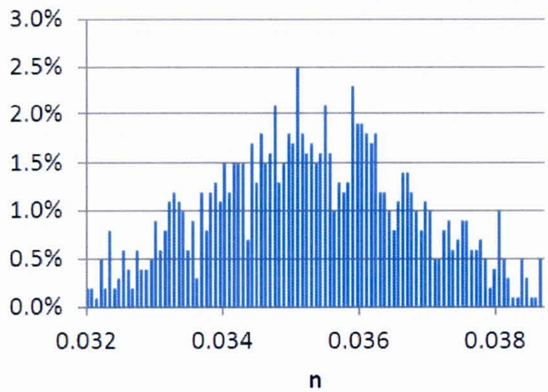
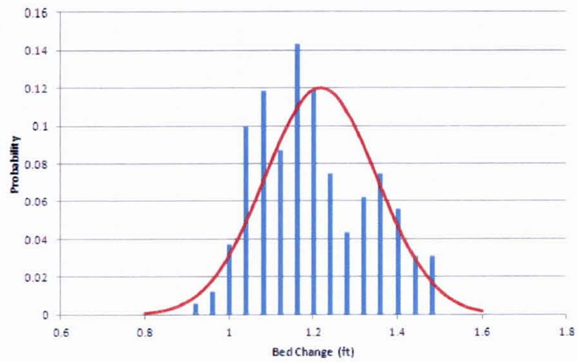
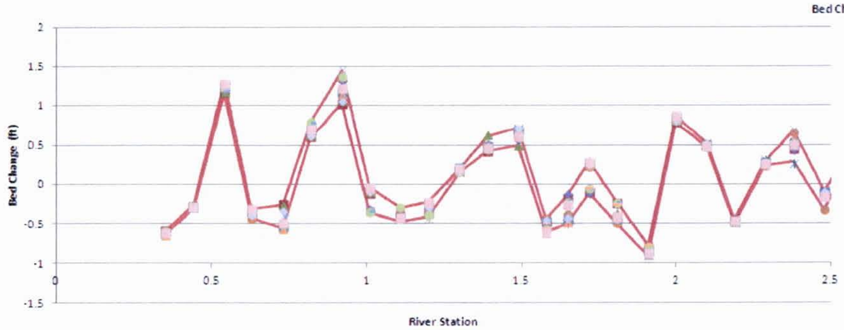
MCSed
Probabilistic Simulation of Sediment Transport using Monte Carlo Method

Version 1.0







April 11, 2013

By WEST Consultants, Inc.

Table of Contents

I. Introduction

MCSed is a Microsoft Excel spreadsheet program that repeatedly runs HEC-6T sediment transport models under a Monte Carlo Method simulation for probabilistic evaluation of output. The convenient Graphical User Interface (GUI) allows for easy entry and editing of data and viewing of results. MCSed is programmed using Visual Basic for Applications (VBA), which is an event driven programming language embedded in many Microsoft Office applications, including Excel. The convenience of VBA is its inherent companionship with Excel, allowing the programmer to make use of the already functional spreadsheet and graphing capabilities. VBA is the programming language used when creating Macros in Microsoft Office applications.

MCSed was developed by WEST Consultants for the Flood Control District of Maricopa County under Contract 2010C027 Assignment #11. The objective of MCSed is to allow water resources engineers at Maricopa County to evaluate sedimentation in rivers and streams under a probabilistic scenario, allowing for risk-based evaluations of alternatives. This project effort was directed by Dr. Bing Zhao with technical guidance and quality control provided by Dr. J. Rafael Pacheco of the Flood Control District of Maricopa County. Dr. Brian Wahlin of WEST Consultants managed the development of MCSED. Dr. Brent Travis and Mr. Chris Goodell of WEST Consultants worked on the research, development, and documentation of MCSed.

II. Requirements

To use MCSed, the user must have a licensed copy of Microsoft Excel, Version 2007 or later, and a licensed copy of HEC-6T Version 4.00.00, Modification 5.13.19. It is possible that other versions and/or modifications of HEC-6T will work, however no other versions or modifications were tested with MCSed. MCSed will run on any Windows-based operating system that can run Microsoft Excel 2007.

III. Opening MCSed

To open MCSed, simply double-click the MCSed icon, wherever it is stored on your computer. Alternatively, you can open Microsoft Excel, then from the Office Button, select Open and navigate to the MCSed.xlsm file. Depending on your security settings, you may receive a Security Warning when opening MCSed. By default, under certain security settings, Microsoft will automatically disable Macros. If you receive the Security Warning when opening MCSed, click on the Options… button, then select "Enable this content". Press OK and MCSed will be fully operational.

Personal settings for enabling macros can be defined in the Trust Center in Microsoft Excel. To access the Trust Center, go to the Office Button, then select Excel Options. Then select the Trust Center link on the left side bar, followed by the Trust Center Settings… button. For highest security and prevention against computer viruses, it is suggested that the default levels for Macro Settings be maintained.

IV. Theory

Monte Carlo Method Introduction

The Monte Carlo Method (MCM) is a method for determining solution outcomes where inputs have a high degree of uncertainty. Instead of providing a deterministic result, probabilities of results are obtained through a repeated re-computation of a given model, with its uncertain inputs randomly selected over a specified statistical distribution. Each of these computations is called a "realization". This approach applied to sediment transport modeling is relatively new in practice, but the applications are profound, particularly when risk-based decisions are required.

