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**Documentation for the Use of GLEAMS
(Version 3) and Auxiliary Programs in Forest
Service Risk Assessments (Version 2.04)**

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TABLE OF CONTENTS

1 INTRODUCTION	1
2 WEATHER FILES	3
3 PESTICIDE FILES	4
4 HYDROLOGY FILE	7
5 EROSION FILE	14
6 AUXILIARY PROGRAMS	17
6.1 Soil Levels	17
6.2 Total Pesticide Loss	17
6.3 Pesticide concentrations in Lake/Pond	17
6.4 Pesticide concentrations in Stream	22
6.5 Consideration of Rainfall, Runoff, and Percolation Water	24
6.6 Summary files for concentration in ambient water	25
7 U.S. EPA TIER 1 SCREENING MODELS	25
8 REFERENCES	26
Table 1: Input and Output files typically used in generic GLEAMS model runs	29
Table 2: Example table for pesticide specific parameters	30
Table 3: Hydrology parameters typically used in GLEAMS modeling	31
Table 4: Erosion parameters typically used in GLEAMS modeling	32
Table 5: Input parameters for GENEEC	33

APPENDICES

APPENDIX 1: Source code for ReadFile() Function
APPENDIX 2: Source code for CalcLake() Function
APPENDIX 3: Source code for CalcStrm() function
APPENDIX 4: Source code for SetSum() function
APPENDIX 5: History of revision

1. INTRODUCTION

GLEAMS (Groundwater Loading Effects of Agricultural Management Systems) is a root zone model that can be used to examine the fate of chemicals in various types of soils under different meteorological and hydrogeological conditions. Previous GLEAMS simulations conducted for Forest Service risk assessments were based on GLEAMS Version 2 (Knisel et al. 1992). This documentation is based on GLEAMS Version 3 (Knisel and Davis 2000). GLEAMS Version 3 is available for downloading at http://www.cpes.peachnet.edu/sewrl/Gleams/gleams_y2k_update.htm. As discussed at this site and detailed further by Knisel and Davis (2000), Version 3 is modified to accommodate annual leaf drop which is added to soil surface residue and incorporates corrections to metric crop height in hydrology parameters. Version 3 also adds Y2K compliance and various other enhancements and additions. The changes relevant to the implementation of GLEAMS modeling in Forest Service risk assessments are discussed in the relevant sections below. Auxiliary programs (Section 6) were ported from Visual dBase (Version 5.7, 16-bit) to dBASE PLUS (Version 2.01, 32-bit) and revised to improve performance. dBase PLUS is a database manage program available commercially (<http://www.dbase.com/>).

The primary purpose of this white paper is to describe and document the GLEAMS input files used in SERA risk assessments and detail the methods used to estimate the concentrations of pesticides in water based on the GLEAMS output files. The description is intended to be sufficiently detailed to allow individuals familiar with the GLEAMS model to critically evaluate and audit the application of this model to a specific risk assessment. In addition, this document is intended to be sufficiently clear so that individuals not specifically familiar with the GLEAMS model may nonetheless be able to understand and critique the basic assumptions used in developing the exposure assessments.

This document is divided into sections explaining each of the basic types of input files used in each model run: weather files (Section 2), pesticide files (Section 3), hydrology files (Section 4), and erosion files (Section 5). This is followed by documentation of the auxiliary programs used to estimate concentrations in ambient water from the GLEAMS model runs (Section 6) and a discussion of other screening models that may be used in SERA risk assessments (Section 7). A list of references is provided in Section 8.

While this document may be useful to individuals attempting to learn GLEAMS, it is not intended to serve as a tutorial. GLEAMS is a very complex model and the user manual prepared by Knisel and Davis (2000) is the best source of information on developing GLEAMS simulations. This white paper does not specifically address the merits of using the GLEAMS model. Nonetheless, GLEAMS has been tested extensively for modeling pesticides (Cohen 1996; Connolly et al. 2001; Garnier et al. 1998; Leonard et al. 1987; Leonard et al. 1987; Sichani et al. 1991; Truman and Leonard 1991) as well as nutrients (e.g., de Paz and Ramos 2002; Djodjic et al. 2002) and is generally comparable to PRZM (Pesticide Root Zone Model), another root zone model developed and used by the U.S. EPA (Jones and Mangels 2002; Mueller et al. 1992; Parrish et al. 1992; Smith et al. 1991).

GLEAMS requires a large number of parameters that are designed to reflect site-specific conditions. The application discussed in this document, however, involves the application of GLEAMS in the development of “generic” exposure assessments intended to reflect a wide range of conditions that may impact off-site movement of pesticides. Apart from pesticide specific parameters, the dominant factors in the off-site movement of pesticides from soil involve both soil type and rainfall rates. Thus, simulations are developed using a wide range of annual rainfall rates (Section 2). Separate runs at each rainfall rate are made for each of three soil types: clay, loam, and sand. As detailed in Sections 3 through 5, ranges of soil specific parameters are often used and are intended to bracket plausible ranges of pesticide losses associated with runoff, sediment, percolation. Various soil parameters are typically selected to maximize runoff from clay and maximize percolation from sand. In general, soil-specific parameters selected for loam are intended to reflect central estimates that neither favor runoff or percolation and lead to higher retention in soil.

As with many environmental fate and transport models, the input and output files for GLEAMS can be complex. In a typical generic model run designed to support a risk assessment, approximately 200 files are used or generated and a summary of these files is presented in Table 1. Required inputs files include one parameter file for the pesticide(s) and any metabolites, a parameter file for erosion, and a parameter file for hydrology. In addition, a parameter file for daily rainfall must be included. GLEAMS output files include summary files for erosion (*.ERO), hydrology (*.HYD), and pesticides (*.PST). These are automatically generated by the GLEAMS program but are not used in developing exposure estimates. Instead, the detailed daily output file (*.VAR) from each simulation is read into various auxiliary dBase (*.DBF) files. These daily DBF files are then used by auxiliary programs written in dBase to generate daily concentrations in a standard pond and stream. These daily data are then summarized in terms of average concentration and maximum concentration and these summary files are typically included as tables in the body of each risk assessment. The specifics of generating the input and output files are detailed in the following sections of this document.

2. Weather Files

In current risk assessments, annual rainfall rates of 5 inches to 250 inches are included. National monthly rainfall statistics covering the period from 1961 to 1990 were obtained from the U.S. Weather Service (<http://www.nws.noaa.gov/climatex.shtml>). Based on these files, national annual summary statistics were generated in a dBase file. Average annual rainfall ranged from a low of 0.3 inches (lower range for Yuma Arizona) to 172.2 inches (upper range for Yakutat, Alaska). Based on these statistics, model runs for are conducted using rainfall rates of 5, 10, 25, 50, 100, 150, 200, and 250 inches per year. [Note that the NOAA link is no longer active. Other data summarized at <http://lwf.ncdc.noaa.gov/oa/ncdc.html> clearly indicate that the range of 5 to 250 inches per year will encompass most areas in the United States.]

Nomenclature for the rainfall files follows the format: *RAIN_“INCHES”.DAT*. For example, *RAIN_050.DAT* has the daily rainfall data for an area with an annual rainfall of 50 inches. Each rainfall file is structured so that the first year and a half of the simulation does nothing but condition the soil moisture. During the first year, the rainfall occurs in a uniform amount each day. In all subsequent years, the rainfall occurs once every tenth day. The chemical is applied on Julian day 180 of the second year of the simulation and thus all losses reflect the every tenth day cycle which tends to increase runoff and sediment losses but may reduce losses through percolation. It should also be noted that the ten day cycle starts anew on Jan. 1 of each year. Thus, the time between the last rainfall of one year and the first rainfall of the next year is five or six days rather than ten days. This typically results in small spikes for the losses at the start of each year.

It should be noted that pesticide loss from a site will vary substantially with different rainfall daily rates. The use of the the every tenth day cycle will generally tend to overestimate pesticide loss over the course of a year. However, extreme rainfall events may occur in which a single rainfall event may exceed the every tenth day estimate. For example, at an annual rainfall rate of 100 inches, each individual rainfall event is modeled as about 2.78 inches – i.e., $100 \text{ inches} \div 36 \text{ events}$. In some cases, however, a greater daily rainfall could occur such as 5 inches in a severe storm. In such an instance, actual runoff immediately following a pesticide spray could be better estimated by using the simulation conducted at an annual rainfall rate of 200 inches – i.e., individual rainfall events of 5.55 inches. Again, this sort of situational variability cannot be completely encompassed in a generic modeling approach and judgement will be necessary in applying the results of the modeling effort to a specific site. If a site-specific estimate is required, the best approach is to use site-specific information including daily patterns of rainfall rates.

3. PESTICIDE FILE

This input file contains all pesticide specific information as well as information relating to when the simulation should begin. There are typically three pesticide files for each run:

CLAY_PST.PAR, **LOAM_PST.PAR**, and **SAND_PST.PAR**. This approach permits the inclusion of any chemical specific data indicating that persistence or binding (apparent K_{oc}) that may differ depending on the type of soil.

The contents of this file are discussed in detail in Knisel and Davis (2000) and the following brief synopsis is provided for convenience along with some notes on how pesticide parameters are selected. No specific pesticide parameters are discussed here. All pesticide parameters are included in a table in each SERA risk assessment. An example of a pesticide data table is given in Table 2.

GLEAMS Version 3 comes with a simple and very easy to use DOS program, **PST.EXE**, Version 2, that is extremely useful in auditing or developing of a specific pesticide input file. It allows navigation among the different parameter fields and displays the field name, appropriate units, and help information. Note that versions of these files that were provided with GLEAMS Version 2 should not be used with GLEAMS Version 3 input files. The correct versions of **PST.EXE** as well as the other input file editing programs is typically provide on the CD which contains the files developed by SERA for each exposure assessment. These programs are also provided with the download of GLEAMS 3.

In the description of the input file below, as well as similar descriptions in Sections 4 and 5, the term *Card* number corresponds to the nomenclature in the GLEAMS documentation. These may not correspond to the physical line number. The description of each *card* in the input put file is taken from Knisel and Davis (2000) – often with little modification – and annotated as necessary to explain the value selected for each entry in the generic model runs conducted for most Forest Service risk assessments.

