GeoTool User's Manual

Submitted to:

Commander
U.S. Army Corps of Engineers
Engineering Research and Development Center
Vicksburg, Mississippi 39180

November 25, 2003

Colorado State University

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Developed at the
Engineering Research Center
Colorado State University

David A. Raff[1]
Brian P. Bledsoe[2]
Alejandro N. Flores[3]

GeoTool Version 3

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[1] Engineer, United States Department of the Interior, Bureau of Reclamation, Denver Office, Flood Hydrology Group, raff@daraff.net
[2] Assistant Professor, Colorado State University, Department of Civil Engineering, Engineering Research Center, 1320 Campus Delivery, Fort Collins, CO 80523, bbledsoe@engr.colostate.edu
[3] Graduate Student, Department of Civil and Environmental Engineering, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge, MA 02139, lejo@mit.edu, (formerly at CSU)

DISCLAIMER

Although the authors have ensured that the methods and procedures included in the computational package are valid and reliable, neither the authors, Colorado State University, the U.S. Bureau of Reclamation, nor the U.S. Army Corps of Engineers accepts responsibility for real or alleged error, loss, damage, or injury resulting from its use.

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LIST OF VARIABLES AND ABBREVIATIONS

a	=	coefficient
A	=	coefficient in two fraction sediment transport model, fitted parameter
b	=	exponent
B	=	bin index
B_N	=	number of flows in a bin
BSI	=	bed stability indicator
c	=	regression coefficient
c_B	=	sediment transport coefficient
C_{ppm}	=	concentration of sediment in parts per million
C_v	=	concentration of sediment by volume
CV	=	coefficient of variation
d	=	regression exponent
d_s	=	characteristic sediment diameter
d_*	=	dimensionless particle size
d_{16}	=	particle size at which 16% of bed material is finer by weight
d_{50}	=	particle size at which 50% of bed material is finer by weight, median particle diameter
d_{84}	=	particle size at which 84% of bed material is finer by weight
d_{90}	=	particle size at which 90% of bed material is finer by weight
D_s	=	characteristic sand size in two fraction sediment transport model
D_g	=	characteristic gravel size in two fraction sediment transport model
e	=	coefficient
e_B	=	bedload efficiency factor
f	=	exponent
F_s	=	proportion of sediment in sand fraction (value from 0 to 1)
g	=	gravitational acceleration
G	=	ratio of specific gravity of sediment to that of water
H_c	=	coefficient used in calculating mean scour/fill depth
H_e	=	exponent used in calculating mean scour/fill depth

i	=	dummy counting index
LI	=	logarithmic bin interval
MI	=	mobility index
n	=	Manning's *n*
N	=	generic total number used in empirical frequency distribution function
N_B	=	number of bins used in effective discharge analysis
N_Q	=	number of flows
N_T	=	total number of discharges in historical flow record within period of analysis
$P(i)$	=	EFD plotting position
q_{bv}	=	volumetric bedload transport per unit width of channel
q_g	=	volumetric gravel transport per unit width of channel
q_s	=	volumetric sand transport per unit width of channel
q_t	=	total sediment load per unit width of channel
Q	=	discharge
$Q_{1.5}$	=	1.5-year recurrence interval discharge
Q_2	=	2-year recurrence interval discharge
Q_B	=	discharge in bin *B*
$\overline{Q_B}$	=	mean discharge in bin *B*
$Q_{B_{\max}}$	=	maximum discharge in bin *B*
$Q_{B_{\min}}$	=	minimum discharge in bin *B*
Q_e	=	effective discharge
Q_{ma}	=	mean annual flow
$Q_{\max}$	=	maximum discharge in historical flow record within period of analysis
$Q_{mean\ annual}$	=	mean annual flow
$Q_{\min}$	=	minimum discharge in historical flow record within period of analysis
Q_N	=	average across all flows
Q_s	=	sediment discharge
Q_{s_B}	=	sediment discharge associated with bin *B*
$Q^T{}_{s_B}$	=	total sediment discharge for all bins $B = 1$ to N_B

$\overline{Q}_{y\max}$	=	mean of the annual maxima
R	=	hydraulic radius
S	=	subscript for sediment
S	=	slope
S_f	=	friction slope
u_*	=	shear velocity
V	=	mean flow velocity
V_c	=	critical velocity
w	=	channel width

Greek

α	=	coefficient used in empirical frequency distribution function
β	=	coefficient used in empirical frequency distribution function
γ	=	specific gravity of water
$(_m$	=	specific weight of water and sediment mixture
$(_Q$	=	coefficient of skewness
θ	=	$1/\theta$ is mean scour/fill depth
ν	=	kinematic viscosity of water-sediment mixture
ξ	=	depth
ρ	=	density of water-sediment mixture
σ	=	standard deviation
σ_g	=	geometric standard deviation of the bed material
σ_{Q_N}	=	standard deviation of all flows in the flow record
$\sigma_{Q_{y\max}}$	=	standard deviation of annual maxima
τ_0	=	average boundary shear stress
τ_B	=	shear stress in bin B
τ_c	=	critical shear stress for incipient motion
τ_*	=	dimensionless shear stress

τ_{*_c}	=	critical dimensionless shear stress
τ_r^*	=	dimensionless shear stress used to normalize equation
ϕ	=	angle of repose
P	=	value of a slope of the two parts of the function
ϑ'	=	value of a slope of the two parts of the function
ω_s	=	fall velocity of the sediment
ω	=	specific stream power
Ω	=	total stream power

Abbreviations

°C	degrees Celsius
CDF	cumulative distribution function
cfs	cubic feet per second
DOS	Disk Operating System
EDF	empirical distribution functions
EFD	empirical frequency distribution
EPA	U.S. Environmental Protection Agency
°F	degrees Fahrenheit
ft	feet
ft^2	square feet
ft^3	cubic feet
.GTI	GeoTool Interface file
HEC-RAS	Hydrologic Engineering Center – River Analysis System
HSPF	Hydrological Simulation Program – FORTRAN
kg	kilogram

lb	pound
mm	millimeter
NWIS	National Water Information System
PDF	probability distribution function
ppm	parts per million
s	second
SI	Metric units
SWMM	Storm Water Management Model
USCS	English units
USGS	U.S. Geological Survey

CHAPTER 1
INTRODUCTION

GeoTool was developed at the Engineering Research Center at Colorado State University. This user's manual for GeoTool Version 3 is designed to provide a general understanding of model structure and capabilities, as well as a requisite knowledge of input options and output features necessary to implement the modeling package. Chapters 3 through 7 provide step-by-step options and background information associated with automated effective discharge computations and the "stand alone" components of sediment transport and channel change estimates. Chapter 8 provides the input and output features associated with partial frequency analyses and Chapter 9 presents information with respect to disturbance regime computations.

1.1 OVERVIEW

An important contribution that engineers and geomorphologists can make to environmental management is to develop parsimonious tools that empower non-specialists to make rational planning decisions within the context of a changing environment. Existing models may be used to assess the potential hydrologic effects of land-use change on receiving waters, but practical tools for translating these results into metrics for predicting channel stability and effects on stream biota are essentially unavailable to local watershed planners. To improve watershed management in the context of changing land uses, a flexible, changeable package of models is presented to provide estimates of long-term changes in stream erosion potential, channel processes, and instream disturbance regime. The models are developed in Visual Basic for Applications / Excel and include a suite of stream / land-use management modules designed to operate with either continuous or single-event hydrologic input in a variety of formats. The tools can also be used as a post-processor for the U.S. Environmental Protection Agency's (EPA) SWMM and HSPF models as well as for any general time series of discharges. Based on the input channel geometry and flow series, the various modules can provide users with estimates of the following characteristics for pre- and post-land use change conditions: (1) the temporal distribution of hydraulic parameters including shear stress, specific stream power, and potential mobility of various particle sizes; (2) effective discharge / sediment yield; (3) potential changes in sediment transport and yield as a result of altered flow and sedimentation regimes; (4) frequency, depth, and duration of bed scour; and (5) several geomorphically relevant hydrologic metrics relating to channel form, flow effectiveness, and "flashiness."

Although GeoTool is intended for a broad range of applications, its primary impetus has been the need for practical tools for assessing fluvial processes in urbanizing watersheds. For example, GeoTool may be used to quickly compute *time-integrated* sediment transport and scour characteristics across a range of flows and time periods associated with varying stormwater mitigation schemes. The modules give end users a suite of tools to compare the erosive potential of hydrographs and characterize channel changes that might result from a wide variety of watershed changes, as well as, to aid interpretation of biomonitoring information through quantification of stream disturbance regimes.

1.2 MANUAL CONVENTIONS

Actual titles for menus and frames, within these menus, are shown in a different font, namely, Futura Lt BT. Figure 1.1 is a GeoTool quick reference guide for input options.

Opening menu

Figure 3.1
(p. 8)

User Options frame

- o Effective Discharge (Single File)
- o Effective Discharge Comparison (Multiple Files)
- o Sediment Transport
- o Partial Frequency Analysis
- o Disturbance Regime
- o Channel Change Indices
- o Dynamic Channel

☐ Suppress progress indicators
☐ Suppress log file

RUN and Quit buttons

Excel Input Sheet option

Figure 3.2
(p. 9)

- o Input From File ______________________
- o Use Input Sheet

Run Single File button

Multiple Files Input option

Figure 3.3
(p. 10)

Reference File ______________________
File 1 ______________________
File 2 ______________________
File 3 ______________________
File 4 ______________________

RUN and Quit buttons

INPUT FILE OPTIONS menu

Figure 4.1
(p. 14)

File Format Options frame

- o Default – "date"-stage-discharge
- o File Format 2 – date-stage-discharge
- o Mean Daily USGS Download – "USGS"-site#-date-discharge
- o 15-minute USGS File – year-month-day-minute-stage-discharge
- o USGS Download "Peaks"
- o SWMM ".OUT" file
- o HSPF "P" file
- o Other

☐ Limit Input to Flows > ______

Cancel and Continue buttons

User Input Options menu

Figure 5.1
(p. 21)

Flow Data Selection frame

Enter Range of Years to Calculate Effective Discharge:

- o All Years
- o Specify Years ______ to ______

Please select time interval for input discharge data:

15 minute
1 hour
Daily
Other __________

☐ Fill Missing Values = ________

Effective Discharge Tools frame

Bin Variation Option
Number of Variations: ______

Type and Number of Bins:
Separate number of bins with commas.
☐ Arithmetic Bins
Number: ______
☐ Logarithmic Bins
Number: ______

Figure 1.1 – GeoTool quick reference guide.

User Input Options menu (cont.)

Sediment Transport Tools frame

Minimum Flow Transporting Sediment

☐ Critical Discharge (cfs): ______

○ $Qs = aQ^b$

	Low Discharge (cfs)		High Discharge (cfs)
	☐ Bound		
a = ______ b = ______	_______	to	______
☐ Use Two Rating Functions			
a = ______ b = ______	_______	to	______
☐ Use Three Rating Functions			
a = ______ b = ______	_______	to	______

○ Use sediment transport equation

Channel Change Tools frame

☐ Bed Stability Index	Slope (ft/ft)	____
	d50 (mm)	____
	d84 (mm)	
☐ Mobility Index	d90 (mm)	____
☐ Specific Stream Power	Characteristic Width (ft)	____
☐ Scour/Fill Depth	Specific Weight Sediment (lb/ft³)	____

Output Options frame

☐ Use SI Units (Default = English)

○ No Comparison Charts

○ PDF Comparison Charts

○ CDF Comparison Charts

○ PDF and CDF Comparisons

☐ Leave Application Open When Finished

Cancel and Continue>> buttons

Channel Characteristics menu

Figure 6.2 (p. 39)

First Hydraulic Radius Function frame

Hydraulic radius as a power function as a function of flowrate. $R = cQ^d$

c coefficient = _______ d exponent = ________

☐ Click here to enable the use of two hydraulic radius relationships.

Discharge Separating Relationships frame

Enter discharge at which to switch relationships (cfs): ______

Overbank Hydraulic Radius Function frame

Hydraulic radius as a power function as a function of flowrate for depths exceeding bank height. $R = eQ^f$

e coefficient = _______ f exponent = ________

Velocity Function frame

Enter Manning roughness to calculate average channel velocity. Manning's n = ______

Cancel and Continue>> buttons

Sediment Transport Rate Calculator (Version 1.0) menu

Figure 6.1 (p. 31)

Select Equation frame

Meyer-Peter Müller

Yang's Sand, d50

Bagnold Total Load

Brownlie Total Load

Wilcock

Select Units frame

○ Select S.I. Units

○ Select English Units

Figure 1.1 (cont.) – GeoTool quick reference guide.

Sediment Transport Rate Calculator (Version 1.0) menu (cont.)

Channel Properties frame (*only English Units are listed here*)

Unit	Meyer-Peter Müller	Wilcock	Bagnold	Brownlie	Yang
Average Velocity (ft/s)			________	________	________
Average Width (ft)	________				
Bedload Efficiency			________		
Critical Tau Star	________				
d16 (mm)				________	
d50 (mm)			________	________	________
d84 (mm)				________	
dg (mm)		________			
dm (mm)	________				
ds (mm)		________			
Discharge (ft^3/s)		________		________	________
Effective Width (ft)			________	________	
Energy Slope (ft/ft)	________		________	________	________
Fs		________			
Hydraulic Radius (ft)	________		________	________	________
Temperature (°F)			________	________	________
Shear Stress (lb/ft^2)		________			
Width (ft)		________			

Cancel and Continue>> buttons

Partial Frequency Analysis menu

Figure 8.1 (p. 59)

Input File Name ______________________

File Characteristics frame

Please Enter Time Interval
For Input File ______ [seconds / minutes / hours / days / months / years]

o All Years
o Specify Years ______ to ______

Storm Characteristics frame

Minimum Discharge to Consider _____cfs

☐ Specify Inter Storm Duration
Inter Storm Duration ____ [seconds / minutes / hours / days / months / years]

Plotting Position Options frame

o Weibull
o Median
o APL
o Blom
o Cunnane
o Gringorten
o Hazen

Cancel and Continue buttons

Figure 1.1 (cont.) – GeoTool quick reference guide.

Duration and Time of Sediment Transport menu — Figure 9.1 (p. 63)

Input File Attributes frame

Input File Name ____________________

Please Enter Time Interval for Input File ______ [seconds / minutes / hours / days / months / years]

- o All Years
- o Specify Years ______ to ______

- o Metric Units
- o English Units

Slope ____

Dimensionless critical shear stress for incipient motion ____

Characteristic Grain Size (mm) ____

Specific Weight of Water (lb/ft^3) ____ ☐ Assume specific weight of water

Specific Weight of Sediment (lb/ft^3) ____ ☐ Assume specific weight of sediment

Exit and Run buttons

Channel Change Tool menu — Figure 3.4 (p. 11)

Units frame

- o English (Default)
- o Metric

Options frame

- ☐ Specific-Stream Power
- ☐ Bed Stability Indicator
- ☐ Mobility Index
- ☐ Scour/Fill Depth

Input Parameters frame

Characteristic Discharge (Q) (cfs) ______

Slope (ft/ft) ______

d50 (mm) ______

d84 (mm) ______

d90 (mm) ______

Width (ft) ______

Flow Area (ft^2) ______

Wetted Perimeter (ft) ______

Specific Weight Water (lb/ft^3) ______

Specific Weight Sediment (lb/ft^3)

EXIT and RUN buttons

↓

OUTPUTS

Figure 1.1 (cont.) – GeoTool quick reference guide.

CHAPTER 2

INSTALLATION

Your GeoTool distribution should have come from a "GeoTool_distribution.zip" file. The most current version of GeoTool is available at http://www.daraff.net/geotool.htm and http://www.engr.colostate.edu/~bbledsoe/GeoTool or by contacting David Raff (raff@daraff.net) or Brian Bledsoe (Brian.Bledsoe@ColoState.edu). To install and run GeoTool, unzip the distribution zip file into a directory named "GeoTool."

The current release of GeoTool was designed with Microsoft® Office 2000 and is known also to function properly on Microsoft® Office XP. In an Office XP installation, the security settings must be set to medium or low in order to operate GeoTool, as it does not come with a security certificate. It is expected that the user has installed all appropriate service packs to their installation of Office 2000 or Office XP. GeoTool has not been tested on versions earlier than Microsoft® Office 2000 and these installations are not supported. The following references are necessary within Microsoft® Visual Basic for Applications in the user's Excel installation for proper GeoTool execution:

(1) Visual Basic for Applications,
(2) Microsoft® Excel 9.0 Object Library,
(3) OLE Automation,
(4) Microsoft® Office 9.0 Object Library,
(5) Microsoft® Forms 2.0 Object Library, and
(6) Solver.

Please note that any specific references to release versions of GeoTool or its manual are valid for later release. Happy GeoTooling…

CHAPTER 3

OPENING INPUT OPTIONS

GeoTool is designed to provide users with a variety of tools to assess the geomorphic implications of watershed modifications and to examine the statistical properties and sediment transport characteristics of both simulated and historical flow series. The user is initially presented with options (Figure 3.1) to:

- perform effective discharge computations for one flow series,
- perform effective discharge computations and compare multiple flow series,
- perform stand-alone sediment transport computations
- perform partial frequency analysis,
- calculate disturbance regime characteristics,
- calculate channel change indices, or
- run effective discharge allowing channel adjustment.