Until recently, using MCM for most hydrodynamic and sediment transport applications has been difficult, due to the lack of computing power afforded the typical "desktop" engineer. To achieve statistically valid results, a MCM simulation might require thousands, perhaps even hundreds of thousands of repeated realizations to arrive at a desired statistical accuracy (Goodell, 2012). The true required number of realizations for a sediment transport model is highly variable, and largely dependent on the number of uncertain inputs and their respective correlations. In practice, it is generally acceptable to determine the number of required realizations by continually running more and more realizations until the statistical distribution of the selected output value does not change, within a reasonable tolerance. This tolerance is usually determined by an accepted level of accuracy compared against a reasonable amount of computation time. For example, if the desired level of accuracy is +-1%, but achieving that level of accuracy requires a month of computations, but +- 5% requires 2 days of computations, one might be more willing to accept 5% of error. The first three moments of a normal distribution (mean, standard deviation, and skew) are convenient metrics by which to gage the statistical accuracy provided by a given number of realizations.

MCM works by running repeated realizations. The "Coin-flip" demonstration provides a useful analog to the concept of MCM. For example, if you were to flip a coin 10 times, you would expect to have about 50% heads results and 50% tails results, but it wouldn't be unusual if 7 heads and 3 tails happened. In that case, 70% were heads and 30% were tails. However, the more coin flips you make, the more you will approach 50% heads and 50% tails for your results. Theoretically, an infinite number of coin flips would result in exactly 50% heads and 50% tails.

In MCSed, MCM is applied by re-running the HEC-6T input file (called a "T5" file, because of its file extension *.t5). Prior to each realization, the T5 file is rewritten. Four selected uncertain input parameters, Manning's n values, particle size, streamflow, and sediment load are all adjusted randomly over a pre-prescribed statistical distribution, selected and defined by the user. After each HEC-6T run, the output file (called a "T6" file, because of its file extension *.t6) is read and selected output is retrieved and assembled for statistical analysis. The selected output values are sorted and ranked. The "x" percent non-exceedance probability (NEP) output is then simply the "x" percentile of the sorted and ranked output values.

HEC-6T Input Sampling

HEC-6T is a proprietary and currently maintained version of the original US Army Corps of Engineers program HEC-6, "Scour and Deposition in Rivers and Reservoirs." The software is developed and sold by Mobile Boundary Hydraulics, LLC in Clinton, Mississippi. While HEC-6T and HEC-6 input files are very similar, there are some distinct differences that will not allow HEC-6 to be used within MCSed (Appendix A lists some of the more common differences between HEC-6 and HEC-6T input files).

An HEC-6T input file is an ASCII text file organized by rows of records (sometimes referred to as "Cards"), each with up to ten fields of data. Each field consists of 8 character spaces for entering data. There are records that define the geometry and channel properties, records for sediment data, records for hydrology data, and records for controlling runtime options and output. There are numerous records available to code in a T5 file, but only a select few are adjusted in MCSed. The following paragraphs discuss the uncertain inputs that are considered for MCSed and the corresponding HEC6T records that are rewritten by MCSed. All of the required and optional records used in HEC-6T are discussed in detail in the HEC-6T User's Manual.

Manning's n Values

In MCSed, every Manning's n-value in the T5 file is independently resampled based on the distribution parameters provided by the user. This assumes that errors associated with estimation of one n-value have no relationship to errors associated with the estimation of other n-values. In reality n-values are typically applied for reaches of common roughness characteristics that may span multiple cross sections. It is probable that if the modeler overestimates the n-value for the main channel in a given reach, then that same overestimation will apply to every cross section that was assigned the same n-value within the designated reach of common roughness. In that case, there is correlation between the estimation of n-values over multiple cross sections. However, MCSed does not allow for this. Each n-value is sampled and resampled independently of the others for each realization.

There are four records that can be used in an HEC-6T model to specify n values: NC, ND, NM, and NV. The NM record, which allows the user to determine the n values using Cowan's method, is not used in MCSed. The NM record can be used in the T5 file, but it won't be rewritten with randomly sampled values.

The NC record is the simplest method for specifying n-values in a T5 file. Fields 1, 2, and 3 are used to specify the left overbank n-value, right overbank n-value, and main channel n-value, respectively. Fields 1, 2, and 3 are rewritten with randomly sampled n-values for each realization.

The ND record allows the user to vary n-values by depth. Fields 2, 4, 6, 8, and 10 are reserved for n-values, while fields 3, 5, 7, and 9 are reserved for the companion depths. Together, these values make up a paired data set that define the relationship between depth and Manning's n-value. If a 5^{th} pair is required, Field 1 of a second ND record can be used to define the depth associated with the 5^{th} n-value. Fields 2, 4, 6, 8, and 10 are rewritten with randomly sampled n-values for each realization.

The NV record allows the user to vary n-values by elevation or discharge. This record works the same way as an ND record, only Fields 3, 5, 7, and 9 contain an elevation or discharge, not a depth. If elevation is used, the Manning's n-values in Fields 2, 4, 6, 8, and 10 are entered as positive (+) values (do not actually use the + sign). If discharge is used, then the Manning's n-values are entered as negative (-) values. Fields 2, 4, 6, 8, and 10 are rewritten with randomly sampled n-values for each realization.