Cards 1 to 3:

These are literally the first three lines of the input file and are not read by the GLEAMS program. They typically give the file name and some descriptive information.

Card 4:

PBDATE - Julian Day beginning pesticide simulation.

Typically set to 1990001

Note that this value must be \geq HBDATE in the hydrology file and less than the first day that the pesticide is applied (PDATE = 2180 or 91180).

PEDATE - Julian Day ending the pesticide simulation. Set to 1995365

NPEST - number of pesticides, typically set to 1.

IROT - 1, everything same each year.

PSTOUT - 0, only summary report. As indicated in Section 1, this report is not used by the auxiliary programd.

PESTICIDE FILE continued

Card 4 continued

Note: This card specifies that simulation runs from 1990001 to 1995365 - i.e., Jan. 1, 1990 (year 1 of the cycle) to Dec. 31, 1995 (year 6 of the cycle). These dates are arbitrary and of no consequence to the model results.

Card 5:

NOPEST - pesticide ID. Typically set to a value of 1 – only a single chemical is modeled.

PSTNAM - Name. Up to 16 characters.

METAB - Number of metabolites considered here. Range 0 to 366.

Metabolites are modeled if the information is used quantitatively in the risk assessment. If so, a Card 5 for each metabolite must follow the Card 5 for the parent and must be assigned a unique NOPEST.

Card 6:

NOPEST - The pesticide number. Typically 1 if only a single compound is modeled.

H2OSOL - solubility in water (mg/L).

HAFLIF - foliar half life in days.

KOC - organic carbon to water partition coefficient (Ko/c).

See Section 5 for a discussion of Ko/c.

FOLRES - 0, assume no foliar residue at start of run.

WSHFRC - foliar washoff fraction.

COFTRN - coefficient of transformation of parent to metabolite.

COEFUP - coefficient for pesticide uptake by plant (range of 0 to 1).

Card 7:

SOLLIF() - soil halftime by layer.

RESIDUE()- soil conc. by layer at start of run. None here.

Note: Typically, only one value is given because a uniform soil layer is used in these general model runs.

In general, the preferred value for soil halftime will be from studies that involve only degradation such as biodegradation or hydrolysis. “Field halftimes” that involve both degradation and dispersion may overestimate the disappearance of the compound from the soil because GLEAMS is specifically intended to model the dispersive components of chemical transport.

PESTICIDE FILE continued

Card 8:

PDATE - 2180, First day when parameters on line 9 are valid.

This is 91180, the 180th day of the second year of the simulation.

IPST - number of pesticides applied (typically set to a value of 1).

Note: In the standard simulation, the pesticide is applied once each year starting on the 180th day of the second year. Thus, for the last year, only half of the losses are tracked in the simulation - i.e. from 5180 to 5365. Thus, data from year 5 are not used in the auxiliary programs (Section 6).

Card 9:

NOPEST - Pesticide ID. Typically set to "1" – only one chemical is modelled.

APRATE - Application rate in kg/ha.

DEPINC - depth of incorporation in units of cm.

Set to "1" for surface application.

Note, this value is not sensitive to the metric flag, FLGMET.

FOLFRC - fraction applied to foliage.

SOLFRC - fraction applied to soil.

METH - 0, for surface application.

CHMWAT - this is not included (left blank) in the standard simulations.

NOTE: As specified on p. 102 of the GLEAMS 3 manual, APRATE must be in kg/ha. This is not affected by any of the metric flags such as FLGMET in the hydrology file. For most runs, APRATE is set to 1.121 kg/ha, equivalent to 1 lb/acre. The output is then scaled linearly for the application rate of concern in the risk assessment. This approach is taken because very low application rates - e.g., 0.02 lb/acre - will often lead to erroneous zeros in the output files because GLEAMS outputs fixed decimals out to only six places after the decimal. This is fine for 'typical' application rates but not for very low application rates used with some of the newer herbicides.

If multiple chemicals are applied, there will be additional Card 9's.

Line 10:

0 - just lets the program know there is no more data to read from the file.

4. HYDROLOGY FILE

This file contains all of the hydrology specific information used in a model run. As with the pesticide files, there are typically three hydrology files in each set of simulations: **CLAY_HYD.PAR**, **LOAM_HYD.PAR**, and **SAND_HYD.PAR**. Many of the values included in these files are relatively simple and self-explanatory and discussed below for each *Card* in the file. A summary of the more important values included in the hydrology files is given in Table 3. Comments on the specific values summarized in Table 3 are included in the discussion of the specific parameters below.

GLEAMS also comes with a DOS program called **HYD.EXE**. This is similar to **PST.EXE** and is extremely useful in auditing or developing of a specific hydrology input files, providing information on field names, appropriate units, and help information.

CARDS 1 to 3:

As with the pesticide file, the first three lines of the input file and are not read by the GLEAMS program and typically contain the file name and some descriptive information.

CARD 4:

HBDATE - 1990001, start of hydrology simulation.

This must be less than the first storm date to initialize the soil water storage and not greater than PBDATE on line 4 of the pesticide file (PBDATE=90001).

In all runs, this is 1990001.

HYDOUT - 0, annual summary in hydrology output file. This is not used.

IROPT - 0, irrigation not applied.

FLGNUT - 0, nutrients not run.

FLGPST - 1, pesticide is run.

FLGGEN - 0, do not read temperature data from hydrology parameter file.

FLGMET - 0, climate and parameter data are in English units - not metric.

FLGTMP - 0, mean daily temperature file is not read.

BCKEND - 1, selected output is desired. This refers to the *.VAR files specified in Table 1.

FOREST - type of site.

0 = agricultural field

1 = long leaf conifer forest

2 = short leaf conifer and cedar forest

3 = mixed pine-hardwood forest

4 = hardwood forest.

Note: FOREST is typically set to 3, mixed pine-hardwood forest. This is not a sensitive parameter for total pesticide loss. [Note also that the text editor that comes with GLEAMS, **HYD.EXE**, does not allow a 4 to be entered for this field. This is apparently a bug. A value of 4 can be entered using any standard text file editor.]

HYDROLOGY FILE continued

CARD 5 - The “card” is really two lines for output variables.
The variables typically requested in the input file are:

- 1 Precipitation
- 2 Runoff
- 3 Percolation
- 4 Evapotranspiration
- 601 Runoff loss, g/ha All of the below are for chem 1.
- 651 Sediment loss, g/ha ...
- 701 Percolate loss, g/ha ...
- 751 Total pest. loss, g/ha ...
- 801 Pest. mass by layer, kg/ha ...
- 811 Pest. conc. by layer, ug/g ... soil and water
- 821 Pest. conc. in H₂O by soil layer, mg/L
- 831 Pest. conc. in soil by layer, ug/g

Note: GLEAMS 3 has a new set of output codes for pesticide loss but the old codes can still be used and are currently used.

CARD 6

DAREA - Total drainage area in acres - NOT HECTARES. See FLGMET.
Typically, this is set to 10 hectares or 24.71 acres. This is discussed further in Section 6.3 in terms of the relative size of the field and pond volume.

RC - Effective saturated conductivity of soil horizon, in/hour.
The specific values indicated in Table 3 of this documentation are based on Table H-2, p. 46 in Knisel and Davis (2000), classifying clay as in hydrologic group D, sand in hydrologic group A, and loam between hydrologic groups B and C. For the generic modeling, RC and SATK (see below) are assumed to be equal – i.e., a restrictive soil layer below root zone is not modeled.

BST - This is the fraction of plant available water in the soil at start of run.
Use 1.0 for full wet (field capacity). Use 0 for completely dry (wilting point). In typical run, this is set to 0.5 at the start of the simulation. Because 1.5 years are simulated for soil conditioning, this is not a sensitive parameter in the simulation.

CONA - Soil evaporation parameter, dependant on soil texture.

HYDROLOGY FILE continued

CARD 6 continued

CN2 - Soil curve number.

The specific values given in Table 3 are based on Table H-4, p. 48 in Knisel and Davis (2000), classifying soils in hydrologic groups as specified above for RC. The value for clay is selected to maximize runoff – i.e., upper range for a hard surface. Value for sand (36, central value for fair Group A soil in woods) favors percolation but is not taken as the lowest possible value (i.e., 8). Value for loam is taken as a central value for Group B/C soil with fair hydrologic condition in woods.

CHS - Hydraulic slope.

This will be highly site specific and can make a substantial difference in total loss as well as distribution between runoff and percolation, depending on the type of soil. The slope of 0.1 is essentially arbitrary.

WLW - ratio of field length to field width.

Length is defined by flow path.

$WLW = (\text{Length of flow path in ft}^2) / (\text{acres} \times 43560 \text{ ft}^2/\text{ac})$.

The shape of the field is assumed to be square and the value is set to “1”.

For a right-of-way, the typical assumption is that a 10 hectare area (1,193,980 sq. ft.) is treated and that the dimensions are 50 feet wide and 23,880 feet long. The assumption is made that a body of water runs parallel to the right-of-way. Thus, the flow path is 50 feet and WLW is about 0.002 [$50 \div 23,880 = 0.002094$].

As discussed in Knisel and Davis (2000, p. 26), this is used to estimate the peak rate of runoff but not the volume of runoff. In general, $WLW < 1$ will favor runoff loss over sediment loss and total losses will be less than sites with $WLW=1$ which in turn are less than sites with $WLW>1$. At $WLW<1$, however, absolute values for percolation losses will tend to be greater than other types of sites because of the lesser losses as runoff or sediment. Thus, the geometry of the site influences runoff of the pesticide but this is not a highly sensitive parameter - i.e., differences are generally less than a factor of two.

RD - effective rooting depth in inches (FLDMET=0).

This is set to 12 inches – i.e., a very shallow water table in subsequent calculations of concentrations of the compound in ambient water attributable to percolation.

HYDROLOGY FILE continued

CARD 6 continued

ELEV - Mean sea level elevation, ft (m), of the field. With FLGMET=0 use feet.
For generic runs, use 1000 feet.

LAT - Latitude. (This is always positive unless you are modeling south of the equator.
For generic runs, use 45°.

CARD 7

ISOIL - 0, because FLGNUT is 0.