Discussion of these options follows:

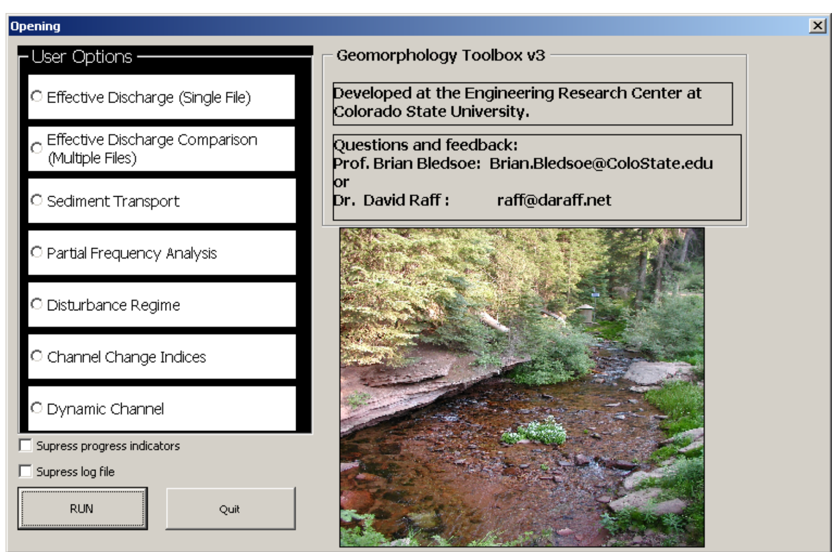

Figure 3.1 – Opening **menu screen shot, where user selects one of six GeoTool modules.**

3.1 EFFECTIVE DISCHARGE (SINGLE FILE)

This option allows the user to determine the discharge responsible for transporting the largest amount of sediment over time. This option should be chosen if the user would like to analyze a single file of historical or single event data. The output includes effective discharge calculations, flow regime (flashiness) statistics as well as distributions of shear stress, stream power (total and unit), and water and sediment discharges among others. Channel change indices may also be selected. The user may specify a flow series file (Input From File option) or use the GeoTool Input sheet (Use Input Sheet option) (Figure 3.2).

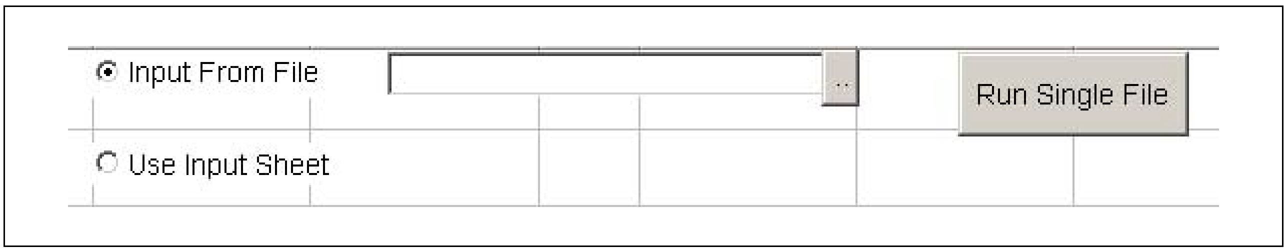

Figure 3.2 – Single File Input sheet screen shot, where the user selects either a flow file or inputs discharge information into an Excel worksheet.

3.2 EFFECTIVE DISCHARGE COMPARISON (MULTIPLE FILES)

This option permits comparison of multiple discharge series within a single run of GeoTool. This permits direct comparison of geomorphically significant factors (*i.e.,* discharge, sediment transport, shear stress, and stream power). The program and calculations are the same as a single-flow record (see above), but allows the user to specify a level of detail in the output not available when using the Effective Discharge (Single File) option. The user must use one input file as the Reference File, and at least one other file to run for comparison (Figure 3.3). GeoTool will generate comparison sheets for probability and cumulative distribution functions for water, sediment, stream power, and shear stress distributions if the user chooses these options. There is also a summary sheet produced which compares flow regimes for each time series used.

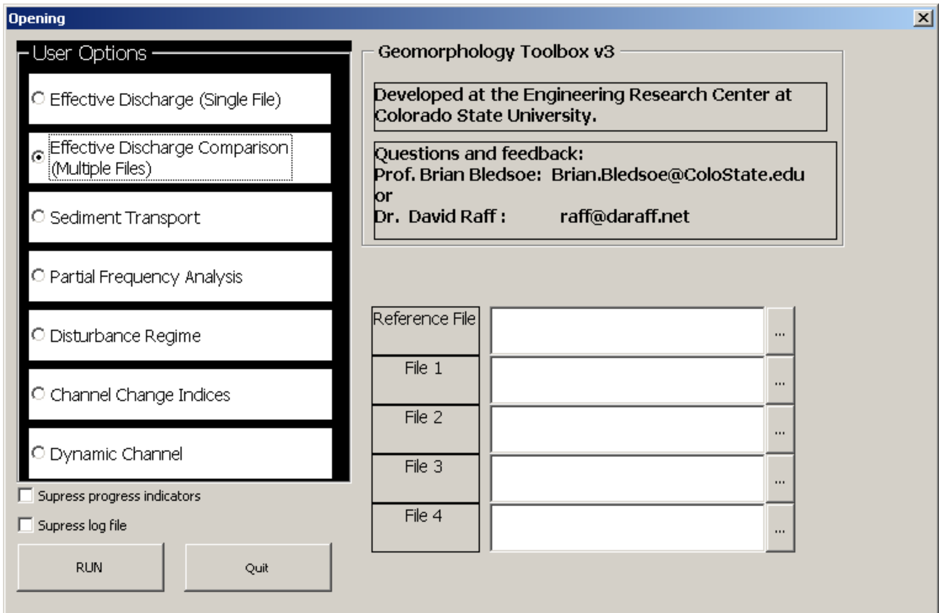

Figure 3.3 – Effective Discharge Comparison (Multiple Files) **screen shot.**

3.3 SEDIMENT TRANSPORT (STAND ALONE)

This option determines the amount of sediment transported for a single discharge entered by the user. The user may specify which sediment transport equation GeoTool will use (*e.g.,* Bagnold, Brownlie, Yang's Sand, or Wilcock) through the Sediment Transport Rate Calculator (Figure 6.1). See Chapter 6 for further information about entering data into the Sediment Transport Rate Calculator and a discussion of the theoretical development for the different sediment transport equations.

3.4 PARTIAL FREQUENCY ANALYSIS

Often accurate flood frequencies are desired for relatively short return periods (< 10 years). In this case, frequency estimates based on annual maximum series may not be appropriate and partial flood frequency analyses are more desirable. This option computes flood frequencies using user-defined plotting positions and general storm characteristics.

3.5 DISTURBANCE REGIME

This module of GeoTool calculates the bed disturbance of a river or stream based on a historical flow record. Specifically, it calculates the number of discrete events as well as the total length of time that a specific grain size is in motion based on incipient motion criteria entered by the user.

3.6 CHANNEL CHANGE INDICES

This option determines the channel change indices available within GeoTool. These include Bed Stability Indicator, Mobility Index, Specific Stream Power, and Scour/Fill Depth distribution. The user inputs data through the Channel Change Tool menu (Figure 3.4).

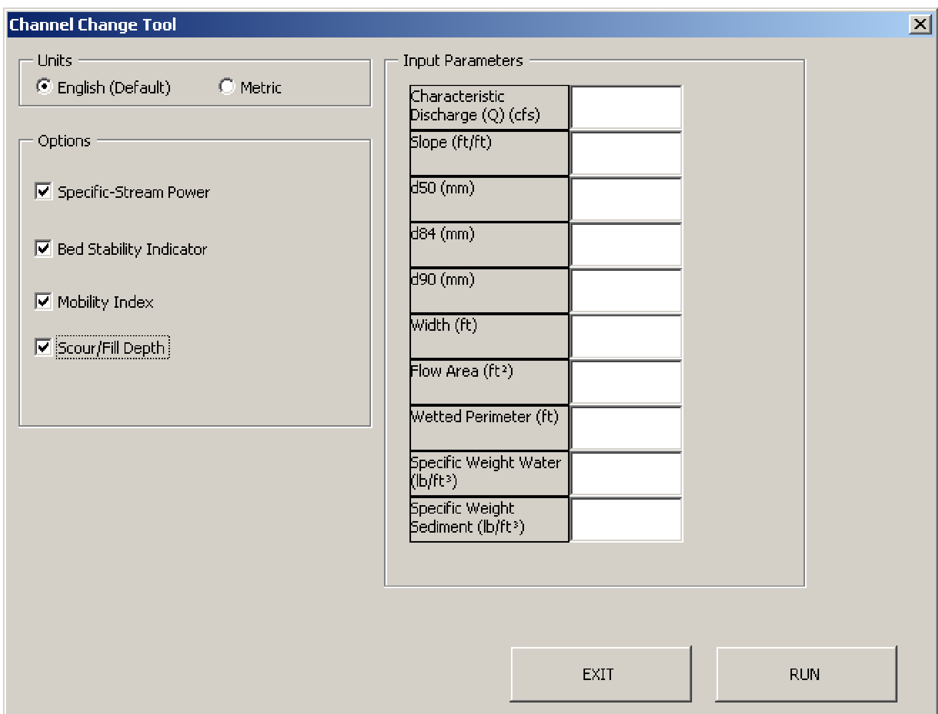

Figure 3.4 – Channel Change Tool **input menu screen shot.**

These indices are calculated for a single-channel flow and geomorphic parameters when running in stand alone mode. The user may chose to enter information in either English (USCS) or Metric (SI) units when running in stand alone mode. The output will be in the same units as the input. Only those text boxes within the Channel Change Tool menu (Figure 3.4), that are relevant to the user-selected channel change indices, will be enabled for input.

3.7 DYNAMIC CHANNEL

This module is currently under development. A new version of GeoTool, incorporating this upgrade, will be posted as soon as possible.

CHAPTER 4

DISCHARGE INPUT FORMAT

With the exception of the sediment transport stand alone mode, GeoTool requires the input of a flow record. The flow record may be inputted in a variety of formats, and can represent either long-term continuous flow or a single-storm event. When inputting a flow record, the file name and location are selected, and then the user is prompted to select the format of the selected file (Figure 4.1). The flow record must be in cubic feet per second (cfs). While stage data are not used in this version of GeoTool, the stage data must be included with the flow record, or placeholders must be used where stage data are expected. If the user has good reason, or files are exceptionally large and the user is only interested in censored discharges, the Limit Input to Flows > can be used, which will only load the data from the file which exceeds the censored value entered in the text box.

4.1 INPUT FILE OPTIONS

GeoTool is capable of loading seven different file formats that are commonly encountered in practice. These seven formats are discussed (with examples) as follows:

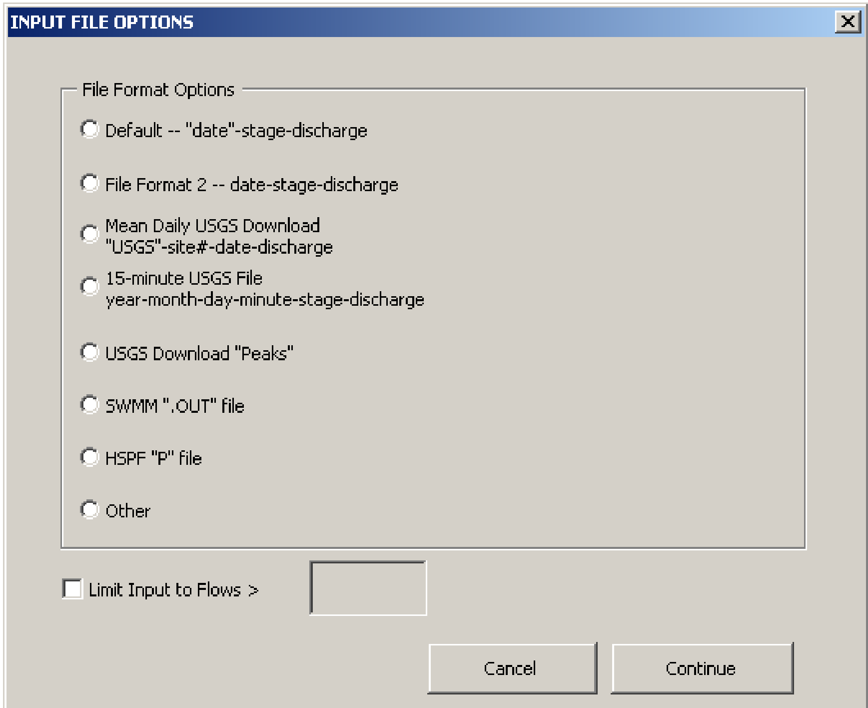

Figure 4.1 – Input File Options **screen shot, where the user selects the format of the input flow record. The current version of GeoTool has the capability of reading five file types including common U.S. Geological Survey (USGS) records and SWMM model outputs.**

4.1.1 Default – "date"-stage-discharge

The default file type within GeoTool is a comma-delimited format with the date and time entry in quotes. Files of this type may not have any header, which if necessary, can be removed using any common text editor. This is a comma-delimited file format, which has the following format:

```
"10/8/1991 5:30:00 PM",7.67,36
"10/8/1991 5:45:00 PM",7.67,36
"10/8/1991 6:00:00 PM",7.65,34
"10/8/1991 6:15:00 PM",7.67,36
"10/8/1991 6:30:00 PM",7.66,35
"10/8/1991 6:45:00 PM",7.68,37
"10/8/1991 7:00:00 PM",7.64,34
"10/8/1991 7:15:00 PM",7.68,37
```

In the above example a time stamp is provided along with the data but is not required. Also note that the stage data are not necessary, and if not present, two commas must separate the date and discharge data (*i.e.*, "10/8/1991 8:45:00 PM", ,33).

4.1.2 File Format 2 – date-stage-discharge

This format is the same as the default format only the date is not contained within quotes. An example is shown below:

```
10/8/1991 5:30:00 PM,7.67,36
10/8/1991 5:45:00 PM,7.67,36
10/8/1991 6:00:00 PM,7.65,34
10/8/1991 6:15:00 PM,7.67,36
10/8/1991 6:30:00 PM,7.66,35
10/8/1991 6:45:00 PM,7.68,37
10/8/1991 7:00:00 PM,7.64,34
```

As with the default format, the time stamps included with the data are not necessary. Additionally, there can be no header. Like the default format, stage data need not be included, and if not included, two commas must hold the place where the stage data would be (*i.e.*, 10/8/1991 8:45:00 PM, ,33).

4.1.3 Mean Daily USGS Download – "USGS"-site #-date-discharge

This input is to be used with mean daily discharge data downloaded from the USGS website. There is no data processing required. The format of a file is as follows:

```
#
# U.S. Geological Survey
# National Water Information System
# Retrieved: 2002-04-10 11:53:48 EDT
#
# This file contains published daily mean streamflow data.
#
# Further Descriptions of the dv_cd column can be found at:
# http://water.usgs.gov/nwis/help?codes_help#dv_cd
#
#
```

```
# This information includes the following fields:
#
#  agency_cd   Agency Code
#  site_no     USGS station number
#  dv_dt       date of daily mean streamflow
#  dv_va       daily mean streamflow value, in cubic-feet per-second
#  dv_cd       daily mean streamflow value qualification code
#
# Sites in this file include:
#  USGS 07287150 ABIACA CREEK NR SEVEN PINES, MS
#
#
agency_cd  site_no dv_dt   dv_va  dv_cd
5s   15s      10d     12n     3s
USGS        07287150        1991-10-01     41        e
USGS        07287150        1991-10-02     41        e
USGS        07287150        1991-10-03     41        e
USGS        07287150        1991-10-04     41        e
USGS        07287150        1991-10-05     41        e
USGS        07287150        1991-10-06     41        e
USGS        07287150        1991-10-07     41        e
USGS        07287150        1991-10-08     42        1
USGS        07287150        1991-10-09     43        1
USGS        07287150        1991-10-10     49        1
```

GeoTool identifies the "USGS" string to note the beginning of a data line. Therefore, there is no limit to the length or location of headers, and the discharge data must be in the format shown above (with "USGS" appearing at the start of every data line).

4.1.4 15-minute USGS File – year-month-day-minute-stage-discharge

This input format is intended to be compatible with 15-minute flow records provided by the USGS. This format usually has a header that must be removed before inputting into GeoTool. Any text editor capable of opening and handling large amounts of data (*e.g.,* Microsoft® WordPad, TextPad, etc.) can be used to remove the header. The form of this file type, once the header has been removed, is as follows:

1991	10	10	630	5.55	40
1991	10	10	645	5.55	40
1991	10	10	660	5.55	40
1991	10	10	675	5.55	40
1991	10	10	690	5.55	40
1991	10	10	705	5.56	41
1991	10	10	720	5.56	41
1991	10	10	735	5.6	44
1991	10	10	750	5.62	45
1991	10	10	765	5.63	46
1991	10	10	780	5.64	47
1991	10	10	795	5.65	48
1991	10	10	810	5.66	48
1991	10	10	825	5.68	50
1991	10	10	840	5.69	51
1991	10	10	855	5.72	53
1991	10	10	870	5.75	56

4.1.5 USGS Download "Peaks"

The USGS produces files of peak discharge values for annual durations available through the National Water Information System (NWIS) web site accessed at http://waterdata.usgs.gov/nwis. These files can be input into GeoTool and used to develop flood frequency analysis. It is unlikely that this file will be used with any effective discharge type of analysis; however, attempting to run the effective discharge modules with this type of input file should not generate an error.