Particle Size

In HEC-6T, particle diameters are entered into the T5 file as gradation curves. Paired data consisting of particle diameters and corresponding percent finer values make up the gradation curve. With MCSed, every gradation curve in the T5 file is independently resampled based on the distribution parameters provided by the user. This assumes that errors associated with estimation of one gradation curve have no relationship to errors associated with the estimation of other gradation curve. Within a given gradation curve, there can be multiple particle diameters and their associated percent finer values. Each of these particle diameters in a given gradation curve will be re-sampled based on the same initial random number seed. The result will be a gradation curve that maintains its shape (distribution) but shifts right or left depending on the randomly computed seed number. For a given realization, one gradation curve may shift left, while another may shift right. Each gradation curve has its own random number seed, so the gradation curves will be resampled independently of each other, but within one gradation curve, each particle size will shift by the same amount. Figure 1 demonstrates how a gradation curve can shift depending on the random number assigned to that curve.

Particle sizes and the gradation curves they are assigned to are coded in the PF and PFC records of a T5 file. The PF record prescribes the gradation of the bed sediment reservoir as values of "percent finer". That is, a given particle diameter will have a corresponding percent finer value that indicates the percentage of sediment in the sample that is finer, by weight, than that diameter. Field 2 of the PF record specifies the cross section ID where this gradation sample will be applied to. Field 3 indicates the fraction of the bed surface that is exposed to erosion. Field 4 indicates the maximum particle size diameter in the sample (D_{100}, or D_{max}). Fields 5, 7, and 9 of the PF record contain particle diameters (in decreasing order, large to small) while Fields 6, 8, and 10 contain percent finer values. Up to three PFC records can be used to continue defining a given gradation curve (Fields 1,3,5,7, and 9 for particle diameters, Fields 2,4,6,8, and 10 for percent finers), which allow for a total of 20 points to define any one gradation curve. Fields 5, 7, and 9 in the PF record and Fields 1, 3, 5, 7, and 9 in the PFC record are resampled for each realization.

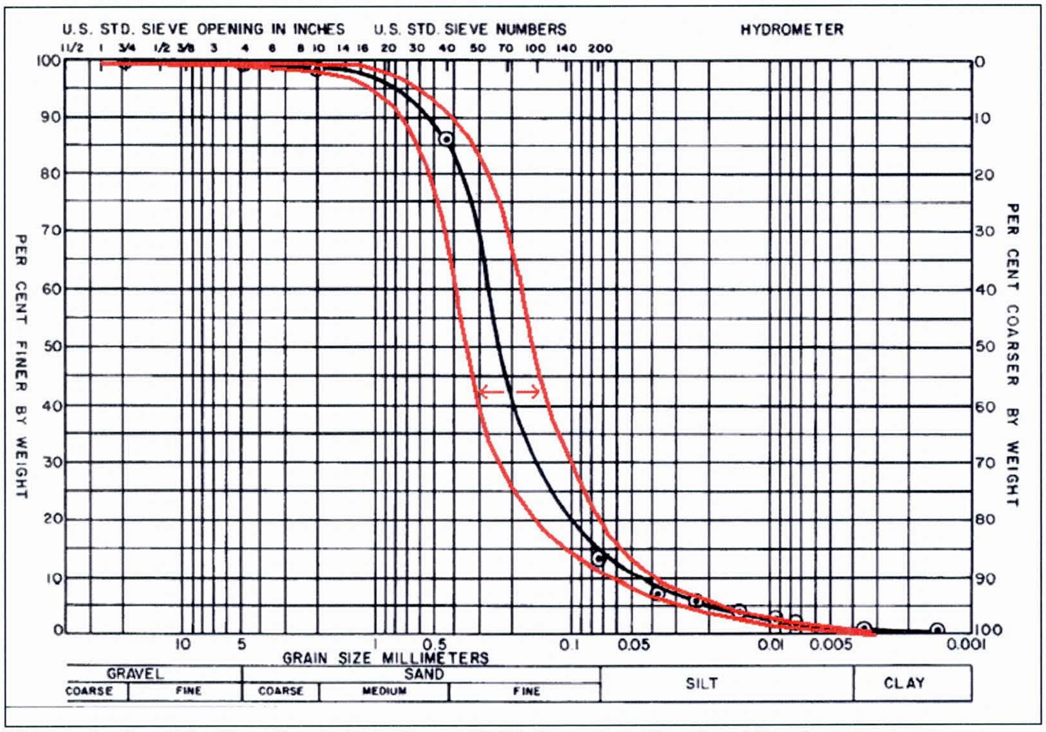


Figure 1. Particle Size Gradation Curve Shift, based on Random Number.

Streamflow Values

Streamflow values are coded into HEC-6T on the Q record. Each Q record can have up to ten inflow discharges. Q records are generally grouped together in blocks of records, each block containing a *, Q, T, and an X record. Together, these records define the hydrology for a single time step of an HEC-6T simulation. The X record specifies the duration of the timestep. With MCSed, every block of hydrologic data (i.e. timestep) in the T5 file is independently resampled based on the streamflow distribution parameters provided by the user. This assumes that errors associated with estimation of one hydrologic inflow set has no relationship to errors associated with the estimation of another hydrologic inflow set. Within a given timestep, there can be multiple inflow values at various locations in the reach/river. Each timestep will receive its own random number seed. This will allow flow records in different timesteps to have different deviations from expected. In other words, one timestep may be shifted up by 10%, another one may shift down by 8%. There is no correlation between the approximation of streamflow from one timestep to the next. However, within one timestep, the shift (upward or downward) will be constant for each inflow in the Q record.