NOSOHZ - 1, for these general model runs, only a single soil horizon is considered.

BOTHOR() - 12, Same as rooting depth (RD) on Card 6.

CARD 8

POR() - porosity of each soil horizon.

CARD 9

FC() - Field capacity.

CARD 10

BR15() - Wilting point

Because the soil horizon is typically not broken down, only a single value is used for Cards 8, 9, and 10. The values listed in Table 3 of this documentation for clay, loam, and sand are taken from Table H-3, p. 46 of Knisel and Davis (2000).

CARD 11

SATK() - Saturated conductivity (inches/hour).

The are identical to the values used for RC (effective saturated conductivity) on Card 6 –
i.e, the soil below the root zone in not assumed to restrict percolation.

HYDROLOGY FILE continued

CARD 12

OM() - % organic matter. NOT PROPORTION.

The %OM is a sensitive parameter for losses in sediment. In general, the higher the organic matter, the greater the sediment losses but the lesser the runoff losses and percolation. Note also that %OM from this card may be used to estimate KOC: $OC = OM * 1.724$ [Knisel and Davis (2000), p. 30]. Lastly, note that this value must be entered as a percent in the GLEAMS hydrology file and NOT as a proportion. In general, there is a correlation between the % CLAY and %OM (e.g., Weber, 1994, Fig. 3, p. 105.) The values listed in Table 3 are based on typical contents but this can be highly variable. These ranges will not encompass the very high organic matter content of peat soils.

CARD 13

CLAY() - percent clay in each layer.

CARD 14

SILT() - percent silt in each layer

Because the soil horizon is typically not broken down, only a single value is used for Cards 13 and 14. The values listed in Table 3 of this documentation for clay, loam, and sand are taken from Table H-5, p. 48 of Knisel and Davis (2000).

Note: Cards 15 to 17 are omitted because ISOIL=0 – i.e., nutrients are not modeled.

CARDS 18 and 19

TEMPX(1-12) Mean monthly maximum temperatures for each month in °F.
10 on one line and 2 on the next.

CARDS 20 AND 21

TEMPN(1-12) Mean monthly min temperatures for each month in °F.
10 on one line and 2 on the next.

Temperature, at least over a range of 20° to 90° F, makes a relatively minor difference in pesticide losses. GLEAMS can model soil nutrients, which is not done in the model runs here, and for soil nutrients temperature probably has a more substantial effect. For these generic model runs, the maximum and minimum temperatures are set to a constant 80° and 60°, respectively.

HYDROLOGY FILE continued

CARDS 22 AND 23

RAD(1-12) Mean monthly solar radiation for each month in Langleys or (MJ/cm² if FLGMET=1).

10 on one line and 2 on the next.

A substantive change in the GLEAMS input files going from Version 2 to Version 3 involves solar radiation. In GLEAMS 2, solar radiation had to input in units of Langleys per day. In GLEAMS 3, the same units are used if English (non-metric) units are used in the simulation (FLGMET=0). If metric units are used (FLGMET=1), radiation must be input in MJ/m²/day. Since English units were used in the GLEAMS 2 model runs conducted previously by SERA (FLGMET=0), no changes were necessary for this parameter. The value of 250 Langleys is arbitrary and taken from the example given in the GLEAMS documentation (Knisel and Davis 2000, p. 16).

CARDS 24 and 25

WIND(1-12)

Wind speed in miles/day (km/day if FLGMET=1)

10 on one line and 2 on the next.

The value of 72 miles per day in Table 3 corresponds to 3 miles per hour.

This set of parameters is new to GLEAMS 3.

CARDS 26 and 27

DEWPT(1-12)

Mean monthly dew point temperature for each month in °F (°C if FLGMET=1)

10 on one line and 2 on the next.

This set of parameters is new to GLEAMS 3

The dew point temperature is set at 55 °F (13 °C). This is based on Magnus-Tetens formula (Paroscientific Inc. 2003):

$$T_d = b * \alpha(T, RH) / (a - \alpha(T, RH))$$

$$a(T, RH) = a \times T / (b + T) + \ln(RH)$$

$$a = 17.27$$

$$b = 237.7$$

T = temperature in degrees centigrade

RH = relative humidity (proportion)

HYDROLOGY FILE continued
CARDS 26 and 27 continued

The average temperature of 70°F (21.2 °C), the mid-point of the minimum (Cards 20 and 21) and maximum (Cards 18 and 19) temperature used in the GLEAMS runs, is used along with a relative humidity of 0.6. The relative humidity of 0.6 is relatively arbitrary but is representative of values listed nationally at <http://www.met.utah.edu/jhorel/html/wx/climate/rh.html>.

CARD 28 [GLEAMS 2 Card 24]

HBYSR - 1990, Beginning year of hydrology simulation.

HEYSR - 1995, Ending year of hydrology simulation.

IROT - Number of years in rotation. Always 1 in our runs.

NYRFOR - Number of year in forest before simulation begins.

This is set to 1.

The cards specifies that simulation runs from 1990001 to 1995365 - i.e., Jan. 1, 1990 (year 1 of the cycle) to Dec. 31, 1995 (year 6 of the cycle). These are the same as Line 4 of the pesticide file(PBDATE, PEDATE). As with the pesticide dates, these specific years and dates are arbitrary and of no consequence to the model results.

CARD 29 [GLEAMS 2 Card 25]

This is the 'crop' data.

In simulations of herbicide applications, crops are not simulated in these runs – i.e., it is assumed that the treated vegetation dies and longer-term residues are not in plant tissue.

For some non-herbicidal compounds, hardwood or conifer should be used for forestry applications.

Thus, this line has a single "0" in data position 1.

Cards 30, 31, and 32 are skipped if crops are not simulated.

CARDS 33

NEWT - 0, do not read new temperatures from file.

NEWR - 0, do not read new radiation values from file.

NEWW - 0, do not read new wind data from file.

NEWD - 0, do not read new dew point temperature values from file.

Note that NEWW and NEWD are new to GLEAMS 3 and are not needed – they can be left blank or a default value of zero can be used.

Last Line

-1 0 0 0 - this signifies the end of the input file.

5. Erosion File

This file contains all of the field information used in a model run that impacts erosion. As with the pesticide files, there are typically three hydrology files in each set of simulations: **CLAY_ERO.PAR**, **LOAM_ERO.PAR**, and **SAND_ERO.PAR**. As with the other parameter files, many of the values included in these files are relatively simple and self-explanatory and discussed below for each *Card* in the file. A summary of the more important values included in the erosion files is given in Table 4. Comments on the specific values summarized in Table 4 are included in the discussion of the specific parameters below.

Erosion files can be somewhat complex if site-specific topographical profiles are modeled and the use of site-specific profiles can very substantially alter estimates of total pesticide loss as well as the proportion lost through runoff, sediment, and percolation. The erosion files used in the generic GLEAMS runs are relatively simple because only a single overland flow profile is used.

ERO.EXE is another DOS program that is provided with GLEAMS. This is similar to **PST.EXE** and **HYD.EXE** and is recommended as a tool for auditing or developing erosion input files.

CARD 4

BYEAR - 1990, Start year.
EYEAR - 1995, End year.
EROOUT - 0, abbreviated annual summary (this file is not used)
FLGSEQ - 1, overland erosion
METFLG - 0, parameters in English (NOT METRIC) units.

The above years must be consistent with the pesticide and hydrology files.

CARD 5

SSCLY - surface area of clay particulates, m²/g.
A value of 125 is generally used for all soils. This value is the approximate geometric mean between kaolinite [20] and montmorillonite [800] from Knisel and Davis (2000), p. 63.

CARD 6

NPTSO - 1, number of points in overland profile.
DAOVR - drainage area in acres NOT HECTARES

Only a single flow profile is used in the general models and the area is taken to be identical to the number of acres that are treated (DAREA on Card 6 of the hydrology file).

EROSION FILE continued

Card 7

- XOV() - Distance *in feet* from upper end of overland flow profile to point where slope is given. Assuming a square 10 hectare (24.71 acre 1076368 sq ft) field, this is typically taken as 1037 feet. For a right-of-way, a value of 50 feet is typically used.
- SLOV() - Slope of overland flow profile (ft/ft).

Because only a single overland profile is modeled, XOVS() is identical to the length of flow path that is used to calculate WLW and SLOV() is identical to the hydraulic slope (CHS), both of which are on Card 6 of the hydrology file.

CARD 8

- NXK - Number of slope segments. Always 1 for a single profile.
- XSOIL() - Relative horizontal distance from top to bottom of slope segment. Again, for the generic models with a single slope segment, this is always 1.
- KSOIL()- Erodibility by soil texture classification.

The equation KSOIL is taken from Table E-1, p. 90, Knisel and Davis (2000).

$$KSOIL = (TF * (12 - \%OM)) + SF + PF$$

The parameter values listed in Table E-1 for each type of soil are:

	%OM	TF	SF	PF	KSOIL
SAND -	0.5	0.01481	0.0325	-0.050	0.153
LOAM -	2.5	0.03618	0.0325	0.025	0.401
CLAY -	5.0	0.01287	0.0650	0.075	0.230

Note: The values for %OM above must be the same as the value used in OM() of Card 12 of the hydrology file.

NOTE: Cards 9 to 12 are not included because we do not use channels in model.

CARD 13

NYEARS - 1, number of years in rotation.

CARD 14

CDATE() - Julian day on which parameters take effects.
Always 001 in these runs, first day of the year.

EROSION FILE continued

CARD 15

NXF - Number of overland flow profile segments. Set to 1 for a single profile.
XFACT()- 1.0, because only one profile is modeled.

CARD 16

CFACT(I,J) Soil loss ratio. Range is 0.01 to 1.

As discussed by Knisel et al. (1992, p. 102), this may be a sensitive parameter. For the simple single slope approach used in these models, the higher the value the greater total pesticides loss and the losses from sediment and the lesser the losses from runoff. Low values also favor percolation because combined losses from runoff and sediment are less. For standard model runs the following values are used:

CLAY: 0.2
LOAM: 0.15
SAND: 0.1

These selections are intended to favor total losses from clay (sediment) and losses from sand (percolation).

