

**USERS MANUAL**

**URBAN DRAINAGE STORM WATER  
MANAGEMENT MODEL  
(UDSWM)**

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**PREPARED BY**



**URBAN DRAINAGE AND FLOOD CONTROL DISTRICT**

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## INTRODUCTION

UDSWM is the name assigned by Urban Drainage and Flood Control District (District) to the Runoff Block of the EPA's SWMM (Storm Water Management Model, Version 2) as modified by the Missouri River Division (MRD) of the U.S. Army Corps of Engineers. This model is being used by the District in its master planning and other studies only after it has been calibrated against the Colorado Urban Hydrograph Procedure (CUHP). UDSWM offers channel, pipe and reservoir routing and the ability to analyze sub-catchments having areas less than 90 acres (i.e., the lower limit of the 1984 version of CUHP). Different versions of this model may have other characters assigned to the name to distinguish between them (e.g., UDSWM2000).

UDSWM includes modifications made by Boyle Engineering Corporation and James C.Y. Guo, Ph.D., under the direction of District, as well as modifications made by District staff. Major modifications incorporated into this version include:

1. Subroutines were reconstructed to use the model conjunctively with the CUHP Computer Program. UDSWM has an option to take hydrographs developed by the CUHP program and to combine and route them through conveyance facilities as specified by a user.
2. Dimensional and common statements and some of the logic in the original main-frame version of the software were modified to be adaptable on a personal computer.
3. Line plotting routines included in the earlier versions were eliminated.
4. Some program "bugs" were corrected. These included a divergence problem experienced with the Newton-Raphson Procedure used in the model, incorrect initialization of some variables, and incorrect procedure to account for diversions.

## **PROGRAM DESCRIPTION**

The original Runoff Block was developed as part of the EPA's SWMM. It was intended to simulate both the quantity and quality runoff from urban drainage catchments and to route flows and contaminants through conveyance elements for linkage with a transport block of the software. The Runoff Block was modified by the MRD of the U.S. Army Corps of Engineers to remove some of the deficiencies experienced with the original model. UDSWM simulates quantity runoff only, and can be conjunctively used with the CUHP and earlier versions.

The Runoff Block represents each catchment by an aggregate of idealized sub-catchments, channels, gutters and pipes. The program accepts rainfall hyetographs and makes a step by step accounting of rainfall infiltration losses in pervious areas, surface retention, overland flow, and gutter flow, leading to the calculation of hydrographs.

The study catchment may be subdivided into a maximum of 1900 sub-catchment areas. The resulting hydrographs from all sub-catchments can be routed through a maximum of 1900 gutters or pipes to compute hydrographs at the end of each conveyance element. Overbank floodway sections may be used in conjunction with gutters and pipes. Up to a total of 500 detention basins, with a specified storage-outflow relationship; diversion elements, with a specified flow vs. diverted flow relationship; and inflow hydrographs, with a specified time vs. flow relationship, may be used. All pipes and gutters/channels are sometimes referred to as "conveyance elements" in this manual.

The user can also specify hydrographs developed by other models and utilize only the drainage system routing routines built in the model. The input format for hydrographs has to be consistent with that feature when conjunctively used with the CUHP output.

### **Surface Flows and Flow Routing**

The core of the Runoff Block is the routing of hydrographs through the drainageway system. This is accomplished by a combination of overland flow and channel, gutter, reservoir and pipe routing.

Two types of elements are available to the user:

1. Sub-catchment elements (overland flow)
2. Conveyance elements (channel flow, pipe flow, storage, etc.)

The sub-catchment elements receive rainfall, account for infiltration loss using Horton's equation, permit surface storage such as ponding or interception on grass or shrubbery, and route excess rainfall to develop overland flows. The overland flows are then routed through the conveyance elements of the study watershed. Pipes and initial channel sections are permitted to surcharge when full or, if desired *and highly recommended*, overflow sections may be provided to convey the flow exceeding the pipe or the initial channel capacity. The routing is based on a kinematic wave approach utilizing Manning's equation both for sub-catchment and conveyance elements.

There are five standard types of conveyance elements and three special elements. The five standard conveyance elements are as follows:

1. Channel - A trapezoidal channel to represent or approximate an open channel or gutter.
2. Pipe - A circular pipe of any diameter.
3. Direct Flow - This element provides only instantaneous direct translation of the flows from the upstream to the downstream conveyance element and does not modify the hydrograph.
4. Channel with Overflow Channel - Same as the channel element above (i.e., #1) except that a larger trapezoidal channel above the smaller one is also specified to convey the flows exceeding the capacity of the initial channel cross-section.
5. Pipe with Over Flow Channel - Same as the pipe element above (i.e., #2) except that a trapezoidal channel above the pipe is also specified to convey the flows exceeding the capacity of the pipe.

The three special elements are as follows:

1. Diversion – Allows the input of up to 100 pairs of flows in a conveyance element vs. the flow diverted to another conveyance element. This option may be used with any routing element. There is a limit of 500 for all special element tables.
2. Storage Reservoir - Allows the input of up to 100 pairs of reservoir storage in acre feet vs. outflow in cubic feet per second. This option may be used in conjunction with the "pipe" routing element only. The pipe capacity has to be exceeded before the storage-outflow function is utilized. *It is recommended that a very small diameter pipe be used and the full storage-outflow function be represented using the table values.* The user may be limited to 500 for all specified element tables.

3. Inflow Hydrograph - This option may be used to specify an input hydrograph table of up to 100 pairs of time in hours vs. the flow in cubic feet per second. The user is limited to 500 for all special element tables.

### **Subroutine Descriptions**

This program has six core subroutines. Their functions and relationships are described below.

Subroutine RUNOFF. This is the subroutine called by the main program. This subroutine prints "entry made to the Runoff Model" and then computes or reads in the hydrograph ordinates with the assistance of five subroutines, RHYDRW, WSHED, INPUTW, RHYDRG, and GUTTER. The subroutines, RHYDRW, WSHED, INPUTW and GUTTER, are called if the option index IOPT = 0. This option calls for estimation of the hydrographs from sub-catchments for given rainfall and watershed parameters. The sub-catchment hydrographs are then routed through conveyance elements. If IOPT = 1, the subroutines, INPUTW, RHYDRG and GUTTER, are called instead, and hydrographs generated by the CUHP software or by the UDSWM sub-catchment portion of the model will be read in and routed through conveyance elements.