Fields 1 through 10 all can have streamflow values. Field 1 always represents the downstream-most inflow point. The last field with a numeric value contains the inflow at the upstream end of the reach. All discharges (Fields 1 through 10), whether they are local lateral inflows, or upstream boundary inflows are rewritten with randomly sampled streamflow values for each realization.

Sediment Inflow Values

Sediment inflow values are found on the LT and LT" records in the T5 file. LT for the upstream sediment inflows, and LTL for the lateral sediment inflows. Sediment inflows (loads) are added to the model as a relationship to streamflow (a sediment rating curve). Generally speaking, as streamflow increases, sediment load at the same location increases. However, the LT and LTL records only define the rating curve. The sediment loads are then computed for each timestep based on the streamflow inputs and the established rating curve. So by adjusting the sediment load records in the T5 file based on random numbers transformed over the selected distribution, it is the sediment rating curve that is actually being adjusted. This is convenient because although there is a correlation between sediment inflow and water inflow at a given inflow point, there is no correlation between the sediment inflow/water inflow relationship and water inflow. In other words, it is certainly possible for the rating curve to shift upwards or downwards, regardless of what the inflow is doing.

In MCSed, each sediment rating curve will receive its own random number seed. This will allow sediment inflow records in different sediment rating curves to have different deviations from expected. In other words, one sediment rating curve at one location may be shifted up by 10%, another one at a different location may shift down by 8%. There is no correlation between the approximations of the sediment inflow/water inflow relationship from one sediment rating curve to the next. However, within one sediment rating curve, the shift (upward or downward) will be constant for each sediment inflow in the LT or LTL record.

Each sediment load requires LQ, LT, and LF records at a minimum. The LQ records lists the discharges on the sediment rating curve table, and LT lists out the corresponding sediment loads. The LF records provide gradation curves for each load point on the sediment rating curve table. For lateral inflows, LQL, LTL, and LFL records are used and work the same way as the LQ, LT, and LF records do. LC and LCL records can be used in place of LT records to define inflowing loads by parts per million (ppm), however, MCSed does not rewrite LC or LCL records. LT\LTL must be used with MCSed.

Only LT/LTL records are rewritten with randomly sampled sediment inflow values. Fields 2 through 10 all can have sediment load values. All sediment loads (Fields 2 through 10), whether they are local lateral sediment inflows, or upstream boundary sediment inflows are rewritten with randomly sampled sediment inflow values for each realization.

Distributions

The current version of MCSed provides three options for defining distributions of the uncertain input parameters: Uniform, Triangular, and Lognormal. Manning's n-values, Streamflow, and Sediment inflow all allow either Triangular or Lognormal distributions. Particle size allows Uniform and Triangular distributions. MCSed is coded to allow for easy addition of statistical distributions, if required for future versions. Travis (2012) describes a literature search, investigation, and recommended parameter distributions for uncertainty modeling simulations. The recommendations presented in Travis (2012) along with direction provided by the Flood Control District of Maricopa County form the basis for the selection of the current lineup of available distributions offered in MCSed.

Uniform Distribution

The Uniform Distribution is only available for particle diameter inputs in MCSed. Rather than the User explicitly specifying the upper and lower bounds of the uniform distribution, MCSed uses a modified version of Pinto's procedure (Pinto et al. 2006). The lower bound particle size a, and upper bound particle size, b are determined by:

$$a = D\left(1 - c\sqrt{3}\right) \qquad b = D\left(1 + c\sqrt{3}\right)$$

Where:

D = expected particle diameter

c = spatial variability coefficient.

Pinto's original procedure defines the "c" value as follows:

$$c = \begin{cases} 0.4, \ D_{50} \le 0.6 \text{ mm} \\ 0.2, \ D_{50} > 0.6 \text{ mm} \end{cases}$$

This works fine when dealing with a single grain size, however, if a gradation is used, a discontinuity in the relationship between D50 and the upper and lower bound particle sizes around the threshold c value of 0.6 mm, as shown in Figure 2.

