AHYMO™

Computer Program

(An Arid-lands HYdrologic MOdel)

User's Manual

Version: AHYMO-S4-R2 for computers running Microsoft Windows 8, 8.1 and 10

Distributed by:
City of Albuquerque
Hydrology Section, Planning Department
Plaza del Sol, 600 2nd St NW
Albuquerque, NM 87102
https://www.cabq.gov/planning/development-review-services/hydrology-section

September 2018

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The AHYMO Program is licensed and distributed by:
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The City of Albuquerque generally grants a Government Agency license for the AHYMO-S4 program to local, state and Federal government agencies at no cost. Other software licenses will be granted to individuals, companies and organizations based in policies established by the City of Albuquerque. The City's policy currently grants a software licenses to all to individuals, companies and organizations who download the program file.

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AHYMO™ Computer Program - User's Manual
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LIST OF AHYMO™ PROGRAM COMMANDS

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PROGRAM DEVELOPMENT AND CONDITIONS FOR ACCEPTANCE

AHYMO™ Computer Program (An
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AHYMO-S4-R2

The AHYMO computer program was developed using portions of the program source code from the HYMO program by Jimmy R. Williams and Roy W. Hann, Jr. for the USDA Agricultural Research Service, (ARS), United States Department of Agriculture. The function of the HYMO program is described in detail in the "HYMO: Problem - Oriented Computer Language for Hydrologic Modeling, User's Manual" (ARS-S-9, May 1973). The AHYMO-S4 program contains approximately 8700 lines of Fortran Source Code, with approximately 600 lines of code remaining from the original ARS HYMO program. The additional source code in the AHYMO-S4 program are revisions and enhancements by C. E. Anderson. The revised and enhanced program has been named the AHYMO, for Arid-lands Hydrologic Model. The "S4" in the program name is a code for the latest major revision to the AHYMO program. C. E. Anderson was the owner of the modifications and enhancements to the HYMO program. In 2018, C. E. Anderson gave the AHYMO-S4 program the City of Albuquerque, and the ownership of AHYMO-S4 was transferred to the City of Albuquerque. The AHYMO program is distributed and licensed by the City of Albuquerque. The name "AHYMO" is a trademark of the City of Albuquerque. C.E. Anderson originally registered the AHYMO trademark in the Office of the Secretary of State of New Mexico. In 2018, the trademark ownership was transferred by gift to the City of Albuquerque.

The AHYMO-S4-R2 version of the AHYMO program, including the COMPUTE NM HYD, RAINFALL, LAND FACTORS, COMPUTE LT TP, SEDIMENT BULK, SEDIMENT TRANS and ROUTE MCUNGE functions, has been reviewed and tested for New Mexico conditions. Program parameters have been established that may allow program use throughout New Mexico, subject to appropriate user verification and testing. The AHYMO program has been used by professional engineers for projects in Bernalillo, Chavez, Eddy, McKinley, Sandoval, Santa Fe and Valencia Counties of New Mexico, including the Cities of Albuquerque, Artesia, Belen, Carlsbad, Gallup, Rio Rancho, Roswell and Santa Fe. The AHYMO computer program and the user's manual have been made available to the Federal Emergency Management Agency (FEMA). The program may be accepted by Federal, state or local agencies for purposes of design of flood control structures or for flood plain land use regulation, when the program is used by Registered Professional Engineers who possess the experience and thorough understanding of the engineering principles that apply to the application of the program. Users are advised to check on agency acceptance prior to use with any project.

There are no warranties, either expressed or implied, as to the quality or performance of the AHYMO program, or that the calculations contained therein will be uninterrupted, accurate or error free. All the calculations are subject to interpretation, and there is no implied or expressed warranty of results obtained by using the AHYMO program. Any use of the program must be based on the understanding by the user that any results are intended to aid the user in performing engineering oriented mathematical calculations, and that the results obtained from the AHYMO program do not necessarily constitute an acceptable engineering design or analysis. The results of the AHYMO program must be reviewed by persons possessing experience and thorough understanding of the engineering principles that apply to the application of the program. The user is advised to test this program thoroughly before relying on the results as the basis for making engineering decisions.

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The following certification may be required if the AHYMO program is used to perform hydrologic analysis in support of a flood insurance map revision by the Federal Emergency Management Agency (FEMA) in accordance with 44CFR Ch. 1, Section 65.6.

CERTIFICATION OF AHYMO™ PROGRAM COPYRIGHT OWNER

The AHYMO computer program (AHYMO, version AHYMO-S4) and user's manuals from 1984 through 2017 were written by C. E. Anderson. The manual text and source code was transferred by gift to the City of Albuquerque in 2018. The City of Albuquerque, assisted by C. E. Anderson updated the user manual text in 2018. The AHYMO program was based in part on the USDA Agricultural Research Service (ARS) HYMO program by Jimmy R. Williams and Roy W. Hann, Jr. for the ARS. The AHYMO program is copyrighted by the City of Albuquerque. The City of Albuquerque has the exclusive rights to distribute or license the AHYMO program. The City of Albuquerque may grant limited rights for others to distribute the software. The AHYMO computer program and user's manuals, including program executable and source code, have been made available free of charge to the Federal Emergency Management Agency (FEMA) and all present and future parties impacted by the flood insurance mapping developed or amended through the use of the AHYMO program. FEMA may release the AHYMO program executable code and manuals to such impacted parties without authorization from the City of Albuquerque, or notification to the City of Albuquerque. FEMA may release the AHYMO program source code to impacted parties only when FEMA determines that release of the executable code is not sufficient to meet the requirements of FEMA. Subsequent release of the executable code, source code and manuals by impacted parties, other than FEMA, is prohibited without written authorization from the City of Albuquerque.

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AHYMO™ Computer Program - User's Manual

(An Arid-lands Hydrologic Model)

PREFACE

This user's manual was developed to describe and demonstrate the use of the AHYMO (Arid-lands HYdrologic MOdel) computer program. The AHYMO program was created by adding new subroutines, functions and capabilities to the HYMO computer program developed by the USDA Agricultural Research Service (ARS). The ARS program is described in "HYMO: Problem-Oriented Computer Language for Hydrologic Modeling, User's Manual" (ARS-S-9, May 1973) by Jimmy R. Williams and Roy W. Hann. The AHYMO Copyright does not include any portion of the A.R.S. HYMO program and user's manual, which is a work of the United States Government. The information in this AHYMO program User's Manual includes extensive new material developed by the Clifford E. Anderson, PE, PhD, D.WRE between 1984 and 2017. While the AHYMO-S4 program can simulate the analysis methods from the ARS HYMO program, modified versions of the HYMO program created by others, the development of the AHYMO-S4 program proceeded independently, using only the ARS HYMO program. Work on the AHYMO program began in 1984 as an initial revision to the ARS HYMO program by C.E. Anderson. Versions of the AHYMO program were released by Anderson-Hydro from1986 to June 2018.

For further information on the history of the development and use of the AHYMO program, and on procedures for use, see the README file in the appendix to this manual or with the program release files.

TRADEMARKS, COPYRIGHT AND WARRANTY

furnishing, performance or use of this material or program. Any use of the AHYMO computer program must be based on the understanding by the user that any results are intended to aid the user in performing engineering oriented mathematical calculations, and that the results obtained do not necessarily constitute an acceptable engineering design or analysis. The results of the AHYMO program must be reviewed by persons possessing experience and thorough understanding of the engineering principles that apply to the application of the program. The user is advised to test the AHYMO program thoroughly before relying on the results as the basis for making engineering decisions.

INSTRUCTIONS FOR USE OF THE AHYMO™ PROGRAM

A. INTRODUCTION:

The original HYMO Program was written by the U.S.D.A. Agricultural Research Service (ARS) in 1973, and the program and user's manual were made available free to the public. The program was run on an IBM computer using punch cards as the input source. The AHYMO program has been revised to run on a personal computer running Microsoft Windows 8, 8.1 and 10 (32 or 64-bit). AHYMO uses text files as the input source. Many commands and capabilities have been added to the AHYMO program by the author to increase its power as a design and analysis tool. The original ARS HYMO program contained 1294 lines of FORTRAN source code; approximately 600 lines from the original code remain in the current version of the AHYMO program. The AHYMO program contains approximately 8700 lines of FORTRAN source code. The program code has been revised so it can be compiled using the Intel® Visual FORTRAN Compiler (Version 11.1).

B. INPUT FILES:

The input for the AHYMO program is a text file. The text file is created or modified by using an ASCII text editor or the ASCII function of a word processor. The following editors have been used to produce data files:

WordPad or Wordpad (Microsoft Editors available with Windows 8, 8.1 and 10).
Program Editor by Corel Corporation.

Word processor programs, such as Microsoft Word, Corel WordPerfect, and Sun OpenOffice can be used to create program input data files. Word processor files commonly include special control characters within files that cannot be accommodated by the AHYMO program. It is recommended that data files be saved as ANSI Windows text or ASCII DOS text files when creating input files for the AHYMO program. Most word processor programs can produce ANSI Windows text or ASCII DOS text files as a part of their document save functions. Be careful with use of "tabs". The AHYMO program can accommodate input files that contain tab characters. However, the display of input data and printing of output data containing tabs may be different with the AHYMO program than with the interpretation used by word processor programs. It is best to avoid use of the tab key or to convert tabs to spaces.

Each line of the input text file can have a maximum of 80 characters (card image format). Each line must have the following general format:

B.1 Command Field

(First 20 columns on a line). The AHYMO program scans the first 20 columns for a command. The commands must be input exactly as identified, beginning at the first space on the line, and with a single blank between words. Remaining spaces (up to column 20) after the command must be filled with blanks, except for comment commands. Commands may be typed with capital or lower case letters.

B.2 Numeric Field

(columns 21 through 79 on a line). Columns 21 through 79 are used for numerical data. The AHYMO program reads the numerical data using free format and does not normally read the nonnumeric characters in the numeric field. Exceptions to only numeric value reading are the alphanumeric HYD NO designation (see Section E.1, "Hydrograph Identification Numbers and HYD Numbers"), and the location names of the LOCATION command. The numerical data can be entered as a whole number or a decimal number. Other characters (such as letters) can be mixed in with the numerical data to identify or label the numbers. The letters will not be read because the program scans for numbers and only reads the numbers. Numerical values need to be input in the correct order for the program commands to function properly. Characters that are read as numbers are 0, l, 2, 3, 4, 5, 6, 7, 8, 9, **-**, +, and the decimal point. If the numerical data needs to be continued on the next line, the command field is left blank and the numerical data is entered between columns 21 and 79 on the next line. Using this procedure, a command can use many lines for the numeric field data. Exponential syntax (i.e.: 1.2E6) is not allowed.

Note: The "numerical value only" and "free format" input of the AHYMO program allows for extensive use of comments with the data and for the identification of units (ft, cfs, sq mi, etc.). Do not use decimal points in comments or units because the program will interpret these decimal points as numeric values of 0.0.

B.3 Page Format Field

(column 80). If an asterisk (*****) symbol is placed in column 80, and on the same line as a command, the output file will have a form feed (skip to next page) prior to printing the command.

C. OUTPUT FILES

The AHYMO program produces a 132 column output text file (ASCII). The output is sent to a file in the C:\Users\Public\AHYMOdata directory or to directory specified by the program user. This file can be viewed and printed by opening the file with a text editor or a word. The output file will have up to 132 characters on a line, so file printing must use compressed mode (small or narrow fonts) and/or landscape orientation. Additionally, printing of output should use a print font that has uniform character spacing. Printing with Courier, Courier New, or Letter Gothic font will commonly provide uniform character spacing. Your text editor or word processor program should provide information on how to specify font type, font size, print margins and landscape page orientation.

The AHYMO program also produces a summary table file (normally AHYMO.SUM) and a simulated punch card file (normally AHYMO.PUN) as a part of program execution. The summary table is a 132-column text file that can be viewed and printed in the same manner as the program output file.

The simulated punch card file is an 80-column text file that can be viewed and printed; this file may also serve as part of the input file for other modeling segments.

D. DESIGNATION OF INPUT AND OUTPUT FILES

The AHYMO-S4 program can be run on a computer using Microsoft Windows 8, 8.1 or 10 (32 or 64-bit). The file AHYMO-S4-r2.EXE, or a shortcut file that calls AHYMO-S4-r2.EXE must be opened to execute the program.

To execute the program in Windows 8, 8.1 or 10, double click on the AHYMO program or shortcut icon and specify the file name (including the directory location if needed), or drag the data file icon to the open AHYMO window and press enter (drag and drop). As an alternative in Windows 7, 8, 8.1, and 10, you may drag the input data file to the shortcut AHYMO-S4 icon, and the AHYMO-S4 program will begin execution. When the program asks for the name of the input file, press the "enter" (return) key without typing a name, and the AHYMO program will use the input file that you specified by dragging. On some Windows systems, you may need to first open the AHYMO_S4 program by double-clicking the shortcut icon, and then drag the data file to the program window that is opened, and hit "enter".

For proper program function, the AHYMO_IO.FIL file must be in the working directory or be locatable by Windows. The AHYMO_IO.FIL contains the input and output file names used by the program, and the user number for registered users. The file AHYMO_IO.FIL will normally contain the following data:

D.1 First Line (input file):

"PROMPT" - The program asks for the input file name during execution. This is the recommended value. You can normally use drag and drop when PROMPT is specified.

blank - The input file name including all directory location information must be specified by the program user.

name - a file name of a locatable data file.

D.2 Second Line (output file)

name - a file name where the output is sent. If the file exists, it is overwritten. If it does not exist, the file is created. A file named AHYMO.OUT is recommended for this line.

"PROMPT" - The program asks for the output file name during execution.

blank - The input file name including all directory location information must be specified by the program user.

D.3 Third Line (simulated punch cards)

name - an output file name to which simulated punch cards are sent. If the file exists, it is overwritten. A file named of AHYMO.PUN is recommended.

"PROMPT" - The program asks for the filename for simulated punch cards.

D.4 Fourth Line (hydrograph input/output file)

name - an output file name to which hydrograph output is sent. If the file exists, it is overwritten. A file name of AHYMO.HYD is recommended.

"PROMPT" - The program asks for the filename for the hydrograph input/output file.

"NONE" - The program will not create a hydrograph input/output file. If the SAVE HYD command is used, a file name for HYDROGRAPH input/output is required.

Note: The AHYMO program may require use of the Hydrograph input/output file to store hydrograph values if identification numbers (IDs) with values above 20 are used extensively.

D.5 Fifth Line (summary table output file)

name - a file name to which output summary is sent. If the file exists, it is overwritten. A file name of AHYMO.SUM is recommended.

"PROMPT" - During execution, the program asks for the filename of the SUMMARY TABLE.

D.6 Sixth Line (user number)

This line is reserved for the 24-character User Identification Code that is assigned to each licensed users and identifies the type of software license held by the program user (Single User, Site, Government Agency, Educational, or Temporary). Licensed program users may be assigned a User Identification Code by the City of Albuquerque, or the City may assign a User Identification to a group of users. This code must be included in the AHYMO_IO.FIL for the program to function. The code may not be revised by the program user. A temporary User Identification Code may be available for testing and evaluation purposes.

D.7 Seventh Line

There may be a seventh line in the AHYMO_IO.FIL with the characters "1234567890123456789012324". This line is used to guide data entry for the fifth line.

For general application, it is recommended that the AHYMO_IO.FIL contain the following (on seven lines):

```
PROMPT
AHYMO.OUT
AHYMO.PUN
AHYMO.HYD
AHYMO.SUM
[Your 24 character user number]
123456789012345678901234
```

When the AHYMO-S4 program is executed, the program will use the information in the AHYMO_IO.FIL to determine the location of the input and output files, and the license status of the User Identification Code. If you use the example AHYMO_IO.FIL format, you can later rename the AHYMO.OUT and AHYMO.SUM files for project archiving. Note that the sixth line in the example above uses a code for a Temporary license. Licensed program users should enter their assigned User Identification Code at this location. Note that the User Identification Code for licensed program users does not expire.

Note: If you have a 24 character user number obtained during use of earlier versions of AHYMO-S4, it will continue to function with AHYMO-S4-R2.

E. IDENTIFICATION NUMBERS

E.1 Hydrograph Identification Numbers and HYD Numbers

Hydrographs are identified by two numbers, an "ID" number that the program uses and a "HYD" number which is used primarily by the program user.

The "ID" Number

The "ID" number must be a whole number between 1 and 99. The ID is the value used by the program to store and identify hydrograph locations in program memory. An ID may be assigned to several different hydrographs throughout the execution of an input file. If a hydrograph is assigned to an ID number, any existing hydrograph values are overwritten. ID numbers with values greater than 20 require more computational processing for data storage and retrieval than ID numbers less than 20. For computational efficiency, it is recommended that use of ID numbers with values greater than 20 be minimized. This is rarely a problem since ID numbers can be overwritten. If a large number with values larger than 20 are used, a file name must be specified for HYDROGRAPH input/output in the AHYMO_IO.FIL. If the HYDROGRAPH input/output file name is not specified and there is extensive use of ID numbers larger than 20, the AHYMO program may terminate with an error message that the AHYMO_IO.FIL must specify the HYDROGRAPH input/output file name.

The "HYD" Number

The "HYD" number, which is not used by the program computations, is a unique number or an alphanumeric sequence assigned to each hydrograph that is computed. It can be a number less than 10,000, with up to two decimal places (9999.99) or it can be an alphanumeric sequence (letter and numbers) if preceded by the appropriate identification. When a hydrograph is printed, the "HYD" number is printed as a title for that hydrograph, along with the type of hydrograph. The hydrograph types are listed as follows:

TYPE	"HYD" No.		
Reaches	1	to	99.99
Partial Hydrographs	100	to	299.99
Areas	300	to	499.99
Reservoirs	500	to	599.99
Areas	600	to	9999.99
Areas	ABC123.DE (Any alphanumeric sequence)		

It is recommended that alphanumeric "HYD" numbers be used for all but the smallest projects. Alphanumeric values will provide improved identification of hydrograph physical locations. The "HYD" number should not be repeated, so that each physical location has a unique hydrograph identification.

EXAMPLE: A Drainage Basin "A" has four sub-basins "A1", "A2", "A3", and "A4". Basin "A" is a partial basin for a total drainage area, sub-basin A3 contains two sub-basins A3A and A3B.

BASIN	Number form of "HYD" No.	Alphanumeric form of "HYD" No.
A	101	A
A1	101.1	A.1
A2	101.2	A.2
A3	101.3	A.3
A3A	101.31	A.3.A
A3B	101.32	A.3.B
A4	101.4	A.4

E.2 Alphanumeric HYD Numbers

Alphanumeric HYD numbers up to 24 characters long may be used with the AHYMO program if the characters are preceded by the HYD NO identification sequence. One of the following identification sequences must be used.

```
HYD=
HYD =
HYD NO=
HYD NO =
```

Lower case letters may also be used (i.e.: `hyd no =`) and a blank space may follow the equal (=) symbol. This sequence is followed by up to 24 alphanumeric characters that are terminated by a blank space. Because the AHYMO program summary table can only print the first 12 characters of an alphanumeric HYD NO, it is recommended that only 12 alphanumeric characters be used. Because the character sequences "HYD NO" create a special meaning for the characters that follow, the specified Hydrograph number identification (i.e.: HYD=, HYD =, HYD NO=, HYD NO =) should not be used at other locations of the input data.

EXAMPLE: The following lines illustrate acceptable forms of the HYD number designation:

```
HYD NO = ABCD
HYD = A.B.C.D
hyd = west.branch
hyd no = Broadway.3A
Hyd No = NW.MAIN.10.1
HYD = 22.1.3
Hyd = 99th.Street
```

Note: The AHYMO program will execute with HYD numbers that are not a unique number or alphanumeric sequence; however, the repeated use of the same HYD number may create problems when interpreting output data and evaluating program results. It is good practice to maintain unique HYD number designations.

E.3 Channel Identification Numbers

The identification number for a channel rating curve (CID) is a whole number between 1 and 6. The CID number for a rating curve should not be confused with the ID number for a hydrograph. The CID numbers are specified with the STORE RATING CURVE and COMPUTE RATING CURVE commands; they are used only by the COMPUTE TRAVEL TIME , ROUTE MCUNGE, and SEDIMENT TRANS commands. For most applications a CID = 1 should be used. The values of CID of 2 through 6 have generally been applied to legacy watersheds, where multiple channel sections were applied to a single channel route command. This is no longer the recommended procedure. Use CID = 1 for new projects.

F. TIME INCREMENT

The AHYMO program uses a maximum of 4000 points to store a hydrograph. If the time increment is too small, a hydrograph may require more than 4000 points to reach a zero value. The points exceeding 4000 are not stored by the AHYMO program, and are lost by the hydrograph computation. If this occurs, the volume of the hydrograph will not be accurate. Depending on the results needed, the time increment can be adjusted. For 6-hour storms a time increment of 0.01 or 0.005 hours is generally used; for 24-hour storms a time increment of 0.01 hours is generally used.

It is normally necessary to specify a time increment (DT) only when identifying a mass rainfall in the first COMPUTE HYD or RAINFALL command, or when using the STORE HYD or RECALL HYD command. At other applications, the DT should be set equal to 0.0 to use the DT from the input hydrograph or the existing rainfall distribution. The use of 0.0 for DT will simplify input file revisions if it is necessary to use an alternate time increment for subsequent hydrologic analysis.

G. AHYMO PROGRAM COMMANDS

The AHYMO program has 31 commands that are used to create a hydrologic model. They are summarized as follows:

Program Control Commands:

* *(COMMENT)*	START
FINISH	LOCATION

Hydrograph Computation Commands:

COMPUTE HYD	COMPUTE NM HYD
COMPUTE ALB HYD	RAINFALL
LAND FACTORS	COMPUTE LT TP

Hydrograph Manipulation Commands:

ADD HYD	DIVIDE HYD
MODIFY TIME	

Hydrograph Save and Restore Commands:

STORE HYD	PUNCH HYD
SAVE HYD	RECALL HYD

Channel, Pipe and Reservoir Routing Commands:

COMPUTE RATING CURVE	STORE RATING CURVE
COMPUTE TRAVEL TIME	STORE TRAVEL TIME
ROUTE	ROUTE MCUNGE
ROUTE RESERVOIR	

Hydrograph Output Commands:

PRINT HYD	PLOT HYD

Special Commands:

COMPUTE K AND TP	ERROR ANALYSIS
SEDIMENT BULK	SEDIMENT TRANS
SED WASH LOAD (SEDIMENT YIELD)	

The following subsections contain specifications on the command functions and examples of command use.

G.1 COMMENTS

When the first character on a line is "*", the line is read as a comment. This allows explanations and descriptions to be inserted with the input data. Comment lines can contain numerical and nonnumeric characters. Comments must be inserted between commands and not in the middle of commands. A comment may also be added to the Summary Table by placing the characters "*S" or "*s" in the first two columns of a line.

EXAMPLES:

```
*    This line of text goes to the output file
*S   This line of text goes to the summary file & output file
```

G.2 START

Except for comments, the START command is the first command in an input file.

The START command is followed by the following data elements:

DATA ELEMENT		DESCRIPTION
TIME	=	the time (in hours) when the rainfall starts
PUNCH CODE	=	a code for sending output to a simulated punch card file (normally AHYMO.PUN). If the PUNCH CODE=1, output is sent to the punch card file; if PUNCH CODE=0, this output is suppressed.
UH	=	A unit hydrograph code to specify special unit hydrograph criteria. Not used by the current program version. Use UH = 0.
MC CODE	=	A code to specify the formulation for Muskingum-Cunge routing in the ROUTE MCUNGE command. If MC CODE = 0 specifies the Ponce formulation for Muskingum-Cunge routing when the computation time step (DT) specified with the RAINFALL command is 0.015 hours or smaller, and the dual mode Ponce then Fread formulations will be used when the DT is larger than 0.015 hours. If MC CODE=1 only the Ponce formulation will be used. If MC CODE=2 the dual mode formulation (Ponce then Fread) will be used. Recommended value is MC CODE = 0 or 1.
PRINT LINES	=	a code to control the program output and summary output for some printers. This function is not normally needed with MS Windows based word processors and text editors. The recommended value is PRINT LINES = 0.

The dual mode Ponce then Fread formulation was generally used with the AHYMO_97 program, although either formulation could be specified with the ROUTE MCUNGE command. When MC CODE=2 the dual mode formulation (Ponce then Fread) that was in AHYMO-97 will be restored for all computation time steps, but this function is only recommended for comparison purposes. For most applications, it is recommended that a DT smaller than 0.015 hours be used and that MC CODE=0 or 1 be specified.

For simulations that include actual rainfall events, the start time can modify the times shown on the program output to reflect actual times of runoff events.

The capability described in this paragraph is not normally needed with MS Windows based word processors and text editors. The START command can be used to control the format of the summary table file (normally AHYMO.SUM) by including a non-zero PRINT LINE data element with the command. If a value between 10 and 200 is specified for the PRINT LINE data element (following the PUNCH CODE element) this value is used to specify the number of lines per page on the summary table. It is possible to specify printer fonts, vertical lines per inch, and horizontal characters per inch by input of printer control characters following the PRINT LINE element. This is done by specifying the decimal value for the ASCII characters the printer will require. This allows output files to be printed in 132 column format (16 to 17 characters per inch) on most printers. Following the PRINT LINE element, 20 decimal values are used to specify the control codes at the beginning of a file, and 20 decimal values are used to specify the ending control codes. If 20 values are not needed for printer control, the remaining positions should be specified with 0 values. If control codes are used to specify summary table printing, these values are also added to the program output file. Your printer manual should contain applicable control codes. The summary table format (PRINT LINE and control code values) can be set for some legacy by specifying a negative value, between -1 and -6, for the PRINT LINE element. This function eliminates the need to further specify printer control codes. Many printers can emulate, or use the same control codes as one of these printers. Consult your printer manual to find out if one is applicable for your use. The printers listed are all legacy printers, but many current printers emulate the function of these older printers. Available are specified in the following table:

Printer Control Available With START Command

PRINT LINES	Printer Type	Max. Lines Per Page	Char. Per Inch (horiz.)	Lines Per Inch (vert.)
-1	HP LaserJet II	63	16.66	6.6
-2	IBM Proprinter	56	17	6
-3	IBM Proprinter	77	17	8
-4	Epson LX	56	17	6
-5	Epson LX	77	17	8
-6	HP LaserJet 4 or 5	76	16.66	8

EXAMPLES:

```
* No PUNCH FILE, UH, MC Code, or Printer Control
* Recommended for most applications
START                 TIME=0.0

* Alternatives to specify the default values are
START
* or
START 0 0 0 0 0
* or
START TIME=0.0 PUNCH=0.0 UH=0 MC CODE=0 PRINT CODE=0

* Specify Lines per Page on AHYMO.SUM
START                 TIME=0.0 HR  PUNCH=0  UH=0  MC CODE=0
                      PRINT LINES=63

* Set Lines per Page & Control Codes for HP LaserJet II
START                 TIME=0.0 HR  PUNCH=0  UH=0  MC CODE=0
                      PRINT LINES=63
                      CONTROL CODES AT START=27  40 115 49 54
                      46 54 54 72 0  0 0 0 0 0 0  0 0 0 0
                      CONTROL CODES  AT END=  27  40 115 49 48
                      72 00 00 00 0  0 0 0 0 0 0  0 0 0 0

* Specify compressed mode with a HP LaserJet 4 or 5 printer
START                 TIME=0.0 HR  PUNCH CODE=0  PRINT LINES=-6
```

G.3 FINISH

The FINISH command is the last command in an input file. It is not followed by any numerical data. The FINISH command may also be inserted at any point in the input file to terminate program execution at that point.

EXAMPLE:

```
FINISH
```

G.4 LOCATION

The LOCATION command is used to identify the site of the hydrologic analysis area. The LOCATION command normally is the next command following the START command. The LOCATION command information is used by the AHYMO program to set default values for items such as unit hydrographs, soil infiltration and rainfall distributions. The most common local condition specified by the LOCATION command are 1) the default soil infiltration used by the COMPUTE NM HYD command and the LAND FACTORS command (with Type = 0) and 2) the rainfall distribution specified by TYPE = 1 or 2 in the RAINFALL command. See the LAND FACTORS and RAINFALL commands for the values that are defined for assigned locations.

The LOCATION command is followed by the following data element:

DATA ELEMENT		DESCRIPTION
NAME	=	The name of the project site

The location command specifies the location for the watershed and establishes special watershed parameters for some of these areas. The LOCATION command recognizes the following names:

AHYMO OLD, AHYMO194, AHYMO97, ALBUQUERQUE, AMAFCA, ARIZONA, ARTESIA, BERNALILLO COUNTY, CARLSBAD, CLOVIS, COLORADO, EL PASO, ESCAFCA, FARMINGTON, FLAGSTAFF, GALLUP, LOS CRUCES, NEW MEXICO, PHOENIX, RIO RANCHO, ROSWELL, SANDOVAL COUNTY, SANTA FE, SSCAFCA, TUCSON.

The program will use default parameters if no LOCATION command is specified or if the location name is not recognized. The LOCATION command is normally placed immediately after the START command. For most of the locations identified, the program will use default parameters because no special program parameters have been specified. The following locations have exceptions to the default parameters:

SANTA FE - Special infiltration values (initial abstraction and uniform infiltration) developed for the Santa Fe area will be used.

AHYMO OLD, AHYMO97, SSCAFCA, or RIO RANCHO - When the TYPE=1 and TYPE=2 distributions are specified in the RAINFALL command, the rainfall distribution based on the equations in the Albuquerque DPM (NOAA Atlas 2) will be used. This is the same equation used in the AHYMO-97 program.

AHYMO194 - the Muskingum-Cunge procedure from the AHYMO194 program will be used with the ROUTE MCUNGE command. This should only be used to make comparisons with an earlier analysis.

For all other locations - When the TYPE=1 and TYPE=2 distributions are specified in the RAINFALL command, the rainfall distribution based on the equations in NOAA Atlas 14 for convective storm areas in Arizona and New Mexico will be used.

One of these names should be included in the location command. Names may be in capital or lower case letters. The names must be correctly spelled and begin in columns 21 through 40 of the data field. Any other name that is entered will be identified by the AHYMO program as "location not known" and the default values for New Mexico will be used. If a LOCATION command is not used in the input data file, the default values for New Mexico will be used.

EXAMPLES:

```
LOCATION            Santa Fe

LOCATION            SSCAFCA

LOCATION            AMAFCA

LOCATION            NEW MEXICO
```

G.5 COMPUTE HYD

The COMPUTE HYD command computes a runoff hydrograph for a basin based on the basin properties and a mass rainfall distribution.

The COMPUTE HYD command is followed by the following data elements:

DATA ELEMENT		DESCRIPTION
ID NUMBER	=	Internal storage location (1 to 99).
HYD NUMBER	=	Hydrograph identification number.
DT	=	Incremental time (hours). If input as 0.0, the previous DT will be used.
DA	=	Drainage area in square miles.
CN	=	NRCS Curve Number (CN)
K	=	Recession constant for unit hydrograph computation. (Input K as a negative number to use the HYMO (3-segment gamma) unit hydrograph. Input K = -999 or K = 0.0 to use an NRCS dimensionless unit hydrograph.)
tp or tc	=	Time to peak (tp) in hours (input as a negative number to specify the time to peak value), or time of concentration (tc) in hours (input as a positive number to specify the time of concentration). The time of concentration must only be used with the NRCS dimensionless unit hydrograph (K=0.0 or -999) and with CN infiltration. Input as 0.0 to use a previously computed value from the COMPUTE LT TP command.
MASS RAINFALL	=	The mass rainfall distribution (inches). The rainfall distribution can contain a maximum of 600 points. If the RAINFALL command is used, input a value of "-1".

Specifying the Unit Hydrograph

A three segment gamma function unit hydrograph (ARS HYMO unit hydrograph) can be designated by specifying K and tp (time to peak) values. The K and tp values are used by the program to establish the shape of the unit hydrograph. K and tp must be entered as negative numbers. Positive numbers direct the AHYMO program to use a time to peak computation and unit hydrograph developed for eastern Texas and not generally applicable to the arid southwest. (See page 6 of the Agricultural Research Service HYMO User's Manual, in Appendix D.)

If K = -999 or K = 0, the NRCS dimensionless unit hydrograph will be used. If the NRCS unit hydrograph and the specified with the time of concentration (positive value), the program will verify that the incremental time is less than 13.33 percent of the time of concentration (tc). If it is not, the program will temporarily establish a smaller time step for the hydrograph computation, then restore the original time step as command output. This computation will also occur with time of concentration determined by the COMPUTE LT TP command. If the time to peak (negative value) is used, the original incremental time will be used for the hydrograph computation.

Specifying Time to Peak (t_p) Values

If the three segment gamma function unit hydrograph (ARS HYMO) is used, the time to peak must be specified along with the K value. If an NRCS dimensionless unit hydrograph is used, the time to peak, tp, can be specified by entering the appropriate value for the tp (negative value) and entering K = 0.0 or -999. A time of concentration, tc, can be specified by a positive value. If the COMPUTE LT TP command is used to compute the time to peak, a tp = 0.0 and K = 0.0 should be input in the COMPUTE HYD command; this will direct the AHYMO program to use the previously computed time to peak. The time to peak will be computed from the computed time of concentration with the following equation from the NRCS procedure:

$$t_p = 0.6 * (\text{time of concentration}) + 0.5 * (\text{time increment})$$

Note: *When the COMPUTE LT TP command is used with the COMPUTE HYD command, the NRCS dimensionless unit hydrograph should be specified (K = 0.0 or K = -999).*

Specifying Rainfall

The COMPUTE HYD command allows for a cumulative rainfall distribution to be specified for the current or subsequent hydrograph computations. The increasing values of cumulative rainfall can contain up to 4000 data points. If a value of "-1" is entered for the mass rainfall distribution, the previously input rainfall distribution is used to compute the hydrograph. If a value of "-2" is entered for the mass rainfall distribution, the previous distribution is used and the hydrograph values generated by the program segment are added to the hydrograph values currently stored in memory at the ID location specified. If the incremental time (DT) has been previously entered and a new rainfall distribution is not entered, a DT=0.0 should be entered to specify use of the previous incremental time. For most applications the mass rainfall should be specified with the RAINFALL command.

Specifying Soil Infiltration

An NRCS runoff curve number (CN) can be used to compute the soil infiltration. As an alternative to the NRCS Curve Number method, initial abstraction and uniform infiltration can be specified. This method is identified by entering the initial abstraction (IA) and uniform infiltration (INF) values as negative numbers. The two numbers are entered into the COMPUTE HYD function in place of the single CN value.

If the infiltration rate (INF) is less than 0.07 inches per hour, the infiltration rate can be set at a uniform rate from 0 to 3 hours, a uniformly declining rate from 3 to 6 hours and 0.0 after 6 hours, by specifying a positive value for the infiltration. The initial abstraction (IA) is input as a negative value. This procedure is consistent with the impervious area infiltration described in "A Comparison of a Gaged Urban Watershed and Computer Modeling Using HYMO" (C.E. Anderson and R.J. Heggen, 1991, in *Inspiration, Come to the Headwaters, Proceedings of the Fifteenth Annual Conference of the Association of State Floodplain Managers*, Denver, Colorado, p 107-112).

NOTE: A separate command is included in the program to allow input of values to a mass rainfall table, or to generate a mass rainfall table for several commonly used rainfall distribution types. The command is called "RAINFALL".

EXAMPLES:

```
*CURVE NUMBER and HYMO (3 segment gamma) UNIT HYDROGRAPH
COMPUTE HYD           ID=3  HYD=121  DT=0.05 HR  DA=0.15 SQ MI
                      CN=68  K=-0.08  TP=-0.16 HR MASSRAIN=-1

*CURVE NUMBER and NRCS DIMENSIONLESS UNIT HYD WITH Tp SPECIFIED
COMPUTE HYD           ID=4  HYD=XYZ  DT=0.00  DA=0.25 SQ MI
                      CN=95  K=-999  TP=-0.25 HR  MASSRAIN=-1

*CURVE NUMBER and NRCS DIMENSIONLESS UNIT HYD WITH Tc SPECIFIED
COMPUTE HYD           ID=4  HYD=XYZ  DT=0.00  DA=0.25 SQ MI
                      CN=95  K=-999  TC=0.40 HR  MASSRAIN=-1

*CURVE NUMBER and NRCS DIMENSIONLESS UNIT HYDROGRAPH with Tc
*    Specified by the COMPUTE LT TP Command
COMPUTE HYD           ID=5  HYD=BASIN.1  DT=0.00  DA=0.50 SQ MI
                      CN=85  K=0.0  TC=0.0 HR  MASSRAIN=-1

*IA/UNIFORM INF AND HYMO UNIT HYDROGRAPH
COMPUTE HYD           ID=3  HYD NO=ABC.2  DT=0.05 HR
                      DA=0.15 SQ MI  IA=-0.50  INF=-0.85
                      K=-0.08 TP=-0.16 HR
                      MASS RAINFALL = 0 0.1 0.2 0.4 0.8
                      1.6 2.4 3.0 3.2 3.4 3.5

*IA/INF FOR IMPERVIOUS AREAS WITH 0.0 INFILT. AFTER 6 HOURS
*
COMPUTE HYD           ID=4  HYD NO=153  DT=0.00  DA=0.25 SQ MI
                      IA=-0.10  INF=0.04  K=-0.125  TP=-0.25
                      MASS RAINFALL= -1
```

Note: The COMPUTE HYD command is commonly used to compute a basin hydrograph using NRCS curve numbers (CNs) and the NRCS dimensionless unit hydrograph. Tables of applicable curve numbers may be found in Urban Hydrology for Small Watersheds (1986, USDA Soil Conservation Service, Technical Release 55, Tables 2-2a through 2-2d). When a watershed has several land cover types or soil conditions that require weighting of curve numbers, the following statement from the NRCS National Engineering Handbook, Section

4, Hydrology should be considered: "This comparison shows that the method of weighted-Q is preferable when small rainfalls are used and there are two or more widely differing CN in a watershed." (Ref: page 10.11) To implement a weighted-Q procedure with the COMPUTE HYD command, the following steps should be performed:

- *Compute the runoff volume in inches (Vi) for each sub-basin segment with a separate curve number (CNi) using:*

  $$Vi = [P + 2 - (200 / CNi)]^2 / [P - 8 + (800 / CNi)] \qquad (g.1)$$

  where P = total rainfall in inches
- *Compute the total area runoff volume (Vt) using:*

  $$Vt = [\Sigma(Vi * Ai)] / \Sigma Ai \qquad (g.2)$$

  where Ai = individual segment area
- *Compute the weighted-Q curve number (CN) using:*

  $$CN = 100 / [1 + Vt + (0.5 * P) - (Vt^2 + (1.25 * P * Vt))^{0.5}] \qquad (g.3)$$

Part E, Section E.1(3) of the City of Albuquerque Development Process Manual, Chapter 22.2, Hydrology, 1997 Edition (page E-3) included additional information on use of NRCS curve numbers appropriate for the Albuquerque area and locations with similar hydrologic conditions. Program Users should seek guidance from reviewing agencies before using Curve Number procedures with the AHYMO-S4 program.