Subroutine RHYDRW. This subroutine is called by RUNOFF to read in the rainfall hyetograph and information related to the sub-catchment areas and to perform some initial preparatory work, such as unit conversion and error detection.

There are three basic categories of input data that is read by this subroutine. These include a number representing the sub-catchment, period of simulation, and a key indicating if the rainfall hyetograph is different from that of the previous sub-catchment. A new rainfall hyetograph will be read if it is so indicated. Otherwise, this part of the "read" operation will be skipped and the rainfall of the previous sub-catchment will be used. The first sub-catchment must have rainfall input.

The program proceeds to read sub-catchment data (e.g., the tributary area, width, ground slope).

It must be noted that the program can detect only logical errors such as indexing numbers. However, the input data are printed so the user can verify the data for correctness.

Subroutine WSHED. This subroutine is called by RUNOFF to compute the depth and the rate of overland flow. A DO loop is formed to compute the hydrograph coordinate for each incremental time-step. In each step, the rainfall intensity is first interpolated from the designated rainfall hyetograph for each sub-catchment. This rainfall intensity is assumed uniform over each sub-catchment.

A DO loop is set up to process each sub-catchment, one at a time. The amount of infiltration loss is calculated using Horton's equation,

$$\text{Infiltration loss} = f = f_o + (f_i - f_o)e^{-\alpha t} \quad (1)$$

in which  $f_o$ ,  $f_i$  and  $\alpha$  are coefficients and  $t$  is the time from the start of rainfall. The loss is compared with the amount of water existing on the sub-catchment at that time increment plus the rainfall. If the loss is larger, it is set equal to the amount of rainfall available and the remainder of the computation is skipped.

The water depth will increase without inducing runoff until it reaches the specified surface retention requirement. Beyond that, the surface flow rate is calculated using Manning's equation with the flow depth as the hydraulic radius. An iterative procedure termed Newton Raphson's technique is used to determine the excess water depth and the outflow rate so that the continuity of water mass is satisfied.

During the process of computation, an accounting is made of the rainfall accumulation which is compared against runoff, retention, and infiltration loss. A mass continuity is therefore checked and printed for reference.

Upon completion, the subroutine will return or, as an option, create a data file containing hydrograph values of all sub-catchments, for the subsequent routing through the conveyance elements.

Subroutine INPUTW. This subroutine is called by RUNOFF to read in sub-catchment hydrographs and the relationship between sub-catchments and conveyance elements when the option, IOPT = 1, is specified. If IOPT = 1 is specified, the subroutines RHYDRW and WSHED are skipped.

The data file containing sub-catchment hydrographs may be created either by the CUHP2000, or earlier versions of CUHP, model using print option NSW=7, 8 or 9 or by the UDSWM with IOPT=10 and NSAVE in Card Group 1.7 being specified. This data file is an ASCII file and the output format used in both models has been set to be consistent with the input format used in the subroutine INPUTW.

Subroutine RHYDRG. This subroutine is called by RUNOFF to read in the information regarding the routing elements (gutters, pipes, channels, etc.). The subroutine also sequences the computational order for all the routing elements according to the upstream and downstream relationships.

Subroutine GUTTER. The function of subroutine GUTTER is very similar to that of WSHED. It calculates a complete set of water depths and flows for all channels, gutters, pipes and other types of routing elements for each time step within a DO loop.

The computation also proceeds one routing element at a time. First, the inflow into the routing element from tributary sub-catchments and other routing elements is computed. The Newton-Raphson's iterative procedure is then used to determine the depth and outflow of the routing elements so that the mass (volume) of water is conserved. The flow is computed by Manning's equation.

The hydraulic radius of trapezoidal channels and circular pipes is calculated separately in different paths of the subroutine. The storage reservoir elements are computed using a modified Puls routing procedure and the diversion and inflow hydrograph values are calculated using table interpolation routines.

A pipe or channel may surcharge when it is full and the inflow is larger than the capacity of the conveyance element. In this case, the surcharged volume is computed and stored at the upstream end of the element unless an overflow conveyance element is specified. A message will be printed to indicate the time, location, and total volume of the surcharge. The pipe or initial channel will remain full until the stored water is completely drained. If an overflow element is provided, the flow exceeding the pipe or initial channel capacity will be routed through the overflow section.

## **DISCUSSION OF DATA PREPARATION**

Use of the surface flows portion of the Runoff Block is accomplished using four basic steps:

Step 1 – Synthesize a geometric representation of the drainage catchment

Step 2 - Estimate of coefficients for sub-catchment areas

Step 3 - Estimate of coefficients for conveyance elements

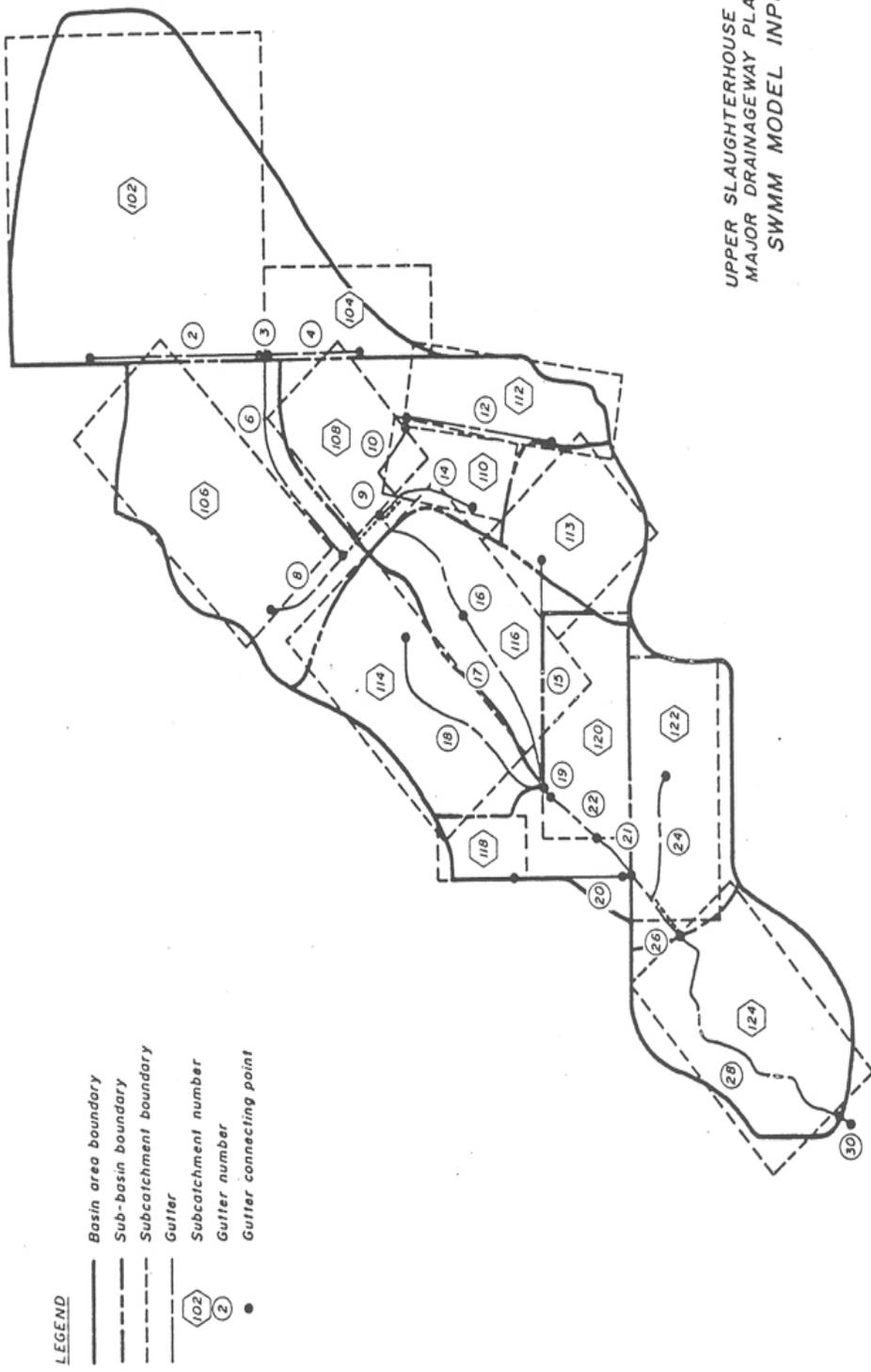
Step 4 - Prepare data for input to the computer program

### **Step 1 - Method of Discretization**

Discretization is a procedure for the mathematical abstraction of the physical drainage system. For the computation of hydrographs, a network of hydraulic elements (i.e., sub-catchments, gutters, pipes, etc.) may conceptually represent the drainage catchment. Hydraulic properties of each element are then characterized by various parameters such as size, slope, and roughness coefficient.

Discretization begins with the identification of catchment drainage boundaries; the location of storm sewers, streets, and channels; and the selection of those routing elements to be included in the system. This is best shown by an example. Figure 1 indicates possible discretizations of the Upper Slaughterhouse Gulch basin in Littleton, CO. In Figure 1 a relatively coarse approach was used resulting in 13 sub-catchments and 21 conveyance elements, including one storage reservoir.

Sub-catchments are represented by idealized rectangular areas with uniform slope and either uniform ground cover (i.e., asphalt, concrete, or turf) or a mix of pervious and impervious ground cover. Each sub-catchment has unique properties in terms of slope and ground cover. While, in theory, the subdivision of the catchment can be taken to infinitesimal detail, manpower requirements to prepare the input become prohibitive in practice. No ready rule for the subdivision can be offered, but a minimum of five sub-catchments per drainage catchment is recommended. This permits flow routing (time offset) between hydrographs.



UPPER SLAUGHTERHOUSE GULCH  
 MAJOR DRAINAGEWAY PLANNING  
 SWMM MODEL INPUT

FIGURE 1

Step 2 - Estimate of Coefficients for Sub-catchments Areas

For sub-catchment areas, coefficients and parameters necessary to characterize their hydraulic properties include surface area, width, ground slope, roughness coefficient, surface retention depth, infiltration rate, and percent imperviousness. Since real sub-catchments are not rectangular areas that experience uniform overland flow, approximations must be made in how to best represent the sub-catchments with idealized rectangular areas for computation purposes.

For the roughness coefficient, one can use the values given in Table 1 which were found to work reasonably well for hydrology studies within the District. Resistance factors for the pervious and impervious parts of a sub-catchment are specified separately, but the program will provide default values of 0.25 and 0.013 (Manning's *n* for overland flow) respectively if values are not specified by the user. Surface ponding depths will depend on specific site conditions. Values for surface ponding depth are recommended in the Runoff section of the *Urban Storm Drainage Criteria Manual (USDCM)*. The infiltration rates can also be estimated using the recommendations given in the *USDCM*.

Table 1  
ESTIMATE OF SUB-BASIN CATCHMENT SURFACE MANNING'S  
ROUGHNESS COEFFICIENTS FOR USE WITH UDSWM

Ground Cover	Manning's <i>n</i> for Overland Flow
Smooth Asphalt	0.016
Asphalt or Concrete Paving	0.020
Native Grass	0.200
Urban Lawns	0.250
Dense Shrubbery and Forest Litter	0.400

**NOTE:** *The District recommends that UDSWM results be calibrated against the CUHP software.* Calibration against CUHP should be performed against three to five design points in the watershed that have more than 90 tributary acres. Such calibration insures that the model is responding in a manner consistent with the rainfall-runoff data collected within District.

In lieu of utilizing UDSWM for the development of hydrographs for sub-catchment areas, the user may use CUHP software. As mentioned before, UDSWM permits direct input of hydrographs developed by CUHP.

### Step 3 - Estimate the Coefficients For Conveyance Elements

For hydrologic routing through conveyance elements such as pipes, gutters and channels, the resistance (Manning's  $n$ ) coefficients should not necessarily be the same as those used in performing hydraulic calculations. As a general rule, it was found that increasing the "typical" values of Manning's  $n$  used for hydraulic calculations by approximately 25 percent is appropriate when using UDSWM. Thus, if a gutter or a pipe are estimated to have  $n = 0.013$  for hydraulic calculations, it is appropriate to use  $n = 0.016$  for UDSWM. When modeling the hydrologic routing of natural streams, grass lined channels or riprap lined channels in Colorado, the Manning's  $n$  should be estimated for UDSWM using Equation 2.

$$n = 0.393S^{0.38}R^{-0.16} \quad (2)$$

In which,       $n$  = Manning roughness coefficient  
                   $S$  = Longitudinal slope (ft/ft)  
                   $R$  = Hydraulic radius or average depth (ft/ft),

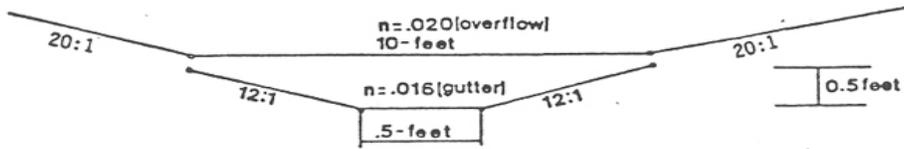
To estimate the hydraulic radius of a natural, grass lined or riprap lined channel for use in Equation 2; it is suggested that the peak flow rate of the hydrograph be used.

