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STORM WATER MANAGEMENT MODEL USER'S MANUAL VERSION 4:

EXTRAN ADDENDUM

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Cooperative Agreement CR-811607

Project Officer

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The Storm Water Management Model (SWMM) described in this manual must be used at the user's own risk. Neither the U.S. Environmental Protection Agency, the State of Florida, the University of Florida, The State of Oregon, Oregon State University, Camp, Dresser and McKee, Inc. or the program authors can assume responsibility for model operation, output, interpretation or usage.

FOREWORD

As environmental controls become more costly to implement and the penalties of judgment errors become more severe, environmental quality management requires more efficient management tools based on greater knowledge of the environmental phenomena to be managed. As part of this Laboratory's research on the occurrence, movement, transformation, impact, and control of environmental contaminants, the Assessment Branch develops state-of-the-art mathematical models for use in water quality evaluation and management.

Mathematical models are an important tool for use in analysis of quantity and quality problems resulting from urban storm water runoff and combined sewer overflows. This report is an updated user's manual and documentation for one of the first of such models, the EPA Storm Water Management Model (SWMM) and its Extended Transport (Extran) Block. Detailed instructions on the use of Extran are given, and its use is illustrated with case studies.

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PREFACE

This document is the user's guide and program documentation for the computer model EXTRAN. EXTRAN is a dynamic flow routing model that routes inflow hydrographs through an open channel and/or closed conduit system, computing the time history of flows and heads throughout the system. While the computer program was developed primarily for use in urban drainage systems -- including combined systems and separate systems -- it also can be used for stream channels through the use of arbitrary cross sections or if the cross-section can be adequately represented as a trapezoidal channel.

EXTRAN is intended for application in systems where the assumption of steady flow, for purposes of computing backwater profiles, cannot be made. The program solves the full dynamic equations for gradually varied flow (St. Venant equations) using an explicit solution technique to step forward in time. As a result, the solution time-step is governed by the wave celerity in the shorter channels or conduits in the system. Time-steps of 5-seconds to 60-seconds are typically used, which means that computer time is a significant consideration in the use of the model.

The conceptual representation of the drainage system is based on the "link-node" concept which does not constrain the drainage system to a dendritic form. This permits a high degree of flexibility in the type of problems that can be examined with EXTRAN. These include parallel pipes, looped systems, lateral diversions such as weirs, orifices, pumps, and partial surcharge within the system.

Because of the versatility of the EXTRAN model, there is a tendency for some users to apply the model to the entire drainage system being analyzed even though flow routing through most of the system could be performed with a simpler model such as Runoff or Transport*. The result is a very large system simulated at relatively small time-steps which produces great quantities of data that are difficult to digest. Where simpler models are applicable (no backwater, surcharging, or bifurcations) substantial savings in data preparation and computer solution time can be realized using the simpler routing model.

EXTRAN has limitations which, if not appreciated, can result in improperly specified systems and the erroneous computation of heads and flows. The significant limitations are these:

*That is, the Runoff and Transport Blocks from the EPA SWMM computer program.

-- Headloss at manholes, expansions, contractions, bends, etc. are not explicitly accounted for. These losses must be reflected in the value of the Manning n specified for the channels or conduits where the loss occurs.

-- Changes in hydraulic head due to rapid expansions or contractions are neglected. At expansions, the headloss will tend to equalize the heads; but at contractions, the headloss could aggravate the problem.

-- At a manhole where the inverts of connecting pipes are different (e.g., a drop manhole), computational errors will occur during surcharge periods if the invert of the highest pipe lies above the crown of the lowest pipe. The severity of the error increases as the separation increases.

-- Computational instabilities can occur at junctions with weirs if: 1) the junction is surcharged, and 2) the weir becomes submerged to the extent that the downstream head equals or exceeds the upstream head.

-- EXTRAN is not capable of simulating water quality. Any quality information input to EXTRAN is ignored by the program.

Methods for dealing with these problems are discussed in Chapter 4.

Finally, a word of caution. EXTRAN is a tool, like a calculator, that can assist engineers in the examination of the hydraulic response of a drainage system to inflow hydrographs. While the model is physically based, approximations in time and space are made in order to address real problems. While the authors have tried to anticipate most prototype configurations, these approximations may not be appropriate in some system configurations or unusual hydraulic situations. Therefore, persons using the computer program must be experienced hydraulicians. The computational results should never be taken for granted, but rather the computer output should be scanned for each simulation to look for suspicious results. The checking procedure should be analogous to that which would be followed in checking a backwater profile that a junior engineer had performed by hand computation. Remember that the major difference between the engineer and the computer is that the computer can't think!

SPECIAL PREFACE TO OCTOBER 1992 PRINTING

This printing differs very little from the February 1989 second printing. However, a few additional program options have been included that for the most part are <u>not</u> documented in this User's Manual. Instead, the user should refer to documentation (.DOC) files for each SWMM block included on the distribution disks. These contain annotated data input templates comparable to the data preparation table (i.e., Table 2-1) found in this manual. These .DOC files include modifications to identify changes in input requirements (e.g., optional BB line). If an Extran user encounters an error message during the data input process that appears to result from the need for an additional or altered input parameter, this is most likely described in the EXTRAN.DOC file.

ABSTRACT

This report contains the documentation and user's manual for Version 4 of the Extended Transport (EXTRAN) Block of the EPA Storm Water Management Model (SWMM). EXTRAN is a dynamic flow routing model used to compute backwater profiles in open channel and/or closed conduit systems experiencing unsteady flow. It represents the drainage system as links and nodes, allowing simulation of parallel or looped pipe networks; weirs, orifices, and pumps; and system surcharges. EXTRAN is used most efficiently if it is only applied to those parts of the drainage system that cannot be simulated accurately by simpler, less costly models.

The EXTRAN manual is designed to give the user complete information in executing of the model both as a block of the SWMM package and as an independent model. Formulation of the input data is discussed in detail and demonstrated by seven example problems. Typical computer output also is discussed. Problem areas that the user may confront are described, as well as the theory on which the EXTRAN model rests. The manual concludes with a comprehensive discussion of the EXTRAN code.

This report was submitted in partial fulfillment of EPA Cooperative Agreement No. CR-811607 to the University of Florida under the partial sponsorship of the U.S. Environmental Protection Agency. Camp Dresser & McKee, Inc. prepared this report as a contractor to the University of Florida. Work was completed as of August 1987.

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TABLES
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ACKNOWLEDGMENTS

The authors are grateful for many suggestions for improvements from EXTRAN users over the years. Significant improvements to Version 4 have resulted from information supplied by Dr. Lothar Fuchs of the University of Hamburg.

Many users served as "beta testers" following the first release of Version 4 of Extran in August 1988. We are grateful for their many helpful suggestions for improvements for the release of February 1989.

CHANGES FOR FEBRUARY 1989 PRINTING

Several changes have been made to the text and tables since the first printing of August 1988. The June 1988 Extran user's manual (e.g., as supplied by the NTIS) should still function, but it will not include a discussion of some added features. Since additional pages have been added and the pages have been renumbered, it is not possible to list every page with changes. However, significant modifications to the user's manual include the following:

- Discussion of alphanumeric input in Section 1.
- Reduction of maximum number of conduits and junctions to 175.
- Additional flow routing options in data group B0, indicated in Table 2-1 and discussed in Appendix C.
- Ability to plot upstream and downstream heads simultaneously for conduits, data group B8.
- Power function option for variable area junctions, group E2.
- Time series of orifice settings, group F2.
- Time series of boundary condition stages, group J4.
- Two additional examples illustrating variable area storage and pump rating curves.
- Output from Section 3 examples altered slightly to correspond to current program output.
- Altered PARAMETER variables, Table B-4.

CHANGES FOR OCTOBER 1992 PRINTING

There are no changes to the main text of the manual. The only changes are in the Title Page, Disclaimer and Preface (and this page!).

SECTION 1

BLOCK DESCRIPTION

BACKGROUND

EXTRAN is a hydraulic flow routing model for open channel and/or closed conduit systems. The EXTRAN Block receives hydrograph input at specific nodal locations by interface file transfer from an upstream block (e.g., the Runoff Block) and/or by direct user input. The model performs dynamic routing of stormwater flows throughout the major storm drainage system to the points of outfall to the receiving water system. The program will simulate branched or looped networks, backwater due to tidal or nontidal conditions, free-surface flow, pressure flow or surcharge, flow reversals, flow transfer by weirs, orifices and pumping facilities, and storage at on- or off-line facilities. Types of channels that can be simulated include circular, rectangular, horseshoe, egg, and baskethandle pipes, trapezoidal, parabolic and natural channels. Simulation output takes the form of water surface elevations and discharge at selected system locations.

EXTRAN was developed for the City of San Francisco in 1973 (Shubinski and Roesner, 1973; Kibler et al., 1975). At that time it was called the San Francisco Model and (more properly) the WRE Transport Model. In 1974, EPA acquired this model and incorporated it into the SWMM package, calling it the Extended Transport Model - EXTRAN - to distinguish it from the Transport Block developed by the University of Florida as part of the original SWMM package. Since that time, the model has been refined, particularly in the way the flow routing is performed under surcharge conditions. Also, much experience has been gained in the use and misuse of the model.

This document is an update of the 1981 User's Manual and Program Documentation (Roesner et al., 1981) with refinements by Camp Dresser & McKee, Inc. and the University of Florida. The documentation section (Chapter 5) includes discussions of program limitations, and the input data descriptions have been revised to provide more guidance in the preparation of data for the model. The program has been converted to optional metric units (used both for input/output and internal calculations when employed), and input and output have been enhanced to reflect a likely microcomputer environment. EXTRAN input lines (or data groups) now have identifiers in columns 1 and 2, and all input is free format.

The remainder of this chapter discusses program operating requirements

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Water Resources Engineers was wholly integrated into Camp Dresser & McKee, Inc. in 1980.

and characteristics of EXTRAN and how it interfaces with other SWMM blocks. Chapter 2 contains instructions for data preparation. Narrative discussions of the input data requirements contain tips for developing a well defined system. Chapter 3 consists of several example problems that demonstrate how to set up EXTRAN for each of the storage/diversion options in the model. Chapter 4 discusses typical problems that can occur with the use of the model and what action should be taken to correct them. A discussion of error messages contained in the program is also presented. Chapter 5 describes the conceptual, mathematical, and functional representation of EXTRAN; the program structure is discussed in Chapter 6.

CHANGES FROM SWMM VERSION 3

Several enhancements to EXTRAN have been accomplished since SWMM 3.0 was released in 1981 (Roesner et al., 1981). These include:

1. Input and simulation of channels with irregular cross-sections, using either selected HEC-2 data lines or user-generated input lines (in HEC-2 format).

2. Power function cross sections for conduits (e.g., parabolic and elliptic channels).

3. Variable-sized storage junctions, input as stage-area data.

4. Pump operating curves.

5. Use of different boundary conditions at each system outfall.

6. Interpolated stage time series boundary condition at an outfall.

7. Variable orifice discharge coefficient and orifice area over time.

8. Flap gates are possible in interior conduits.

9. "Hot start" input and output using saved files. This permits a restart of EXTRAN from the "middle" of a previous run.

10. Optional metric units.

11. Calculation errors in rectangular conduits have been fixed.

12. Alphanumeric conduit and junction names (instead of pure numbers) are optional in EXTRAN.

13. Output summaries and input error checking have been substantially improved over version 3.0.

14. Inclusion of data group identifiers on data input lines and free-format input. Minor editing of prior EXTRAN input files will be necessary to run previous SWMM 3 data.

15. Surcharged weirs are included in the surcharge algorithm.

16. Two additional flow solutions are now included in the model (see Appendix C).

PROGRAM OPERATING REQUIREMENTS

EXTRAN was originally programmed for the Univac 1108 in FORTRAN IV. This version of the FORTRAN compiler is essentially compatible with the IBM FORTRAN LEVEL G compiler and the extended compiler used on CDC 6600 series equipment. The model was subsequently installed on IBM, CDC, VAX, DEC 20, and several other computers. The latest refinements to the model have been performed on a Zenith Z-248 AT-compatible microcomputer in Fortran-77 using Ryan-McFarland Professional Fortran. The program will run on both main-frames and microcomputers (IBM-PC compatible).

EXTRAN is presently sized to simulate drainage systems of up to 175 channels, 175 junctions, 20 storage elements, 60 orifices, 60 weirs, 20 pumps, and 25 outfalls. These limits may be easily altered (within the limits of computer core capacity) through the use of the Fortran PARAMETER statement described in Appendix B. The core storage and peripheral equipment to operate this program are:

Main-frame:
- High speed core: 1 Mb Virtual Storage
- Peripheral storage: 3 disk files
- One monitor
- One line printer

Microcomputer:
- IBM-PC compatible
- 512 K bytes
- 8087 or 80287 math coprocessor
  (coprocessor emulator supplied with EPA SWMM release)
- Hard disk recommended (necessary for EPA SWMM release)

Execution times for EXTRAN are roughly proportional to the number of system conduits and the number of time-steps in the simulation period. A summary of CDM's prior experience in running the EXTRAN on both CDC 6600 and Univac 1108 systems is presented graphically in Figure 1-1. Using the Univac 1108 operating data in Figure 1-1 as an example, it is estimated that the total computation time for a network of 100 pipes, using a 10-second time-step over a 1-hour simulation period, would be approximately 300 system-seconds. Run time for the example problems in Chapter 3 (9 pipes, 8 hour simulation, 20 second time-step) was about 44 seconds on the DEC 20 computer and about 6 minutes on the Z-248 microcomputer. Note that the curves presented in Figure 1-1 become highly nonlinear for $t \leq 10$ seconds because of the increased frequency of internal file transfers and output processing.