CARD 17

PFACT() - Contouring factor. See Table E-4, p. 93 in Knisel and Davis (2000).

Slope 3- 5% == 0.5

Slope 9-12% == 0.6

Slope 21-25 == 0.9

A value of 0.6 (10% slope) is typically used in general GLEAMS runs.

CARD 18

NFACT() - Manning's "n"

See Table E-5, p. 93 in Knisel and Davis (2000).

0.010 no surface depressions

0.015 sparse grass

0.032 fair grass

0.074 excellent grass

0.150 dense grass

0.400 very dense grass

Unless otherwise specified, a value of 0.015 (sparse grass) is used. This is conservative in that it favors pesticide losses in runoff and sediment.

Card 18 is the last card since channels are not modeled.

6. AUXILIARY PROGRAMS

SERA Inc. has developed a series of custom auxiliary programs to read and manipulate the output from GLEAMS. This section briefly summarizes the algorithms used in these programs.

6.1. Soil Levels

A general function, ReadFile(), transfers data from the output files generated by GLEAMS to DBF files used by other functions discussed below. The commented source code for this function is given in Appendix 1. In the call to ReadFile, a non-zero soil depth is specified that is identical to the rooting depth (RD) on Card 6 of the hydrology file from the GLEAMS run. This function calculates the weighted average of the soil concentrations in the root zone and puts this output into one of three data files: CLAYSOIL, LOAMSOIL, and SANDSOIL (Table 1). The units in the GLEAMS output file are $\mu\text{g/g}$, equivalent to mg/kg or ppm (w/w), and the data are stored in these units.

6.2. Total Pesticide Loss

The general program ReadFile() is also used to read and store total pesticide loss in g/ha from the GLEAMS output files. These data are stored in one of three DBF file (CLAYLOSS, LOAMLOSS, and SANDLOSS) in units of g/ha . These are the total losses from runoff, percolation, and sediment - i.e., pesticide adsorbed to the sediment that is transported to the edge of field. In subsequent programs (detailed below) for calculating the concentration of the chemical in ambient water (lake or stream), the rate of contamination from edge of field losses is taken as this total input from all sources.

Note that the application rate used in the standard GLEAMS run is 1.121 kg/ha , which is equivalent to 1 lb/acre . No adjustments for application rate are made in any of the auxiliary programs. This program only reads up to day 95179. This is done so that only 4 full years with 4 pesticide applications are considered.

A subroutine calculates the proportion of the pesticide that is lost from the site over the four year period. This programs uses total pesticide losses in CLAYLOSS, LOAMLOSS, and SANDLOSS to calculate the proportion of the total loss of the pesticide to the total amount applied in four applications. The results are put into another data file, PROPLOST. The contents of this file are often given in a table in the risk assessment. In calculating the proportion, the cumulative total loss (g/ha) is just divided by the total amount applied (g/ha) – $(\text{ApplRate} (\text{kg/ha}) \times 1000 \text{ g/kg} \times \text{number of applications} = \text{cumulative g/ha applied})$.

6.3. Pesticide Concentrations in Lake/Pond

The function CalcLake() implements the algorithms presented in this section. The commented source code for this function is given in Appendix 2. The function first calculates the amount of pesticide entering the lake/pond on a given day and then calculates the change in the volume of water for that day. The pesticide is then distributed between sediment and water based on the K_d and degradation of the pesticide is considered separately in both sediment and water.

Arguments to this function include the name of the DBF file containing the daily loss information, the name of the output file for storing the daily water concentration data, the field name in this file to use, the Kd of the chemical, the names of the DBF files for rainfall, runoff, and percolation, the metric conversion factor to use, the volume of water in the pond at the start of the simulation, the volume of sediment in the pond, the degradation coefficients for water and sediment (days^{-1}), the surface area (m^3) of the treated field draining into the pond and the surface area of the pond. Note that the soil specific database files designated for runoff (**CLAYRUNO.DBF**, **LOADRUNO.DBF**, and **SANDRUNO.DBF**) include losses from both runoff (GLEAMS code 601) and sediment (GLEAMS code 651).

In most risk assessments, this exposure scenario involves a 1 hectare (2.471 acre), 2 meters deep standing body of water that is immediately adjacent to and fed by drainage from a square 10 hectare treated plot - i.e., an area of 1037 feet wide and 1037 feet long. The pond depth and field area to pond area ratio of 10:1 is consistent with the approach taken by U.S. EPA in their standard pond scenario (http://www.epa.gov/oppefed1/models/water/geneec2_description.htm). The volume of sediment is typically taken as 0.01 of the initial volume of water in the pond.

Note that the 10 hectare, 2 meter deep pond in the GLEAMS modeling is different from the smaller 0.25 acre, 1 meter deep pond used in the accidental spill scenario. This approach is taken because the accidental spill scenario used in the human health risk assessment is intended to be extremely conservative. For longer-term exposure assessments, it does not seem reasonable to assume that anyone will drink water from a very small shallow pond.

Calculations of the concentration of the pesticide in a lake or pond use total pesticide losses in CLAYLOSS, LOAMLOSS, and SANDLOSS. The results are put into CLAYLAKE, LOAMLAKE, and SANDLAKE. Units are typically in $\mu\text{g/L}$ but this can be altered by setting an argument, *MetricConv*, as detailed below. The estimated values, concentration in water at an application rate of 1 lb/acre, are entered in a worksheet (usually Worksheet B07 in Version 2.03 worksheets) and adjustments for the application rate are made in the worksheets as appropriate.

The amount of chemical added on a given day in units of g/ha is read directly from GLEAMS output files and converted to units of grams in the program code in the following commented lines:

```
* Convert g/ha to grams by multiplying by treated area in ha.  
TodaysAmnt = TodaysAmnt * FieldAreaMeters / 10000
```

The constant 10,000 converts field area in meters to field area in hectares. The amount of chemical added in units of mg, μg , or ng (*delta* in the program file) on a given day is calculated as:

```
delta = TodaysAmnt * MetricConversion
```

where the constant *MetricConversion* converts grams (g) to mg, µg, or ng depending on its value: 1,000 for mg, 1,000,000 for µg, or 1,000,000,000 for ng.

Thus, the total amount of the chemical in the lake on a given day is calculated as the amount at the end of the previous day (*Atot*) plus the amount added that day:

$$Atot = Atot + delta$$

Explicit in the GLEAMS model is the assumption that runoff and/or percolation containing the pesticide contaminates the standing body of water. These values are stored in data files (CLRUNOIN LMRUNOIN and SNRUNOIN and CLPERCIN, LMPERCIN and SNPERCIN) in units of inches and are generated by calls to ReadFile() (Appendix 1). In addition, explicit in the physical model for this scenario is that the rainfall, which causes the runoff and percolation, will fall directly into the body of water as well as the adjacent field. The rainfall values are read directly from the GLEAMS output files by a call to ReadFile() and stored in data files (CLRRAININ, LMRRAININ and SNRAININ), also in units of inches.

In considering the volume of water added to the pond by rainfall, runoff, and percolation, the water lost from the pond by evaporation is also considered. The evaporation of water from a body of open water is a very complex process that depends on a number of factors such as temperature of the air and water, relative humidity, atmospheric pressure, and wind speed (e.g., Penman's equation, LOICZ 2000). For the general exposure assessments, a relatively simple approximation recommended by Hamon (1961) and adapted by Haith and Shoemaker (1987) is used:

$$E_{(m)} = 0.0021 L^2 P_{sv} \div (T+273.2) = 0.002167$$

where $E_{(m)}$ is evaporation in units of meters/day, L is the average number of daylight hours per day, T is the temperature in °C, and P_{sv} is the saturated vapor pressure at temperature T. P_{sv} is calculated as:

$$P_{sv} = 0.6108 \exp(17.27 T \div (273.2 + T))$$

The volume of water evaporated over the course of the day in units of liters (*Evap* in Appendix 2) is calculated as the product of the surface area of the pond in meters (*S*), the evaporation rate in m/day (*ER*), and the constant 1000L/m³:

$$EV(L/day) = S(m^2) * ER(m/day) * 1000 (L/m^3)$$

The volume of rainfall (*RainVol*) added to the pond in liters is calculated by converting the inches of rainfall to meters (0.0254 × inches = meters) and then multiplying the meters of rain by the number of square meters of surface area in the pond, yielding cubic meters of rain. This is converted to units of liters by multiplying by 1000 – i.e., 1 cubic meter is equal to 1000 L :

$$\text{RainVol (Liters)} = \text{Rain(inches)} \times 0.0254 \text{ (meters/inch)} \times \text{LakeArea (meters)} \times 1000 \text{ (liters/m}^3\text{)}$$

The volume of runoff (*RunoVol*) and percolation (*PercVol*) are calculated similarly except that the surface area of the field rather than the surface area of the the pond is used. The volume of water in the pond at the end of the day (V_w) is then calculated as:

$$V_w = \text{PreviousVol} + \text{RainVol} + \text{RunoVol} + \text{PercVol} - \text{Evap}$$

In some model runs involving very arid climates for very low initial water volumes in the pond, the volume of the pond can be substantially reduced by evaporative losses. For general modeling, it is assumed that the water volume will be maintained to at least one half of the initial nominal volume – i.e., underground streams. Thus, the total volume of the pond is not allowed to go below one-half of the initial nominal volume, referred to as *MinVolume* in Appendix 2. This component of the algorithm generally has no impact on standard model runs used in Forest Service risk assessments but is included for other applications of the programs.

The next step involves calculating the concentrations in soil and water. By definition:

$$Kd = Cs/Cw$$

where C_s and C_w are the concentrations in soil and water, respectively, and Kd is the partition coefficient. Using A_s and A_w for the amounts in soil and water and V_s and V_w for the volume of soil and water, this is equivalent to:

$$Kd = (A_s/V_s) \div (A_w/V_w) = C_s/C_w.$$

All of these variables must be supplied as arguments to `CalcLake()`, as specified in Appendix 2.