Equation 2 is the result of research work in Colorado by Robert D. Jarrett of U.S.G.S. (Jarrett, R.D., "Hydraulics of High Gradient Streams," *Journal of Hydraulic Engineering*, Vol. 110, No. 11, ASCE, November, 1984).

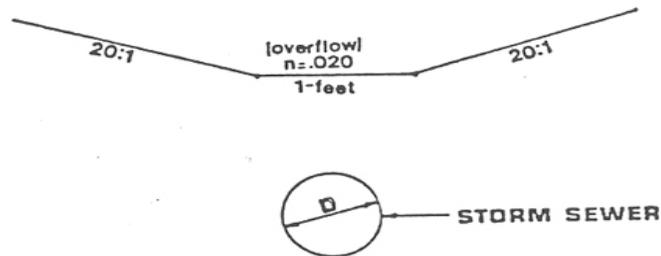
UDSWM does not have a conveyance element that directly simulates the geometry of flow along a street. When a street configuration needs to be used, its hydraulics approximated by the use of a trapezoidal section shown in Figure 2 generally produces a satisfactory result.

Figure 2

SUGGESTED TRAPEZOIDAL APPROXIMATIONS FOR STREETS



FULL STREET (TWO GUTTER) W/O STORM SEWER  
(FOR ONE GUTTER USE ONE-HALF OF SECTION)



FULL STREET WITH A STORM SEWER

#### Step 4 – Input Data Preparation

Data input should be prepared according to the section "Summary of Instruction of UDSWM, Data Input Cards." The appendix of this manual lists and describes most of the variables used in the Runoff Block. Some variables listed in the appendix are for the EPA version of the model, which includes the Transport Block for flow routing and water quality simulation, and are not applicable to UDSWM.

The first step in the data preparation is the determination of the number of time-steps to be used and the length of each time-step. The time-step length is usually 5 minutes but may range from 1 to 15 minutes, depending on the length and intensity of storm and the degree of accuracy required. There needs to be sufficient time steps that extend past the storm termination to account for the storm runoff and the emptying of storage basins after the rainfall ends. Along with the input of time-steps, the number of hyetographs for the drainage catchment is needed. The rainfall data is then prepared for each hyetograph. The number of time-steps of the hyetograph is limited to a maximum of 1900 and the time interval need not be the same as used in the flow simulation of the Runoff Block.

It is strongly recommended that a flow chart structure of the conveyance elements and sub-catchments be prepared at the very beginning. The conveyance elements network is obtained from catchment maps, subdivision plans and "as built" drawings of drainage system. Pipes with little or no backwater effects, channels, reservoirs, flow dividers, are usually designated as conveyance elements for computation by the Runoff Block. Once the conveyance element system is labeled with numbers (use numbers 1 through 1900), the sub-catchment areas are formed reflecting the existing conveyance network, ground cover, and land slope. Input is then coded for each numbered sub-catchment, defined by its tributary width, area, slope, percent imperviousness, etc., along with the conveyance element into which the flows are routed. Next, the conveyance element input is prepared giving the required information.

As mentioned earlier, UDSWM can be utilized with external runoff hydrograph tables to simulate the effects of conveyance and special elements only. In this case, the user needs to develop an input file containing hydrograph information of the sub-catchment areas. This can be achieved by use of UDSWM or CHUPE/PC software. The time interval of the hydrographs in the file should be the same as used in the conveyance element simulation.

## DESCRIPTION OF INPUT DATA CARDS

The input of UDSWM is described in terms of card groups. **The program provides a user interface that sets up the input in the required fixed format for the UDSWM engine to process.** The individual user can, if he or she wishes, develop their own input writing and editing package to organize the input into a form specified in the Input Data Section.

### Card Group A

This card identifies input and output units for the computer.

### Card Group B

This card identifies a scratch file for the program.

### Card Group 0

WATERSHED calls and initializes the UDSWM Runoff Block.

IOPT is an index to indicate if the sub-catchment hydrographs are to be simulated or not by UDSWM.

If IOPT = 0, the hydrographs of sub-catchments and conveyance elements are to be simulated by UDSWM.

In addition, the sub-catchment hydrographs can be saved by specifying NSAVE in Card Group 1.7. This option requires Card Groups 1.1 through 1.10 while skipping Card Groups 2.1 through 2.4.

The IOPT = 0 option allows for the use of sub-catchment hydrographs developed by other models. CUHP software creates a file containing hydrographs, which has a format consistent with UDSWM requirements. The hydrograph file can also be developed by the use of UDSWM itself. When a number of conveyance system alternatives are needed to be analyzed, the user may first develop and save sub-catchment hydrographs for subsequent use to route through various alternatives of a conveyance system.

If IOPT = 1 is used, Card Groups 2.1 through 2.4 and an input file containing hydrographs are required and Card Groups 1.1 through 1.10 are to be skipped.

### Card Group 1.1

TITLE: Requires two lines identifying the job that is used as headings on the printed output.

### Card Group 1.2

INLET: Specifies the number of inlets that may be connected to TRANSPORT block of the EPA version. However, in UDSWM this variable is not used and should be left blank.

NSTEP: Number of time steps to be calculated. Number of time steps should be sufficient to insure that most of the runoff has occurred and will depend on the size of the watershed and the size of the time step (DELTA).

NHR: Hour at start of storm. May be left blank.

NMN: Minute at start of storm. May be left blank.

DELTA: Integration period (i.e., size of time step) in minutes. Unless the sub-basins are very small, use DELTA = 5-minutes.

NRGAG: The number of hyetographs to be used for any one storm cannot exceed ten. When using design storms, usually only one hyetograph is used at a time.

PCTZER: Percent of the impervious area that has no ponding depth and results in immediate runoff to a conveyance element. For the District region a value of 10 percent is recommended. If the field is left blank, a value of 25% is used by the program.