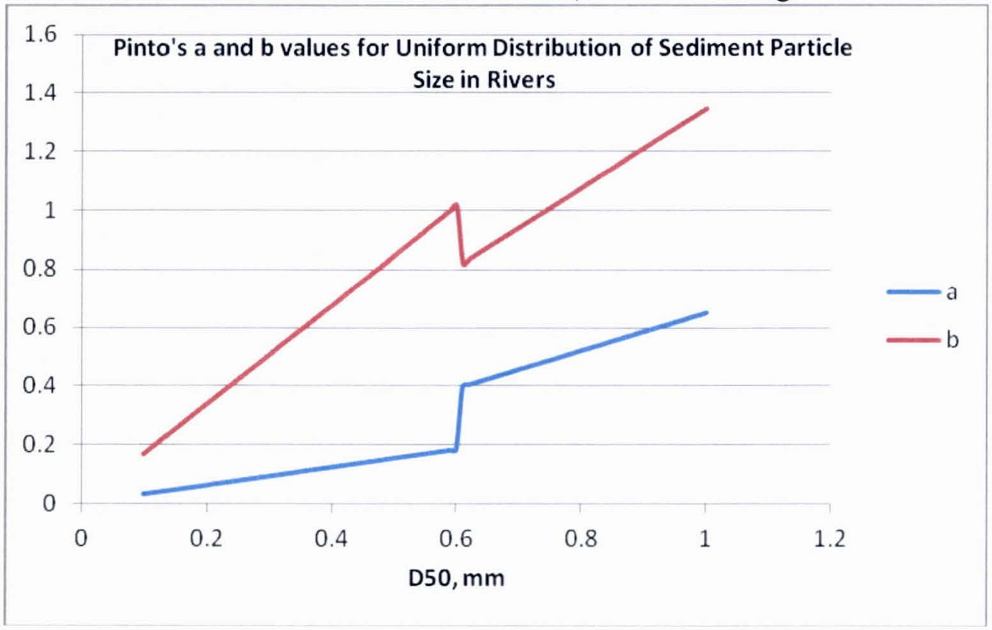


Figure 2. Pinto's a and b values.

To smooth out the relationships, MCSed uses a transition equation for particle sizes between 0.5 mm and 0.7 mm as follows:

$$c = 0.4 - \left(\frac{D50 - 0.5}{0.7 - 0.5}\right)(0.4 - 0.2)$$

Figure 3 demonstrates a much smoother transition through 0.6 mm, using the modified Pinto method.

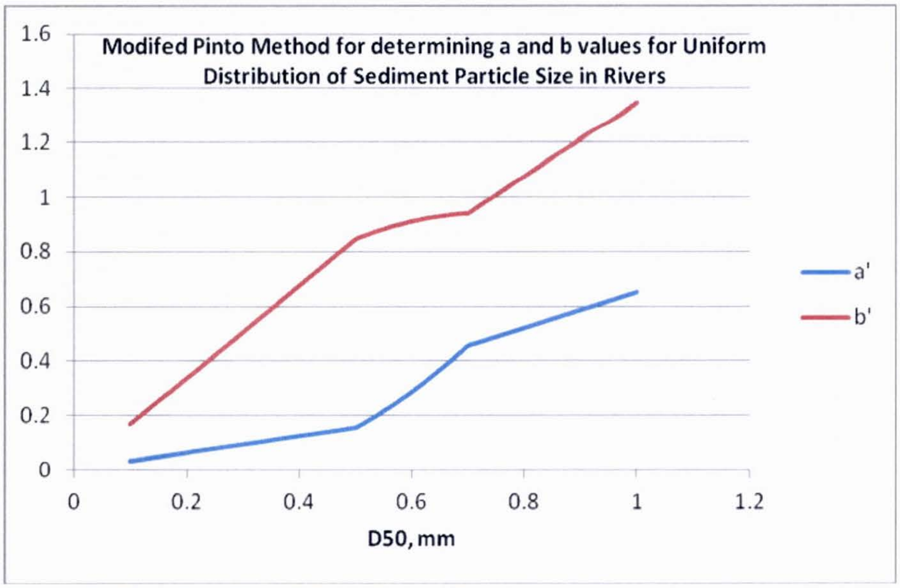


Figure 3. Modified Pinto Method a and b values.

The probability density function for the Uniform Distribution is:

$$f(x) = \frac{1}{b-a}, a \leq x \leq b$$

Where:

a = lower bound value
b = upper bound value

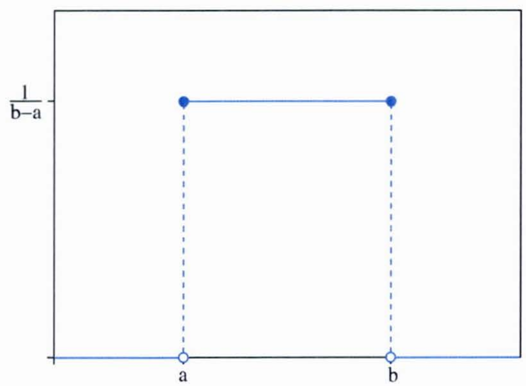


Figure 4. Probability Density Function for Uniform Distribution (Wikipedia).

Triangular Distribution

The triangular distribution is available for all four of the uncertain inputs. The advantage of the triangular distribution is its ease of use. An upper and lower bound are defined by the user by inputting a Minimum Factor and a Maximum Factor. The factors are multiplied by the expected value found in the original T5 file to define the upper and lower bounds of the distribution. For example, a user enters a Minimum Factor of 0.9 and a Maximum Factor of 1.1 for Manning's n values. If MCSed finds an n value of 0.035 in an NV record of the original T5 file, the lower bound for sampling about a triangular distribution becomes (0.9*0.035) = 0.0315. The upper bound becomes 0.0385. The triangular distribution also requires an input value for the mode, which defines the most probable outcome (i.e. the "peak" of the triangle). The mode is simply set to the respective input value found in the original T5 file.

The probability density function for the Triangular Distribution is:

$$f(x) = \frac{2(x-a)}{(b-a)(c-a)}, a \le x \le c$$

$$f(x) = \frac{2(x-a)}{(b-a)(c-a)}, c < x \le b$$

Where:

a = lower bound value
b = upper bound value
c = mode.