The total amount, A_{tot} , will be equal to $A_s + A_w$ and thus,

$$A_w = A_{tot} - A_s.$$

Substituting this into the equation for Kd ,

$$Kd = (A_s/V_s) \div ((A_{tot} - A_s)/V_w)$$

and solving for A_s ,

$$A_s = (A_{tot} * Kd * V_s) / ((Kd * V_s) + V_w)$$

A_w can then be calculated as above ($A_{tot} - A_s$) and the concentration in both water and soil sediment can be calculated.

In most cases, different K_d 's are used for clay, loam, and sand with the highest K_d being in clay and the lowest in sand. If soil specific data are not available, $K_{o/c}$ may be used from the fourth number on line 6 of the pesticide file along with the %OM from Card 12 of the hydrology file. Current standard values for %OM in this file are: 0.5% (a proportion of 0.005) for sand, 2.5% (a proportion of 0.025) for loam, and 5% (a proportion of 0.05) for clay. Using the relationship,

$$OC = OM/1.724$$

(e.g., Knisel and Davis 2000, p. 30; Winegardner 1996, p. 117), organic carbon accounts for about 58% or a 0.58 proportion of organic matter in soil. Using this equation, the proportion of OC in sand, loam, and clay is estimated as 0.003 for sand, 0.015 for loam, and 0.030 for clay. The soil specific $K_{o/c}$ values may then be converted to K_d by the relationship:

$$K_d = K_{o/c} \times OC$$

where OC is the proportion of organic carbon in the soil (e.g., mg/mg). Alternatively,

$$K_d = K_{o/m} \times OM$$

(Winegardner 1996, p. 116). Note the OC and OM are given as a proportion and not as percent as in the GLEAMS model input files.

Degradation in water and sediment is assumed to follow first order kinetics. Typically, this is characterized as halftimes and the degradation rate constants, k_{wat} and k_{sed} are calculated from the relationship, $k = \ln(2)/t_{1/2}$. Thus, the amount of the chemical in sediment and water at the end of each day is calculated as:

$$A_s = A_s \times \exp(-k_{sed} \times 1 \text{ day})$$

$$A_w = A_w \times \exp(-k_{wat} \times 1 \text{ day})$$

The concentration in the water (C_w) at the end of the day is then calculated as the amount of the compound in the water (A_w as defined above) divided by the volume of water at the end of the day (V_w) as defined above. The concentration in sediment can be calculated from the definition of K_d :

$$K_d = C_s/C_w$$

$$C_s = K_d \times C_w$$

The concentration in sediment is not stored by CalcLake() but can be calculated from the above equation.

6.4. Pesticide concentrations in Streams

CalcStrm() is the function that implements the algorithms presented in this section. The commented source code for this function is given in Appendix 3. Arguments to this function are similar to those of CalcLake(): the name of the DBF file containing the daily loss information, the name of the output file for storing the daily water concentration data, the field name in this file to use, the metric conversion factor to use, the names of the DBF files for rainfall, runoff, and percolation, the flow rate (meters/day) and flow volume (liters/day), the stream length to be modeled (m), the degradation coefficients for water (days^{-1}), the surface area (in hectares) of the treated field draining into the stream and the surface area (m^2) of the portion of the stream being modeled.

This program uses total pesticide losses in CLAYLOSS.DBF, LOAMLOSS.DBF, and SANDLOSS.DBF to calculate the concentration of the pesticide in a stream. The results are put into CLAYSTRM.DBF, LOAMSTRM.DBF, and SANDSTRM.DBF. The DBF files contain values that may be in units of mg/L, $\mu\text{g/L}$, or ng/L, depending on the setting of *MetricConv*, as discussed in Section 6.3.

This program implements a general point source dilution model for stream flow:

$$\text{delta (amount/day)} \div \text{Flow(L/day)} = \text{Conc (amount/L)}$$

or

$$C_s = \delta \div F$$

where δ (delta) is the daily load to the stream. This is a point source model. In the context of the a rights-of-way or treated field, this approach essentially assumes that all of the loss from the treated field is channeled so that it enters the stream at a single point. The length downstream that is contaminated is simply the daily flow rate of the stream. This length of stream is modeled to have the concentration, C_s , calculated above.

For each day, the load to the stream is read from the appropriate dBASE file in units of g/ha and converted to g/day by:

$$\text{Loss}_{(\text{g/ha/day})} \times A_{(\text{ha})} = \delta_{(\text{g/day})}$$

where $A_{(\text{ha})}$ is the area of the treated field in hectares.

Flow rates of streams are highly variable. Many stream flow rates can be found on the USGS web site (www.usgs.gov) and Hampshire Research Institute (1995) has compiled average flow data as well as velocities of flow from USGS records on 55,701 streams as part of their Risk*Assistant program.

For the generic modeling of a 10 ha plot, USGS data were downloaded from http://nwis.waterdata.usgs.gov/usa/nwis/annual/calendar_year for streams with drainage area of 9.8 to 10 ha – i.e., 0.0380 to 0.0386 square miles. A total of 30 streams with 1712 measurements were identified. The 1712 records were sorted by annual mean flow rates, given in cubic-feet per-second. The lowest 1% value – i.e., record 17 – is 0.29 cubic-feet per-second which corresponds to 709,585.92 L/day [0.29 cu ft/sec × 28.32 L/cu ft × 60 seconds/min × 60 minutes per hour × 24 hours/day]. The lowest 5% value – i.e., record 85 – is 9.62 cu ft./sec (23,500,800 L/day). For the generic modeling, the more conservative 1% value is used but is rounded to 710,000 L/day.

The USGS does not provide data on flow velocity. In previous versions of this documentation, a rate of 0.08 meters/second is used based on data from Hampshire Research Institute (1995). This value is maintained and a flow velocity of 6912 meters/day is used:

$$0.08 \text{ m/sec} \times 60 \text{ sec/min} \times 60 \text{ min/h} \times 24 \text{ h/day} = 6912 \text{ m/day.}$$

The point source assumption is a simplification and is reasonably conservative - i.e., it will lead to somewhat higher concentration estimates than alternate assumptions. For example, if the assumption were made that the runoff comes uniformly off of a 2655 m rights-of-way into a stream that flows at a rate of 6912 m/day, the total contaminated length of the stream would be 9567 meters [2655 m + 6912 m]. Assuming that the concentration in the incoming water is zero, the average concentration would be about 72% [6912/9567 = 0.7225] of that using the point source assumption.

The value of $\delta \div F$ is the concentration at the point source and the concentration that would remain in the water if no degradation were to occur. Using a first order degradation rate coefficient of k (days^{-1}), the concentration at a distance, d , downstream may be calculated as:

$$C_s = (\delta \div F)e^{-k d/v}$$

where d is the distance in meters and v is the velocity of flow in meters/day. C_s is the concentration at the specified distance, d , downstream. Note that d/v is simply the time it takes to travel distance d and thus the expression $k d/v$ is unitless: ($\text{hr}^{-1} \times (\text{m} \div (\text{m/hr}))$) = $\text{hr}^{-1} \times \text{hr}$ = unity.

The average concentration in the stream from the input point source to a point d meters downstream may be calculated as the integral of C_s between zero and d divided by the distance d :

$$C_{\text{Ave}} = [(\delta v)/(k F) - (\delta v e^{-k x/v} / (k F))] \div d$$

For a typical scenario, the distance, d , is set to the length of the stream that will be contaminated in a single day - i.e., equivalent to the flow velocity in meters/day. The longer the distance, the

lower the average concentration over the length, d , because of the increased time and hence increased degradation.

As with the lake scenario described in the previous section, the amount of water entering the stream through rainfall, percolation, or runoff is considered. As detailed in Appendix 3, the algorithms are essentially identical to those used for the pond scenario except that evaporation is not considered - i.e., the source water and thus the flow rate for the stream is presumed to be constant except on days in which rain occurs. Binding to sediment is not considered - i.e., the stream bed is assumed to consist primarily of rock. This is a conservative assumption in that it leads to somewhat higher estimates of concentrations of the pesticide in water.

In terms of estimating rainfall - as well as scenarios that involve contamination from drift - it is assumed that the stream is 2 meters (about 6.6 feet) wide with an average depth of about 2 inches. The depth is calculated from the volume flow, taken as 710,000 L/day, which corresponds to 0.051 m³/second $[710,000 \text{ L/day} \div (24 \times 60 \times 60) = 8.2 \text{ L/sec} \approx 0.0082 \text{ m}^3/\text{sec}]$. Given the flow rate of 0.08 m/sec and the flow volume of 0.0082 m³/sec, the cross sectional area of the stream is about 0.1025 m² $[0.0082 \text{ m}^3/\text{sec} \div 0.08 \text{ m/sec}]$. Given a width of 2 meters, the average depth is thus 0.051 m $[0.1025 \text{ m}^2 \div 2\text{m}]$ or about 0.167 foot or 2 inches.

6.5. Consideration of Rainfall, Runoff, and Percolation Water

It should be noted that the consideration of water added to the stream as well as the pond can have a substantial impact on the modeled concentrations, which will be lower than if the contribution of rainfall, runoff and percolation is ignored. This may be viewed as anti-conservative or non-protective. This is not the case. Each of the above two scenarios assumes that only water from the treated area is added to the pond or stream and that the entire drainage area for the stream or pond is treated. This is the most conservative assumption that could be made without ignoring the water added to the pond or lake, which would in turn ignore a physical reality - i.e., the chemical reaches the stream and pond by runoff and percolation and neither runoff nor percolation will occur without rainfall. The way in which this is considered in CalcLake() and CalcStrm() is the most conservative approach that is plausible. For the pond, the scenario essentially assumes that the entire drainage area for the pond is treated. In many cases, this will not be the case. For the stream, a similar assumption is made: the only drainage into the stream will be from the treated area. This is identical to assuming that the entire length of the stream and all of the area feeding the stream is treated. Again, in most cases, this will not be the case and additional water will drain into the stream from untreated areas, reducing the actual concentration of the pesticide in the stream.

6.6. Summary files for concentration in ambient water and soil

The outputs of the lake and stream programs consist of daily estimates of water concentrations over a four year period for each rainfall rate that is modeled in each of three soil types. An auxiliary function, `SetSummary()`, takes each of these DBF files on concentrations in soil, streams, and lakes and gives the peak and average concentrations in water or for each soil type at

each rainfall rate. The source code for this program is given in Appendix 4. These summary data are typically included as tables in the risk assessment.