INTERFACING WITH OTHER SWMM BLOCKS

The EXTRAN Program is interfaced with the other SWMM Blocks through the

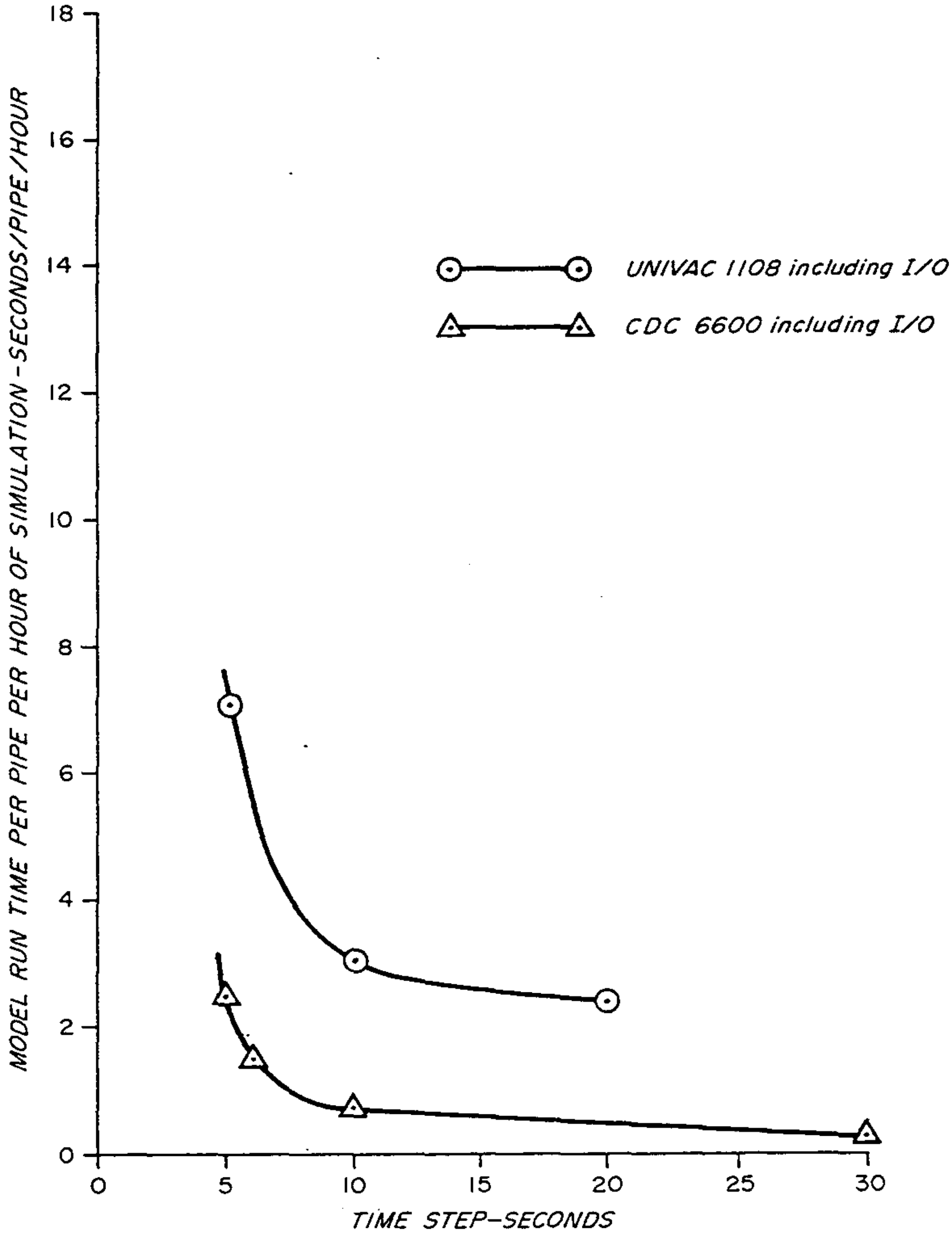

Figure 1-1. Summary of EXTRAN Run Times.

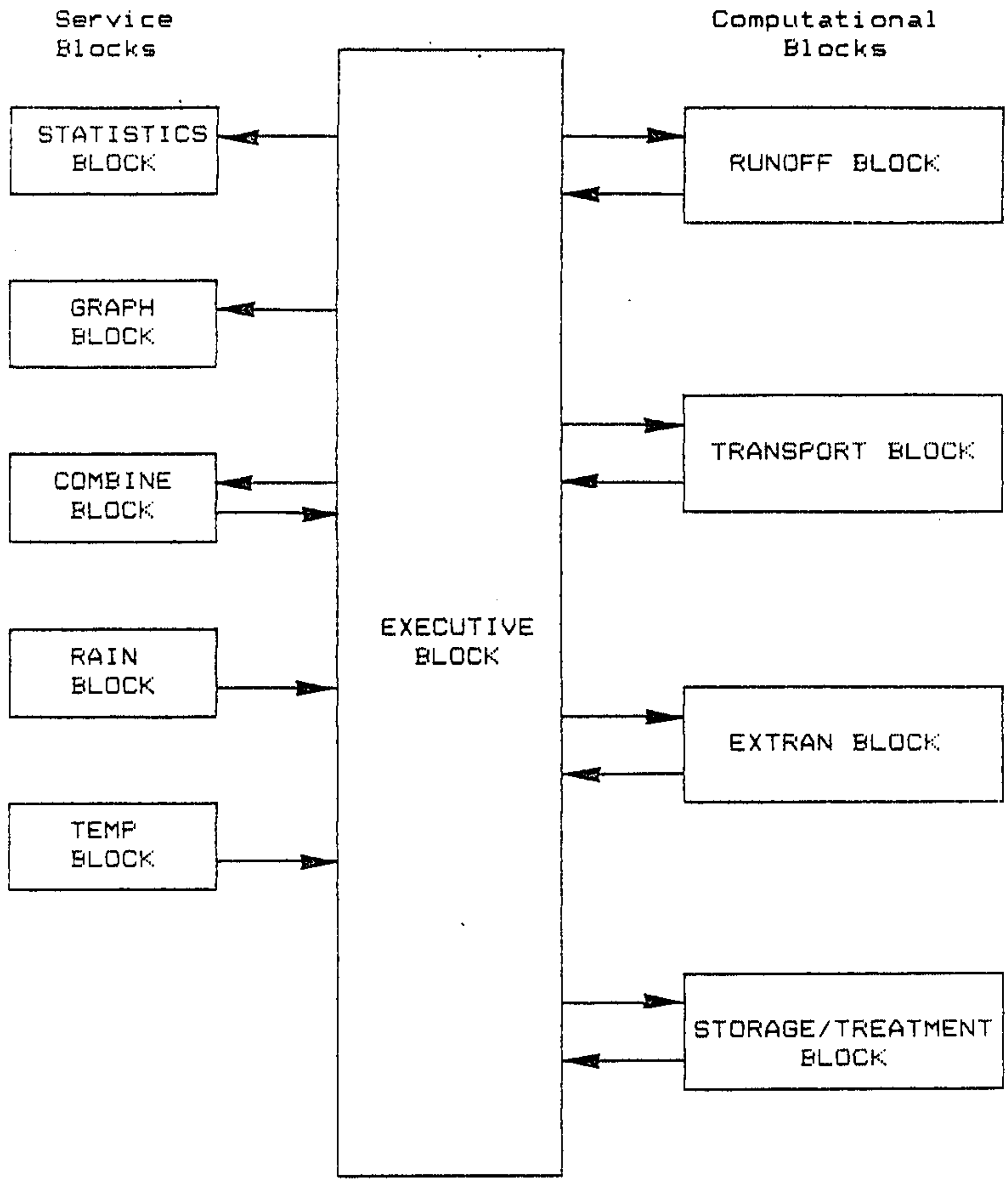

Figure 1-2. Relationship Among SWMM Blocks. Executive Block Manipulates Interface File and Other Off-line Files. All Blocks May Receive Off-line Input (e.g., Tapes, Disks) and User Line Input (e.g., Terminal, Cards, etc.).

Executive Block. Figure 1-2 shows a schematic of the relationship to SWMM system control and input data lines. The EXTRAN Block receives hydrograph input at specific nodal locations either by interface file (e.g., disk, tape) transfer from a preceding block, usually Runoff, or by line input, described in Section 2. ("Line" input replaces the use of "card" input in previous documentation in recognition of the fact that almost all user input will be through the use of file generation using an editor at a terminal.) Users may generate their own interface file using other programs; see Appendix B. An output interface file, which contains hydrographs at all system outfall points, can be generated if desired. This output file can then be used as input to any subsequent SWMM Block or plotted using the Graph Block.

The EXTRAN program itself is called as a subroutine by the Executive Block. The EXTRAN Block, in turn, reads the input data it requires to perform its flow routing function. Further information on file generation and block interaction is contained in Section 2 of the main SWMM user's manual (Huber and Dickinson, 1988). Any alternative hydrologic program may be used to produce input data for EXTRAN by creating an interface file with the required structure.

Although SWMM is designed to run successive blocks consecutively without user intervention, it is <u>strongly</u> recommended that this option not be used with EXTRAN. Simulation results should be examined before they are used as input to EXTRAN; EXTRAN results should be reviewed, in turn, for reasonableness before they are input to subsequent blocks. To bypass the inter-block review process is to invite undetected errors in the analysis results and/or to require expensive reruns of blocks that used erroneous output data from a preceding block.

STARTING UP EXTRAN

If EXTRAN is the only block called from the Executive Block, input data for the Executive Block would be structured as follows:

Data Group SW - Interface Files

SW = enter SW on columns 1 and 2.

NBLOCK = number of SWMM blocks in a run, e.g. 1 or 2 typically for an EXTRAN simulation.

JIN = input interface file number from, typically, the Runoff Block if Runoff hydrographs are to be used in simulation.

= 0 if input hydrographs are from data groups only (see Data Groups K1-K3 in EXTRAN Block input data description).

JOUT = output interface file number that will be used to input outfall hydrographs from EXTRAN into a subsequent block, such as Graph.

= 0 if the outfall hydrographs are not required by a subsequent block.

Note that there is no EXTRAN Quality Block. If pollutographs are to be routed through the drainage system, it is suggested that Runoff or Transport be used for this purpose.

Data Group MM - Scratch file assignment

MM = enter MM in columns 1 and 2.

NITCH = number of scratch files. Extran may use up to two scratch files.

NSCRAT(1)= scratch file used by Subroutine Output. REQUIRED.

NSCRAT(2)= restart file for "hot start." OPTIONAL.

Block Control - Block control line.

Enter $EXTRAN in columns 1 - 7 to start the Extran Block.

Alphanumeric input option: To input conduit and junction names as alphanumeric variables (i.e., able to include letters and symbols as well as numbers), enter $ANUM in columns 1 - 5 before the $EXTRAN line. This means that all references to junction or conduit "number/names" will now refer to alphanumeric variables <u>and must be enclosed in single quotes</u>. E.g., a junction could be numbered 5405 and entered as an integer (the default condition) or could be named N5405 and entered as 'N5405' (if $ANUM has been entered). Of course, alphanumeric names can consist only of numbers if desired. The only disadvantage of using alphanumeric names exclusively is the need to enter all such values within quotes. If pure integer numbers are used (the default option if $ANUM is omitted), then values are read as integers and the quotes are not required. The alphanumeric option is available for the Runoff, Transport, EXTRAN, Combine and Graph blocks. Note that when interfacing between two blocks, <u>both</u> blocks must use the same option. That is, if Runoff is used to generate an input file to EXTRAN, both blocks must either use the pure number option or else both must use the alphanumeric option. Finally, if more than one block (or EXTRAN run) is performed within one input data file, the $ANUM entry means that alphanumeric input will be used in <u>all</u> succeeding blocks called; the program must be restarted to return to the default numeric option.

As described at the beginning of Table 2-1, all input is free format. At least one space should separate each data entry on a line. Comment lines may be entered by entering an asterisk (*) in column 1. Subroutine STRIP removes these lines from the input file before processing by EXTRAN. Comment lines are very useful for documentation of input files. Full details of Executive Block input are contained in Section 2 of the companion main SWMM User's Manual (Huber and Dickinson, 1988).

SECTION 2

INSTRUCTIONS FOR DATA PREPARATION

INTRODUCTION AND SCHEMATIZATION

When a drainage system is to be analyzed with EXTRAN, the first step in the study is generally to define the sewer system and the watershed ("sewer-shed") that it drains. This information is usually available from the agency responsible for operation and maintenance of the system. Care should be taken in this step to insure that "as built" drawings of the system are used. Where information is suspect, a field investigation is in order.

Once the sewer system and watershed have been defined, the watershed is subdivided into subareas in accordance with the guidelines presented in the SWMM Runoff Block documentation. Figure 2-1 shows the South Boston combined sewer system and its watershed subdivided into subbasins. Figure 2-2 is a schematic representation of the South Boston combined sewer system. Note that "TRANSPORT" refers to EXTRAN in this case. The figure shows all pipes and channels to be simulated in the study, the location and type of all diversion structures and all system outlets and overflow points. It may be of interest to note here that the 6000-series channels at the Columbus Park Headworks represent the four-channel grit chambers in the headworks that determine the stage-discharge relationship at junction 60101 in the system.

Note that conduits are distinguished on Figure 2-2 between those that will be simulated in Runoff and those to be simulated in EXTRAN. As a general rule, the upstream portions of the drainage system should be represented in Runoff as much as possible because the data preparation is simpler and the flow routing takes less computer time. The dividing point for the two systems is the point where backwater effects, surcharge, and/or diversion facilities affect the flow and head computation. Pipes and channels downstream of this point should be included in EXTRAN.