4.1.6 SWMM ".OUT" file

The use of GeoTool as a post-processing tool for the Storm Water Management Model (SWMM)* is handled through an interface program written in FORTRAN programming

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* SWMM contacts:

Dr. Wayne C. Huber, Dept. of Civil, Construction, and Environmental Engineering, Oregon State University, 202 Apperson Hall, Corvallis, Oregon 97331-2302, Phone: (541) 737-4934, Fax: (541) 737-3099, e-mail: wayne.huber@orst.edu.

Dr. William James, Computational Hydraulics International, 36 Stuart St., Guelph, Ontario N1E 4S5, Phone: (519) 767-0197, Fax: (519) 767-2770, e-mail: wjames@uoguelph.ca.

language. The interface program is readSWMM.exe, and when called by the GeoTool main program it opens and operates in a DOS (Disk Operating System) shell (Figure 4.2). When the interface program has completed a flow record, the user must signify that the interface program is complete by clicking the SWMM Interface Complete button on the Input File Options menu. The user must identify the location of the readSWMM.exe file and completed interface file. ReadSWMM.exe operates by taking a SWMM output file (filename and directory entered by the user) and converting the information into a comma delimited file with a new extension ".GTI" (GeoTool Interface) which is formatted as File Format 2. Once the ".GTI" file is created, the readSWMM executable need not be run on the same ".out" SWMM file again. The ".GTI" file can be read in using the File Format 2 option. The readSWMM executable is capable of handling output from either the "RUNOFF" or "TRANSPORT" blocks within SWMM Version 4 (or any later version with the same output format). For examples of these types of output files please consult the SWMM Manual for Version 4 (or later version with the same output format).

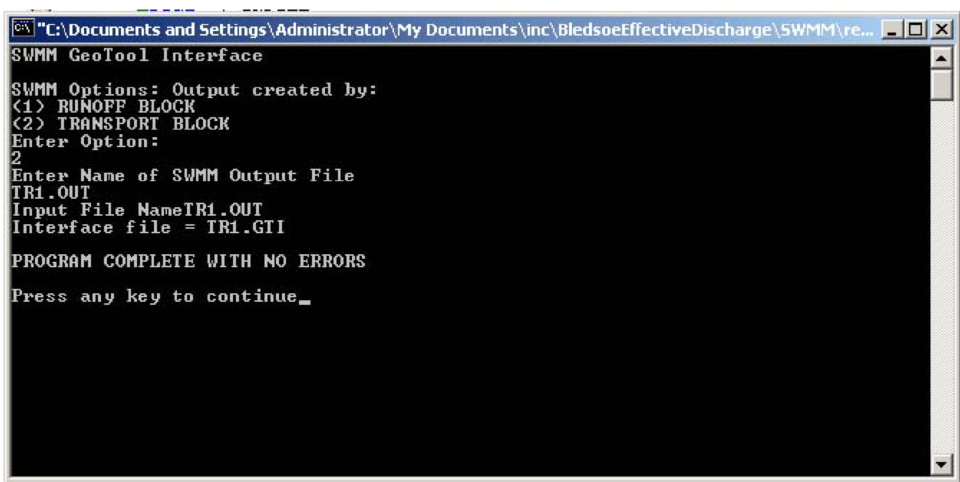

Figure 4.2 – SWMM interface screen shot. To use SWMM model output, an interface program that runs in the DOS environment is launched from within GeoTool.

4.1.7 HSPF "P" File

GeoTool is also capable of reading in Hydrological Simulation Program – FORTRAN (HSPF) files. The input algorithm for this type of file assumes that the "P" file has been generated using the following format (Table 4.1) (HSPF-12-2 documentation available at http://smig.usgs.gov/cgi-bin/SMIC/model_home_pages/model_home?selection=hspf).

Table 4.1 – HSPF format table.

Columns	Contents
1 – 4	Identifier (first 4 characters of title)
6 – 10	Year
11 – 13	Month
14 – 16	Day
17 – 19	Hour
20 – 22	Minute
25 – 36	Value for curve 1, for this date/time
39 – 50	Value for curve 2, for this date/time
Etc... (repeats until data for all curves are supplied)	
Format: A4, 1X, I5, 4I3,20(2X,G12.5)	

Please note that the Format statement in Table 4.1 refers to the FORTRAN code used to develop HSPF. The user of GeoTool can simply open up their “P” file in any text editor and check to see whether their file conforms to the necessary format. If the user desires more information about HSPF and its output please contact the developers at the EPA, specifically the USGS Hydrologic Analysis Software Support Team, 437 National Center, Reston, VA 20192 or by e-mail at h2osoft@usgs.gov.

4.1.8 Other

This option is currently under development. A new version of GeoTool, incorporating this upgrade, will be posted as soon as possible.

CHAPTER 5
USER INPUT OPTIONS

When utilizing the effective discharge portions of GeoTool, most of the user options are provided through the User Input Options menu (Figure 5.1). The inputs are divided into five categories:

- Flow Data Selection,
- Sediment Transport Tools,
- Effective Discharge Tools (Bin Information),
- Channel Change Tools, and
- Output Options.

These frames that comprise the User Input Options menu are discussed below:

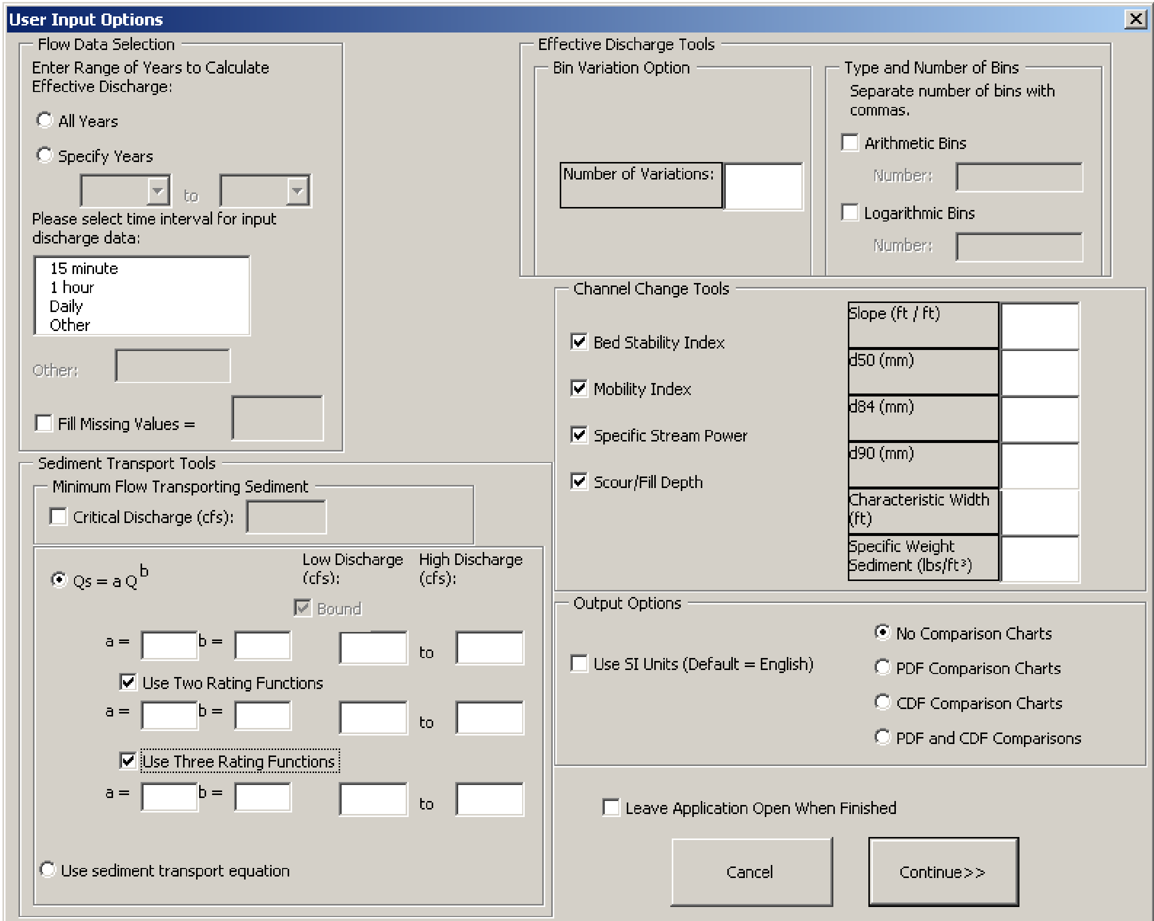

Figure 5.1 – User Input Options **menu screen shot, where the user specifies most of the parameters necessary to run the effective discharge processes within GeoTool.**

5.1 FLOW DATA SELECTION

After specifying the file name and the format, the user must identify the time period of the analysis and whether it corresponds to all of the dates within the flow record or whether the analysis should be performed on subsets of the data (Figure 5.2). For example, if the user would like to perform an analysis comparing the years 1950 through 1970 to 1970 through 1999 of one flow record, the single file can be entered in the Reference File and File 2 text boxes on the Opening menu with GeoTool running in Effective Discharge Comparison (Multiple Files) mode and selecting the two time periods respectively.

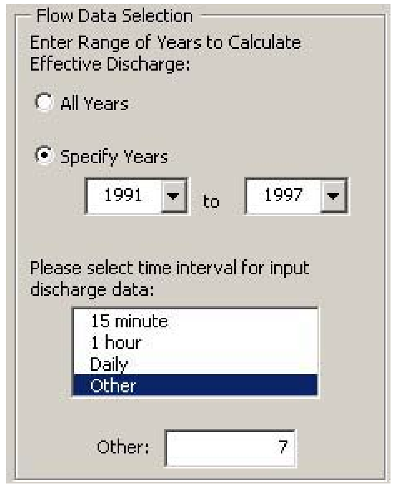

Figure 5.2 – Flow Data Selection **screen shot, where the user chooses the period of the flow record analysis, the data time interval, and whether missing values will be filled in.**

In addition, the user must specify the time interval for the discharge data (*e.g.*, daily, hourly, 15-minute, etc.). GeoTool offers a series of common data time intervals but if the user wishes to select a different value, they can enter an integer number of hours corresponding to the file time step. Additionally GeoTool offers some data filling for files that may have holes in their data. If probability distribution function (PDF) and cumulative distribution function (CDF) comparisons are to be made among multiple files with differing amounts of missing data, these values will be misrepresented unless the missing data are filled. We suggest filling in the missing values with an appropriate base flow value for the system being analyzed.

5.1.1 Range of Years to Calculate Effective Discharge

5.1.1.1 All Years

Select this option if you would like the entire data set to be analyzed. The years within the pull-down menus should correspond to the dates within the inputted flow record and is a good way to verify that the data were loaded correctly.

5.1.1.2 Specify Years

This option should be selected if there is a specific period within the flow record for which the analysis is desired. If this option is selected, the earliest year must be selected from the pull-down menu on the left and the latest year must be selected from the pull-down menu on the right. The values within the pull-down menus should represent the extent of the entire flow record. If there is a discrepancy between the dates in the pull-down menu and the inputted flow record, then there is an error with the input data process that must be resolved prior to analysis.

5.1.1.3 Select time interval for input discharge data

The time format of the input file must be selected here. The standard options are:

15 minute
1 hour
Daily
Other

If Other is selected, then the actual time step must be specified as an integer number of hours.

5.1.1.4 Fill Missing Values

GeoTool calculates the maximum total number of records that should appear within the first and last records of the input file given the time interval selected by the user. If the actual number of records loaded is not equal to the maximum value, then the user can choose to fill in the missing values with a value entered in cfs. This option is particularly useful when comparing flow files which differ in the number of missing days because these values influence the CDFs and PDFs. The missing values are not entered date specific, meaning that they will not affect the annual maximum and minimum series that are used to calculate the flood statistics.

5.2 SEDIMENT TRANSPORT TOOLS

The GeoTool effective discharge calculations provide the user with multiple sediment transport solutions to analyze their data set including theoretical and empirical equations (Figure 5.3).

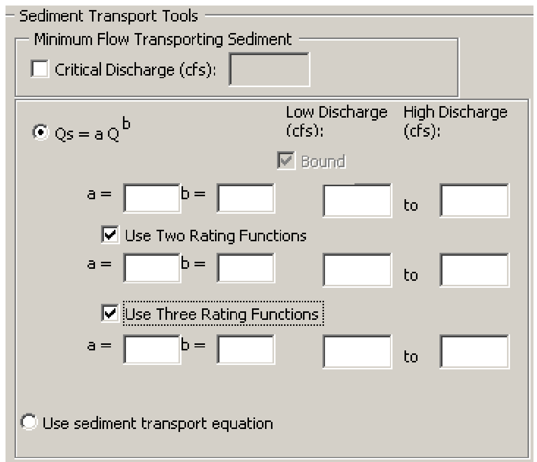

Figure 5.3 – Sediment Transport Tools **screen shot, where the user specifies the parameters of rating curve(s) describing sediment transport and its applicability range or selects a total load or bedload transport equation.**

5.2.1 Minimum Flow Transporting Sediment

5.2.1.1 Critical Discharge (cfs)

If a discharge exists below which it is known that no sediment is transported, then the Critical Discharge (cfs) check box should be selected and the value inputted in the enabled text box.

5.2.2 Sediment Transport Relationships

5.2.2.1 $Qs = aQ^b$

This option should be selected if an appropriate rating curve is known for the river segment being studied. Sediment transport capacity of a given discharge during the duration of

GeoTool operation will simply be calculated by the above function. If the rating curve is only valid for a range of flows, than those values can be entered by selecting Bound. Any flows not within these values will be assigned a sediment discharge of zero. If a rating curve is only valid above a certain flow, a Critical Discharge (cfs) can be specified and all flows below this value will be assigned a sediment discharge of zero.

Up to three different rating curves may be selected for flows of increasing magnitude. The High Discharge box of rating curve 1 must correspond to the Low Discharge box of rating curve 2 and the High Discharge box of rating curve 2 must correspond to the Low Discharge of rating curve 3. If a High Discharge is identified for any rating curve it must be selected for all rating curves and any discharge inputs above the largest High Discharge boundary will be assigned a zero sediment discharge.

5.2.3 Use Sediment Transport Equation

The user may select the Use sediment transport equation instead of a sediment transport rating curve. This option will trigger an additional menu once the Continue button is pressed. See Chapter 6 for a description of sediment transport options.

5.3 EFFECTIVE DISCHARGE TOOL (BIN INFORMATION)

The effective discharge method as performed within GeoTool is categorized as a magnitude-frequency analysis. The distribution of flows is divided into a number of "bins" (Figure 5.4), which span from the minimum discharge to the maximum discharge. The distribution of these bins can be either arithmetically or logarithmically distributed (henceforth called the "type" of binning). The number and type of bins substantially affects the determination of the effective discharge and great care should be taken when making these choices. GeoTool provides the user an efficient method of examining many different bin size distributions for making the "best" determination of the effective discharge.

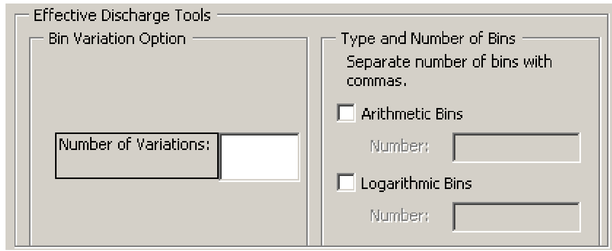

Figure 5.4 – Bin Selection screen shot, where the user specifies the number and type of bins to use in the effective discharge analysis.

5.3.1 Bin Variation Option

5.3.1.1 Number of Variations

It is well known that bin specification is an important factor when determining an effective discharge (*e.g.*, Bidenharn *et al.* 2000, Hey 1997, Holmquist-Johnson 2002). Holmquist-Johnson (2002) also discussed some standards for selecting the number and type (*i.e.*, Arithmetic or Logarithmic) of bins. Therefore, it may be desirable to run many different bin set ups for the same input file. It is possible to run the program multiple times for each flow record file specifying a different number of bins for each run only when no file comparisons are being made. If Effective Discharge (Single File) was selected on the Opening menu than the user may enter up to 50 different bin number variations that they would like run for a single type. If Effective Discharge (Compare Multiple Files) was chosen from the Opening menu the Number of Variations option will be disabled and the integer 1 will be observed in this text box. This is to ensure that the same numbers of bins are being used for each of the files being compared.