IPKCHK: A value of "1" will cause a printing of a peak flow and depth of flow summary table at the end of the run. Use of this option is recommended.

### Card Group 1.3

NHISTO: Number of data points (maximum of 1900) for each hyetograph (e.g., 2-hour storm at 5-minute increments will have NHISTO = 24).

THISTO: Time interval in minutes between the individual values of the hyetograph. This does not have to be the same value as used for DELT.

Card Group 1.4

RAIN (1): First value of rainfall intensity in inches/hour of the hyetograph.

RAIN (2): Second value of rainfall intensity.

RAIN (NHISTO): Last value of rainfall intensity.

Card Group 1.5 (Repeat Card 1.5 for Each Sub-catchment)

JK: Hyetograph number, which is based on the consecutive number in which they are read. For most storm water management studies there will be only one hyetograph unless the study is in an area covered by more than one rainfall intensity zone (e.g., foothills area).

N: The sub-catchment identification number (has to be 1900 or less.).

NGOTO: The identification number (less than 1900) of the conveyance element in Card Group 3.1 into which the sub-catchment (i.e., N) connects.

WWIDTH: The tributary width in feet of the sub-catchment. This is the width of the downstream side of the idealized sloping rectangular sub-catchment area. When the conveyance element approximately bisects a sub-catchment, it is possible to use approximately twice the length of the conveyance element for WWIDTH.

WAREA: Area of the sub-catchment in acres.

PCIMP: Percent of the sub-catchment that has an impervious surface consisting of paved roads, paved parking lots, roofs, sidewalks, driveways, etc.

WSLOPE: The average ground slope in feet per foot of the sub-catchment normal to the tributary width. If left blank, program will use 0.03 ft/ft.

W5: Surface resistance factor (Manning's  $n$ ) for the impervious surfaces of the sub-catchment. If left blank, program will use 0.013.

<u>W6:</u>	Surface resistance factor (Manning's $n$ ) for the pervious surfaces of the sub-catchment. If left blank, program will use 0.250.
<u>W7:</u>	Impervious surface retention storage (loss) in inches. If left blank, program will assign 0.062 inches.
<u>W8:</u>	Pervious surface retention storage (loss) in inches. If left blank program will use 0.184 inches.
<u>WLMAX:</u>	Maximum infiltration rate in Horton's Equation in inches per hour. If left blank, program will use 3.00 in/hr.
<u>WLMIN:</u>	Minimum infiltration rate in Horton's Equation in inches per hour. If left blank, program will use 0.52 in/hr.
<u>DECAY:</u>	Decay rate of infiltration per second in Horton's Equation. If left blank program will use 0.00115/sec.

The MRD modification to subroutine WSHED limits the infiltration loss to no greater than the current rainfall intensity, except that the loss is always at least 5 percent of the computed infiltration rate. The revised algorithm is more in line with the practice of handling rainfall loss rates in MRD.

The default values for any variable having default values may be changed at any point of the input card sequence by entering "-2" (i.e., minus 2) in columns 9 and 10. Any non-zero value entered in the field of any variable will replace the value in the default value table.

To expedite calibration of the model, it is possible to alter all values that follow in subsequent data lines for a given variable by a desired adjustment ratio. This is done by entering "-1" (i.e., minus 1) in columns 9 and 10 and then entering the adjustment ratio in the desired variable field(s). Initially, all adjustment ratios are set equal to 1.0. The final value of any variable is determined by multiplying the input value for the variable by the given adjustment ratio. The adjustment ratios may be changed at any point in the input sequence for Card Group 1.5. Once changed they will apply to all subsequent input lines until another adjustment ratio is used.

#### Card Group 1.6

Use a blank card to signal the end of Card Group 1.5 cards.

### Card Group 1.7

If IOPT = 0 is used on Card Group 0, this line is used to specify the total number (i.e., NSAVE) of sub-catchments for which the hydrograph values will be saved on a data file (name for the output data file will be asked for by the model interactively) for the subsequent when running UDSWM using IOPT=1.

### Card Group 1.8

ISAVE: Up to 16 sub-catchment identification numbers to be saved may be specified per line. The total may not exceed the value of NSAVE in card group 1.7.

### Card Group 1.9

NPRNT: The number of sub-catchments for which hydrograph values are to be printed.

INTERV: Number of time-steps between printed hydrograph values. As an example, INTERV=1 will print every time step.

### Card Group 1.10

IPRNT: Up to 16 sub-catchment identification numbers per line may be specified for which hydrograph values are to be printed.

### Card Groups 2.1, 2.2, 2.3, and 2.4

These groups of card's are required if IOPT = 1, is used on Card Group 0. They are similar to Card Groups 1.1, 1.2, 1.5, and 1.6 respectively. However, in card groups 2.2 and 2.3, only variables required are NSTEP, NHR, DELT, IPKCHK, N and NGOTO.

### Card Group 3.1 (Repeat Card 3.1 for Each Conveyance Element)

JK: This variable, in combination with NDP, is used to identify the type of conveyance element to be used.

If NDP is blank or zero, JK is ignored and one of the five standard conveyance elements is used.

If NDP is a positive number then JK flags on of the following special conveyance elements:

If JK = a positive number, it identifies the conveyance element as a diversion to a conveyance element identified by the number entered for JK. The conveyance element card must be followed by a card group 3.1A that contains a table of the total flow in the conveyance element vs. the diverted flow in cubic feet per second (maximum of 500 tables in total). NDP specifies the number of tabular value pairs (maximum of 100 pairs) to be input by card group 3.1A, four pair per card using 8F10.0 format.

If JK = zero or a blank, it identifies the conveyance element as a detention reservoir (maximum of 500 tables in total). The conveyance element card must be followed by card group 3.1A that contains a table of detention storage in acre feet vs. outflow in cubic feet per second. NDP specified the number of storage vs. outflow pairs (maximum of 100 pairs) to be input by card group 3.1A, four pair per card using 8F10.0 format.

If JK = -1, an inflow hydrograph is indicated for this conveyance element. The card group 3.1A that follows contains a table of time in hours vs. inflow values in cubic feet per second that are used as an input hydrograph for this element (maximum of 500 tables in total). NDP specifies the number of time vs. inflow pairs (maximum of 100 pairs) to be input by card group 3.1A, four pair per card using 8F10.0 format.

N: Conveyance element identification number (has to be 1900 or less).

NGOTO: The number of the conveyance element immediately downstream of the element identified by N.