Junction points should be identified as each:

- -- Upstream terminal point(s) in the system,
- -- Outfall and discharge point(s),
- -- Ocean boundaries
- -- Pump station, storage point, orifice and weir diversion,
- -- Junction where inflow hydrographs will be input (either by line input or from Runoff),
- -- Pipe junction,
- -- Point where pipe size/shape changes significantly,
- -- Point where pipe slope changes significantly, and

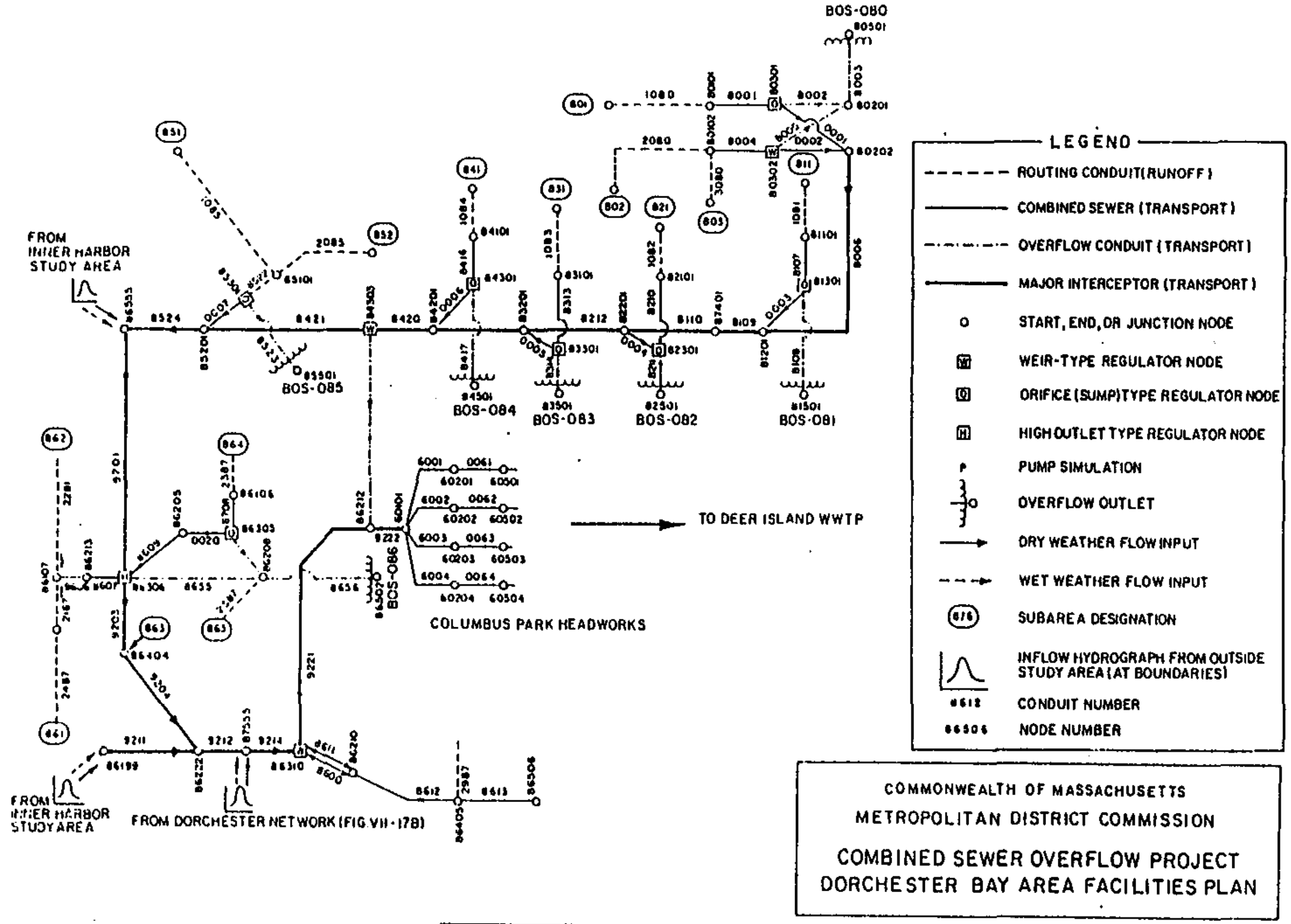

Figure 2-2. Schematic Representation of the South Boston Sewerage System for Use in the EXTRAN Model.

-- Point where pipe inverts are significantly different.

Following the preliminary identification of junction points, a check should be made to eliminate extremely long or short distances between junctions. As a rule of thumb, the longest conduit should not exceed four or five times the length of the shortest conduit. If this occurs, short conduits can be increased in length by use of equivalent pipes and long conduits can be shortened by adding intermediate junction points.

Keep in mind when setting conduits length (placing junctions) that the time-step is generally controlled by the wave celerity in the system. To estimate the time-step, first compute for wide open channels or circular pipes:

$$\Delta t_c = L/(gD)^{1/2} \tag{2-1}$$

Or, compute for a general open channel or conduit cross section:

$$\Delta t_c = L/(gA/T)^{1/2} \tag{2-2}$$

where Δt_c = time for a surface wave to travel from one end of a conduit to the other, seconds,
L = conduit length, ft [m],
g = gravitational acceleration = 32.2 ft/sec^2 or 9.8 m/sec^2,
D = diameter or depth, ft [m],
A = maximum cross sectional area, ft^2 [m^2],
T = full flow top width, ft [m].

Use of the circular pipe diameter in equation 2-1 to compute the critical flow velocity in the denominator corresponds to a ratio of depth to diameter of about 85% (Chow, 1959). The time-step can usually exceed Δt_c by a factor of 1.5 to 2.0 for a few widely separated conduits. For most problems, conduit lengths can be of such length that a 15 to 30 second time-step can be used. Occasionally, a 5 to 10 second time-step is required. A time-step of 60 to 90 seconds should not be exceeded even in large open channel systems where the celerity criterion is not violated with a larger time-step.

If an extremely short pipe is included in the system, as indicated by a small Δt_c, an equivalent longer pipe can be developed using the following steps. First, set the Manning equation for the pipe and its proposed equivalent equal to each other:

$$(m/n_p)A_pR_p^{2/3}S_p^{1/2} = (m/n_e)A_eR_e^{2/3}S_e^{1/2} \tag{2-3}$$

where m = 1.486 for U.S. customary units (ft and sec) and 1.0 for metric units (m and sec),
p = (subscript) actual pipe,
e = (subscript) equivalent pipe,
n = Manning's roughness coefficient,
A = cross-sectional area,
R = hydraulic radius, and
S = slope of the hydraulic grade line.

Assuming that the equivalent pipe will have the same cross-sectional area and hydraulic radius as the pipe it replaces results in:

$$S_p^{1/2}/n_p = S_e^{1/2}/n_e \qquad (2\text{-}4)$$

Now, since

$$S = h_L/L \qquad (2\text{-}5)$$

where h_L = the total head loss over the conduit length, and
L = conduit length,

and since the head losses are to be equal in both pipes, equation 2-3 can be simplified to:

$$n_e = n_p L_p^{1/2}/L_e^{1/2} \qquad (2\text{-}6)$$

where L_e is the desired equivalent pipe length, either no smaller than four to five times smaller than the longest pipe in the system, or large enough to give a Δt_c within the range indicated above. The user, through experience, will be able to determine the pipe length changes required to achieve stability and an acceptable time-step for the simulation.

By coding NEQUAL = 1 on data group B1 the program will automatically adjust the pipe or channel lengths using an equivalent longer length to achieve a Δt_c in balance with the user-selected time-step (Δt). All pipes in which $\Delta t/\Delta t_c$ exceeds 1.0 will be adjusted, with the new pipe/channel lengths and roughness printed. When NEQUAL is greater than 1 an equivalent pipe or channel length will be created based on NEQUAL in seconds. For example, selecting NEQUAL = 15 will create an equivalent pipe based on a time step of 15 seconds. A before and after analysis of the full flow system volume is printed by the program for NEQUAL values greater than 1. This enables the user to estimate the effect of the increase in system volume from using equivalent pipes or channels.

At this point, the system schematic should be satisfactory for developing model input data. The remaining sections of this chapter describe, step-by-step, how to develop the input data file for EXTRAN.

INPUT DATA GROUPS

Specifications for input data preparation are contained in Table 2-1. The table defines the input sequence and variable description and name. (Input is free format; specific column locations are not required.) Perusal of Table 2-1 reveals that the input data are divided into 27 data groups. Data groups A1 and B0-B8 are control lines that identify the simulation, set the time-step and start time, and identify junctions for line input hydrograph, and junction and conduits for printing and plotting of heads and flows. The identification of conduits and junctions is done in data groups C1-C4 and D1, respectively. Groups E1-H1 identify storage and diversion junctions, while groups I1-J4 identify system outfalls and boundary conditions at the outfalls.

Groups K1-K3 define line input hydrographs. Further descriptions of the data to be entered in each data group are given below.

RUN IDENTIFICATION AND CONTROL

Data Group A1: Run Identification

Data group A1 consists of 2 lines, each having 80 columns or less, which typically describe the system and the particular storm being simulated. Remember to enclose all character data in single quotes for free-format input.

Data Groups B0, B1 and B2: Run Control

Routing options (group B0) are explained in Appendix C. Data group B1 is a single line defining the number of time-steps (integration steps) in the simulation period (NTCYC), the length of each time-step (DELT), the starting time of day of the simulation (TZERO), the time-step at which to begin printing of intermediate output (NSTART), intermediate output print interval (INTER), summary output print interval (JNTER), and information on saving or using a saved run to start the present one -- the "hot start" capability (REDO). Data group B2 is a second line defining the choice of U.S. customary or metric units (METRIC), whether or not to modify short pipe lengths (NEQUAL), the area of manholes (AMEN), and number of iterations (ITMAX) and allowable error (SURTOL) during surcharge conditions and iterative calculations.

The time-step, DELT, is most critical to the cost and stability of the EXTRAN model run and must be selected carefully. The time-step should be selected according to the guideline described in the Introduction to this chapter (see equations 2-1 and 2-2). The computer program will check each conduit for violation of the surface wave criterion and will print the message:

——> WARNING !! (C*DELT/LEN) IN CONDUIT IS rrr AT FULL DEPTH

where rrr is the ratio

$$rrr = \Delta t \sqrt{gD}/L \qquad (2\text{-}7)$$

for enclosed conduits, and

$$rrr = \Delta t \sqrt{gA/T}\,/L \qquad (2\text{-}8)$$

for open channels,

where t = the time-step,
g = gravity,
D = conduit height or pipe diameter,
A = maximum cross sectional area,
T = full flow top width, and
L = conduit length.

As already noted, if rrr is greater than 1.5 or 2.0 for any conduit, or if several conduits have rrr over 1.5, the time-step should be reduced. <u>rrr should never exceed 1.0 in a terminal conduit</u> (i.e., an upstream terminal conduit or a downstream outfall). These restrictions are less stringent for ISOL = 1 and ISOL = 2 solutions (see Appendix C).

The total simulation period is defined as the product of NTCYC and DELT. This period may extend in time beyond the simulation period of any preceding block. However, flow input into the junctions no longer occurs beyond the end of the input interface file. Outfalls with tidal boundary conditions are affected by the rise and fall of the tide during the entire simulation. Outfalls with a stage history boundary condition use the first input stage value until the simulation "catches" up with the input time history (group J4). The last stage value is used if the simulation continues beyond the last input time.

The printing interval, INTER, controls the interval at which heads, velocities, and flows are printed during the simulation (intermediate printout), beginning at time step NSTART. (Surcharge information is also printed during the simulation at these intervals.) Interval JNTER serves the same purpose for the summary printout at the end of the run. Intermediate printout is for all junctions and conduits, whereas the summary printouts are only for those specified in data groups B4 and B5. The intermediate printout is very useful in case an error occurs before the program reaches its desired simulation length, but tends to produce bulky output. If intermediate printout is to be avoided entirely, set INTER to a number greater than NTCYC, but be warned that debugging may be more difficult. Subroutine OUTPUT prints nodal water depth, elevation, conduit flow, and velocity. The output looks better if NSTART and JNTER are selected so that the first and subsequent output occurs at an even minutes or half-minutes. EXTRAN uses an off-line file, indicated by unit number NSCRAT(1), to store data for the summary printouts.

A "hot start" or restart capability is available for EXTRAN, governed by parameter REDO on data group B1. Basically, a file may be read and/or created to establish initial conditions for a run. This may avoid re-running of, say, dry-weather flow conditions prior to the start of a storm runoff simulation. Another use would be with a run that fails late in the program. The initial portion of the run could be saved and used as initial conditions for the latter portion during the debugging phase. If REDO is 0 then a "hot start" file is neither read or created. Coding REDO as 1 will cause EXTRAN to read NSCRAT(2) for the initial conduit flows and velocities and junction depths, but a new restart file is not created. Coding REDO as 2 causes EXTRAN to create a new "hot start" file, but the initial conditions are defined on data groups C1 and D1. REDO = 3 reads the previously created "hot start" file for the simulation initial conditions, then erases the file to create a new restart file.

The input/output and computation units are governed by parameter METRIC on data group B2; U.S. customary units, typically ft, cfs and ft/sec are METRIC = 0, and metric units, m, m^3/sec and m/sec, are METRIC = 1. Internal calculations are also conducted in the chosen units.

The user can modify the pipe length and roughness as in equation 2-3, or if NEQUAL is set equal to 1, the program will automatically create an equivalent longer pipe for pipes exceeding an rrr of 1.0. Equivalent pipes based on time steps different from DELT can be created by coding NEQUAL greater than 1.

AMEN is the default surface area for all junctions that may be surcharged. The junction surface area is used in the junction continuity equation and is especially important during surcharge. If 0.0 is entered for AMEN a 4 ft [1.22 m] diameter manhole is assumed.

The variables ITMAX and SURTOL control the accuracy of the solution in surcharged areas; details of the computations are described in Section 5. In reality, the inflow to a surcharged area should equal the outflow from it. Therefore, the flows and heads in surcharged areas are recalculated until either the difference in inflows and outflows is less than a tolerance, defined as SURTOL (a fraction error) times the average flow in the surcharged area, or else the number of iterations exceeds ITMAX. It has been found that good starting values for ITMAX and SURTOL are 30 and 0.05, respectively. The user should be careful to check the intermediate printout to determine whether or not the surcharge iterations are converging. Also, if there is more than one surcharged section of the drainage system, special rules apply. More details on checking convergence of the surcharge iterations are found in Sections 4 and 5. Appendix C explains ITMAX and SURTOL during iterative routing.

<u>Data Group B3: Number of Junctions for Printing, Plotting and Input</u>

The numbers of junction numbers to be entered in subsequent data groups for printing, plotting and user-input hydrographs (line-input hydrographs in data groups K1-K3) are listed on this group. Regarding the latter, the NJSW points are additions to input generated by an upstream block, or EXTRAN may be run with only this user-supplied input.

<u>Data Groups B4 and B5: Detailed Printing for Junctions and Conduits</u>

Data group B4 contains the list of individual junctions (up to 30) for which water depth and water surface elevations are to be printed in summary tables at the end of the simulation period. Data group B5 contains the list of individual conduits (up to 30) for which flows and velocities are to be printed.

<u>Data Groups B6, B7 and B8: Detailed Plotting for Junctions and Conduits</u>

Data groups B6 and B7 contain, respectively, the lists of junctions and conduits for which time histories of water surface elevations and flows are to be plotted (up to 30 for each). Data group B8 plots selected upstream and downstream conduit depths on the same plot.