As with the application of any modeling approach, these results are compared to any available monitoring data.

7. U.S. EPA TIER 1 SCREENING MODELS

The U.S. EPA has developed and uses a large number of models designed for estimating concentrations of pesticides in water. As noted above, PRZM is another root zone model comparable to GLEAMS that is often linked with EXAMS (Exposure Analysis Modeling System). The PRZM/EXAMS modeling approach may be used in complex probabilistic risk assessments that are sometimes referred to as Tier 2 or Tier 3 models. Because probabilistic risk assessments typically involve the use of less conservative exposure assumptions, this approach is not typically used by the Forest Service.

Tier 1 models, on the other hand, are intended to provide very conservative yet plausible upper range estimates of exposure. Two Tier 1 models, GENEEC and SCI-GROW and may be used in some Forest Service risk assessments.

GENEEC is fully described the the U.S. EPA web site, http://www.epa.gov/oppefed1/models/water/geneec2_description.htm. GENEEC simulates a farm pond identical to the pond scenario used with GLEAMS (Section 6.3) – i.e., a 1 ha pond that is 2 meters deep and fed by a 10 ha drainage area. GENEEC simulates runoff and drift as well as the standard degradation processes used in the GLEAMS modeling as well as many of the processes used in PRZM/EXAMS modeling. Specifically, GENEEC is designed to provide upper range estimates that would be obtained from using the PRZM/EXAMS approach with uniformly conservative assumptions. GENEEC may be used in Forest Service risk assessments as a surrogate for PRZM/EXAMS and as a basis for comparison to the GLEAMS pond outputs. Currently, GENEEC Version 2 is used and a copy of the program can be downloaded from <http://www.epa.gov/oppefed1/models/water/>. A summary and description of the input parameters for GENEEC 2 is given in Table 5. When GENEEC is used, a table similar to that of Table 5 but with the appropriate chemical specific data is included in the risk assessment.

The auxiliary programs described in Section 5 for use with GLEAMS as well as PRZM/EXAMS and GENEEC are all surface water models. SCI-GROW is a Tier 1 model designed specifically to estimate concentrations in ground water – i.e., wells that might be used as a source of drinking water by humans or livestock. As with GENEEC, SCI-GROW considers the application rate and a number of specific environmental fate properties – i.e., aerobic soil degradation and adsorption coefficient normalized for organic carbon in soil, and estimates ground water contamination for sites with sandy soils and shallow ground water. Version 2.3 of SCI-GROW is currently used and is available at <http://www.epa.gov/oppefed1/models/water/> with full documentation. In general, the inputs used for SCI-GROW will be identical to but a subset of those used for GENEEC.

8. References

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Table 1: Input and Output files typically used in generic GLEAMS model runs

File Name(s)	Description
GLEAMS INPUT FILES	
CLAY_PST.PAR LOAM_PST.PAR SAND_PST.PAR	Pesticide parameter input files for clay, loam, and sand.
CLAY_ERO.PAR LOAM_ERO.PAR SAND_ERO.PAR	Erosion parameter input files for clay, loam, and sand.
CLAY_HYD.PAR LOAM_HYD.PAR SAND_HYD.PAR	Hydrology parameter input files for clay, loam, and sand.
RAIN_005.DAT...RAIN_250.DAT	Daily rainfall input files for annual rainfall rates from 5"(005) to 250" (250). Annual rainfall rates of 5", 10", 15", 20", 25", 50", 100", 150", 200", 250" are typically included.
GLEAMS OUTPUT FILES	
CL_RN005.VAR...CL_RN250.VAR LM_RN005.VAR...LM_RN250.VAR SN_RN005.VAR...SN_RN250.VAR	Daily output of simulation with values for GLEAMS output codes specified in the hydrology parameter files for clay [CL], loam [LM], and sand [SN].
CL_RN005.ERO...CL_RN250.ERO LM_RN005.ERO...LM_RN250.ERO SN_RN005.ERO...SN_RN250.ERO	Erosion summary output files for clay [CL], loam [LM], and sand [SN]. [Generally not used.]
CL_RN005.HYD...CL_RN250.HYD LM_RN005.HYD...LM_RN250.HYD SN_RN005.HYD...SN_RN250.HYD	Hydrology summary output files clay [CL], loam [LM], and sand [SN]. [Generally not used.]
CL_RN005.PST...CL_RN250.PST LM_RN005.PST...LM_RN250.PST SN_RN005.PST...SN_RN250.PST	Pesticide summary output files clay [CL], loam [LM], and sand [SN]. [Generally not used.]
AUXILIARY FILES	
CLAYLOSS.DBF LOAMLOSS.DBF SANDLOSS.DBF	dBase files ¹ for daily total pesticide loss from site for each soil type in units of g/ha
CLAYSOIL.DBF LOAMSOIL.DBF SANDSOIL.DBF	dBase files ¹ for daily pesticide concentration in each soil type in units of mg/kg.
CLRainIn.DBF, LMRainIn.DBF, SNRainIn.DBF	dBase files ¹ for daily rainfall in inches.
CLPercIn.DBF, LMPercIn.DBF, SNPercIn.DBF	dBase files ¹ for daily water loss from percolation in inches.
CLRunoIn.DBF, LMRunoIn.DBF, SNRunoIn.DBF	dBase files ¹ for daily water loss from runoff in inches.
ClayLake.DBF, LoamLake.DBF, SandLake.DBF	dBase files for daily water concentration (mg/L) in pond/lake generated by CalcLake() ² .
ClayStrm.DBF, LoamStrm.DBF, SandStrm.DBF	dBase files for daily water concentration (mg/L) in stream generated by CalcStrm() ² .
ClayRuno.DBF, LoamRuno.DBF, SandRuno.DBF	dBase files ¹ for daily runoff and sediment losses from site for each soil type in units of g/ha.
PropLost.DBF	dBase summary files ³ for proportion of applied pesticide that moves off-site in runoff. Used for seedling emergence, Worksheet G04.
Lake_Sum.DBF, Strm_Sum.DBF, SoilSum.DBF	dBase summary files ³ for average and maximum concentrations in standard pond (mg/L), stream (mg/L), and soil (mg/kg). These are typically included as tables in each risk assessment.

¹ Each DBF file includes fields for all rainfall rates. All data is read from individual VAR text files.

² See Section 6 for discussion of these models.

³ Each DBF file includes fields for all rainfall rates. Read from corresponding DBF file that contains daily data.

Table 2: Example table for pesticide specific parameters.

Parameter	Clay	Loam	Sand	Comment/ Reference
Halftimes (days)				
Aquatic Sediment	400	400	400	Note 1
Foliar	8	8	8	Knisel and Davis 2000
Soil	24	90	272	Note 2
Water	14	14	14	Scifres et al. (1977)
K _{o/c}	48	29	7	Note 3
K _d	1.44	0.43	0.021	Note 4
Water Solubility, mg/L	200000	200000	200000	Knisel and Davis 2000
Foliar wash-off fraction	0.6	0.6	0.6	Knisel and Davis 2000
Note 1	Aquatic sediment halftimes not encountered. Value of 400 days based on halftime of 417 (158-676) day for deep soil layer (Close et al. 1999, Table 5, p. 70).			
Note 2	Central value and range taken from Havens et al. 2001. Based on field dissipation halftimes reported by Close et al. (1998, 1999), the higher ranges are estimated to occur in sandy soil, followed by loam and clay.			
Note 3	Central value and range taken from USDA/ARS (1995) assuming highest value in clay, followed by loam and then sand. Value for loam supported by Close et al. (1998, 1999)			
Note 4	Based on K _{o/c} and estimates of proportion (<i>P</i>) of organic carbon in clay (0.03), loam (0.015), and sand (0.003), where K _d = K _{o/c} * <i>P</i> .			

Table 3: Hydrology parameters typically used in GLEAMS modeling [see text for discussion]

Parameter	Description, units [Reference/Note]	Clay	Loam	Sand
DAREA	Total drainage area, acres	10	10	10
RC	Effective saturated conductivity, in/hr	0.01	0.15	0.4
CONA	Soil evaporation parameter	3.5	4.5	3.3
CN2	SCS curve number for moisture condition II	93	66	36
CHS	Hydraulic slope	0.1	0.1	0.1
WLW	ratio of field length to field width [see text]	1	1	1
RD	effective rooting depth, inches	12	12	12
ELEV	Mean sea level elevation, ft	1000	1000	1000
LAT	Latitude, degrees (positive for above equator)	45	45	45
NOSOHZ	number of soil horizons	1	1	1
BOTHOR	depth of soil horizon, inches	12	12	12
POR	soil porosity, unitless	0.47	0.4	0.4
FC	field capacity, unitless	0.39	0.26	0.16
BR15	wilting point, unitless	0.28	0.11	0.03
SATK	saturated conductivity, inches/hour	0.01	0.15	0.4
OM	organic matter, % not proportion	5	2.5	0.5
CLAY	percent clay, % not proportion	50	20	5
SILT	percent silt, % not proportion	30	35	5
TEMPX()	mean monthly max temperatures for each month in °F.	80	80	80
TEMPN()	mean monthly min temperatures for each month in °F.	60	60	60
RAD()	mean monthly solar radiation for each month in Langleys	250	250	250
WIND()	wind speed, miles/day	72	72	72
DEWPT()	mean monthly dew point temperature for each month in °F	55	55	55

Table 4: Erosion parameters typically used in GLEAMS modeling

Parameter	Description, units [Reference/Note]	Clay	Loam	Sand
SSCLY	surface area of clay particulates, m ² /g .	125	125	125
DAOVR	drainage area in overland flow profile, acres (Note that 24.71 acres = 10 hectares)	24.71	24.71	24.71
XOV	distance from upper end of overland flow profile to point where slope is given, feet. (Depends on WLW in hydrology file. Values here are for a square 10 ha field, 24.71 acres. 1 acre = 43560 ft ² , 435,600 ft ² * 10 acres * 2.471 acres/ha = 1,076,367.6 ft ² , (1,076,367.6 ft ²) ^{0.5} =1037.48 feet	1038	1038	1038
SLOV	slope of overland flow profile, unitless	Identical to hydraulic slope in hydrology file.		
KSOIL	erodibility by soil texture classification	0.230	0.401	0.153
CFACT	soil loss ratio	0.2	0.15	0.1
PFACT	Contouring factor	0.6	0.6	0.6
NFACT	Manning's "n"	0.015	0.015	0.015

Table 5: Input Parameters for GENEEC ¹.