G.6 COMPUTE NM HYD

The COMPUTE NM HYD command is utilized to compute a combined sub-basin hydrograph using initial abstraction/uniform infiltration, and separate infiltration factors and unit hydrographs for pervious and impervious portions of the sub-basin. This "split hydrograph" procedure is described in "A Comparison of A Gaged Urban Watershed and Computer Modeling Using HYMO" (C.E. Anderson and R.J. Heggen, 1991, in *Inspiration: Come to the Headwaters*, Proceedings of the Fifteenth Annual Conference of the Association of State Floodplain Managers, Denver, Colorado, pp. 107-112.) The computation of k/t_p ratios, infiltration, initial abstraction, and separate pervious and impervious hydrographs of the "split hydrograph" procedure is all performed by the program.

The command uses four land treatment types that correspond to the following land use classifications: A = natural, B = irrigated lawns, C = compacted earth, and D = impervious. The four land treatment types are further defined by the following Table G1:

Table G1. Definitions of Land Treatment Types

Land Treatment	**Land Condition**
A (Natural)	Soil uncompacted by human activity with 0 to 10 percent slopes. Native grasses, weeds and shrubs in typical densities with minimal disturbance to grading, groundcover and infiltration capacity. Croplands. Unlined arroyos.
B (Irrigated Lawns)	Irrigated lawns, parks and golf courses with 0 to 10 percent slopes. Native grasses, weeds and shrubs, and soil uncompacted by human activity with slopes greater than 10 percent and less than 20 percent.
C (Compacted Earth)	Soil compacted by human activity. Minimal vegetation. Unpaved parking, roads, trails. Most vacant lots. Gravel or rock on plastic (desert landscaping). Irrigated lawns and parks with slopes greater than 10 percent. Native grasses, weeds and shrubs, and soil uncompacted by human activity with slopes at 20 percent or greater. Native grass, weed and shrub areas with clay or clay loam soils and other soils of very low permeability as classified by NRCS Hydrologic Soil Group D.
D (Impervious)	Impervious areas, pavement and roofs.
Most watersheds contain a mix of land treatments. To determine proportional treatments, measure respective subareas.	

Note: Local jurisdictions may require modification of the above definitions based on appropriate basin properties. In some watersheds, the land treatment types may have multiple definitions within a single hydrologic analysis. The soil infiltration factors may be specified using the LAND FACTORS command. See the LAND FACTORS command for the default initial abstraction and uniform infiltration values used by the AHYMO program.

The following data elements are input into the COMPUTE NM HYD command:

DATA ELEMENT		DESCRIPTION
ID NUMBER	=	Internal storage location (1 to 99)
HYD NUMBER	=	Hydrograph identification number
DRAINAGE AREA	=	The total sub-basin area (in square miles)
AREA OF LAND TREATMENT A, B, C, AND D	=	As a percentage of total (0 to 100), as a ratio (0 to 1), or as an area in square miles or acres (four values are input)
t_p	=	Time to peak for the entire sub-basin (hours) which is equal to 2/3 t_c. (Input as a negative or positive number.) Input t_p = 0.0 to use a previously computed value from the COMPUTE LT TP command.
MASS RAINFALL	=	A table of cumulative rainfall values in inches. If the RAINFALL command was previously used, input a "-1"

Note: If the COMPUTE LT TP command is used to compute the time to peak (t_p), input t_p = 0.0 with the COMPUTE NM HYD command.

EXAMPLES:

```
* HYDROGRAPH COMPUTED WITH LAND TREATMENT TYPE PERCENTAGES
COMPUTE NM HYD         ID=2  HYD NO=102.25  AREA=1.75 SQ MI
                       PER A=20  PER B=36  PER C=16  PER D=28
                       TP=-0.418 HR  MASS RAIN=-1

* HYDROGRAPH COMPUTED WITH LAND TREATMENT AREAS SPECIFIED
COMPUTE NM HYD         ID=2   HYD NO=102.AA  AREA=1.75 SQ MI
                       A=224 AC  B=403.2 AC  C=179.2    AC
                       D=313.6 ACTP=0.43 HR  MASS RAIN=-1


* HYDROGRAPH COMPUTATION WITH Tp SPECIFIED BY PRIOR
```

```
*    COMPUTE LT TP COMMAND
COMPUTE NM HYD        ID=3   HYD NO=BAS.12.A  AREA=1.75 SQ MI
                      Per A=15  Per B=0  Per C=45 Per D=40
                      TP=0.0 HR  MASS RAIN=-1
```

If a mass rainfall table is to be input, enter a DT value as a negative number, followed by the mass rainfall quantities. The DT should generally be smaller than 0.01 hour. The RAINFALL command should normally be used to input a mass rainfall.

EXAMPLE:

```
COMPUTE NM HYD        ID=2  HYD NO=101.A2  DA=0.06 SQ MI
                      PER A=6.3  PER B=38.1  PER C=6.3
                      PER D=49.3  TP=-0.151111 HR
                       DT=-0.25 HR
                      MASS RAINFALL=0.00  0.15  0.28  0.36
                      0.45  0.49  0.51  0.55  0.58  0.62
                      0.75  0.80  0.81   0.82
```

Note: *Only the numbers in the numerical data area are read by the program. Numerical data can be continued on the next line if the command area is left blank.*

G.7 COMPUTE ALB HYD

THE COMPUTE ALB HYD command is similar to the COMPUTE NM HYD command. It is included only to provide compatibility with earlier versions of the AHYMO program that did not have the COMPUTE NM HYD command. The COMPUTE ALB HYD command should not be used for new projects.

The following is input into the COMPUTE ALB HYD command:

DATA ELEMENT		DESCRIPTION
ID NUMBER	=	Internal storage location (1 to 99)
HYD NUMBER	=	Hydrograph identification number
DRAINAGE AREA	=	The total sub-basin area (square miles)
AREA OF LAND TREATMENT D	=	As a percentage (0 to 100) only
AREA OF LAND TREATMENT A	=	As a percentage (0 to 100) only
t_p	=	Time to peak for entire sub-basin (hours). Input as a positive or negative number.
MASS RAINFALL	=	A table of cumulative rainfall values in inches. If the RAINFALL command was previously used, input a "-1".

The COMPUTE ALB HYD command always assumes that area of Land Treatment B = 0.0. Land Treatment C is equal to 100 - percent treatment D - percent treatment A (i.e.: C = 100 - D - A). The COMPUTE ALB HYD command actually calls the COMPUTE NM HYD command and the COMPUTE NM HYD command will appear on the summary table.

EXAMPLE:

```
COMPUTE ALB HYD ID=2 HYD NO=101.0 DA=0.060 SQ MI
                     PER D=49.3     PER A=25.35
                     TP=-0.151111 hr   MASS RAIN=-1
```

G.8 RAINFALL

The RAINFALL command is used to compute a mass rainfall table for a known rainfall distribution or to input a mass rainfall table from gaged rainfall data.

The RAINFALL command is followed by the following data elements:

DATA ELEMENT		DESCRIPTION
RAINFALL TYPE	=	An integer number for one of the 17 rainfall distributions available with the AHYMO program, or a 0 to input a mass rainfall table. See the Table of Rainfall Distributions for a description of the rainfall types. If this value is input as a negative number, the printing of the rainfall distribution table on the AHYMO program output will be suppressed.
QUARTER HOUR RAINFALL	=	P_{15} = 15-minute rainfall (Used only for type 3 distribution. Use 0.0 for all other distributions.)
ONE HOUR RAINFALL	=	P_{60} = 60-minute rainfall
SIX HOUR RAINFALL	=	P_{360} = 360-minute rainfall
DAILY RAINFALL	=	P_{1440} = 24-hour rainfall
DT	=	Incremental time (hours). If input as 0.0, the previous DT will be used. A DT value is normally specified with the RAINFALL command. A DT= 0.01 or smaller is recommended to achieve channel routing precision.

Note: The following DT values are recommended for most applications: for a 24-hour rainfall use a DT = 0.01 hr, and for a 6-hour rainfall use a DT = 0.01 or 0.005 hr. These values will generally provide hydrographs that do not exceed the 4000-point program limits and allow for accurate channel routing computations.

The rainfall distribution types are described in the following table:

TABLE OF RAINFALL DISTRIBUTIONS

RAINFALL TYPE	DESCRIPTION
0	Input mass rainfall table (with format changed from AHYMO_97.)
1	A 6-hour distribution that uses the TYPE=20 or TYPE=12 distribution depending on the name specified in the LOCATION command. When AHYMO97, SSCAFCA, or RIO RANCHO are specified, the TYPE=12 distribution (based on NOAA Atlas 2) is used. For the program default and at all other locations the TYPE=20 distribution (based on NOAA Atlas 14) is used.
2	A 24-hour distribution that uses the TYPE=21 or TYPE=13 distribution depending on the name specified in the LOCATION command. When AHYMO97, SSCAFCA, or RIO RANCHO are specified, TYPE=13 (based NOAA Atlas 2) is used. For the program default and at all other locations TYPE=21 (based on NOAA Atlas 14) is used.
3	6-hour PMP distribution based on an HMR-55a Local Storm with peak intensity at 2.25 hours. (See Appendix C for the equations used by the AHYMO program with this rainfall distribution.)
4	24-hour PMP Distribution based on an HMR-55a General Storm and the USBR Urban Hydrology Manual with peak intensity at 15.5 hours. (See Appendix C for the equations used by the AHYMO program with this rainfall distribution.)
5	24-hour NRCS TYPE II-a distribution for New Mexico with peak intensity at 6.0 hours. The "a" in this distribution name refers to the ratio of the one-hour rainfall to the 24-hour rainfall, (i.e.: Set P_{60} equal to 60 percent of P_{1440} for a Type II-60 distribution.) The peak 15-minute intensity is used in the peak 15-minute period for time increments smaller than 15 minutes; this gives a uniform intensity for the peak 15-minute period.

RAINFALL TYPE	DESCRIPTION
6	6-hour distribution based on a power formula: $(P_{60}/P_{360}) * t^{B}$ *(g.4)* where $B = [\log_{10}(P_{360} / P_{60}) / \log_{10}(6.02172)]$ as used in the "Albuquerque Master Drainage Study" (1981) with peak intensity at 0.02 hours. Use for comparison with existing studies only and not for new projects. *Note: The "Albuquerque Master Drainage Study" (AMDS, 1981) used the following equation:* $R(t) = Q * A * t^{B}$ *(g.5)* *Where: R(t) is accumulated rainfall, Q is total rainfall, t is elapsed time in hours, and A and B are empirical coefficients. For a 6-hour rainfall, the AMDS used A=0.85 and B=0.090521. To obtain a similar function with RAINFALL type 6, use the following:* $P_{60} = Q * A$ *(Use the absolute value of Q)* $P_{360} = Q * A * (10^{(B * 0.779721)}) = Q$
7	Distribution obtained by placing the 6-hour rainfall into a 35-minute time period as used in the City of Albuquerque, Far Northwest Drainage Management Plan. Use for comparison with existing studies only and not for new projects.
8	24-hour NRCS Type II distribution, based on the NRCS National Engineering Handbook - Section 4 (Hydrology) with peak intensity at 12.0 hours. This distribution is not generally applicable to the arid southwest where NOAA Atlas 2 rainfall values are used.
9	24-hour distribution based on the NOAA Atlas 2 for New Mexico with peak intensity at 6.0 hours. This distribution is applicable with use of NRCS Curve Numbers (CNs). (See Appendix C for the equations used by the AHYMO program with this rainfall distribution.)
10	6-hour distribution based on the NOAA Atlas 2 for New Mexico with peak intensity at 0.4 hours. Use for comparison with existing studies only and not for new projects.
11	24-hour distribution based on the NOAA Atlas 2 for New Mexico with peak intensity at 0.4 hours. Use for comparison with existing studies only and not for new projects.

12 A 6-hour distribution based on NOAA Atlas 2 for New Mexico with a peak at 1.40 hours. (This was distribution TYPE=1 in AHYMO_97.)

13 A 24-hour distribution based on NOAA Atlas 2 for New Mexico with a peak at 1.40 hours. (This was distribution TYPE=2 in AHYMO_97.)

14 A 6-hour distribution based on NOAA Atlas 2 for New Mexico with a peak at 1.40 hours and 5-minute incremental time steps. This distribution uses the same equations as the TYPE=12 distribution, except that only 5-minute incremental values are computed. Linear interpolation is used to compute intermediate values when the DT is not equal to 5 minutes.

15 A 24-hour distribution based on NOAA Atlas 2 for New Mexico with a peak at 1.40 hours and 5-minute incremental time steps. This distribution uses the same equations as the TYPE=13 distribution, except that only 5-minute incremental values are computed. Linear interpolation is used to compute intermediate values when the DT is not equal to 5 minutes.

16 A 6-hour distribution based on NOAA Atlas 14 for convective storm areas in Arizona and New Mexico. The distribution has a peak at 1.4 hours, with the peak 1-hour precipitation placed between 60 and 120 minutes. The distribution uses the following 5-minute peak precipitation sequence: 48, 45, 42, 39, 36, 33, 30, 27, 24, 21, 18, 15, 12, 9, 6, 3, 1, 2, 4, 5, 7, 8, 10, 11, 13, 14, 16, 17, 19, 20, 22, 23, 25, 26, 28, 29, 31, 32, 34, 35, 37, 38, 40, 41, 43, 44, 46, 47, 49, 50, 51, 52 to 72.

17 A 24-hour distribution based on NOAA Atlas 14 for convective storm areas in Arizona and New Mexico. The distribution has a peak at 1.4 hours, with the peak 1-hour precipitation placed between 60 and 120 minutes. The distribution uses the following 5-minute peak precipitation sequence: 48, 45, 42, 39, 36, 33, 30, 27, 24, 21, 18, 15, 12, 9, 6, 3, 1, 2, 4, 5, 7, 8, 10, 11, 13, 14, 16, 17, 19, 20, 22, 23, 25, 26, 28, 29, 31, 32, 34, 35, 37, 38, 40, 41, 43, 44, 46, 47, 49, 50, 51, 52 to 288.

18 Reserved for a future distribution.

19 Reserved for a future distribution.

20 A 6-hour distribution based on NOAA Atlas 14 for convective storm areas in Arizona and New Mexico. The distribution has a peak at 1.4 hours, and is similar to the TYPE=16 distribution. The distribution sequence is based on the sequence indicated with Table A.1.3 in NOAA Atlas 14. The distribution uses the following 5-minute peak precipitation sequence: 39, 35, 31, 27, 24, 21, 19, 18, 17, 15, 13, 11, 9, 7, 5, 3, 1, 2, 4, 6, 8, 10, 12, 14, 16, 20, 22, 23, 25, 26, 28, 29, 30, 32, 33, 34, 36, 37, 38, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52 to 72.

21 A 24-hour distribution based on NOAA Atlas 14 for convective storm areas in Arizona and New Mexico. The distribution has a peak at 1.4 hours, and is similar to the TYPE=17 distribution. The distribution sequence is based on the sequence indicated with Table A.1.3 in NOAA Atlas 14. The distribution uses the following 5-minute peak precipitation sequence: 39, 35, 31, 27, 24, 21, 19, 18, 17, 15, 13, 11, 9, 7, 5, 3, 1, 2, 4, 6, 8, 10, 12, 14, 16, 20, 22, 23, 25, 26, 28, 29, 30, 32, 33, 34, 36, 37, 38, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52 to 288.

Note: Rainfall types 5 or 9 are commonly used with an NRCS Curve Number analysis when hydrographs are computed using the COMPUTE HYD command. The 6-hour TYPE = 1, 12 or 20, and 24 hour TYPE = 2, 13 or 21 rainfall distributions are ***not*** *recommended for use with NRCS Curve Numbers.*

The following table shows the required input values for the rainfall distributions. If input is not required for a given distribution, input a 0 value or other number as a place holder. Examples of all the rainfall types can be obtained by executing the RAINTEST.DAT data file. If the rainfall type is input as a negative number, the printing of the mass rainfall table will be suppressed on the AHYMO program output.

Required input values for AHYMO Rainfall Distributions

Rainfall Type	1/4 Hour	One Hour	Six Hour	Daily Rain	Rainfall Type	1/4 Hour	One Hour	Six Hour	Daily Rain
1	N	R	R	N	11	N	R	R	R
2	N	R	R	R	12	N	R	R	N
3	O	R	R	N	13	N	R	R	R
4	N	R	R	R	14	N	R	R	N
5	N	R	N	R	15	N	R	R	R
6	N	R	R	N	16	N	R	R	N
7	N	N	R	N	17	N	R	R	R
8	N	N	N	R	20	N	R	R	N
9	N	R	R	R	21	N	R	R	R
10	N	R	R	N					

Legend
- N Not required or used - input as 0.0 or actual value
- R Required
- O Optional - input as 0.0 or actual value

If RAINFALL TYPE = 3, the input of the quarter hour rainfall amount is optional. If the quarter hour rainfall (P_{15}) is input as 0.0, the P_{15} is set to 68 percent of the one hour rainfall (P_{60}).

EXAMPLES:

```
RAINFALL                TYPE=1  RAIN QUARTER=0.0
                        RAIN ONE=1.87 IN  RAIN SIX=2.20 IN
                        RAIN DAY=2.60 IN  DT=0.01 HRS

RAINFALL                TYPE=3  RAIN QUARTER=7.58 IN
                        RAIN ONE=11.38 IN  RAIN SIX=15.84 IN
                        RAIN DAY=0.0  DT=0.01 HRS

RAINFALL                TYPE=5  RAIN QUARTER=0.00 IN
                        RAIN ONE=1.95 IN  RAIN SIX=0.0 IN
                        RAIN DAY=3.20 IN DT=0.01 HRS
```

If RAINFALL TYPE = 0, a mass rainfall table may be directly input. Following the rainfall type, the computation incremental time (DT) is specified. Then the incremental time for the mass rainfall values (RDT) is input. This is followed by the mass rainfall table with up to 4000 values.

The following example shows a specified TYPE=0 RAINFALL with DT=0.01 hours and an RDT=0.083333 hours (5 minutes):

```
RAINFALL                     TYPE=0    DT=0.01 HR   RDT=0.083333   HR
                             MASS RAIN=  0.00  0.01  0.02  0.04  0.06
                             0.09  0.12  0.15  0.21  0.27  0.34  0.42
                             0.53  0.63  0.74  0.85  0.97  1.10  1.25
                             1.40  1.58  1.79  1.88  2.00  2.10  2.18
                              2.24
```

The format of the TYPE=0 command used with the earlier versions of the AHYMO program is also supported. Note that the first value of the Mass Rainfall table must be 0.0. This older format is not recommended for general use because the a DT = 0.01 hours is difficult to implement.

```
RAINFALL                     TYPE = 0   DT = 0.083333 HR
                             MASS RAIN = 0.0   0.01  0.02  0.04  0.06
                             0.09  0.12  0.15  0.21  0.27  0.34  0.42
                             0.53  0.63  0.74  0.85  0.97  1.10  1.25
                             1.40  1.58  1.79  1.88  2.00  2.10  2.18
                             2.24
```

Note: It is common practice to specify the true P_{1440} (daily rainfall) value even if a 6-hour rainfall distribution is used. This will simplify future input file revisions if it is necessary to include a 24-hour distribution in the hydrologic analysis.

G.9 LAND FACTORS

The LAND FACTORS command is used to change the default initial abstraction (IA) and uniform infiltration (INF) factors that are used by the COMPUTE NM HYD command.

- When the **LOCATION** command specifies ALBUQUERQUE, AMAFCA, BERNALILLO COUNTY, ESCAFCA, RIO RANCHO, SANDOVAL COUNTY, SSCAFCA or NEW MEXICO as the location of the analysis, the program uses the following default values:

LAND TREATMENT	GENERAL LAND USE	IA(inches)	INF (inches/hour)
A	natural	0.65	1.67
B	irrigated lawns	0.50	1.25
C	compacted earth	0.35	0.83
D	impervious	0.10	0.04*

Note: The above values are used when the location is "not known" or when a LOCATION command is not in the input file.

- When the **LOCATION** command specifies SANTA FE as the location of the analysis, the program uses the following default values:

LAND TREATMENT	GENERAL LAND USE	IA(inches)	INF (inches/hour)
A	natural	0.70	1.79
B	irrigated lawns	0.54	1.34
C	compacted earth	0.37	0.89
D	impervious	0.10	0.04*

* The Land Treatment D infiltration rate is applicable from 0 to 3 hours; the program uses a uniform reduction from 3 to 6 hours, and 0.0 infiltration after 6 hours.

The above values may be revised by using the LAND FACTORS command with the following input data:

TYPE = 1 This specifies that the location dependent default values are to be revised.

For each of the (4) land treatment types input the following:

IA Initial abstraction in inches. If an IA value is specified as 0.0, use the default value for this land treatment type and any remaining land treatments. To specify a zero value for IA, use a very small positive number (i.e.: 0.0001).

INF Uniform infiltration rate in inches per hour. To specify a zero value for INF, use a very small positive number (i.e.: 0.0001).

TYPE = 0 The location dependent default values will be restored for use by subsequent COMPUTE NM HYD commands.

EXAMPLES:

```
LAND FACTORS         TYPE=1
                     TREATMENT A      IA=0.50      INF=1.00
                     TREATMENT B      IA=0.50      INF=0.60
                     TREATMENT C      IA=0.50      INF=0.20
                     TREATMENT D      IA=0.0001    INF=0.0001

LAND FACTORS         TYPE=0      RESTORES DEFAULT VALUES
```

If TYPE = 1 and the land treatment D infiltration rate is less than 0.07 inches per hour, the specified impervious infiltration rate is used from 0 to 3 hours, a uniform reduction in infiltration is used from 3 to 6 hours, and 0.0 infiltration is used after 6 hours.

G.10 COMPUTE LT TP

The COMPUTE LT TP command is used to compute the lag time (L_G) and time to peak (tp) of a sub-basin using one of the standard methods that is available with the AHYMO program. The command will also compute the time of concentration (tc); the time of concentration can be used with the NRCS dimensionless unit hydrograph to compute a watershed or sub-basin hydrograph with the COMPUTE HYD command. The time to peak (tp) is used to compute a watershed or sub-basin hydrograph with the COMPUTE NM HYD command.

The COMPUTE LT TP command is followed by the following data elements:

DATA ELEMENT		DESCRIPTION
LCODE	=	A number that identifies the computation procedure. LCODE values of 1, 4, 5, 6 or 7 may be used.
LENGTH, SLOPE AND ROUGHNESS	=	A table of sub-basin properties for the selected computation procedure

The following computation options are available:

UPLAND/LAG TIME METHOD (LCODE= 1)

The Upland/Lag Time procedure is based on the NRCS (formerly the SCS) Upland Method for sub-basins shorter than 4000 feet, and on the USDI Bureau of Reclamation Lag Time method for sub-basins longer than 12,000 feet. A transition equation is used for sub-basins between 4000 feet and 12,000 feet long. This procedure was first identified by the City of Albuquerque, *Section 22.2, Hydrology of the Development Process Manual* (The D.P.M. Drainage Design Criteria Committee, 1993, p 90). The Upland/Lag Time method also incorporates the steep slope watershed slope adjustment first identified in graphical form by the *Urban Storm Drainage Criteria Manual* (Wright-McLaughlin Engineers, 1990, "Runoff, Figure 4-1", for the Urban Drainage and Flood Control District, Denver, Colorado), and as further defined as an equation in "Evaluating Storm Water Runoff from Steep Slope Arid Lands" (C.E. Anderson and R.J. Heggen, 1996, in *Coast to Coast, 20 Years of Progress, Proceedings Twentieth Annual Conference, Association of State Floodplain Managers*, San Diego, CA, pp. 135-141).

The NRCS Upland Method uses the following equations to compute time of concentration (tc) in hours, given the segment slopes in foot/foot (s_X), the segment lengths in feet (L_X) and conveyance factors (K_X):

$$tc = L/\left(10 * K * \sqrt{s}\right)/3600\ sec/hr \qquad (g.6)$$

Where: $K = (L/\sqrt{s})/(L_1/(K_1 * \sqrt{s_1}) + L_2/(K_2 * \sqrt{s_2}) + \cdots + L_X/(K_X * \sqrt{s_X}))$

$L = L_1 + L_2 + \cdots + L_X$

and, $s = (L_1 * s_1 + L_2 * s_2 + \cdots + L_X * s_X)/L$

The Lag Time method uses the following equations to compute lag time (L_G) and time of concentration (tc) in hours, given the sub-basin slope in foot per foot (s), the sub-basin length in feet (L), the basin centroid length in feet (L_{CA}),and the basin factor (KN):

$$L_G = 26 * KN * ((L * L_{CA}/(5280^2 * (s * 5280)^{0.5}))^{0.33})$$

(g.7)

With: $tc = (4/3) * L_G$

With sub-basin lengths between 4000 feet and 12000 feet a linear transition is used.

For natural channel conditions with steep slopes, the measured slope (s) is converted to an adjusted slope (s') with the following equation (Anderson and Heggen, 1996), when s exceeds 0.04 foot per foot:

$$s' = 0.052467 + (0.063627*s) - 0.18197*e^{(-62.375*s)} \qquad (g.8)$$

The time of concentration (tc) is converted to the time to peak (tp) for use in the COMPUTE NM HYD command by the following equation:

$$tp = (2 / 3)*tc \qquad (g.9)$$

If the computed time to peak (tp) is less than 0.133333 hour, the program will use 0.133333 hour (8 minutes) as the minimum value.

The Upland/Lag Time method in the COMPUTE LT TP command contains the following data elements:

DATA ELEMENT		DESCRIPTION
LCODE	=	1 (To identify the Upland/LAG time method.)
NK	=	Number of Length-Slope segments in the sub-basin. (A number from 0 to 12 may be entered.)
ISLOPE	=	Steep slope adjustment code. Use 0 or 1 to allow the use of the steep slope adjustment factor for natural slopes greater than 0.04 ft/ft. Use -1 to suppress use of the steep slope adjustment.

For each Length-Slope segment (NK) the following three data elements must be entered:

LENGTH	=	The segment length in feet.
SLOPE	=	The segment slope in ft/ft. If the slope is entered as a negative number, the absolute value of the slope will be used and any steep slope adjustment will be suppressed for the segment.

K = NRCS Upland Method conveyance factor. See Table G2 in this section for suggested values.

Note: Enter one set of LENGTH, SLOPE and K values even if NK = 0. This is the suggested procedure when the sub-basin is longer than 12,000 feet.

Following entry of the Length-Slope segment data, the following data must be entered for sub-basins longer than 4000 feet:

KN = Lag Time Equation Basin Factor. The Basin Factor is based on an estimate of the weighted, by stream length, average Manning's n value for the principal watercourses in the drainage basin. See Table G3 in this section for suggested values. If a value of 0.0 is entered for the basin factor, a default value of 0.025 (for low density urban) will be used.

CENTROID DISTANCE or
CENTROID RATIO = Lag Time Equation distance to centroid. Enter the distance in feet from the from the point of concentration to the point opposite the centroid of the sub-basin. If the value input is less than 1.0, the value is used as a ratio of the overall sub- basin length. If a value of 0.0 is entered for the Centroid Ratio, a default value of 0.50 will be used.

Qp = Estimated peak flow rate in CFS for the sub-basin. This value is only used with the steep slope conversion factor. This value is used to check for the maximum and minimum conveyance factors (K) based on the Froude number and the steep slope conversion factor. The following formulas are used to compute the conveyance adjustment:

$K' = 0.302 * s'^{(-0.5)} * Qp^{(0.18)}$

$K'' = 0.207 * s'^{(-0.5)} * Qp^{(0.18)}$

An adjusted conveyance factor (K) is then obtained based on the following:

If $K > K'$ then $K = K'$

If $K' \geq K \geq K''$ then no adjustment

If $K < K''$ then $K = K''$

For best results the Qp value used should be within 10 percent of the peak flow rate computed for the watershed by the COMPUTE HYD or COMPUTE NM HYD command. A single adjustment factor is computed based in the weighted average of all steep slope segments and Qp. The adjusted conveyance factor is applied only to the segments with a steep slope adjustment.

Note: For an example of use of the Qp data element see the Test_DPM_all.dat and Test_DPM_all.out files in the AHYMO-S4 samples directory.

Table G2. Suggested NRCS Upland Method Conveyance Factors

K	Conveyance Condition
0.7	Turf, landscaped areas and undisturbed natural areas (sheet flow* only).
1	Bare or disturbed soil areas and paved areas (sheet flow* only).
2	Shallow concentrated flow (paved or unpaved).
3	Street flow, storm sewers and natural channels, and that portion of sub-basins (without constructed channels) below the upper 2000 feet for sub-basins longer than 2000 feet.
4	Constructed channels (for example: riprap, soil cement or concrete lined channels**).

* Sheet flow is flow over plane surfaces, with flow depths up to 0.1 feet. The most current guidance on sheet flow would limit it to the upper 100 feet (expected maximum) of a sub-basin. Earlier guidance suggesting up to 400 feet for sheet flow may produce peak flows that underestimates true watershed rates.

** A steep slope adjustment is not appropriate for K greater than 3.001.

Note: The AHYMO program performs checking to verify that the restrictions of the above table are met by the input data. For example: K less than 2.0 cannot be used beyond the upper 400 feet of a sub-basin, and K less than 3.0 cannot be used beyond the upper 2000 feet of a sub-basin. If these values are exceeded, the program will modify the input to fit the restrictions and issue a warning on the output file.

Table G3. Suggested Lag Equation Basin Factors

KN	Basin Condition
0.200	Drainage area has uniform slopes so that channelization does not occur. Ground cover of cultivated crops or substantial growths of grass and fairly dense small shrubs, or similar vegetation. No drainage improvements in the area.
0.050	Drainage area is quite rugged, with sharp ridges and narrow, steep canyons through which watercourses meander around sharp bends, over large boulders and considerable debris obstruction. Ground cover, excluding small rock outcrops, includes many trees and considerable underbrush. No drainage improvements in the area.
0.042	Mountain Brush and Juniper. No drainage improvements in the area.
0.033	Desert Terrain (Desert Brush). No drainage improvements in the area.
0.030	Drainage area is generally rolling, with rounded ridges and moderate side slopes. Watercourses meander in fairly straight, unimproved channels with some boulders and lodged debris. Ground cover includes scattered brush and grasses. No drainage improvements in the area.
0.025	Very Low Density Urban (Minimal improvements to watershed channels)
0.021	Low to Medium Density Urban (Flow in streets, storm sewers and improved channels)
0.016	High Density Urban (Concrete and rip-rap lined channels)

EXAMPLES FOR UPLAND/LAG TIME METHOD:

```
* FOR SUB-BASIN LENGTH SHORTER THAN 4000 FEET
COMPUTE LT TP         LCODE=1  NK=3  ISLOPE=0
                      LENGTH=100 FT   SLOPE=0.03   K=0.7
                      LENGTH=1900 FT  SLOPE=0.02   K=2.0
                      LENGTH=1000 FT  SLOPE=0.015  K=3.0

* FOR SUB-BASIN LENGTH BETWEEN 4000 AND 12000 FEET
COMPUTE LT TP         LCODE=1  NK=4  ISLOPE=0
                      LENGTH=100 FT   SLOPE=0.03   K=0.7
                      LENGTH=1900 FT  SLOPE=0.02   K=2.0
                      LENGTH=1000 FT  SLOPE=0.015  K=3.0
                      LENGTH=4000 FT  SLOPE=0.012  K=4.0
                      KN=0.021   CENTROID DISTANCE=4200 FT
```

```
* TO SUPPRESS STEEP SLOPE ADJUSTMENT AT ONE SEGMENT
COMPUTE LT TP         LCODE=1  NK=4  ISLOPE=0
                      LENGTH=100 FT   SLOPE=0.08   K=0.7
                      LENGTH=1900 FT  SLOPE=-0.05  K=2.0
                      LENGTH=1000 FT  SLOPE=0.03   K=3.0
                      LENGTH=4000 FT  SLOPE=0.012  K=4.0
                      KN=0.035   CENTROID RATIO=0.65

* FOR SUB-BASIN LENGTH LONGER THAN 12000 FEET
COMPUTE LT TP         LCODE=1  NK=0  ISLOPE=0
                      LENGTH=14000 FT  SLOPE=0.02   K=3.0
                      KN=0.033   CENTROID RATIO=0.62
```

NRCS (SCS) TR FIFTY-FIVE METHOD (LCODE= 4)

The NRCS TR FIFTY-FIVE method is based on the procedures described in the NRCS (formerly the SCS) Technical Release-55 (TR-55) *Urban Hydrology for Small Watersheds* (June 1986, U.S.D.A. Soil Conservation Service, now the Natural Resources Conservation Service.) This procedure uses equations based on sheet flow segments, shallow concentrated flow segments, and channel flow segments.

The sheet flow segments represent flow over plane surfaces at the headwater of sub-basins. The sheet flow segments should generally be used only for the upper 100 feet of the sub-basin. Earlier guidance indicated that the upper 300 could have sheet flow. The following NRCS (SCS) sheet flow equation is used to compute the travel time in hours (Tt), given Manning's roughness coefficient (n), the flow length in feet (L), the 2-year 24-hour rainfall in inches (P_2), and the land slope in ft/ft (s):

$$Tt = (0.007 * (n * L)^{0.8}) / ((P_2)^{0.5} * s^{0.4}) \qquad (g.10)$$

The Manning's roughness coefficient (n) for the sheet flow segments can be estimated from the values in the following Table G4.

Table G4. Roughness coefficients (Manning's n) for sheet flow

n[1]	Surface description
0.011	Smooth surfaces (concrete, asphalt, gravel, or bare soil)
0.05	Fallow (no residue)
	Cultivated soils:
0.06	Residue cover ≤ 20%
0.17	Residue cover > 20%
	Grass:
0.15	Short grass prairie
0.24	Dense grasses (lovegrass, bluegrass, buffalo grass)
0.41	Bermuda grass
0.13	Range (natural)
	Woods:[2]
0.40	Light underbrush
0.80	Dense underbrush

[1] These values are only applicable to plane surface sheet flow (generally only the upper 100 ft, but the upper 300 ft may apply for some watershed conditions). The conditions described by NRCS represent general United States conditions and are not specific for arid or semi-arid conditions.
[2] When selecting n, consider cover under a height of about 0.1 ft. This is the only part of the plant cover that will obstruct sheet flow.

After the sheet flow, the sub-basin flow usually becomes shallow concentrated flow. The travel time in hours (Tt) for the shallow concentrated flow is computed using the NRCS (SCS) upland equation as follows, given the watercourse slope in foot per foot (s), the flow length in feet (L), and the conveyance factor (K):

$$Tt = L / (10 * K * \sqrt{s}) / 3600 \text{ sec/hr} \qquad \textit{(g.11)}$$

The shallow concentrated flow velocity computation in NRCS TR-55 is equivalent to using the following conveyance factors:

Unpaved: K = 1.613455 Paved: K = 2.03282

These conditions (paved and unpaved) are the only two included in the 1986 edition of TR-55. Use of any other values represents a deviation from standard NRCS (SCS) procedures.

The NRCS *Win TR-55 Computer Model* (Version 1.0.08, 2005) limits shallow concentrated flow data entry to two segments of 1000 feet each. Thus, 2000 feet is a standard limit for shallow concentrated flow when the above Unpaved and Paved conveyance factors are used. The AHYMO program will issue a warning on the output file of this limit is exceeded.

The channel flow segments should begin where surveyed cross section information has been obtained, where channels are visible on aerial photographs, or where streams (generally indicated by blue lines) appear on US Geological Survey quadrangle maps. The travel time for channel flow segments is obtained using Manning's equation. The Manning's nvalues for open channel flow can be obtained from standard textbooks, US Geological survey guides, or local agency guidelines. The travel time in hours (Tt) for the channel flow segments is computed using Manning's equation, given the watercourse slope in foot per foot (s), the flow length in feet (L), Manning's roughness coefficient (n), the cross sectional flow area in square feet (a), and the wetted perimeter in feet (P_w):

$$Tt = L / ((1.49 * (a / P_w)^{2/3} * \sqrt{s}) / n) / 3600 \text{ sec/hr} \qquad \textit{(g.12)}$$

The time of concentration (tc) for the sub-basin or watershed is computed by the following:

$$tc = \Sigma Tt \text{ (sheet flow seg.)} + \Sigma Tt \text{ (shallow conc. flow seg.)} + \Sigma Tt \text{ (channel flow seg.)} \qquad \textit{(g.13)}$$

If the computed time of concentration (tc) is less than 0.1 hour, the program will use 0.1 hour as the minimum value. This is the minimum value specified by the NRCS Win TR-55 manual.

If the computed time of concentration is used with the Curve Number procedure in the COMPUTE HYD command, the time to peak (tp) will be computed from the time of concentration (tc), and the incremental time (ΔD) using the following NRCS dimensionless unit hydrograph equation:

$$tp = (0.6 * tc) + (\Delta D / 2) \qquad \textit{(g.14)}$$

If the computed time of concentration is used with the COMPUTE NM HYD command and the three segment gamma function unit hydrograph, the time to peak (tp) equation is:

$$tp = (2/3) * tc \qquad (g.15)$$

The NRCS TR FIFTY FIVE method in the COMPUTE LT TP command is followed by the following data elements:

DATA ELEMENT		DESCRIPTION
LCODE	=	4 (To identify the NRCS TR FIFTY-FIVE method.)
NK	=	Number of sheet flow segments in the sub-basin. (A number from 0 to 2 may be entered.) The program can use a maximum of 2 segments. The total length of sheet flow segments should not exceed 300 feet.
NSC	=	Number of shallow concentrated flow segments in the sub-basin. (A number from 0 to 3 may be entered.) The program can use a maximum of 3 segments. The total length of shallow concentrated flow segments should not exceed 2000 feet.
NCF	=	Number of channel flow segments in the sub-basin. (A number from 0 to 6 may be entered.) The program can use a maximum of 6 segments.
TYD RAIN	=	Two-year one-day rainfall (P_2) in inches. This value is used to compute the travel time for the sheet flow portion of the sub-basin.

For each sheet flow segment (NK) the following three data elements must be entered:

LENGTH	=	The segment length in feet.
SLOPE	=	The segment slope in ft/ft.
N	=	Roughness coefficient (Manning's n) for sheet flow. See Table G4 in this section for suggested values.

For each shallow concentrated flow segment (NSC) the following three data elements must be entered:

LENGTH	=	The segment length in feet.
SLOPE	=	The segment slope in ft/ft.

SURFACE or K = Surface type: enter 0 or 1 for an Unpaved surface (K=1.61345), enter 2 for a Paved surface (K=2.03282). If the NRCS Upland Method conveyance factor (K) is to be directly entered, input the value as a negative number and the absolute value will be used.

For each channel flow segment (NCF) the following five data elements must be entered (or 2 data elements for a specified velocity):

LENGTH = The segment length in feet.

SLOPE = The segment slope in ft/ft.

N = Roughness coefficient (Manning's n) for open channel flow. Do **not** use the sheet flow values from Table G4 in this section.

X AREA = Cross sectional area of flow in the channel segment in square feet.

