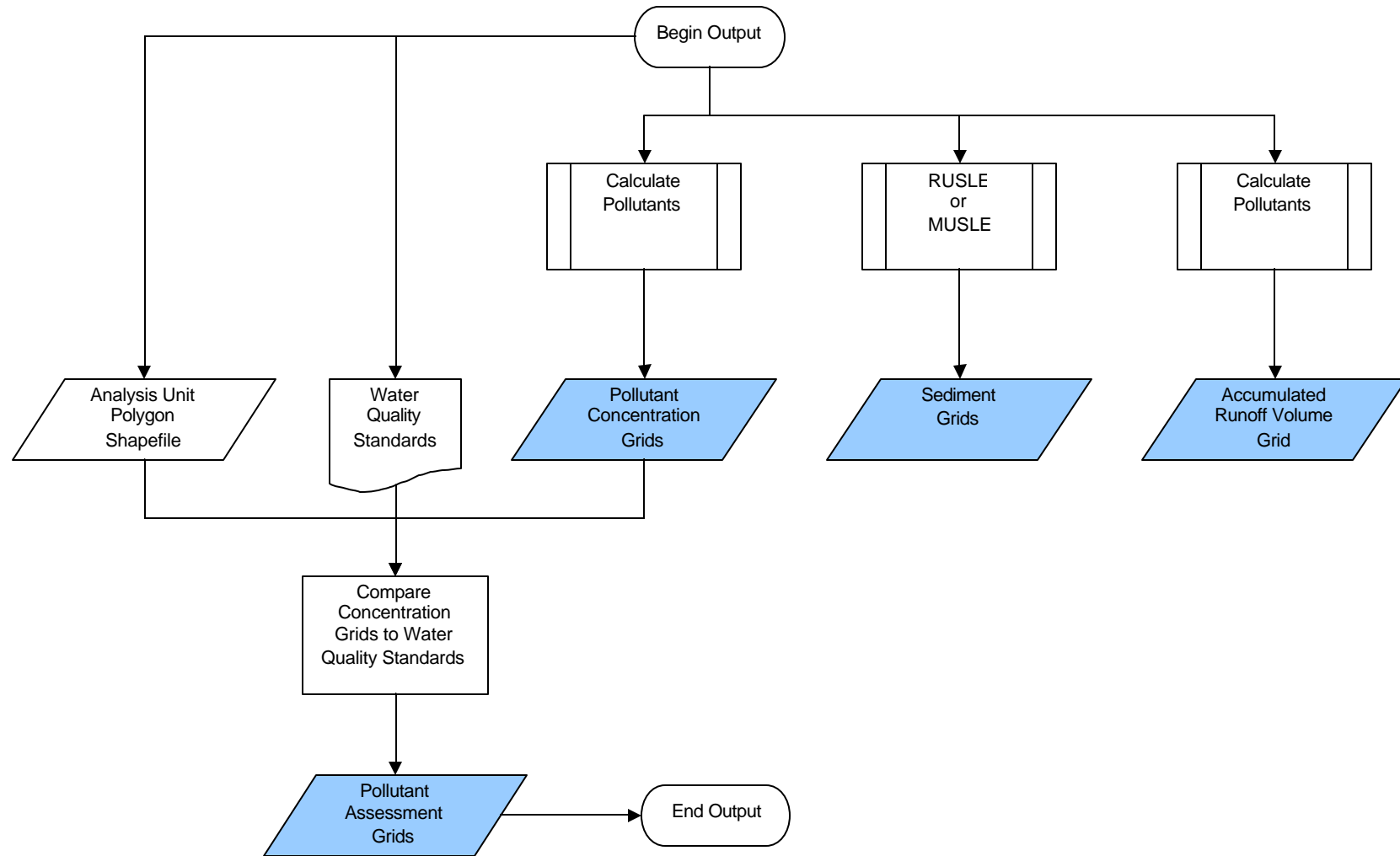
Assessment and Reporting Method

Pollutant and suspended sediment concentration grids are compared with user-specified water quality standards, and a shapefile of analysis unit polygons (which may or may not be hydrologically defined) is color-coded to indicate deviation from the target level. Output data sets are organized and displayed in the ArcGIS® table of contents using group layers.