5.3.1.2 Type and Number of Bins

As stated previously, it has been documented that bin specification plays an important role in effective discharge results (Holmquist-Johnson 2002). Therefore, care should be taken when choosing the Type and Number of Bins. When multiple numbers of variations have been entered (Figure 5.4), each variation must be entered into the text box next to either the Arithmetic or Logarithmic option in a comma-delimited manner. Only one choice may be made for program execution. Thus, if five has been entered into the Number of Variations text box (Figure 5.4) then five integers must be entered into either the text box corresponding to the Arithmetic option or the text field corresponding to the Logarithmic option. An example of an incorrect entry is to put three integers into the Arithmetic text box and two integers into the Logarithmic text box. This will generate an error.

- Arithmetic Bins

Arithmetic Bins are specified as follows. The lowest bin boundary is set to the minimum flow in the flow record. Each bin has a domain size equal to:

$$\frac{Q_{\max} - Q_{\min}}{N_B}, \tag{5.1}$$

where:

$Q_{\max}$ = maximum flow in the record;

$Q_{\min}$ = minimum flow in the record; and

N_B = number of bins.

Thus if the user specifies 10 bins for a flow record with a maximum value of 110 cfs and a minimum value of 10 cfs then the bins will be divided as shown in Table 5.1.

Table 5.1– Sample arithmetic bin distribution.

Bin Number	Lower Bin Boundary	Upper Bin Boundary
1	10	20
2	20	30
3	30	40
4	40	50
5	50	60
6	60	70
7	70	80
8	80	90
9	90	100
10	100	110

If a flow corresponds exactly to one of the bin boundaries, it is assigned to the lower bin, except in the case of the minimum flow in the record, which always goes into the first bin.

- Logarithmic Bins

If Logarithmic Bins are selected, the specification is as follows. A preliminary bin is specified with a flow range of 0 to 0 (Table 5.2). The rest of the flow record is divided into the number of bins selected by the user, where the lower and upper bin boundaries are:

$$e^{(Log(Q_{min})+(B-2)*LI)} \text{ and} \tag{5.2}$$

$$e^{(Log(Q_{min})+(B-1)*LI)} , \tag{5.3}$$

respectively, where B is the bin number (*i.e.,* $B \in 1, N_B$, where N_B is the total number of bins; for the case represented in Table 5.1, $N_B = 10$), LI is the Logarithmic interval between the minimum and maximum flows defined as:

$$LI = \frac{\ln(Q_{max}) - \ln(Q_{min})}{N_B - 1}. \tag{5.4}$$

Table 5.2 – Sample logarithmic bin distribution with minimum nonzero flow equal to 3.11(10^{-4}) and maximum flow equal to 37.1. The dimensions are L^3/T.

Bin Number	Lower Bin Boundary	Upper Bin Boundary
	0.00E+00	0.00E+00
1	3.11E-04	1.00E-03
2	1.00E-03	3.22E-03
3	3.22E-03	1.04E-02
4	1.04E-02	3.33E-02
5	3.33E-02	1.07E-01
6	1.07E-01	3.46E-01
7	3.46E-01	1.11E+00
8	1.11E+00	3.58E+00
9	3.58E+00	1.15E+01
10	1.15E+01	3.71E+01

5.4 CHANNEL CHANGE TOOLS

GeoTool offers the opportunity to calculate four indices related to channel stability and change:

- Bed Stability Index,
- Mobility Index,
- Specific Stream Power, and
- Scour/Fill Depth.

The actual calculations of these indices are described in the output section of this manual (see Section 7.1.1). The user must enter the information required to make the calculations for each of the indices that they select to have calculated. Only those text boxes relevant to the chosen indices are enabled in Figure 5.5.

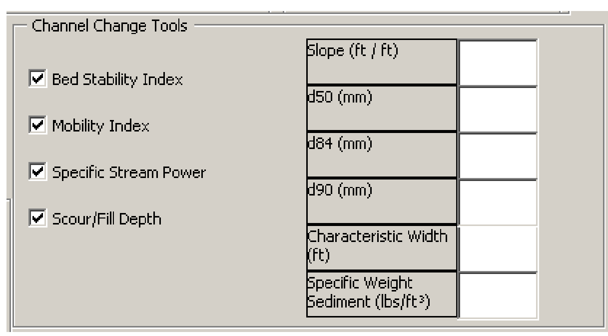

Figure 5.5 – Channel Change Tools **frame screen shot. Only the input text fields necessary to calculate the desired indices are enabled.**

5.5 OUTPUT OPTIONS

Although GeoTool requires input files to have English units, the user can specify that outputs have either English or SI units (Figure 5.6). In addition, GeoTool output in effective discharge file comparison mode allows the user to specify whether comparison is made between PDFs, CDFs, both PDF and CDF, or neither. If PDF/CDF comparisons are to be made, the parameters compared are discharge, sediment transport, shear stress, stream power and specific stream power, and scour/fill depths.

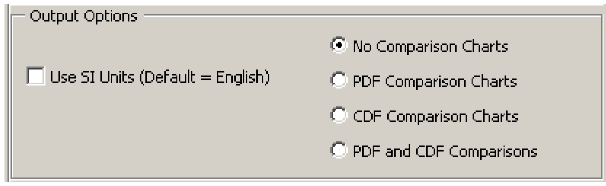

Figure 5.6 – Output Options **screen shot, where the user specifies which units are used for outputs. For comparisons of multiple flow records the user can specify what types of comparisons are made. The user can also elect to leave the application open when computations are complete.**

By default, GeoTool closes itself at the end of effective discharge calculations. If the user would like to keep the program open and restart it from the Input Sheet they can choose this option by checking the Leave Application Open When Finished check box.

CHAPTER 6
SEDIMENT TRANSPORT OPTIONS

In addition to using a sediment rating curve (described in Section 5.2.2), the user also has the option to use one of several theoretical sediment transport equations. The sediment transport equation interface is shown in Figure 6.1. This interface allows the user to specify which sediment transport equation they would like to implement as well as prompts for the required parameters to perform the calculations. Sediment transport options are discussed below.

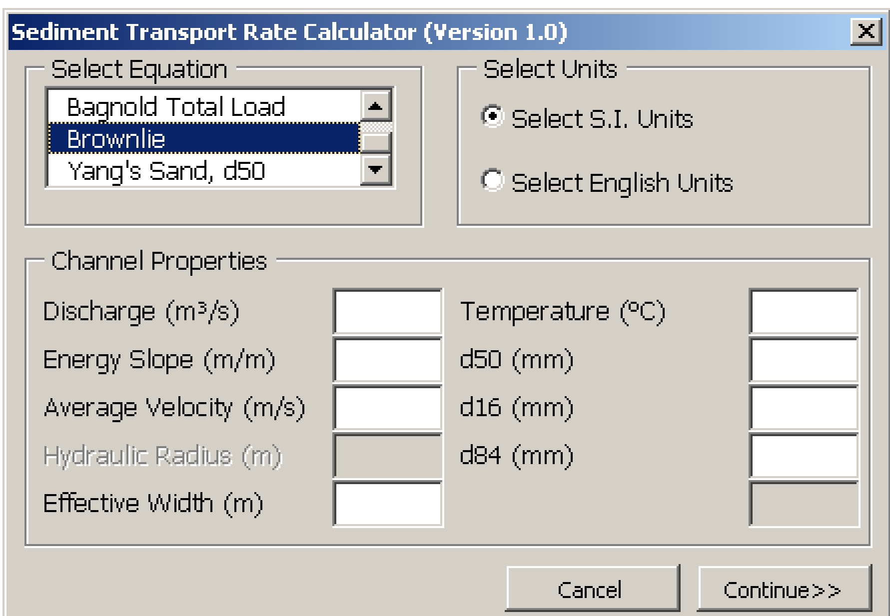

Figure 6.1 – Sediment Transport Rate Calculator **screen shot, where the user selects a sediment transport equation to use and inputs the necessary parameters to complete the computations.**

6.1 SELECT EQUATION

In the Select Equation frame (upper left corner of the sediment transport equation interface, Figure 6.1), the sediment transport equation list is displayed. For each calculation of effective discharge the user can choose one of five sediment transport equations that have been previously developed and are widely used in calculations of sediment transport rate. These equations are discussed in the following sections.

6.1.1 Brownlie Total Load

The Brownlie (1981) total load equation is given as:

$$C_{ppm} = 7115 c_B \left(\frac{V - V_c}{\sqrt{(G-1) g d_s}} \right)^{1.978} S_f^{\,0.6601} \left(\frac{R}{d_s} \right)^{-0.3301} \qquad \textbf{(6.1)}$$

where:

C_{ppm} = concentration of sediment (parts per million (ppm));

c_B = coefficient that is assumed to be 1.268 for field data [dimensionless];

V = mean flow velocity [L/T];

V_c = critical velocity [L/T];

G = ratio of the specific gravity of sediment to that of water;

g = gravitational acceleration [L/T^2];

d_s = diameter of sediment [L];

S_f = friction slope [L/L]; and

R = hydraulic radius [L].

The critical velocity, V_c, is determined by the following equation:

$$V_c = 4.596 \tau_{*c}^{0.529} S_f^{\,-0.1405} \sigma_g^{-0.1606} \sqrt{(G-1) g d_s} \qquad \textbf{(6.2)}$$

where:

τ_{*c} = critical dimensionless shear stress; and

σ_g = geometric standard deviation of the bed material [dimensionless].

The geometric standard deviation is calculated as:

$$\sigma_g = \left(\frac{d_{84}}{d_{16}}\right)^{1/2} \qquad \textbf{(6.3)}$$

in which d_{84} is the particle size at which 84 % of the bed material is finer by weight and d_{16} is the particle size at which 16 % of the bed material is finer by weight. Note that d_{84} and d_{16} must be of the same dimension for σ_g to be dimensionless. If σ_g is calculated to be greater than 5 it defaults to 5. The critical dimensionless shear stress is a function of the dimensionless particle size, d_*, which can be expressed as:

$$d_* = d_s\left(\frac{(G-1)g}{\nu^2}\right)^{1/3} \qquad \textbf{(6.4)}$$

where ν is the kinematic viscosity of the water-sediment mixture. The concentration of sediment is assumed low enough to approximate the viscosity of the water-sediment mixture as the viscosity of clear water. Furthermore, the median particle diameter, d_{50} (m), is used as d_s in Equations (6.2) and (6.4). The critical dimensionless shear stress is determined by solving the following equations (Brownlie 1981):

$$\tau_{*c} = 0.22Y + 0.06(10)^{-7.7Y} \qquad \textbf{(6.5)}$$

where:

$$Y = \left(\sqrt{\frac{\rho_s - \rho}{\rho}}\frac{u_* d_s}{\nu}\right)^{-0.6}. \qquad \textbf{(6.6)}$$

The sediment discharge, Q_s, is computed as:

$$Q_S = C_V Q \tag{6.7}$$

where:

Q = water discharge [L^3/T]; and

C_V = concentration of sediment by volume [dimensionless].

C_V is determined from the concentration in ppm and specific gravity of the sediment. The units of the sediment discharge, Q_S, are volume of sediment per time. The sediment discharge can be converted to units of weight of sediment per unit time (*e.g.,* sediment discharge is commonly reported in units of U.S. tons per day, a U.S. ton is a short ton = 907.18 kg) using the specific gravity of sediment.

6.1.2 Bagnold Total Load

The Bagnold (1966) Total Load equation may be expressed as (Julien 1995):

$$q_t = \frac{\tau_0 V}{(G-1)}\left(e_B + 0.01\frac{V}{\omega_s}\right) \tag{6.8}$$

where:

q_t = total sediment load per unit width of channel [F/L/T];

τ_0 = average boundary shear stress [F/L^2];

e_B = bedload efficiency factor and is typically between 0.2 to 0.3 [dimensionless]; and

ω_s = fall velocity of the sediment [L/T].

The average boundary shear is computed from:

$$\tau_0 = \gamma R S_f \tag{6.9}$$

where γ is the specific weight of water. The bedload efficiency factor, e_B, is assumed 0.25.

The particle fall velocity, ω_s, is computed according to Rubey's (1933) equation, which Julien (1995) presents as:

$$\omega_s = \left[\sqrt{\frac{2}{3} + \frac{36\nu^2}{(G-1)gd_s^3}} - \sqrt{\frac{36\nu^2}{(G-1)gd_s^3}} \right] \sqrt{(G-1)gd_s} \ . \qquad \textbf{(6.10)}$$

Multiplying q_t by the channel width gives the sediment load in units of weight of sediment per unit time, which is converted into units of U.S. tons per day (1 U.S. ton = 907.18 kg). Julien (1995) notes that the Bagnold equation is best suited for fully turbulent flows where the transport rate is large.

6.1.3 Meyer-Peter and Müller Bedload

The Meyer-Peter and Müller (1948) equation computes the volumetric bedload transport rate per unit width of channel. The simplified form (Chien 1956) is presented by Julien (1995) as:

$$q_{bv} = 8(\tau_* - \tau_{*c})^{3/2} \sqrt{(G-1)gd_s^3} \ , \qquad \textbf{(6.11)}$$

where

q_{bv} = volumetric bedload transport rate per unit width of channel [L^3/T/L]; and

τ_* = dimensionless shear stress.

For the Meyer-Peter and Müller (1948) equation, a value of 0.047 is recommended for the critical dimensionless shear stress, τ_{*c}. The dimensionless shear stress is computed as:

$$\tau_* = \frac{\tau_0}{(G-1)\gamma d_s} = \frac{RS_f}{(G-1)d_s} \ . \qquad \textbf{(6.12)}$$

Note that the Meyer-Peter and Müller equation is valid only for $\tau_* > \tau_{*c}$. Therefore, when $\tau_* < \tau_{*c}$ the bedload transport rate is zero.

Knowing the specific gravity of the sediment and the width of the channel, the volumetric bedload transport rate, q_{bv}, is converted to a daily sediment load in units of tons per day.

6.1.4 Yang's Sand, d_{50} Total Load

The total sediment concentration in ppm can also be estimated using the method presented by Yang (1996). For bed material consisting of predominately sand, Yang's relationship is:

$$\log C_{ppm} = 5.435 - 0.286 \log \frac{\omega_s d_s}{\nu} - 0.457 \log \frac{u_*}{\omega_s} + \left(1.799 - 0.409 \log \frac{\omega_s d_s}{\nu} - 0.314 \log \frac{u_*}{\omega_s}\right) \log\left(\frac{V}{\omega_s} S_f - \frac{V_c}{\omega_s} S_f\right), \tag{6.13}$$

where u_* is the shear velocity [L/T], and is computed as:

$$u_* = \sqrt{\frac{\tau_0}{\rho}} = \sqrt{gRS_f} \ , \tag{6.14}$$

where ρ is the density of the water sediment mixture [M/L^3], which is assumed to be equal to the density of clear water at 20°C. In the Yang equation, the ratio of critical velocity to particle fall velocity is given according to the following equation (Yang 1995):

$$\frac{V_c}{\omega_s} = \frac{2.5}{\log\left(\frac{u_* d_s}{\nu}\right) - 0.06} + 0.66 \qquad \text{for} \qquad 1.2 < \frac{u_* d_s}{\nu} < 70 \tag{6.15}$$

and

$$\frac{V_c}{\omega_s} = 2.05 \qquad \text{for} \qquad \frac{u_* d_s}{\nu} \geq 70 \ . \tag{6.16}$$

Note that the Yang approach yields a zero concentration when $V_c \geq V$ or when $u_* d_s / \nu < 1.2$.

6.1.5 Wilcock Two-phase Bedload Transport

GeoTool can also compute sediment transport based on the work of Wilcock and Kenworthy (2002). This method uses a two fraction, sand and gravel, transport model which accounts for the nonlinear effects of sand mixing with gravel on total sediment transport rates. The surface transport model from Wilcock and Kenworthy (2002) is implemented within GeoTool. The user must provide GeoTool with values of D_s and D_g characteristic surface grain sizes for the sand and gravel fractions, respectively. The value of F_s, somewhere between 0 and 1, is the proportion of the surface sediment in the sand fraction and must also be provided along with values of channel width, w, and slope, S. The sediment transport is calculated for sand and gravel size fractions separately. In Equations (6.17) to (6.21), the subscript i represents either the sand or gravel size fraction. To calculate the sediment transport per unit channel width the following procedure is completed. First the dimensionless incipient motion criteria is solved for as:

$$\tau_{ri}^* = \left(\tau_{ri}^*\right)_1 + \left[\left(\tau_{ri}^*\right)_0 - \left(\tau_{ri}^*\right)_1\right]e^{-14F_x} \qquad \textbf{(6.17)}$$

where the incipient motion parameters are given for the surface transport model in Wilcock and Kenworthy (2002) Table 3 as $\left(\tau_{rg}^*\right)_0 = 0.035$, $\left(\tau_{rg}^*\right)_1 = 0.011$, $\left(\tau_{rs}^*\right)_1 = 0.065$, and

$$\left(\tau_{rs}^*\right)_0 = \left(\tau_{rg}^*\right)_0 \left(D_g \big/ D_s \right). \qquad \textbf{(6.18)}$$

The reference shear stress for each size fraction is then calculated as:

$$\tau_{ri} = \tau_{ri}^*\left(s-1\right)\rho g D_i \ . \qquad \textbf{(6.19)}$$

A parameter designated as the ratio of actual shear stress to reference shear stress:

$$\vartheta = \frac{\tau}{\tau_{ri}} \qquad \textbf{(6.20)}$$

is necessary to calculate the transport function of the form:

$$W_i^* = \begin{cases} 0.002\vartheta^{7.5} & \text{for } \vartheta < \vartheta' \\ A\left(1 - \dfrac{\chi}{\vartheta^{0.25}}\right)^{4.5} & \text{for } \vartheta \geq \vartheta' \end{cases} . \quad \textbf{(6.21)}$$

Within the transport function in Equation (6.21), A is a fitted parameter, and ϑ' and χ are chosen to match the value of a slope of the two parts of the function. The values implemented within GeoTool are taken from the calibration for field data from Wilcock and Kenworthy (2002) in which A = 115, ϑ' = 1.27, and χ = 0.923. The sediment transport per unit channel width is then calculated for each size fraction as:

$$q_{bi} = \frac{F_i u_*^3 W_i^*}{g(s-1)} . \quad \textbf{(6.22)}$$

The total sediment transport, per unit channel width, is calculated as the sum of q_s and q_g.