NDP: This variable is normally zero (or blank) unless one of the special conveyance options are being exercised in conjunction with JK. In that case NDP is a positive number equal to the number of paired tabular values to be input by card group 3.1A.

NP: The type of standard conveyance element as described by the following codes:

If NP = 1, the element is a trapezoidal channel.

If NP = 2, the element is a circular pipe.

If NP = 3, the element is a direct flow element and no routing takes place. The hydrograph at its downstream end should be almost identical to the hydrograph at the upstream end. (Note that this element will not be shown on the table of tree structure unless its length is specified as a positive number.)

If NP = 4, the element is a trapezoidal channel with a larger trapezoidal channel acting as an overflow conveyance once the capacity of the smaller channel is exceeded.

If NP = 5, the element is a pipe with a trapezoidal channel acting as an overflow conveyance once the pipe capacity is exceeded.

GWIDTH: Bottom width of channel or the diameter of a circular pipe in feet.

GLEN: Length of the conveyance element in feet.

GSLOPE: Invert slope of the channel or pipe in feet per foot. Slope is measured as vertical divided by horizontal (i.e., ft/ft).

GS1 & GS2: Left and right hand side slopes, respectively, of the trapezoidal channel in feet/foot. Slope is measured as horizontal divided by vertical (i.e., H:V).

GS: Manning's roughness coefficient.

DFULL: The depth in channel when full or the pipe diameter, both measured in feet. If an overflow section is specified, DFULL specifies the depth at which overflow begins, otherwise it specifies when the conveyance element will begin to store the excess flow as volume. If left blank, the program will use 10 feet.

To expedite calibration it is possible to use conveyance element data adjustment ratio line. The concept is identical to watershed data adjustment

line described under card group 1.5 above, except that the minus one (-1) must be entered in columns 9 and 10. Also, changes may only be made in any data fields to the right of column 20. Changes for the conveyance element data will not cause changes in the overflow data, which will be described below.

If NP = 4 or 5 (in column 20 of the Gutter Data Card), it must be followed by an Overflow Data Card. The Overflow Data Card describes a trapezoidal overflow section. Columns 1-20 are blank. The data fields to the right of columns 20 have the same format as the Gutter Data Card described above and contain the data to describe a trapezoidal channel. The bottom width (columns 21-28) does not include the width of the initial channel or pipe. The depth field (columns 29-36) is the maximum surcharge depth above the overflow channel bottom. Either the invert gradient (columns 37-44) or the length (columns 45-52) may be specified different from the initial channel or pipe to account for different sinuosity. If they are left blank, they are assumed to be the same as the initial channel or pipe. The program assumes that the overflow section has the same fall over its length as the initial channel pipe. If the overflow length is specified, the corresponding invert gradient is computed. If the gradient is specified, the appropriate length is computed.

To expedite calibration it is also possible to specify overflow data adjustment ratios. The concept is identical to the conveyance element data-change card described above. Minus one (-1) must appear in columns 9-10 and modifying ratios may be entered in any data field to the right of column 20. Changes for overflow data cards will not affect the initial conveyance element data cards.

Whenever a storage-outflow element is specified (i.e., JK=0 (or blank) and NDP = number of storage-outflow pairs), the outlet pipe discharge is computed first by the normal pipe flow routine until it is surcharged; at which time the storage-outflow table is used. The program does not perform a pressurized conduit computation; therefore, pipe outlet discharge is constant for all surcharge levels. If it is desired that the outlet pipe discharge increase with surcharge, this additional discharge can be added to the storage-outflow table. To avoid confusion, a very small outlet pipe can be specified (i.e., near zero

flow) and the combined pipe and spillway outflow characteristics can then be described by the storage-outflow table.

#### Card Group 3.2

Use a blank card to signal the end of card group 3.1 cards.

#### Card Group 4.1

This card is used to specify (NSAVE) the total number of conveyance elements for which the flow and depth (or surcharge) data will be saved on peripheral storage for use in printing or plotting.

#### Card Group 4.2

IS AVE: Up to 16 conveyance element identification numbers to be saved may be specified per line. The total may not exceed the value specified under NSAVE in card group 4.1.

#### Card Group 4.3

NPRNT: The number of conveyance elements for which hydrograph values are to be printed.

INTERV: Number of time-steps between printed hydrograph values. As an example INTERV = 1 will print every time step, INTERV = 2 every other time step, etc.

#### Card Group 4.4

IPRNT: Up to 16 conveyance element identification numbers per line may be specified for which hydrographs are to be printed. Total number of elements may not exceed NPRNT.

#### Card Group 5.0

Enter ENDPROGRAM to terminate run. If additional data sets are to be processed, skip card group 5.0 (i.e., ENDPROGRAM) and continue with a new card group 0.

## UDSWM

### DESCRIPTION OF DATA INPUT

Card Group	Format	Columns	Mandatory Entry	Description	Variable Name	Default Value
A	4I4	4	2	(Initializes Devices)	JIN(1)	none
		8	1	(Initializes Devices)	JOUT(1)	none
		12	2	(Initializes Devices)	JIN(2)	none
		16	2	(Initializes Devices)	JOUT(2)	none
B	2I4	4	3	(Initializes Devices)	NSCRAT(1)	none
		8	2	(Initializes Devices)	NSCRAT(2)	none
0	3A4	1-12	WATERSHED	Initiates <i>Runoff Block</i> calculations	CNAME(2)	none
	I1	13		Options for sub-catchment routing If IOPT = 0; data sets 1.1 - 1.10 have to be provided to proceed with the sub-catchment overland runoff calculation using UDSWM2-PC. If IOPT = 1; data sets 2.1 - 2.4 have to be provided. A request of an input file containing sub-catchment hydrographs appears on the screen. This file may be created either by UDSWM model with IOPT=0 and NSAVE on data set 1.7 being specified, or by CUHP model with PRINT options NSW = 7,8,9.	IOPT	none