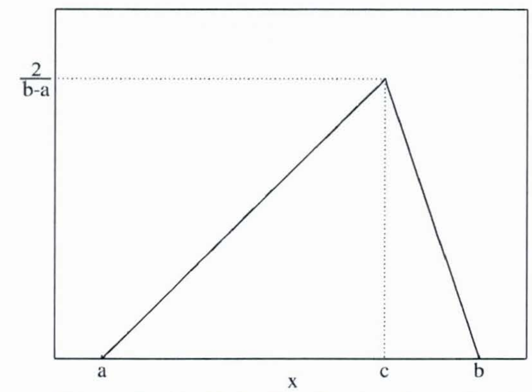


Figure 5. Probability Density Function for Triangular Distribution (Wikipedia).

Lognormal Distribution

The Lognormal distribution is available for Manning's n values, streamflow, and sediment inflow. The advantage of the log-normal distribution is its ability to reliably return values greater than zero, without specifying upper and lower bounds. This is important for MCSed in that all of the uncertain input values are inherently bounded by zero. For example, it is not possible to have a Manning's n value of less than zero.

When applying the lognormal distribution to Manning's n values, the standard deviation of the natural log estimate is calculated by (United States Army Corps of Engineers 1986):

$s_n = 0.582 + 0.1 \ln(n_o)$

Where:

n_o = the original estimated Manning's n value.

For streamflow and sediment inflow, the user must provide a standard error, by which MCSed will compute the transformed standard deviation and mean by:

$$\sigma_x = \sqrt{\ln(1+\varepsilon_x^2}$$

$$\mu_x = \ln\left(\frac{x}{\sqrt{1+\varepsilon_x^2}}\right)$$

Where:

- σ_x = standard deviation of the natural log of "x".
- ε_x = the standard error of "x"
- μ_x = the mean of the natural log of "x"
- x = the expected value of the uncertain input parameter (streamflow or sediment inflow), $x > 0$.

The probability density function for the lognormal distribution is:

$$f(x) = \frac{1}{x\sigma\sqrt{2\pi}} e^{-\frac{(\ln x-\mu)^2}{2\sigma^2}}$$

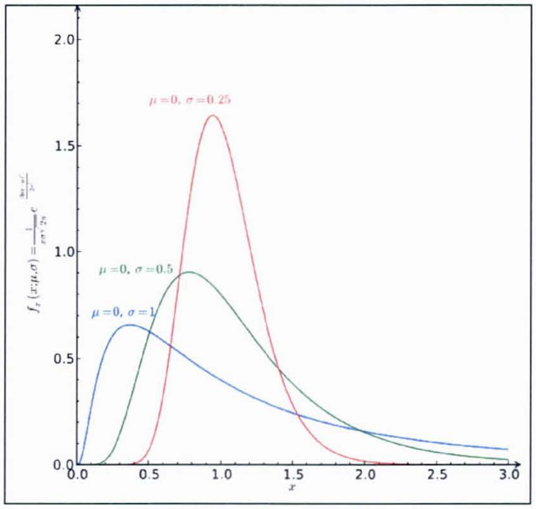


Figure 6. Probability Density Function for Log-normal Distribution (Wikipedia).

Random Number Generators

The Monte Carlo Method relies on repeated sampling of random numbers. In MCSed, thousands of random numbers, or more, may be required to provide a statistically accurate and meaningful result. The user has two options for computing random numbers, the Wichmann Hill method and Excel's VBA random number generator. When computing arrays of random numbers, both methods work very well at producing nonsequential, non-repeating numbers. However, when single discrete random numbers are computed, the Wichmann Hill method tends to produce repeated values and patterns.

MCSed can compute single discrete random numbers two different ways:

1. Compute single discrete random numbers, on the fly, as they are needed in the rewriting of the T5 file.
2. Compute an array of random numbers. MCSed then draws random numbers from the array as they are needed in the rewriting of the T5 file.

If Wichmann Hill is selected as the random number generator, it is recommended that the user have MCSed compute an array of random numbers to draw from.

V. Distribution Test

There are two computation functions in MCSed: The Distribution Test and Run Monte Carlo Simulation. The Distribution Test allows the user to test the adequacy of the selected distributions and numbers of realizations for each of the four input parameters. The "Test" values, Estimated n value or n Value mode, Estimated D50 or D50 Mode, Mean Q or Q Mode, and Mean Qsed or Qsed Mode, should be entered as representative values for the HEC-6T file that will be run with the Monte Carlo analysis. These test values are not used in the Monte Carlo run, rather they are only used for testing the distributions and numbers of realizations. Sampling of the actual input parameters in the T5 file is only carried out during the Monte Carlo simulation. It is suggested that before a Monte Carlo analysis is run, the Distribution Test be run to gage the quality of the distributions and number of realizations.

If, for example, the lognormal distribution is selected for streamflow, the user should expect to see a smooth bell curve shape on the probability histogram plot. However, if the number of realizations is too small, the quality of the population set will be diminished and the bell curve will not be recognizable, as shown in Figure 7 with 100 realizations.

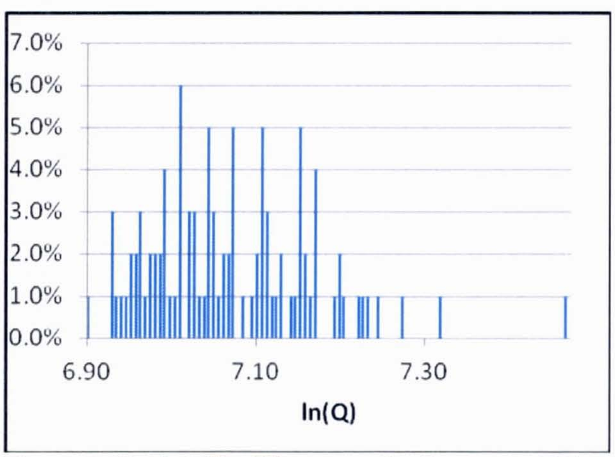


Figure 7. Probability Histogram for Lognormal Distribution and 100 Realizations.