CONDUIT AND JUNCTION DATA

Data Groups C1-C4: Conduit Data

Regular Conduits --

Data groups C1-C4 contain data input specification for conduits including shape, size, length, hydraulic roughness, connecting junctions, initial flows and invert distances referenced from the junction invert. Conduit shapes are standard, except for parabolic, power function and irregular channels. The latter is discussed subsequently. A parabolic or power function shape is an open channel, defined by

$$WIDE = 2 \cdot a \cdot DEEP^{1/n} \tag{2-9}$$

where WIDE = top width,
DEEP = depth when full,
n = coefficient (any positive value), and
a = coefficient.

The shape is defined by DEEP and WIDE entered on group C1; parameter a is not required. The factor of 2 in equation 2-9 accounts for the fact that the half-width would actually be used in the calculation. A parabolic channel has a exponent (n) of 2.

Most other input data parameters on data group C1 are self-explanatory, with the exception of junction/conduit invert elevations. Basic definitions of conduit invert distances ZP(N,1) and ZP(N,2) are illustrated in Figure 2-3. The junction invert elevation is specified in data group D1. The distance ZP is the height of the invert of connecting conduits above the junction floor. Note, however, that the lowest pipe connected to the junction (pipe N in Figure 2-3) should have a ZP of zero. If it does not, the junction may behave irratically, e.g., as a sink for water flowing into the junction. In general, no conduit should have an invert above the crowns of all other pipes. A warning message is printed when a junction invert is below the invert of all connecting conduits and also when there is a drop between connecting conduits in a junction. These situations are not fatal, but depending on the critical/subcritical decisions made by Subroutine HEAD in the assignment of junction areas, they may cause instabilities and continuity errors.

Initialization of Flows --

Frequently, it is desired to initialize the drainage network with starting flow values which represent either the dry weather or antecedent flow conditions just prior to the storm to be simulated. QO(N) on data group C1 supplies these initial conditions throughout the drainage system at the beginning of the simulation. These in turn will be used to estimate initial depths -- if initial heads are not entered in data group D1. This is accomplished by computing normal depth in each conduit. An initial flow for conduits with initial upstream and downstream junction depths is not estimated in the model. Alternatively, initial depths may also be entered (in data group D1), and the

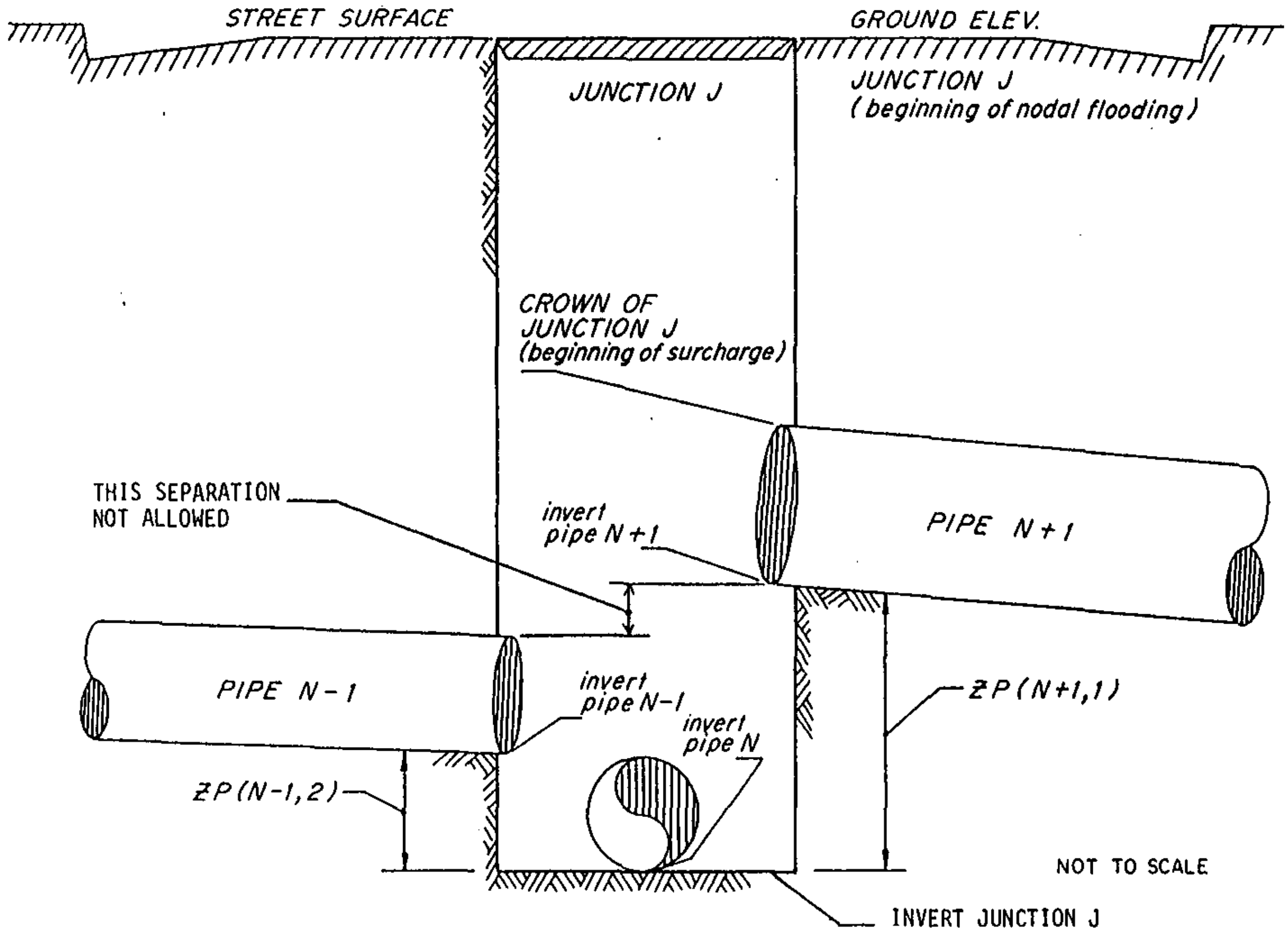

Figure 2-3. Definition of Elevation Terms for Three-pipe Junction.

model will begin the simulation based on these values, but unless they are taken from a prior run, depths and flows input in this manner may not be consistent, leading to irregular output during the first few time-steps. Finally, constant inflows may be input using data group D1 to a dry system and "initial conditions" established by letting the model run for enough time steps to establish steady-state flows and heads. The "hot start" capability may then be used to provide these initial conditions to other runs, or more laboriously, heads and flows from the EXTRAN output may be entered in data groups D1 and C1.

Irregular Cross-Section Data --

Data groups C2, C3 and C4 define irregular (e.g., natural channel) cross-sections. Irregular cross-section channels may be mixed with regular cross-section channels, but the data for the irregular channels are grouped together in the C2-C4 lines after <u>all</u> of the C1 lines are entered. The natural channel data should be entered in the order in which they appear in the C1 data group. Irregular cross-section data are entered in the same format as used in the HEC-2 computer program. In fact, the relevant data may be extracted from an existing HEC-2 input data file for use in groups C2 - C4. Some of the required parameters are illustrated in Figure 2-4 which also shows that a trapezoidal approximation may not be very good for many natural channels.

Elevations entered on data group C4 are used <u>only</u> to determine the shape of the cross section. Invert elevations for EXTRAN are defined in the Junction Data (group D1) and the ZP parameter of group C1. The total cross-section depth is computed as the difference between the highest and lowest points on the cross section. A non-zero value of the variable DEEP (group C1) may be entered to reduce the total cross-section depth if the maximum depth of flow for a particular simulation is significantly less than the maximum cross-section depth. This option increases the accuracy of the interpolation performed by EXTRAN. Data group C2 is the first entry for irregular cross sections and should be inserted again wherever Manning's n changes.

Conduits Generated by the Program --

In addition to conduits, EXTRAN must compute a flow through all orifices, weirs and outfalls. In order to maintain internal connectivities for all flows, artificial conduits (labeled with numbers in the 90000-range or with alphanumeric names if $ANUM is used) are generated for these elements. Some have real conduit properties since they are used for routing (equivalent pipes for orifices), while the others are inserted only for bookkeeping purposes. The user should refrain from using conduit numbers betweeen 90001 and 90175 to eliminate duplication. Any integer number is permissable but for printing purposes numbers with nine digits or less (or names with nine characters or less) produce better looking output.

<u>Data Group D1: Junction Data</u>

The explanation of ground and invert elevations is also shown in Figure 2-3. One junction data line is required for <u>every</u> junction in the network including regular junctions, storage and diversion (orifice and weir) junc-

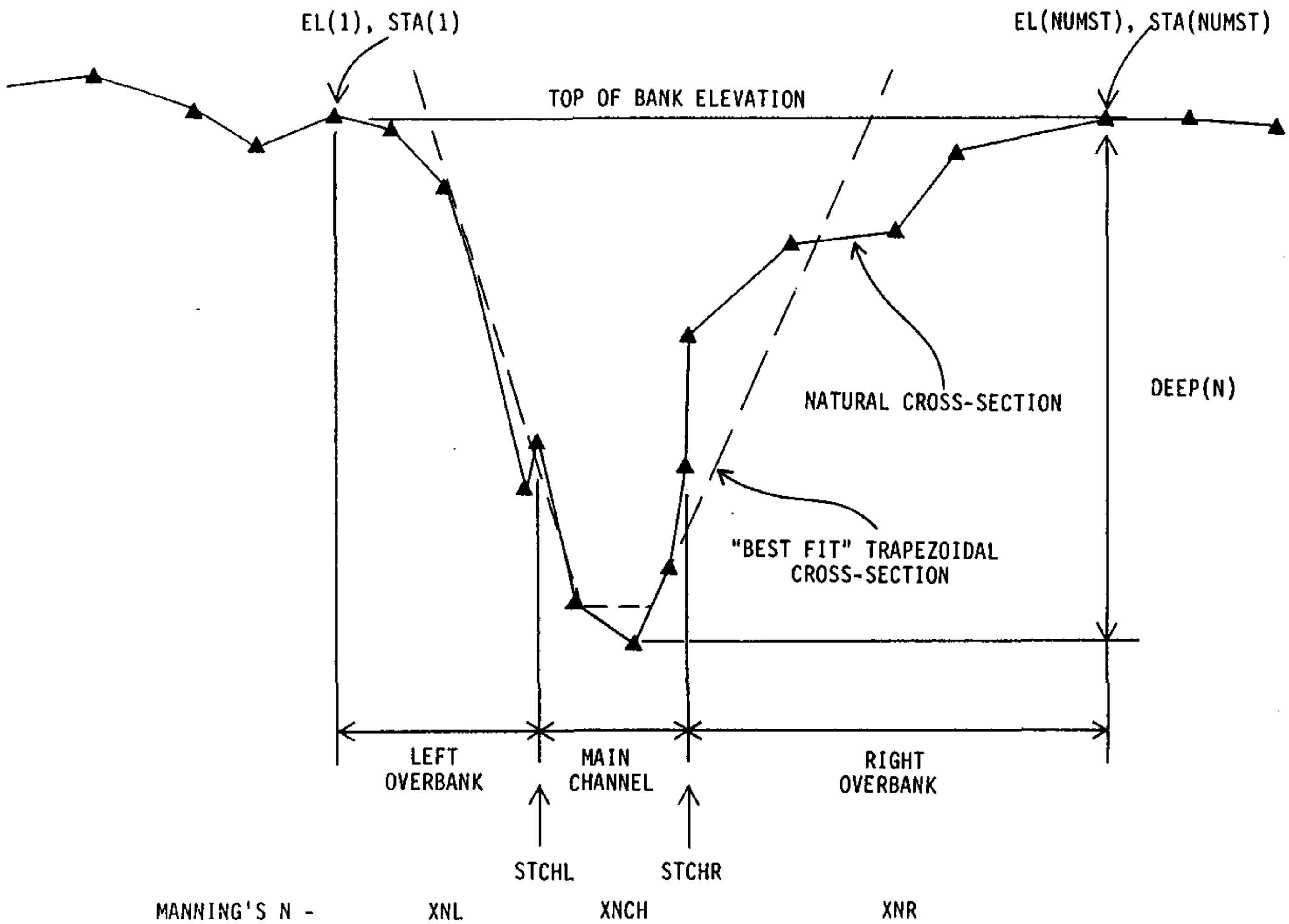

Figure 2-4. Definition Sketch of an Irregular Cross-Section.

tions, pump junctions, and outfall junctions. It is emphasized again that the junction invert elevation is defined as the invert elevation of the lowest pipe connected to the junction. The program will print a warning message:

```
---> WARNING !!! ALL CONDUITS CONNECTING TO JUNCTION ____
                 LIE ABOVE THE JUNCTION INVERT
```

unless there is at least one pipe having a zero ZP at the junction.

The surcharge level or junction crown elevation is defined as the crown elevation of the highest connecting pipe and is computed automatically by EXTRAN. Note that the junction must not surcharge except when the water surface elevation exceeds the crown of the highest pipe connected to the junction. Pipe N+1 in Figure 2-3 is too high. This junction would go into surcharge during the period when the water surface is between the crown of pipe N-1 and the invert of pipe N+1. If a junction is specified as shown in Figure 2-3 and the water surface rises above the crown of pipe N-1, the program will print an error message:

```
---> ERROR  !!! SURFACE AREA AT JUNCTION ______ IS ZERO,
     CHECK FOR HIGH PIPE
```

and will then stop. This situation can be modeled using two methods: (1) A new junction should be specified that connects to pipe N+1. A "dummy conduit" is specified which connects the old junction with pipes N-1 and N to the new junction which connects to pipe N+1. The pipe diameter should be that of N+1 and the length selected to meet the stability criterion given by equations 2-7 and 2-8. The Manning n for the "dummy pipe" is computed to reflect the energy loss that occurs during surcharge as water moves up through the manhole and into pipe N+1. (2) A positive value for the manhole surface area will alleviate this problem and usually allow a drop to be simulated without a "dummy conduit".

The exceptions to this rule are storage junctions. Pipes connected to storage nodes do not have to overlap if they are within the elevation of the facility.

The "ground elevation," GRELEV(J), is the elevation at which the assumption of pressure flow is no longer valid. Normally, this will be the street or ground elevation; however, if the manholes are bolted down, the GRELEV(J) should be set sufficiently high so that the simulated water surface elevation does not exceed it. When the hydraulic head must exceed GRELEV(J) to maintain continuity at the junction, the program allows the excess junction inflow to "overflow onto the ground" and become lost from the system for the remainder of the simulation period (but the "lost" water is included in the final continuity check).