If IOPT = 1, Skip Card Sets 1.1 through 1.10

Card Group	Format	Columns	Description	Variable Name	Default Value
1.1	20A4	1-80	<b>IF IOPT = 1, SKIP CARD SETS 1.1 THROUGH 1.10</b> <b>Titles for project</b> Two input lines containing headings to be printed that describes the project	TITLE	none
1.2			<b>Control Line (Card)</b>		
	2I5	1-5	Number of inlets (leave blank)	INLET	1
		6-10	Number of time-steps to be calculated	NSTEP	none
	I3	11-13	Hour of start of storm	NHR	none
	I2	14-15	Minutes of start of storm	NMN	none
	F5.1	16-20	Integration period in minutes	DELT*	none
	I5	21-25	Number of hyetograph	NRGAG	none
	F5.0	26-30	Percent of impervious area with zero detention (i.e., immediate runoff)	PCTZER*	25.0
	I1	80	Enter "1" in this column to print a summary of peak flows and depths at end of printed output	IPKCHK	0
1.3			<b>Rainfall Control Line (Card)</b>		
	I5	1-5	Number of data points for each hyetograph	NHISTO	none
	F5.0	6-10	Time interval between values in minutes	THISTO*	none
1.4			<b>REPEAT CARD GROUP 1.4 FOR EACH HYETOGRAPH</b> <i>Rainfall hyetographs - 10 intervals per line</i> If 0.00 rainfall is entered for several steps before the first positive value of rainfall is entered, an underflow problem in computations can result.		
	10F5.0	1-5	Rainfall intensity, first interval in in/hr	RAIN(1)*	none
		6-10	Rainfall intensity, first interval in in/hr	RAIN(2)*	none
		11-15	Rainfall intensity, first interval in in/hr	RAIN(3)*	none
		.	.		
		.	.		
		.	.	RAIN(NHISTO)	

Card Group	Format	Columns	Description	Variable Name	Default Value
1.5			<b>REPEAT CARD GROUP 1.5 FOR EACH SUB-CATCHMENT</b> One line per sub-catchment		
	3I5	1-5	Hyetograph number <i>(Based on the order in which they are listed in Card Group 1.4)</i>	JK	1
		6-10**	Sub-catchment number <i>(Maximum of 1900 sub-catchments)</i>	N	none
		11-15	Conveyance element number draining this sub-catchment <i>(Maximum of 1900 elements)</i>	NGOTO	none
	10F5.0	16-20	Total tributary width of sub-catchment	WWIDTH=W1*	none
		21-25	Area of sub-catchment	WAREA=W2*	none
		26-30	Percent imperviousness of the sub-catchment	PCIMP=W3*	0.001
		31-35	Ground slope (ft. vertical/ft. horizontal)	WSLOPE=W4*	0.030
		36-40	Impervious area surface Manning's <i>n</i> factor	W5=W5*	0.013
		41-45	Pervious area surface Manning's <i>n</i> factor	W6=W6*	0.250
		46-50	Impervious area surface retention storage (in.)	WSTORE=W7*	0.062
		51-55	Pervious area storage (in.)	WSTORE=W8*	0.184
		56-60	Maximum infiltration rate (in/hr)	WLMAX=W9*	3.00
		61-65	Minimum infiltration rate (in/hr)	WLMIN=W10*	0.52
	F5.0	66-75	Decay rate of infiltration (1/sec)	DECAY=W11*	0.00115

\* Note: All parameters marked with "\*" need to have a decimal point entered in their input field

\*\* Need to define an inlet or gutter-pipe for each sub-catchment

\*\*\* For sub-catchments having inflow on both sides of the conveyance element use twice the length of conveyance element within the sub-catchment

#### Comments For Card Group 1.5

Default values may be changed at any point in input line sequence by entering "-2" in Columns 9 and 10 of an input line. Any non-zero value then entered in any parameter field on that same line replaces the default parameter values in the default table.

Input parameters for the sub-catchment lines that follow may be altered by a user-specified multiplier by inserting a new line containing "-1" in Columns 9 and 10. Any non-blank (or non-zero) numerical value entered on the same line in any given parameter's field will be used as a multiplier for the parameter values entered by the user after that line. Initially, parameter modification ratios are set equal to 1.0 by the program. The final parameter value used by the software is determined by multiplying the user input value for the parameter by the multiplier number entered by the user. These multipliers may be changed at any point in the sub-catchment input sequence, but once multipliers are input, they are applied to all subsequent sub-catchment parameter lines until another change line (i.e., -1) in sub-catchment number is used.

1.6			Enter Blank line (card) to end sub-catchment inputs		
-----	--	--	---	--	--

Card Group	Format	Columns	Description	Variable Name	Default Value
1.7			<b><i>SUB-CATCHMENT SAVE CONTROL LINE</i></b>		
	I5	1-5	Number of sub-catchments for which hydrographs are to be saved for subsequent gutter routing using IOPT = 1 in future runs of UDSWM	NSAVE	none
1.8			<b><i>IF NSAVE = 0, SKIP CARD GROUP 1.8</i></b> <b><i>Sub-catchments to save: 16 values per line</i></b>		
	16I5	1-5	Number of sub-catchment for which to save values	ISAVE (1)	none
		6-10	.	ISAVE (2)	none
		11-15	.	.	.
		.	.	.	.
		.	.	ISAVE (NSAVE)	none
1.9			<b><i>Sub-catchment to print control line</i></b>		
		1-5	Number of sub-catchments for which hydrographs will be printed	NPRINT	none
		6-10	Number of time steps between printed values	INTERV	1
1.10			<b><i>IF NPRINT = 0, SKIP CARD GROUP 1.10</i></b> <b><i>Sub-catchments to print: 16 values per line</i></b>		
	16I5	1-5	Number of sub-catchment to print	IPRNT (1)	none
		6-10	Number of sub-catchment to print	IPRNT (2)	none
		11-15	.	.	.
		.	.	.	.
		.	.	.	.
		.	.	IPRNT (NPRINT)	none

**If IOPT = 0, Skip Card Sets 2.1 through 2.4**

Card Group	Format	Columns	Description	Variable Name	Default Value
2.1	20A4		<b>IF IOPT = 0, SKIP CARD GROUPS 2.1 - 2.4</b> <b>Titles for project</b> Two input lines containing headings to be printed that describes the project	TITLE	none
2.2			<b>Control Line</b>		
	2I5	1-5	Number of inlets (leave blank)	INLET	1
		6-10	Number of time-steps to be calculated	NSTEP	none
	I3	11-13	Hour of start of storm	NHR	none
	I2	14-15	Minutes of start of storm	NMN	none
	F5.1	16-20	Integration period in minutes	DELT*	none
	I1	80	Enter "1" in this column to print a summary of peak flows and depths at end of printed output	IPKCHK	0
2.3			<b>REPEAT CARD GROUP 2.3 FOR EACH SUB-CATCHMENT</b> One line per sub-catchment		
		6-10**	Sub-catchment number (Maximum of 1900 sub-catchments)	N	none
		11-15	Conveyance element number draining this sub-catchment (Maximum of 1900 elements)	NGOTO	none
2.4			<b>Blank line to terminate sub-catchment</b>		