6.2 SELECT UNITS

Although the current release of GeoTool allows the user to select whether output data will be displayed in either SI or English units, the user must enter sediment transport equation parameters in units consistent with the English system of measurement (*e.g.,* ft, ft/s, and °F). The only exception is substrate particle diameter, which must be entered in units of millimeters. The toggle to Select SI Units is disabled for the sediment transport equation interface when computing effective discharge, and English units will be selected automatically.

6.3 CHANNEL PROPERTIES

Once a sediment transport equation has been selected from the Select Equation frame, labels will appear in the Channel Properties frame for only those text boxes where Channel Properties must be entered. The labels will instruct the user as to which property is to be entered, as well as the necessary units (see Figure 6.1). The user is prompted to enter the required information about the channel geometry and substrate in the text boxes at the center of the interface based on the equation selected. Since the different equations require different input data, the program will enable only those text boxes and labels for the required values. All other text boxes and their corresponding labels will be disabled. If a user opts to change equations, the text boxes and their labels will change accordingly, and clear the data already entered into text boxes.

6.4 EFFECTIVE DISCHARGE INFORMATION

When the user selects Continue on the sediment transport equation interface after entering all pertinent data, the Channel Characteristics menu appears (Figure 6.2). Because some of the sediment transport equations utilized by GeoTool rely upon parameters that vary with discharge (specifically, mean flow velocity, V, and hydraulic radius, R), GeoTool has the capability to allow these parameters to vary with discharge.

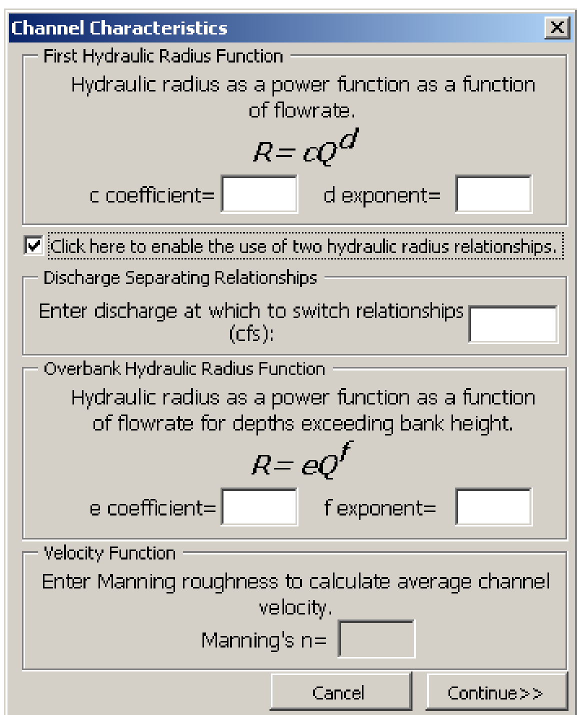

Figure 6.2 – Channel Characteristics **screen shot, where the user defines information about channel geometry as a function of volumetric flow rate. The user can simulate a floodplain as well as define channel roughness if necessary.**

6.4.1 First Hydraulic Radius Function

To obtain the hydraulic radius for each bin of the input flow record, the following relationship is utilized by GeoTool:

$$R = cQ^d \qquad \textbf{(6.23)}$$

where

c = regression coefficient; and

d = regression exponent.

The user must specify the values of the coefficient and exponent for *R* = *f*(*Q*) in English Units. It is recommended that the user determine c and d from regression of concurrent observations of hydraulic radius, R, and discharge, Q. If concurrent measurements of hydraulic radius and discharge are unavailable, the user may consider using a hydraulic simulation model such as HEC-RAS (http://www.hec.usace.army.mil/) to generate values of hydraulic radius over a range of discharges. Then, nonlinear regression methods may be used to determine the regression parameters. A nonlinear regression approach is more appropriate when the input flow record contains discharges across several orders of magnitude.

6.4.2 Discharge Separating Relationships and Overbank Hydraulic Radius Function

Recognizing that relationships describing hydraulic radius may be different depending on whether the flow is in-channel or overbank, an option is available to input a second relationship for hydraulic radius. This allows the user to specify hydraulic radius for those discharges in the input record that produce stages above the bankfull stage. The user simply selects the option to use a second function (Figure 6.2), and enters the coefficient and exponent of the second function. The user then inputs the discharge above which the second relationship is to be used. If the discharge corresponding to the overbank stage is not known one method of estimating it is to visually inspect or utilize a statistical technique (*e.g.,* piecewise regression plot of hydraulic radius versus discharge) to discern the discharge that coincides with the approximate overbank stage. Regardless of the technique utilized, the effort should determine the discharge at which a change in the slope of a regression line in the log-log domain between hydraulic radius and discharge occurs.

6.4.3 Velocity Function

Sediment transport equations requiring a mean flow velocity as an input will require that the user input the Manning roughness coefficient. The user is cautioned that the value selected for the Manning roughness coefficient should be representative of the entire flow record. When possible, it may be reasonable to estimate the Manning roughness coefficient at various values of discharge and subsequently use an average value. Again, a hydraulic simulation model may be utilized when observations are unavailable.

It is also suggested that the user consider the idea that the friction slope may change significantly with changes in discharge. Hence, for sediment transport equations where a friction slope is required, the value should be representative of the entire flow record. Again, the user may utilize some average value determined by using a hydraulic simulation model to generate friction slope at various values of discharge.

6.5 COMMENTS ON SELECTING SEDIMENT TRANSPORT FORMULAE

It is expected that users have some familiarity with the underlying concepts of sediment transport. Specifically, the user should understand that the various sediment transport equations were developed with differing field/experimental conditions, data, assumptions, and purposes. The user is strongly encouraged to carefully assess the flow, channel, and substrate characteristics against the range of applicability for a specific sediment transport equation. The user should carefully consider the predominant mode of transport in their situation. One method of determining the mode of sediment transport suggested by Julien (1995) utilizes the ratio of shear velocity, u_*, to particle fall velocity, ω_s, and the criteria listed in Table 6.1.

Table 6.1 – Identifying the mode of sediment transport.

u_*/ω_s	Transport Mode
< 0.4	Bedload
0.4 < u_*/ω_s < 2.5	Mixed load
> 2.5	Suspended load

The user should also consider that all sediment transport equations yield estimates of sediment transport capacity. However, the actual amount of sediment available for transport may be less than the transport capacity of the channel (*i.e.*, supply limited). The sediment transport capacity as determined through use of sediment transport equations will be equivalent to the *actual* sediment transport rate only when the sediment supply exceeds the sediment transport capacity (*i.e.*, capacity limited). The user is encouraged to refer to Julien (1995), Reid and Dunne (1996), Yang (1996), and Richardson *et al.* (2001) for further guidance on selection criteria for sediment transport relationships.

CHAPTER 7
OUTPUTS

7.1 SINGLE FILE EFFECTIVE DISCHARGE

When using the Effective Discharge portion of GeoTool, each flow record generates a summary sheet of outputs as well as a sheet with the input values selected by the user.

7.1.1 Summary Sheet

The summary sheet generated by GeoTool provides a variety of information. The items included are the flow parameters associated with the:

- effective discharge calculations,
- scour/fill distributions,
- annual maximum flow series,
- annual minimum flow series, and
- annual average series.

Additionally, a table of flow regime statistics and a series of charts are displayed. The output provides the user with data that describes the parameters for each bin. Each of these components of the summary sheet is discussed in the following sections, including a description of how the parameters are derived.

7.1.1.1 Bin Outputs

GeoTool calculates 20 values associated with the bin index and the flow record for each bin, except the 0 – 0 bin with logarithmic distributions. A sample output sheet is presented in Figure 7.1. The specific equations used for the calculations are as follows:

Effective Discharge Chart		Non-Exceedance Chart		Scour/Fill Distribution Chart		Effective Discharge Scour/Fill Chart													
Lower Bin Boundary [cfs]	Upper Bin Boundary [cfs]	Average Flow [cfs]	Flow Frequency	PDF	CDF	Sediment Transport [tons/day] / 1000	Bin Sediment Load	Hydraulic Radius [ft]	Shear Stress [lb/ft²]	Stream Power [lb/s]	Water PDF	Water CDF	Sediment PDF	Sediment CDF	Mobility Index [ft/s^0.5]	Specific Stream Power [lb/ft*s]	Bed Stability Index []	Mean Scour /Fill Depth [ft]	90% Scour /Fill Depth [ft]
0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00														
1.1E-01	5.7E+00	2.9E+00	7.0E+03	7.0E-01	7.0E-01	2.9E-03	2.0E+00	6.1E-01	3.8E-01	1.8E+00	3.4E-01	3.4E-01	3.4E-01	3.4E-01	N/A	0.0E+00	6.8E+01	N/A	N/A
5.7E+00	1.1E+01	8.5E+00	1.9E+03	1.9E-01	8.9E-01	8.5E-03	1.6E+00	9.4E-01	5.9E-01	5.3E+00	2.7E-01	6.1E-01	2.7E-01	6.1E-01	N/A	2.6E-01	1.0E+02	N/A	N/A
1.1E+01	1.7E+01	1.4E+01	6.0E+02	6.0E-02	9.5E-01	1.4E-02	8.4E-01	1.2E+00	7.2E-01	8.8E+00	1.4E-01	7.6E-01	1.4E-01	7.6E-01	N/A	7.6E-01	1.3E+02	N/A	N/A
1.7E+01	2.2E+01	2.0E+01	2.5E+02	2.5E-02	9.7E-01	2.0E-02	4.9E-01	1.3E+00	8.2E-01	1.2E+01	8.3E-02	8.4E-01	8.3E-02	8.4E-01	N/A	1.3E+00	1.5E+02	N/A	N/A
2.2E+01	2.8E+01	2.5E+01	9.2E+01	9.2E-03	9.8E-01	2.5E-02	2.3E-01	1.5E+00	9.1E-01	1.6E+01	3.9E-02	8.8E-01	3.9E-02	8.8E-01	N/A	1.8E+00	1.6E+02	N/A	N/A
2.8E+01	3.4E+01	3.1E+01	6.1E+01	6.1E-03	9.9E-01	3.1E-02	1.9E-01	1.6E+00	9.8E-01	1.9E+01	3.2E-02	9.1E-01	3.2E-02	9.1E-01	N/A	2.3E+00	1.7E+02	N/A	N/A
3.4E+01	3.9E+01	3.6E+01	3.7E+01	3.7E-03	9.9E-01	3.6E-02	1.3E-01	1.7E+00	1.1E+00	2.3E+01	2.3E-02	9.3E-01	2.3E-02	9.3E-01	N/A	2.8E+00	1.9E+02	N/A	N/A
3.9E+01	4.5E+01	4.2E+01	2.5E+01	2.5E-03	1.0E+00	4.2E-02	1.1E-01	1.8E+00	1.1E+00	2.6E+01	1.8E-02	9.5E-01	1.8E-02	9.5E-01	N/A	3.3E+00	2.0E+02	N/A	N/A
4.5E+01	5.0E+01	4.8E+01	1.6E+01	1.6E-03	1.0E+00	4.8E-02	7.6E-02	1.9E+00	1.2E+00	3.0E+01	1.3E-02	9.6E-01	1.3E-02	9.6E-01	N/A	3.8E+00	2.1E+02	N/A	N/A
5.0E+01	5.6E+01	5.3E+01	1.0E+01	1.0E-03	1.0E+00	5.3E-02	5.3E-02	2.0E+00	1.2E+00	3.3E+01	9.0E-03	9.7E-01	9.0E-03	9.7E-01	N/A	4.2E+00	2.2E+02	N/A	N/A
5.6E+01	6.2E+01	5.9E+01	1.0E+01	1.0E-03	1.0E+00	5.9E-02	5.9E-02	2.0E+00	1.3E+00	3.7E+01	9.9E-03	9.8E-01	9.9E-03	9.8E-01	N/A	4.7E+00	2.3E+02	N/A	N/A
6.2E+01	6.7E+01	6.4E+01	3.0E+00	3.0E-04	1.0E+00	6.4E-02	1.9E-02	2.1E+00	1.3E+00	4.0E+01	3.3E-03	9.8E-01	3.3E-03	9.8E-01	N/A	5.2E+00	2.3E+02	N/A	N/A
6.7E+01	7.3E+01	7.0E+01	4.0E+00	4.0E-04	1.0E+00	7.0E-02	2.8E-02	2.2E+00	1.4E+00	4.4E+01	4.7E-03	9.9E-01	4.7E-03	9.9E-01	N/A	5.7E+00	2.4E+02	N/A	N/A
7.3E+01	7.8E+01	7.6E+01	0.0E+00	0.0E+00	1.0E+00	7.6E-02	0.0E+00	2.3E+00	1.4E+00	4.7E+01	0.0E+00	9.9E-01	0.0E+00	9.9E-01	N/A	6.2E+00	2.5E+02	N/A	N/A
7.8E+01	8.4E+01	8.1E+01	1.0E+00	1.0E-04	1.0E+00	8.1E-02	8.1E-03	2.3E+00	1.4E+00	5.1E+01	1.4E-03	9.9E-01	1.4E-03	9.9E-01	N/A	6.7E+00	2.6E+02	N/A	N/A
8.4E+01	9.0E+01	8.7E+01	1.0E+00	1.0E-04	1.0E+00	8.7E-02	8.7E-03	2.4E+00	1.5E+00	5.4E+01	1.5E-03	9.9E-01	1.5E-03	9.9E-01	N/A	7.2E+00	2.6E+02	N/A	N/A
9.0E+01	9.5E+01	9.2E+01	0.0E+00	0.0E+00	1.0E+00	9.2E-02	0.0E+00	2.4E+00	1.5E+00	5.8E+01	0.0E+00	9.9E-01	0.0E+00	9.9E-01	N/A	7.7E+00	2.7E+02	N/A	N/A
9.5E+01	1.0E+02	9.8E+01	1.0E+00	1.0E-04	1.0E+00	9.8E-02	9.8E-03	2.5E+00	1.6E+00	6.1E+01	1.7E-03	9.9E-01	1.7E-03	9.9E-01	N/A	8.2E+00	2.8E+02	N/A	N/A
1.0E+02	1.1E+02	1.0E+02	2.0E+00	2.0E-04	1.0E+00	1.0E-01	2.1E-02	2.6E+00	1.6E+00	6.5E+01	3.5E-03	1.0E+00	3.5E-03	1.0E+00	N/A	8.7E+00	2.8E+02	N/A	N/A
1.1E+02	1.1E+02	1.1E+02	0.0E+00	0.0E+00	1.0E+00	1.1E-01	0.0E+00	2.6E+00	1.6E+00	6.8E+01	0.0E+00	1.0E+00	0.0E+00	1.0E+00	N/A	9.2E+00	2.9E+02	N/A	N/A
1.1E+02	1.2E+02	1.1E+02	0.0E+00	0.0E+00	1.0E+00	1.1E-01	0.0E+00	2.7E+00	1.7E+00	7.2E+01	0.0E+00	1.0E+00	0.0E+00	1.0E+00	N/A	9.7E+00	3.0E+02	N/A	N/A
1.2E+02	1.2E+02	1.2E+02	0.0E+00	0.0E+00	1.0E+00	1.2E-01	0.0E+00	2.7E+00	1.7E+00	7.5E+01	0.0E+00	1.0E+00	0.0E+00	1.0E+00	N/A	1.0E+01	3.0E+02	N/A	N/A
1.2E+02	1.3E+02	1.3E+02	0.0E+00	0.0E+00	1.0E+00	1.3E-01	0.0E+00	2.8E+00	1.7E+00	7.9E+01	0.0E+00	1.0E+00	0.0E+00	1.0E+00	N/A	1.1E+01	3.1E+02	N/A	N/A
1.3E+02	1.3E+02	1.3E+02	0.0E+00	0.0E+00	1.0E+00	1.3E-01	0.0E+00	2.8E+00	1.8E+00	8.2E+01	0.0E+00	1.0E+00	0.0E+00	1.0E+00	N/A	1.1E+01	3.1E+02	N/A	N/A
1.3E+02	1.4E+02	1.4E+02	1.0E+00	1.0E-04	1.0E+00	1.4E-01	1.4E-02	2.9E+00	1.8E+00	8.6E+01	2.3E-03	1.0E+00	2.3E-03	1.0E+00	N/A	1.2E+01	3.2E+02	N/A	N/A
						SUM BIN SEDIMENT LOAD	5.9E+00												

Figure 7.1 – Sample bin outputs section screen shot from a summary sheet generated by GeoTool when running 35 logarithmic bins in effective discharge calculation mode.