X WP = The wetted perimeter of the flow in the channel segment in feet.

Note: The SLOPE, N, X AREA and X WP data elements will be applied to Manning's equation to compute a velocity for the channel segment. The X AREA and X WP values must be estimated from expected flow rates. NRCS TR-55 suggests use of bank-full conditions. The peak watershed flow rate can be used with an iterative process. It is possible to directly input the channel velocity (feet per second) by input of a negative number as the second data element; the program will use the absolute value as the segment velocity. This alternate procedure may be applied to any channel flow segment and requires input of LENGTH and VELOCITY only, with the other data elements not used.

EXAMPLES FOR NRCS TR FIFTY-FIVE METHOD:

```
* EXAMPLE FROM FIGURE 3-2 OF NRCS TR-55
COMPUTE LT TP         LCODE=4 NRCS TR FIFTY FIVE METHOD
                      NK=1  NSC=1  NCF=1 TYD RAIN=3.6 IN
                      LENGTH=100 FT    SLOPE=0.01   N=0.24
                      LENGTH=1400 FT   SLOPE=0.01   K=-1.6
                      LENGTH=7300 FT   SLOPE=0.005  N=0.05
                           X AREA=27.0 SQ FT    X WP=28.2 FT
```

```
* A SUB-BASIN WITH SEVEN SEGMENTS (2-SHEET,
* 2-SHALLOW & 3-CHANNEL)
COMPUTE LT TP         LCODE=4 NRCS TR FIFTY FIVE METHOD
                      NK=2  NSC=2  NCF=3  TYD RAIN=3.6 IN
                      LENGTH=100 FT  SLOPE=0.10   N=0.15
                      LENGTH=200 FT  SLOPE=0.02   N=0.24
                      LENGTH=1000 FT SLOPE=0.02 SURFACE=1 UNPAVED
                      LENGTH=1000 FT SLOPE=0.03 SURFACE=2 PAVED
                      LENGTH=3000 FT SLOPE=0.015  N=0.035
                           X AREA=200 SQ FT   X WP=120 FT
                      LENGTH=5000 FT VELOCITY=-5.2 FT PER SECOND
                      LENGTH=7900 FT SLOPE=0.012  N=0.019
                           X AREA=25.0 SQ FT  X WP=25.0 FT
```

LAG TIME METHOD (LCODE= 5)

The LAG TIME method is based on the equation to compute the Snyder's Lag Time (L_G) that is commonly used by the USDI Bureau of Reclamation (A.G. Cudworth, 1989, *Flood Hydrology Manual*) and by the US Army Corps of Engineers (1990, *HEC-1, Flood Hydrograph Package, User's Manual*, CPD-1A). The Snyder's Lag Time (L_G) in hours is represented by the following equation, where Ct is a constant, L_M is the length of the watershed in miles, L_{CAM} is length to the basin centroid in miles, S_M is the watershed slope in foot per mile, and Ne is an exponent:

$$Lg = Ct * (L_M * L_{CAM} / S_M^{\ 0.5})^{Ne} \qquad (g.16)$$

The USDI Bureau of Reclamation commonly uses the following factors for Ct and Ne:

$$Ct = 26 * KN \qquad (g.17)$$

Where KN is the Lag Time Equation Basin Factor. The Basin Factor is based on an estimate of the weighted, by stream length, average Manning's n value for the principal watercourses in the drainage basin. See the table of suggested values in this section (Upland/Lag Time Method).

Ne = 0.33

In Arizona, the US Army Corps of Engineers has used the following factors for Ct and Ne (1982, *Gila River Basin, Phoenix, Arizona and vicinity (including New River), Design Memorandum No. 2, Hydrology Part 2*, Los Angeles District):

Ct = 24 * KN
Ne = 0.38

These values have also been used for the unit hydrograph-lag relationship in Carlsbad, New Mexico. The US Army Corps of Engineers has used the following factors for Ct and Ne for a study in Albuquerque, New Mexico (1992, *Interim Feasibility Report, Albuquerque Arroyos, Albuquerque, New Mexico, Volume II Engineering Appendix*, Albuquerque District):

Ct = 24 * KN
Ne = 0.36

Users of the Lag Time Method should contact reviewing agencies to determine if appropriate values of Ct, Ne and KN have been established for their area of investigation.

The Lag Time Method has adopted Snyder's lag time equation to use foot based length units, and uses the following equations to compute lag time in hours (L_G) and time of concentration in hours (tc), given the sub-basin slope in foot per foot (s), the sub-basin length in feet (L), the basin centroid length in feet (L_{CA}), the basin factor (KN), the Lag equation coefficient (C_L = Ct / KN) and the equation exponent (Ne):

$L_G = C_L * KN * ((L * L_{CA}/(5280^2 * (s * 5280)^{0.5}))^{Ne})$ *(g.18)*

With: $tc = (4 / 3) * L_G$

The LAG TIME method in the COMPUTE LT TP command is followed by the following data elements:

DATA ELEMENT		DESCRIPTION
LCODE	=	5 (To identify the LAG TIME method.)
NK	=	Number of sub-basin segments used to compute the lag time. (A number from 0 to 12 may be entered.)
EQ COEF	=	The lag time equation coefficient (C_L). Generally a value of 26 (Bureau of Reclamation) or 24 (Corps of Engineers) should be used. If a value of 0.0 is entered, a default value of 26 will be used.
EQ EXP	=	The lag time equation exponent (Ne). Generally a value of 0.33 (Bureau of Reclamation) or 0.036 to 0.038 (Corps of Engineers) should be used. If a value of 0.0 is entered, a default value of 0.33 will be used.
LAG TO TP FACT	=	The lag time to time-to-peak conversion factor. This factor is used to convert the lag time (L_G) to a time to peak (tp) that is used by the COMPUTE HYD and COMPUTE NM HYD commands. It is suggested that a value of 0.0 be entered, and the program will use a default value of 0.888889 or (8 / 9).

For each sub-basin segment (NK) the following three data elements must be entered:

LENGTH	=	The segment length in feet.
SLOPE	=	The segment slope in ft/ft. If the slope is greater than 0.04 ft/ft and KN is greater than 0.021, the AHYMO program will perform a steep slope adjustment using the equation described in the Upland/Lag Time method. To suppress the steep slope adjustment, enter a negative value for the slope, and the absolute value will be used in the Lag Time equation.

KN = Lag Time Equation Basin Factor. The Basin Factor is based on an estimate of the average Manning's n value for the principal watercourses in the drainage basin. If a single segment is used, input a factor weighted by stream length. See Table G3 in this section for suggested values. If a value of 0.0 is entered for the basin factor, a default value of 0.016 (for high density urban) will be used.

Following entry of the Length-Slope-KN segment data, the following data must be entered:

CENTROID DISTANCE or CENTROID RATIO Lag Time Equation distance to centroid (L_{CA}). Enter the distance in feet from the point of concentration to the point opposite the centroid of the sub-basin. If the value input is less than 1.0, the value is used as a ratio of the overall sub- basin length. If a value of 0.0 is entered for the Centroid Ratio, a default value of 0.50 will be used.

EXAMPLES FOR LAG TIME METHOD:

```
* COMPUTE THE LAG TIME FOR A SINGLE SEGMENT USING DEFAULT FACTORS
COMPUTE LT TP          LCODE=5 LAG TIME METHOD
                       NK=1  EQ COEF=0  EQ EXP=0  LAG TO TP FACT=0
                       LENGTH=12000 FT   SLOPE=0.015 KN=0.05
                       CENTROID DISTANCE=7000 FT

* COMPUTE THE LAG TIME FOR THREE SEGMENTS USING DEFAULT FACTORS
*       AND THE STEEP SLOPE ADJUSTMENT SUPPRESSED
COMPUTE LT TP          LCODE=5 LAG TIME METHOD
                       NK=3  EQ COEF=0  EQ EXP=0  LAG TO TP FACT=0
           +           LENGTH=2000 FT   SLOPE=-0.065 KN=0.05
           +           LENGTH=4000 FT   SLOPE=-0.045 KN=0.05
           +           LENGTH=12000 FT  SLOPE=0.020  KN=0.025
                       CENTROID RATIO=0.65

* COMPUTE THE LAG TIME FOR A SINGLE SEGMENT USING CORPS OF
*       ENGINEERS FACTORS FROM ARIZONA STUDY
COMPUTE LT TP          LCODE=5 LAG TIME METHOD
                       NK=1 EQ COEF=24 EQ EXP=0.38
                       LAG TO TP FACT=0 LENGTH=12000 FT
                       SLOPE=0.015 KN=0.030 CENTROID RATIO=0.62
```

KIRPICH METHOD (LCODE=6)

The KIRPICH method is based on the equation developed from seven rural basins in Tennessee (Z.P. Kirpich, 1940, "Time of Concentration of Small Agricultural Watersheds", *Civil Engineering*, American Society of Civil Engineers, vol. 10, p. 362). The equation was developed from NRCS data and well-defined channels with steep slopes (0.03 to 0.10 ft/ft). Other basin flow conditions require that the time of concentration be multiplied by a factor, for example: 0.4 for overland flow on concrete or asphalt, and 0.2 for concrete channels. The AHYMO program does not provide for input of adjustment factors. A form of the equation was also adopted for use in California (1942, *California Culverts Practice, California Highways and Public Works*). The Kirpich method is used to compute the time of concentration in hours (tc) with the following equation, where L is the length of the watershed in feet, S is the average watershed slope in foot per foot:

$$tc = 0.00013 * L^{0.77} * S^{-0.385} \qquad (g.19)$$

If the computed time of concentration (tc) is used with the Curve Number procedure in the COMPUTE HYD command, the time to peak (tp) will be computed from the time of concentration (tc), and the incremental time (ΔD) using the following NRCS (SCS) dimensionless unit hydrograph equation:

$$tp = (0.6 * tc) + (\Delta D / 2) \qquad (g.20)$$

If the computed time of concentration (tc) is used with the COMPUTE NM HYD command and the three segment gamma function unit hydrograph, the time to peak (tp) equation is:

$$tp = (2/3) * tc \qquad (g.21)$$

Note: The KIRPICH method is included primarily because of its long history of use and to facilitate comparison with previous studies. This method should not be used for modeling urbanized conditions or basins with constructed channels. The development of the equation was based on an agricultural watershed in Tennessee and is not likely to be representative of the arid and semi-arid conditions commonly found in New Mexico.

The KIRPICH method in the COMPUTE LT TP command is followed by the following data elements:

DATA ELEMENT		DESCRIPTION
LCODE	=	6 (To identify the KIRPICH method.)
NK	=	Number of sub-basin segments used to compute the time of concentration. (A number from 1 to 4 may be entered.)

For each sub-basin segment (NK) the following two data elements must be entered:

LENGTH	=	The segment length in feet.
SLOPE	=	The segment slope in ft/ft.

EXAMPLES FOR KIRPICH METHOD:

```
* COMPUTE THE TIME OF CONCENTRATION FOR A SINGLE SEGMENT
COMPUTE LT TP         LCODE=6 KIRPICH METHOD
                      NK=1
                      LENGTH=12000 FT   SLOPE=0.015


* COMPUTE THE TIME OF CONCENTRATION FOR A THREE SEGMENT SUB-BASIN
COMPUTE LT TP         LCODE=6 KIRPICH METHOD
                      NK=3
                      LENGTH=2000 FT  SLOPE=0.050
                      LENGTH=4000 FT  SLOPE=0.020
                      LENGTH=1000 FT  SLOPE=0.015
```

NRCS (SCS) CN-LAG METHOD (LCODE=7)

The NRCS CN-LAG method is based on the equation developed by the NRCS (formerly the SCS) for agricultural watersheds smaller than 2000 acres (USDA Soil Conservation Service, 1964, *National Engineering Handbook, Section 4, Hydrology*, "Chapter 15. Travel Time, Time of Concentration and Lag"). The NRCS CN-LAG method is used to compute the NRCS lag time in hours (L_{SCS}) with the following equation, where L is the length of the watershed in feet, S is the average watershed slope in ft/ft, and CN is the NRCS runoff curve number:

$$L_{SCS} = L^{0.8} * [(1000 / CN) - 9]^{0.7} / [\ 1900 * (S * 100)^{0.5}] \qquad \textit{(g.22)}$$

The time of concentration in hours (tc) is computed from the NRCS lag time (L_{SCS}) using the following equation:

$$tc = L_{SCS} / 0.6 \qquad \textit{(g.23)}$$

If the computed time of concentration (tc) is used with the Curve Number procedure in the COMPUTE HYD command, the time to peak (tp) will be computed from the time of concentration (tc), and the incremental time (ΔD) using the following NRCS (SCS) dimensionless unit hydrograph equation:

$$tp = (0.6 * tc) + (\Delta D / 2) \qquad \textit{(g.24)}$$

If the computed time of concentration (tc) is used with the COMPUTE NM HYD command and the three segment gamma function unit hydrograph, the time to peak (tp) equation is:

$$tp = (2/3) * tc \qquad \textit{(g.25)}$$

Note: The NRCS CN-LAG method is included in the AHYMO program primarily because of its inclusion in the NRCS National Engineering Handbook. There is no known documented calibration for arid or semi-arid conditions. This method should not be used for new modeling studies except with specific authorization by approving agencies or with calibration studies based on study area conditions. Limited testing indicates that the NRCS CN-LAG will ***not*** *provide accurate computation of lag time and time of concentration for arid and semi-arid conditions.*

The NRCS CN-LAG method in the COMPUTE LT TP command is followed by the following data elements:

DATA ELEMENT		DESCRIPTION
LCODE	=	7 (To identify the NRCS CN-LAG method.)
NK	=	Number of sub-basin segments used to compute the NRCS lag time and time of concentration. (A number from 1 to 4 may be entered.)

For each sub-basin segment (NK) the following three data elements must be entered:

LENGTH	=	The segment length in feet.
SLOPE	=	The segment slope in ft/ft.
CN	=	The segment runoff curve number (CN).

EXAMPLES FOR NRCS CN-LAG METHOD:

```
* COMPUTE THE NRCS LAG TIME & TIME OF CONC. FOR A SINGLE SEGMENT
COMPUTE LT TP         LCODE=7 NRCS CN-LAG METHOD
                      NK=1
                      LENGTH=2000 FT   SLOPE=0.015 CN=85


* COMPUTE THE NRCS LAG TIME & TIME OF CONC. FOR THREE SEGMENTS
COMPUTE LT TP         LCODE=7 NRCS CN-LAG METHOD
                      NK=3
                      LENGTH=500 FT   SLOPE=0.050 CN=66
                      LENGTH=1000 FT  SLOPE=0.020 CN=75
                      LENGTH=2000 FT  SLOPE=0.015 CN=90
```

G.11 ADD HYD

The ADD HYD command is used to add two hydrographs together.

The ADD HYD command contains by the following data elements:

DATA ELEMENT		DESCRIPTION
ID NUMBER	=	Internal storage location of the combined hydrograph (1 to 99)
HYD NUMBER	=	Hydrograph identification number of the combined hydrograph
ID ONE	=	Internal storage number of the first existing hydrograph
ID TWO	=	Internal storage location of the second existing hydrograph

The ADD HYD command performs the following function:

ID (new) = ID (first) + ID (second)

The ID of the new hydrograph may be equal to the ID of one of the two existing hydrographs. If more than two hydrographs are to be added, multiple ADD HYD commands must be used.

Specifying the Incremental Time for the New Hydrograph

If the incremental times of the two existing hydrographs are different, the incremental time of the new hydrograph is normally set to the smallest incremental time of either of the existing hydrographs. This default procedure is specified by using positive values for the ID number of the existing hydrographs. The default procedure to use the smallest incremental time can be suppressed by specifying one of the ID numbers as the basis for time increment computation. The ID number that will be used for the incremental time can be specified by input if the ID number as a negative number. With this method, the largest incremental time of the two existing hydrographs can be specified with the ADD HYD computation.

EXAMPLES:

```
ADD HYD         ID=4 HYD=103 ID I=2 ID II=4

ADD HYD         ID=25 HYD NO=23NW.2B IDS=25 AND 10

*S USE THE TIME INCREMENT FROM ID 12
ADD HYD         ID=16 HYD NO=USE_LARGER_DT IDS=6 AND -12
```

G.12 DIVIDE HYD

The DIVIDE HYD command splits a single hydrograph into two separate hydrographs. The hydrograph can be split on a percentage basis, by a maximum flow rate for one of the hydrographs, or by specifying a rating curve.

The DIVIDE HYD command contains the following data elements:

DATA ELEMENT		DESCRIPTION
ID NUMBER	=	Internal storage location of the hydrograph to be split
Q or RATIO or CODE	=	flow rate (cfs if positive) or ratio/percentage (if negative) or 999 (for a rating curve)
ID ONE	=	Internal storage number of the first outflow hydrograph (1 to 99)
HYD ONE	=	Hydrograph identification number of the first outflow hydrograph
ID TWO	=	Internal storage location of the second outflow hydrograph (1 to 99)
HYD TWO	=	Hydrograph identification number of the second outflow hydrograph

If the second data element (CODE) is entered as 999, a table of up to 20 rating curve values are entered as follows:

TOTAL FLOW	=	The total inflow in CFS used by the rating table.
DIVIDED FLOW	=	The portion of the flow in CFS that is sent to the first outflow hydrograph. The remainder of the flow (TOTAL FLOW - DIVIDED FLOW) is sent to the second outflow hydrograph.

To divide a hydrograph by a maximum flow rate, the value of flow rate (second data element) is input as a positive value in units of cubic feet per second. The first hydrograph receives the flow in the original hydrograph up to the flow rate specified. The second hydrograph receives the amount of flow that exceeds the specified rate. To divide a hydrograph on a percentage basis, the percentage value (second element) is entered as a negative number in percent, or as a decimal. Values with an absolute value greater than or equal to 1.0 are assumed to be in percentage format; values with an absolute value less than 1.0 are assumed to be in decimal format. (i.e.: -44 is 44 percent, and -0.33 is 33 percent). The percentage value of the original hydrograph is stored in the first hydrograph and the remaining part is placed in the second hydrograph.

The percentage value (second element) may have an absolute value greater than 100 to multiply a hydrograph by a specified percentage. This capability may be useful for adding a sediment bulking factor to a single hydrograph.

To divide a hydrograph by a rating curve, the second element is entered as 999. Values of total flow and divided flow (up to 20) are entered following the second outflow HYD number.

EXAMPLES:

```
* DIVIDE BY A MAXIMUM FLOW RATE
DIVIDE HYD            ID=5  Q=23.5  ID I=6   HYD NO=103
                                    ID II=7  HYD NO=104

* DIVIDE BY A RATIO
DIVIDE HYD            ID=5   RATIO=-0.85    ID I=6   HYD=103
                                            ID II=7  HYD=104

*DIVIDE BY A PERCENTAGE
DIVIDE HYD            ID=5  PER=-85    ID I=6   HYD NO=103.PIPE
                                       ID II=7  HYD =104.STREET

*DIVIDE HYDROGRAPH BY A RATING CURVE
DIVIDE HYD            ID=1  CODE=999   ID=4   HYD  NO=306.A1
                                        ID=5   HYD NO=306.82
                    TOTAL FLOW      DIVIDED FLOW
                      78.0          78.0
                       78.9         78.4
                     112.0          84.8
                     183.0          91.0
                     286.0          95.0
```

G.13 MODIFY TIME

The MODIFY TIME command provides four (4) functions. It is used, (1) to change the incremental time for a hydrograph, (2) to shift a hydrograph by a specified time period, (3) to establish a minimum base flow value, and (4) to divide a hydrograph according to time.

Changing the Incremental Time

To change the incremental time of a hydrograph the MODIFY TIME command contains the following data elements:

DATA ELEMENT		DESCRIPTION	
ID NUMBER	=	Internal storage location (1 to 99)	
DT	=	Incremental time (hours) for the modified hydrograph. This value must be less than 1.0 hours.	
CODE	=	0	Interpolate incremental flows
		1	Interpolate incremental flows and then adjust so that peak flow equals previous peak.
		2	Interpolate incremental flows and then adjust so that total volume equals previous volume.
		3	Interpolate incremental flows and then adjust so that peak flow and total volume equals previous values. If the flow rate is truncated by the 600 data point hydrograph maximum, only the time of the truncation is used to adjust the volume.

To Shift a Hydrograph by a Specified Time or Set a Minimum Base Flow

To shift a hydrograph by a specified time period or set a minimum base flow, the MODIFY TIME command contains the following data elements:

DATA ELEMENT		DESCRIPTION
ID NUMBER	=	Internal storage location (1 to 99)
TIME	=	Time (in hours) to shift the hydrograph. The value must be a positive number greater than 1.0 or else CODE must be a negative number.

CODE	=	To specify a time shift less than 1.0 hour, set CODE (third value) to negative one or less (CODE = -1). [If CODE is less than -1, the absolute value of the code is used as a minimum base flow value. The hydrograph is checked to see that all hydrograph points exceed this value; if not, the hydrograph points are set to the base flow value.]

To Save the Remainder of the Flow or Divide a Hydrograph According to Time

The use of a smaller incremental time or the shifting of a hydrograph by time may cause the hydrograph to lose a portion of the flow volume that is not included in the 600 data point limit for hydrograph storage. The portion of the hydrograph volume, that would be lost, can be saved to an additional hydrograph. This saving of the flow volume is accomplished by specifying the ID number and the HYD number of the additional hydrograph.

The MODIFY TIME command will allow the specification of a time in hours to terminate the modified hydrograph, with the remaining flow quantity going to an additional hydrograph. This allows the division of a hydrograph by a specified time.

To specify that a hydrograph is to be divided by time, the MODIFY TIME command contains the following data elements:

DATA ELEMENT		DESCRIPTION
ID NUMBER	=	The primary internal storage location (1 to 99)
TIME	=	Same as required to change the incremental time or shift by a specified time.
CODE	=	Same as required to change the incremental time or shift by a specified time.
ID REMAINDER	=	The internal storage location (ID number) for the remaining flow not sent to the primary internal storage location.
HYD REMAINDER	=	The hydrograph name (HYD number) associated with the ID remainder.
MAX TIME	=	The time in hours when the original (primary) hydrograph will be terminated and the remainder hydrograph will receive the flow data.

EXAMPLES:

```
* MODIFY INCREMENTAL TIME
MODIFY TIME           ID=2  DT=0.05 HR  CODE=3

* SHIFT HYDROGRAPH BY 2.0 HOURS
MODIFY TIME           ID=3  TIME=2.0 HRS

* SHIFT HYDROGRAPH BY 30 MINUTES
MODIFY TIME           ID=3  TIME=0.5 HRS  CODE=-1

* CHANGE THE HYDROGRAPH SO IT HAS A MINIMUM BASE FLOW OF 70 CFS
MODIFY TIME           ID=5  TIME SHIFT=0.0  BASE FLOW=-70 CFS

* COMPUTE A MINIMUM BASE FLOW OF 50 CFS AND SHIFT
*          TIME BY 30 MINUTES
MODIFY TIME           ID=4  TIME SHIFT=0.5 HR  BASE FLOW=-50.0

* MODIFY THE INCREMENTAL TIME AND STORE THE REMAINDER IN ID=12
MODIFY TIME           ID=10 DT=0.033333 HR  CODE=3
                      ID REMAINDER=12 HYD NO=THE.REMAINDER

* SHIFT HYDROGRAPH BY 2.0 HRS AND STORE REMAINDER IN ID=12
MODIFY TIME           ID=10  TIME SHIFT=2.0 HR CODE=0
                      ID REMAINDER=12 HYD NO=REMAINING.VOLUME

* MODIFY THE INCREMENTAL TIME, STORE THE REMAINDER IN ID=12 AND
*          SET THE TIME FOR HYDROGRAPH DIVISION AT 10.0 HOURS
MODIFY TIMEID=10 DT=0.033333 HR CODE=0
                      ID REMAINDER=12 HYD NO=SECOND.PART
                      MAX TIME=10.0 HOURS
```

G.14 STORE HYD

The STORE HYD command is used to store a runoff hydrograph into program memory. The hydrograph cannot contain over 4000 data points.

The STORE HYD command contains the following data elements:

DATA ELEMENT		DESCRIPTION
ID NUMBER	=	Internal storage location (1 to 99).
HYD NUMBER	=	Hydrograph identification number.
DT	=	Incremental time (hours).
DA	=	Drainage area in square miles.
FLOW RATES	=	A table of hydrograph flow rates in CFS. Up to 600 data values may be used.

EXAMPLE:

```
STORE HYD            ID=1 HYD NO=ABC  DT=0.2 HR  DA=1.5 SQ MI
                     FLOW RATES = 0 10 50 100 500 1000 1800
                     2000 1900 1500 1200 1000 800 600 500 400
                     300 200 100 50 10 1 0
```

G.15 PUNCH HYD

The PUNCH HYD command is used to send hydrograph output to a simulated output punch card file (80 columns) in the proper form for the RECALL HYD command. Normally, the output file for the PUNCH HYD command is titled AHYMO.PUN. The command can be used to save a hydrograph for future use by a separate computer analysis.

The PUNCH HYD command is followed by the following data element:

DATA ELEMENT		DESCRIPTION
ID NUMBER	=	Internal storage location (1 to 99).

EXAMPLE:

```
PUNCH HYD            ID=17
```

G.16 SAVE HYD

The SAVE HYD command is used to save a runoff hydrograph by placing it onto the Hydrograph input/output file (i.e.: AHYMO.HYD) for later input by the RECALL HYD command. The SAVE HYD command can be used to extend the number of hydrographs that can be saved beyond the limitation imposed by the maximum ID value (ID = 99). It is primarily included for compatibility with earlier versions of the program, when the number of hydrographs was more limited.

The HYD number of the hydrograph is used by the command to identify each hydrograph on the hydrograph input/output (AHYMO.HYD) file. Therefore, each hydrograph that is saved with the SAVE HYD command must have a unique HYD number.

The SAVE HYD command contains the following data elements:

DATA ELEMENT		DESCRIPTION
ID NUMBER	=	Internal storage location of the hydrograph to be saved. If a new HYD NUMBER (second data element) is not used, the hydrograph is saved with the HYD number associated with this ID number.
HYD NUMBER	=	If a HYD number is also included with the command, this HYD number will be saved on the AHYMO.HYD file in place of the HYD number that was previously associated with the ID number. This data element is optional.

The values that the program sends to the hydrograph input/output (AHYMO.HYD) file are:

the HYD number,
incremental time (hours),
area (square miles),
peak flow rate (cfs),
runoff volume (inches),
number of hydrograph points, and
the incremental flow rates (cfs) of the hydrograph.

A maximum of 10 hydrographs may be saved at with a single input/output watershed file using this command. If this value is exceeded, a previous hydrograph value is overwritten. If a hydrograph value is restored using the RECALL HYD command, the storage space is cleared and an additional SAVE HYD command may be used.

Note: The use of the SAVE HYD command requires that a Hydrograph input/output file (commonly AHYMO.HYD) be specified with the AHYMO_IO.FIL. If this file is not specified, the program will create an error message.

EXAMPLES:

```
SAVE A HYDROGRAPH AND USE THE HYD NUMBER PREVIOUSLY DEFINED
SAVE HYD                   ID=3

SAVE A HYDROGRAPH AND DEFINE WITH A NEW HYD NUMBER
SAVE HYD                   ID=4     HYD=101.21

SAVE A HYDROGRAPH AND USE A NEW ALPHA-NUMERIC HYD NUMBER
SAVE HYD                   ID=22    HYD=OUT.OF.BASIN.2A
```

G.17 RECALL HYD

The RECALL HYD command is used to read hydrograph data that was produced by the PUNCH HYD command, or to recall data saved with the SAVE HYD command. The command has similar uses to the STORE HYD command, but the format is different.

For normal input, the RECALL HYD command contains the following data elements:

DATA ELEMENT		DESCRIPTION
ID NUMBER	=	Internal storage location (1 to 99).
HYD NUMBER	=	Hydrograph identification number.
DT	=	Incremental time (hours).
DA	=	Drainage area in square miles.
PEAK Q	=	Peak flow rate in cfs.
RUNOFF VOL	=	Runoff volume in inches.
NO PTS	=	Number of hydrograph values to be entered in the flow rate table.
FLOW RATES	=	A table of incremental hydrograph flow rates in CFS. Up to 4000 data values may be used.

If the DT=0.0 for the RECALL HYD command, the command will read the hydrograph values that were saved onto the hydrograph input/output (commonly AHYMO.HYD) file with the SAVE HYD command. The HYD number of the RECALL HYD command must be identical to one of the HYD numbers used with a previous SAVE HYD command. With this alternate command format, no other data follows the DT=0.0 input.

EXAMPLES:

```
* READ A PUNCH HYD FORMAT
RECALL HYD            ID=15   HYD NO=101.25   DT=0.133333 HRS
                      DA=3.5000 SQ MI  PEAK=1550.000 CFS
                      RO=0.3333 INCHES  NO PTS=25 FLOW RATES=
                         0.000  120.000   250.000   380.000
                       520.000  660.000   810.000   970.000
                      1130.000 1300.000  1470.000  1550.000
                      1500.000 1420.000  1280.000  1100.000
                       930.000  770.000   610.000   480.000
                       380.000  390.000   200.000   100.000
                         0.000

* READ TWO HYDROGRAPHS THAT WERE SAVED WITH THE SAVE HYD COMMAND
RECALL HYD            ID=15  HYD NO=101.21        DT=0.00
RECALL HYD            ID=30  HYD=OUT.OF.BASIN.2A   DT=0.00
```

G.18 COMPUTE RATING CURVE

The COMPUTE RATING CURVE command is used to compute the rating curve of a drainage way. The program uses Manning's equation and will accept up to twenty "n" values for different portions of the cross-section. Each cross section segment, with a different "n" value, is defined by an offset from the cross-section initial point. The cross-section is defined by elevations and offsets from the cross-section initial point.

The COMPUTE RATING CURVE command contains the following data elements:

DATA ELEMENT		DESCRIPTION
CID	=	Channel identification number used for internal parameter storage (1 to 6) For most applications use CID = 1.
VS NUMBER	=	Valley section number. This is an identification number that is used to identify the unique channel segment or reach. A number between 0.1 and 999.9 may be used.
NO SEGS	=	the number of cross section segments with different Manning's "n" values. A value from 1 to 20 may be used.
MIN ELEV	=	the minimum water surface elevation in feet, that is used to compute the cross-section rating curve
MAX ELEV	=	the maximum water surface elevation in feet, that is used to compute the cross-section rating curve. This value may be lower than the maximum elevation of the cross section data.
CHANNEL SLP	=	the channel slope (foot per foot)
FP SLP	=	The flood plain or overbank slope (foot per foot)

For each cross section segment (NO SEGS) the following two data elements must be entered:

N	=	Manning's n for the cross section segment
SEG DIST	=	The offset distance for the cross section segment that defines the ending station of the segment (ft).

The shape of the channel cross section is defined by a table of offsets and elevations. The cross section table can have a maximum of twenty (20) points that described by the following two data elements:

DIST	=	The offset distance for the cross section point (ft).
ELEV	=	The elevation for the cross section point (ft).

The sign of the Manning's "n" value will determine the slope used (+ for flood plain slope, - for channel slope).

> *Note: The flood plain slope (FP SLP) should be input as a value equal to the channel slope (CHANNEL SLP) so that the sign of the Manning's "n" value does not alter the slope used in the rating curve computation. It would be very unusual for the hydraulic slope of the floodplain to be different from the hydraulic slope of the channel.*

A pipe section can be specified by placing a code of -1 (CODE = -1) for the third data element (NO SEGS) in place of the number of segments. This option contains the following data elements:

DATA ELEMENT		DESCRIPTION
SLP	=	Pipe slope (foot per foot)
DIAMETER	=	Pipe diameter (inches or feet). If the pipe diameter value is less than 12.0, units of feet are assumed; otherwise, units of inches are assumed.
N	=	Manning's "n" value for the pipe.

For a drainage way with a single rating curve (cross section), the CID is normally set to 1. If the CID is set to a negative number, the program will compute but will not print out the drainage way rating curve table.

For a channel section, the offset distance for the "n" values must correspond with one of the offset distances for the cross section points. The offset distances should increase for each cross section point. Use a small increase (i.e.: 0.01 or 0.001) to specify a vertical channel section. The current version of the AHYMO program can compute rating curves for vertical sections (offsets of 0.0) but increasing values should be used to clarify the section properties used in the rating curve computation.

The determination of the total flow conveyance for a channel cross section requires that the conveyance and velocity be computed for individual channel segments that have a uniform velocity. The COMPUTE RATING CURVE command uses the n-value break points as the basis for subdivision of the conveyance computation. The total flow conveyance for the channel is computed as the sum of the conveyances of the individual n-value segments. This approach is similar to the default conveyance method used with the *HEC-RAS River Analysis System* (US Army Corps of Engineers, Hydraulic Reference Manual, Version 1.0, July 1995). In order to follow the HEC-RAS computation convention, it is necessary for the AHYMO program input file to identify the channel and overbank areas as separate segments, even if the same n-value is specified for the separate segments. Specifying different n-values in the overbank area provides for the separate computation of overbank conveyance for each n-value location.

The *HEC-2 Water Surface Profiles* computer program (US Army Corps of Engineers, User's Manual, 1990) computes a separate conveyance for each overbank segment even when the n-value does not change. The main channel area is computed with a single conveyance factor with HEC-2. In order to follow the HEC-2 method of conveyance computation with the AHYMO program, each overbank area segment must be identified as a separate n-value segment. The main channel segment should be included as one segment with a single n-value.

CHANNEL EXAMPLES:

```
* CHANNEL WITH THREE SEGMENTS & DIFFERENT MAIN
* AND OVERBANK SLOPES
COMPUTE RATING CURVE CID=1 VS NO=10 NO SEGS=3
                      MIN ELEV=482 FT  MAX ELEV=492 FT
                      CH SLP=0.006  FP SLP=0.0075  N=0.05
                      DIST=175 FT  N=-0.03  DIST=205  N=0.05
                      DIST=450 FT
                     DIST  ELEV   DIST  ELEV    DIST  ELEV
                       0   492.0  100  490.0    175  484.0
                     188  482.0   190  482.0    205  484.0
                     250  486.0   175  488.0    310  490.0
                     450  492.0

* CHANNEL WITH THREE SEGMENTS, AND WITH UNIFORM N-VALUES
* AND SLOPES
COMPUTE RATING CURVE  CID=1  VS NO=11  NO SEGS=3
                      MIN ELEV=482 FT  MAX ELEV=492 FT
                      CH SLP=0.006  FP SLP=0.006  N=0.05
                      DIST=175 FT  N=0.05  DIST=205  N=0.05
                      DIST=450 FT
                      DIST  ELEV    DIST  ELEV    DIST  ELEV
                        0  492.0    100  490.0    175  484.0
                      188  482.0    190  482.0    205  484.0
                      250  486.0    175  488.0    310  490.0
                      450  492.0
```

PIPE EXAMPLE:

```
COMPUTE RATING CURVE CID=1 VS NO=1 CODE=-1  SLP=0.005
                    DIA=4.0 FT  N=0.015
```

G.19 STORE RATING CURVE

The STORE RATING CURVE command is used to store the rating curve of a channel or drainage way cross-section.

The STORE RATING CURVE command contains the following data elements:

DATA ELEMENT		DESCRIPTION
CID	=	Channel identification number used for internal parameter storage (1 to 6). For most applications use CID=1
VS NUMBER	=	Valley section number. This is an identification number that is used to identify the unique channel segment or reach. A number between 0.1 and 999.9 may be used. A negative number will specify use of flow width in the channel rating table.

The remaining data is a channel rating table of twenty table elements, with each table element having the following data elements:

ELEVATION	=	elevation of water level in feet
AREA	=	cross-section area of flow (sq ft)
FLOW	=	flow rate (cfs).

If the valley section number (VS NUMBER) is input as a negative value, the channel rating table must have the following additional data element:

F WIDTH	=	width of the water surface in feet. This value is used only if the VS NUMBER is negative.

The ROUTE MCUNGE command requires the input of a flow width at each element of the channel rating table. If the STORE RATING CURVE command is used with input of only the elevation, area and flow values in the channel rating table, the AHYMO program will compute an estimate of the width of water surface (F WIDTH) using the elevation and area values.

> *Note: The CID numbers for a channel rating curve are independent of the ID numbers used for hydrographs.*

The program expects that 20 table elements will be input with this command. If less than 20 table elements are used, the program will fill the table with extrapolated values, which may not accurately represent the channel properties. Therefore, it is recommended that 20 elements be used.

The first element should be at the elevation of the channel low point with area = 0.0 and flow rate = 0.0. For a channel or drainageway reach with a single rating curve, the CID is normally set to 1.

EXAMPLES:

```
STORE RATING CURVE CID=1 VS NO=15
                    ELEV     AREA      FLOW
                     (FT)  (SQ FT)     (CFS)
                     100       0         0
                     100.4     2         1
                     101.4     9        19
                     102.4    19        52
                     103.4    30        98
                               ●         ●     TWENTY
                               ●         ●     POINTS
                               ●         ●     ARE
                     118.4   300       500    RECOMMENDED

STORE RATING CURVE CID=1 VS NO=-15
                    ELEV     AREA      FLOW     FLOW WIDTH
                     (FT)  (SQ FT)     (CFS)     (FT)
                     490.      0.0      0.0      10.0
                     492.     24.      17.       14.0
                     494.     56.      57.       18.0
                     495.     75.      86.       20.0
                     495.5    96.     106.       64.0
                     496.    138.     132.      104.0
                     496.5   202.     164.      152.0
                     497.    287.     205.      188.0
                     498.    522.     319.      282.0
                     499.    843.     482.      360.0
                     500.   1250.     705.      454.0
                     502.   2330.    1362.      626.0
                     504.   3770.    2361.      814.0
```

G.20 COMPUTE TRAVEL TIME

The COMPUTE TRAVEL TIME command is used to compute a travel time table from a rating curve table. This command is only used with the ROUTE command; it is not used with the ROUTE MCUNGE command.

The COMPUTE TRAVEL TIME command contains the following data elements:

DATA ELEMENT		DESCRIPTION
ID NUMBER	=	Internal storage location (1 to 99). The travel time ID number must equal the outflow hydrograph ID number used in the subsequent ROUTE command.
REACH NUMBER	=	A channel reach identification number. The reach number is used by the program user to identify the travel time table; it is not used by the program for computation.
NO VS	=	Number of valley sections. If the number of valley sections (NO VS) is greater than 1, the program looks for that many rating curves. If one (1) valley section is used, the program normally uses the rating curve from channel CID=1. If 3 valley sections are used in a reach, 3 rating curves identified with consecutive channel CID numbers (CID=1, CID=2, and CID=3) will be averaged to compute the travel time table.
LENGTH	=	Reach Length (feet).
SLP	=	Slope of the reach (foot per foot)

If the "number of valley sections" (NO VS) is entered as a negative number, only a single rating curve is used with the rating curve CID equal to the absolute value of the valley section number specified. This allows the travel time computation to select a rating curve for a CID value other than 1.

To avoid convergence problems with the ROUTE command use a **length * slope greater than 0.030**.

If the ID number is input as a negative number, the program will compute but not print out the drainage way "rating curve-travel time" table.