N-SPECT allows users to perform basic scenario analysis. Using the management scenarios functionality, a user can change the land cover inside a polygon shapefile to a different (but preexisting) land cover class. An interesting application of this functionality might involve the conversion of wetland areas to a low-intensity developed classification. A comparison of the output data sets produced by this run with those produced under the initial conditions would highlight the impacts of development and emphasize the linkages between land cover and water quality.

Users may also specify a land use (new land cover class) and attach it to the features of a polygon shapefile. This functionality is accessed through the Land Uses tab on the main menu. In addition to a polygon shapefile, the user must specify runoff curve numbers, the erosion cover management factor, and pollutant coefficients. For example, users could specify the location of landfills with a polygon shapefile, create a new land use, and then enter the supporting curve numbers and coefficients. Assuming the parameters provided for the new land use are accurate, the larger analysis also becomes more accurate.

Figure 14: Assessment and Reporting Process



Note: Shading indicates output data set.

Input Data Sets

Data sets produced by other components of N-SPECT become inputs to the reporting and assessment process. N-SPECT evaluates pollutant and sediment concentration grids against default or user-defined standards to provide insight into the overall water quality of a particular area. Relevant data sets include:

- Pollutant grids
- Sediment/erosion grids
- Runoff grids
- Water quality standards
- Analysis unit polygons

The only input data sets that may require user interaction are the water quality standards and analysis unit polygons. Default water quality standards are included for Waianae based on Hawaii Department of Health guidelines, but users may specify new standards as well. The analysis unit polygons are used to organize data for output reporting. Typically, this shapefile will consist of delineated watersheds but can be anything that fits the user's needs.

Output Data Sets

Each cell in a pollutant concentration grid has a unique value, but these grids alone do not necessarily answer questions about larger water quality issues. The pollutant assessment grids provide a cell-by-cell evaluation of how the local conditions compare with an established or user-defined standard for water quality. Output data sets include:

- Accumulated runoff volume grid (L)
- Accumulated pollutant grid(s) (kg)
- Pollutant concentration grid(s) (mg/L)
- Pollutant assessment grid(s) (exceeds standard or below standard)
- Accumulated sediment grid (kg)
- Sediment concentration grid (kg/L)

The pollutant assessment grids and shaded analysis unit polygons are the primary products of the reporting process. The grids show how the estimated pollutant concentration compares with the selected water quality standard at each cell. This approach allows the user to more easily identify specific areas of concern that may be logical targets for further investigation and monitoring. The shaded polygon shapefile focuses on larger areas and reports the degree of compliance by comparing a weighted average of the pollutant concentration of all cells within a given polygon to the water quality standard. This ensures that a single cell with an unusually high pollutant concentration does not skew the overall assessment for its analysis polygon.

Resources

State of Hawaii Department of Health, Environmental Planning Office/Clean Water Branch. 2000. Hawaii Administrative Rules. "Title 11, Chapter 54: Water Quality Standards."

Appendix A: Upstream Contributing Area Scripts

AML Script: Prepare DEM

```

/*****
/* This AML preps the DEM and creates grids that will be used in the following AMLs (snap_gages.aml,
/* landcover.aml) to isolate the upstream land uses for a given point on the stream network.
/*
/* Created by: Bev Wilson
/* Created on: October 17, 2003
/*
/* Required inputs: Digital elevation model (grid) with filename dem
*****/
&echo &off
&TYPE Entering GRID session
grid

/*-----
/* fill the grid
&if [exists filldem -grid] &then
    kill filldem all
&if ^ [exists filldem -grid] &then
    fill dem filldem
&TYPE DEM was filled successfully

/*-----
/* create flowdirection grid
&if [exists flodir -grid] &then
    kill flodir all
&if ^ [exists flodir -grid] &then
    flodir = flowdirection (filldem)
&TYPE Flowdirection was calculated successfully

/*-----
/* create flowaccumulation grid
&if [exists floacc -grid] &then
    kill floacc all
&if ^ [exists floacc -grid] &then
    floacc = flowaccumulation (flodir)
&TYPE Flowaccumulation was calculated successfully

/*-----
/* create drainage network grid
&if [exists flownetgrd -grid] &then
    kill flownetgrd all
&if ^ [exists flownetgrd -grid] &then
    flownetgrd = con (floacc gt 1000, 4)
&TYPE Drainage network grid was created successfully

/*-----
/* create drainage network line cover
&if [exists flownet -arc] &then
    kill flownet all
&if ^ [exists flownet -arc] &then
    flownet = streamline (flownetgrd, flodir)
&TYPE Drainage network coverage was derived successfully

/*-----
q