Parameter	Value	Source/Comment
Maximum single application rate (lb/acre)	program specific	Program description, Section 2 of risk assessments
Application Method	program specific	can be aerial, ground spray, airblast, or granular
Droplet size	program specific	can be very fine, fine, medium, or course
Number of Applications per Year	program specific	Program description, Section 2 of risk assessments ²
Application Interval (days)	program specific	STIK Clear Crop Label (Platte Chemical Co.) ²
PCA factor (decimal)	0.87 default	The is the proportion of drainage area that is treated (Effland et al. 2000).
Depth of Incorporation	0	Set to zero for broadcast spray or aerial application.
Adsorption/Desorption Coefficient (K_{oc})	chemical specific	K_d can be used instead of K_{oc} .
Aerobic Soil met. $t_{1/2}$ (days)	chemical specific	
Aerobic aquatic met. $t_{1/2}$ (days)	chemical specific	If not available, EFED recommends using twice the aerobic soil metabolism $t_{1/2}$.
Water Solubility (mg/L)	chemical specific	
Hydrolysis (pH 7) $t_{1/2}$ (days)	chemical specific	Used only is aquatic halftime is entered as zero.
Aqueous photolysis $t_{1/2}$ (days)	chemical specific	To account for light attenuation of the pond, this value is multiplied by 124 within the program.

¹ See http://www.epa.gov/oppefed1/models/water/geneec2_users_manual.htm for a fuller discussion.

² A single application of the maximum allowable rate is typically used when the maximum annual rate is equal to the maximum single application rate. This results in the highest peak estimates of exposure.

³ Per input guidelines, available value (3.9 days × 3) (Meléndez 2003)

APPENDIX 1: Source code for READFILE() Program

```
* READFILE.PRG
* Based on SoilLvls.PRG
* Developed on April 13, 2003 by PD.
* Modified further in February 2004 based on external review.
* For a specified file name and GLEAMS code, return the requested value.
* This can be an average, as with soil levels (811), or a single number, as with total loss (751).

* Modified ReadFile on April 14, 2003. Different criteria for identifying a new day.
```

```
* The typical block of data will look like the following:
```

```
*1991180
*   1   0.000000
*   2   0.000000
*   3   0.002734
*   4   0.020761
*  601   0.000000
*  651   0.000000
*  701   0.000000
*  751   0.000000
*  801   0.560500   0.000000   0.000000   0.000000
*  811   3.990752   0.000000   0.000000   0.000000
*  821   2.517761   0.000000   0.000000   0.000000
*  831   3.488814   0.000000   0.000000   0.000000
*1991181
*   1   6.850000
*   2   5.946039
*   3   0.130133
*   .....
```

```
* Note that the Date width is 7, the DataCode width is 6, and the width of the data is 12.
* This is important in Procedure GetData(fp, DataLabel), which must be changed if the above values change
```

```
PROCEDURE ReadFile(TargetFieldNm, GLMSOutpFileNm, StartDay, EndDay, ;
                  aGLMS_OutpCodes, aDpthCodes, aTargetDBFNms)
  Private DFBNm
  Local fptr

  * Handle the text file.
  fptr = fopen(GLMSOutpFileNm)
  if(fptr > 0)
    *?DataFileNm + " is open"
    ProcessFile(fptr, TargetFieldNm, StartDay, EndDay, ;
              aGLMS_OutpCodes, aDpthCodes, aTargetDBFNms)
    fclose(fptr)
  else
    ?chr(7)
    ?FileName + " could not be found."
    suspend
  endif
  Return(0)

PROCEDURE ProcessFile(fp, fieldname, StartDate, EndDate, ;
                    aGLMS_Codes, aDpth, aTargetDBF)
  * If soil depth is >0, return an average.
  * Otherwise, return only one value.
  Local ThisDay, numb, nDay, CurrentIndex, numIndex, numTargetDBFs, i
  Private FldNm, DbfName

  DateFieldWidth = 7  && This is a constant
  FldNm = fieldName  && "FldNm" is something like RN025 associated with a specific GLEAMS file. Does not
  change in program.

  * Must start at the top of each DBF file.
  numTargetDBFs = aLen(aTargetDBF)
```

```

for i = 1 to numTargetDBFs
  DbfName = aTargetDBF[i]
  sele &DbfName.
  go top
next

* NOTE: We look for all of the GLEAMS output codes in "aGLMS_Codes"
*       The program assumes that these are in the order that they are in in the
*       GLEAMS output file, used here as input for the DBF files.
numIndex = aLen(aGLMS_Codes)

ThisDay = NextDay(fp, DateFieldWidth)

* Note that the data file ends with a zero value for a day, e.g., "0000000".
* Do not try to read past this or there will be an EOF() error.
do while(ThisDay <= EndDate .and. Val(ThisDay) <> 0)
  * Now get the data within this day.
  if(ThisDay >= StartDate .and. ThisDay <= EndDate)
    nDay = VAL(ThisDay)

    * Must read and then store each value
    for CurrentIndex = 1 to numIndex
      numb = GetData(fp, aGLMS_Codes[CurrentIndex], ThisDay, aDpth[CurrentIndex])
      DbfName = aTargetDBF[CurrentIndex]
      sele &DbfName.
      if eof()
        append blank
        replace &FldNm with numb, Day with nDay, REC_NO with RECNO()-1
        skip
      else
        replace &FldNm with numb
        skip
      endif
    next
  endif
  ThisDay = NextDay(fp, DateFieldWidth)
enddo
Return(0)

PROCEDURE NextDay(fp, fldWidth)
  Local ThisDay, s
  * This takes the file pointer to the next day and returns the day.
  * When called initially, it skips past the GLEAMS codes at the top of the output file.
  s = rtrim(fgets(fp))
  do while .not.(len(s) = fldWidth)
    s = rtrim(fgets(fp))
  enddo
  ThisDay = s
Return(ThisDay)

Procedure GetData(fp, DataLabel, SubjectDay, SoilDepth)
  *Modified on Feb 7, 2004 to combine runoff and sediment loss if we are
  * looking for runoff loss, code 601.
  Local ret, CurrentLabel
  Local ctmp, ntmp
  Local DataCodeWidth, ValueFieldWidth, DateFieldWidth
  Local SoilLayerWgts
  Local SedLoss
  * Note that the Date width is 7, the DataCode width is 6, and the width of the data is 12.
  * Added these as variables just to make things easier to maintain.
  Local DateFieldWidth, DataCodeWidth, ValueFieldWidth
  DataCodeWidth = 6
  ValueFieldWidth = 12
  DateFieldWidth = len(SubjectDay)
  SoilLayerWgts = {0.0328, 0.3224, 0.3224, 0.3224}
  ret = 0

```

```

*Get the first label. We should be at the first line after the date.
s = rtrim(fgets(fp))
CurrentLabel = ltrim(left(s, DataCodeWidth))
do while (CurrentLabel <> DataLabel)
  * Get the next data label/code.
  s = rtrim(fgets(fp))
  CurrentLabel = ltrim(left(s, DataCodeWidth))

  * Until we get to a new Day, the length of "s" should not be equal to "DateFieldWidth".
  if(len(s) = DateFieldWidth)
    ?"WARNING"
    ?"Unexpected event #2 in GetData()while looking for " + DataLabel + " on Day " + SubjectDay
    ?"The requested output code (" + DataLabel + "cannot be found."
    suspend
  endif
enddo

* Now get the values.
* As currently written, SoilDepth is only non-zero if we are not looking for
* a soil concentration.
if SoilDepth = 0
  * A single numeric is a zero indicting just to read one value.
  v1 = SubStr(s, 1 + DataCodeWidth, ValueFieldWidth)
  v1 = VAL(v1)
  * If the code is "601", runoff loss, read the next line, which should be
  * "651", sediminet loos.
  * Add the sediment loss to runoff loss.
  If DataLabel = "601"
    *Get the next line
    s = rtrim(fgets(fp))
    CurrentLabel = ltrim(left(s, DataCodeWidth))
    If CurrentLabel <> "651"
      ?"Unexpected event #3 in GetData()while looking for " + CurrentLabel + " on Day " + SubjectDay
      ?"Expected to find '651', Sediment loss"
      suspend
    Endif
    SedLoss = Val(SubStr(s, 1 + DataCodeWidth, ValueFieldWidth))
  Else
    SedLoss = 0
  Endif
  ret = v1 + SedLoss
else
  * This is an array of soil depths.
  ntmp = 0
  totalwgt = 0
  *There are always 4 computational layers with the speified wghts for 12"

  for cntArgs = 1 to 4
    cntmp = SubStr(s, 1 + DataCodeWidth + ((cntArgs-1)*ValueFieldWidth), ValueFieldWidth)
    ntmp = ntmp + (VAL(cntmp) * SoilLayerWgts[cntArgs])
  next
  ret = ntmp
endif
Return(ret)