EXAMPLES:

```
*COMPUTE A TRAVEL TIME TABLE FROM 3 RATING CURVES
COMPUTE TRAVEL TIME   ID=3  REACH NO=8  NO VS=3  L=4500 FT
                      SLP=0.0075

*COMPUTE A TRAVEL TIME TABLE FROM A SINGLE RATING CURVE
COMPUTE TRAVEL TIME   ID=3  REACH NO=2  NO VS=1  L=2000 FT
                      SLP=0.0075

*COMPUTE A TRAVEL TIME TABLE FROM A RATING CURVE W/ CID=4
COMPUTE TRAVEL TIME   ID=3  REACH NO=8  NO VS=-4  L=2500 FT
                       SLP=0.0075
```

G.21 STORE TRAVEL TIME

The STORE TRAVEL TIME command is used to store a travel time table. A travel time table is required to route a hydrograph through a pipe or channel using the ROUTE command. This command is not required by the ROUTE MCUNGE command.

The STORE TRAVEL TIME command contains the following data elements:

DATA ELEMENT		DESCRIPTION
ID NUMBER	=	Internal storage location (1 to 99). The travel time ID number must equal the outflow hydrograph ID number used in the subsequent ROUTE command.
REACH NUMBER	=	A channel reach identification number. The reach number is used by the program user to identify the travel time table; it is not used by the program for computation.
LENGTH	=	Reach Length (feet).
SLP	=	Slope of the reach (foot per foot)

A table with up to nineteen table elements must be input, with each table element having the following data elements:

DEPTH	=	depth of flow (ft)
FLOW	=	rate of flow (cfs)
TRAVEL TIME	=	travel time (hr)

The program expects that 19 table elements will be input with this command. If less than 19 elements are used, the program will fill the table with extrapolated values that may not accurately represent the channel properties. Therefore, it is recommended that 19 elements be used. The first element input must contain non-zero depth, flow and travel time values.

EXAMPLE:

```
STORE TRAVEL TIME     ID=2  REACH NO=7  L=1000 FT
                       SLOPE=0.00125
                      DEPTH (FT) FLOW (CFS) TRAVEL TIME (HR)
                      0.11         0.4        0.730
                      0.53         6.3        0.267
                      1.25        29.9        0.162
                      1.79        57.1        0.134
                      2.00        70.6        0.126
                        •          •            •
                        •          •            •    NINETEEN
                        •          •            •    POINTS ARE
                      5.00       125.8        0.034  RECOMMENDED
```

G.22 ROUTE

The ROUTE command uses the previously computed or input travel time table (with the same ID number) to route a hydrograph through a channel reach and lag it by the travel time. This command uses the variable storage coefficient flood-routing method to account for variation in water surface slope during a flood. See the ARS HYMO Manual for further details on this procedure. The ROUTE command must follow the travel time table.

The ROUTE command contains the following data elements:

DATA ELEMENT		DESCRIPTION
ID NUMBER	=	Internal storage location of the outflow hydrograph (1 to 99).
HYD NUMBER	=	Hydrograph identification number of the outflow hydrograph.
INFLOW ID	=	The internal storage location of the inflow hydrograph.
DT	=	Computation time step in hours. If the computation time (DT) is not changed from the inflow hydrograph, a DT=0.0 should be specified to use the DT from the inflow hydrograph.

The ID number of the inflow hydrograph must be different from the ID number of the outflow hydrograph.

EXAMPLES:

```
ROUTE                    ID=7 HYD NO=120.3 INFLOW ID=15 DT=0.25 HR

ROUTE                    ID=35 HYD NO=PARK.5A INFLOW ID=3  DT=0.0
```

Note: The ROUTE command uses the variable storage coefficient routing procedure that was a part of the Agricultural Research Service HYMO program. Program users should note the following statement contained in the conclusions of "Application of Muskingum-Cunge Routing to Steep Slope Arid Arroyos" (C.E. Anderson and R.J. Heggen, 1995, Proceedings of the Conference on Arid West Floodplain Management Issues, San Diego, California, Association of State Flood Plain Managers and Arizona Floodplain Management Association) "The variable storage coefficient (VSC) routing procedure of AHYMO that has been commonly used in the Albuquerque area, may produce significant routing errors for sharply peaked hydrographs in natural arroyos. The Muskingum-Cunge method should be generally be (sic) used in preference to VSC routing."

G.23 ROUTE MCUNGE

The ROUTE MCUNGE command uses the Muskingum-Cunge procedure to route a hydrograph through a channel reach. "The Muskingum-Cunge routing technique is a non-linear coefficient method that accounts for hydraulic diffusion based on physical channel properties and the inflowing hydrograph." (Ref: *HEC-1 Flood Hydrology Package User's Manual*, US Army Corps of Engineers, Davis California, 1990, p. 30) The ROUTE MCUNGE command must follow a COMPUTE RATING CURVE or STORE RATING CURVE command. The COMPUTE TRAVEL TIME command is not used with this command. The ROUTE MCUNGE command always uses the rating data from the previously defined rating curve (as created by the COMPUTE RATING CURVE command or the STORE RATING CURVE command).

The ROUTE MCUNGE command requires the following data elements:

DATA ELEMENT		DESCRIPTION
Outflow Hydrograph ID Number	=	Internal storage location (1 to 99).
Outflow HYD Number	=	Hydrograph identification number.
Inflow Hydrograph ID Number	=	Previously defined internal storage location (1 to 99).
DT	=	Computation time step in hours. Suggested value is 0.0, and the time step from the inflow hydrograph is used. If the time step is positive, the minimum of that value or a value determined by the program is used. If the time step is negative, that absolute value is used. Unless there is a need to change the DT value from the value specified in the RAINFALL command, use DT = 0.0.
Length	=	Length of the channel or arroyo reach in feet.
Number of Subreaches	=	Number into which the channel or arroyo reach is to be computationally divided. Suggested value is 0, and the program determines the appropriate value. If the number of subreaches is positive, the maximum of that value or a value determined by the program is used. If the number is negative, that absolute value is used.
Slope	=	Slope of the channel or arroyo reach in foot per foot. For mild slope conditions, the slope of the energy grade should be used.

Matrix Code = The matrix code is 1 if detail of the routing solution is to be printed, 0 if it is not to be printed. The matrix may allow confirmation of numeric stability, but the printout will likely be very long. A value of 0 is normally used.

Regression Code = The regression code is 0 if the Muskingum-Cunge C's are to be fit to the rating curve using non-linear interpolation. Use 1 if the C's are to be fit to a logarithmic function of the Q values. Regression may smooth computational anomalies, but can mask hydraulic consequences of significant changes in adjacent roughness. Use 2 if data is to be fit to the rating curve using linear interpolation. Use 3 if data is to be fit to the rating curve using a step function and if a non-iterative 3-point average will be used in the routing computation; this is similar to the function of the AHYMO194 computer program. A Regression Code of 0 should be used in most applications.

C Code = C code is 1 if the C's must each be nonnegative (Fread's suggested procedure), 2 if C1 must be nonnegative (Ponce's suggested procedure), and 3 if the C's may take any sign. If C code is 0 and the DT is larger than 0.015 hours, the program first routes with Ponce's suggested procedure; then, if the routing is unstable, flow is rerouted with Fread's suggested procedure. If C code is 0 and the DT is 0.015 hours or smaller, the program only uses Ponce's suggested procedure for routing. The program identifies an unstable condition as a negative flow rate, or as the outflow peak higher than the inflow peak. The usual suggested value for C Code is 0 with a DT = 0.01 or 0.005 hours specified in the RAINFALL command.

MM Code = This data item specifies the ratio between the minimum flow and the maximum flow that will be used in the computation of the incremental time of routing. If MM Code is 1, the maximum flow rate will be used. If MM Code is less than 1, a ratio between the maximum and minimum value will be used. The default value is 0.5. The usual suggested value is 0, and the program will use the default ratio of 0.5. Since the MM Code is the last data element of the ROUTE MCUNGE command, the value need not be specified and the default value will be used.

The ID number of the inflow hydrograph must be different from the ID number of the outflow hydrograph.

Further information on the Muskingum-Cunge method of flood routing is contained in Appendix A. The Fread and Ponce suggested procedures are further explained in *Engineering Hydrology, Principles and Practices* (V.M. Ponce, 1989, Prentice Hall, Englewood Cliffs, NJ) and D.L. Fread, "Flow Routing" (Chapter 10, *Handbook of Hydrology*, David R. Maidment, Editor, 1992, McGraw-Hill, New York, NY). Testing of the AHYMO program in 2009 (Stantec, Inc. for SSCAFCA) indicated the use of Fread's suggested procedure shifted the peak intensity of the resulting hydrograph and that when the routed hydrographs were added to other hydrographs in a complex hydrologic model, the resulting peak flow rates were lower than should have been computed. The use of Ponce's suggested procedure did not produce this problem. In order to avoid numerical instability with Ponce's suggested procedure, it was necessary to reduce the computation time interval (DT) to 0.01 hours or less. Use of a small computation time interval required a large number of hydrograph points to represent the entire outflow hydrograph for a 6-hour or 24-hour store event. To meet this requirement, the current version of AHYMO can now accommodate 4000 data points in a hydrograph.

Recommendation: The ROUTE MCUNGE command should be specified for all natural and constructed open channels, with C CODE = 0 and with the RAINFALL command having a DT= 0.01 hours (or smaller) to restrict Muskingum-Cunge channel routing to the Ponce's formulation.

EXAMPLES:

```
* SPECIFY VALUES FOR DT, MATRIX CODE, REGRESSION CODE, C CODE
*      AND MM CODE
ROUTE MCUNGE ID=2 HYD NO=110 INFLOW ID=1
                      DT=0.01 HR   LENGTH=20000 FT
                      NS=0   SLOPE=0.001   MATCODE=1
                      REGCODE=3  CCODE=2   MM CODE=0.6

* SPECIFY VALUES FOR MATRIX CODE, REGRESSION CODE AND C CODE,
*     BUT NOT FOR MM CODE
ROUTE MCUNGE ID=3 HYD NO=113 INFLOW ID=1
                      DT=0.0   LENGTH=20000 FT
                      NS=0   SLOPE=0.001   MATCODE=1
                      REGCODE=1  CCODE=0

* DO NOT SPECIFY VALUES FOR DT, MATRIX CODE, REGRESSION CODE,
*      C CODE OR MM CODE (USE DEFAULT VALUES)
ROUTE MCUNGE ID=2 HYD NO=110 INFLOW ID=1  DT=0.0
                      LENGTH=20000 FT   NS=0   SLOPE=0.001
```

G.24 ROUTE RESERVOIR

The ROUTE RESERVOIR command is used to route a hydrograph through a detention system using the storage-indication method. A table, containing a maximum of fifty points, defines the outflow and storage characteristics of the detention system.

The ROUTE RESERVOIR command contains the following data elements:

DATA ELEMENT		DESCRIPTION
ID NUMBER	=	Internal storage location of the outflow (routed) hydrograph (1 to 99).
HYD NUMBER	=	Hydrograph identification number of the outflow (routed) hydrograph.
INFLOW ID	=	The internal storage location of the inflow hydrograph.

This data is followed by a table of up to fifty (50) outflow-storage elements, with each table element having the following data elements:

OUTFLOW	=	Reservoir outflow (cfs).
STORAGE	=	Reservoir storage (ac ft).

The outflow and storage values must increase for each point in the outflow-storage table. The first line of the outflow-storage table must have 0.0 values for outflow and storage. A maximum of 50 outflow storage lines may be input.

If the HYD number (HYD NO) is input as a negative number, the inflow hydrograph values are transferred to the outflow hydrograph and reservoir routing is bypassed. This capability is useful when evaluating a watershed network with and without a reservoir in place.

EXAMPLE:

```
ROUTE RESERVOIR       ID=5  HYD NO=501   INFLOW ID=3
                      OUTFLOW (CFS)      STORAGE (AC FT)
                         0                    0
                        22                  533
                       200                  555
                      1000                  601
                      2000                  648
                      3000                  694
```

A preferred alternate form of the ROUTE RESERVOIR command allows the input and output of elevation data. If a code designation is added after the INFLOW ID (after the third data element, input of CODE = a number greater than 0.0), the reservoir table must contain the following data elements:

DATA ELEMENT		DESCRIPTION
OUTFLOW	=	Reservoir outflow (cfs).
STORAGE	=	Reservoir storage (ac ft).
ELEVATION	=	Reservoir elevation (ft)

The following example shows the command format with input of elevation data:

EXAMPLE:

```
ROUTE RESERVOIR       ID=4  HYD=POND.103  INFLOW ID=3 CODE=5
                      OUTFLOW(CFS)  STORAGE(AC FT)  ELEV(FT)
                       0             0               100
                      10             0.5             102
                      15             1.0             104
                      20             2.0             106
                      25             4.0             108
```

The outflow (cfs) and storage (ac ft) for the first line of the outflow-storage-elevation table must be input as 0.0. A maximum of 50 outflow-storage-elevation lines may be included on the input table.

The value of the code designation refers to the number of points that will appear on the hydrograph routing table in the ROUTE RESERVOIR output. Integer codes, with values up to 24, are accepted by the AHYMO program; for example:

Code	Meaning
1	All points appear in output
2	Every 2nd point appears in output
3	Every 3rd point appears in output
5	Every 5th point appears in output
10	Every 10th point appears in output
24	Every 24th point appears in output

A CODE=0 is not permitted since this would show the original ROUTE RESERVOIR format with no elevation data.

If a code number is entered as a real number with a non-zero number following the decimal point, the outflow hydrograph is given a DT (incremental time) equal to the inflow DT times the integer value in the "tenth position", to the right of the decimal point. "Tenth position" numbers from 1 to 8 are accepted by the program (i.e., 1.1 to 8.8). The "tenth position" number must be an even ratio of the whole number portion to the left of the decimal (i.e., 3.3, 4.2, 6.3, 9.3, 12.4, 15.5, 20.5, 21.7, 24.8). If not, the code number will be adjusted by the program to meet this condition. This option is useful when the time to route through a reservoir exceeds the inflow hydrograph DT times 4000.

When the Route Reservoir command is used with the real number code option to increase the DT of the outflow hydrograph, this DT value may not be preserved with the next ADD HYD command. The ADD HYD command normally uses the smallest DT for the new hydrograph. The MODIFY TIME command can be used to change the DT for a hydrograph so that the longer DT can be maintained. The largest DT can be specified in the ADD HYD command by assigning a negative number to the ID number with the largest DT.

G.25 PRINT HYD

The print HYD command is used to print the 4000 points of a hydrograph, the peak flow rate, time of peak flow, runoff volume, and basin area.

The PRINT HYD command contains the following data elements:

DATA ELEMENT		DESCRIPTION
ID NUMBER	=	Internal storage location of the hydrograph (1 to 99).
CODE	=	A code number used to control the detail of the hydrograph printing.

The code number indicates the number of points of the hydrograph to be printed based on the following table:

CODE	VALUES
0	All values and totals
1	Only totals
2	Every 2nd value and totals
3	Every 3rd value and totals
5	Every 5th value and totals
10	Every 10th value and totals
20	Every 20th value and totals

EXAMPLES:

```
PRINT HYD           ID=12 CODE=1

PRINT HYD           ID=50 CODE=5
```

Note: It is good practice to include a PRINT HYD command after every hydrograph computation (COMPUTE HYD and COMPUTE NM HYD commands), after every routing command (ROUTE, ROUTE MCUNGE and ROUTE RESERVOIR), after every hydrograph addition (ADD HYD command) and after every hydrograph division (DIVIDE HYD and MODIFY TIME commands).

G.26 PLOT HYD

The PLOT HYD command is used to plot one or two hydrographs using line printer characters.

The PLOT HYD command contains the following data elements:

DATA ELEMENT		DESCRIPTION
ID ONE	=	Internal storage location of the first hydrograph,
ID TWO	=	Internal storage location of the second hydrograph. Enter 0 of only one hydrograph is to be plotted.
Q SCALE	=	The scale of the ordinate (peak flow). Enter 0 if the scale will be determined by the maximum hydrograph flow rate. If the maximum peak flow of either hydrograph exceeds the Q SCALE maximum value, this hydrograph value will override the specified value.
T SCALE	=	The scale of the abscissa (time) for the plot. Enter 0 if the time scale is to be established by the maximum time of hydrograph flow.

EXAMPLES:

```
* PLOT ONE HYDROGRAPH
PLOT HYD              ID=17

* PLOT TWO HYDROGRAPHS
PLOT HYD              ID=16  ID=17

* PLOT ONE HYDROGRAPH TO SPECIFIED SCALE
PLOT HYD              ID=16  ID=0   Q SCALE=500  T SCALE=6.0

* PLOT TWO HYDROGRAPHS TO SPECIFIED SCALE
PLOT HYD              ID=16  ID=17  Q SCALE=500  T SCALE=12.0
```

G.27 COMPUTE K AND TP

The COMPUTE K AND TP command is used to calibrate the AHYMO unit hydrograph shape (three segment gamma function) so that the peak flow and/or time to peak of a hydrograph are equal to specified values. This is accomplished by modifying the K and TP values until the values are equal to the specified values. The shape of the HYMO unit hydrograph is determined by K/TP, and the peak flow will vary by the K/TP ratio.

The COMPUTE K AND TP command makes calls to the COMPUTE HYD command and the input data includes the COMPUTE HYD command data elements, followed by the calibration data. If the calibration data only contains a peak flow quantity, only the K value is calibrated. If both a peak flow and a time to peak flow value is specified, both the K and TP values will be calibrated. If a previously computed hydrograph is specified by input of a negative number as the calibration value (the absolute value will represent the ID of a previously computed hydrograph), both the K (k) and TP (t_p) values are calibrated so that the hydrograph values match the values of the previously computed hydrograph.

Note: This command will generate a large quantity of printout and its use should normally be used for specialized output. In addition to normal program output, calibration output is sent to the AHYMO.PUN file (simulated punch cards) to simplify acquisition of calibration data.

EXAMPLES:

```
* CALIBRATE K TO A PEAK FLOW RATE
COMPUTE K AND TP      ID=3   HYD NO=121   DT=0.01 HR
                      DA=0.15 SQ MI   CN=68   K=-0.08
                      TP=-0.16 HR   MASS      RAIN=-1
                      CALIBRATED PEAK=300 CFS

* CALIBRATE K AND TP TO A PEAK FLOW RATE AND TIME OF PEAK
COMPUTE K AND TP      ID=3   HYD NO=121   DT=0.01 HR
                      DA=0.15 SQ MI   IA=-0.05   INF=-0.85
                      K=-0.08   TP=0.16   MASS     RAIN=-1
                      CALIBRATED PEAK=250 CFS
                      CALIBRATED TIME OF PEAK=1.75 HRS

* CALIBRATE K AND TP TO PEAK AND TIME OF AN EXISTING HYDROGRAPH
COMPUTE K AND TP      ID=4   HYD NO=153   DT=0.00
                      DA=0.25 SQ MI  CN=95   K=-0.125
                      TP=0.250   MASS         RAIN=-1
                      CALIBRATE TO ID=-2
```

G.28 ERROR ANALYSIS

The ERROR ANALYSIS command will determine the error at each hydrograph point, the error standard deviation and the percentage error in peak flows, between two hydrographs.

The ERROR ANALYSIS command contains the following data elements:

DATA ELEMENT		DESCRIPTION
ID ONE	=	Internal storage location of the first hydrograph (1 to 99).
ID TWO	=	Internal storage location of the second hydrograph (1 to 99).

EXAMPLE:

```
ERROR ANALYSIS      ID=5   ID=2
```

G.29 SEDIMENT BULK

The SEDIMENT BULK command multiplies the values of computed hydrographs by a factor to simulate the effects of sediment bulking (the increase in flow rate caused by the movement of sediment with the water). A single bulking factor or a table of bulking factors based on flow rate (cfs) may be input. The bulking factor is applied to the hydrographs computed by the COMPUTE HYD, COMPUTE NM HYD and COMPUTE ALB HYD commands. The factor is applied to hydrographs that are computed by commands that follow the SEDIMENT BULK command.

The SEDIMENT BULK command contains the following data elements:

DATA ELEMENT		DESCRIPTION
CODE	=	a code to specify a single bulking factor (CODE=1) or a table of flow rates and bulking factors (CODE=2). If CODE=1, the single bulking factor is the next input value. If CODE=2, the table of flow rates (cfs) and bulking factors is input. A table with up to 10 bulking factor elements may be included if CODE=2.
BULK FACTOR	=	the single bulking factor when CODE=1, or

when CODE=2, enter a table of flow rates and bulking factors as follows:

Q	=	The flow rate in CFS associated with the bulking factor
BULK FACTOR	=	The bulking factor for the given flow rate.

Note: Program users are cautioned that the use of a SEDIMENT BULKING factor is frequently not sufficient to examine all concerns when addressing the ability of a structure or conveyance to safely transport sediment. When the sediment conveyed to a facility exceeds the transport capacity, aggradation (deposition) may significantly reduce the ability to convey water. This is particularly a concern at bridges, culverts and small ponding areas where headwater conditions may significantly reduce sediment transport capacity and cause plugging of structures.

EXAMPLES:

```
* SINGLE FACTOR
SEDIMENT BULK CODE = 1    BULK FACTOR = 1.10

* BULK FACTOR TABLE
SEDIMENT BULK          CODE = 2
                      AT Q = 220 CFS   FACTOR = 1.02
                      AT Q = 500 CFS   FACTOR = 1.05
                      AT Q = 2000 CFS  FACTOR = 1.15
```

G.30 SED WASH LOAD (SEDIMENT YIELD)

The SED WASH LOAD command computes the wash load sediment yield, in tons, from a watershed area based on a basin hydrograph using the Modified Universal Soil Loss Equation (MUSLE, Ref: J.R. Williams, 1975, "Sediment-Yield Prediction With Universal Equation Using Runoff Energy Factor", in *Present and Prospective Technology for Predicting Sediment Yields and Sources,* US Dept. Agriculture, ARS-S-40, pp 244-252) . The command was called SEDIMENT YIELD in ARS HYMO and in earlier versions of this program, but was renamed to more clearly identify the command applicability. The original command name may be used with the current program version to provide compatibility with previous input file structures.

The SED WASH LOAD command contains the following data elements:

DATA ELEMENT		DESCRIPTION
ID NUMBER	=	Internal storage location of the watershed area (1 to 99).
SOIL K	=	A soil erodibility factor (K).
CROP C	=	A cropping management factor (C).
EROSION PRACTICE P	=	An erosion control practice factor (P).
LS	=	A watershed length and gradient factor (LS).
PER IMPERV	=	A percentage of impervious watershed treatment.
WASH LOAD FACTOR	=	A wash load factor that defines an adjustment for arid or local conditions. If a wash load factor of 0.0 is specified, the program uses the default value of 3.0. A value of 1.0 will negate the wash load factor. A value of 0 or 3 is recommended.

Recent tests in New Mexico suggest that the MUSLE equation may be used to estimate wash load (suspended fine sediment load, but not including any transport of bed material) when the sediment yield from the MUSLE equation is multiplied by three (3.0). The WASH LOAD FACTOR in this command is used to input this multiplication value.

The SED WASH LOAD command is best applied when local calibration is available. It will compute total sediment load only for very mild slope conditions that are applicable for the MUSLE equation, where bed material is not a significant percentage of total sediment loading. In the arid southwest, sediment from bed load may be substantially greater than the wash load, so that the SED WASH LOAD command alone cannot be used to directly compute total sediment yield. If appropriate local factors are available, the SEDIMENT TRANS command may be combined with the SED WASH LOAD command to compute the bed material load and total sediment load that can be transported in a channel section.

EXAMPLES:

```
* PREFERRED FORM OF COMMAND NAME
SED WASH LOAD         ID=5  SOIL K=0.34  CROP C=0.5
                      EROSION PRACTICE P=0.6  LS=1.3
                      PER IMPERV=10  WASH LOAD FACTOR=0.0

* ALTERNATE FORM OF COMMAND NAME
SEDIMENT YIELD        ID=5  SOIL K=0.34  CROP C=0.5
                      EROSION PRACTICE P=0.6  LS=1.3
                      PER IMPERV=10  WASH LOAD FACTOR=3.0
```

G.31 SEDIMENT TRANS

The SEDIMENT TRANS command computes the bed material transport capacity of an arroyo or channel section. The command uses a power function of the following form:

$$q_s = a\,V^b\,Y^c\,(1 - C_f)^d \qquad \textit{(g.26)}$$

where:	q_s	=	unit bed material load (cfs/ft)
	V	=	average velocity (fps)
	Y	=	hydraulic depth (feet) = area/top width
	C_f	=	fine sediment or wash load (silt and clay) concentration by weight expressed as a fraction (i.e.: 0.020)
	a, b, c and d	=	factors or coefficients defined for local soil conditions.

For arid and semi-arid conditions similar to those in Albuquerque, New Mexico area, factors and coefficients (a, b, c and d) have been developed for the Meyer-Peter and Muller bed load equation, and Woo's modification to the H.A. Einstein method for computing suspended sediment concentration (R.A. Mussetter, P.F. Lagasse and M.D. Harvey for Resource Consultants & Engineers, Inc. and C.E. Anderson contributing editor for AMAFCA, *Sediment and Erosion Design Guide*, November 1994). The factors for the MPM-Woo Method will vary based on the gradation of the bed material. See Figure 3.10 of the *Sediment and Erosion Design Guide* (page 3-38) for a diagram of the a, b, c and d factors. Other forms of the equation coefficients are described in *Engineering Analysis of Fluvial Systems* (Simons, Li and Associates, 1982) and in *Design Guidelines for Channels and Hydraulic Structures on Sandy Soils* (Simons, Li and Associates, 1981, for Urban Drainage and Flood Control District, Denver, Colorado). Zeller and Fullerton developed a relationship for channels with very low fine sediment loads ("A Theoretically Derived Sediment Transport Equation for Sand-Bed Channels in Arid Regions" *Proc. of the D.B. Simons Symposium on Erosion and Sedimentation*, 1983) with the following form:

$$q_s = 0.0064\, n^{1.77}\, V^{4.32}\, G^{0.45}\, Y^{-0.30}\, D_{50}^{-0.61} \qquad \textit{(g.27)}$$

where:	n	=	Manning's Roughness Coefficient
	D_{50}	=	Average bed material gradation (mm)
	G	=	gradation coefficient of bed material

The power function equation of the SEDIMENT TRANS command can then be applied to the Zeller and Fullerton equation by use of the following relation:

$$a = 0.0064\, n^{1.77}\, G^{0.45}\, D_{50}^{-0.61} \qquad (g.28)$$
$$b = 4.32$$
$$c = -0.30$$
$$d = 0.0$$

For the Albuquerque area and similar New Mexico conditions, it is recommended that the MPM-Woo method be used and along with the coefficients from Figure 3.10 (p. 3-38) of the *Sediment and Erosion Design Guide*.

The change in sediment volume of a channel reach can be estimated from the following equation:

$$dv = [q_s(inflow) - q_s(outflow)]\, dt \qquad (g.29)$$

where:

dv	=	volume of sediment stored(+) or lost(-) in the channel reach.
qs(inflow)	=	sediment transport rate into the reach from upstream and lateral sources.
qs(outflow)	=	sediment transport rate out of reach.
dt	=	incremental time for volume change

The SEDIMENT TRANS command contains the following data elements:

DATA ELEMENT		DESCRIPTION
ID NUMBER	=	Internal storage location of the hydrograph being routed through the channel (1 to 99).
IDS	=	A sediment storage location for sediment data (1 to 6).
CODE	=	A code to determine the frequency of printing the hydrograph values and sediment transport factors (use CODE = 1 to print every hydrograph value, CODE = 2 prints every 2nd value, etc).
a Coef b Exp c Exp d Exp	=	The coefficient and exponent factors for the power function equation.
NUMB WASH	=	Number of elements in the table of wash load concentration values. If this value is 1 only a single concentration value is required, If it is -1, the concentration is obtained from the previous SED WASH LOAD command, and no concentration values are specified.
WASH LOAD concentration table	=	A table of flow rates and wash load concentrations (PPM-w). The first flow rate is set by the program to zero (0.0) and is not input. Up to 10 flow rate/concentration elements are allowed.

Number of section elements = Number of elements in the section properties table. If this value is negative, (CID = -1 to -6) the section properties are obtained from the from the previous COMPUTE RATING CURVE command for the CID identified.

Section Properties Table (Flow, Velocity & Width) = A table of section properties used to describe a channel section, defined as flow (cfs), velocity (ft/sec) and top width (ft). It is recommended that the section properties be based on a channel analysis using various flow rates and a standard step water surface profile analysis (using HEC-RAS, HEC-2 or WSPRO). The use of section properties based on the Manning's equation in the COMPUTE RATING CURVE command may provide a less accurate estimate of the sediment transport capacity of a channel reach.

The SEDIMENT TRANS command uses a maximum wash load concentration of 60,000 PPM-w when computing bed material transport rate, when the wash load concentration comes from the SED WASH LOAD command (NUMB WASH = -1). In this case, higher concentrations are set to 60,000 PPM-w in the power function equation, but the higher concentration is included in the wash load and total sediment computations. If wash load concentrations are directly input into the command, these input values are used even if they exceed 60,000 PPM-w. Bed material concentrations are not allowed to exceed 650,000 PPM-w. This is the approximate upper limit for mud flooding, and above this value, the water/sediment mixture is no longer a Newtonian Fluid and the basic hydraulic and sediment transport assumptions no longer apply.

EXAMPLES:

```
* Using wash load concentration table and
* section properties from COMPUTE RATING CURVE command
SEDIMENT TRANS        ID=41   IDS=2   CODE=10
                      A FACT=0.0000015   B EXP=5.75
                      C EXP=-0.6   D EXP=-2.1   NUMBER WASH=4
                                      CONC=10000 at ZERO cfs
                      AT Q=1000 cfs   CONC=20000 PPM
                      AT Q=3000 cfs   CONC=30000 PPM
                      AT Q=10000 cfs  CONC=40000 PPM  CID=-1
```

```
* Using a single wash load concentration and
* section properties table based on a HEC-2 Analysis
SEDIMENT TRANS         ID=41  IDS=1  Code=1
                       A FACT=0.0000015  B EXP=5.75
                       C EXP=0.6  D EXP=-2.1   NUMBER WASH=1
                       WASH CONC=22000 PPM   Number Sections=6
                       Flow       Velocity     Width
                       (CFS)     (Feet/Sec)    (FT)
                       25           4.02       18.1
                       50           5.22       18.3
                       100          6.68       19.1
                       350          9.96       24.1
                       680         12.18       26.9
                       1050        13.72       28.6

* Using wash load concentration from SED WASH LOAD command
* and section properties from COMPUTE RATING CURVE command
SEDIMENT TRANS         ID=25  IDS=3   CODE=20
                       A COEF=0.0000015  B EXP=5.75
                       C EXP=-0.6  D EXP=-2.1
                       NUMBER WASH=-1   CID=-1
```

H. PROGRAM ERRORS

Occasionally program execution will terminate abnormally due to input data errors. These may be in the form of messages generated by the program or by system errors generated by the operating system. When experiencing errors, the first step should be to check the output file. The program will frequently terminate immediately after an input error is detected in a command. Since the program only reads numbers, signs and the decimal point, in columns 21 through 79 (except at HYD NOs and the LOCATION command) these elements should be checked carefully. Some common errors experienced by users are:

- Not spelling the command names exactly (in columns 1 through 20). Lowercase letters are allowed in the command field, in the numeric field and in comments.

- Placing numerical data in columns 1 through 20, except in comments.

- Placing decimal points in text abbreviations in the numeric data fields (columns 21 through 79)

  i.e.
  ```
  ID          No.=2
  DIAM.=4.0 SQ. FT.
  AREA =1.25 SQ. MI.
  DIST.=125
  HYD.NO.=125
  ```
  are not allowed.

- Mixing numeric characters in text comments.

i.e.			
	`ID N0=2`	in place of	`ID NO=2`
	`1D NO=3`	in place of	`ID    NO=3`
	`FL0W RATES`	in place of	`FLOW RATES`
	`SQ M1`	in place of	`SQ MI`

  Note: The character with the error is underlined.

- Placing extra spaces in numbers.

  i.e.: `10 1.0` in place of `101.0`

- Leaving out any required data element. Each data element must be included in the sequence specified, even if the input data has a value of 0.0.

- Having hydrograph flow rates that exceed the peak flow values allowed in the channel ROUTE command and the ROUTE RESERVOIR command.

- Specifying ID numbers larger than 99.

- Inputting numbers in the form: `1.2E6`. This exponential format is not allowed. Use the following form for input `1200000.0`.

- Specifying a CID other than 1 when routing through a channel section with a single rating curve (single cross section).

I. PROGRAM UNITS

The AHYMO program uses the following units of measure for input and output:

MEASUREMENT	UNITS
Area (Cross Section)	square feet (FT)
Area (Land)	square miles (SQ MI)
Diameter (Pipe)	feet (FT) or inches (IN)
Distance	feet (FT)
Elevation	feet (FT)
Flow Rate	cubic feet per second (CFS)
Initial Abstraction	inches (IN)
Concentration	parts per million by weight (PPM-w)
Rainfall	inches (IN)
Runoff	inches (IN)
Sediment Yield	tons (T)
Slope	foot per foot (FT PER FT)
Time	hours (HRS)
Uniform Infiltration	inches per hour (IN PER HR)
Velocity	feet per second (FT PER SEC)
Volume	acre-feet (AC FT)

J. DIFFERENCES BETWEEN OTHER VERSIONS OF THE PROGRAM

There are other versions of the HYMO program in general use, which may have some capabilities of the AHYMO™ program or which may have functions not available with this version of HYMO. The program differences are summarized as follows:

J.1 USDA Agricultural Resource Service Version of HYMO (HYMO1548)

a. A maximum of 6 ID numbers and 300 hydrograph data points are available.
b. HYD number may only have integer values and may not use other alphanumeric characters.
c. The COMPUTE HYD command cannot use IA and INF soil losses. Only the NRCS CN is allowable. The NRCS dimensionless unit hydrograph is not available.
d. The resultant hydrograph for the ADD HYD command must be different from the two existing hydrographs.
e. The PRINT HYD command can only use Code=0 or Code=1.
f. The PLOT HYD command cannot specify scale.
g. The ROUTE command may not be able to use some shorter or flatter channel sections.
h. The COMPUTE RATING CURVE command cannot compute a rating curve for a pipe section.
i. The STORE RATING CURVE command must use 20 table elements and the STORE TRAVEL TIME command must use 19 table elements.
j. The ROUTE RESERVOIR command cannot use the elevation with the outflow-storage table. The incremental time for the output file cannot be modified. A maximum of 20 outflow storage values can be used.
k. The summary table is not available.
l. Only the SEDIMENT YIELD form of the SED WASH LOAD command is available. The percent of impervious and wash load factors are not available.
m. The DIVIDE HYD, RAINFALL, COMPUTE NM HYD, COMPUTE ALB HYD, LAND FACTORS, MODIFY TIME, SAVE HYD, COMPUTE K AND TP, SEDIMENT BULK, SEDIMENT TRANS, ROUTE MCUNGE, LOCATION and COMPUTE LT TP commands are not available.
n. Only capital letters can be used in the command names.

J.2 The modified version of HYMO (HYMO103A)

a. A maximum of 6 ID numbers and 300 hydrograph data points are available.
b. HYD numbers will only print out with integer values and may not use other alphanumeric characters.
c. The COMPUTE HYD command does not have the NRCS dimensionless unit hydrograph.
d. Items e, f, g, h, i, j, k, l, m and n, from the previous section J.1 (HYMO1548) also apply.

J.3 HYMO_86, a version of HYMO with modifications and enhancements written by C.E. Anderson, and used in the Albuquerque area. (© C. E. Anderson, unpublished)

a. A maximum of 12 ID numbers and 300 hydrograph data points are available.
b. HYD numbers may use numbers with 2 decimal places but may not use other alphanumeric characters.
c. The COMPUTE HYD command cannot use IA and INF soil losses. Only the NRCS CN is available.
d. The RAINFALL, COMPUTE NM HYD, COMPUTE ALB HYD, LAND FACTORS, MODIFY TIME, SAVE HYD, COMPUTE K AND TP, SEDIMENT BULK, SEDIMENT TRANS, ROUTE MCUNGE, LOCATION and COMPUTE LT TP commands are not available.
e. The HYMO_86 version of HYMO has a SUBTRACT HYD command that is not available on the AHYMO program. The rating curve capability of the DIVIDE HYD command in the AHYMO program can be used to provide a similar function.
f. The HYMO_86 COMPUTE RATING CURVE command for pipes section must use a pipe diameter in feet. The AHYMO program can use feet or inches.
g. A maximum of 20 outflow-storage values may be used with the ROUTE RESERVOIR command.
h. Items f, i, j, k, l and n from the previous section J.1 (HYMO1548) also apply.

K. HISTORY OF AHYMO PROGRAM DEVELOPMENT

K.1 AHYMO990 (© 1990, C. E. Anderson)

This was the first publication and major release of the program and the first to be designated as the AHYMO program. This version included the following enhancements from ARS HYMO:

a. Ability of the COMPUTE HYD command to use initial abstraction and uniform infiltration in place of the standard NRCS Curve Number.
b. Revisions to the channel ROUTE command to enhance routing accuracy.
c. Ability to use a standard NRCS dimensionless unit hydrograph in place of the HYMO unit hydrograph.
d. A new RAINFALL command was added. Eight rainfall distribution types were available.
e. A new COMPUTE NM HYD command was added to simplify use of the split hydrograph procedure with initial abstraction and uniform infiltration soil losses.
f. A new DIVIDE HYD command was added to divide a flow by a percentage, a maximum flow rate or a rating curve.
g. The ROUTE RESERVOIR command was revised to allow input and output of elevation data in addition to storage and discharge values.
h. The PRINT HYD command was revised to allow printing in specified time steps.
i. The COMPUTE RATING CURVE command was enhanced to allow a pipe section to be specified.
j. The HYD NO element used for hydrograph labeling was revised so that two numbers could be input following the decimal point (ie:123.45)
k. The program storage was expanded to allow storage of up to 20 hydrograph ID numbers. The hydrograph storage was expanded to accommodate 600 data points.

The sample data set from the original ARS HYMO program could be run on the AHYMO990 program. The only numerical change was in the channel ROUTE command, where computational accuracy and equation convergence was enhanced.

K.2 AHYMO991 (© 1991, C. E. Anderson)

This update of the AHYMO program made revisions so that the program was consistent with the revision of the City of Albuquerque Development Process Manual that was being revised at the time (August 1991 DPM). The following features were revised from the AHYMO990 program version:

a. The RAINFALL command included three new rainfall distributions and renumbered the distribution types.
b. The COMPUTE NM HYD command was revised to incorporate the unit hydrograph parameters from the August 1991 City of Albuquerque DPM. This changed the computational results of the command.
c. The mass rainfall storage of the RAINFALL, COMPUTE HYD and COMPUTE NM HYD commands were expanded to allow 600 incremental values.
d. The PLOT HYD command was revised to allow specification of scales.
e. The ability to bypass the routing of the ROUTE RESERVOIR command was added.
f. A new LAND FACTORS command was added to allow specification of local infiltration rates. These variable rates were integrated into the COMPUTE NM HYD command.
g. A new subroutine was developed to allow creation of a summary table during program execution. Each command that computes or modifies a hydrograph generates a line on the summary table.