```

AML Script: Snap Gages to Stream Network

```

/*****
/* This AML snaps the monitoring stations to the stream network and converts the resulting grid to a shapefile. After
/* this AML finishes, use ToolBox to convert snapshape.shp to a coverage called snpcov. Use ArcInfo to add xy
/* coordinates to the coverage and export the .vat as a .dbf file. Use Notepad to create an input file of xy coordinates.
/* Then, run landcover.aml.
*
/* Created by: Bev Wilson
/* Created on: April 2, 2004
/*
/* Required inputs: Monitoring station(s) as a shapefile
/*****
&echo &off
&TYPE Entering GRID session
grid
/*-----
/* convert shapefile to grid
&if [exists points -grid] &then
    kill points all
        points = shapegrid(stations_utm04_nad83_pt1.shp, ID, 10)
&TYPE Shapefile was converted successfully
/*-----
/* snap gages to flowacc grid
&if [exists snap -grid] &then
    kill snap all
        snap = snappour(points, floacc, 20)
&TYPE Gages were snapped successfully
/*-----
/* Convert to shapefile
        snapshape = gridshape(points)
&TYPE Grid was converted successfully
/*-----
q

```

AML Script: Derive Land Cover Percentages

```

/*****
/* This AML isolates the contributing upstream land uses for a given point on the stream network. It will be used to
/* derive pollutant coefficients for N-SPECT based on local WQ sampling data. Run dem_prep.aml before running this
/* AML.
/*
/* Created by: Bev Wilson
/* Created on: October 17, 2003
/*
/* Required inputs: ASCII text file with x,y coordinates for points in
/*          Flowdirection grid (flodir)
/*          Flowaccumulation grid (floacc)
/*          Land cover grid (lulc)
*****/

&echo &on
/*specify text file with coordinates
&sv file = [response 'Enter name of coordinates text file']
grid
/*-----
/* create a list of old files to be deleted
&sv numobs = [filelist wshed* wshed_file.txt -grid]
&sv numobs = [filelist lulc_subset* lulc_file.txt -grid]
&sv numobs = [filelist outfile* dbf_file.txt -file]
&sv eof = 0
&sv open_status = 0
&type %eof%
/*-----
/* cleanup existing wshed grids
&s wfile = [open wshed_file.txt open_status -r]
&if %open_status% ne 0 &then
  &return Could not open file wshed_file
&do &while %eof% ne 102
  &sv vals = [read %wfile% eof]
  &if %eof% eq 102 &then &goto the_end
  &sv w = %vals%
  kill %w% all
  &label the_end
&end
&sv eof = 0
/*-----
/* cleanup existing lulc_subset grids
&s lfile = [open lulc_file.txt open_status -r]
&if %open_status% ne 0 &then
  &return Could not open file lulc_file.txt
&do &while %eof% ne 102
  &sv vals = [read %lfile% eof]
  &if %eof% eq 102 &then &goto the_end
  &sv l = %vals%
  kill %l% all
  &label the_end
&end
&sv eof = 0