The bin boundaries are calculated as specified in the Effective Discharge Tool (Bin Information) (Section 5.3). The average flow within the bin is the arithmetic average for arithmetic bins (Equation (7.1)) and geometric average for logarithmic bins (Equation (7.2)),

$$\overline{Q}_B = \frac{Q_{B_{\min}} + Q_{B_{\max}}}{2} \text{ and} \qquad \textbf{(7.1)}$$

$$\overline{Q}_B = \sqrt{Q_{B_{\min}} Q_{B_{\max}}} \qquad \textbf{(7.2)}$$

where:

$\overline{Q}_B$ = mean discharge for the bin (units/dim);

$Q_{B_{\min}}$ = minimum discharge (units/dim) for the bin; and

$Q_{B_{\max}}$ = maximum discharge (units/dim) for the bin.

The flow frequency, B_N, is the number of flows that occurred during the length of record between the lower and upper bin boundary. The Bin Probability is:

$$\text{Bin Probability} = \frac{B_N}{N_T}, \quad \textbf{(7.3)}$$

where, N_T is the total number of flows within the record. The Cumulative Bin Probability is:

$$\text{Cumulative Bin Probability} = \sum_{i=1}^{N_B} \text{Bin Probability}_i . \quad \textbf{(7.4)}$$

The sediment transport, Q_s, is determined from mean bin flow, $\overline{Q_B}$, using the sediment transport relationship selected by the user on the User Input Options menu (Figure 5.1). The bin sediment load, Q_{S_B}, is:

$$Q_{S_B} = Q_S \cdot \text{Bin Probability} . \quad \textbf{(7.5)}$$

Since effective discharge is the term applied to the single value of discharge responsible for transporting the most flow over a range of flows, it is often identified as the bin with the highest value of Q_{S_B}. The row with the bin reflecting the highest value of Q_{S_B} is highlighted in green (Figure 7.1). Frequently two peaks exist in the distribution of sediment transport across the range of bins. In this situation, one of the peaks may reflect the sediment transported by very large, infrequent flow events or very frequent low flows in fine-grained channels. While flow events with extremely high or low frequencies are geomorphically influential, research indicates that more frequent flow events with recurrence intervals between 1 to 5 years are primarily responsible for channel dimensions in many instances. Therefore, when the effective discharge algorithm results in more than one peak in the distribution of sediment transported across the bins, the bin (row) corresponding to the second peak is highlighted in light blue. The total sediment transport over time, $Q^T{}_{S_B}$, in the flow record is:

$$Q^T{}_{S_B} = \sum_{i=1}^{N_B} Q^i{}_{S_B} , \quad \textbf{(7.6)}$$

and is shown at the bottom of the Q_{S_B} column on the summary sheet and is highlighted in bright blue. The hydraulic radius, R, is calculated at $\overline{Q}_B$ as a power function using the parameters specified by the user in the Channel Characteristics menu (Figure 6.2). For additional information and help interpreting effective discharge calculations, the user is directed to Watson *et al.* (1997), Soar (2000), and Holmquist-Johnson (2002).

The shear stress is defined as in Equation (6.9). The slope entered in the User Input Options menu or Sediment Transport Options menu is either the bed slope or friction slope as determined by the user. If no slope is entered, a default value of 0.01 [L/L] is used. The stream power, Ω, is:

$$\Omega = \gamma \overline{Q_B} S_f \, . \tag{7.7}$$

The flow Bin Probability and Cumulative Bin Probability, Bin Probability$_\Omega$ and Cumulative Bin Probability$_\Omega$, respectively, are:

$$\text{Bin Probability}_\Omega = \frac{\overline{Q_B}}{\sum_{i=1}^{N_B} \overline{Q_{B\,i}}} \text{ and} \tag{7.8}$$

$$\text{Cumulative Bin Probability}_\Omega = \sum_{i=1}^{B} \text{Bin Probability}_\Omega \, , \tag{7.9}$$

where:

N_B = total number of bins; and

B = bin of interest.

The sediment PDF and CDF, PDF$_S$ and CDF$_S$, respectively, are calculated as in Equations (7.8) and (7.9), using Q_{S_B} in lieu of Q_B. The mobility index (*MI*) is defined as:

$$MI = S\sqrt{\frac{Q}{d_{50}}} \, , \tag{7.10}$$

where, d_{50} is the median grain size [L] (Chang 1988, Bledsoe and Watson 2001). This index was developed in part as a measure of channel form and adjustment in cases where channel width data are unavailable (*e.g.*, van den Berg 1995). Specific stream power is:

$$\omega = \frac{\Omega}{w} = \frac{\gamma_m \overline{Q} S}{w}, \tag{7.11}$$

where:

w = channel width [L]; and

γ_m = specific weight of water and sediment mixture.

The user should acknowledge that in this version of GeoTool, discharge and width are not partitioned to floodplain and channel values. Therefore, GeoTool inadequately represents the stream power for a floodplain scenario with overbank flows. Specific stream power has also been used as a measure of channel form and response (*e.g.,* Bledsoe and Watson 2001).

The bed stability indicator (*BSI*) is (Olsen *et al.* 1997):

$$BSI = \frac{\tau_{Bi}}{\tau_c}, \tag{7.12}$$

where:

τ_B = shear stress associated with $\overline{Q_B}$; and

τ_c = shear stress at which d_{84} is mobilized [L].

The *BSI* represents excess energy relative to that which mobilizes d_{84}, the grain size often held as the grain size responsible for controlling channel form.

The mean scour fill depth and the 90% confidence interval scour fill depth are determined (after Haschenburger 1999) as:

$$\overline{\theta} = H_c e^{-H_e \frac{\tau_*}{\tau_r^*}}, \tag{7.13}$$

where:

$1/\overline{\theta}$ = mean scour/fill depth (cm);

τ_* = dimensionless shear stress at $\overline{Q_B}$;

τ_r^* = dimensionless shear stress used to normalize the equation (assumed as 0.04);

H_c = characteristic constant assumed 3.33; and

H_e = characteristic exponent assumed 1.52 (after Haschenburger 1999).

Future modifications to GeoTool will allow the user to specify these parameters. If $1/\theta$ is greater than a theoretical maximum ($2d_{90}$, after DeVries 2002), the corresponding cells will be highlighted in red. If τ_* is determined to be less than a critical value (0.045), then the cell within the summary sheet will be identified as "OUT OF RANGE." The 90% confidence interval scour/fill depth is determined using the exponential density function (Haschenburger 1999):

$$f(\xi) = \theta e^{-\theta\xi} \quad \textbf{(7.14)}$$

where, ξ is the depth in cm.

7.1.1.2 Scour Depth/Fill Table

If the user selects the option to calculate the scour depth/fill table in the User Input Options menu (Scour/Fill Depth box selected), then GeoTool will provide an output table of depths associated with the exponential distribution at the effective discharge (Figure 7.2). Each depth associated with a non-exceedance probability is calculated using Equation (7.14).

Scour Depth/Fill Table	
Depth [ft]	Non-Exceedance Probability
3.5E-01	9.0E-01
2.4E-01	8.0E-01
1.8E-01	7.0E-01
1.4E-01	6.0E-01
1.0E-01	5.0E-01
7.7E-02	4.0E-01
5.4E-02	3.0E-01
3.4E-02	2.0E-01
1.6E-02	1.0E-01
7.7E-03	5.0E-02

Figure 7.2 – Scour Depth/Fill Table **screen shot, provides the scour/fill depths associated with 10 non-exceedance probabilities ranging from 5 to 90 %.**

7.1.1.3 Annual Time Series

For each year over the period of analysis specified by the user, GeoTool outputs the maximum discharge in that year as well as the minimum discharge in that year and the annual average discharge (Figure 7.3). The annual maximum series is used to determine the recurrence interval of flow events.

Year	Annual Maximum [cfs]	Annual Minimum [cfs]	Annual Average Flow [cfs]
1948	6.0E+00	8.9E-01	6.3E-04
1949	1.6E+01	1.3E+00	8.7E-04
1950	1.3E+01	7.8E-01	3.4E-03
1952	5.7E+00	1.0E+00	5.7E-04
1956	2.0E+01	9.9E-01	1.1E-03
1959	2.6E+00	7.3E-01	1.5E-04
1960	1.6E+01	7.0E-01	1.0E-03
1961	2.3E+01	1.8E+00	2.7E-03
1962	3.9E+00	8.0E-01	4.4E-04
1964	2.4E+01	2.0E+00	2.8E-03
1966	1.1E+00	7.2E-01	2.0E-04
1969	1.2E+00	7.1E-01	1.3E-04
1973	7.5E-01	7.5E-01	2.1E-05
1975	6.5E+00	8.0E-01	1.0E-03
1977	2.7E+01	9.5E-01	3.3E-03
1978	3.2E+00	7.4E-01	3.7E-04
1979	4.6E+00	8.4E-01	2.4E-04
1980	8.4E-01	8.4E-01	2.4E-05
1982	1.4E+01	8.4E-01	9.9E-04
1984	5.3E+00	7.3E-01	5.0E-04
1987	2.0E+00	7.8E-01	2.1E-04
1989	1.0E+00	1.0E+00	2.9E-05
1990	2.9E+00	7.4E-01	1.7E-04
1991	2.9E+01	7.8E-01	3.1E-03
1993	1.0E+01	8.9E-01	1.4E-03
1996	3.7E+01	0.0E+00	7.4E-03

Figure 7.3 – Annual Time Series table screen shot, includes all of the years analyzed and the respective maximum, minimum, and average discharges.

7.1.1.4 Flow Regime Statistics

Figure 7.4 lists the flow statistics and indices of the flow record. This table includes the mean annual flow, $Q_{mean\ annual}$ or Q_{ma}, effective discharge, and flows with 1.5- and 2-year recurrence intervals. Effective discharge is the green highlighted row in Figure 7.1. The flow with recurrence intervals of 1.5 and 2 years is calculated from the Annual Maximum Series (Figure 7.3), using an empirical frequency distribution (EFD):

$$P(i) = \frac{i - \alpha}{N + \beta - 2\alpha}, \qquad \textbf{(7.15)}$$

where, N is the number of years, and α and β are assumed as 0.4 and 1, respectively, an approximation when the underlying distribution is not known (Cunnane 1978).

Flow Regime Statistics	
Qmean annual [cfs]	5.4E+00
Q effective [cfs]	5.1E+00
Q1_5 [cfs]	5.4E+01
Q2 [cfs]	5.8E+01
Q1_5 / Qma	1.0E+01
Q1_5 / Q_e	1.1E+01
Q2 / Qma	1.1E+01
Q2 / Q_e	1.1E+01
Mean Discharge [cfs]	5.5E+00
Mean Discharge Exceedance Time	1.3E-01
CV annual maximums	3.8E-01
coefficient of skewness	4.8E+00
Sediment Transport [tons/year]	2.6E+03

Figure 7.4 – Sample Flow Regime Statistics **table screen shot.**

The flood with 1.5- and 2-year recurrence intervals have $P(i)$ = 0.3333 and 0.5, respectively. Linear interpolation is used to determine a flood rate if necessary. Flashiness indices ($Q_{1.5}/Q_{ma}$, $Q_{1.5}/Q_e$, Q_2/Q_{ma}, and Q_2/Q_e) are provided as measures of the skew within the distributions and thus the flashiness of the flow regime. The Mean Discharge is simply the mean of all of the flows over the given period of interest including the filled data if specified by the user. The mean discharge exceedance time is calculated by determining the 1 – Cumulative Bin Probability of the mean discharge. The coefficient of variation (CV) of the annual maximum series is:

$$CV = \frac{\sigma_{Q_{y\max}}}{\overline{Q}_{y\max}}, \tag{7.16}$$

where:

$\overline{Q}_{y\max}$ = mean of the annual maxima; and

$\sigma_{Q_{y\max}}$ = standard deviation of annual maxima.

The coefficient of skewness, γ_Q, is:

$$\gamma_Q = \frac{N_T}{(N_T - 1)(N_T - 2)} \sum_{i=1}^{N_Q} \frac{Q_i - \overline{Q_N}}{\sigma_{Q_N}} \quad . \qquad \textbf{(7.17)}$$

where:

N_Q = number of flows;

Q_N = average across all flows; and

σ_{Q_N} = standard deviation of all flows in the flow record.

7.1.1.5 Output Charts

GeoTool provides graphical outputs of CDF, PDF, effective discharge, and non-exceedance probabilities. Figure 7.5 is a CDF of flow and sediment and represents the amount of time that water and sediment are being transported.

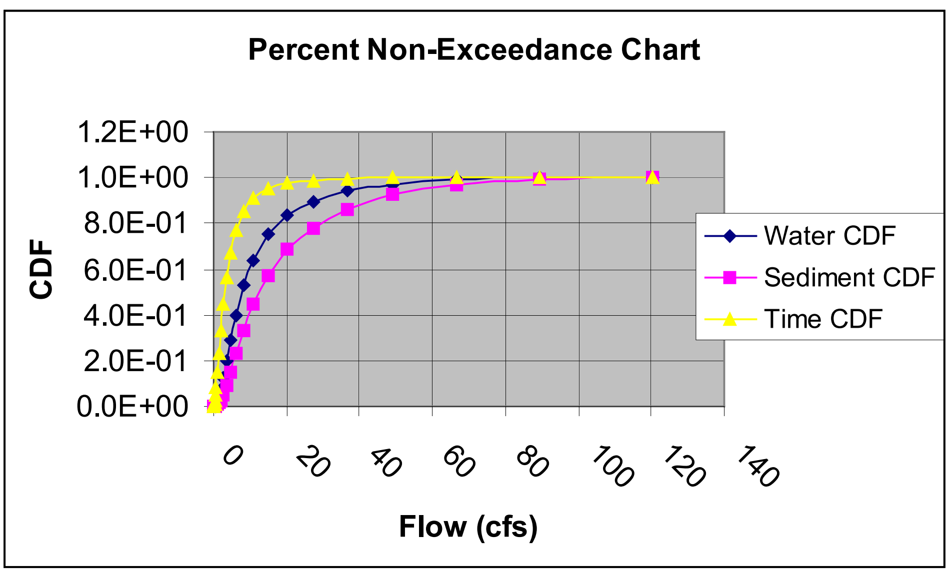

Figure 7.5 – Percent Non-Exceedance Chart**. This chart provides information about the amount of time that a given flow, corresponding to a given sediment transport rate, is exceeded in time.**

For example, Figure 7.5 demonstrates that 82% of the flow events are less than or equal to 20 cfs, and that 70% of the sediment is transported by flows $\leq$ 20 cfs. Further, 97% of the time, flows are $\leq$ 20 cfs. The Effective Discharge characteristics are presented in Figure 7.6. Figure 7.6 presents the distribution of water, the sediment transport function, as well as, the bin sediment load. As described previously, the effective discharge is defined as the flow responsible for the largest bin sediment transport. The maximum value is identified with the green data point. As described in Bin Outputs (Section 7.1.1.1), a second peak in bin sediment load is identified by a light blue data point. The probability distribution of flow is presented on the effective discharge plot.

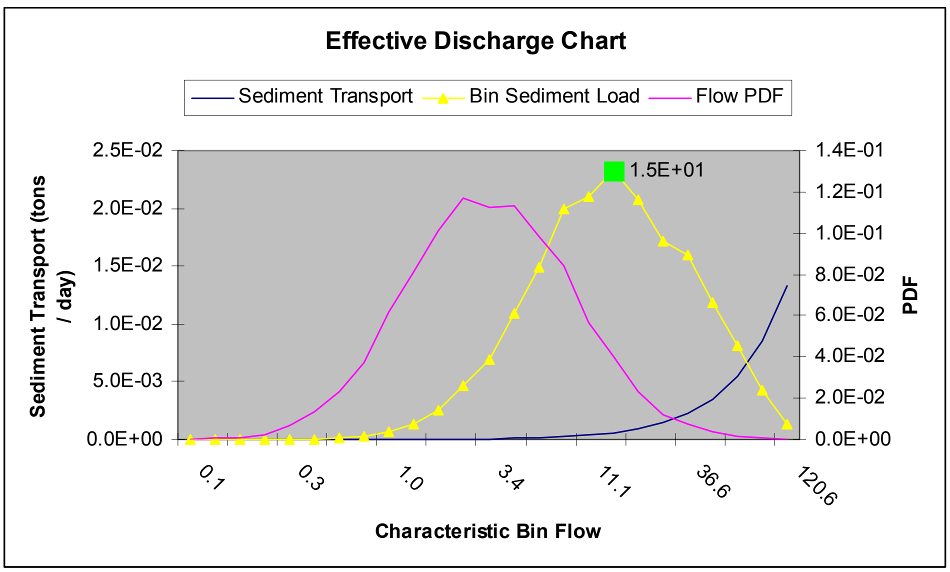

Figure 7.6 – Effective Discharge Chart **depicting the flow distribution, sediment transport function, and corresponding bin sediment load. The effective discharge is flagged as the green data point corresponding to the green highlighted row on the bin summary output (Figure 7.1).**

GeoTool outputs two charts associated with the scour/fill option. Figure 7.7(a) presents the time distribution of scour/fill depths associated with each bin. Figure 7.7(b) is the distribution of scour/fill depths associated with the effective discharge and corresponds to the values in the scour/fill table (Figure 7.2). The red line in both plots represents the theoretical maximum value of scour depth ($2d_{90}$).