This version of the AHYMO program was submitted to Federal Emergency Management Agency (FEMA) in conformance with National Flood Insurance Program Regulations (44 CFR Ch 1, Section 65.6).

K.3 AHYMO392 (© 1992, C. E. Anderson)

This version of the program did not incorporate major changes to the computational modules, but did change elements to enhance output. The following revisions were included:

a. The START command included a new capability to specify compressed mode printing (16 to 17 cpi) for many printers.
b. The summary output table was enhanced to include additional information.

The AHYMO392 program included an enhanced user's manual to explain program use.

K.4 AHYMO993 (© 1993, C. E. Anderson)

This version included major revisions to enhance program utility, but only minor revisions to the computational modules. The following revisions were included:

a. The name for the input-output specification file was changed from HYMO FILE.DAT to AHYMO_IO.FIL.
b. The creation of the external hydrograph storage file (commonly AHYMO.HYD) was made optional.

c. The SEDIMENT YIELD command was renamed to SED WASH LOAD. The original command name can also be used. The command was revised to use percentage of impervious area and a wash load factor.
d. The input file interpreter was revised to use both upper and lower case letters in the command names.
e. A capability was added to allow alphanumeric characters in the HYD NO hydrograph designations. Up to 24 characters could be used.
f. The program was revised to allow use of TAB characters (ASCII[9]) in input files.
g. The program was revised to allow use of up to 99 hydrograph ID numbers in place of the 20 available with previous revisions.
h. The COMPUTE RATING CURVE command was revised to include a top width. This value is used by the sediment transportation function.
i. A table of 20 elements was no longer required in the STORE RATING CURVE command, and a table of 19 elements was no longer required in the STORE TRAVEL TIME command.
j. A new SEDIMENT BULK command was added. This command will multiply computed hydrographs by a sediment bulking factor, or table of factors.
k. A new SEDIMENT TRANS command was added. This command will compute a sediment transport capacity and volume for an arroyo or channel reach using a power function equation.

This version of the program did not change the computation of peak flow rates and volume of water from the AHYMO392 version of the program, if the input files were not revised. Input files created with previous versions of the program could be used with the AHYMO993 program.

K.5 AHYMO194

This version added the ROUTE MCUNGE command; this command implemented the Muskingum-Cunge flood routing method for channels and arroyos. This version did not change the computation of peak flow rates and volume of water from the AHYMO993 version of the program, if the input files were not revised. The AHYMO194 program was a derivative product of previously copyrighted material by C. E. Anderson.

K.6 AHYMO_97 (© 1997, C. E. Anderson)

This version of the program implemented major revisions to enhance program utility and revisions to some computational modules. The following revisions were included:

a. A new user identification number system was initiated.
b. A new LOCATION command was added to specify default computation parameters based on project location.
c. A new COMPUTE LT TP command was added. This command will allow computation of lag time, time of concentration and time to peak by the Upland/Lag Time Method, the NRCS TR-55 Method, the Lag Time Method, the Kirpich Method, and the NRCS CN-Lag Method.

d. The COMPUTE HYD and COMPUTE NM HYD commands were revised to allow input of time to peak or time of concentration values that are computed by the COMPUTE LT TP command.
e. The ADD HYD command was revised to allow hydrograph addition based on the larger time increment, when the incremental times of the two hydrographs are different.
f. The COMPUTE RATING CURVE command was revised to recognize a flat bottom cross section, when computing flow widths. The command also allowed a larger number of cross section segments.
g. The MODIFY TIME command was revised to allow subdivision of a hydrograph by time.
h. The Type 5 rainfall distribution of the RAINFALL command (NRCS Type II-a) was revised to provide a uniform distribution within the peak 15 minute period. This revision provided consistency with the NRCS Type II-a methodology that only provided rainfall data at 15 minute intervals and used linear interpolation for intermediate values.
i. The ROUTE MCUNGE command was entirely rewritten from the previous version. The routing parameters from the channel rating curve incorporated a parabolic curve fitting technique. An iterative four point averaging scheme was used to solve the routing differential equation. The Fread and Ponce limitations on routing coefficients were incorporated into the program.

K.7 AHYMO-S4 (© 2009, C. E. Anderson)

This version of the program implemented major revisions to enhance program utility and computational precision, add location specific program options, and allow the program to efficiently executed on Windows based computers: MS Windows XP, Vista, and Windows 7 (32 or 64-bit). The following revisions were included:

a. A revised user identification number system was initiated.
b. The LOCATION command was revised to specify additional sites for custom program properties.
c. The COMPUTE RATING CURVE command was revised to allow channel sections with vertical walls.
d. The Type 12, 13, 14, 15, 16, 17, 20 and 21 rainfall distributions were added to the RAINFALL command. Several of these distributions addressed the requirement to use tabulated rainfall from NWS NOAA Atlas 14. The type 1 and 2 distributions were revised to provide for specification of the default distribution based on the value of the LOCATION command.
e. The ROUTE MCUNGE command was rewritten to reduce use of Fread's suggested procedure for routing coefficients in Muskingum-Cunge channel routing. The Fread procedure reduced numerical instability but changed the computed celerity for the routed hydrographs. For complex watersheds this caused loss of peak flow rates. The use of Ponce's suggested procedure did not experience these problems but some numerical instability in hydrograph computations remained. The remaining instability was eliminated by allowing use of smaller computation time steps.

f. The computation of hydrographs was changed to use 4000 data values in hydrographs and rainfall distributions. This revision allowed time steps for hydrograph computations to be substantially reduced and eliminated numerical instability when using Ponce's suggested procedure in Muskingum-Cunge channel routing. This revision changed most subroutines in the AHYMO source code.
g. The computation of the HYMO unit hydrograph was revised to improve numerical precision and eliminate numerical instability warnings that would occasional appear in some hydrograph computations.
h. Major sections of program code were rewritten to use the if/else/then, select case/case, and do/end do constructs that are available with modern Fortran compilers.
i. The program was revised so it could be compiled using the Intel® Visual Fortran Compiler, Professional Edition 11.1 for Windows (June 2009). This allowed the AHYMO program to be used with the latest Microsoft Windows operating systems.
j. Data files from watersheds evaluated using earlier versions of AHYMO were re-executed to verify that they would run on the new AHYMO-S4 version. A new AHYMO97 designation was added to the LOCATION command to simplify emulation of legacy watershed analyses. Watershed data from the original ARS HYMO program can executed with AHYMO-S4.

K.8 AHYMO-S4-R2 (© 2018, the City of Albuquerque)

This version of the program transferred ownership of the AHYMO-S4 program, source code, and user manual text by gift from C. E. Anderson to the City of Albuquerque. Program ownership information and copyright notices were updated. All the technical functions of the AHYMO-S4 program remained in release R2 (AHYMO-S4-R2). The program was recompiled using an Intel Fortran compiler and an updated program Install Shield installer dialog was created. The program can be executed on Windows based computers using MS Windows 8, 8.1 and 10.

L. EXAMPLE PROBLEMS

L.1 Example 1- A Watershed with a Proposed Flood Control Reservoir

A partially developed watershed is located at the base of a mountainous area. A topographic map of the area was used to define the watershed boundaries and the channel reaches. The upper portion of the watershed is undeveloped. The lower portion of the watershed is not yet developed, but is planned for high density housing. The middle portions of the watershed are developed as low density residential. A new flood control reservoir is proposed at the lower end of the watershed to protect properties further downstream. The watershed has a configuration and flow schematic as shown on Figure 1.

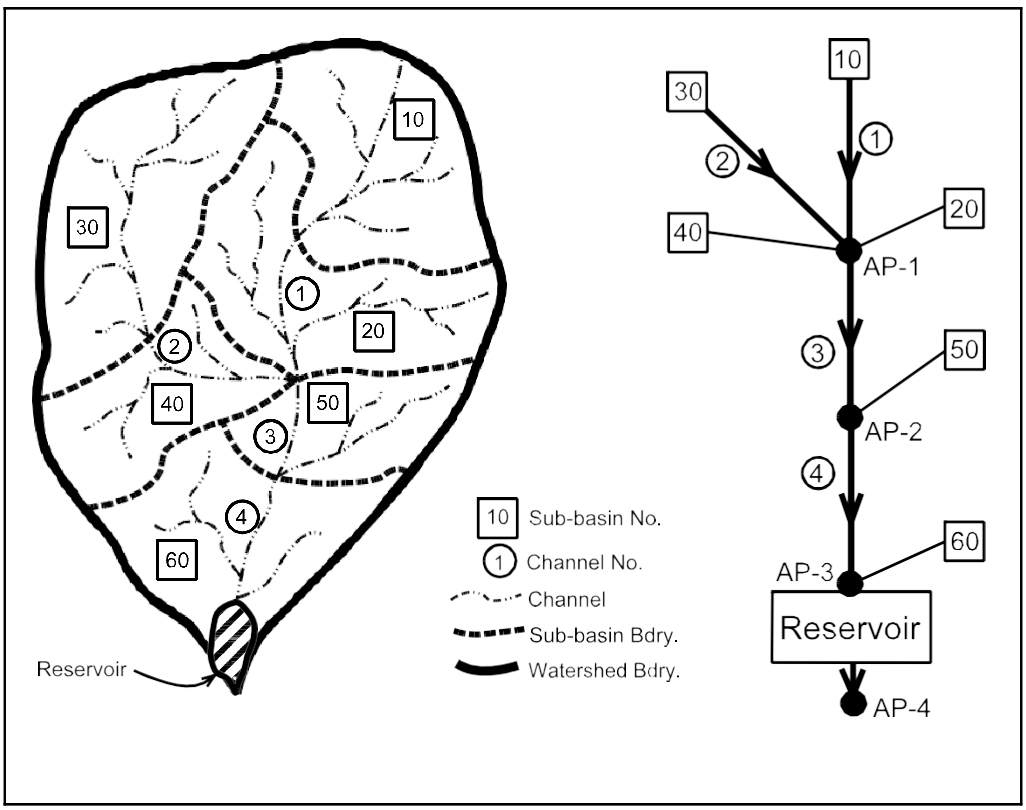

Figure 1

The watershed is divided into six (6) sub-basins with the following future condition properties as shown on Table L1:

Table L1. Sub-basin Properties for Example 1

Sub-basin Number	Sub-basin Area (sq mi)	Maximum Sub-basin Length (ft)	Centroid Length (ft)	Sub-basin slope (ft/ft)	Sub-basin Channel Treatment	Sub-basin Land Cover	Impervious Area (percent)
10	1.31	7600	3800	0.084	Natural	Pinyon-juniper w/ 40% ground cover- Undevel.	0
20	1.36	8500	4300	0.044	Natural	Desert shrub w/ 20% ground cover Residential-1/3 DU/ac.	10
30	1.66	10800	4400	0.059	Natural	Pinyon-juniper w/ 40% ground cover- Undevel.	5
40	0.93	8600	4800	0.032	Stabilized	Desert shrub w/ 20% ground cover Residential-1DU/acre	20
50	0.77	6900	2700	0.031	Stabilized	Desert Shrub w/ 20% ground cover & lawns Residential-2 DU/acre	26
60	1.23	8100	5000	0.024	Paved	Lawns and landscaping Residential-5 DU/acre	50

The watershed has four channel segments where flow from one or more sub-basins is routed through another sub-basin. They are defined by the following Table L2:

Table L2. Channel Segment Properties for Example 1

Channel number	Length (ft)	Ave. Slope (ft/ft)	Ave. Bottom width (ft)	Ave. Side slope (H to V)	Channel Treatment	Ave. Manning's roughness (N)
1	4900	0.038	20	1.2 to 1	Natural	0.038
2	5500	0.033	25	1.8 to 1	Natural - stabilized	0.032
3	3400	0.027	30	2.5 to 1	Natural - stabilized	0.035
4	4700	0.018	12	2 to 1	Hard lined	0.013

The proposed flood control reservoir at the downstream portion of the watershed must be able to carry the inflow from a 100-year 24-hour storm event without flow through the emergency spillway. The reservoir will have a bottom area of 0.016 square miles (10.24 acres) and average side slopes of 4 horizontal to 1 vertical (0.25 foot per foot). The principal spillway of the reservoir is a pipe through the reservoir embankment; it must be sized so that the peak outflow will not exceed 25 percent of the peak inflow during a 100-year storm event.

Note: For actual reservoir design, the analysis must also include the sizing of an emergency spillway and determination of the embankment crest elevation. For a high hazard reservoir, this will likely include evaluation of the Probable Maximum Flood (PMF) or one-half of the Probable Maximum Flood (½ PMF)

The 100-year storm event is characterized by the following precipitation amounts: one day precipitation (P_{1440}) of 3.7 inches, six hour precipitation (P_{360}) of 2.9 inches and one hour precipitation (P_{60}) of 2.2 inches.

The AHYMO program can be used to compute the flow from each sub-basin, the flow in each channel, and the inflow to the reservoir. It can also be used to establish the size of the reservoir for the criteria given.

Using the USDA Natural Resources Conservation Service (NRCS) CN Method for Example 1

The NRCS method requires that a curve number (CN) be computed for each sub-basin. The CN will be computed using the guidance from the NRCS *Urban Hydrology for Small Watersheds*, TR-55 and the method of Weighted-Q from the NRCS *National Engineering Handbook, Section 4, Hydrology*. The soils in the watershed area are assumed to be divided between Hydrologic Soil Group B and C. The Hydrologic Soil Group can be found from published soil surveys of the watershed region; the NRCS has published soil surveys for most counties. This computation is summarized in the following Table L3.

Note: A CN of 81 was used for lawn areas. This value considers that lawns in arid or semi-arid areas are irrigated, so that the CN values must be increased to account for a higher antecedent moisture than is anticipated by general United States tables. If unirrigated lawns have a CN of 74, and if half are irrigated to produce antecedent moisture with a CN of 88, then an average CN of 81 would be applicable. A similar value is suggested by the City of Albuquerque Development Process Manual, Chapter 22.2, Hydrology.

Table L3. Sub-basin NRCS Curve Numbers for Example 1

Sub-basin Number	Pervious Portion		Impervious Portion		Total Sub-basin	
	Area (sq mi)	CN	Area (sq mi)	CN	Area (sq mi)	CN by Weighted-Q
10	1.310	66	0.000	---	1.31	66.00
20	1.224	81	0.136	98	1.36	83.04
30	1.577	66	0.083	98	1.66	68.35
40	0.744	81	0.186	98	0.93	84.99
50	0.570	81	0.200	98	0.77	86.11
60	0.615	81	0.615	98	1.23	90.35

The sub-basin hydrographs can be computed using the COMPUTE HYD command. The time of concentration (tc) can be computed using the COMPUTE LT TP command. While several of the LCODE options of the COMPUTE LT TP command are applicable, this evaluation will use the NRCS TR Fifty-Five Method (LCODE = 4). It is necessary to estimate some flow roughness, conveyance condition, cross section area and wetted perimeter values to use this method. The NRCS TR Fifty-Five Method requires input of the 2-year 24-hour rainfall; assume that this value us 43 percent of the 100-year 24-hour rainfall. The COMPUTE LT TP values used are included in the following Table L4.

Table L4. Channel Segment NRCS TR Fifty-Five Values for Example 1 (LCODE = 4)

Sub-basin Number	Slope (ft/ft)	Sheet Flow		Shallow Conc. Flow		Channel Flow			
		Length (ft)	N	Length (ft)	Surface	Length (ft)	N	X-Area (sq ft)	Wet. P. (ft)
10	0.084	300	0.130	2000	Unpaved	5300	0.045	44.0	25.7
20	0.044	300	0.130	2000	Unpaved	6200	0.038	44.8	26.2
30	0.059	300	0.130	2000	Unpaved	8500	0.045	44.0	25.7
40	0.032	300	0.130	2000	Unpaved	6300	0.032	57.2	33.2
50	0.031	300	0.130	2000	Paved	4600	0.028	50.6	38.1
60	0.024	300	0.011	2000	Paved	5800	0.013	54.0	25.4

The channel conveyance is computed from the values defined by the example watershed using the COMPUTE RATING CURVE and ROUTE MCUNGE commands. The reservoir elevation-storage-outflow data is required for the ROUTE RESERVOIR command. The dimensions of the reservoir can be computed from the defined bottom area and side slopes. The outflow is established by assuming a pipe size and using an inlet control headwater depth-discharge rating curve or nomograph. The reservoir properties are established by the following Table L5.

Table L5. Proposed Reservoir Properties for Example 1

Depth (ft)	Surface Area (acres)	Incremental volume (ac ft)	Total volume (ac ft)	Outflow for 96 in. diameter pipe (cfs)
0.0	10.240	0.000	0.000	0.0
2.0	10.736	20.975	20.975	50.0
4.0	11.245	21.979	42.954	130.0
6.0	11.765	23.008	65.962	260.0
8.0	12.297	24.059	90.021	410.0
12.0	13.395	51.368	141.389	630.0
16.0	14.541	55.856	197.245	820.0
20.0	15.734	60.534	257.779	950.0
24.0	16.974	65.400	323.179	1080.0
28.0	18.261	70.454	393.633	1180.0
32.0	19.594	75.694	469.327	1270.0
36.0	20.975	81.122	550.449	1360.0

The 24-hour NRCS TYPE II-a distribution for New Mexico (RAINFALL TYPE=5) in the RAINFALL command will be used with the NRCS CN method. (Another distribution for consideration is the 24-hour distribution based on NOAA Atlas 2 for New Mexico with peak intensity at 6.0 hours.) The RAINFALL command options with TYPE=1, 2, 6, 7, 8, 10 and 11 are **not** appropriate for the given watershed analysis.

The following is the AHYMO Program input data for the Natural Resources Conservation Service (NRCS) CN Method with Example 1:

```
*S      AHYMO - EXAMPLE 1 - A WATERSHED WITH 5 SUBBASINS
*S              USE THE NRCS CN METHOD TO COMPUTE THE RUNOFF
*S              FILE: EX1-NRCS-S4.DAT
START                TIME=0.0
LOCATION             NEW MEXICO
RAINFALL             TYPE=-5
                     QUARTER=0.0    ONE= 2.20 IN
                     SIX= 2.90 IN   DAY= 3.70 IN   DT = 0.01 HR
**** SUB-BASIN 10 ****
```

```
COMPUTE LT TP        LCODE=4  NRCS TR FIFTY FIVE METHOD
                     NK=1   NSC=1   NCF=1   TYD RAIN=1.6
                    LENGTH=300 FT  SLOPE=0.084  N=0.130
                    LENGTH=2000 FT  SLOPE=0.084  SURFACE=1 UNPAVED
                    LENGTH=5300 FT  SLOPE=0.084  N=0.045
                          X AREA=44.0   X WP=25.7
COMPUTE HYD          ID=1  HYD NO=101  DT=0.0  DA= 1.310 SQ MI
                     CN=66.00  K=0.0  TP=0.0  MASSRAIN=-1
PRINT HYD            ID=1  CODE=1
* ROUTE 10 THRU 20 IN CHANNEL NO. 1
COMPUTE RATING CURVE  CID=1   VS NO=1   NO SEGS=1
                      MIN ELEV=0        MAX ELEV=3.80
                      CH SLOPE=0.038    FP SLOPE=0.038
                      N=0.038           DIST=32.0
                      DIST  ELEV    DIST  ELEV
                       0.0  5.0      6.0  0.0
                      26.0  0.0     32.0  5.0
ROUTE MCUNGE         ID=2   HYD NO=101.01   INFLOW ID=1
                     DT=0.0   L=4900 FT   NS=0   SLOPE=0.038
PRINT HYD            ID=2   CODE=1
**** SUB-BASIN 20 ****
COMPUTE LT TP        LCODE=4  NRCS TR FIFTY FIVE METHOD
                     NK=1   NSC=1   NCF=1   TYD RAIN=1.6
                    LENGTH=300 FT   SLOPE=0.044   N=0.130
                    LENGTH=2000 FT  SLOPE=0.044  SURFACE=1 UNPAVED
                    LENGTH=6200 FT  SLOPE=0.084   N=0.038
                          X AREA=44.8   X WP=26.2
COMPUTE HYD          ID=1   HYD NO=102  DT=0.0   DA= 1.360 SQ MI
                     CN=83.04   K=0.0   TP=0.0   MASSRAIN=-1
PRINT HYD            ID=1   CODE=1
* ADD SUB-BASIN 10 TO SUB-BASIN 20
ADD HYD              ID=3   HYD NO=102.01   IDS=1 AND 2
PRINT HYD            ID=3   CODE=1
**** SUB-BASIN 30 ****
COMPUTE LT TP        LCODE=4  NRCS TR FIFTY FIVE METHOD
                     NK=1   NSC=1   NCF=1   TYD RAIN=1.6
                    LENGTH=300 FT   SLOPE=0.059   N=0.130
                    LENGTH=2000 FT  SLOPE=0.059  SURFACE=1 UNPAVED
                    LENGTH=8500 FT  SLOPE=0.059   N=0.045
                          X AREA=44.0   X WP=25.7
COMPUTE HYD          ID=1  HYD NO=103  DT=0.0   DA= 1.660 SQ MI
                     CN=68.35  K=0.0   TP=0.0   MASSRAIN=-1
PRINT HYD            ID=1  CODE=1
* ROUTE 30 THRU 40 IN CHANNEL NO. 2
COMPUTE RATING CURVE  CID=1   VS NO=1   NO SEGS=1
                      MIN ELEV=0        MAX ELEV=3.80
                      CH SLOPE=0.033    FP SLOPE=0.033
                      N=0.032           DIST=43.0
                      DIST  ELEV    DIST  ELEV
                       0.0  5.0      9.0  0.0
                      34.0  0.0     43.0  5.0
ROUTE MCUNGE         ID=2   HYD NO=103.01   INFLOW ID=1
                     DT=0.0   L=5500 FT   NS=0   SLOPE=0.033
PRINT HYD            ID=2   CODE=1
**** SUB-BASIN 40 ****
COMPUTE LT TP        LCODE=4  NRCS TR FIFTY FIVE METHOD
                     NK=1   NSC=1   NCF=1   TYD RAIN=1.6
                    LENGTH=300 FT   SLOPE=0.032   N=0.130
                    LENGTH=2000 FT  SLOPE=0.032  SURFACE=1 UNPAVED
```

```
                    LENGTH=6300 FT  SLOPE=0.032   N=0.032
                            X AREA=57.2   X WP=33.2
COMPUTE HYD         ID=1   HYD NO=104  DT=0.0   DA= 0.930 SQ MI
                    CN=84.99   K=0.0   TP=0.0   MASSRAIN=-1
PRINT HYD           ID=1   CODE=1
* ADD SUB-BASIN 10 TO SUB-BASIN 20
ADD HYD             ID=2   HYD NO=104.01   IDS=1 AND 2
PRINT HYD           ID=2   CODE=1
* ADD SUB-BASINS 30 AND 40 TO SUB-BASINS 10 AND 20
ADD HYD             ID=3   HYD NO=104.02_AP1   IDS=2 AND 3
PRINT HYD           ID=3   CODE=1
* ROUTE SUB-BASINS 10, 20, 30 AND 40 THRU 50 IN CHANNEL NO. 3
COMPUTE RATING CURVE  CID=1   VS NO=1   NO SEGS=1
                      MIN ELEV=0        MAX ELEV=7.60
                      CH SLOPE=0.027    FP SLOPE=0.027
                      N=0.035           DIST=80.0
                      DIST  ELEV    DIST  ELEV
                       0.0  10.0    25.0  0.0
                      55.0  0.0     80.0  10.0
ROUTE MCUNGE        ID=2   HYD NO=104.03   INFLOW ID=3
                    DT=0.0   L=3400 FT   NS=0   SLOPE=0.027
PRINT HYD           ID=2   CODE=1
**** SUB-BASIN 50 ****
COMPUTE LT TP       LCODE=4  NRCS TR FIFTY FIVE METHOD
                    NK=1   NSC=1   NCF=1   TYD RAIN=1.6
                    LENGTH=300 FT   SLOPE=0.031   N=0.130
                    LENGTH=2000 FT  SLOPE=0.031  SURFACE=2 PAVED
                    LENGTH=4600 FT  SLOPE=0.031   N=0.028
                          X AREA=50.6   X WP=38.1
COMPUTE HYD         ID=1   HYD NO=105  DT=0.0   DA= 0.770 SQ MI
                    CN=86.11   K=0.0   TP=0.0   MASSRAIN=-1
PRINT HYD           ID=1   CODE=1
* ADD SUB-BASIN 10, 20, 30 AND 40 TO SUB-BASIN 50
ADD HYD             ID=3   HYD NO=105.01_AP2   IDS=1 AND 2
PRINT HYD           ID=3   CODE=1
* ROUTE SUB-BASINS 10, 20, 30, 40 AND 50 THRU 60 IN CHANNEL NO. 4
COMPUTE RATING CURVE  CID=1   VS NO=1   NO SEGS=1
                      MIN ELEV=0        MAX ELEV=9.50
                      CH SLOPE=0.018    FP SLOPE=0.018
                      N=0.013           DIST=72.0
                      DIST  ELEV    DIST  ELEV
                       0.0  15.0    30.0  0.0
                      42.0  0.0     72.0  15.0
ROUTE MCUNGE        ID=2   HYD NO=105.02   INFLOW ID=3
                    DT=0.0   L=4700 FT   NS=0   SLOPE=0.018
PRINT HYD           ID=2   CODE=1
**** SUB-BASIN 60 ****
COMPUTE LT TP       LCODE=4  NRCS TR FIFTY FIVE METHOD
                    NK=1   NSC=1   NCF=1   TYD RAIN=1.6
                    LENGTH=300 FT   SLOPE=0.024   N=0.011
                    LENGTH=2000 FT  SLOPE=0.024   SURFACE=2 PAVED
                    LENGTH=5800 FT  SLOPE=0.024   N=0.013
                          X AREA=54.0   X WP=25.4
COMPUTE HYD         ID=1   HYD NO=106  DT=0.0   DA= 1.230 SQ MI
                    CN=90.35   K=0.0   TP=0.0   MASSRAIN=-1
PRINT HYD           ID=1   CODE=1
* ADD SUB-BASIN 10, 20, 30, 40 AND 50 TO SUB-BASIN 60
ADD HYD             ID=3   HYD NO=106.01_AP3   IDS=1 AND 2
PRINT HYD           ID=3   CODE=1
```

```
* ROUTE THE TOTAL FLOW THROUGH THE PROPOSED RESERVOIR
ROUTE RESERVOIR     ID=1   HYD NO=106.02_AP4   INFLOW=3   CODE=20
                    OUTFLOW(CFS)    STORAGE(AC-FT)    ELEV(FT)
                       0.0               0.000        0.00
                      50.0              20.975        2.00
                     130.0              42.954        4.00
                     260.0              65.962        6.00
                     410.0              90.021        8.00
                     630.0             141.389       12.00
                     820.0             197.245       16.00
                     950.0             257.779       20.00
                    1080.0             323.179       24.00
                    1180.0             393.633       28.00
                    1270.0             469.327       32.00
                    1360.0             550.449       36.00
PRINT HYD           ID=1    CODE=1
FINISH
```

The AHYMO Program output summary table is included to show the results of the Example 1 watershed analysis. The summary table shows peak flow rates and volumes for the sub-basins, channels and the reservoir. Note that the reservoir sizing provides for greater flow attenuation than was required by the design criteria; This additional storage capacity could be required if sediment accumulation was included in the reservoir design. (See Example 2 herein.) The complete program output (commonly AHYMO.OUT or OUT) should be reviewed to verify sub-basin travel time computations, routing parameters, and reservoir routing levels. This complete output may also contain program warnings that need to be addressed. The complete output file can be obtained by executing the example 1 input file (EX1-NRCS-S4.dat) that is included with the AHYMO Program distribution files.

AHYMO PROGRAM SUMMARY TABLE (AHYMO-S4) - Ver. S4.02a, Rel: 02a RUN DATE (MON/DAY/YR) =07/09/2018
INPUT FILE = C:\Users\Public\AHYMOdata\EX1-NRCS-S4.DAT USER NO.= AHYMO_Temp_User:20122010

PAGE = 1

COMMAND	HYDROGRAPH IDENTIFICATION	FROM ID NO.	TO ID NO.	AREA (SQ MI)	PEAK DISCHARGE (CFS)	RUNOFF VOLUME (AC-FT)	RUNOFF (INCHES)	TIME TO PEAK (HOURS)	CFS PER ACRE	NOTATION
*S AHYMO - EXAMPLE 1 - A WATERSHED WITH 5 SUBBASINS										
*S USE THE NRCS CN METHOD TO COMPUTE THE RUNOFF										
*S FILE: EX1-NRCS-S4.DAT										
START										TIME= 0.00
LOCATION		NEW MEXICO								
RAINFALL TYPE= 5										RAIN24= 3.700
COMPUTE HYD	101.00	-	1	1.31000	713.44	63.668	0.91128	6.270	0.851	CN= 66.00
ROUTE MCUNGE	101.01	1	2	1.31000	713.10	63.666	0.91125	6.340	0.851	CCODE = 0.2
COMPUTE HYD	102.00	-	1	1.36000	1787.59	147.328	2.03118	6.300	2.054	CN= 83.04
ADD HYD	102.01	1& 2	3	2.67000	2492.09	210.994	1.48170	6.320	1.458	
COMPUTE HYD	103.00	-	1	1.66000	873.94	92.000	1.03916	6.370	0.823	CN= 68.35
ROUTE MCUNGE	103.01	1	2	1.66000	873.70	91.997	1.03912	6.450	0.822	CCODE = 0.2
COMPUTE HYD	104.00	-	1	0.93000	1170.97	108.660	2.19073	6.370	1.967	CN= 84.99
ADD HYD	104.01	1& 2	2	2.59000	2024.46	200.657	1.45264	6.410	1.221	
ADD HYD	104.02_AP1	2& 3	3	5.26000	4426.48	411.651	1.46739	6.360	1.315	
ROUTE MCUNGE	104.03	3	2	5.26000	4424.80	411.633	1.46732	6.390	1.314	CCODE = 0.2
COMPUTE HYD	105.00	-	1	0.77000	1094.23	93.867	2.28572	6.330	2.220	CN= 86.11
ADD HYD	105.01_AP2	1& 2	3	6.03000	5490.35	505.500	1.57183	6.380	1.423	
ROUTE MCUNGE	105.02	3	2	6.03000	5489.87	505.490	1.57180	6.410	1.423	CCODE = 0.2
COMPUTE HYD	106.00	-	1	1.23000	3567.53	175.073	2.66879	6.090	4.532	CN= 90.35
ADD HYD	106.01_AP3	1& 2	3	7.26000	6340.17	680.562	1.75765	6.370	1.365	
ROUTE RESERVOIR	106.02_AP4	3	1	7.26000	1100.67	678.912	1.75339	7.280	0.237	AC-FT= 337.745
FINISH										

Using the Initial Abstraction/Uniform Infiltration (IA/INF) Method for Example 1

The IA/INF method requires that initial abstraction and uniform infiltration values be obtained for the local watershed conditions. The IA/INF method will use the COMPUTE NM HYD command to compute sub-basin runoff. This command requires that IA/INF values be established for four land treatment types generally defined as: Natural (Treatment A), Irrigated Lawns (Treatment B), Compacted Earth (Treatment C) and Impervious (Treatment D). See the COMPUTE NM HYD command for a more detailed description of the land factors. The IA/INF factors can be defined by the program default values as determined by the project location and established by the LOCATION Command. The default IA/INF values can be modified by use of the LAND FACTORS command.

For the example 1 watershed, the computation will use the default values for the NEW MEXICO location. The percentages of each treatment type need to be specified based on the sub-basin conditions identified in the watershed example. For low density residential areas, the area of irrigated lawns will be assumed to be equal to the impervious area. The area of compacted earth will be assumed to be equal to 50 to 75 percent of the impervious area. The sub-basin properties are defined by the following Table L6.

Table L6. Sub-basin Land Treatment Areas (IA / INF Method) for Example 1

Sub-basin Number	Area (sq mi)	Percentage of Total Sub-basin Area			
		Treatment A (Natural)	Treatment B (Irrigated lawns)	Treatment C (Compacted Earth)	Treatment D (Impervious)
10	1.310	100	0	0	0
20	1.360	73	10	7	10
30	1.660	95	0	0	5
40	0.930	45	20	15	20
50	0.770	30	26	18	26
60	1.230	10	30	10	50

The sub-basin hydrographs will be computed using the COMPUTE NM HYD command. The time of concentration (tc) will be computed using the COMPUTE LT TP command. While several of the LCODE options of the COMPUTE LT TP command are applicable, this IA/INF evaluation will use the Upland/Lag Time Method (LCODE = 1). It is necessary to estimate flow roughness, and conveyance condition to use this method. The COMPUTE LT TP values used are included in the following Table L7.

Table L7. Channel Segment Upland/Lag Time Values for Example 1 (LCODE = 1)

Sub-basin Number	Slope (ft/ft)	NRCS Upland Method						Lag Equation Factors	
		Sheet Flow		Shallow Conc. Flow		Channel Flow			
		Length (ft)	K	Length (ft)	K	Length (ft)	K	KN	Centroid Dist. (ft)
10	0.084	400	0.70	1600	2.0	5600	3.0	0.042	3800
20	0.044	400	0.70	1600	2.0	6500	3.0	0.033	4300
30	0.059	400	0.70	1600	2.0	8800	3.0	0.042	4400
40	0.032	400	0.70	1600	2.0	6600	3.0	0.025	4800
50	0.031	400	0.70	1600	2.0	4900	3.0	0.023	2700
60	0.024	400	1.00	1600	2.0	6100	4.0	0.016	5000

The channel conveyance is computed from the values defined by the example watershed using the COMPUTE RATING CURVE and ROUTE MCUNGE commands. The reservoir elevation-storage-outflow data is required for the ROUTE RESERVOIR command. The channel flow input and the reservoir input for the IA/INF method will follow the format previously used with the NRCS CN method.

The 24-hour rainfall distribution based on NOAA Atlas 2 with peak intensity at 1.4 hours. (RAINFALL TYPE = 2) in the RAINFALL command will be used with the IA/INF method. The RAINFALL command options with TYPE = 6, 7, 8, 10 and 11 are **not** appropriate for the given watershed analysis.