If an open channel (trapezoidal or irregular cross section) is connected to a junction, EXTRAN will compute GRELEV(J). The elevation where surface flooding occurs is set at the elevation where the HGL exceeds the defined cross section. It is important that cross-sections are defined to be large enough to convey the peak flow. The simulation will stop when the conduit depth exceeds the maximum open channel depth more than 100 times. Nodal flooding of open-channel systems should only be allowed if the HGL elevation cannot significantly rise above a certain elevation. Figure 2-5 is a definition sketch of junctions in an open-channel system.

Occasionally it is necessary to perform routing on the water that surcharges onto the ground. In this case, the ground surface (e.g., a street and gutter system) must be simulated as a conduit in order to route the flows and maintain continuity. In addition, manholes must be simulated as vertical pipes in order to transport water to and from the surface channel. Since an infinite slope (vertical) is not permitted, equivalent pipes are used for the manholes. With this arrangement, water may surcharge (move vertically out of a "manhole-pipe") and return to the sewer system at a downstream location through another "manhole-pipe." Inflow constrictions by inlets etc. can be simulated as orificies if their hydraulic characteristics are known. With this extra effort, dual "major" (street surface) and "minor" (subsurface sewer network) drainage systems can be simulated.

QINST(J) is the net constant flow entering (positive) or leaving (negative) the junction. Variable inflows must be entered using groups K1 - K3.

Initial heads at junctions are optional. If they are entered they will be used to begin the simulation, in conjunction with initial flows entered in data group C1. If initial heads are omitted but initial flows are entered, then initial heads will be estimated on the basis of normal depth in adjacent conduits.

Data Groups E1 - E2: Storage Junctions

Constant Surface Area --

Conceptually, storage junctions are "tanks" of constant surface area over their depth. A storage "tank" may be placed at any junction in the system, either in-line or off-line. The elevation of the top of the tank is specified in the storage junction data and must be at least as high as the highest pipe crown at the junction. If this condition is violated, the system will go into simulated surcharge before the highest pipe is flowing full.

If ASTORE(I) is negative, then NUMST depth-area data points describing a variable-area storage junction must be given for this junction immediately following in data group E2.

If NUMST(I) is -2, then a power function variable-area storage junction is simulated using data immediately following in data group E2.

Variable Area Junctions --

Data group E2 is required if ASTORE(I) < 0 or NUMST = -2 on the preceding line. The depth-area data are integrated to determine the depth-volume relationship for the junction. A variable-area storage junction is illustrated in Figure 2-6. In group E2, a power function is given by

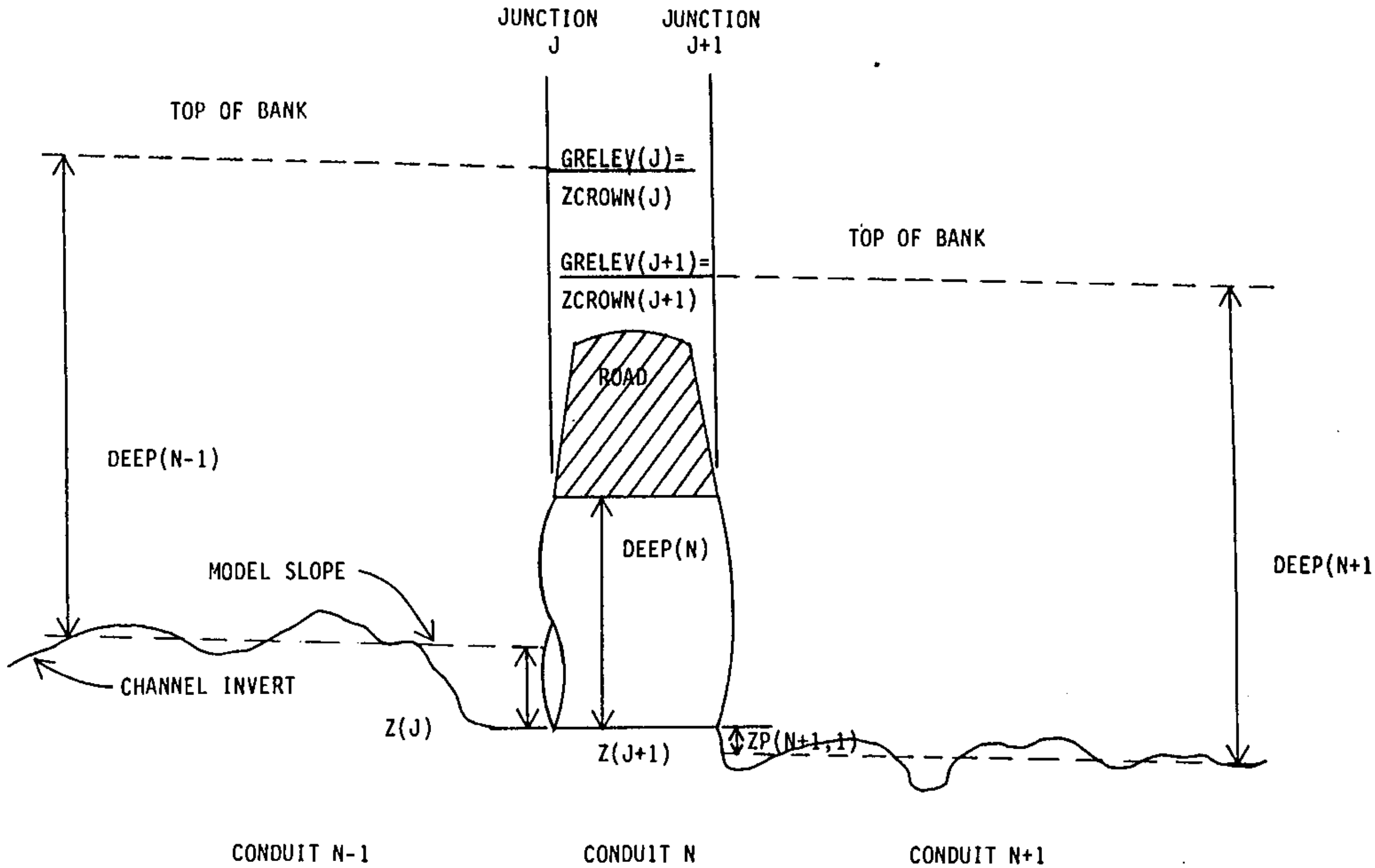

Figure 2-5. Definition of Elevation Terms in an Open Channel System.

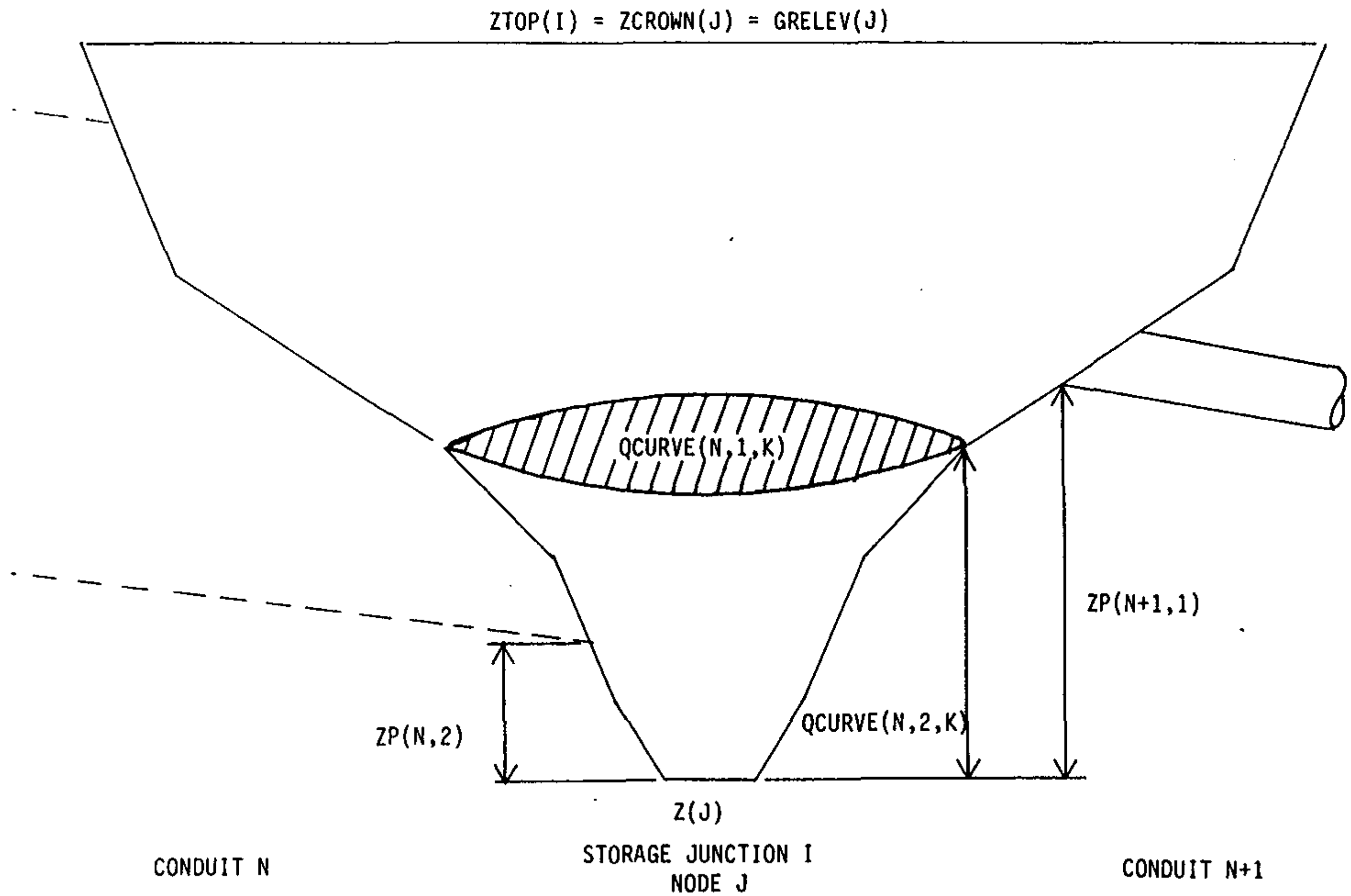

Figure 2-6. Definition Sketch of a Variable Area Storage Junction.

$$AREASURF = QCURVE(N,1,1)\ DEPTH^{QCURVE(N,2,1)} \quad (2\text{-}10)$$

where AREASURF = surface area, ac [ha],
QCURVE(N,1,1) = coefficient (appropriate units),
QCURVE(N,2,1) = exponent, and
DEPTH = depth above junction invert, ft [m].

DIVERSION STRUCTURES

Data Groups F1 and F2: Orifice Data

EXTRAN simulates orifices as equivalent pipes (see Section 5). Data entry is straightforward. For sump orifices, the program automatically sets the invert of the orifice 0.96 times the diameter below the junction invert so that the orifice is flowing full before there is any discharge (overflow) to conduits downstream of the junction containing the orifice. Orifice settings may be varied with time (F2 data group) to simulate external controls. Orifice settings should not be closed "too fast" because this can cause numerical instabilities that mimic hydraulic instabilities that would occur in the prototype.

Data Group G1: Weir Data

The following types of weirs can be simulated in EXTRAN:

-- Internal diversions (from one junction to another via a transverse or side-flow weir).

-- Outfall weirs which discharge to the receiving waters. These weirs may be transverse or side-flow types, and may be equipped with flap gates that prevent back-flow. Outfall weirs must also have an accompanying I1 or I2 data group line with the appropriate boundary condition for the outfall junction.

Transverse weir and side-flow weirs are distinguished in EXTRAN by the value of the exponent to which the head on the weir is taken. For transverse weirs, head is taken to the 3/2 power (i.e., $Q_w \sim H^{3/2}$) while for side-flow weirs the exponent is 5/3 (i.e., $Q_w \sim H^{5/3}$). Weir parameters are illustrated in Figure 2-7.

When the water depth at the weir junction exceeds YTOP (see Figure 2-7) the weir functions as an orifice ($Q_w \sim H^{1/2}$). The discharge coefficient for the orifice flow conditions is computed internally in EXTRAN (see Section 5). An equivalent pipe automatically replaces the weir for the duration of surcharge.

Stability problems can be encountered at weir junctions. If this happens or is suspected of happening, the weir may be represented as an equivalent pipe. To do this, equate the pipe and weir discharge equations, e.g.,

$$(m/n)AR^{2/3}S^{1/2} = C_w WH^{3/2} \quad (2\text{-}11)$$

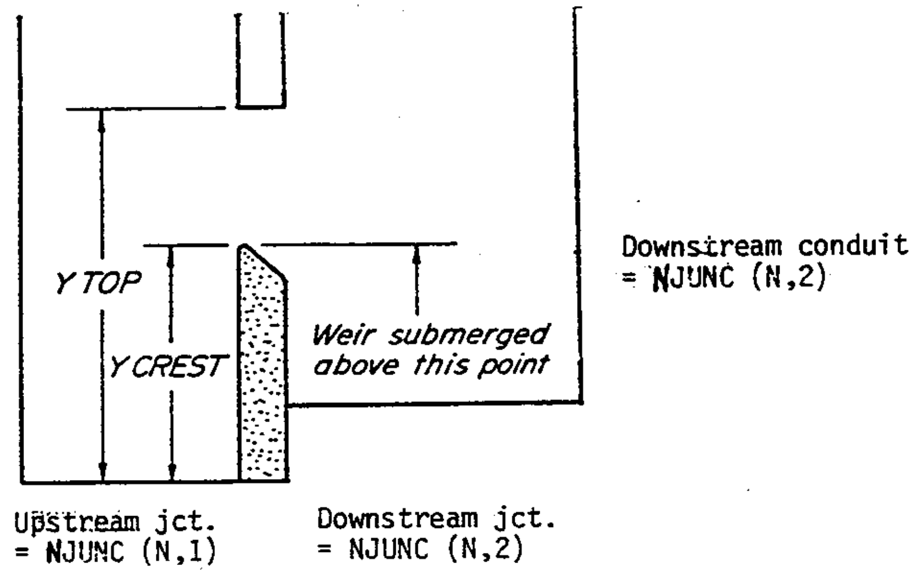

Figure 2-7. Definition Sketch of Weir Input Data.