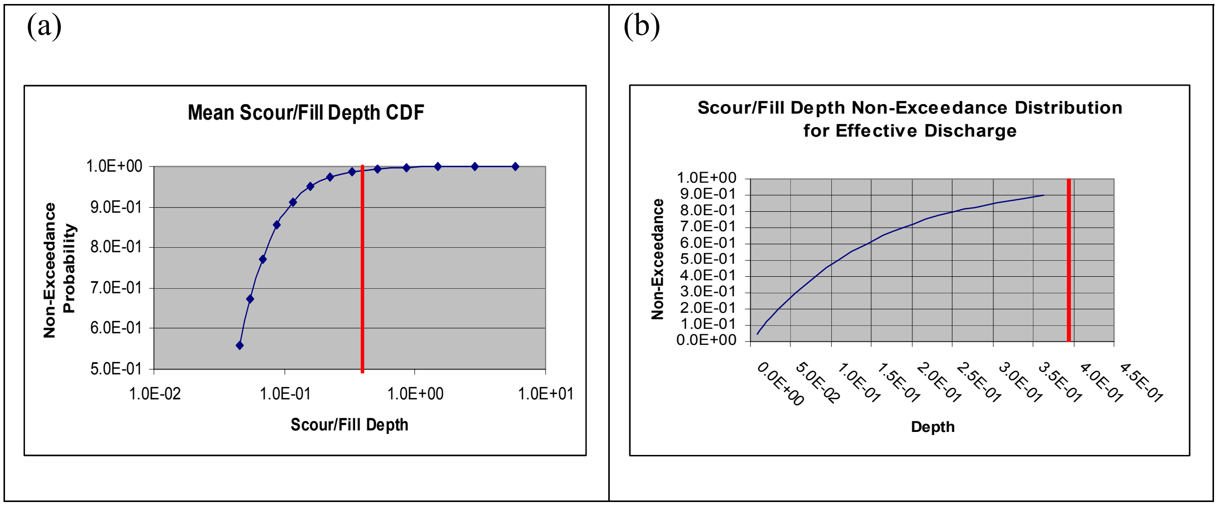

Figure 7.7 – Scour/Fill Depth Charts**: (a) The** Mean Scour/Fill Depth CDF **Chart is a plot of the time distribution of scour/fill depths associated with each bin. (b) The** Scour/Fill Depth Non-Exceedance Distribution **is a chart corresponding to the** Scour/Fill Depth Table **(Figure 7.1).**

7.1.2 Input Summary

User-specified inputs are provided in an Input Summary table (Figure 7.8). The Input Sheet summarizes the years used in the analysis, and the time interval for flow record. The Input Sheet also identifies the mode of hydraulic radius determination as well as mode of sediment transport selected, and the corresponding input variables are listed.

Input Type	Option	Option Value
All Years	Selected	
Time Interval for Discharges	Daily	
Hydraulic Radius Input	a coefficient	0.4
Hydraulic Radius Input	b coefficient	0.5
Meyer-Peter Müller Input	Slope	0.012
Meyer-Peter Müller Input	Effective Width	3.5
Meyer-Peter Müller Input	dm (mm)	30
Meyer-Peter Müller Input	Critical Shear Stress	0.047

Figure 7.8 – Sample Input Summary screen shot, lists the input used in the effective discharge calculation.

7.2 EFFECTIVE DISCHARGE FILE COMPARISON

When used to compare multiple files in the effective discharge mode, GeoTool provides output and summary sheets similar to those discussed in previous sections (Figure 7.1 to Figure 7.7). In addition, the input summary is provided as in Figure 7.8. Comparison of flow statistics and indices between flow records is presented in the Flow Regime Statistics comparison sheet (Figure 7.9).

Flow Regime Statistics	_earlyArith bin = 25	t_lateArith bin = 25	teCompArith bin = 25
Qmean annual [cfs]	5.4E+00	1.9E+01	3.2E+01
Q effective [cfs]	8.5E+00	4.4E+01	7.2E+01
Q1_5 [cfs]	5.4E+01	3.3E+02	5.4E+02
Q2 [cfs]	5.8E+01	4.0E+02	6.6E+02
Q1_5 / Qma	1.0E+01	1.7E+01	1.7E+01
Q1_5 / Q_e	6.3E+00	7.5E+00	7.5E+00
Q2 / Qma	1.1E+01	2.0E+01	2.0E+01
Q2 / Q_e	6.8E+00	9.1E+00	9.1E+00
Mean Discharge [cfs]	5.5E+00	2.0E+01	3.3E+01
Mean Discharge Exceedance Time	2.1E-01	5.6E-01	5.6E-01
CV annual maximums	3.8E-01	7.6E-01	7.6E-01
coefficient of skewness	4.8E+00	1.5E+01	1.5E+01
Sediment Transport [tons/year]	3.0E+02	1.4E+04	4.3E+04
Sum Bin Sediment Load	8.17E-01	3.86E+01	1.18E+02

Figure 7.9 – The Sample Flow Regime Statistics **comparison sheet screen shot, depicts the comparison of three different historical records.**

The user has the option of specifying whether they want comparisons made of PDFs, CDFs, both, or neither. If a comparison is desired, then discharge, sediment transport, stream power, shear stress, scour/fill depths,[*] and specific stream power[*] are all determined for comparison. An additional sheet is added to the output workbook (Figure 7.10) in which columns providing the PDF, CDF, and other values (*e.g.,* sediment transport and shear stress) are presented for each flow file. As illustrated in Figure 7.10 the effective discharge and second peak, if appropriate, are highlighted in green and blue, respectively. In addition to the tabular comparison, a chart is presented which graphically presents the variables (Figure 7.11).

[*] Only if these options are selected (Figure 5.5)

Bin Number	Sediment Transport [tons/day] / 1000	0%imp.GTLog bin = 35	Sediment Transport [tons/day] / 1000	6%imp.GTLog bin = 35	Sediment Transport [tons/day] / 1000	7%imp.GTLog bin = 35	Sediment Transport [tons/day] / 1000	0&2yr.GTLog bin = 35	Sediment Transport [tons/day] / 1000	0&BMP.GTLog bin = 35
1	0.0E+00	5.9E-07	0.0E+00	5.7E-07	0.0E+00	5.7E-07	0.0E+00	5.8E-07	0.0E+00	5.7E-07
2	0.0E+00	1.1E-05	0.0E+00	3.9E-04	0.0E+00	6.3E-04	0.0E+00	2.4E-03	0.0E+00	6.9E-05
3	0.0E+00	1.1E-05	0.0E+00	1.4E-04	0.0E+00	6.3E-04	0.0E+00	2.8E-03	0.0E+00	7.7E-05
4	0.0E+00	8.9E-06	0.0E+00	1.3E-04	0.0E+00	6.7E-04	0.0E+00	2.0E-03	0.0E+00	1.0E-04
5	0.0E+00	5.9E-06	0.0E+00	1.0E-04	0.0E+00	7.4E-04	0.0E+00	1.4E-03	0.0E+00	1.4E-04
6	0.0E+00	2.4E-06	0.0E+00	1.2E-04	0.0E+00	4.2E-04	0.0E+00	1.8E-03	0.0E+00	8.8E-05
7	0.0E+00	5.3E-06	0.0E+00	8.7E-05	0.0E+00	3.3E-04	0.0E+00	1.2E-03	0.0E+00	6.5E-05
8	0.0E+00	4.2E-06	0.0E+00	9.2E-05	0.0E+00	2.9E-04	0.0E+00	1.1E-03	0.0E+00	5.9E-05
9	0.0E+00	2.4E-06	0.0E+00	4.9E-05	0.0E+00	2.4E-04	0.0E+00	9.8E-04	0.0E+00	1.4E-04
10	0.0E+00	4.7E-06	0.0E+00	5.3E-05	0.0E+00	2.7E-04	0.0E+00	5.8E-04	0.0E+00	1.7E-04
11	0.0E+00	5.9E-06	0.0E+00	3.3E-05	0.0E+00	2.7E-04	0.0E+00	2.8E-04	0.0E+00	5.0E-05
12	0.0E+00	2.4E-06	0.0E+00	3.4E-05	0.0E+00	1.3E-04	0.0E+00	4.8E-05	0.0E+00	4.2E-05
13	0.0E+00	4.2E-06	0.0E+00	1.3E-05	5.2E-04	1.2E-04	0.0E+00	5.3E-05	0.0E+00	3.5E-05
14	1.4E-03	3.0E-06	3.0E-03	2.7E-05	6.8E-03	1.1E-04	1.0E-03	4.2E-05	1.1E-03	2.7E-05
15	8.1E-03	1.8E-06	1.1E-02	1.3E-05	1.7E-02	8.9E-05	7.4E-03	6.5E-05	7.5E-03	2.2E-05
16	1.8E-02	3.0E-06	2.3E-02	1.1E-05	3.1E-02	8.5E-05	1.7E-02	6.0E-05	1.7E-02	1.7E-05
17	3.2E-02	3.0E-06	3.7E-02	1.3E-05	4.9E-02	5.9E-05	3.0E-02	1.3E-05	3.0E-02	2.0E-05
18	4.8E-02	3.6E-06	5.5E-02	9.1E-06	7.0E-02	4.7E-05	4.6E-02	1.2E-05	4.7E-02	3.7E-05
19	6.7E-02	4.7E-06	7.7E-02	7.4E-06	9.5E-02	3.1E-05	6.5E-02	1.3E-05	6.6E-02	2.1E-05
20	9.0E-02	2.4E-06	1.0E-01	5.1E-06	1.2E-01	2.5E-05	8.7E-02	6.9E-06	8.8E-02	1.7E-05
21	1.2E-01	5.9E-07	1.3E-01	6.9E-06	1.6E-01	1.8E-05	1.1E-01	5.8E-06	1.1E-01	2.2E-05
22	1.4E-01	3.0E-06	1.6E-01	2.3E-06	1.9E-01	2.4E-05	1.4E-01	2.3E-06	1.4E-01	2.6E-05
23	1.8E-01	1.8E-06	2.0E-01	7.4E-06	2.3E-01	1.4E-05	1.7E-01	4.6E-06	1.7E-01	1.9E-05
24	2.1E-01	3.0E-06	2.4E-01	3.4E-06	2.8E-01	1.0E-05	2.1E-01	3.5E-06	2.1E-01	9.1E-06
25	2.6E-01	1.2E-06	2.8E-01	4.0E-06	3.3E-01	1.3E-05	2.5E-01	2.3E-06	2.5E-01	2.9E-06
26	3.0E-01	7.1E-06	3.3E-01	4.0E-06	3.9E-01	8.6E-06	2.9E-01	5.2E-06	3.0E-01	3.4E-06
27	3.5E-01	1.2E-06	3.9E-01	5.1E-06	4.5E-01	1.1E-05	3.4E-01	2.3E-06	3.5E-01	1.7E-06
28	4.1E-01	3.0E-06	4.5E-01	3.4E-06	5.2E-01	9.7E-06	4.0E-01	3.5E-06	4.0E-01	3.4E-06
29	4.7E-01	1.2E-06	5.1E-01	2.3E-06	6.0E-01	3.4E-06	4.6E-01	8.7E-06	4.6E-01	4.0E-06
30	5.3E-01	1.8E-06	5.9E-01	2.3E-06	6.8E-01	6.3E-06	5.2E-01	1.7E-06	5.3E-01	6.3E-06
31	6.1E-01	2.4E-06	6.7E-01	1.1E-06	7.8E-01	3.4E-06	5.9E-01	2.3E-06	6.0E-01	3.4E-06
32	6.9E-01	1.2E-06	7.5E-01	3.4E-06	8.8E-01	3.4E-06	6.7E-01	3.5E-06	6.8E-01	4.0E-06
33	7.7E-01	2.4E-06	8.5E-01	1.1E-06	9.9E-01	4.0E-06	7.6E-01	1.2E-06	7.6E-01	3.4E-06
34	8.7E-01	0.0E+00	9.5E-01	2.3E-06	1.1E+00	4.0E-06	8.5E-01	5.8E-07	8.6E-01	1.7E-06
35	9.7E-01	1.8E-06	1.1E+00	1.7E-06	1.2E+00	5.2E-06	9.5E-01	2.3E-06	9.6E-01	1.7E-06

Figure 7.10 – Sample PDF comparison of sediment transports for five files. For each file there is a column of sediment transports and a column of PDF values.

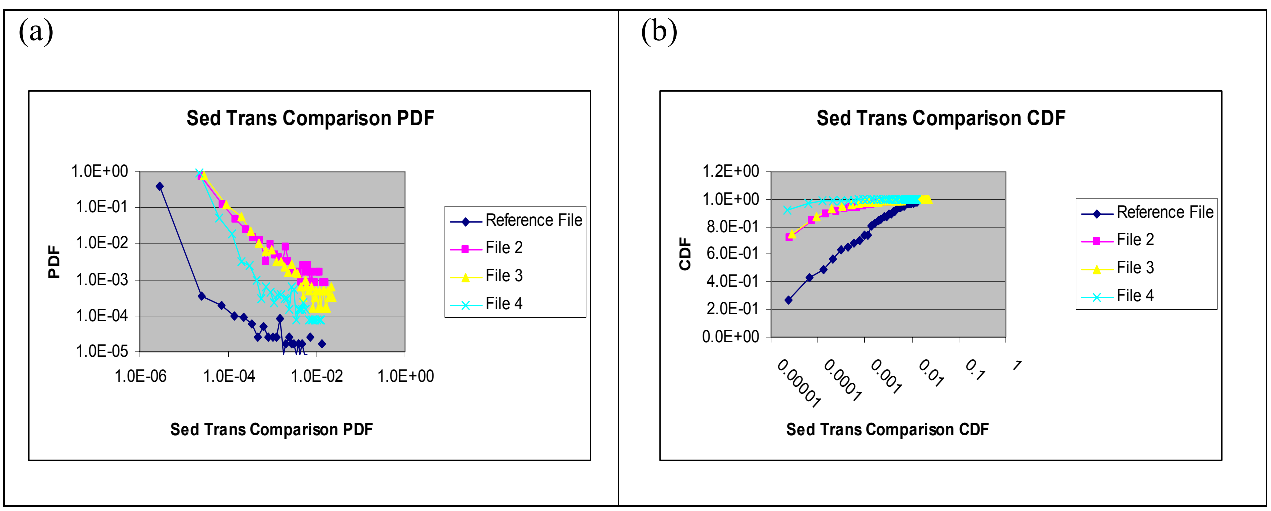

Figure 7.11 – Sample comparison sheet charts for (a) PDF comparison, and (b) CDF comparison, each for four files.

7.3 STAND ALONE SEDIMENT TRANSPORT

When running GeoTool in the Sediment Transport mode (Figure 3.1 and Figure 6.1), the output is Sediment Transport Rate and Sediment Concentration (Figure 7.12). The user can chose to Write Sediment Transport Rate to Excel? to create a new sheet within a new Excel book that the user can save.

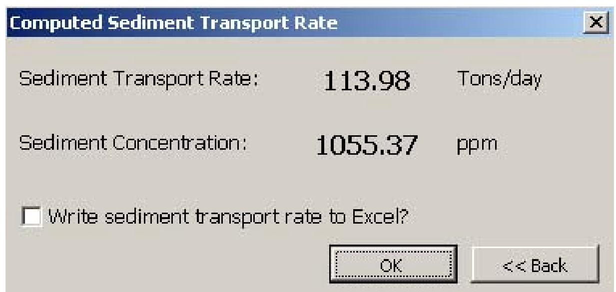

Figure 7.12 – Computed Sediment Transport Rate **menu screen shot. Output format when using the** Sediment Transport (Stand Alone) **module.**

7.4 STAND ALONE CHANNEL CHANGE INDICES

If GeoTool is run in Channel Change mode, then the output is a new worksheet within a new Excel workbook. The new sheet contains up to three tables and one chart, depending on the number of channel change indices selected. The tables list the input parameters, the channel change outputs, and a scour/fill depth non-exceedance table; the chart is a plot of the non-exceedance table (Figure 7.13). The Mobility Index, Specific Stream Power, Bed Stability Indicator, and mean Scour/fill Depth are determined as within the effective discharge mode (Equation (7.9) through (7.12), respectively). The scour/fill depth table is similar to the scour/fill depth table under the effective discharge output (Figure 7.2) and the chart is similar to Figure 7.7(b).