The following is the AHYMO Program input data for the Initial Abstraction/Uniform Infiltration (IA/INF) Method with Example 1:

```
*S      AHYMO - EXAMPLE 1 - A WATERSHED WITH 5 SUBBASINS
*S              USE THE IA/INF METHOD TO COMPUTE THE RUNOFF
*S              FILE: EX1-IAI-S4.DAT
START                TIME=0.0
LOCATION             New Mexico
RAINFALL             TYPE=-2
                     QUARTER=0.0 ONE= 2.20 IN
                     SIX= 2.90 IN DAY= 3.70 IN DT = 0.01 HR
**** SUB-BASIN 10 ****
COMPUTE LT TP        LCODE=1  UPLAND/LAG TIME METHOD
                     NK=3  ISLOPE=0
                     LENGTH=400   FT   SLOPE=0.084   K=0.7
                     LENGTH=1600  FT   SLOPE=0.084   K=2.0
                     LENGTH=5600  FT   SLOPE=0.084   K=3.0
                     KN=0.042 CENTROID DIST=3800 FT
COMPUTE NM HYD       ID=1  HYD NO=101  DA= 1.310 SQ MI
                     PER A=100  PER B=0  PER C=0  PER D=0
                     TP=0.0  MASSRAIN=-1
PRINT HYD            ID=1  CODE=1
* ROUTE 10 THRU 20 IN CHANNEL NO. 1
COMPUTE RATING CURVE  CID=1   VS NO=1   NO SEGS=1
                       MIN ELEV=0         MAX ELEV=3.80
                       CH SLOPE=0.038     FP SLOPE=0.038
                       N=0.038            DIST=32.0
                       DIST  ELEV    DIST  ELEV
                        0.0  5.0      6.0  0.0
                       26.0  0.0     32.0  5.0
ROUTE MCUNGE         ID=2   HYD NO=101.01   INFLOW ID=1
                     DT=0.0 L=4900 FT NS=0 SLOPE=0.038
PRINT HYD            ID=2   CODE=1
**** SUB-BASIN 20 ****
COMPUTE LT TP        LCODE=1  UPLAND/LAG TIME METHOD
                     NK=3  ISLOPE=0
                     LENGTH=400   FT   SLOPE=0.044   K=0.7
                     LENGTH=1600  FT   SLOPE=0.044   K=2.0
                     LENGTH=6500  FT   SLOPE=0.044   K=3.0
                     KN=0.033 CENTROID DIST=4300 FT
COMPUTE NM HYD       ID=1   HYD NO=102   DA= 1.360 SQ MI
                     PER A=73  PER B=10  PER C=7  PER D=10
                     TP=0.0   MASSRAIN=-1
PRINT HYD            ID=1   CODE=1
```

```
* ADD SUB-BASIN 10 TO SUB-BASIN 20
ADD HYD             ID=3   HYD NO=102.01   IDS=1 AND 2
PRINT HYD           ID=3   CODE=1
**** SUB-BASIN 30 ****
COMPUTE LT TP       LCODE=1  UPLAND/LAG TIME METHOD
                    NK=3  ISLOPE=0
                    LENGTH=400   FT   SLOPE=0.059   K=0.7
                    LENGTH=1600  FT   SLOPE=0.059  K=2.0
                    LENGTH=8800  FT   SLOPE=0.059  K=3.0
                    KN=0.042 CENTROID DIST=4400 FT
COMPUTE NM HYD      ID=1  HYD NO=103    DA= 1.660 SQ MI
                    PER  A=95  PER  B=0  PER  C=0  PER  D=5
                    TP=0.0 MASSRAIN=-1
PRINT HYD           ID=1  CODE=1
* ROUTE 30 THRU 40 IN CHANNEL NO. 2
COMPUTE RATING CURVE  CID=1   VS NO=1   NO SEGS=1
                      MIN ELEV=0        MAX ELEV=3.80
                      CH SLOPE=0.033    FP SLOPE=0.033
                      N=0.032           DIST=43.0
                      DIST  ELEV    DIST  ELEV
                       0.0  5.0      9.0  0.0
                      34.0  0.0     43.0  5.0
ROUTE MCUNGE        ID=2   HYD NO=103.01   INFLOW ID=1
                    DT=0.0 L=5500 FT NS=0 SLOPE=0.033
PRINT HYD           ID=2   CODE=1
**** SUB-BASIN 40 ****
COMPUTE LT TP       LCODE=1  UPLAND/LAG TIME METHOD
                    NK=3  ISLOPE=0
                    LENGTH=400   FT   SLOPE=0.032   K=0.7
                    LENGTH=1600  FT   SLOPE=0.032  K=2.0
                    LENGTH=6600  FT   SLOPE=0.032  K=3.0
                    KN=0.025 CENTROID DIST=4800 FT
COMPUTE NM HYD      ID=1   HYD NO=104   DA= 0.930 SQ MI
                    PER A=45  PER B=20  PER C=15  PER D=20
                    TP=0.0   MASSRAIN=-1
PRINT HYD           ID=1   CODE=1
* ADD SUB-BASIN 10 TO SUB-BASIN 20
ADD HYD             ID=2   HYD NO=104.01   IDS=1 AND 2
PRINT HYD           ID=2   CODE=1
* ADD SUB-BASINS 30 AND 40 TO SUB-BASINS 10 AND 20
ADD HYD             ID=3   HYD NO=104.02_AP1   IDS=2 AND 3
PRINT HYD           ID=3   CODE=1
* ROUTE SUB-BASINS 10, 20, 30 AND 40 THRU 50 IN CHANNEL NO. 3
COMPUTE RATING CURVE  CID=1   VS NO=1   NO SEGS=1
                      MIN ELEV=0        MAX ELEV=7.60
                      CH SLOPE=0.027    FP SLOPE=0.027
                      N=0.035           DIST=80.0
                      DIST  ELEV    DIST  ELEV
                       0.0  10.0    25.0  0.0
                      55.0  0.0     80.0  10.0
ROUTE MCUNGE        ID=2   HYD NO=104.03   INFLOW ID=3
                    DT=0.0 L=3400 FT NS=0 SLOPE=0.027
PRINT HYD           ID=2   CODE=1
**** SUB-BASIN 50 ****
COMPUTE LT TP       LCODE=1  UPLAND/LAG TIME METHOD
                    NK=3  ISLOPE=0
                    LENGTH=400 FT   SLOPE=0.031   K=0.7
                    LENGTH=1600 FT  SLOPE=0.031   K=2.0
                    LENGTH=4900 FT  SLOPE=0.031   K=3.0
```

```
                    KN=0.023  CENTROID DIST=2700 FT
COMPUTE NM HYD      ID=1   HYD NO=105   DA= 0.770 SQ MI
                    PER A=30  PER B=26  PER C=18  PER D=26
                    TP=0.0   MASSRAIN=-1
PRINT HYD           ID=1   CODE=1
* ADD SUB-BASIN 10, 20, 30 AND 40 TO SUB-BASIN 50
ADD HYD             ID=3   HYD NO=105.01_AP2   IDS=1 AND 2
PRINT HYD           ID=3   CODE=1
* ROUTE SUB-BASINS 10, 20, 30, 40 AND 50 THRU 60 IN CHANNEL NO. 4
COMPUTE RATING CURVE  CID=1   VS NO=1   NO SEGS=1
                      MIN ELEV=0        MAX ELEV=9.50
                      CH SLOPE=0.018    FP SLOPE=0.018
                      N=0.013           DIST=72.0
                      DIST  ELEV    DIST  ELEV
                       0.0  15.0    30.0  0.0
                      42.0  0.0     72.0  15.0
ROUTE MCUNGE        ID=2   HYD NO=105.02   INFLOW ID=3
                    DT=0.0 L=4700 FT NS=0 SLOPE=0.018
PRINT HYD           ID=2   CODE=1
**** SUB-BASIN 60 ****
COMPUTE LT TP       LCODE=1  UPLAND/LAG TIME METHOD
                    NK=3  ISLOPE=0
                    LENGTH=400   FT   SLOPE=0.024  K=1.0
                    LENGTH=1600  FT   SLOPE=0.024  K=2.0
                    LENGTH=6100  FT   SLOPE=0.024  K=4.0
                    KN=0.016 CENTROID DIST=5000 FT
COMPUTE NM HYD      ID=1   HYD NO=106   DA= 1.230 SQ MI
                    PER A=10  PER B=30  PER C=10  PER D=50
                    TP=0.0   MASSRAIN=-1
PRINT HYD           ID=1   CODE=1
* ADD SUB-BASIN 10, 20, 30, 40 AND 50 TO SUB-BASIN 60
ADD HYD             ID=3   HYD NO=106.01_AP3   IDS=1 AND 2
PRINT HYD           ID=3   CODE=1
* ROUTE THE TOTAL FLOW THROUGH THE PROPOSED RESERVOIR
ROUTE RESERVOIR     ID=1   HYD NO=106.02_AP4   INFLOW=3   CODE=20
                    OUTFLOW(CFS) STORAGE(AC-FT) ELEV(FT)
                       0.0             0.000        0.00
                      50.0            20.975        2.00
                     130.0            42.954        4.00
                     260.0            65.962        6.00
                     410.0            90.021        8.00
                     630.0           141.389       12.00
                     820.0           197.245       16.00
                     950.0           257.779       20.00
                    1080.0           323.179       24.00
                    1180.0           393.633       28.00
                    1270.0           469.327       32.00
                    1360.0           550.449       36.00
PRINT HYD           ID=1   CODE=1
FINISH
```

The AHYMO Program output summary table is included to show the results of the Example 1 watershed analysis. The summary table shows peak flow rates and volumes for the sub-basins, channels and the reservoir. The complete program output (commonly AHYMO.OUT or OUT) should be reviewed to verify sub-basin travel time computations, routing parameters, and reservoir routing levels. This complete output may also contain program warnings that need to be addressed. The complete output file can be obtained by executing the Example 1 input file (EX1-IAI-S4.dat) that is contained with the AHYMO Program distribution files.

AHYMO PROGRAM SUMMARY TABLE (AHYMO-S4) - Ver. S4.02a, Rel: 02a RUN DATE (MON/DAY/YR) =07/09/2018
INPUT FILE = C:\Users\Public\AHYMOdata\EX1-IAI-S4.DAT USER NO.= AHYMO_Temp_User:20122010

COMMAND	HYDROGRAPH IDENTIFICATION	FROM ID NO.	TO ID NO.	AREA (SQ MI)	PEAK DISCHARGE (CFS)	RUNOFF VOLUME (AC-FT)	RUNOFF (INCHES)	TIME TO PEAK (HOURS)	CFS PER ACRE	PAGE = 1 NOTATION
*S AHYMO - EXAMPLE 1 - A WATERSHED WITH 5 SUBBASINS										
*S USE THE IA/INF METHOD TO COMPUTE THE RUNOFF										
*S FILE: EX1-IAI-S4.DAT										
START										TIME= 0.00
LOCATION		NEW MEXICO								
RAINFALL TYPE= 2 NOAA 14										RAIN24= 3.700
COMPUTE NM HYD	101.00	-	1	1.31000	1291.04	66.209	0.94764	1.710	1.540	PER IMP= 0.00
ROUTE MCUNGE	101.01	1	2	1.31000	1290.43	66.202	0.94754	1.770	1.539	CCODE = 0.2
COMPUTE NM HYD	102.00	-	1	1.36000	1610.53	90.115	1.24240	1.710	1.850	PER IMP= 10.00
ADD HYD	102.01	1& 2	3	2.67000	2861.88	156.317	1.09773	1.740	1.675	
COMPUTE NM HYD	103.00	-	1	1.66000	1276.69	94.932	1.07227	1.840	1.202	PER IMP= 5.00
ROUTE MCUNGE	103.01	1	2	1.66000	1276.32	94.926	1.07220	1.910	1.201	CCODE = 0.2
COMPUTE NM HYD	104.00	-	1	0.93000	1388.19	76.386	1.54004	1.680	2.332	PER IMP= 20.00
ADD HYD	104.01	1& 2	2	2.59000	2302.09	171.312	1.24019	1.770	1.389	
ADD HYD	104.02_AP1	2& 3	3	5.26000	5146.46	327.629	1.16788	1.750	1.529	
ROUTE MCUNGE	104.03	3	2	5.26000	5143.45	327.604	1.16779	1.790	1.528	CCODE = 0.2
COMPUTE NM HYD	105.00	-	1	0.77000	1431.80	70.575	1.71854	1.630	2.905	PER IMP= 26.00
ADD HYD	105.01_AP2	1& 2	3	6.03000	6141.54	398.179	1.23812	1.760	1.591	
ROUTE MCUNGE	105.02	3	2	6.03000	6140.76	398.167	1.23808	1.780	1.591	CCODE = 0.2
COMPUTE NM HYD	106.00	-	1	1.23000	2805.47	150.667	2.29675	1.600	3.564	PER IMP= 50.00
ADD HYD	106.01_AP3	1& 2	3	7.26000	7990.09	548.834	1.41744	1.730	1.720	
ROUTE RESERVOIR	106.02_AP4	3	1	7.26000	1111.06	548.159	1.41570	2.610	0.239	AC-FT= 345.062
FINISH										

Note: The flow rates and runoff volumes computed by the NRCS CN method and the IA/INF method are different for the same watershed analysis. These differences are due to the manner that the two methods compute infiltration losses, to differences in the time to peak computation, and to rainfall distribution differences. The NRCS CN method is very sensitive to the Hydrologic Soil Group. There is no basis in this analysis to establish that one method is superior to another based in the information provided in the example. The calibration and verification of a particular procedure may lead to a method preference by a local government organization or reviewing agency. Program users should consult with reviewing agencies prior to selecting a particular method for evaluating storm drainage runoff.

L.2 Example 2- Compute the Sediment Yield to a Proposed Flood Control Reservoir

For the watershed from Example 1, compute the total sediment yield that would reach the proposed flood control reservoir from a single 100-year 24-hour storm. Use the watershed and channel conditions that are identified in Example 1. Sources of sediment include overland flow from sub-basin areas and bed material transported in channel reaches. Since channels numbered 1, 2 and 3 are natural or stabilized, they are sources of bed material load. Channel number 4 is hard lined but it should be checked to verify that it can carry the sediment from the upstream channels and watersheds. The SED WASH LOAD and SEDIMENT TRANS commands of the AHYMO Program will be used in this analysis. The coefficient and exponent factors (a Coef, b Exp, c Exp, d Exp) for the MPM-Woo Method from the *Sediment and Erosion Design Guide* (1994, for the Albuquerque Metropolitan Arroyo Flood Control Authority, reference Figure 3.10 at page 3-38) will be used, based on the medium bed material size in mm (D_{50}). The following Table L8 presents the bed material size, and coefficient and exponent factors, that are assumed for the channel segments and are used by the SEDIMENT TRANS command. These bed material values would normally be obtained by a sieve analysis of samples from the channel bed of each channel segment.

Table L8. Channel Segment Bed Material Coefficients for Example 2

Channel Number	Length (ft)	Ave. Slope (ft/ft)	Med Bed size (D50, mm)	From *Sediment and Erosion Design Guide*			
				a-Coef	b-Exp	c-Exp	d-Exp
1	4900	0.038	3.0	1.4E-6	5.57	-0.78	-1.4
2	5500	0.033	2.4	1.3E-6	5.75	-0.75	-1.65
3	3400	0.027	1.3	3.7E-6	5.65	-0.50	-2.30
4	4700	0.018	Hard Lined	---	---	---	---

When evaluating the sediment transport capacity of channel number 4, the bed material size and factors from the upstream channel segment (number 3) will be used. The SED WASH LOAD command requires that basin factors for the Modified Universal Soil Loss Equation (MUSLE, Ref: J.R. Williams, 1975) be used for the watershed area above each channel reach. These factors should be obtained by on site surveys of basin vegetation and soils, and by review if existing soil surveys. For the example problem, the assumed factors are given in the following Table L9.

Table L9. Channel Segment MUSLE Equation Factors for Example 2

Above Channel Number	Contributin g g Sub-basins	MUSLE Equation Basin Factors				Percent Impervious
		Soil K	Crop C	Erosion Practice P	LS	
1	10	0.10	0.18	1.0	3.0	0.0
2	30	0.10	.018	1.0	2.0	5.0
3	10 thru 40	0.18	0.25	1.0	1.5	7.7
4	10 thru 50	0.20	0.30	1.0	1.2	10.0
to Res.	60	0.25	.035	1.0	0.4	50.0

The sediment yield can be computed in conjunction with the NRCS CN method or the IA/INF method. The computation of sediment in this example will modify the input file created with the NRCS CN method of Example 1, but similar results would be obtained with the IA/INF method.

The following is the AHYMO Program input data used to compute the sediment yield to the reservoir, with the Natural Resources Conservation Service (NRCS) CN Method used to compute the watershed runoff:

```
*S      AHYMO - EXAMPLE 2 - A WATERSHED WITH 5 SUBBASINS
*S       USE THE NRCS CN METHOD TO COMPUTE THE TOTAL SEDIMENT YIELD
*S                 TO THE RESERVOIR FROM A 100-YEAR 24-HOUR STORM
*S               FILE: EX2-SED-S4.DAT
START                TIME=0.0
LOCATION             NEW MEXICO
RAINFALL             TYPE=-5
                     QUARTER=0.0    ONE= 2.20 IN
                     SIX= 2.90 IN   DAY= 3.70 IN   DT = 0.01 HR
**** SUB-BASIN 10 ****
COMPUTE LT TP        LCODE=4  NRCS TR FIFTY FIVE METHOD
                     NK=1   NSC=1   NCF=1   TYD RAIN=1.6
                    LENGTH=300 FT   SLOPE=0.084   N=0.130
                    LENGTH=2000 FT  SLOPE=0.084  SURFACE=1 UNPAVED
                    LENGTH=5300 FT  SLOPE=0.084   N=0.045
                             X AREA=44.0   X WP=25.7
COMPUTE HYD          ID=1  HYD NO=101  DT=0.0  DA= 1.310 SQ MI
                     CN=66.00  K=0.0  TP=0.0  MASSRAIN=-1
PRINT HYD            ID=1  CODE=1
* ROUTE 10 THRU 20 IN CHANNEL NO. 1
COMPUTE RATING CURVE  CID=1   VS NO=1   NO SEGS=1
                       MIN ELEV=0        MAX ELEV=3.80
                       CH SLOPE=0.038    FP SLOPE=0.038
                       N=0.038           DIST=32.0
                       DIST  ELEV    DIST  ELEV
                        0.0  5.0      6.0  0.0
                       26.0  0.0     32.0  5.0
* COMPUTE THE WASH LOAD FOR WATERSHED 10
SED WASH LOAD        ID=1  SOIL K=0.10  CROP C=0.18
                     EROSION PRACTICE P=1.0  LS=3.0
                     PER IMPERV=0.0  WASH LOAD FACTOR=0.0
* COMPUTE THE SEDIMENT YIELD FOR CHANNEL NUMBER 1
SEDIMENT TRANS       ID=1   IDS=1   CODE=100  A COEF=0.0000014
                     B EXP=5.57   C EXP=-0.78   D EXP=-1.4
                     NUMB WASH=-1   CID=-1
ROUTE MCUNGE         ID=2   HYD NO=101.01   INFLOW ID=1
                     DT=0.0   L=4900 FT   NS=0   SLOPE=0.038
PRINT HYD            ID=2   CODE=1
**** SUB-BASIN 20 ****
COMPUTE LT TP        LCODE=4  NRCS TR FIFTY FIVE METHOD
                     NK=1   NSC=1   NCF=1   TYD RAIN=1.6
                    LENGTH=300 FT   SLOPE=0.044   N=0.130
                    LENGTH=2000 FT  SLOPE=0.044  SURFACE=1 UNPAVED
                    LENGTH=6200 FT  SLOPE=0.084   N=0.038
                             X AREA=44.8   X WP=26.2
COMPUTE HYD          ID=1   HYD NO=102  DT=0.0   DA= 1.360 SQ MI
                     CN=83.04   K=0.0   TP=0.0   MASSRAIN=-1
PRINT HYD            ID=1   CODE=1
* ADD SUB-BASIN 10 TO SUB-BASIN 20
ADD HYD              ID=3   HYD NO=102.01   IDS=1 AND 2
PRINT HYD            ID=3   CODE=1
**** SUB-BASIN 30 ****
COMPUTE LT TP        LCODE=4  NRCS TR FIFTY FIVE METHOD
                     NK=1   NSC=1   NCF=1   TYD RAIN=1.6
```

```
                    LENGTH=300 FT   SLOPE=0.059   N=0.130
                    LENGTH=2000 FT  SLOPE=0.059  SURFACE=1 UNPAVED
                    LENGTH=8500 FT  SLOPE=0.059   N=0.045
                          X AREA=44.0   X WP=25.7
COMPUTE HYD         ID=1  HYD NO=103  DT=0.0   DA= 1.660 SQ MI
                    CN=68.35  K=0.0   TP=0.0   MASSRAIN=-1
PRINT HYD           ID=1  CODE=1
* ROUTE 30 THRU 40 IN CHANNEL NO. 2
COMPUTE RATING CURVE  CID=1   VS NO=1   NO SEGS=1
                      MIN ELEV=0        MAX  ELEV=3.80
                      CH SLOPE=0.033    FP SLOPE=0.033
                      N=0.032           DIST=43.0
                      DIST  ELEV    DIST  ELEV
                       0.0  5.0      9.0  0.0
                      34.0  0.0     43.0  5.0
* COMPUTE THE WASH LOAD FOR WATERSHED 30
SED WASH LOAD       ID=1  SOIL K=0.10  CROP C=0.18
                    EROSION PRACTICE P=1.0  LS=2.0
                    PER IMPERV=5.0  WASH LOAD FACTOR=0.0
* COMPUTE THE SEDIMENT YIELD FOR CHANNEL NUMBER 2
SEDIMENT TRANS      ID=1   IDS=1   CODE=100  A COEF=0.0000013
                    B EXP=5.75   C EXP=-0.75   D EXP=-1.65
                    NUMB WASH=-1   CID=-1
ROUTE MCUNGE        ID=2   HYD NO=103.01   INFLOW ID=1
                    DT=0.0   L=5500 FT   NS=0   SLOPE=0.033
PRINT HYD           ID=2   CODE=1
**** SUB-BASIN 40 ****
COMPUTE LT TP       LCODE=4  NRCS TR FIFTY FIVE METHOD
                    NK=1   NSC=1   NCF=1   TYD           RAIN=1.6
                    LENGTH=300 FT   SLOPE=0.032   N=0.130
                    LENGTH=2000 FT  SLOPE=0.032  SURFACE=1 UNPAVED
                    LENGTH=6300 FT  SLOPE=0.032   N=0.032
                          X AREA=57.2   X WP=33.2
COMPUTE HYD         ID=1   HYD NO=104  DT=0.0   DA= 0.930 SQ MI
                    CN=84.99   K=0.0   TP=0.0   MASSRAIN=-1
PRINT HYD           ID=1   CODE=1
* ADD SUB-BASIN 10 TO SUB-BASIN 20
ADD HYD             ID=2   HYD NO=104.01   IDS=1 AND 2
PRINT HYD           ID=2   CODE=1
* ADD SUB-BASINS 30 AND 40 TO SUB-BASINS 10 AND 20
ADD HYD             ID=3   HYD NO=104.02_AP1   IDS=2 AND 3
PRINT HYD           ID=3   CODE=1
* ROUTE SUB-BASINS 10, 20, 30 AND 40 THRU 50 IN CHANNEL NO. 3
COMPUTE RATING CURVE  CID=1   VS NO=1   NO SEGS=1
                      MIN ELEV=0        MAX  ELEV=7.60
                      CH SLOPE=0.027    FP SLOPE=0.027
                      N=0.035           DIST=80.0
                      DIST  ELEV    DIST  ELEV
                       0.0  10.0    25.0  0.0
                      55.0  0.0     80.0  10.0
* COMPUTE THE WASH LOAD FOR WATERSHEDS 10 THROUGH 40
SED WASH LOAD       ID=3  SOIL K=0.18  CROP C=0.25
                    EROSION PRACTICE P=1.0  LS=1.5
                    PER IMPERV=7.7  WASH LOAD FACTOR=0.0
* COMPUTE THE SEDIMENT YIELD FOR CHANNEL NUMBER 3
SEDIMENT TRANS      ID=3   IDS=1   CODE=100  A COEF=0.0000037
                    B EXP=5.65   C EXP=-0.50   D EXP=-2.3
                    NUMB WASH=-1   CID=-1
ROUTE MCUNGE        ID=2   HYD NO=104.03   INFLOW ID=3
```

```
                    DT=0.0   L=3400 FT   NS=0   SLOPE=0.027
PRINT HYD           ID=2   CODE=1
**** SUB-BASIN 50 ****
COMPUTE LT TP       LCODE=4  NRCS TR FIFTY FIVE METHOD
                    NK=1   NSC=1   NCF=1   TYD           RAIN=1.6
                    LENGTH=300 FT   SLOPE=0.031   N=0.130
                    LENGTH=2000 FT  SLOPE=0.031   SURFACE=2 PAVED
                    LENGTH=4600 FT  SLOPE=0.031   N=0.028
                          X AREA=50.6   X WP=38.1
COMPUTE HYD         ID=1   HYD NO=105  DT=0.0   DA= 0.770 SQ MI
                    CN=86.11   K=0.0   TP=0.0   MASSRAIN=-1
PRINT HYD           ID=1   CODE=1
* ADD SUB-BASIN 10, 20, 30 AND 40 TO SUB-BASIN 50
ADD HYD             ID=3   HYD NO=105.01_AP2   IDS=1 AND 2
PRINT HYD           ID=3   CODE=1
* ROUTE SUB-BASINS 10, 20, 30, 40 AND 50 THRU 60 IN CHANNEL NO. 4
COMPUTE RATING CURVE  CID=1   VS NO=1   NO SEGS=1
                      MIN ELEV=0         MAX  ELEV=9.50
                      CH SLOPE=0.018     FP SLOPE=0.018
                      N=0.013            DIST=72.0
                      DIST  ELEV    DIST  ELEV
                       0.0  15.0    30.0  0.0
                      42.0  0.0     72.0  15.0
* COMPUTE THE WASH LOAD FOR WATERSHEDS 10 THROUGH 50
SED WASH LOAD       ID=3  SOIL K=0.20  CROP C=0.30
                    EROSION PRACTICE P=1.0  LS=1.2
                    PER IMPERV=10.0  WASH LOAD FACTOR=0.0
* COMPUTE THE SEDIMENT YIELD FOR CHANNEL NUMBER 4
SEDIMENT TRANS      ID=3   IDS=1   CODE=100  A COEF=0.0000037
                    B EXP=5.65   C EXP=-0.50   D EXP=-2.3
                    NUMB WASH=-1   CID=-1
ROUTE MCUNGE        ID=2   HYD NO=105.02   INFLOW ID=3
                    DT=0.0   L=4700 FT   NS=0   SLOPE=0.018
PRINT HYD           ID=2   CODE=1
**** SUB-BASIN 60 ****
COMPUTE LT TP       LCODE=4  NRCS TR FIFTY FIVE METHOD
                    NK=1   NSC=1   NCF=1   TYD           RAIN=1.6
                    LENGTH=300 FT   SLOPE=0.024   N=0.011
                    LENGTH=2000 FT  SLOPE=0.024   SURFACE=2 PAVED
                    LENGTH=5800 FT  SLOPE=0.024   N=0.013
                          X AREA=54.0   X WP=25.4
COMPUTE HYD         ID=1   HYD NO=106  DT=0.0   DA= 1.230 SQ MI
                    CN=90.35   K=0.0   TP=0.0   MASSRAIN=-1
PRINT HYD           ID=1   CODE=1
* COMPUTE THE WASH LOAD FOR WATERSHED 60
SED WASH LOAD       ID=1  SOIL K=0.25  CROP C=0.35
                    EROSION PRACTICE P=1.0  LS=0.4
                    PER IMPERV=50.0  WASH LOAD FACTOR=0.0
* ADD SUB-BASIN 10, 20, 30, 40 AND 50 TO SUB-BASIN 60
ADD HYD             ID=3   HYD NO=106.01_AP3   IDS=1 AND 2
PRINT HYD           ID=3   CODE=1
* ROUTE THE TOTAL FLOW THROUGH THE PROPOSED RESERVOIR
ROUTE RESERVOIR     ID=1   HYD NO=106.02_AP4   INFLOW=3   CODE=20
                    OUTFLOW(CFS)    STORAGE(AC-FT)    ELEV(FT)
                       0.0              0.000         0.00
                      50.0             20.975         2.00
                     130.0             42.954         4.00
                     260.0             65.962         6.00
                     410.0             90.021         8.00
```

```
                           630.0             141.389         12.00
                           820.0             197.245         16.00
                           950.0             257.779         20.00
                          1080.0             323.179         24.00
                          1180.0             393.633         28.00
                          1270.0             469.327         32.00
                          1360.0             550.449         36.00
PRINT HYD                 ID=1   CODE=1
FINISH
```

The AHYMO Program output summary table is included to show the results of the Example 2, total sediment yield analysis. The summary table shows the sub-basin peak flow rates and volumes. It also shows the wash load (fine suspended material) concentration in parts per million by weight (PPM-w), and the total sediment transport capacity, in tons, for the channel segments.

AHYMO PROGRAM SUMMARY TABLE (AHYMO-S4) - Ver. S4.02a, Rel: 02a RUN DATE (MON/DAY/YR) =07/09/2018
INPUT FILE = C:\Users\Public\AHYMOdata\EX2-SED-S4.DAT USER NO.= AHYMO_Temp_User:20122010

COMMAND	HYDROGRAPH IDENTIFICATION	FROM ID NO.	TO ID NO.	AREA (SQ MI)	PEAK DISCHARGE (CFS)	RUNOFF VOLUME (AC-FT)	RUNOFF (INCHES)	TIME TO PEAK (HOURS)	CFS PER ACRE	NOTATION PAGE = 1
*S	AHYMO - EXAMPLE 2 - A WATERSHED WITH 5 SUBBASINS									
*S	USE THE NRCS CN METHOD TO COMPUTE THE TOTAL SEDIMENT YIELD									
*S	TO THE RESERVOIR FROM A 100-YEAR 24-HOUR STORM									
*S	FILE: EX2-SED-S4.DAT									
START										TIME= 0.00
LOCATION		NEW MEXICO								
RAINFALL	TYPE= 5									RAIN24= 3.700
COMPUTE HYD	101.00	-	1	1.31000	713.44	63.668	0.91128	6.270	0.851	CN= 66.00
SED WASH LOAD	101.00	1								WASH CONC.(PPM-w) = 67282
SEDIMENT TRANSP	101.00	1		SED ID = 1	PEAK CONC.(PPM-w) = 144637					TOTAL SED.(TONS) = 9971.46
ROUTE MCUNGE	101.01	1	2	1.31000	713.10	63.666	0.91125	6.340	0.851	CCODE = 0.2
COMPUTE HYD	102.00	-	1	1.36000	1787.59	147.328	2.03118	6.300	2.054	CN= 83.04
ADD HYD	102.01	1& 2	3	2.67000	2492.09	210.994	1.48170	6.320	1.458	
COMPUTE HYD	103.00	-	1	1.66000	873.94	92.000	1.03916	6.370	0.823	CN= 68.35
SED WASH LOAD	103.00	1								WASH CONC.(PPM-w) = 41714
SEDIMENT TRANSP	103.00	1		SED ID = 1	PEAK CONC.(PPM-w) = 209978					TOTAL SED.(TONS) = 17815.95
ROUTE MCUNGE	103.01	1	2	1.66000	873.70	91.997	1.03912	6.450	0.822	CCODE = 0.2
COMPUTE HYD	104.00	-	1	0.93000	1170.97	108.660	2.19073	6.370	1.967	CN= 84.99
ADD HYD	104.01	1& 2	2	2.59000	2024.46	200.657	1.45264	6.410	1.221	
ADD HYD	104.02_AP1	2& 3	3	5.26000	4426.48	411.651	1.46739	6.360	1.315	
SED WASH LOAD	104.02_AP1	3								WASH CONC.(PPM-w) = 92347
SEDIMENT TRANSP			104.02_AP1		3			SED ID = 1		PEAK CONC.(PPM-w) =
	489943 TOTAL SED.(TONS) = 280922.00									
ROUTE MCUNGE	104.03	3	2	5.26000	4424.80	411.633	1.46732	6.390	1.314	CCODE = 0.2
COMPUTE HYD	105.00	-	1	0.77000	1094.23	93.867	2.28572	6.330	2.220	CN= 86.11
ADD HYD	105.01_AP2	1& 2	3	6.03000	5490.35	505.500	1.57183	6.380	1.423	
SED WASH LOAD	105.01_AP2	3								WASH CONC.(PPM-w) = 98345
SEDIMENT TRANSP	105.01_AP2		3	SED ID = 1	PEAK CONC.(PPM-w) = 662870					TOTAL SED.(TONS) = 1304805.50
ROUTE MCUNGE	105.02	3	2	6.03000	5489.87 505.490		1.57180	6.410	1.423	CCODE = 0.2
COMPUTE HYD	106.00	-	1	1.23000	3567.53	175.073	2.66879	6.090	4.532	CN= 90.35
SED WASH LOAD	106.00	1								WASH CONC.(PPM-w) = 35580
ADD HYD	106.01_AP3	1& 2	3	7.26000	6340.17	680.562	1.75765	6.370	1.365	
ROUTE RESERVOIR			106.02_AP4	3	1	7.26000	1100.67	678.912	1.75339	7.280
	0.237 AC-FT= 337.745									
FINISH										

The complete program output (commonly AHYMO.OUT or OUT) should be reviewed to verify reservoir routing levels, and sediment yield and bulking factor computations. The complete output file can be obtained by executing the Example 1 input file (EX2-SED-S4.DAT) that is contained on the AHYMO Program distribution files. A portion of the EX2-SED-S4.OUT file is as follows.

```
      AHYMO PROGRAM (AHYMO-S4)                  - Version: S4.02a - Rel: 02a RUN
          DATE (MON/DAY/YR) = 07/09/2018
          START TIME (HR:MIN:SEC) = 09:31:05        USER NO.= AHYMO_Temp_User:20122010
          INPUT FILE = C:\Users\Public\AHYMOdata\EX2-SED-S4.DAT

*S      AHYMO - EXAMPLE 2 - A WATERSHED WITH 5 SUBBASINS
*S       USE THE NRCS CN METHOD TO COMPUTE THE TOTAL SEDIMENT YIELD
*S                TO THE RESERVOIR FROM A 100-YEAR 24-HOUR STORM
*S              FILE: EX2-SED-S4.DAT START
                TIME=0.0
LOCATION            NEW MEXICO

-------------------------------------- Output lines deleted---------------------------

* COMPUTE THE WASH LOAD FOR WATERSHED 10
SED WASH LOAD       ID=1  SOIL K=0.10  CROP C=0.18
                    EROSION PRACTICE P=1.0  LS=3.0
                    PER IMPERV=0.0 WASH LOAD FACTOR=0.0
        SEDIMENT YIELD (Wash Mat.) =      6241.9 (TONS)      WASH LOAD CONCENTRATION =    67282 (ppm-w)
        PERCENTAGE IMPERVIOUS AREA = 0.000                   WASH LOAD FACTOR =           3.00000

* COMPUTE THE SEDIMENT YIELD FOR CHANNEL NUMBER 1
SEDIMENT TRANS      ID=1    IDS=1    CODE=100 A COEF=0.0000014
                    B EXP=5.57    C EXP=-0.78    D EXP=-1.4
                    NUMB WASH=-1                 CID=-1
            Use wash load from SED WASH LOAD command -Concentration =          67282 (PPM-w)
            Use channel data from COMPUTE RATING CURVE command -CID =          1

-------------------------------------- Output lines deleted---------------------------

        AT PEAK FLOW OF    713.440 WITH TIME AT      6.27 HOURS:  BEDMAT =   1233.63 (TONS) =       0.5664 (AC-FT bulked)
                                                                TOTAL SED =   2344.46 (TONS) =       1.0764 (AC-FT bulked)
        PEAK BULKING FACTOR =                    1.063810 =            144638. (PPM-w)

            Bed Material Transport computed using maximum wash load concentration = 60000 PPM-w
```

	WEIGHT (TONS)	UNBULKED VOLUME (AC-FT)	BULKED VOLUME (AC-FT)	CONCENTRATIO N BY WEIGHT (PPM)	AVERAGE BULKING FACTOR
WASHMAT =	6241.82	1.7331	2.8658	67282.	
BEDMAT =	3729.64	1.0356	1.7124	41322.	
TOTAL SEDIMENT =	9971.46	2.7687	4.5783	103331.	1.043486

```
        SEDIMENT TRANSPORT CAPACITY:                          3.49486 AC-FT/SQ MI (bulked) =    11.8934   TONS/ACRE   (at
        Porosity=0.395)

-------------------------------------- Output lines deleted---------------------------

* COMPUTE THE WASH LOAD FOR WATERSHED 30
SED WASH LOAD       ID=1  SOIL K=0.10  CROP C=0.18
                    EROSION PRACTICE P=1.0  LS=2.0
                    PER IMPERV=5.0 WASH LOAD FACTOR=0.0
        SEDIMENT YIELD (Wash Mat.) =     5442.8 (TONS)     WASH LOAD CONCENTRATION =        41714
        (ppm-w) PERCENTAGE IMPERVIOUS AREA =                                  5.000     WASH      LOAD
        FACTOR =                         3.00000

* COMPUTE THE SEDIMENT YIELD FOR CHANNEL NUMBER 2
SEDIMENT TRANS      ID=1    IDS=1    CODE=100 A COEF=0.0000013
                    B EXP=5.75    C EXP=-0.75    D       EXP=-1.65
                    NUMB WASH=-1                 CID=-1
            Use wash load from SED WASH LOAD command -Concentration =       41714 (PPM-w) Use
            channel data from COMPUTE RATING CURVE command -CID =           1

-------------------------------------- Output lines deleted---------------------------

        AT PEAK FLOW OF    873.935 WITH TIME AT      6.37 HOURS:  BEDMAT =   4281.90 (TONS) =       1.9660 (AC-FT bulked)
```

TOTAL SED = 5321.35 (TONS) = 2.4432 (AC-FT bulked)
PEAK BULKING FACTOR = 1.100297 = 209978. (PPM-w)

	WEIGHT (TONS)	UNBULKED VOLUME (AC-FT)	BULKED VOLUME (AC-FT)	CONCENTRATION BY WEIGHT (PPM)	AVERAGE BULKING FACTOR
WASHMAT =	5442.75	1.5112	2.4990	41714.	
BEDMAT =	12373.20	3.4355	5.6810	90047.	
TOTAL SEDIMENT =	17815.95	4.9468	8.1800	124717.	1.053769

SEDIMENT TRANSPORT CAPACITY: 4.92769 AC-FT/SQ MI (bulked) = 16.7695 TONS/ACRE (at Porosity=0.395)

-------------------------------------- Output lines deleted---------------------------

```
* COMPUTE THE WASH LOAD FOR WATERSHEDS 10 THROUGH
40 SED WASH LOAD          ID=3 SOIL K=0.18 CROP C=0.25
                          EROSION PRACTICE P=1.0  LS=1.5
                          PER IMPERV=7.7 WASH LOAD FACTOR=0.0
    SEDIMENT YIELD (Wash Mat.) =  56921.9 (TONS)   WASH LOAD CONCENTRATION =  92347 (ppm-w)
    PERCENTAGE IMPERVIOUS AREA =    7.700          WASH LOAD FACTOR =   3.00000

* COMPUTE THE SEDIMENT YIELD FOR CHANNEL NUMBER 3
SEDIMENT TRANS            ID=3     IDS=1    CODE=100 A COEF=0.0000037
                          B EXP=5.65   C EXP=-0.50   D EXP=-2.3
                          NUMB WASH=-1   CID=-1
                 Use wash load from SED WASH LOAD command -Concentration =   92347 (PPM-w)
                 Use channel data from COMPUTE RATING CURVE command -CID =   1
```

****

TIME (HRS)	WATER FLOW (CFS)	VELOCITY (FT/SEC)	HYD. DEPTH (FT)	WIDTH (FT)	WASHLOAD CONC. (PPM-w)	BED MAT. TRANSPORT (CFS)	BED CONC. (PPM-w)	TOTAL CONC. (PPM-w)	BULKING FACTOR	ACCUM. SEDIMENT (TONS)
0.000	0.00	0.000	0.000	0.00	92347.	0.00	0.	92347.	1.0000	0.00
1.000	0.00	0.000	0.000	0.00	92347.	0.00	0.	92347.	1.0000	0.00
2.000	0.00	0.000	0.000	0.00	92347.	0.00	0.	92347.	1.0000	0.00
3.000	0.00	0.000	0.000	0.00	92347.	0.00	0.	92347.	1.0000	0.00
4.000	0.00	0.000	0.000	0.00	92347.	0.00	0.	92347.	1.0000	0.00
5.000	1.71	0.612	0.093	30.03	92347.	0.00	41.	92381.	1.0384	2.25
6.000	695.54	9.981	1.744	39.96	92347.	57.03	178498.	241864.	1.1204	1834.03
7.000	1145.46	11.786	2.248	43.24	92347.	139.05	243394.	297473.	1.1598	233057.81
8.000	320.29	7.622	1.157	36.31	92347.	13.87	102911.	177942.	1.0817	252860.77
9.000	200.29	6.436	0.896	34.74	92347.	5.80	71284.	151462.	1.0674	258284.28
10.000	150.93	5.797	0.765	34.06	92347.	3.41	56484.	139125.	1.0610	261573.41
11.000	122.71	5.372	0.681	33.52	92347.	2.31	47539.	131684.	1.0572	263954.22
12.000	104.13	5.054	0.622	33.15	92347.	1.70	41358.	126549.	1.0547	265829.56
13.000	99.88	4.975	0.607	33.07	92347.	1.57	39905.	125343.	1.0541	267458.28
14.000	94.66	4.876	0.589	32.97	92347.	1.41	38102.	123847.	1.0533	269013.50
15.000	89.58	4.776	0.571	32.87	92347.	1.27	36328.	122376.	1.0526	270464.19
16.000	85.12	4.685	0.554	32.78	92347.	1.16	34750.	121068.	1.0520	271822.88
17.000	81.19	4.602	0.540	32.70	92347.	1.06	33347.	119904.	1.0514	273101.12
18.000	77.56	4.523	0.526	32.63	92347.	0.97	32040.	118821.	1.0509	274308.88
19.000	74.36	4.451	0.513	32.56	92347.	0.89	30874.	117855.	1.0504	275453.50
20.000	71.42	4.383	0.501	32.51	92347.	0.83	29798.	116963.	1.0500	276541.34
21.000	68.74	4.319	0.490	32.45	92347.	0.77	28807.	116143.	1.0496	277579.91
22.000	66.28	4.260	0.480	32.40	92347.	0.72	27893.	115386.	1.0492	278572.06
23.000	64.00	4.203	0.471	32.36	92347.	0.67	27041.	114680.	1.0489	279522.47
24.000	61.88	4.149	0.461	32.32	92347.	0.63	26244.	114021.	1.0486	280435.16
25.000	4.71	1.195	0.131	30.17	92347.	0.00	547.	92798.	1.0386	280909.97
26.000	0.03	0.166	0.024	8.41	92347.	0.00	1.	92348.	1.0384	280922.00

AT PEAK FLOW OF 4426.479 WITH TIME AT 6.36 HOURS: BEDMAT = 80757.23 (TONS) = 37.0786 (AC-FT bulked)
TOTAL SED = 93198.90 (TONS) = 42.7910 (AC-FT bulked)
PEAK BULKING FACTOR = 1.362478 = 489943. (PPM-w)

Bed Material Transport computed using maximum wash load concentration = 60000 PPM-w

UNBULKED BULKEDCONCENTRATION AVERAGE

	WEIGHT (TONS)	VOLUME (AC-FT)	VOLUME (AC-FT)	BY WEIGHT (PPM)	BULKING FACTOR
WASHMAT =	56921.28	15.8047	26.1347	92347.	
BEDMAT =	224000.72	62.1958	102.8470	285911.	
TOTAL SEDIMENT =	280922.00	78.0005	128.9816	334278.	1.189482

SEDIMENT TRANSPORT CAPACITY: 24.52122 AC-FT/SQ MI (bulked) = 83.4488 TONS/ACRE (at Porosity=0.395)

-------------------------------------- Output lines deleted---------------------------

```
* COMPUTE THE WASH LOAD FOR WATERSHED 60
SED WASH LOAD          ID=1  SOIL K=0.25  CROP C=0.35
                       EROSION PRACTICE P=1.0   LS=0.4
                       PER IMPERV=50.0 WASH LOAD FACTOR=0.0
      SEDIMENT YIELD (Wash Mat.) =        8778.3 (TONS)     WASH LOAD CONCENTRATION =        35580 (ppm-
      w)
      PERCENTAGE IMPERVIOUS AREA =        50.000            WASH LOAD FACTOR =3.00000
```

-------------------------------------- Output lines deleted---------------------------

```
* ROUTE THE TOTAL FLOW THROUGH THE PROPOSED RESERVOIR
ROUTE RESERVOIR        ID=1    HYD NO=106.02_AP4  INFLOW=3  CODE=20
                       OUTFLOW(CFS)     STORAGE(AC-FT)   ELEV(FT)
                           0.0              0.000           0.00
                          50.0             20.975           2.00
                         130.0             42.954           4.00
                         260.0             65.962           6.00
                         410.0             90.021           8.00
                         630.0            141.389          12.00
                         820.0            197.245          16.00
                         950.0            257.779          20.00
                        1080.0            323.179          24.00
                        1180.0            393.633          28.00
                        1270.0            469.327          32.00
                        1360.0            550.449          36.00
```

-------------------------------------- Output lines deleted---------------------------

```
PEAK DISCHARGE =              1100.675 CFS - PEAK OCCURS AT HOUR    7.28
MAXIMUM WATER SURFACE ELEVATION =          24.827
MAXIMUM STORAGE =               337.7451 AC-FT         INCREMENTAL TIME=0.010000HRS
```

-------------------------------------- Output lines deleted---------------------------

```
FINISH

        NORMAL PROGRAM FINISH        END TIME (HR:MIN:SEC) = 09:31:05
```

The AHYMO Program output file (EX2-SED-S4.OUT) and summary file (EX2-SED-S4.SUM) can be used to evaluate the watershed total sediment yield as follows:

a. The sediment transport capacity of channel number 3 (HYD NO=104.02) is much larger than the sum of channel number 1 (HYD NO=101.00) and channel number 2 (HYD NO=103.00) so that channel number 3 can convey all the sediment from the upstream channels. Because this channel is assumed to have an unlined bed (soft lined), the channel is likely to erode (degrade) as a result of sediment delivery deficiency from upstream channels. The channel erosion will introduce more sediment into the flow so that the computed sediment yield of 280922 tons will be discharged at the lower end of channel segment 3.

b. The sediment transport capacity of channel number 4 (HYD NO=105.01) is much larger than the sediment transport capacity of channel number 3 (HYD NO=104.02). Because channel number 4 is hard lined, there will be no increased sediment yield from the channel bed of channel number 4, and the sediment yield from channel number 3 (280922 tons) will be discharged at the lower end of channel number 4.

c. The wash load sediment yield from sub-basin 60 is computed to be 35580 PPM-w or 8778 tons. This quantity should be added to the sediment yield from channel number 3, to compute the total sediment to the reservoir. If the sediment has a porosity of 0.395 and a specific gravity of 2.65 (both are reasonable values for deposited sediment), then the total computed sediment yield 289700 tons will create a bulked sediment volume of 133.01 acre-feet from the 100-year 24-hour storm.

d. The peak volume and outflow of the reservoir occurs at 7.28 hours from the beginning of the storm period. At 7.28 hours, the accumulated sediment from channel number 3 is approximately 84.9 percent of the total sediment yield. It is appropriate to use this ratio to estimate the additional reservoir capacity that is required to carry the expected sediment from the watershed. Based on a total bulked sediment volume of 133.01 acre-feet, the additional reservoir capacity required to carry the expected sediment is 112.9 acre-feet. The reservoir was computed to have a clear water volume of 337.75 acre feet, so that the reservoir capacity would need to increase by approximately 33.5 percent. The average sediment bulking factor is 1.19, but this value should not be used for reservoir sizing because the sediment is more concentrated during reservoir filling.

e. The peak bulking factor (volume of water plus sediment/volume of water) in channel number 3 was computed to be 1.36 with a sediment concentration of 489943 PPM by weight. This factor should be applied to the computed peak flow rate, when evaluating the existing channel capacity and water surface elevations for channel numbers 3 and 4.

f. The high levels of sediment concentration indicated by this analysis are characteristic of "mud flood" conditions. Local variances in channel properties are likely to create scouring or deposition, and highly unstable flow.

g. The bulking factors computed by the sediment yield analysis can be applied to the watershed analysis using the SEDIMENT BULK command.