```

```

/*-----
/* cleanup existing outfile .dbfs
&s dfile = [open dbf_file.txt open_status -r]
&if %open_status% ne 0 &then
  &return Could not open file dbf_file.txt
&do &while %eof% ne 102
  &sv vals = [read %dfile% eof]
  &if %eof% eq 102 &then &goto the_end
  &sv d = %vals%
  &sv delstat = [delete %d%]
  &label the_end
&end
&sv eof = 0
/*-----
/* initialize variables and open points file
&TYPE Initialize the record number
&sv eof = 0
&sv vals =
&sv coord_record =
&sv xcoord =
&sv ycoord =
&sv fileunit1 = [open %file% openstat -READ]
&if %open_status% ne 0 &then
  &return Could not open file %file%.
&sv rec_no = 1
/*-----
/* start the watershed delineation process
&TYPE Starting the DO loop
&do &while %eof% ne 102
  &sv vals = [read %fileunit1% readstat]
  &if %eof% eq 102 &then &goto the_end
  &sv xcoor = [substr %vals% 1 10]
  &sv ycoor = [substr %vals% 13 11]
  &sv coord_record = %xcoor%, %ycoor%
&type %coord_record%
&TYPE Delineating contributing upstream area for coordinates %coord_record%
wshed%rec_no% = watershed(flodir, selectpoint(floacc, %coord_record%, inside))
buildvat wshed%rec_no%
/*-----
/* create land cover grid based on watershed mask
&TYPE Setting mask to contributing upstream area for location %rec_no%
setmask wshed%rec_no%
&TYPE Creating masked lulc grid for location %rec_no%
lulc_subset%rec_no% = lulc
buildvat lulc_subset%rec_no%
/*-----
/* write statistics out to a .dbf file
&TYPE Writing statistics to dbf for location %rec_no%
infodbase lulc_subset%rec_no%.vat outfile%rec_no%
/*-----
/* get ready for the next record
&sv rec_no = %rec_no% + 1
  &label the_end
setmask off
&TYPE Next record number is %rec_no%
&end
q

```

Appendix B: Default Pollutant Coefficients

Table 10: Default Pollutant Coefficients (Literature Sources)

| C-CAP Value | C-CAP Land Cover Class | Total Phosphorus (mg/L) | Total Nitrogen (mg/L) | Total Suspended Solids (mg/L) | Total Zinc (mg/L) | Total Lead (mg/L) | BOD (mg/L) | Source |
|-------------|--------------------------------|-------------------------|-----------------------|-------------------------------|-------------------|-------------------|------------|--|
| 2 | High-Intensity Developed | 0.47 | 2.22 | 71.00 | 0.06 | 0.09 | 10.60 | Adamus and Bergman, 1995 (High-Density Residential) |
| 3 | Low-Intensity Developed | 0.18 | 1.77 | 19.10 | 0.03 | 0.06 | 4.40 | Adamus and Bergman, 1995 (Low-Density Residential) |
| 4 | Cultivated Land | 0.42 | 2.68 | 55.30 | 0.03 | 0.03 | 3.83 | Adamus and Bergman, 1995 (Crops) |
| 5 | Grassland | 0.48 | 2.48 | 55.30 | 0.03 | 0.03 | 3.83 | Adamus and Bergman, 1995 (Pasture) |
| 6 | Deciduous Forest | 0.05 | 1.25 | 11.10 | 0.01 | 0.03 | 1.45 | Adamus and Bergman, 1995 (Recreation, Open Space, Range) |
| 7 | Evergreen Forest | 0.05 | 1.25 | 11.10 | 0.01 | 0.03 | 1.45 | Adamus and Bergman, 1995 (Recreation, Open Space, Range) |
| 8 | Mixed Forest | 0.05 | 1.25 | 11.10 | 0.01 | 0.03 | 1.45 | Adamus and Bergman, 1995 (Recreation, Open Space, Range) |
| 9 | Scrub/Shrub | 0.05 | 1.25 | 11.10 | 0.01 | 0.03 | 1.45 | Adamus and Bergman, 1995 (Recreation, Open Space, Range) |
| 10 | Palustrine Forested Wetland | 0.20 | 1.10 | 19.00 | 0.02 | 0.00 | 4.10 | CH2M Hill, 2000 (Forested Wetland) |
| 11 | Palustrine Scrub/Shrub Wetland | 0.20 | 1.10 | 19.00 | 0.02 | 0.00 | 4.10 | CH2M Hill, 2000 (Forested Wetland) |
| 12 | Palustrine Emergent Wetland | 0.20 | 1.10 | 19.00 | 0.02 | 0.00 | 4.10 | CH2M Hill, 2000 (Forested Wetland) |
| 13 | Estuarine Forested Wetland | 0.20 | 1.10 | 19.00 | 0.02 | 0.00 | 4.10 | CH2M Hill, 2000 (Forested Wetland) |
| 14 | Estuarine Scrub/Shrub Wetland | 0.20 | 1.10 | 19.00 | 0.02 | 0.00 | 4.10 | CH2M Hill, 2000 (Forested Wetland) |
| 15 | Estuarine Emergent Wetland | 0.20 | 1.10 | 19.00 | 0.02 | 0.00 | 4.10 | CH2M Hill, 2000 (Forested Wetland) |
| 16 | Unconsolidated Shore | 0.12 | 0.97 | 70.00 | 0.20 | 0.03 | N/A | NURP, 1983 (Open/Nonurban) |