If the number of realizations is increased substantially to 10,000, the quality of the distribution improves and the test produces a nice bell curve distribution, as shown in Figure 8.

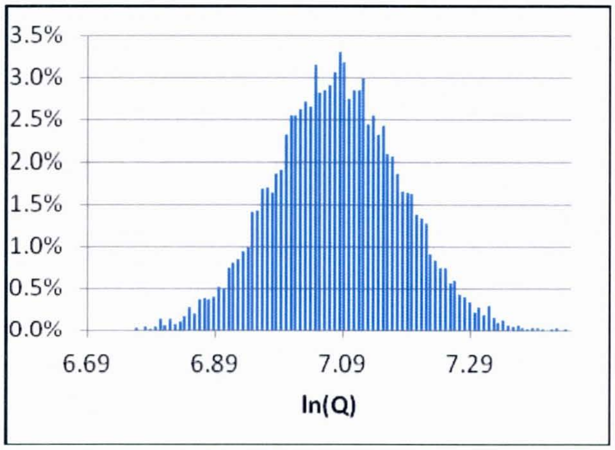


Figure 8. Probability Histogram for Lognormal Distribution and 10,000 realizations.

The higher the number of realizations, the better the distribution of the sampled input parameters will be, which is the underlying principle of the Monte Carlo Method. However, a large number of realizations will also substantially increase the computation time of the Monte Carlo analysis. If the number of realizations is too large, the Monte Carlo analysis becomes impracticle to use. The user must weigh the quality of the distribution to the acceptable length of computation time.

VI. Run Monte Carlo Simulation

Once the user has tested the selected distributions and found reasonable results with the number realizations, the next step is to run the Monte Carlo Simulation. The "Run Monte Carlo Simulation" function does not use the "Test" input values, rather it reads and resamples the input parameters found in the specified T5 file.

For each realization, MCSed will read the T5 file and locate every instance of the target uncertain input parameters, Mannings n values, particle diameters, streamflow, and sediment inflow. When it finds a target input parameter it resamples that input parameter by selecting a random number over domain (0,1], and then transforming that random number to a new input value based on the original (expected) input value and the specified distribution. The result is a new, rewritten T5 file with newly sampled target input parameters. MCSed then runs HEC-6T using the new T5 file and then retrieves selected outputs and stores them immediately on the output tabs, "BedChangeOuput" and "TrapEfficiencyOutput." This process is repeated for every realization.

During the simulation, MCSed will store in memory the sampled n-values to memory. At the end of the entire Monte Carlo Analysis, MCSed will write that stored data to the "nValueCompare" tab.

VI. Performing a MCSed Simulation

The following steps are required to run a MCSed simulation:

1. Fill in the number of realizations to test (cell I3).

2. Select a Target Non-Exceedance Probability (cell I4). This allows the user to view non-exceedance probability Bed Change results for a non-exceedance probability other than the defaults, which are 1, 10, 50, 90, and 99%.

3. Choose the HEC-6T T5 file to use (cell D5). The user can either type the path and filename in the input cell, or click the "open" button next to the cell. It is recommended that the user select the T5 file by clicking the "open" button to avoid mis-typing the path or filename.

4. Choose the HEC-6T executable to use for the analysis (cell D6). This executable should be in the same folder as the T5 file specified in cell D5.

5. Fill in the number of bins for the probability histograms for each of the target input parameters (cells D9, H9, L9, and P9). This gives the user control over the display of the probability histogram plots and is only used for the "Test Distribution" function.

6. Select the desired distributions for each target input parameter (Cells D10, H10, L10, and P10). The triangular distribution is available for all target input parameters, while the lognormal distribution is available for Manning's n, Streamflow, and Sediment Inflow. The uniform distribution is only available for particle diameter.

7. Enter "Test" values for each target input parameters (cells D11, H11, L11, and P11). This is only used for the "Test Distribution" function.

8. Enter in the distribution input parameters (cells D12-13, H12-13, L12-13, and P12-13). The required distribution input parameters vary, depending on which distribution is selected. .

9. Enter in a maximum run time for HEC-6T (cell P4). This allows the user to control how long MCSed will wait for HEC-6T to run for any given realization before abandoning that run and moving on to the next realization. This feature is meant to prevent MCSed from stalling on an HEC-6T run that is caught in a loop or is taking an abnormally long time to compute because of numerical instabilities. The user should estimate how long the T5 file will take to run, and make sure the Max Time value is larger than that.

10. Enter in Optional data as necessary (cells W2-W5, V6, W7, and V8-V10).

11. Test the adequacy of the number of realizations by clicking the Test Distribution button.

12. Once the user is pleased with the distribution test, run the Monte Carlo Simulation by clicking on the "Run Monte Carl Simulation" button. This may take a long time, depending on the size and complexity of the T5 file, and the number of realizations. It is recommended to start with a small number of realizations (less than 5) to gage the simulation speed, before going to the full amount of desired realizations.