Reservoir sizing to accommodate this single 100-year 24-hour storm assumes that the reservoir is initially clean and that the sediment is removed immediately after every storm, so that the capacity of the reservoir is preserved. An initially clean condition is not likely at most locations because sediment is normally allowed to accumulate until some maintenance threshold is reached. To determine reasonable sediment accumulation levels for maintenance, it may be necessary to consider a sequence of storms or a weighted average of storms as described in the *Sediment and Erosion Design Guide*. The capacity of a flood control reservoir should include consideration of the frequency and availability of sediment maintenance that will be available, and the accumulation of sediment from the design storm event, in addition to the clear water capacity.

APPENDIX A

Notes on the Muskingum-Cunge Method

by Clifford E. Anderson, PE, D.WRE
Anderson-Hydro

December 2009

Notes on the Muskingum-Cunge Method

by Clifford E. Anderson, PE, D.WRE

The AHYMO Program ROUTE MCUNGE command uses the Muskingum-Cunge Method to route a hydrograph through a channel reach. The Muskingum-Cunge Method is an explicit finite difference scheme first proposed by J. A. Cunge ("On the Subject of a Flood Propagation Model (Muskingum Method)", *Journal of Hydraulic Research*, Vol. 7, No. 2, 1969, pp 205-230). Cunge showed that the parameters of the Muskingum Method could be calculated from formulas derived from the physical properties of a channel.

"The Muskingum-Cunge routing technique is a non-linear coefficient method that accounts for hydrograph diffusion based on physical channel properties and the inflowing hydrograph. The advantages of this method over other hydrologic techniques are: (1) the parameters of the model are physically based; (2) the method has been shown to compare well against the full unsteady flow equations over a wide range of flow situations (Ponce, 1983 and Brunner, 1989); and (3) the solution is independent of the user specified computation interval. The major limitations if the Muskingum-Cunge application in HEC-1" [also AHYMO] *are that: (1) it can not account for backwater effects; and (2) the method begins to diverge from the full unsteady flow solution when very rapidly rising hydrographs are routed through very flat slopes (i.e. channel slopes less than 1 ft./mile)."* (Ref: *HEC-1 Flood Hydrograph Package User's Manual*, 1990, p. 30, U.S. Army Corps of Engineers, Davis, CA)

The basic formulation of the Muskingum-Cunge technique was identified in the U.S. Army Corps of Engineers, *HEC-1 Flood Hydrograph Package User's Manual*. The Muskingum-Cunge is now includes in the U.S. Army Corps of Engineers HEC-HMS program (Ref: *Hydrologic Modeling System HEC-HMS User's Manual,* Version 3.3, September 2008, U.S. Army Corps of Engineers, Hydrologic Engineering Center, Davis, CA). The formulation of the Muskingum-Cunge procedures in the ROUTE MCUNGE command of the AHYMO Program follows a very similar method. In a manner similar to the HEC-1 and HEC-HMS programs, the AHYMO Program uses an iterative four point averaging scheme and variable routing parameters, as described by Victor M. Ponce and Vujica Yevjevich (1978, "Muskingum-Cunge Method with Variable Parameters", ASCE, *Journal of Hydraulic Division*, V. 104, pp 1663-1667).

The Muskingum-Cunge routing coefficients C0, C1 and C2 may impact the precision and stability of the routing computation. Some users of the HEC-1 Program had reported computational problems when routing sharply peaked hydrographs that are commonly found with arid watersheds. One example of documented computational problems was documented in George Sabol's (Phoenix, Arizona) letter of October 1, 1992 to the U.S. Army Corps of Engineers., Hydrologic Engineering Center. To resolve numerical stability problems, Victor M. Ponce (1989, *Engineering Hydrology Principles and Practices*, Prentice Hall) recommended that the C0 coefficient be greater than zero. D. L. Fread (1993, "Flow Routing", Chapter 10, *Handbook of Hydrology*, David R. Maidment, Editor in Chief, pp 10.1 to 10.36) indicated that coefficients C0, C1 and C2 should all be positive values. The U.S. Army Corps of Engineers resolved the computational instability in the HEC-HMS program by applying very small computation time steps

Testing of the C0, C1 and C2 coefficient constraints was performed by C.E. Anderson and R. J. Heggen (1985, "Application of Muskingum-Cunge Channel Routing to Steep Slope Arid Arroyos", *Proceedings of the Conference on Arid West Floodplain Management Issues*, San Diego, CA, January 24-26, 1995, Association of State Floodplain Managers, Madison, WI). This document described a method of coefficient constraint that was incorporated into the AHYMO (version AHYMO194) program.

The current version of the AHYMO program uses source code and procedures derived independently from the AHYMO194 and AHYMO_97 versions. The AHYMO_97 program (version of 1997) used C0, C1 and C2 coefficient constraints in the manner described in the paper by Anderson and Heggen. The paper by Anderson and Heggen (1995) used the terms "Maidment's constraint" or Maidment's coefficient constraint" to describe the positive values for the C0, C1 and C2 that were suggested by D.L. Fread (1993). The current version of the AHYMO Program uses the terms "Fread's constraint" or "Fread's suggested procedure" to describe these coefficient constraints.

With the AHYMO_97 program(1997 version), the default procedure in the ROUTE MCUNGE command first used Ponce's constraint of C0 to route the hydrograph. Then if the result is numerically unstable, the routing was performed using Fread's (Maidment's) constraint of C0, C1 and C2. This process was intended to optimize numerical accuracy, with the more precise Ponce's constraint, and when necessary provide numerical stability with Fread's constraint. Testing of the AHYMO_97 program in 2009 (Stantec, Inc. for SSCAFCA) indicated the use of Fread's suggested procedure changed the computed celerity for the routed hydrographs. This shifted the peak intensity of the resulting hydrograph and that when the routed hydrographs were added to other hydrographs in a complex hydrologic model, the resulting peak flow rates were lower than should have been computed. The use of Ponce's suggested procedure did not produce this problem, but there was frequent numerical instability in the routed hydrographs when incremental times of 0.033333 and 0.05 hours (2 or 3 minutes) were used. In order to avoid numerical instability with Ponce's suggested procedure, it was necessary to reduce the computation time interval (DT) to 0.01 hours or less.

The AHYMO-S4 program included revisions to the ROUTE-MCUNGE command to reduce use of Fread's suggested procedure for routing coefficients. With this revision, Ponce's suggested procedure was applied to channel routing, but smaller computation time steps were needed to eliminate numerical instability problems. To address this requirement, the AHYMO-S4 version of the program was revised to accommodate 4000 data points in a hydrograph. This allowed computation time steps of 0.01 or 0.005 hours for 6-hour precipitation events and 0.01 hours for 24-hour events. When computation time steps at 0.015 hours or less are specified, the AHYMO-S4 program will only use Ponce's suggested procedure.

The AHYMO-S4 version provides the following features with Muskingum-Cunge channel routing:

a. An iterative four point averaging scheme is used as the default analysis procedure.

b. A non-liner function is used to interpolate intermediate flow from the channel rating table.

c. When the computation time step is 0.015 hours or less only Ponce's suggested constraint is used. When the computation time step is larger than 0.015 hours, the Muskingum-Cunge routing parameters are first computed with Ponce's constraint. If numerical instability is detected, Fread's constraint is used. Program users can also specify exclusive use of Ponce's suggested constraint with computation time steps longer than 0.015 hours. The recommended computation time step for the AHYMO-S4 program is 0.01 hours or smaller.

d. If any of the C0, C1 or C2 coefficients are set to zero to satisfy sign constraints, the remaining coefficients are recomputed from the fundamental routing equations.

Each of the above features will serve to improve accuracy or computational efficiency of the ROUTE MCUNGE command. A comparison of individual channel reach routing revealed only small differences between the application of Ponce's constraint and Fread's constraint for a single sub-basin channel segment. There were differences in the peak flow rate and the timing of peak flows. However, when sharply peaked flows were added together in a watershed analysis, the minor timing differences resulted in much larger peak flow differences. Improved computational procedures are implemented by exclusive use of Ponce's recommended procedure in the AHYMO-S4 version.

The ROUTE MCUNGE command shows good agreement with numerically stable HEC-1 computations. The paper by Anderson and Heggen (1995) concluded that the use of the combination of Ponce's constraint, a numerical stability test, then Fread's (Maidment's) constraint could improve computational stability without loss of computational accuracy. The comparisons with several HEC-1 channel routing examples indicated strong agreement. Subsequent comparisons of AHYMO and HEC-HMS of more complex watersheds indicates that only Ponce's constraint should be used. The paper by Anderson and Heggen (1995) contained a table that documented a comparison of HEC-1 results with AHYMO194 program results; updated values are included as Table App-A-1.

Table App-A-1. HEC-1/AHYMO Comparison	Test						
	1a Fig 21	1b Fig 23	1c Fig 25	2a Dead Wash	2b Bob Ward	3a Ex 15 sub1	3b Ex 15 sub2
HEC-1 and AHYMO Qp in	7450	44300	70400	1198	2099	3381	12131
HEC-1 Qp out	6987	43589	55816	Unstable	Unstable	3330	10008
AHYMO Qp out, Interpolated Negative Cs allowed	6950 Unstable STQ**	43649 STQ**	57727 ST**	1315 Unstable Negative	2253 Unstable Negative	3316 Unstable Negative STQ	10209 STQ**
AHYMO Qp out, Interpolated $C_0 \geq 0$ (Ponce)	**6950** **STQ****	**43649** **STQ****	**57727** **ST****	1244 Unstable	2139 Unstable	**3316** **STQ****	**10209** **STQ****
AHYMO Qp out, Interpolated C_0, C_1 and $C_2 \geq 0$	6950 STQ**	43128 Q	57784 ST	1185 Q**	2022 Q**	3316 STQ**	10455 ST
S = Shapes match, T = Times to peak match, Q = Peak discharges match, ** = Optimum Performance							

Additionally, Anderson and Heggen (1995) showed the differences between the original HYMO variable storage coefficient (VSC) channel routing procedure (using the ROUTE command of the AHYMO program) and the Muskingum-Cunge routing with the AHYMO194 program. The results of analysis are presented in the following Table App-A-2.

Table App-A-2. Summary of VSC & Muskingum-Cunge Channel Routing

Name of Area	Basin Area (SQ MI)	Number Sub-basins	Number Routing Segments	Percent w/ Fread's Constraint	AHYMO Flow (CFS) w/ Var.S.C.	AHYMO Flow (CFS) w/ M.-Cunge
Montoyas Arroyo	61.4	24	22	18%	9963	11965
Pino Dam	6.3	52	48	60%	6568	6035
Bear Arroyo	9.4	15	10	30%	6534	7423
N. Domingo Baca Arroyo	6.9	20	16	25%	3502	3097
Piedras Marcadas Dam	5.8	40	50	44%	2062	1939

A review of channel routing for individual segments indicates that the variable storage coefficient (VSC) method may have serious routing errors for natural arroyo conditions subjected to sharply peaked hydrographs. For the sharply peaked hydrographs that are common to arid and semi-arid natural channels, the Muskingum-Cunge routing procedure (ROUTE MCUNGE command) represents a significant improvement over the variable storage coefficient method (as specified with the ROUTE command of the AHYMO program). Testing of the current program version supports this assertion.

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APPENDIX B

README file for the AHYMO™ Computer Program

APPENDIX B - README FILE

README - AHYMO-S4-R2

README file for the

AHYMO COMPUTER PROGRAM
(An Arid-lands HYdrologic MOdel)

Program Version: AHYMO-S4 Release 2

Copyright does not include any portion of the A.R.S. HYMO program, which is a work of the United States Government. AHYMO is a trademark registered in the State of New Mexico. The AHYMO program is distributed by the City of Albuquerque, and by other distributers authorized by the City of Albuquerque.

I. Distribution of the AHYMO program to FEMA:

The AHYMO computer program and documentation, including all data files containing program source code (AHYMOwin.FOR, AHYMAwin.FOR, AHYMBwin.FOR, AHYMCwin.FOR, AHYMDwin.FOR, AHYMEwin.FOR, AHYMOFwin.FOR and AHYMGwin.FOR) and executable code AHYMO-S4-R1.EXE), and the user's manuals have been made available, free of charge, to the Federal Emergency Management Agency (FEMA) and all present and future parties impacted by the flood insurance mapping developed or amended through the use of the program. FEMA may release the AHYMO Program executable code and manuals to such impacted parties without authorization by or notification to the City of Albuquerque. FEMA may release the AHYMO Program source code to impacted parties only when FEMA determines that release of the executable code is not sufficient to meet the requirements of FEMA. Subsequent release of the code and manuals by impacted parties, other than FEMA, is prohibited without written authorization from the City of Albuquerque.

Any distribution of the program or manuals in machine readable form or printed form shall include this README file. All output files created with the AHYMO computer program contain a 24 character user number; the source code and executable code made available to FEMA produce the characters "FEMA" within the first 15 positions (characters 1 to 15) of the user number.

II. Ownership by City of Albuquerque

The City of Albuquerque is the owner of the 1990 through 2018 modifications and enhancements made to the USDA Agricultural Research Service (ARS) version of the HYMO program, which have been used to create the AHYMO Program. The City of Albuquerque has the exclusive rights to distribute or license the AHYMO program. The modified and enhanced version of the program is referred to herein as the AHYMO or AHYMO-S4 program. Revisions and enhancements were acquired by the City of Albuquerque through an agreement between the City of Albuquerque and by C. E. Anderson. The program lines revised from the original ARS HYMO code can be identified within the source code because they have the characters AHYM*** or SCAN*** in columns 73 through 80, where *** represents a revision code; and by the subroutines labeled PEAKVO, PIPE, DIVHYD, CMPABQ, CMPNM, MODTIM, UNITHY, COMPKT, SAVHYD, RAINFALL, RAIN2, RAIN3, SUMMARY, LANDF, START, FINISH, SEDBF, COMPBF,

SEDREG, CHRHYD, CONXHD, IDSORT, HYDSHFT, TIMINC, MCROUT, MCSTEP, MCRT2, LOCCOD, LOCSETUP, MCPARAB, MCPCOR, LTTP and LTTP2. Except for the rights granted hereinbefore to FEMA, the City of Albuquerque retains all rights to sell, distribute, copy and license the executable code, program source code, and user's manuals developed or revised. Except for the rights specifically granted to FEMA and FEMA's "impacted parties", as described herein; copying, distributing, posting on computer bulletin boards, and all application and use of the AHYMO program are prohibited without written authorization from the City of Albuquerque. The AHYMO program is distributed subject to a license agreement. The City of Albuquerque reserves the right to amend and revise the program.

It is recommended that all references to this program and distributed copies of this program include a reference as follows:

The City of Albuquerque, 2018, "AHYMO (AHYMO-S4-R2) Computer Program, User's Manual." Published and distributed by the City of Albuquerque, Hydrology Section, Planning Department, Albuquerque, New Mexico, Plaza del Sol Bldg, 600 2nd St NW, Albuquerque, NM 87102, https://www.cabq.gov/planning/development-review-services/hydrology-section

Copying and distribution of the ARS HYMO User's Manual (ARS-S-9) is permitted by ARS.

III. Conditions for use of the AHYMO program:

The use of the AHYMO-S4 program is limited to persons, corporations and agencies licensed by the City of Albuquerque. Licensed users are assigned a user number that is provided to all program users and printed with the program output. The user number assigned by the City of Albuquerque must be included on the program AHYMO_IO.FIL that is required for program execution.

The following license forms can be assigned:

a) License type: Single User - with the characters "Single" or "SINGLE" at characters 1 through 15

b) License type: Site - with the characters "Site" or "SITE" at characters 1 through 15

c) License type: Government Agency - with the characters "Gov" or "GOV" at characters 1 to 15

d) License type: Educational - with the characters "Edu" or "EDU" at characters 1 through 15

e) License type: Temporary - with the characters "Temp" at characters 1 through 15

f) License type: Group - with the characters "Group" at characters 1 through 15

Program licenses obtained for the AHYMO-S4 program prior to program ownership by the City of Albuquerque remain valid with AHYMO-S4-R2, and user numbers assigned for the AHYMO-S4 program can be used with the AHYMO-S4-R2 program.

Program users are not allowed to distribute their license number for use by others. Authorized transfer of the Single User and Site licenses is allowed, and the City of Albuquerque may authorize a new license number as an alternative to a transfer of the software.

The City of Albuquerque may allow temporary use of the AHYMO_S4 program for testing and evaluation purposes only.

The City of Albuquerque makes no warranties, either expressed or implied, as to the quality or performance of the AHYMO or AHYMO-S4 program, or that the calculations contained therein will be uninterrupted, accurate or error free. All the calculations are subject to interpretation, and the City of Albuquerque therefore makes no implied or expressed warranty of results obtained by using the AHYMO or AHYMO-S4 program. Any use of this program must be based on the understanding by the user that any results are intended to aid the user in performing engineering oriented mathematical calculations, and that the results obtained from the AHYMO or AHYMO-S4 program does not necessarily constitute an acceptable engineering design or analysis. The results of the AHYMO or AHYMO-S4 program must be reviewed by persons possessing experience and thorough understanding of the engineering principles that apply to the application of the program. The user is advised to test this program thoroughly before relying on the results as the basis for making engineering decisions. The ARS has not endorsed any program modifications made by the City of Albuquerque.

IV. History of the AHYMO program:

The AHYMO computer program is based on the program developed by Jimmy R. Williams and Roy W. Hann, Jr. for the Agricultural Research Service, (ARS), United States Department of Agriculture in cooperation with the Texas Agricultural Experiment Station, Texas A&M University. The function of the program is described in detail in the "HYMO: Problem - Oriented Computer Language for Hydrologic Modeling, User's Manual" (ARS-S-9, May 1973). Fortran Source code came from ARS version HYMO1548 (P.C. Version). Dr. Clifford E. Anderson, PE, D.WRE was the developer of all the Fortran source code revisions to the ARS HYMO program that were known as AHYMO. These revisions began in 1986 and continued through 2017. The 2007 through 2011 program codes was compiled using the Intel (R) Visual Fortran Compiler Professional Edition for Windows, version 11. In 2018, Clifford E. Anderson entered into an agreement with the City of Albuquerque that donated all ownership of the AHYMO and AHYMO-S4 versions of the program to the City.

V. Arid and Semi-arid area use of the HYMO and AHYMO programs:

The HYMO program has been used on the following projects:

a. "Albuquerque Master Drainage Study", by Bohannan-Huston, Inc., for the City of Albuquerque, (1981)
b. "Seven-Bar Channel Design Memorandum", by Bohannan-Huston, Inc., for the Albuquerque Metropolitan Arroyo Flood Control Authority (AMAFCA), (1982)
c. "Raymac Dam Preliminary Engineering Report", by Scanlon and Associates, Inc., for AMAFCA, (1982)
d. "Piedras Marcadas Basin Drainage Management Plan", by Tom Mann and Associates, Inc., for AMAFCA, (1983)
e. "North Coors Drainage Management Plan", by Scanlon and Associates, Inc., for AMAFCA, (1984)
f. "Black Arroyo Drainage Management Study", by Bohannan-Huston, Inc., for AMAFCA, (1986)

g. "Far Northwest Drainage Management Plan", by Bohannan-Huston, Inc., for the City of Albuquerque, (1986)
h. "Denison Park Drainage Management Plan", by Scanlon and Associates, Inc., for AMAFCA, (1987)
i. "West Bluff Drainage Plan", by Andrews, Asbury and Robert, Inc., for the City of Albuquerque, (1987)
j. "Southeast Valley Drainage Management Plan", by Wilson and Company, for AMAFCA, (1988)
k. "Northwest Mesa Drainage Management Plan", by Scanlon and Associates, Inc., for the City of Albuquerque, (1989)
l. "Far Northeast Heights Master Drainage Plan", by Roy F. Weston, Inc., for the City of Albuquerque, (1989)

The AHYMO program has been used on the following projects:

a. "Southwest Valley Drainage Management Plan", by Andrews, Asbury & Robert, Inc., for AMAFCA, (1990)
b. "Black Arroyo Detention Dam - Final Hydrology and Sediment Issues", by Bohannan-Huston, Inc., for AMAFCA, (1991)
c. "North and South Domingo Baca Arroyos and Paseo del Norte Corridor Drainage Management Plan", by Resource Technology, Inc., for AMAFCA, (1991)
d. "Design Analysis - Vineyard Channel West of I-25", by Greiner Engineering, Inc., for AMAFCA, (1992)
e. "Amole Arroyo-Westgate Dam Drainage Management Plan Revision", by Scanlon & Associates, Inc., for AMAFCA, (1993)
f. "Piedras Marcadas Drainage Management Plan Revision", by Molzen-Corbin and Associates, Inc., for AMAFCA, (1993)
g. "City of Santa Fe Drainage Management Plan CLOMR", by Bohannan-Huston, Inc., for the City of Santa Fe, (1996)
h. "Update to North Coors Drainage Management Plan - Middle Portion", by Smith Engineering Company., for AMAFCA, (1997)
i. "Santa Fe Drainage Management Plan, Santa Fe River Watershed", by Bohannan-Huston, Inc., for the City of Santa Fe, (1997)

The AHYMO-S4 version of the HYMO program, including the COMPUTE NM HYD, RAINFALL, LAND FACTORS, LOCATION, COMPUTE LT TP, MODIFY TIME, SEDIMENT BULK, SEDIMENT TRANS and ROUTE MCUNGE commands, has been reviewed and tested for New Mexico conditions, and for areas with similar hydrologic conditions. Upon appropriate determination of rainfall, terrain, vegetation and soil infiltration parameters, the program is applicable to conditions commonly found in New Mexico. The program may be applicable for the similar arid and semi-arid conditions found in Arizona, Colorado, Nevada, Utah, and western Texas, provided that appropriate calibration and verification of rainfall, terrain, vegetation and infiltration parameters is performed. The program is intended to be used for design of flood control structures or for flood plain land use regulation, when the program is used by Registered Professional Engineers who possess the experience and thorough understanding of the engineering principles that apply to the application of the program. Users are advised to verify agency acceptance prior to use with any project.

VI. The AHYMO-S4 version of the AHYMO program:

The AHYMO program has been modified and enhanced, beginning with portions of the ARS version of the program, to create the AHYMO-S4 program. The original ARS version of HYMO contained 1294 lines of FORTRAN source code; 623 lines from the original code remain in the current version of the AHYMO program. The AHYMO-S4 program contains 8707 lines of FORTRAN source code.

The following modifications and enhancements have been added to ARS HYMO with this version of the program:

l. The COMPUTE HYD command can utilize initial abstraction (IA) and uniform infiltration (INF) in place of the standard NRCS curve number runoff computation. IA and INF are input as negative numbers in place of the CN data.

2. The COMPUTE HYD command can directly add a new hydrograph to an existing hydrograph. This is accomplished by placing a "-2" in the first data item of the mass rainfall table.

3. The PLOT HYD command was modified so that output can be sent directly to a "PRN" file or to a disk file for subsequent printing.

4. When using the ADD HYD command, the ID number of the added hydrograph may be the same as the ID of one of the inflow hydrographs. Hydrographs can have differing time steps.

5. When using the COMPUTE RATING CURVE command, the program no longer will change the Manning's "n" value based on flow depth. The original function of the ARS program can be restored by placing a negative value in the "number of segments" position.

6. It is no longer necessary to input the ZALFA card and the Command Table at the front of the input data. Input of this data is optional and usually not required.

7. Infiltration can be decreased from a uniform value after 3.0 hours to a value of 0.0 after 6.0 hours by setting the infiltration entry to a positive value in the COMPUTE HYD command. This is applicable for infiltration values less than 0.07 inches per hour. This function is compatible with the impervious land treatment condition in "Section 22.2, Hydrology, of the Development Process Manual, Volume 2, Design Criteria", by the City of Albuquerque, 1997.

8. The incremental time (DT) does not need to be repeated for subsequent data entries in the COMPUTE HYD and ROUTE commands. The previous DT entry is used when DT is specified as 0.0.

9. The COMPUTE HYD command can use a standard NRCS dimensionless unit hydrograph in place of the HYMO unit hydrograph. To specify the NRCS unit hydrograph, enter "K=-999".

10. The RAINFALL command has been added to allow input of standard rainfall distributions. This command is described in the AHYMO Computer Program User's Manual. Many commonly applied rainfall distribution functions are available.

11. The COMPUTE NM HYD command has been added to simplify use of the split hydrograph procedure with initial abstraction and uniform infiltration soil losses. This command is described in the AHYMO Computer Program User's Manual.

12. A new DIVIDE HYD command has been added. This command can divide a hydrograph based on a percentage, a maximum flow rate, or a rating curve.

13. The ROUTE RESERVOIR command allows input of elevation in addition to the storage and discharge values. When elevations are specified, a reservoir routing table is included in the output file. The CODE element of the ROUTE RESERVOIR command controls the number of hydrograph points included on the table. The command allows up to 50 outfall-storage-elevation points.

14. The PRINT HYD command can print the hydrograph in specified incremental time steps. The CODE element of the PRINT HYD command specifies the step size.

15. The HYD NUMBER element of the COMPUTE HYD, COMPUTE NM HYD, ROUTE, ADD HYD, DIVIDE HYD and ROUTE RESERVOIR commands can accommodate two numbers following the decimal point (i.e.: 123.45) or alphanumeric hydrograph identifications (i.e.: NW.BASIN.A12) up to 24 characters long.

16. The program can store up to 99 hydrograph ID numbers. Each hydrograph can contain 4000 data points. The mass rainfall table in the RAINFALL, COMPUTE HYD and COMPUTE NM HYD commands can have 4000 incremental values.

17. A computation summary table is generated as a separate text file by the program. Each command that computes or modifies a hydrograph generates a line on the summary table. The default file name for the summary table is AHYMO.SUM; it is created in the working directory.

18. A comment line can be added to the summary table by placing "*S" as the first two characters on an input file line.

19. Additional capability to control the scale of the hydrograph plots has been added to the PLOT HYD command.

20. A LAND FACTORS command has been added. This command is used to change from the default value of the initial abstraction and infiltration rates to new values, for the land treatments A, B, C and D that are used by the COMPUTE NM HYD command.

21. A SEDIMENT BULK command has been added. This command can simulate sediment bulking by multiplying computed hydrographs by a single factor or a factor based on a table of bulking factors.

22. A SEDIMENT TRANS command has been added. This command will compute the sediment transport capacity and volume transported by hydrograph flow through an arroyo or channel section using a power function equation.

23. A ROUTE MCUNGE command has been added to allow use if the Muskingum-Cunge methodology of channel routing. This is a modified diffusion equation variation of kinematic routing.

24. A new LOCATION command was added to specify default computation parameters based on project location.

25. A new COMPUTE LT TP command was added. This command will allow computation of lag time, time of concentration and time to peak by the Upland/Lag Time Method, the NRCS TR-55 Method, the Lag Time Method, the Kirpich Method, and the NRCS CN-Lag Method.

26. The COMPUTE HYD and COMPUTE NM HYD commands were revised to allow input of time to peak or time of concentration values that are computed by the COMPUTE LT TP command.

27. The ADD HYD command was revised to allow hydrograph addition based on selecting the larger or smaller time increment, when the incremental times of the two hydrographs are different.

28. The MODIFY TIME command was revised to allow subdivision of a hydrograph by time.

29. The ROUTE MCUNGE command was substantially rewritten from the previous version. An iterative four point averaging scheme is used to solve the routing differential equation. The Fread and Ponce limitations on routing coefficients were originally incorporated into the program default values. When a computation time step smaller than 0.015 hours is specified, only the Ponce limitation is now applied as a default condition.

30. The source code has been modified to be compiled using the Intel® Visual Fortran Compiler (Version 11.1, June 2009).

VII. Files for the AHYMO program user:

AHYMO-S4-R1.EXE - The executable version of the AHYMO computer program.

AHYMO_IO.FIL - A file containing the input and output file names used by the program. This file is required for program execution. The file also contains the user number for licensed program users.

README-S4.TXT - The ASCII file containing this README text.

HYMO.EXM - The input file for the example program in the ARS User's Manual. A negative value has been placed at the "number of segments" position of the COMPUTE RATING CURVE command to restore the adjustment of Manning's "n" which was a part of the original HYMO program. Minor differences between the output from this file and the sample output in the ARS User Manual are a result of more precise convergence with the routing functions in the AHYMO-S4 version and additional storage of hydrograph values.

TESTDPM.DAT - Input file for examples from "Section 22.2, Hydrology, of the Development Process Manual", City of Albuquerque, 1997. Output and summary files (TESTDPM.OUT and TESTDPM.SUM) using TESTDPM.DAT as the input file are also included.

EX1-NRCS-S4.DAT - Input file for Example 1 of the User's Manual using the NRCS CN method. The output and summary files (EX1-NRCS-S4.OUT and EX1-NRCS-S4.SUM) are also included.

EX2-SED-S4.DAT - Input file for Example 2 of the User's Manual. This is a sediment yield analysis. The output and summary files (EX2-SED-S4.OUT and EX2-SED-S4.SUM) are also included.

Additional sample input and output files are located in a "Samples" directory. Sample shortcut files are located in a "Shortcuts" directory.

VIII.Running the Program:

The AHYMO-S4 program can be run on a computer using Microsoft Windows 7, 8, 8.1, or 10 (32 or 64-bit). The file AHYMO-S4-R2.EXE, or a shortcut file that calls AHYMO-S4-R2.EXE must be opened to execute the program.

To execute the program in MS Windows, double click on the AHYMO icon and specify the file name (including the directory location if needed), or drag the data file icon to the open AHYMO window and press enter. As an alternative in Windows 7, 8, or 10, you may drag the input data file to an AHYMO-S4 shortcut icon, and the AHYMO-S4 program will begin execution. When the program asks for the name of the input file, press the enter (return) key without typing a name, and the AHYMO program will use the input file that you specified by dragging.

Also, the AHYMO_IO.FIL file must be in the working directory or be locatable by Windows. The AHYMO_IO.FIL contains the input and output file names used by the program, and the user number for registered users. The file AHYMO_IO.FIL may contain data as follows:

a. First line (input file):

"PROMPT" - The program asks for the input file name during execution. This is the recommended value.

blank - The input file name including all directory location information must be specified by the program user.

name - a file name of a locatable data file.

b. Second line (output file):

name - a file name to which the output is sent. If the file exists, it is overwritten. If it does not exist, the file is created. A file named AHYMO.OUT is recommended for this line.

"PROMPT" - The program asks for the output file name during execution.

blank - The input file name including all directory location information must be specified by the program user.

c. Third line (simulated punch card file):

name - an output file name to which simulated punch cards are sent. If the file exists, it is overwritten. A file name of AHYMO.PUN is recommended.

"PROMPT" - The program asks for the filename for simulated punch cards.

d. Fourth line (hydrograph input/output file):

name - an output file name to which hydrograph output is sent. If the file exists, it is overwritten. A file name of AHYMO.HYD.

"PROMPT" - The program asks for the filename for the hydrograph input/output file.

"NONE" - The program will not create a hydrograph input/output file.

e. Fifth line (Summary Table output file):

name - an file name to which output summary is sent. If the file exists, it is overwritten. A file name of AHYMO.SUM is recommended.

"PROMPT" - During execution the program asks for the filename of the SUMMARY TABLE.

e. Sixth line (User Number):

This line is reserved for the user number of licensed program users. Licensed users should include their 24 character code on this line.

f. There may be a seventh line in the AHYMO_IO.FIL with the characters "1234567890123456789012324". This line is used to guide data entry for the fifth line.

For general application, it is recommended that the AHYMO_IO.FIL contain the following (on four lines):

PROMPT
AHYMO.OUT
AHYMO.PUN

AHYMO.HYD
AHYMO.SUM
[Your 24 character user number]
123456789012345678901234

The input file must be in ASCII (text only) format with not more than 80 columns of data. The following editors have been used to produce data files: WordPad or Wordpad (Microsoft Editors available with Windows 7, 8, 8.1, and 10). Program Editor by Corel Corporation.

Word processor programs, such as Microsoft Word, Corel WordPerfect, and Sun OpenOffice can be used to create program input data files. Word processor files commonly include special control characters within files that cannot be accommodated by the AHYMO program. It is recommended that you save your data files as ANSI Windows text or ASCII DOS text files when creating files for the AHYMO program. Most word processor programs can produce ASCII (text only) files as a part of their document save functions. Be careful with your use "tabs". The AHYMO program can accommodate input files that contain tab characters. However, the interpretation of input data with tabs, and printing of output data, may be different with the AHYMO program than with the interpretation used by your word processor program. It is best to avoid use of the tab key or to convert tabs to spaces.

The AHYMO-S4 version of the HYMO program was designed to execute on an Personal Computer (PC) with an Intel or equivalent based processor. The operating system should be Microsoft Windows 7, 8, 8.1, or 10 (32 or 64-bit).

IX. Further information.

For more information on hydrologic modeling using the AHYMO program, and to obtain authorization for program use, please contact:

City of Albuquerque
Hydrology Section, Planning Department
Plaza del Sol, 600 2nd St NW Albuquerque, NM 87102
https://www.cabq.gov/planning/development-review-services/hydrology-section

End of README file. (September 2018)

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APPENDIX C

Rainfall Distribution Equations

(Equations used by the RAINFALL command of the AHYMO Program.)

Rainfall Distribution Equations

The following equations are used by the RAINFALL command of the AHYMO Program to compute the cumulative rainfall using any time increment. The cumulative rainfall is also referred to as the mass rainfall or the mass rainfall distribution.

All the equations in this Appendix come from the text of *Section 22.2, Hydrology of the Development Process Manual* (DPM) by the D.P.M. Drainage Design Criteria Committee, for the City of Albuquerque, New Mexico in cooperation with Bernalillo County, New Mexico and the Albuquerque Metropolitan Arroyo Flood Control Authority (January 1993). The equation numbers shown herein are the numbers referenced in the DPM, Section 22.2.