\*\* Need to define a conveyance element for each sub-catchment

Card Group	Format	Columns	Description	Variable Name	Default Value
3.1			<b>REPEAT CARD GROUP 3.1 FOR EACH CONVEYANCE ELEMENT</b> <b>Conveyance element line - one line per conveyance element unless the JK/NDP codes require follow-up lines</b>		
	I5	1-5	<p>If NDP (Col 17-18) = 0, JK is ignored.</p> <p>If NDP is a positive number, card group 3.1A needs to follow this line and JK signals the following input options:</p> <p>JK = positive; a diversion from this gutter to the gutter number indicated by JK is defined. The gutter line(s) for this gutter must be followed by a card group 3.1A that inputs a table of Total Q in gutter vs. Q diverted in cfs. NDP is the number of sets of tabular values.</p> <p>JK = 0 (or blank); a detention dam at this gutter is defined. The gutter line(s) for this gutter must be followed by a card group 3.1A that inputs a table of detention storage in ac/ft vs. dam outflow capacity in cfs. NDP is the number of sets of tabular values.</p> <p>JK = minus one (-1); an inflow hydrograph is defined for this gutter. The line(s) for this gutter must be followed by a card group 3.1A that inputs a table of time in hrs. vs. inflow in cfs. NDP is the number of sets of tabular values.</p>	JK	none
	I5	6-10	Conveyance element number (-1 in Col 9 & 10 indicates this is a conveyance element or overflow change line)	N	none
	I5	11-15	Next downstream conveyance element number	NGOTO	none

	I2	17-18	NDP is normally zero, unless one of the options explained for JK is to be exercised, in which case, NDP is a positive number equal to the number of sets of tabular values to be input under one of the options explained for JK.	NDP	none
	I1	20	TYPE of Conveyance Element 1 = channel 2 = pipe 3 = direct flow (no routing) 4 = channel with overflow channel 5 = pipe with overflow channel	NP	none
	7F8.0	21-28	Bottom width of channel or pipe diameter (ft.)	GWIDTH=G1*	0.001
		29-36	Length of conveyance element (ft.)	GLEN=G2*	none
		37-44	Invert slope (ft vertical/ft horizontal or %/100)	GSLOPE=G3*	0.001
		45-52	Left-hand side slope (ft Horizontal:ft Vertical)	GS1=G4*	0.001
		53-60	Right-hand side slope(ft Horizontal:ft Vertical)	GS2=G5*	0.001
		61-68	Manning's coefficient	GS=G6*	0.020
		69-76	Depth of channel in feet when full or the pipe diameter. When an overflow section is specified (Code 4 or 5 in Column 20) the DFULL specifies the depth in the gutter (or pipe) at which overflow begins.	DFULL=G7	10

### Comments For Card Group 3.1

If NP = 4 or 5 (i.e., in Col 20), an overflow trapezoidal channel is defined and Card group 3.1 for this element should include a second line containing the overflow trapezoidal channel parameters in the same format as specified for the preceding conveyance element line, except Columns 1 through 20 are left blank. The bottom width of the overflow channel is treated as a separate channel with its own bottom width. Overflow input parameters may be also modified by a constant factor by using a modifier line before the first overflow line which is similar in every way to the description provided at the end of card group 3.1 and begins by a -1 in Columns 9 and 10.

Input parameters for conveyance elements may be altered by a given ratio. If conveyance element number is in as -1, non-blank (non-zero) values in parameter fields replace previous default ratios in default table. Initially default ratios are set equal 1.0. For each variable, final parameter value used is determined by multiplying input card value, by the given ratio. Ratios may be changed at any point in the conveyance element input line sequence.

Card Group	Format	Columns	Description	Variable Name	Default Value
3.1A			<b><i>CARD group 3.1A used only as required by the JK/NDP codes conveyance element lines, otherwise skip this line</i></b>		
	8F10.0	1-80	<p>If NDP (Col 17-18) on the previous conveyance element line(s) = 0, no card group 3.1A will be provided.</p> <p>If NDP is a positive number, card group 3.1A must follow the previous gutter card. NDP pairs of tabular values are expected, up to 4 pairs (8 values) on a line, using as many lines as needed.</p> <p><u>When JK &gt;0:</u> Diversion Option is used and tabular values are Q in gutter vs. diverted Q in cfs. <i>JK is the conveyance element number into which the diverted Q flows.</i></p> <p><u>When JK = 0:</u> Detention Dam Option is used and tabular values are Storage in acre-feet vs. Outflow discharge in cfs.</p> <p><u>When JK &lt;0:</u> Inflow Hydrograph Option is used and tabular values are Time in hours vs. Inflow in cfs.</p>	SD, QD	none
3.2			<b><i>Blank line to terminate conveyance element*</i></b>		

\* Need this line even though there are no conveyance element lines

Card Group	Format	Columns	Description	Variable Name	Default Value
4.1			<b>CONVEYANCE ELEMENT SAVE CONTROL LINE</b>		
	I5	1-5	Number of conveyance elements for which hydrographs are to be saved	NSAVE	none
4.2			<b>IF NSAVE = 0, SKIP CARD GROUP 4.2</b> <b>Conveyance elements to save: 16 values per line</b>		
	16I5	1-5	Number of conveyance elements for which to save values	ISAVE (1)	none
		6-10	.	ISAVE (2)	none
		11-15	.	ISAVE (3)	none
		.	.	.	.
		.	.	.	.
		.	.	ISAVE (NSAVE)	none
4.3			<b>Conveyance elements to print control line</b>		
	2I5	1-5	Number of conveyance elements for which values are to be printed	NPRINT	none
		6-10	Number of time steps between printed values		
4.4			<b>IF NPRINT = 0, SKIP CARD GROUP 4.4</b> <b>Conveyance elements to print: up to 16 values per line</b>		
	16I5	1-5	Number of conveyance elements for which to print values	IPRNT (1)	none
		6-10	.	IPRNT (2)	none
		11-15	.	IPRNT (3)	none
		.	.	.	.
		.	.	.	.
		.	.	IPRNT (NPRINT)	none
5.0	2A4	1-8	<b>END PROGRAM - Terminates run</b> <b>If additional data set is to be run, skip</b> <b>ENDPROGRAM line and go to line 0</b>	CNAME	none