VII. Options

The following optional properties are available in MCSed:

1. Detailed n Value Results for XS. Enter the River Station ID of the Cross Section you wish to view detailed n value results. Type "All" if you want all the cross sections. Leave Blank if you don't want detailed n value results. This compares original n values to transformed n values. **Warning: Typing "All" could produce a LOT of data and significantly extend computation times.**
2. Realization for Detailed n Value Results. The realization you want to show detailed n value results for. Type "All" for all realizations. Leave blank if you don't want detailed n value results. **Warning: Typing "All" could produce a LOT of data and significantly extend computation times.**
3. Recomputing Random Numbers for n-Values. This specifies how random numbers will be applied to n-Values. Selecting "Once per n Value" will force MCSed to reselect a random number for every instance of an n Value found in the T5. Selecting "Once per Record" forces MCSed to reselect a random number for each Manning's n Value record. A record may contain multiple n Values and can be applied to one or more cross sections. Selecting "Once per T5 File" forces MCSed to select one random number to be applied to all instances of n Values in the T5 file.
4. Debug Level. 0 through 5. 0 means debugging is off. 1 gives the least detail, 5 the most. In version 1.0, use 4 or greater to create individual 6T input and output files for each realization. 3 or less creates just one 6T input and set of output files that are copied over for each realization.
5. Show or Hide HEC-6T while Running. Show or hide HEC6T during the Monte Carlo simulation. Showing HEC-6T allows the user to view the process of each HEC-6T run, but also slightly increases the computation time.
6. Random Number Generator to Use. Select the Random Number Generator to use. Version 1.0 allows the user to select between Wichmann Hill and the VBA random number generator.
7. Random Number Selection. Direct MCSed to compute random numbers as they are needed, or to select random numbers from an array of random numbers that is computed at the beginning of the simulation. Wichmann-Hill works better when selecting from an array.
8. Print BedChangeOutput. Direct MCSed to print the bed change output that shows up on the BedChangeOutput tab. Select "Yes" or "No".

9. Print MaxScourOutput. Direct MCSed to print the bed change output that shows up on the MaxScourOutput tab. Select "Yes" or "No".
10. Print MaxDepositionOutput. Direct MCSed to print the bed change output that shows up on the MaxDepositionOutput tab. Select "Yes" or "No".

VII. Output Tabs

MCSed Version 1.0 offers four output tabs and one input comparison tab (nValueCompare).

1. Bed Change Output. The bed change output tab (BedChangeOutput), is updated after each realization and provides the change in bed elevation from the initial geometry for each cross section. The cross sections are listed across the sheet in row 3. Subsequent rows contain the bed change values for given realizations. Also included, in column B, is the simulation time for each realization. Summary statistics are provided below the bed change output for each cross section. This includes the non-exceedance probability bed change values. Bed change output is pulled from the SB-2 table in the HEC-6T output T6 file after each realization. MCSed will read from the last SB-2 table in the T6 file. Therefore it is important that the user plants a $VOL record at the end of the T5 file (the $VOL record directs HEC-6T to write certain output, including the SB-2 table), after the last * block of hydrology records. If a $VOL card does not exist in the T5 file, no bed change output will be written to the BedChangeOutput tab.

2. Maximum Scour Output. The maximum amount of scour computed at a given cross section at any time during a single realization is presented in the MaxScourOutput tab. In this table, a positive value indicates that scour has occurred. I negative value indicates the bed surface never degraded below the original bed surface elevation during the realization.

3. Maximum Deposition Output. The maximum amount of deposition computed at a given cross section at any time during a single realization is presented in the MaxDepositionOutput tab. In this table, a positive value indicates that deposition has occurred. I negative value indicates the bed surface never aggraded above the original bed surface elevation during the realization.

4. Trap Efficiency Output. The trap efficiency for a given reach is the percentage of the inflowing sediment load that remains in the reach (versus passes through the reach further downstream). A negative value implies reach-wide degradation, while a positive value implies reach-wide aggradation. The trap efficiency values are retrieved from the SA-1 table in the T6 file after each realization. An SA-1 table is provided anytime during the simulation where an "A" or "B" variable is placed in column6, field 0/1 of the * record.

   Trap efficiency output for the reaches in the HEC-6T file is provided in the TrapEfficiencyOutput tab for each realization.

5. N Value Input Comparison. The n value comparison is actually not output, but rather a comparison of the originally selected n values and their randomly transformed values. During the running of MCSed, everytime an n value is read from the T5 file and replaced by a new randomly sampled n value, that information is stored to memory for later access. At the end of the MCSed simulation, all of this stored data is written to the nValueCompare tab.

   The nValueCompare tab arranges the n value data by cross section, from left to right, and by realization number, from top to bottom. To reduce the quantity of data here, the user has the option to just look at one cross section, or to look at them all. Likewise, the user can look at just one realization, or all of them. Selecting all realizations will significantly extend the computation time. For a given cross section, MCSed will list the cross section ID at the top of the block of data. Below the cross section ID, the "card" values are presented. For each card, all of the n values listed in that card are displayed, along with the random number (0,1], labeled as "P", and the distribution parameters. Finally the transformed n value is also provided in the last column.

   The nValueCompare tab will allow the user to quickly see the process taken to transform the input n values to the randomly sampled n values at any location and time of the MCSed simulation.