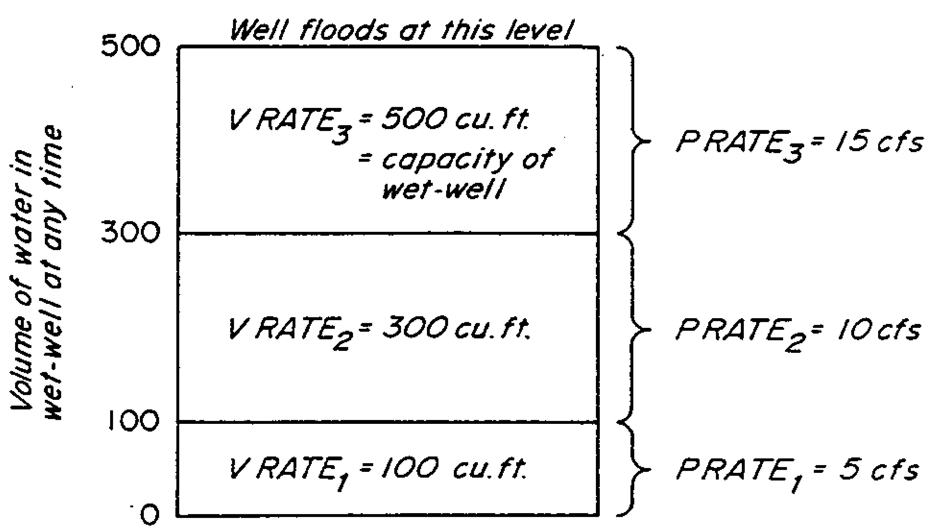

Figure 2-8. Definition Sketch of Pump Input Data.

where m = 1.486 for units of feet and seconds or 1.0 for units of meters and seconds,
n = Manning n for the pipe,
A = cross-sectional area,
R = hydraulic radius,
S = hydraulic grade line for the pipe,
H = head across the weir,
C_w = weir discharge coefficient, and
W = weir length.

In this equation, $S = H/L$ where L is the pipe length, and $A = WH$. If R is set at the value of the hydraulic radius where the head is half way between YCREST and YTOP, and L is set in accordance with equations 2-7 and 2-8, then n can be computed as

$$n = \frac{R^{2/3}}{C_w L^{1/2}} \tag{2-12}$$

for the equivalent pipe.

Data Group H1: Pump Data

Pumps may be of three types:

1. An off-line pump station with a wet well: the rate of pumping depends upon the volume of water in the wet well.

2. An on-line station that pumps according to the level of the water surface at the junction being pumped.

3. Either an on-line or off-line pump that pumps according to the head difference over the pump, i.e., uses a three-point pump curve.

The definition sketch in Figure 2-8 defines the input variable for Type 1 pump. For a Type 2 pump station, the following operating rule is used:

$$\begin{array}{lll} Y \le \text{VRATE(I,1)} & Q_p = & \text{Junction inflow or PRATE(I,1), whichever is less} \\ \text{VRATE(I,1)} < Y \le \text{VRATE(I,2)} & Q_p = & \text{PRATE(I,2)} \\ \text{VRATE(I,2)} < Y & Q_p = & \text{PRATE(I,3)} \end{array} \tag{2-13}$$

Note that for pump stations of type 2 and 3 VRATE is the water depth at the pump junction, while for a Type 1 station it is the volume of water in the wet well. Note also that only one conduit may be connected to a Type 1 pump station junction.

A type 3 pump station in EXTRAN uses a storage junction upstream for a wet well. (Multiple pumps with different characteristics may be connected to the same storage junction to simulate more than one pump in a pumping station.) The dynamic head difference between the upstream and downstream nodes determines the pumping rate according to a three-point head-discharge relationship for the pump. The operating condition (i.e., on/off) for the pump is determined from the wet well elevation from the previous half-step computation, as shown in Figure 2-9. If the model detects that a pump is on (wet well elevation above PON -- data group H1), then its flow is computed from the dynamic head difference based on a linearized pump operating curve shown in Figure 2-10. The pump's operating range is limited to the range between PRATE(1) and PRATE(3) regardless of the detected dynamic head. Pump rates will remain fixed at either PRATE(1) or PRATE(3) until the system returns to the normal operating range of the pump.

Data Group I1: Free Outfall (No Flap Gate) Pipes

Three types of outfalls can be simulated in EXTRAN:

1. A weir outfall with or without a flap (tide) gate (data group G1),

2. A conduit outfall without a flap (tide) gate (data group I1), or

3. A conduit outfall with a flap (tide) gate (data group I2).

Note that outflows through any outfall junction can be saved on an interface file if JOUT $\neq$ 0 in Executive Block data group SW. These flows can then be graphed (using the Graph Block) or input to a subsequent block. For example, flows may be input to a subsequent Extran run in the event of disaggregation of a large drainage system. (The graphing option is an alternative to that provided within Extran itself using data group B7.) An interface file may be converted to an ASCII/text file using the Combine Block of SWMM. Such a file can easily be read by other programs.

Under data group I1, enter the outfall junction number (JFREE) for outfall conduits or outfall weirs without flap gates and the boundary condition number (NBCF) to which it applies. The boundary condition is indicated by the sequence of J-group lines entered below. E.g., if NBCF = 3, junction JFREE is governed by the third group of J1-J4 lines entered.

Data Group I2: Outfall Pipes With Flap Gates

Enter the outfall junction number (JGATE) and boundary condition number (NBCG) for outfall conduits or outfall weirs with flap gates.

BOUNDARY CONDITIONS AND HYDROGRAPH INPUTS

Data Groups J1-J4: Boundary Condition Data

Up to five sets of data groups J1 - J4 are used to describe the boundary conditions which may be applied to any outfall (identified in data groups I1 and I2) in the drainage system. The sequence of the J-data groups determines the value of NBCF or NBCG on data groups I1 and I2. Parameter NTIDE specifies the type of boundary condition: 1) no water surface at the outfall (pipe or weir discharges above any tail water); 2) a water surface at constant eleva-

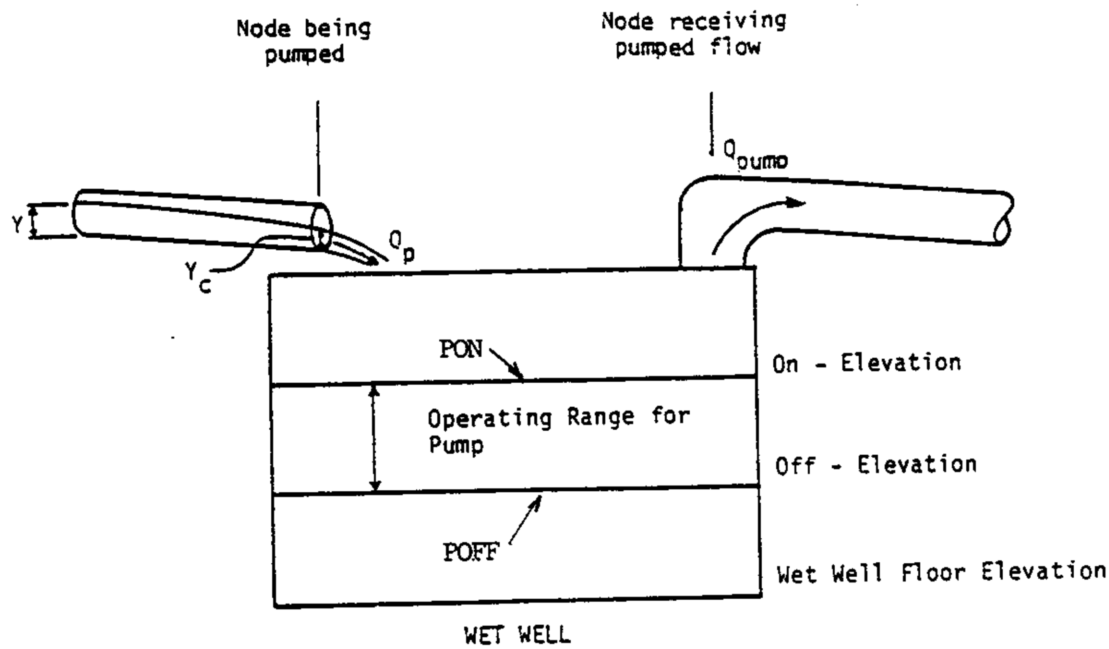

Figure 2-9. Schematic Presentation of Pump Diversion.

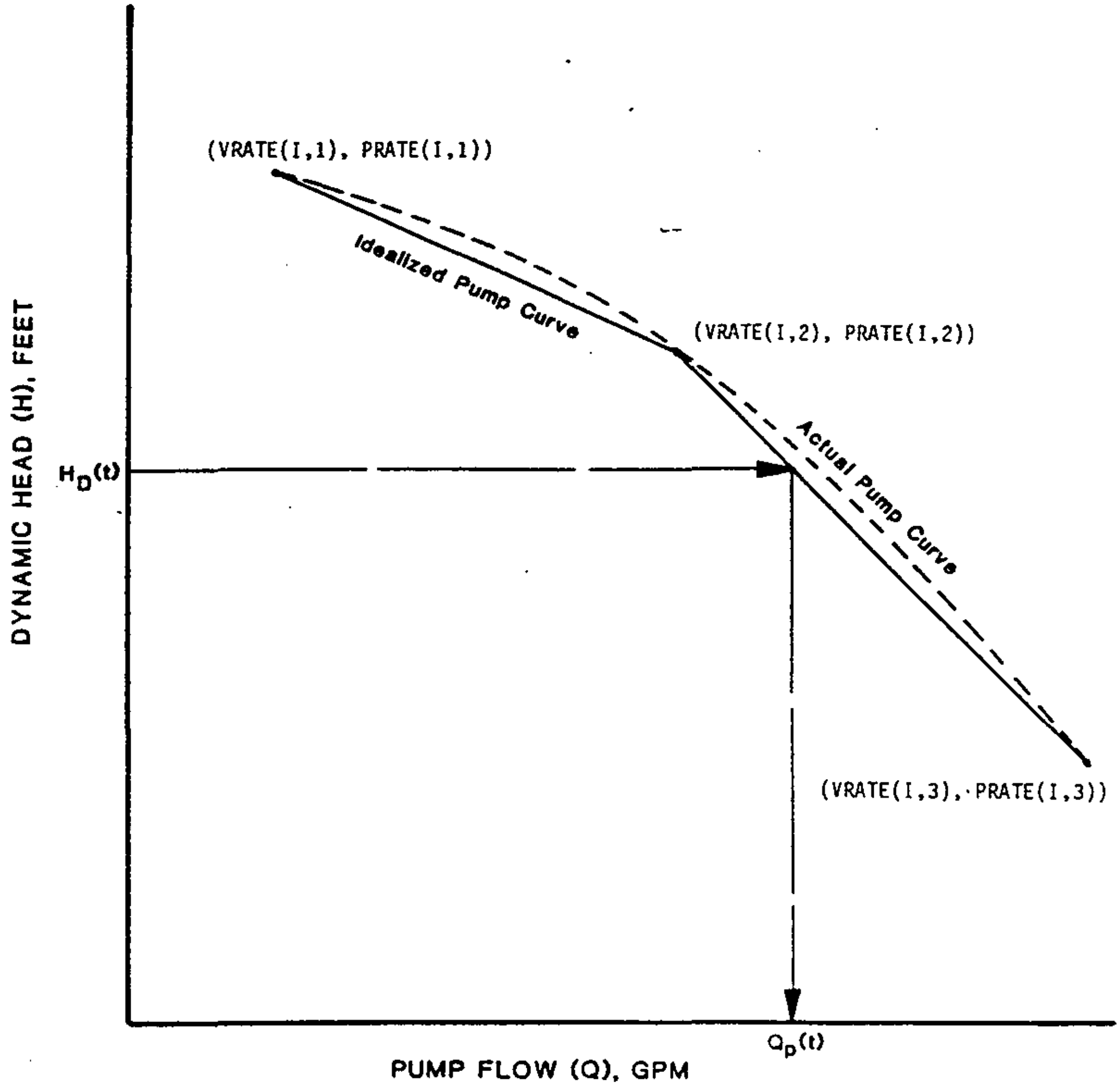

Figure 2-10. Typical Pump Operating Curve.

tion A1 (data group J2); 3) a tide whose period and amplitude are described by user-supplied tide coefficients (equation 2-14); 4) a tide for which coefficients for equation 2-14 will be computed by EXTRAN based on a specified number of stage-time points describing a single tidal cycle, or 5) a user-input time series of tail water elevations with linear interpolation between values. The functional form used for the tide in EXTRAN is

$$\begin{aligned} HTIDE = {} & A1 + A2 \sin \omega t + A3 \sin 2\omega t + A4 \sin 3\omega t \\ & + A5 \cos \omega t + A6 \cos 2\omega t + A7 \cos 3\omega t \end{aligned} \qquad (2\text{-}14)$$

where HTIDE = elevation of outfall water surface, ft [m],
t = current time, hrs,
ω = angular frequency 2 pi/W, radians/hr,
W = tidal period, hrs, and
A1 - A7 = coefficients, ft [m].

Typical tidal periods are 12.5 and 25 hours, although any value may be used. A convergence value, DELTA, is used during the iterative fit of the function of equation 2-14 to the data.

<u>Data Groups K1-K3: Hydrograph Input Data</u>

EXTRAN provides for input of up to 65 inflow hydrographs as input data lines in cases where it is desirable to run EXTRAN alone without prior use of an upstream (e.g., Runoff) block or to add additional input hydrographs, either at the same or different nodes, to those computed by an upstream block. The specification of individual junctions receiving hydrograph input by data lines is given in data group K2. Multiple hydrographs coming into a given junction can be indicated by repeating the junction number in group K2 for each inflow hydrograph. The order of hydrograph time-discharge points in data group K3 must correspond exactly with the order specified by data group K2. The time of day, TEO, of each discharge value is given in decimal clock hours; e.g., 10:45 a.m. is entered as 10.75. Should the simulation extend beyond midnight, times should continue beyond 24 (e.g., 1:30 a.m. would be 25.5 if the simulation began the previous day). The first value of TEO should be ≥ TZERO (data group B1).