| C-CAP Value | C-CAP Land Cover Class | Total Phosphorus (mg/L) | Total Nitrogen (mg/L) | Total Suspended Solids (mg/L) | Total Zinc (mg/L) | Total Lead (mg/L) | BOD (mg/L) | Source |
|-------------|------------------------|-------------------------|-----------------------|-------------------------------|-------------------|-------------------|------------|-------------------------------|
| 17 | Bare Land | 0.12 | 0.97 | 70.00 | 0.20 | 0.03 | N/A | NURP, 1983 (Open/Nonurban) |
| 18 | Water | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | N/A |
| 19 | Palustrine Aquatic Bed | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | N/A |
| 20 | Estuarine Aquatic Bed | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | N/A |

Appendix C: R Factor Grid

Avenue Script: Convert Lines to Points

```

'-- Script: pline2pt.ave
'-- This script converts a polyline theme into a point
'-- theme, where each point represents each vertex on
'-- all polylines.
,
'-- This script should be run on an elevation contour
'-- line theme in order to prepare it for surface
'-- interpolation using the Spatial Analyst extension.
,
'-- To run:
'-- Make View the active window
'-- Make your contour line theme the active theme
'-- Ensure the contour line theme has a field that
'-- contains the elevation value for each line

'-- Set up input objects
theView = av.getactivedoc
theTheme = theView.Getactivethemes.get(0)
origFTab = theTheme.GetFTab
theFieldList = origFTab.GetFields
origShapeFld = origFTab.FindField("Shape")
elevFldChoice = MsgBox.ChoiceAsString
    (theFieldList,
    "Which field contains the contour elevation values ",
    "")
origElevFld = origFTab.FindField(elevFldChoice.asstring)

'-- Create the new point shapefile template
newShapefileName = FileDialog.Put("*.shp".asfilename,"*.shp","")
idBaseName = newShapefileName.GetBaseName.AsString.Trim.Left(4)
newFTab = FTab.MakeNew(newShapefileName,POINT)

'-- Populate the new shapefile with fields
newShapeFld = newFTab.FindField("Shape")
newElevFld = Field.Make("Elev",#FIELD_LONG,12,0)
newIDFld = Field.Make(idBaseName+" "+ID",#FIELD_LONG,12,0)
newFTab.AddFields({newElevFld,newIDFld})

'-- Process each polyline in the input line theme
for each rec in origFTab
    av.ShowMsg("Converting Polylines to Vertex Points...")
    av.SetStatus((rec+1/(origFTab.GetNumRecords)) *100)
    thePolyline = origFTab.ReturnValue(origShapeFld,rec)
    elevValue = origFTab.ReturnValue(origElevFld,rec)

'-- Process each part of the polyline
for each aListofPoints in (thePolyline.AsList)
    pointCount = aListofPoints.Count

'-- Process each point in each polyline part, and populate the
'new shapefile with each vertex point you find.
    for each i in (0..(pointCount - 1))
        newPoint = aListofPoints.Get(i)
        newRecNum = newFTab.AddRecord
        newFTab.SetValue(newShapeFld,newRecNum,newPoint)
        newFTab.SetValue(newElevFld,newRecNum,elevValue)
        newFTab.SetValue(newIDFld,newRecNum,newRecNum)

    end '-- for each i
end '-- for each aListofPoints
end '-- for each rec

```

```
'-- Add the new point shapefile to the View  
newFTheme = FTheme.Make(newFTab)  
theView.AddTheme(newFTheme)  
newFTheme.SetVisible(true)
```

```
'-- Clean Up  
newFTab.SetEditable(false)  
theView.Invalidate  
av.ClearMsg  
av.ClearStatus
```

```
'-- End of Script: Pline2Pt.ave
```

Figure 15: R Factor Map of Oahu.