INPUT PARAMETERS		
Characteristic Discharge	(cfs)	40
Slope	(ft/ft)	0.001
d50	(mm)	0.5
Flow Area	(ft*ft)	10
Wetted Perimeter	(ft)	9
Specific Weight Water	(lb/ft^3)	165
Width	(ft)	5
d84	(mm)	1
d90	(mm)	2
Specific Weight Sediment	(lb/ft^3)	1650

CHANNEL CHANGE OUTPUTS		
Specific Stream Power	1.32	(lb/ft*s)
Bed Stability Indicator	18.68	(lb/ft^2)/(lb/ft^2)
Mobility Index	0.01	(ft/s$^{1.5}$)
Scour/Fill Depth	0.13	ft

Depth (ft)	Non-Exceedance Probability
2.9E-01	0.9
2.0E-01	0.8
1.5E-01	0.7
1.1E-01	0.6
8.7E-02	0.5
6.4E-02	0.4
4.5E-02	0.3
2.8E-02	0.2
1.3E-02	0.1
6.4E-03	0.05

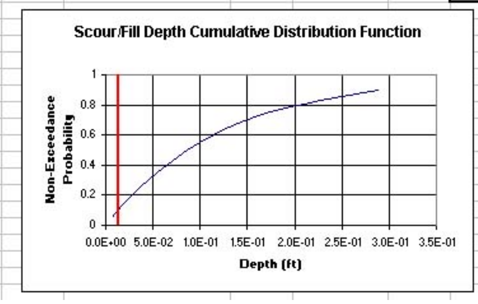

Figure 7.13 – Channel Change Indices **output sheet screen shot. Output sheet generated when using the stand alone** Channel Change **module.**

CHAPTER 8
PARTIAL FREQUENCY ANALYSIS

Flood recurrence intervals are based on user-defined empirical distribution functions (EDFs). The EDF is based in turn on a plotting position characterization of the flow data. The user must define the characteristics of a discrete event as well as the parameters used within the EDF. The plotting position is a measure of the historical relative exceedance frequencies of events; the inverse of the plotting position is a measure of the non-exceedance frequency. The partial frequency analysis theoretically gives a better estimate of events of recurrence intervals less than 10 years than does the exceedance/non-exceedance probabilities associated with the annual maximum series. This is because events that may not be an annual maximum in one year but would be in another are ignored in the annual maximum series but are considered in the Partial Frequency Analysis.

8.1 PARTIAL FREQUENCY INPUTS

The input for the Partial Frequency Analysis menu (Figure 8.1) is a stream flow record in any of the formats described previously (Chapter 4). The time properties of the input file must be specified. As mentioned above, the user must define the characteristics of a discrete event; specifically the minimum discharge to consider and optionally an inter-event duration. The minimum discharge to consider is treated as a strict censoring border below which any discharge cannot be considered a flood. An inter-event duration is a period over which only one discharge will be considered a discrete event specifying an inter-event duration prevents multiple peaks in the same event from being considered as two different events. The user must also specify the plotting position function used to calculate the relative exceedance frequencies of events.

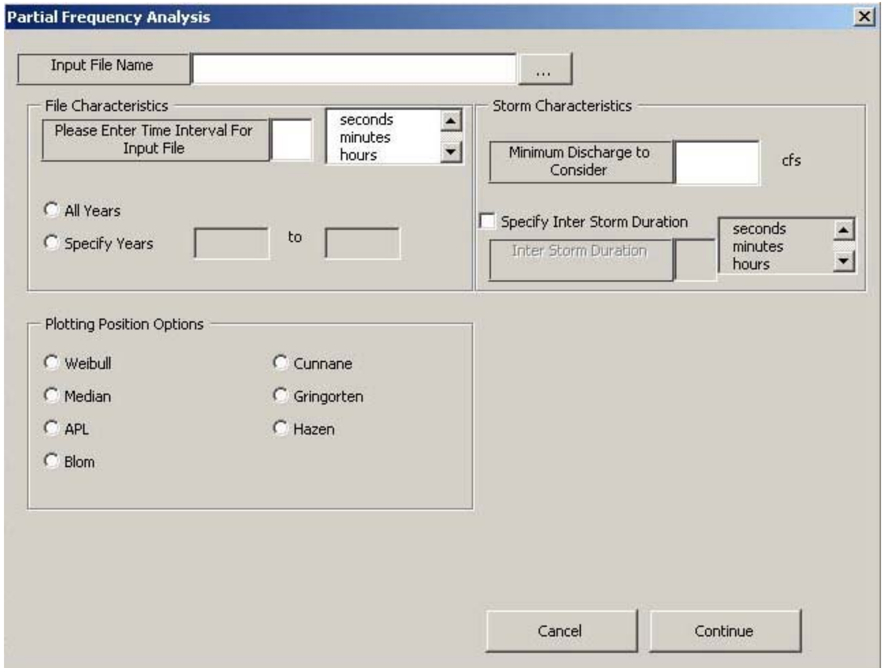

Figure 8.1 – Partial Frequency Analysis **menu screen shot, where the user specifies the necessary input arguments for computing empirical distributions and return periods of elements within a hydrologic time series.**

The recurrence interval for events is based of an EDF. The flow data are ordered from greatest to smallest and each flood is then assigned a plotting position. The general plotting position formula is described by:

$$PP(i) = \frac{(i - \alpha)}{N + \beta - 2\alpha} \quad . \tag{8.1}$$

Many various alterations of the α and β parameters have been developed in the literature corresponding to assumptions about the underlying distribution of the floods. A good description of the various plotting positions is provided by Salas *et al*. (2000):

> "Various plotting position formulas have been suggested in the literature. Two commonly used formulas are *i/N* and *i/(N+1)*. Cunnane (1978) compared various plotting positions and suggested a general plotting position formula [after some slight modification] which will give unbiased quantile estimates….. when β = 1, α =

0 for a uniform distribution, " = 3/8 for a normal distribution, and " = 0.44 for the Gumbel distribution…"

The plotting position formulas included in GeoTool are listed in Table 8.1.

Table 8.1 – Plotting function choices for use in partial flood duration analyses. The user has a choice of seven plotting position formulas.

Weibull (1939)	$\frac{i}{N+1}$
Median	$\frac{i-0.3175}{N+0.365}$
APL	$\frac{i-0.35}{N}$
Blom (1958)	$\frac{i-3/8}{N+1/4}$
Cunnane (1978)	$\frac{i-0.4}{N+0.2}$
Gringorten (1963)	$\frac{i-0.44}{N+0.12}$
Hazen (1914)	$\frac{i-0.5}{N}$

It is noted here that regardless of the plotting position formula chosen, the same flood will always come from the same quantile of the population of floods (Klemeš 2000a). Additionally, Klemeš (2000a,b) notes that plotting position formulas can under and/or over estimate a flood's position by a number of quantiles, a function of the sample size, and assumptions of sample independence. Caution is therefore recommended when using this information to make assumptions about the underlying distribution of the data and making extrapolations from historical data to events of rare occurrence.

8.2 PARTIAL FREQUENCY OUTPUT

8.2.1 Partial Frequency Tabular Output

The tabular output produced by the Partial Frequency Analysis module (Figure 8.2) is two columns of sorted flow rates from least to greatest in column ("B") and the number of exceedances per year in column ("A"). The number of exceedances per year is assumed equal to the plotting position as calculated above. The inverse of the plotting position or the inverse of the number of exceedances per year is interpreted as the probability of observing an event of equal or larger magnitude in any one particular year.

Number of Exceedances Per Year	Flowrate (cfs)
1.21	49.02
1.17	49.78
1.14	50.63
1.10	50.76
1.07	50.86
1.03	51.09
.	.
.	.
.	.
0.21	82.27
0.17	86.76
0.14	95.95
0.10	102.26
0.07	103.25
0.03	139.99

Figure 8.2 – Sample tabular output for Partial Frequency Analysis **module. This output lists the number of exceedances of a specific (or greater) value in any one year.**

Because the Partial Frequency Analysis module uses an Excel worksheet to output the table of events, it is possible that there are more events than rows within a worksheet. This number is approximately 65,000; omissions will occur if the number of events exceeds the number of rows.

8.2.2 Partial Frequency Graphical Output

The graphical output associated with the partial frequency analysis module is a chart of discharge versus number of exceedances per year (Figure 8.3). The data for the graph is taken from the partial frequency analysis output table (Figure 8.2).

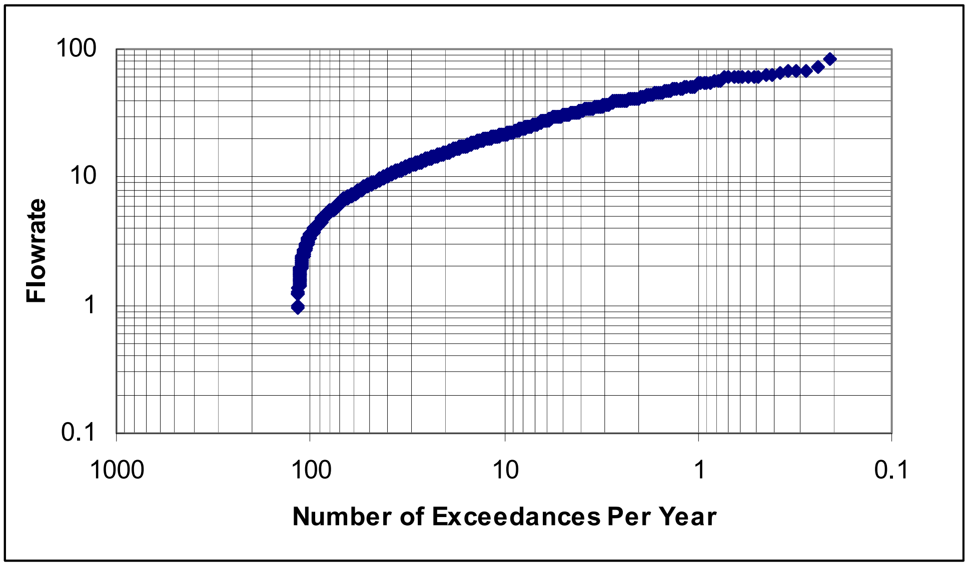

Figure 8.3 – Sample graphical output for the Partial Frequency Analysis **module depicting the data listed in Figure 8.2.**

CHAPTER 9
DISTURBANCE REGIME

9.1 DISTURBANCE REGIME INPUT

The input for the disturbance regime module is a stream flow record in any of the formats described previously (Chapter 4). The time properties of the input file must be specified. The user must also specify the attributes pertaining to incipient motion, namely the slope of the channel, the dimensionless critical shear stress for incipient motion, a characteristic grain size, specific weight of the water, and the specific weight of the sediment. Default options are provided for the specific weights of the water and sediment (Figure 9.1).

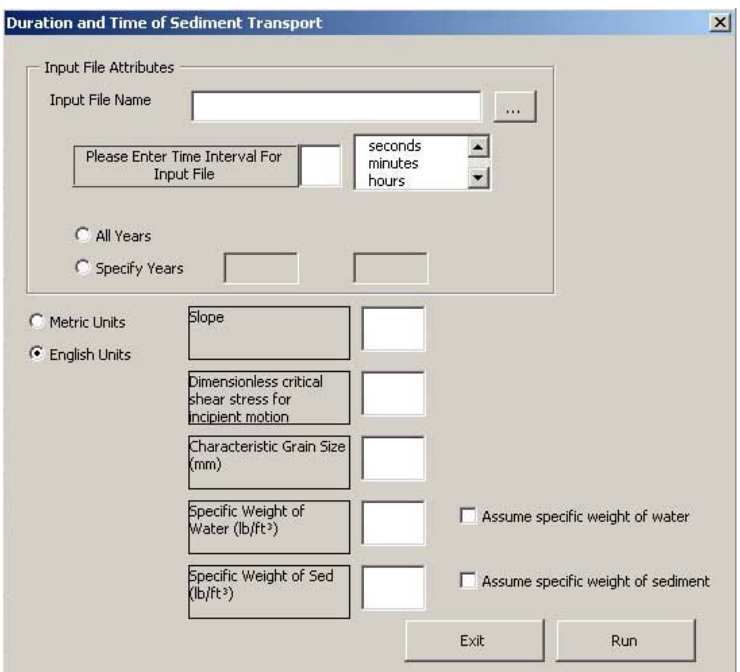

Figure 9.1 – Duration and Time of Sediment Transport **menu screen shot, where the user specifies the necessary input arguments to calculate threshold for, the number of, and durations of sediment transport within a hydrologic time series.**

9.2 DISTURBANCE REGIME OUTPUT

9.2.1 Disturbance Regime Tabular Output

The tabular output (Figure 9.2) produced by the disturbance regime output consists of (a) the threshold for sediment transport; (b) the total duration of time that the threshold for incipient motion was exceeded in the input file; (c) the number of discrete times that the threshold for incipient motion was crossed; and (d) the average length of time that once the threshold for incipient motion was exceeded that sediment stayed in motion. It is assumed by GeoTool that if there are missing records within the input file that the missing time periods had the same sediment transport as the time period immediately preceding the missing records.

Number of Discrete Times Exceeding Incipient Motion	2172			
Total Duration Incipient Motion Exceeded	586483200	**seconds =**	6788	**days**
Average Length of Event Exceeding Incipient Motion	270019.89	**seconds =**	3.13	**days**
Coefficient of Variation of Events Exceeding Incipient Motion	0.82	**seconds =**	0	**days**
Flow Necessary for Incipient Motion		**cfs**	2.11	

Figure 9.2 – Sample tabular Disturbance Regime **output screen shot containing the values associated with incipient motion and the numbers and durations of times that incipient motion was exceeded in the input time series.**

9.2.2 Disturbance Regime Graphical Output

A chart is also provided showing the discharge time series provided by the user's input file along with the threshold for sediment transport (Figure 9.3). It is possible for the user to alter the scale of the chart in order to examine more specific aspects of transport regime (*e.g.,* seasonality).

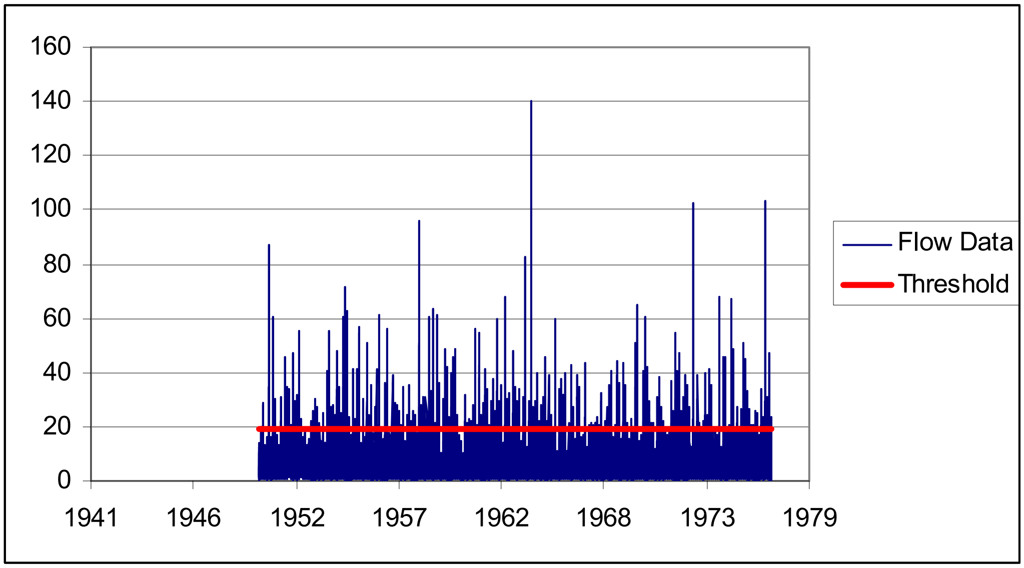

Figure 9.3 – Sample graphical output for Disturbance Regime **module. The abscissa represents time (years) and the ordinates are discharge values (ft^3/s).**

CHAPTER 10
COMMON ERRORS

The most frequent GeoTool error reported to date, is a missing add-in or reference library in the user's Visual Basic for Application installation. The following files are necessary for proper GeoTool execution:

(1) Visual Basic For Applications,

(2) Microsoft® Excel 9.0 Object Library,

(3) OLE Automation,

(4) Microsoft® Office 9.0 Object Library,

(5) Microsoft® Forms 2.0 Object Library, and

(6) Solver.

The Analysis ToolPack, Analysis Toolpack-VBA, and Solver Add-Ins should be installed under the Excel → Tools → Add-Ins tool bar. Additional errors may be generated during code execution if all available service packs from Microsoft® have not been installed for the user's version of Excel.

These files should be checked in the Visual Basic for Applications editor under the "Tools/References" menu. If any of these files are listed as "MISSING" it will cause a run-time error in GeoTool. **To fix this error uncheck the "MISSING" and try to install the missing reference.**

There are a number of variations on SWMM programs as well as HSPF programs and, therefore, there will be circumstances for which an input file may generate an error in GeoTool. The input conditions for these types of files are very specific to a format expected. In this event, please contact David Raff at raff@daraff.net with specific information about the version of the program used to generate the input file and send this information along with the input file to the e-mail address above. Another option is to convert your SWMM or HSPF file into a GeoTool default file.

In the event that an error occurs during operation of GeoTool and it is not addressed within this user's manual, please contact David Raff at raff@daraff.net or Brian Bledsoe at Brian.Bledsoe@ColoState.edu. Please include as much information as possible in your message in addition to the "log.out" file, which GeoTool creates in your base directory. For Windows users, the base directory is most likely your "My Documents" folder unless you have changed the default settings.

CHAPTER 11

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