R.1 RAINFALL TYPE = 12 6-hour rainfall distribution based on NOAA Atlas 2 with peak intensity at 1.4 hours.

(Ref: Section C.3 at page C-3 of Section 22.2, Hydrology, DPM)

Compute the depth of cumulative precipitation, P_T, at any time, $t \leq 360$ minutes, as follows:

$$P_T = 2.334 * (P_{360} - P\ \ ) * (1.5^A - (1.5 - t / 60)^A), \quad \text{at } 0 \leq t < 60 \qquad (c\text{-}1)$$

$$P_T = P_{T=60} + P_{60} * 0.4754 * (0.5^{0.09} - (1.5 - t / 60)^{0.09}), \quad \text{at } 60 \leq t < 67 \qquad (c\text{-}2)$$

$$P_T = P_{T=60} + P_{60} * \{0.0001818182 * (t - 60) + 0.000018338 * (t - 60)^{3.2}\}, \quad \text{at } 67 \leq t < 85.3 \qquad (c\text{-}3)$$

$$P_T = P_{T=60} + P_{60} * \{0.07 * (t - 60) - 1.1886 - 0.0404768 * (t - 85)^{1.0985865}\}, \quad \text{at } 85.3 \leq t < 120 \qquad (c\text{-}4)$$

$$P_T = P_{360} + (P_{T=60} + P_{60} - P_{360}) * (4.4^{(3*A)} - (t / 60 - 1.6)^{(3*A)}) / (4.4^{(3*A)} - 0.4^{(3*A)}), \quad \text{at } 120 \leq t \leq 360 \qquad (c\text{-}5)$$

where $A = \log_{10}(P_{360} / P_{60}) / \log_{10}(6.0)$

R.2 RAINFALL TYPE = 13 24-hour rainfall distribution based on NOAA Atlas 2 with peak intensity at 1.4 hours.

(Ref: Section C.3 at page C-3 of Section 22.2, Hydrology, DPM)

Compute the depth of cumulative precipitation, P_T, for a time $0 < t \leq 360$ minutes using the equations from RAINFALL TYPE = 12. Compute the depth of cumulative precipitation, P_T, at a time $360 < t \leq 1440$ minutes, as follows:

$$P_T = P_{1440} + (P_{360} - P_{1440}))* (30^B - (t / 60 + 6)^B) / (30^B - 12^B), \quad \text{at } 360 < t \leq 1440 \qquad (c\text{-}6)$$

where $B = \log_{10}(P_{1440} / P_{360}) / \log_{10}(4.0)$

R.3 RAINFALL TYPE = 3 6-hour PMP distribution based on an HMR-55a Local Storm with peak intensity at 2.25 hours.

(Ref: Section D.4 at page D-7 of Section 22.2, Hydrology, DPM)

Compute the depth of cumulative precipitation, PMP_T, at any time, $t \leq 360$ minutes, as follows:

$$PMP_T = \{(0.000272 * t) + (1.1123E\text{-}6 * t^{2.3})\} * (PMP_{360} - PMP_{60}) / 0.35 \quad \text{at } t \leq 120 \qquad (d\text{-}6)$$

$$PMP_T = ((PMP_{360} - PMP_{60}) / 3.5) + \{(.0147 * (t - 120)) + (0.005174 * (t - 120)^{2.818}) - (0.0030346 * (t - 120)^3)\} * PMP_{15} / 0.68 \quad \text{at } 120 < t \leq 134 \qquad (d\text{-}7)$$

$$PMP_T = PMP_{60} + ((PMP_{360} - PMP_{60}) / 3.5) + [-0.65956 + (0.003671 * t) - (0.001217 * EXP(19.44 - 0.108 * t))] * (PMP_{60} - PMP_{15}) / 0.32 \quad \text{at } 135 \leq t \leq 180 \qquad (d\text{-}8)$$

$$PMP_T = PMP_{360} - [0.23354 - (0.000649 * t) + (0.0000995 * EXP(14.4 - 0.04 * t))] * (PMP_{360} - PMP_{60}) / 0.35 \quad \text{at } 180 \leq t \leq 360 \qquad (d\text{-}9)$$

where $EXP(x) = e^x = 2.71828^x$

R.4 RAINFALL TYPE = 4

24-hour PMP Distribution based on an HMR-55a General Storm and the USBR Urban Hydrology Manual with peak intensity at 15.5 hours.

(Ref: Section D.5 at page D-13 of Section 22.2, Hydrology, DPM)

Compute the depth of cumulative precipitation, PMP_T, at any time, $t \leq 1440$ minutes, as follows:

$$PMP_T = 0.6093 * (PMP_{1440} - PMP_{360}) * (15.4^B - (15.4 - t / 60)^B) / (15.4^B - 4.4^B)$$

at $t \leq 660$ *(d-13)*

where $B = \log_{10}(PMP_{1440} / PMP_{360}) / \log_{10}(4.0)$

$$PMP_T = PMP_{T=660} + 0.8394 * (PMP_{360} – PMP_{360}) * (4.12^A - (15.12 - t / 60)^A) / (4.12^A - 0.12^A)$$

at $660 < t \leq 900$ *(d-14)*

where $A = \log_{10}(PMP_{360} / PMP_{60}) / \log_{10}(6.0)$

and $PMP_{T=660} = 0.6093 * (PMP_{1440} - PMP_{360})$

$$PMP_T = PMP_{T=900} + PMP_{60} * \log_{10}(60 / (960 - t)) / \log_{10}(6.0)$$

at $900 < t \leq 930$ *(d-15)*

where $PMP_{T=900} = PMP_{T=660} + 0.8394 * (PMP_{360} - PMP_{60})$

$$PMP_T = PMP_{T=900} + PMP_{60} * (1 - ((960 - t) / 30) * \log_{10}(3.0) / \log_{10}(6.0))$$

at $930 < t \leq 960$ *(d-16)*

$$PMP_T = PMP_{T=660} + PMP_{360} - (PMP_{360} - PMP_{60}) * 0.1606 * ((t / 60 - 15.5)^A - 1.5^A) / (0.5^A - 1.5^A)$$

at $960 < t \leq 1020$ *(d-17)*

$$PMP_T = PMP_{1440} - (PMP_{1440} – PMP_{360}) * 0.3907 * ((t / 60 - 15.25)^B - 8.75^B) / (1.75^B - 8.75^B)$$

at $1020 < t \leq 1440$ *(d-18)*

R.5 RAINFALL TYPE = 9

24-hour distribution based on the NOAA Atlas 2 for New Mexico with peak intensity at 6.0 hours. This distribution is applicable with use of NRCS Curve Numbers (CNs).

(Ref: Section E.1 at pages E-2 and E-3 of Section 22.2, Hydrology, DPM)

Compute the depth of cumulative precipitation, P_T, at any time, $t \leq 1440$ minutes, as follows:

$P_T = 0.4597 * P_{360} * (6^A - (6 - t/60)^A)$, at $t < 180$ *(e-1)*

$P_T = P_{T=180} + 0.5947 * P_{60} * (3^A - (6 - t/60)^A)$, at $180 \leq t < 330$ *(e-2)*

$P_T = P_{T=330} + P_{60} * (0.9757 * (5.5 - t/60) - 2.55 * \log_{10}(1.02 * (5.5 - t/60) + 1))$, at $330 \leq t < 375$ *(e-3)*

$P_T = P_{T=330} + P_{60} + (P_{60} * 1.02449 * \log_{10}(t/60 - 5.5))$, at $375 \leq t < 390$ *(e-4)*

$P_T = P_{T=180} + P_{360} + (P_{T=330} + P_{60} - P_{360} - P_{T=180}) * (3^{(3*A)} - (t/60 - 6)^{(3*A)}) / (3^{(3*A)} - 0.5^{(3*A)})$ at $390 \leq t < 540$ *(e-5)*

$P_T = P_{1440} + (P_{360} + P_{T=180} - P_{1440}) * (18^{(3*A)} - (t/60 - 6)^{(3*A)}) / (18^{(3*A)} - 3^{(3*A)})$ at $540 \leq t \leq 1440$ *(e-6)*

where $A = \log_{10}(P_{1440} / P_{60}) / \log_{10}(24)$

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APPENDIX D

USDA Agricultural Research Service
HYMO User's Manual

ARS-S-9, May 1973, pp. 1-9 & 53
(Note: Pages 10 through 52 of ARS-S-9 contain a sample output file and Fortran source code.)

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HYMO:
PROBLEM-ORIENTED COMPUTER LANGUAGE FOR HYDROLOGIC MODELING
Users Manual

ARS-S-9
May 1973

SOUTHERN REGION

AGRICULTURAL RESEARCH SERVICE • U.S. DEPARTMENT OF AGRICULTURE

Agricultural Research Service

UNITED STATES DEPARTMENT OF AGRICULTURE

In Cooperation With

Texas Agricultural Experiment Station
Texas A&M University

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HYMO:
PROBLEM-ORIENTED COMPUTER LANGUAGE FOR HYDROLOGIC MODELING

Users Manual

By Jimmy R. Williams[1] and Roy W. Hann, Jr.[2]

INTRODUCTION

HYMO *(7)*[3] is a problem-oriented computer language for modeling surface runoff and sediment yield from watersheds. The language is called HYMO from the words "hydrologic model." HYMO was designed for planning flood prevention projects, forecasting floods, and research studies. It consists of a main program and 16 subroutines written in FORTRAN IV, but it can be used by hydrologists with little knowledge of computer programing. The language provides 17 commands for the hydrologist to use in any sequence for application to any watershed.

HYMO was designed to transform rainfall data into runoff hydrographs and to route these hydrographs through streams and valleys or reservoirs. It will also compute the amount of sediment produced by a storm at any point on a watershed. It will be useful to research hydrologists in studying the effects of watershed and storm characteristics on the flood hydrograph. HYMO is also a good research tool for testing hydrologic procedures; for example, a new flood-routing method could be added to HYMO and tested easily, because the inflow hydrographs and the rating curves are available in a HYMO program.

HYMO is flexible. Present hydrologic procedures can be modified or deleted, and other hydrologic procedures can be added by hydrologists familiar with FORTRAN IV programing. Adding a new command simply requires the addition of a new subroutine.

HYMO is efficient, practical, and generally applicable. HYMO programs can be written and the results interpreted by hydrologists who have no conventional computer programing experience. The hydrologic procedures used in HYMO are practical — required inputs are easy to obtain for most watersheds.

HYMO was written for the IBM 360-65 computer, but it could be run on an IBM 1130 with little modification. The storage requirement is about 73 K.

OPERATION OF HYMO

HYMO consists of a main program and 16 subroutines. The HYMO card deck is set up in the following order:

1. Main program.
2. Subroutines.
3. A data card containing the number of commands in the command table.
4. A data card containing the ZALFA array.
5. Seventeen data cards containing the command table.
6. The users program deck consisting of program and data cards.

A printout of the main program, subroutines, ZALFA array, and command table is given in the appendix.

[1]Hydraulic engineer, College Station Area, Southern Region, Agricultural Research Service, U. S. Department of Agriculture, Riesel, Tex.

[2]Head, Environmental Engineering Division, Civil Engineering, Texas A&M University, College Station, Tex.

[3]Italicized number in parentheses refer to items in "Literature Cited" preceding the appendix.

The main program reads the command table and then calls the HONDO subroutine (*2*) to read a program data card. Subroutine HONDO determines the command name and number by comparing columns 1 through 20 of the program data card with the command table. Then HONDO determines individual data items by comparing columns 21 through 80 of the program data card with the ZALFA array. The data are placed in an array and returned to the main program. Based on the command number, the main program calls the proper subroutine to do the desired calculations. When the calculations are complete, control is returned to the main program, and HONDO is called again to read the next program card.

HYDROLOGIC PROCEDURES USED IN HYMO

The procedures used in HYMO were selected because of their accuracy, general applicability, practicality of inputs, and computational efficiency. For most watersheds the input is easy to obtain, and the procedures produce reasonably accurate results without excessive computer time.

Hydrograph Computation

When flood routing is performed, a watershed is divided into many small areas according to its hydraulic characteristics. The hydrographs from these areas must be estimated, since streamflow measurements are seldom available. A procedure for computing unit hydrographs was developed previously (*4*). A modification of this procedure is used in HYMO. Unit hydrographs are divided into three parts for computation (fig. 1). From the beginning of rise to the inflection point, t_0, the hydrograph is computed by the two-parameter gamma distribution equation

$$q = q_p \left[t/t_p \right]^{(n-1)} e^{(1-n)(t/t_p - 1)} \tag{1}$$

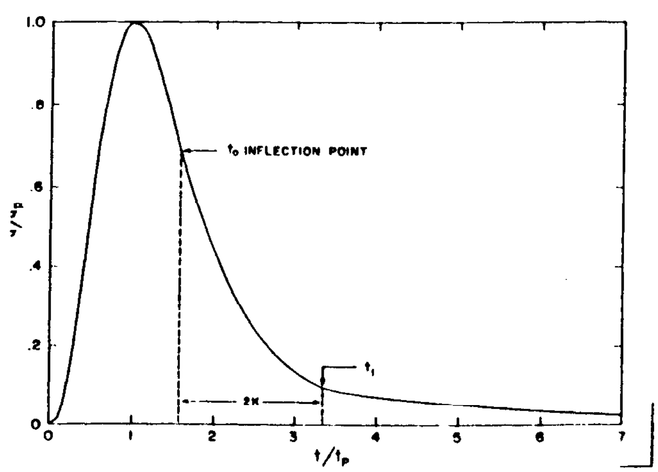

Figure 1. Dimensionless unit hydrograph.

where q = flow rate in cubic feet per second at time t,
q_p = peak flow rate in cubic feet per second,
t_p = time to peak in hours,
and n = dimensionless parameter.

From t_0 to t_1 ($t_1 = t_0 + 2K$) the hydrograph is computed by the recession depletion equation

$$q = q_0 e^{\frac{t_0 - t}{K}} \tag{2}$$

where q_0 = flow rate at the inflection point,
t_0 = time at the inflection point,
and K = recession constant in hours.

From t_1 to ∞ the recession depletion equation becomes

$$q = q_1 e^{\frac{t_1 - t}{K_1}} \tag{3}$$

where q_1 = flow rate at t_1,
and K_1 = $3K$ = second recession constant.

The dimensionless shape parameter, n, is a function of K/t_p, as shown in figure 2. The peak flow rate is computed by the equation

$$q_p = \frac{BAQ}{t_p} \tag{4}$$

where B = a watershed parameter, a function of n as shown in figure 3,
A = watershed area in square miles,
and Q = volume of runoff in inches.

Therefore, the entire unit hydrograph can be computed if K and t_p are known. K and t_p can be determined by hydrograph analysis (*4*) for gaged watersheds. To compute K and t_p for ungaged watersheds, HYMO uses the equations

$$K = 27.0 A^{0.231} SLP^{-0.777} (L/W)^{0.124} \tag{5}$$

and $tp = 4.63 A^{0.422} SLP^{-0.46} (L/W)^{0.133}$ (6)

where SLP = difference in elevation in feet, divided by flood-plain distance in miles, between watershed outlet and most distant point on the watershed,

and L/W = watershed length-width ratio.

Storm hydrographs are computed by convolving unit hydrographs with incremental source runoff. To compute incremental source runoff, the mass rainfall curve is broken into equal time increments, and the Soil Conservation Service (SCS) rainfall-runoff relationship (*3*) is applied. The SCS rainfall-runoff relationship is expressed in a set of numbered curves. The SCS National Engineering Handbook (*3*) provides detailed instructions for selecting the proper curve number.

Hydrographs computed by this procedure compared closely with measured hydrographs from 34 watersheds located in Texas, Oklahoma, Arkansas, Louisiana, Mississippi, and Tennessee. The watershed areas ranged from 0.5 to 25 square miles.

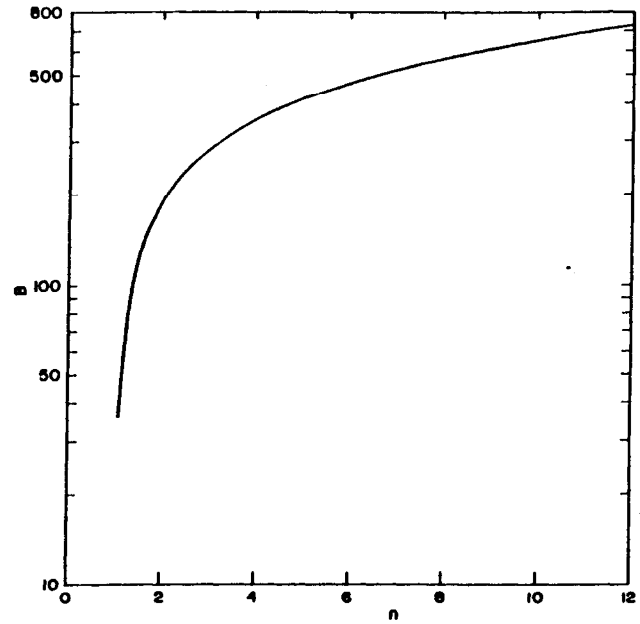

Figure 3. Relationship between dimensionless shape parameter *n* and watershed parameter *B*.

Flood Routing

Streams and valleys

The variable storage coefficient (VSC) flood-routing method (*5*) was selected for HYMO.

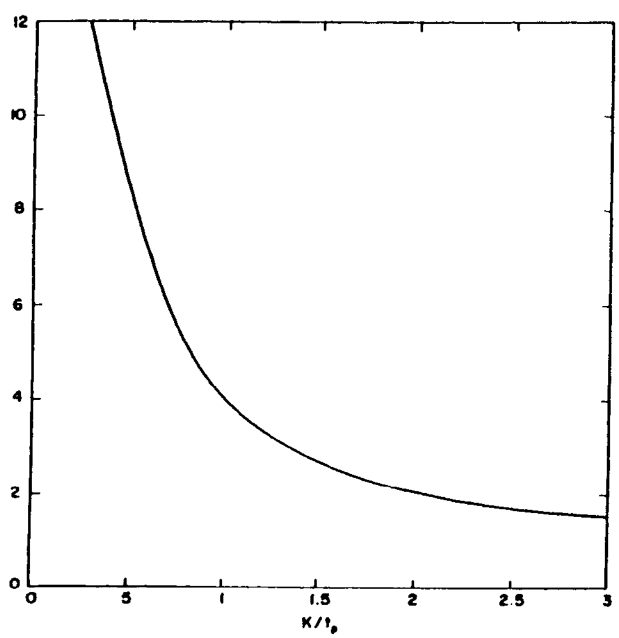

Figure 2. Relationship between dimensionless shape parameter and recession constant/time to peak.

The VSC method has been revised (*6*) to account for the variation in water surface slope during a flood. The revised VSC method is about as accurate as the implicit method (*1*) and has the general applicability of simpler storage methods. Although an iterative solution is used, the VSC method requires little computer time and is free of convergence problems.

The VSC routing equations are

$$O_2 = C_2\left[I_a + \left(\frac{1}{C_1} - 1\right) O_1\right]. \quad (7)$$

$$C_2 = \frac{2\Delta t}{2T_2 + \Delta t}. \quad (8)$$

$$C_1 = \frac{2\Delta t}{2T_1 + \Delta t}. \quad (9)$$

$$T_1 = \left(\frac{L}{1800(V_{I_1} + V_{O_1})}\right) \times \left(\frac{L \times SLP_0}{L \times SLP_0 + D_{I_1} - D_{O_1}}\right)^{1/2} \quad (10)$$

$$T_2 = \left(\frac{L}{1800(V_{I_2} + V_{O_2})}\right) \times \left(\frac{L \times SLP_0}{L \times SLP_0 + D_{I_2} - D_{O_2}}\right)^{1/2} \quad (11)$$

In these equations subscripts 1 and 2 refer to the beginning and end of the time interval Δt; the units are cubic feet per second for flow, hours for time, feet per second for velocity, and feet for length and depth. The symbols are defined as follows:

I = inflow rate.
O = outflow rate.
$I_a = \frac{I_1 + I_2}{2}$ = average inflow rate.
C = storage coefficient.
T = travel time through the reach.
L = reach length.
V = velocity.
SLP_0 = normal slope.
D = depth.

Since T_2 and C_2 are dependent upon O_2, an iterative technique is required to solve the routing equations. In equation 7, I_a and O_1 are known, and C_1 can be computed from equation 9. This leaves only O_2 and C_2 as unknowns. O_1 can be used as a first approximation of O_2. The normal depth and velocity for the approximate value of O_2 are entered into equation 11 for computing T_2. Then equation 8 is used to compute C_2. The second approximation of O_2 is then obtained from equation 7. This iterative process continues until the difference between successive O_2 values is acceptable. HYMO is set to accept differences of 0.1 percent or less. Usually about four iterations are required.

Reservoirs

HYMO uses the storage-indication method (*3*) to route floods through reservoirs. This method has been widely used and accepted because it is practical and accurate. The SCS National Engineering Handbook gives detailed instructions for using the method.

Rating Curves

Rating curves must be available at enough locations along a valley to adequately describe the hydraulics of the stream and valley. Most of these rating curves must be computed because there are never enough measured rating curves.

HYMO uses Manning's equation to compute the normal flow-rating curves that are used in the VSC flood-routing method. The normal flood-plain slope is determined for each valley section by plotting a profile of the flood plain. The normal channel slope is determined by plotting a profile of the flood plain with channel distances.

Sediment Yields

The universal soil loss equation (*8*) was modified to compute the sediment yield for individual storms on watersheds. The modified equation is

$$S = 95\,(q_p \times Q)^{0.56} \times K \times C \times P \times LS, \qquad (12)$$

where S = sediment yield in tons,
q_p = peak flow rate in cubic feet per second,
Q = volume of runoff in acre-feet,
K = the soil-erodibility factor,
C = the cropping-management factor,
P = the erosion control practice factor,
and LS = the slope length and gradient factor.

Detailed instructions for determining *K*, *C*, *P*, and *LS* are given by Wischmeier and Smith (*8*).

Since equation 12 was designed to compute sediment yield from watersheds, a delivery ratio is not needed. The delivery ratio is built into equation 12 by including the peak flow rate. Many of the watershed characteristics that influence the peak flow rate also affect the delivery ratio. Equation 12 has performed well under limited testing, but future refinements are expected.

RULES FOR USING HYMO

The reader should refer to the table, "Example Input for HYMO Commands," as he follows the narrative description of the rules. The example HYMO program that is presented near the end of the manual may also be helpful.

General Rules

HYMO commands are expressed in the first 20 columns of the data card, and columns 21 through 79 are used for numeric data and keywords. Column 80 is reserved for a page-change code (an asterisk in column 80 causes the card to be printed on a new page). Continuation cards are allowed when 59 characters are insufficient to express the data.

The data can be written in any format, but at least one blank space must be left between data items. A decimal is required for numbers containing fractions, but not for whole numbers. Keywords can be written with the data to describe individual data items. Comment cards may be used at any point in a HYMO program by punching an asterisk in column 1 and the comment in columns 2 through 79.

Example input for HYMO commands

Command	Required input
START	RAINFALL BEGINS AT 12.5 HRS PUNCH CODE=1
STORE HYD	ID=1 HYD NO=301 DT=.2 HR DA=1.5 SQ MI FLOW RATES= 0 10 50 100 500 1000 1800 2000 1900 1500 1200 1000 800 600 500 400 300 200 100 50 10 1
COMPUTE HYD	ID=2 HYD NO=302 DT=.5 HR DA=2.1 SQ MI CN=90 HT=100 FT L=3.3 MI MASS RAINFALL = 0 .31 .61 1.04 1.84 2.74 3.06 3.45 4.33 4.75
PRINT HYD	ID=2 CODE=1
PUNCH HYD	ID=2
PLOT HYD	ID I=3 ID II=4
ADD HYD	ID=4 HYD NO=101 ID I=5 ID II=6
STORE RATING CURVE	ID=2 VS NO=15 ELEV AREA FLOW 496.6 0 0 497 2 1 498 9 19 499 19 52 500 30 98
COMPUTE RATING CURVE	ID=1 VS NO=10 NO SEGS=3 MIN ELEV=482 FT MAX ELEV=492 FT CH SLP=.006 FP SLP=.0075 N=.05 DIST=175 FT N=.03 DIST=205 FT N=.05 DIST=450 FT DIST ELEV DIST ELEV DIST ELEV DIST ELEV 0 492.0 100 490.0 175 484.0 188 482.0 190 482.0 205 484.0 250 486.0 275 488.0 310 490.0 450 492.0
COMPUTE TRAVEL TIME	ID=3 REACH NO=8 NO VS=5 L=4500 FT SLP=.0075
ROUTE	ID=3 HYD NO=8 INFLOW ID=6 DT=.25 HR
ROUTE RESERVOIR	ID=5 HYD NO=501 INFLOW ID=1 OUTFLOW (CFS) STORAGE (AC FT) 0 0 22 533 200 555 1000 601 2000 648 3000 694
ERROR ANALYSIS	ID I=3 ID II=5
SEDIMENT YIELD	ID=5 SOIL=.34 CROP=.5 EP=.6 LS=.3
FINISH	

Six hydrographs can be stored in a HYMO program at a time. The hydrographs are identified by storage location numbers 1 through 6. Therefore, the same storage location number must be used for many hydrographs in a HYMO program. This is especially true when routing is done through large watersheds. However, no more than six hydrographs are ever needed at one time because HYMO programs begin at the head of a watershed and work downstream through one reach at a time. When a storage location number is used to store or compute another hydrograph, the first hydrograph is lost. The user should be sure that the hydrograph will not be referred to again before using the storage location number for another command.

To store, compute, or route a hydrograph, the user must specify the time increment. There are no rigid rules about selecting the time increment, but generally it should not be greater than one-fifth of the time to the peak of the hydrograph. This rule usually provides enough points to adequately define the hydrograph. All hydrographs are limited to 300 points.

For the commands "STORE HYD," "COMPUTE HYD," "ADD HYD," "ROUTE," and "ROUTE RESERVOIR," the user must specify the number of the outflow hydrograph. The hydrograph identification numbers are used to designate specific routing reaches, incremental areas, reservoirs, and partial hydrographs. The partial hydrograph number is given to all hydrographs other than outflow hydrographs from reaches, incremental areas, or reservoirs. The identification numbers for each group are

Reaches	1-100
Partial hydrographs	101-300
Incremental areas	301-500
Reservoirs	501+

Command Rules

The first command for any watershed is START. The two data items associated with this command are the time rainfall begins on the watershed and a code for punching output data. If a storm is to be routed through a watershed only once, the punch code is deleted. However, if more than one routing is to be performed, set the punch code equal to a positive number, and the output data for the first routing will be punched for use in the second routing. More than one routing is usually required.

Two commands, RECALL HYD and STORE TRAVEL TIME, were designed to be computer punched for second routings; consequently, these commands do not appear in the table.

The STORE HYD command is used to store the coordinates of a hydrograph in the computer. It can be used for storing measured hydrographs or hydrographs computed by methods other than the one used in HYMO. The input data required for STORE HYD are storage location number, hydrograph identification number, time increment, watershed area, and flow rates of the hydrograph at the specified time increment.

The COMPUTE HYD command is used to compute hydrographs from the incremental areas of the watershed. The first five items of data are storage location number, hydrograph identification number, time increment, watershed area, and SCS runoff curve number (*3*). Normally, data items 6 and 7 are watershed height and main stem length. The height and length are used to compute the recession constant *K* and the time to peak t_p. However, if *K* and t_p are known or estimated by some other method, they can be entered directly into the program. This is accomplished by placing a minus sign before the values of *K* and t_p and entering them as data items 6 and 7, respectively. The remaining data items are values of the mass rainfall at the specified time increment.

Since most watersheds have a limited number of rain gages, the same mass rainfall data may be used to develop several hydrographs. Once the mass rainfall data have been entered in a COMPUTE HYD command, they can be repeated for any number of COMPUTE HYD commands without repunching the data. Instead, punch a negative number for the eighth data item of all COMPUTE HYD commands that use the same rain gage. When data from another rain gage are entered, the data from the first rain gage are lost and cannot be recalled by using the negative number code.

The RECALL HYD command is one of the two commands that are computer punched. When the punch code is a positive number, the output from STORE HYD and COMPUTE HYD are punched on cards with the RECALL HYD command. The RECALL HYD command stores the computed and stored hydrographs on cards; it is therefore not necessary to recompute hydrographs for future routings. Instead, the previously computed hydrographs are read into the program, thus saving considerable computer time.

Although the input data for the RECALL HYD command are never punched manually, a list of the data items may be helpful in checking computer-punched cards. The input data are storage location number, hydrograph identification number, time increment, drainage area, peak flow rate, runoff volume, number of hydrograph points, and flow rates of the hydrograph.

The PRINT HYD command is used to print coordinates of a hydrograph, volume of runoff, and peak flow rate. The required input data are the storage location number and a peak-volume code. The peak-volume code is deleted if a complete hydrograph printout is desired. If a printout of only the runoff volume and the peak flow rate is needed, the peak-volume code is set to a positive value.

The PUNCH HYD command is used to punch any hydrograph in a HYMO program in the proper form for the RECALL HYD command. PUNCH HYD has two purposes: (1) If the punch code is not used, PUNCH HYD can be used to punch one or more hydrographs for future use; and (2) if it is desirable to punch outflow hydrographs associated with ROUTE, ROUTE RESERVOIR, or ADD HYD, PUNCH HYD must be used because the punch code only provides for punching hydrographs associated with STORE HYD and COMPUTE HYD. The only datum required for PUNCH HYD is the storage location number of the hydrograph to be punched.

The PLOT HYD command is used to plot hydrographs in a HYMO program. It will plot one hydrograph on a set of axes, or if a comparison is desired, it will plot two hydrographs on the same set of axes. The required input data are the storage location numbers of the hydrographs to be plotted.

The ADD HYD command adds the coordinates of any two hydrographs. The hydrographs are added at a time increment equal to that of the hydrograph with the shorter time increment. The only data required are the storage location number and hydrograph identification number of the added hydrograph and the storage location numbers of the two hydrographs to be added.

The STORE RATING CURVE command is used to store rating curves that have been measured or computed previously. STORE RATING CURVE will save considerable computer time if measured or computed rating curves are available. The input data are the storage location number, valley section number, and individual rating curve points described by elevation, end-area, and flow rate. The number of points used to describe a rating curve is limited to 20.

The COMPUTE RATING CURVE command is used to compute the stage-area-flow relationship for a valley section. The input data are storage location number, valley section number, number of segments in the valley section, minimum elevation, maximum elevation, channel and flood-plain slopes, Manning's *n* value and segment boundary point for each segment, and horizontal and vertical position of points describing the valley section.

The storage location numbers of the valley sections in a particular reach must begin with 1 and increase by one for each valley section in the reach. However, the numbers are assigned without regard to upstream or downstream order. The valley section identification number can be any number from 0.1 to 999.9. These rules concerning storage location and valley section identification numbers also apply to the STORE RATING CURVE command.

Normally, valley sections are divided into three segments (two flood-plain segments and a channel segment) for computing the rating curve. However, some valley sections may have more than one channel or may have an extreme variation in *n* values across the flood plain, thus requiring more than three segments. A maximum of six segments is permitted. Manning's *n* values for each segment are input with segment boundary point (distance from the beginning of the valley section to the end of the segment). Flood-plain *n* values are positive and channel *n* values are negative.

Twenty points are used to define a rating curve. The location of the points is determined by dividing the difference between the maximum and minimum elevations into 19 equal increments.

The COMPUTE TRAVEL TIME command is used to compute the normal flow travel time relationship used in ROUTE. The input data are storage location number, reach identification number, number of valley sections in the reach, reach length, and slope. The reach identification number can be any number from 0.1 to 999.9. The maximum number of valley sections per reach is six. The slope can be either the channel or flood-plain slope or a weighted average of the two. If flow is confined to the channel, the channel slope is of course applicable. If most of the flow is in the flood plain, usually the flood-plain slope is used. However, a weighted slope based on the relative rates of flow in the channel and the flood plain may be used.

The COMPUTE TRAVEL TIME command considers each rating curve in the reach in computing the travel time flow relationship. COMPUTE TRAVEL TIME automatically selects the flow rates that are used in computing individual travel times. The flow rates of the rating curve with the lowest maximum flow rate are chosen. If the flow rates of any other rating curve in the reach were chosen, the rating curve with the lowest maximum flow rate would have to be extrapolated. The travel time table is limited to 19 points because of the 20-point limit for rating curves.

The STORE TRAVEL TIME command is one of the two computer-punched commands. When the punch code is a positive number, the output from COMPUTE TRAVEL TIME is punched on cards with the STORE TRAVEL TIME command. Therefore, it is not necessary to recompute rating curves or travel time for future routings. Instead, STORE TRAVEL TIME reads the previously computed travel time flow relationship into the program, thus saving considerable computer time.

The input data for STORE TRAVEL TIME are not punched manually, but a list of data items may be helpful in checking computer-punched cards. The input data are storage location number, reach identification number, reach length, slope, and individual points of the relationship defined by depth, flow, and travel time.

The ROUTE command is used to route floods through streams and valleys. The input data are storage location number and hydrograph identification number of the outflow hydrograph, storage location number of the inflow hydrograph, and time increment. The storage location number of the outflow hydrograph must be the same as the storage location number used in COMPUTE TRAVEL TIME for the reach. To prevent unnecessary program stoppage, ROUTE extrapolates the travel-time table when it is exceeded and writes the message, "TRAVEL TIME TABLE EXCEEDED."

The ROUTE RESERVOIR command is used to route floods through reservoirs. The input data are storage location number and hydrograph identification number of the outflow hydrograph, storage location number of the inflow hydrograph, and individual points of the reservoir's outflow-storage relationship. The outflow-storage relationship must be expressed in 20 points or less. If the outflow-storage relationship is exceeded, ROUTE RESERVOIR will extrapolate the relationship and write the message, "STORAGE-DISCHARGE TABLE EXCEEDED."

The ERROR ANALYSIS command is used to determine the error standard deviation and the percentage error in peak flow between any two hydrographs in a HYMO program. These functions make ERROR ANALYSIS useful in research. The input data are the storage location numbers of the two hydrographs to be analyzed.

The SEDIMENT YIELD command is used to compute the sediment yield at any point in a watershed. Input data required are storage location number of the hydrograph from the area, a soils factor, a crop factor, a slope length and gradient factor, and a conservation practice factor (*8*).

The FINISH command is used to end HYMO programs. There are no data associated with FINISH.

EXAMPLE HYMO PROGRAM

A short example problem is presented to demonstrate HYMO. Figure 4 is a map of the 6.84-square-mile Brushy Creek watershed near Riesel, Tex. A flood will be routed through the watershed in its present condition, and the routed outflow hydrograph will be compared to the hydrograph measured at gaging station G. Also the sediment yield will be predicted and compared with the measured sediment yield. Then the same flood will be routed through the watershed with two proposed reservoirs. To determine the effects of the reservoirs, the outflow hydrograph and sediment yield will be compared to the outflow hydrograph and sediment yield of the present-condition routing.

Comment cards and keywords are used liberally in the example problem to acquaint the user with HYMO. After becoming familiar with HYMO, the user may write fewer comments and keywords, but generally users find them both quite helpful in describing the problem. To save space in the example problem, few of the hydrographs are printed or plotted. Some users may choose to print and plot all hydrographs.

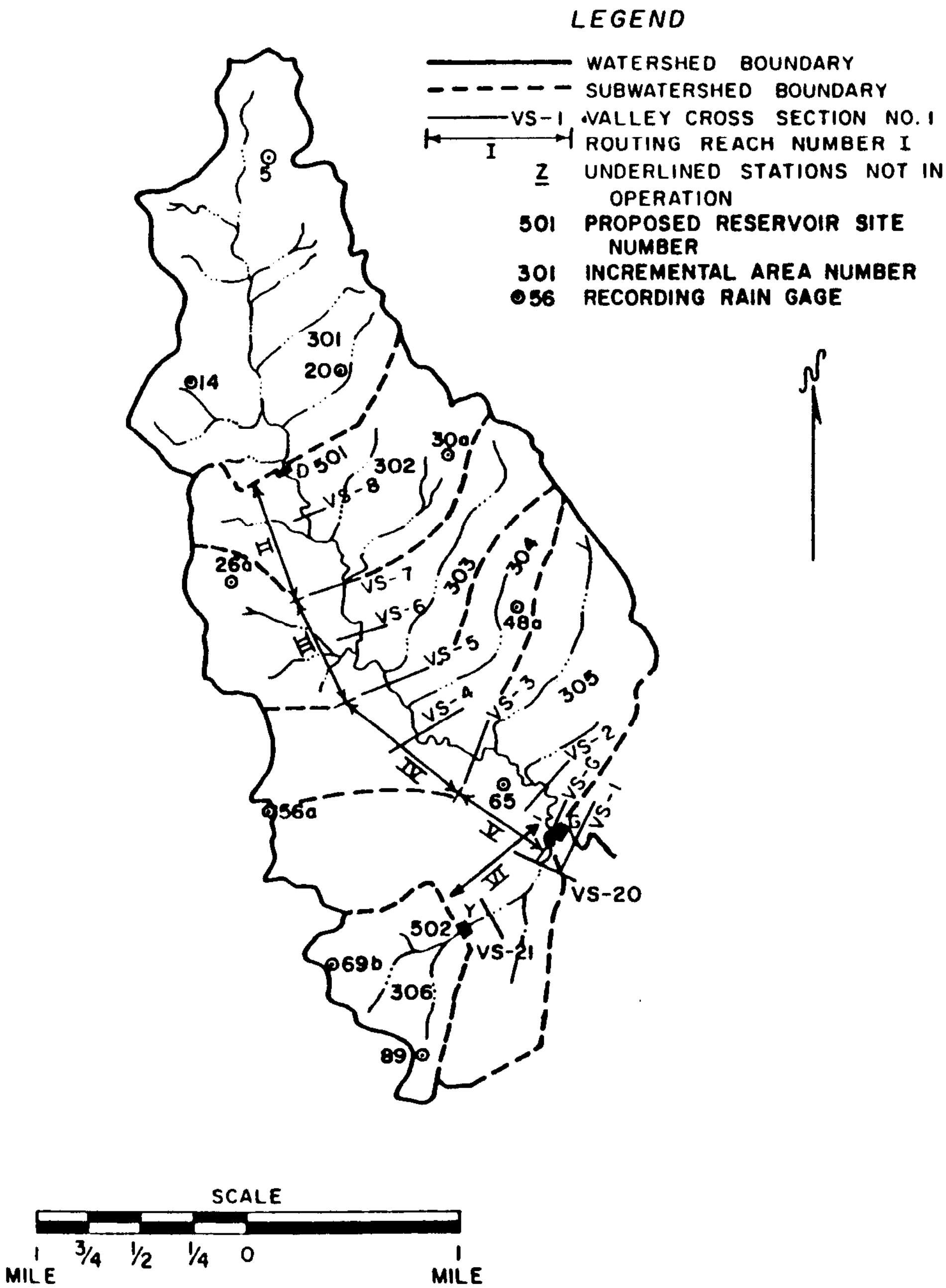

Figure 4. Brushy Creek watershed near Riesel, Tex.

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