```

APPENDIX 2: Source code for CalcLake() Function

```
* LAKECALC.PRG
* Contains:
*   PROCEDURE CalcLake()
*   PROCEDURE GetEvaporation()
*****
PROCEDURE CalcLake(inpName, outName, fldName, Kd, ;
                  RainDBF, RunoDBF, PercDBF,;
                  MetricConv,VolWat, VolSed,;
                  k_Wat, k_Sed, FieldAreaMeters, LakeAreaMeters, ;
                  AdjustWaterVolume)

Private FldNm    && This must be private for the replace operation.
Local TodaysAmnt
Local AmntTotal
Local Atot
Local Vw, Vs, Cw, Cs
Local temperatureC, EvapRate_LitersPerDay
Local tempVal
Local RainVol, RunoVol, PercVol, InitVolume
Local InchesToMeters
? "CalcLake() is doing " + outName + " from " + inpName + " for " + fldName

* Set up constants.
InchesToMeters = 0.0254

* For now, this is set to the value of "AverageTemperatureF" in "DRIVER.PRG"
*   At some point, enhance to consider mean monthly or daily temperatures.
temperatureC = (AverageTemperatureF * 0.556) - 17.8

* Get the evaporation rate in units of liters/day.
*   When daily or monthly temperatures are added, will have to move this
*   to inside the loop.
EvapRate_LitersPerDay = GetEvaporation(temperatureC, LakeAreaMeters)

* Store the initial volume of water in the pond.
*   Do not allow volume of pond to go below this amount.  See below.
MinVolume = VolWat * 0.5
* Liters for water adjacent to ROW.
Vw = VolWat
* Liters of sediment in pond.  Set by caller,
Vs = VolSed

* Set up the databases.
sele 1
use (inpName)
sele 2
use (outName)
sele 3
use (RainDBF)
sele 4
use (RunoDBF)
sele 5
use (PercDBF)

sele (inpName)
Atot = 0
FldNm = fldName
do while .not. eof()
*****
***** FIRST,GET AMOUNT OF CHEMICAL ADDED TODAY *****
*****
* Below is in g/ha
TodaysAmnt = &FldNm
```

```

* Note that the above value is given in "grams/ha" in GLEAMS output file.
* Convert g/ha to grams by multiplying by treated area in ha.
*   hectares = FieldAreaMeters / 10000
* Use MetricConv to Cconvert grams to mg, ug, or ng depending on value of MetricConv
TodaysAmnt = MetricConv * TodaysAmnt * FieldAreaMeters / 10000

*****
***** SECOND,GET THE VOLUME OF WATER ADDED TODAY *****
*****
*   Liters of rainfall on pond.
sele (RainDBF)
* Below converts inches to meters, gets cubic meters and converts this to Liters.
tempVal = &FldNm
  RainVol = tempVal * InchesToMeters * LakeAreaMeters * 1000

*   Liters of runoff from field.
sele (RunoDBF)
* Below converts inches to meters, gets cubic meters and converts this to Liters.
tempVal = &FldNm
  RunoVol = tempVal * InchesToMeters * FieldAreaMeters * 1000

*   Liters of percolation from field.
sele (PercDBF)
* Below converts inches to meters, gets cubic meters and converts this to Liters.
tempVal = &FldNm
  PercVol = tempVal * InchesToMeters * FieldAreaMeters * 1000

* Note that all of the above volumes are the liters added/removed this day.
* Get the new volume in liters.
if ConsiderAddedWater = .t.
  Vw = Vw + RainVol + RunoVol + PercVol - EvapRate_LitersPerDay
  * Do not let the volume go below any set minimum. See above.
  if Vw < MinVolume
    Vw = MinVolume
  endif
endif
*****
***** THIRD,DISTRIBUTE CHEMICAL BETWEEN WATER AND SOIL *****
*****
* Get the total amount in the water today.
Atot = Atot + TodaysAmnt

* Get the amount in soil. See Mathematica file for check of this.
As = (Atot*Kd*Vs)/((Kd*Vs) + Vw)

* Get the amount in water as the difference.
Aw = Atot-As

* Factor in degradation in sediment. Note that delta t=1 is implicit.
As = As * exp(-k_Sed)

* Factor in degradation in water. Note that delta t=1 is again implicit.
Aw = Aw * exp(-k_Wat)

* Update the total water and sediment combined after factoring in degradation.
Atot = As + Aw

* Get the concentrations in sediment and water in mg/L.
Cs = As/Vs
Cw = Aw/Vw

*****
***** LAST,STORE THE INFORMATION *****
*****
* Notice that we do not append here.
* Calling program is responsible for making sure that the records are there.
* Should probably change this at some point by checking (outName). If it is
* Reccount() = 0, always do append. If not, just replace.

```

```

sele (outName)
replace &FldNm. with Cw
* Skip to next record in target database.
skip

* Skip to next record in Rainfall database.
sele (RainDBF)
skip

* Skip to next record in Runoff database.
sele (RunoDBF)
skip

* Skip to next record in Percolation database.
sele (PercDBF)
skip

* This must be the last thing done at end of loop.
* We must be in the Source database to read the total loss.
* Skip to next record in source database.
sele (inpName)
skip

enddo

* Close the opened databases
sele (inpName)
use
sele (outName)
use
sele (RainDBF)
use
sele (RunoDBF)
use
sele (PercDBF)
use
return(0)
*****

```

APPENDIX 3: Source code for CalcStrm() function

```
*STRMCALC.PRG
* Note that CalcStrm() gets field area in ha and not m^2.
*       CalcLake() does get field area in m^2.

* NOTE on "Cave".
* This stores the daily value of Cave, the "average" concentration over the length
* of the stream. This daily concentration is then used to get the daily max
* in other programs. This approach basically assumes that the pesticide
* enters the stream evenly over the course of a day. This is just like the
* assumption concerning rainfall. It would not make sense to assume that all
* water enters instantaneously. See/writer discussion in documentation.

PROCEDURE CalcStrm(inpName, outName, fldName, MetricConv, ;
    RainDBF, RunoDBF, PercDBF, ;
    FlowRate, FlowVelocity, StrmLength, ;
    k, HectaresTreated, StreamAreaM2, ;
    AdjustWaterVolume)
Private FldNm && This must be private for replace operation and such.
Local TodaysAmnt, delta
Local F, v, Cave, x, Conc
Local TodaysAddedFlow
Local RainVol, RunoVol, PercVol
Local Fadj

? "Doing stream " + inpName + " from " + outName + " for " + fldName
* Flow rate of stream in L/day.
F = FlowRate
* Velocity of stream in m/day.
v = FlowVelocity
* Length of stream in meters.
x = StreamLength

* Set up the databases.
sele 1
use (inpName)
sele 2
use (outName)
sele 3
use (RainDBF)
sele 4
use (RunoDBF)
sele 5
use (PercDBF)

* Start in the input (total loss) database
sele (inpName)
FldNm = fldName
do while .not. eof()
    * Below is in g/ha
    TodaysAmnt = &FldNm

    * Convert to mg, ug, or ng depending on MetricConversion value
    delta = TodaysAmnt * HectaresTreated * MetricConv

    * Get the added flow to the stream from rainfall, runoff, and percolation.
    * Liters of rainfall on stream.
    sele (RainDBF)
    * Below converts inches to liters, gets cubic meters and converts this to Liters.
    tempVal = &FldNm
    RainVol = tempVal * 0.0254 * StreamAreaM2 * 1000

    * Liters of runoff from field into stream.
    sele (RunoDBF)
    * Below converts inches to liters and hectares to m2
```

```

* Then converts cubic meters to Liters.
tempVal = &FldNm
RunoVol = tempVal * 0.0254 * HectaresTreated * 10000 * 1000

* Liters of percolation from field into stream.
sele (PercDBF)
* Below converts inches to liters and hectares to m2
* Then converts cubic meters to Liters.
tempVal = &FldNm
PercVol = tempVal * 0.0254 * HectaresTreated * 10000 * 1000

* Get the added flow to the stream.
TodaysAddedFlow = RainVol + RunoVol + PercVol

* amount/day divided by L/day --> concentration
if AdjustWaterVolume = .t.
    Fadj = F+TodaysAddedFlow
    Conc = delta / (Fadj)
    Cave = ( ((delta * v)/(k * Fadj) ) - ;
             ( (delta*v*exp(-k*x/v))/(k*Fadj) ) ) / x
else
    Conc = delta / F
    Cave = ( ((delta * v)/(k * F) ) - ;
             ( (delta*v*exp(-k*x/v))/(k*F) ) ) / x
endif

sele (outName)
replace &FldNm. with Cave
* Skip to next record in target database.
skip

* Skip to next record in Rainfall database.
sele (RainDBF)
skip

* Skip to next record in Runoff database.
sele (RunoDBF)
skip

* Skip to next record in Percolation database.
sele (PercDBF)
skip

* NOTE: Below MUST be the last skip.
* At the top of the loop we must be in the source/inp database WA
* Skip to next record in source database.
sele (inpName)
skip

enddo

* Close the open databases
sele 1
use
sele 2
use
sele (RainDBF)
use
sele (RunoDBF)
use
sele (PercDBF)
use

return(0)

```

APPENDIX 4: Source code for SetSum() function

```
SUMMARY.PRG
*****
*Contains
*  PROCEDURE SetSum(inpName, fldName)
*  PROCEDURE SetTotal(aFldNames, TargetField)
*****
PROCEDURE SetSum(inpName, fldName)
  *This does the Summary DBFs.  Currently Lake and Stream

  Private FldNm, val, TargetField, AmntRain, maxConc

  FldNm = fldName

  ? "Doing summary of " + inpName + " for " + fldName
  sele 2
  use (inpName)

  * Get the average.
  average &FldNm to val

  ? fldNm + " average " + " for " + inpName + " is "
  ?? val

  *Store average
  sele 1
  locate for RAINFALL = FldNm
  TargetField = left(inpName,4)+"AVE"
  replace &TargetField with val

  *Get the max.
  maxConc = 0
  sele 2
  go top
  do while .not. eof()
    if maxConc < &FldNm
      maxConc = &FldNm

      ?"New max is "
      ?? maxConc

    endif
    skip
  enddo

  *Store maximum. No need to re-"locate".
  sele 1
  TargetField = left(inpName,4)+"MAX"
  replace &TargetField with maxConc

  * Clean up.  Keep WA 1 open!!  Needed for next call.
  sele 2
  use
return(0)

*****
* This sums all the values in the fields specified by "aFldNames" and puts the total in TargetField.
PROCEDURE SetTotal(aFldNames, TargetField)
  Local nFlds, i
  Private tot, target, fldnm

  * Assumes that the active WA is the DBF to be operated on.
  go top
  target = TargetField
  nFlds = alen(aFldNames)
```

```
do while .not. eof()
  tot = 0
  for i = 1 to nFlds
    fldnm = aFldNames[i]
    tot = tot + &fldnm.
  next
  replace &target. with tot
  skip
enddo
return(0)
```

APPENDIX 5: History of Revisions

February 10, 2004

Minor edits of documentation, SERA TD 2004-02.04a dated February 8, 2004.