Hydrograph time input points can be specified at any convenient time (not necessarily evenly spaced) as long as a value is included for each junction specified in data group K2 and parameter NJSW on data group B3. The number of input times per line is defined by parameter NINC on data group K1. The hydrographs at each time step are then formed by linear interpolation between consecutive input values of the time series.

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Table 2-1. Extran Block Input Data

EXTRAN INPUT GUIDELINES

There have been many changes made to the input format of EXTRAN. Following is a short list of the major changes along with explanations and guidelines.

1. Free format input. Input is no longer restricted to fixed columns. Free format has the requirement, however, that at least one space separate each data field. Free format input also has the following strictures on real, integer, and character data.

   a. No decimal points are allowed in integer fields. A variable is integer if it has a 0 in the default column. A variable is real if it has a 0.0 in the default column.

   b. Character data must be enclosed by single quotation marks, including both of the two title lines. Use a double single-quote ('') to represent an apostrophe within a character field, e.g., USER''S MANUAL.

2. Data group identifiers are a requirement and <u>must</u> be entered in columns 1 and 2. The program uses these for line and input error identification, and they are an aid to the EXTRAN user. 99999 lines no longer are required to signal the end of sets of data group lines; the data group identifiers are used to distinguish one data group from another.

3. The data lines may be up to 230 columns long.

4. Input lines can wrap around. For example, a line that requires 10 numbers may have 6 on the first line and 4 on the second line. The FORTRAN READ statement will continue reading until it finds 10 numbers, e.g.,

```
Z1   1  2   3  4  5  6
     7  8   9 10
```

Notice that the line identifier is <u>not</u> used on the second line.

5. In most cases an entry must be made for <u>every</u> parameter in a data group, even if it is not used or zero and even if it is the last required field on a line. Trailing blanks are not assumed to be zero. Rather, the program will continue to search on subsequent lines for the "last" required parameter. Zeros can be used to enter and "mark" unused parameters on a line. This requirement also applies to character data. A set of quotes must be found for each character entry field. E.g., if the two run title lines (data group A1) are to consist of one line followed by a blank line, the entry would be:

```
A1 'This is line 1.'
A1 ''
```

6. See Section 2 of the SWMM User's Manual for use of comment lines (indicated by an asterisk in column 1) and additional information.

Table 2-1 (continued). Extran Block Input Data

Since EXTRAN is often run by itself as a "stand alone" model, necessary input to the SWMM Executive Block is repeated here from the main SWMM User's Manual.

VARIABLE	DESCRIPTION	DEFAULT
	Executive Block Input Data	
	I/O File Assignments (Unit Numbers)	
SW	Group identifier	None
NBLOCK	Number of blocks to be run (max of 25).	1
JIN(1)	Input file (logical unit number) for the first block.	0
JOUT(1)	Output file for the first block.	0
.	.	
.	.	
JIN(NBLOCK)	Input file for the last block.	0
JOUT(NBLOCK)	Output file for the last block.	0
	Scratch File Assignments (Unit Numbers)	
MM	Group identifier	None
NITCH	Number of scratch files to be opened (max of 6). EXTRAN requires at least one scratch file.	0
NSCRAT(1)	First scratch file assignment.	0
.	.	
.	.	
NSCRAT(NITCH)	Last scratch file assignment.	0
	Control Data Indicating Files To Be Permanently Saved (Optional)	
	REPEAT THE @ LINE FOR EACH FILE TO BE SAVED.	
@	Group identifier	None
FILENUM	Unit number of the JIN, JOUT, or NSCRAT file to be permanently saved (or used) by the SWMM program.	None
FILENAM	Name for permanently saved file. Enclose in single quotes, e.g. 'SAVE.OUT'.	None

Enter $ANUM in columns 1-5 in order to use alphanumeric conduit/junction names in this (and all following) block(s).
Enter $EXTRAN in columns 1-7 to call the EXTRAN Block.

Table 2-1 (continued). Extran Block Input Data

VARIABLE	DESCRIPTION	DEFAULT
	Run Title	
A1	Group identifier	None
ALPHA	Description of computer run (2 lines, maximum of 80 columns per line). Both lines must be enclosed in quotes. Will be printed on output (2 lines).	Blank
	Optional Routing Solution Control Parameters This data group is not a requirement and may be omitted.	
B0	Group identifier	None
ISOL	Solution technique parameter (see Appendix C). = 0, Explicit solution of Section 5 (default), = 1, Enhanced explicit solution, = 2, Iterative explicit solution using variable time-steps ≤ DELT (group B1). Iteration limit is ITMAX and convergence criterion is SURTOL (group B2).	0
KSUPER	= 0, Use minimum of normal flow and dynamic flow when water surface slope < conduit slope (default), = 1, Normal flow always used when flow is supercritical.	0
	First Group of Run Control Parameters	
B1	Group identifier	None
NTCYC	Number of time-steps desired.	1
DELT	Length of time-step, seconds.	1.0
TZERO	Start time of simulation, decimal hours. Time zero is midnight (beginning) of first simulation day.	0.00
NSTART	First time-step to begin print cycle.	1
INTER	Interval between intermediate print cycles during simulation. Number of cycles printed is (NTCYC - NSTART)/INTER.	1
JNTER	Interval between time-history summary print cycles at end of simulation. Number of cycles printed is NTCYC/JNTER.	1

Table 2-1 (continued). Extran Block Input Data

VARIABLE	DESCRIPTION	DEFAULT
REDO	Hot-start file manipulation parameter. = 0, No hot-start file is created or used, = 1, Read NSCRAT(2) for initial flows, heads, areas, and velocities, = 2, Create a new hot-start file on NSCRAT(2), = 3, Create a new hot-start file but use the old file as the initial conditions. The old file is subsequently erased and a new file created.	0
	Second Group of Run Control Parameters	
B2	Group identifier	None
METRIC	U.S. customary or metric units for input/output. = 0, U.S. customary units, = 1, Metric units.	0
NEQUAL	Modify short pipe lengths using an equivalent pipe to ease time step limitations (see equation 2-3). = 0, Do not modify, = 1, Modify short pipe lengths.	0
AMEN	Default surface area for all manholes ft^2 [m^2]. Used for surcharge calculations in Extran. Manhole default diameter is 4 ft (1.22 m).	12.566
ITMAX	Maximum number of iterations to be used in surcharge and iterative calculations (30 recommended).	None
SURTOL	Fraction of average flow in surcharged areas to be used as convergence criterion for surcharge iterations (0.05 recommended). Also, convergence criterion during flow iterations, ISOL = 2 (Appen. C).	None
	Third Group of Run Control Parameters	
B3	Group identifier	None
NHPRT	Number of junctions for detailed printing of head output (30 nodes max.).	0
NQPRT	Number of conduits for detailed printing of discharge output (30 conduits max.).	0
NPLT	Number of junction heads to be plotted (30 max.).	0

Table 2-1 (continued). Extran Block Input Data

VARIABLE	DESCRIPTION	DEFAULT
LPLT	Number of conduits for flows to be plotted (30 max.).	0
NJSW	Number of input junctions (data group K2), if user input hydrographs are used (65 max.).	0

Note: For groups B4 - B8, enter each name in single quotes if alphanumeric option is being used.

Printed Heads

Enter 10 junction numbers per line. Data group B4 is required only if NHPRT > 0 on data group B3.

B4	Group identifier	None
JPRT(1)	First junction number/name for detailed printing.	0
JPRT(2)	Second junction number/name, etc., up to number of nodes defined by NHPRT.	0

Printed Flows

Enter 10 conduit numbers per line. Data group B5 is required only if NQPRT > 0 on data group B3.

B5	Group identifier	None
CPRT(1)	First conduit number/name for detailed printing.	0
CPRT(2)	Second conduit number/name, etc., up to number of nodes defined by NQPRT.	0

Plotted Heads

Enter 10 junction numbers per line. Data group B6 is required only if NPLT > 0 on data group B3.

B6	Group identifier	None
JPLT(1)	First junction number/name for plotting.	0
JPLT(2)	Second junction number/name, etc., up to number of nodes defined by NPLT.	0

Table 2-1 (continued). Extran Block Input Data

VARIABLE	DESCRIPTION	DEFAULT
	Plotted Flows	
	Enter 10 conduit numbers per line. Data group B7 is required only if LPLT > 0 on data group B3.	
B7	Group identifier	None
KPLT(1)	First conduit number/name for plotting.	0
KPLT(2)	Second conduit number/name for plotting, etc., up to the number of nodes defined by LPLT. This option is for the conduit flow rate.	0
	Upstream/Downstream Heads Plotted on Same Graph for Conduits	
	Enter 30 conduit numbers per line. Data group B8 is optional and may be omitted.	
B8	Group identifier	None
NSURF	Number of conduit upstream/downstream plots.	1
JSURF(1)	First conduit number/name for plotting.	0
JSURF(2)	Second conduit number/name for plotting, etc., up to the number of conduits defined by NSURF.	0
	Conduit Data (1 line/conduit, 175 Max.)	
C1	Group identifier	None
NCOND(N)	Conduit number (any valid integer), or conduit name (enclose in single quotes).	1 'Name'
NJUNC(N,1)	Junction number at upstream end of conduit, or junction name (enclose in single quotes).	0
NJUNC(N,2)	Junction number at downstream end of conduit, or junction name (enclose in single quotes).	0
QO(N)	Initial flow, ft^3/s [m^3/s].	0.0

Table 2-1 (continued). Extran Block Input Data

VARIABLE	DESCRIPTION	DEFAULT
NKLASS(N)	Type of conduit shape. 1 = circular 2 = rectangular 3 = horseshoe 4 = egg 5 = baskethandle 6 = trapezoidal channel 7 = parabolic/power function channel 8 = irregular (natural) channel	1

(Types 9 and 10 are used internally for orifice and weir connections.)

Note: A negative NKLASS(N) creates a flap gate that will only let water move from the <u>downstream</u> (lower elevation) node to the upstream node.

VARIABLE	DESCRIPTION	DEFAULT
AFULL(N)	Cross sectional area of conduit, ft^2 [m^2] enter only for types 3, 4, and 5. (Geometric properties for types 3-5 may be found in Section 6 of the main SWMM User's Manual.)	0.0
DEEP(N)	Vertical depth (diameter for type 1) of conduit, ft [m]. Not required for type 8.	0.0
WIDE(N)	Maximum width of conduit, ft [m]. Bottom width for trapezoid, ft [m]. Top width for parabolic, ft [m]. Not required (N.R.) for types 1 and 8.	0.0

Note, bold face text below describes differences for type 8 channels.

VARIABLE	DESCRIPTION	DEFAULT
LEN(N)	Length of conduit, ft [m]. **N.R. for type 8. Enter in data group C3.**	0.0

Note: A negative LEN(N) creates a flap gate that will only let water move from the <u>upstream</u> (higher elevation) node to the downstream node.

VARIABLE	DESCRIPTION	DEFAULT
ZP(N,1)	Distance of conduit invert above junction invert at NJUNC(N,1), ft [m].	0.0
ZP(N,2)	Distance of conduit invert above junction invert at NJUNC(N,2), ft [m].	0.0
ROUGH(N)	Manning coefficient (includes entrance, exit, expansion, and contraction losses). **N.R. for type 8. Uses XNCH in data group C2.**	0.014

Table 2-1 (continued). Extran Block Input Data

VARIABLE	DESCRIPTION	DEFAULT
STHETA(N)	Slope of one side of trapezoid. Required only for type = 6, (horizontal/vertical; 0 = vertical walls). For type 7, the channel exponent(2.0, 3.0, etc.). For type 8, the cross-section identification number (SECNO, group C3) of the cross section used for this EXTRAN channel. Unlike HEC-2, EXTRAN uses only a single cross section to represent a natural channel reach for type 8 channels. A negative STHETA(N) will eliminate the printing of the dimensionless curves associated with each natural channel or power-function channel.	0.0
SPHI(N)	Slope of other side of trapezoid. Required only for type = 6, (horizontal/vertical; 0 = vertical walls). The average channel slope for type 8. This slope is used only for developing a rating curve for the channel. Routing calculations use invert elevation differences divided by length.	0.0

The C2 (NC), C3 (X1), and C4 (GR) data lines for any type 8 conduits follow as a group after all C1 lines have been entered. The sequence for channels <u>must</u> be in the same order as the earlier sequence of type-8 C1-lines.

Data groups C2, C3 and C4 correspond to HEC-2 lines NC, X1 and GR. HEC-2 input may be used directly if desired. Lines may be identified either by EXTRAN identifiers (C2, C3, C4) or HEC-2 identifiers (NC, X1, GR).

Channel Roughness

This is an optional data line that permanently modifies the Manning's roughness coefficients (n) for the remaining natural channels. This data group may repeated for later channels. It <u>must</u> be included for the first natural channel modeled.

C2 or NC	Group identifier	None
XNL	n for the left overbank. = 0.0, No change, > 0.0, New Manning's n.	0.0
XNR	n for the right overbank. = 0.0, No change, > 0.0, New Manning's n.	0.0

Table 2-1 (continued). Extran Block Input Data

VARIABLE	DESCRIPTION	DEFAULT
XNCH	n for the channel. = 0.0, No change, > 0.0, New Manning's n.	0.0

Note, XNCH is used to develop normalized flow routing curves.

Cross Section Data

Required for each type 8 conduit in earlier C1 data lines.

Enter pairs of C3 and C4 lines in same sequence as appearance of corresponding type 8 conduit in earlier C1 lines.

VARIABLE	DESCRIPTION	DEFAULT
C3 or X1	Group identifier	None
SECNO	Cross section identification number.	1
NUMST	Total number of stations on the following C4 (GR) data group lines. NUMST must be < 99.	0
STCHL	The station of the left bank of the channel, ft [m]. Must be equal to one of the STA(N) on the C4 (GR) data lines.	0.0
STCHR	The station of the right bank of the channel, ft [m]. Must be equal to one of the STA(N) on the C4 (GR) data lines.	0.0
XLOBL	Not required for EXTRAN (enter 0.0).	0.0
XLOBR	Not required for EXTRAN (enter 0.0).	0.0
LEN(N)	Length of <u>channel</u> reach represented by this cross section, ft [m].	0.0
PXSECR	Factor to modify the horizontal dimensions for a cross section. The distances between adjacent C4 (GR) stations (STA) are multiplied by this factor to expand or narrow a cross section. The STA of the first C4 (GR) point remains the same. The factor can apply to a repeated cross section or a current one. A factor of 1.1 will increase the horizontal distance between the C4 (GR) stations by 10 percent. Enter 0.0 for no modification.	0.0

Table 2-1 (continued). Extran Block Input Data

VARIABLE	DESCRIPTION	DEFAULT
PSXECE	Constant to be added (+ or -) to C4 (GR) elevation data on next C4 (GR) line. Enter 0.0 to use C4 (GR) values as entered.	0.0

Cross-Section Profile

Required for type 8 conduits in data group C1.
Enter C3 and C4 lines in pairs.

C4 or GR	Group identifier	None
EL(1)	Elevation of cross section at STA(1). May be positive or negative, ft [m].	0.0
STA(1)	Station of cross section 1, ft [m].	0.0
EL(2)	Elevation of cross section at STA(2), ft [m].	0.0
STA(2)	Station of cross section 2, ft [m].	0.0

Enter NUMST elevations and stations to describe the cross section. Enter 5 pairs of elevations and stations per data line. (Include group identifier, C4 or GR, on each line.) Stations should be in increasing order progressing from left to right across the section. Cross section data are traditionally oriented looking downstream (HEC, 1982).

Junction Data (1 line/junction, 175 Max.)

D1	Group identifier	None
JUN(J)	Junction number (any valid integer), or junction name (enclose in single quotes).	0
GRELEV(J)	Ground elevation, ft [m].	0.0
Z(J)	Invert elevation, ft [m].	0.0
QINST(J)	Net constant flow into junction, cfs [m^3/s]. Positive indicates inflow. Negative indicates withdrawl or loss.	0.0
YO(J)	Initial depth above junction invert elevation, ft [m].	0.0

Table 2-1 (continued). Extran Block Input Data

VARIABLE	DESCRIPTION	DEFAULT
	Storage Junctions (20 Max.)	
	Note: Each storage junction must also have been entered in the junction data (Group D1).	
E1	Group identifier	None
JSTORE(I)	Junction number containing storage facility, or junction name (enter in single quotes).	0
ZTOP(I)	Junction crown elevation (must be higher than crown of highest pipe connected to the storage junction), ft [m].	0.0
ASTORE(J)	Storage volume per foot (or meter) of depth (i.e., constant surface area) ft^3/ft [m^3/m]. Set ASTORE(J) < 0 to indicate a variable-area storage junction.	0.0
	NUMST required only if ASTORE < 0.	
NUMST	Total number of stage/storage area points on following E2 data lines. NUMST < 99. Enter a value of -2 for NUMST to generate area vs. stage using a power function, $A = a\ depth^b$.	0

Follow E1 line with E2 line(s) only if ASTORE < 0,
or NUMST equals -2 on line E1.

Variable-Area Storage Junction, Stage vs. Surface Area Points

E2	Group identifier	None
QCURVE(N,1,1)	Surface area of storage junction at depth point 1, acres [hectares]. If NUMST equals -2 this is the coefficient of the power function.	0.0
QCURVE(N,2,1)	Depth above junction invert at point 1, ft [m]. If NUMST equals -2 this is the exponent of the power function. This is the last value entered if NUMST equals -2.	0.0
QCURVE(N,1,2)	Surface area of storage junction at depth point 2, acres [hectares].	0.0

Table 2-1 (continued). Extran Block Input Data

VARIABLE	DESCRIPTION	DEFAULT
QCURVE(N,2,2)	Depth above junction invert at point 2, ft [m].	0.0
.		
.		
.		

Continue entering total of NUMST (data group E1) area-stage points. Use only one E2 group identifier for the E2 data group. If more than one line is required leave the first two columns blank.

Orifice Data (60 Max.)

VARIABLE	DESCRIPTION	DEFAULT
F1	Group identifier	None
NJUNC(N,1)	Junction number containing orifice, or junction name (enter in single quotes).	None
NJUNC(N,2)	Junction number to which orifice discharges, or junction name (enter in single quotes).	None
NKLASS(N)	Type of orifice. 1 = side outlet, 2 = bottom outlet, -1 = time-history side outlet orifice, with data entered on data group F2. -2 = time-history bottom outlet orifice, with data entered on data group F2.	1
AORIF(I)	Orifice area, ft^2 [m^2].	0.0
CORIF(I)	Orifice discharge coefficient.	1.0
ZP(I)	Distance of orifice invert above junction floor (define only for side outlet orifices), ft [m].	0.0

Time-History Orifice Data

Each F2 line follows the appropriate F1 line.

VARIABLE	DESCRIPTION	DEFAULT
F2	Group identifier	None
NTIME	Number of data points to describe the time history of the orifice (50 max.).	1

Table 2-1 (continued). Extran Block Input Data

VARIABLE	DESCRIPTION	DEFAULT
VORIF(I,1,1)	First time, hours, that the orifice discharge coefficient and area change values from intial settings of group F1 above. Time zero refers to beginning (midnight) of beginning day of simulation. E.g., VORIF(I,1,1) = 22.0 means first change in orifice setting occurs at 10:00 p.m. on first day of simulation. Increase hours past 24 (e.g., 25, 26) for multi-day simulations.	0.0
VORIF(I,1,2)	First new value of orifice discharge coefficient.	0.0
VORIF(I,1,3)	First new value of orifice area.	0.0
.	.	
.	.	
	Enter NTIME values of time/coefficient/area. Only one F2 group identifier is required, on the first data line. Subsequent lines (if required) should not include F2 identifier.	

Weir Data (1 line/weir, 60 Max.)

VARIABLE	DESCRIPTION	DEFAULT
G1	Group identifier	None
NJUNC(N,1)	Junction number at which weir is located, or junction name (enter in single quotes).	0
NJUNC(N,2)	Junction number to which weir discharges, or junction name (enter in single quotes). Note: To designate outfall weir, set NJUNC(N,2) equal to zero or ' ' (one space between quotes).	0
KWEIR(I)	Type of weir. 1 = transverse, 2 = transverse with tide gate, 3 = side flow, 4 = side flow with tide gate.	1
YCREST(I)	Height of weir crest above invert, ft [m].	0.0
YTOP(I)	Height to top of weir opening above invert (surcharge level) ft [m].	0.0
WLEN(I)	Weir length, ft [m].	0.0
COEF(I)	Coefficient of discharge for weir.	1.0

Table 2-1 (continued). Extran Block Input Data

VARIABLE	DESCRIPTION	DEFAULT
	Pump Data (1 line/pump, 20 Max.)	
Note:	ONLY ONE PIPE CAN BE CONNECTED TO A TYPE 1 PUMP NODE.	
H1	Group identifier	None
IPTYP(I)	Type of pump. 1 = off-line pump with wet well (program will set pump junction invert to -100), 2 = in-line lift pump, 3 = three-point head-discharge pump curve.	1
NJUNC(N,1)	Junction number being pumped, or junction name (enter in single quotes).	0
NJUNC(N,2)	Pump discharge goes to this junction number, or junction name (enter in single quotes).	0
PRATE(I,1)	Lower pumping rate, ft^3/s [m^3/s].	0.0
PRATE(I,2)	Mid-pumping rate, ft^3/s [m^3/s].	0.0
PRATE(I,3)	High pumping rate, ft^3/s [m^3/s].	0.0
VRATE(I,1)	If IPTYP = 1 enter the wet well volume for mid-rate pumps to start, ft^3 [m^3]. If IPTYP = 2 enter the junction depth for mid-rate pumps to start, ft [m]. If IPTYP = 3 enter the head difference (head at junction downstream of pump minus head at junction upstream of pump) associated with the lowest pumping rate, ft [m]. (This will be the highest head difference.)	0.0
VRATE(I,2)	If IPTYP = 1 enter the wet well volume for high-rate pumps to start, ft^3 [m^3]. If IPTYP = 2 enter the junction depth for high-rate pumps to start, ft [m]. If IPTYP = 3 enter the head difference associated with the mid-pumping rate, ft [m].	0.0
	Non-zero VRATE(I,3) and VWELL(I) required only if IPTYP = 1 or 3.	

Table 2-1 (continued). Extran Block Input Data

VARIABLE	DESCRIPTION	DEFAULT
VRATE(I,3)	If IPTYP = 1 enter total wet well capacity, ft^3 $[m^3]$. If IPTYP = 3 then enter the head difference associated with highest pumping rate, ft [m]. (This will be the lowest head difference.)	0.0
VWELL(I)	If IPTYP = 1 then enter initial wet well volume, ft^3 $[m^3]$. If IPTYP = 3 then enter the initial depth in pump inflow junction, ft [m].	0.0
	Enter PON(I) and POFF(I) if IPTYP = 2 or 3.	
PON(I)	Depth in pump inflow junction to turn pump on, ft [m].	0.0
POFF(I)	Depth in pump inflow junction to turn pump off, ft [m].	0.0

Note: for groups I1 and I2, enter junction name in single quotes if alphanumeric option is being used.

Outfalls Without Tide Gates (1 line/outfall, 25 Max.)

Note: ONLY ONE CONNECTING CONDUIT IS PERMITTED TO AN OUTFALL NODE.

VARIABLE	DESCRIPTION	DEFAULT
I1	Group identifier	None
JFREE(I)	Number/name of outfall junction without tide gate (no back-flow restriction).	0
NBCF(I)	Type of boundary condition, from sequence of data group J1 - J4.	1

Outfalls with Tide Gates (1 line/outfall, 25 max.)

Note: ONLY ONE CONNECTING CONDUIT IS PERMITTED TO AN OUTFALL NODE.

VARIABLE	DESCRIPTION	DEFAULT
I2	Group identifier	None
JGATE(I)	Number/name of outfall junction with tide gate (back-flow not allowed).	0
NBCG(I)	Type of boundary condition, from sequence of data groups J1 - J4.	1

Table 2-1 (continued). Extran Block Input Data

VARIABLE	DESCRIPTION	DEFAULT
	Boundary Condition Information	
	Note: Repeat sequence of data groups J1-J4 for up to 20 different boundary conditions. Appearance in sequence (e.g., first, second... fifth...) determines value for NBCF and NBCG in data groups I1 and I2.	
J1	Group identifier	None
NTIDE(I)	Boundary condition index. 1 = No water surface at outfalls (elevated discharge), 2 = Controlling water surface at outfall at constant elevation A1 (group J2), ft [m], Types 3, 4 and possibly 5 are used for tidal variations at outfall. 3 = Tide coefficients (group J2) provided by user, 4 = Program will compute tide coefficients, 5 = Stage-history of water surface elevations input by user. Program uses linear interpolation between data points.	1
	Stage and/or Tidal Coefficients	
	Note: NOT REQUIRED (OMIT) IF NTIDE(I) = 1 OR 5 ON DATA GROUP J1.	
J2	Group identifier	None
A1(I)	First tide coefficient, ft [m].	0.0
W(I)	Tidal period, hours. Required only if NTIDE(I) = 3 or 4.	0.0
	Note: NEXT SIX FIELDS NOT REQUIRED UNLESS NTIDE(I) = 3 See equation 2-14 for definition of coefficients.	
A2(I)	Second tide coefficient, ft [m].	0.0
A3(I)	Third tide coefficient, ft [m].	0.0
A4(I)	Fourth tide coefficient, ft [m].	0.0
A5(I)	Fifth tide coefficient, ft [m].	0.0

Table 2-1 (continued). Extran Block Input Data

VARIABLE	DESCRIPTION	DEFAULT
A6(I)	Sixth tide coefficient, ft [m].	0.0
A7(I)	Seventh tide coefficient, ft [m].	0.0
	Tidal/Stage Information	
	REQUIRED ONLY IF NTIDE = 4 OR 5	
J3	Group identifier	None
KO	Type of tidal input. = 0, Input is in the form of a time series of NI tidal heights. This parameter is not used if NTIDE equals 5. = 1, Input is in the form of the high and low water values found in the tide tables, (HHW, LLW, LHW, and HLW). NI must be 4.	0
NI	Number of information points.	4
NCHTID	Tide information print control. = 0, Do not print information, = 1, Print information on tide coefficients or stage history.	1
DELTA	Convergence criterion for fitting of tidal function, ft [m]. Not required for NTIDE = 5.	0.005
	Time and stage information	
	REQUIRED IF NTIDE = 4 OR 5	
J4	Group identifier	None
TT(1)	Time of day, first information point, hours. (Increase hours past 24 if necessary.)	0.0
YY(1)	Tide/stage at time above, ft [m].	0.0
TT(2)	Time of day, second information points, hours.	0.0
YY(2)	Tide/stage, at time above, up to number of points as defined by NI, ft [m].	0.0

Note: Enter 5 pairs of time and stage information per data line. (Repeat group identifier on each line.)

Table 2-1 (continued). Extran Block Input Data

VARIABLE	DESCRIPTION	DEFAULT
	User Input Hydrographs	
	IF NJSW = 0 (GROUP B3), SKIP DATA GROUPS K1, K2 AND K3	
K1	Group identifier	None
NINC	Number of input nodes and flows per line in group K3.	1
	Hydrograph Nodes	
K2	Group identifier	None
JSW(1)	First input node number for line hydrograph, or node name (enter in single quotes).	0
JSW(2)	Second input node number for line hydrograph, or node name (enter in single quotes).	0
.	.	
.	.	
	Enter NINC nodes per line until NJSW nodes are entered. (Repeat group identifier on each line.)	
	User Input Hydrographs	
K3	Group identifier	None
TEO	Time of day, decimal hours.	0.0
QCARD(1,1)	Flow rate for first input node, JSW(1), ft^3/s [m^3/s].	0.0
QCARD(2,1)	Flow rate for second input node, JSW(2), ft^3/s [m^3/s].	0.0
.		
.		

Enter TEO plus NINC flows per line until NJSW flows are entered. Enter TEO only on first of multiple ("wrapped around") lines and do not include group identifier K3 on lines that are "wrapped around." Repeat the sequence for each TEO time. Times do not have to be evenly spaced; linear interpolation is used to interpolate between entries. The last K3 line will signal the end of the user hydrograph input. The last TEO value should be ≥ length of simulation. Increase TEO past 24 for multi-day simulations.

END OF EXTRAN DATA INPUT

Control now returns to the Executive Block of SWMM.

If no more SWMM blocks are to be called, end input with $ENDPROGRAM in columns 1-11.

SECTION 3

EXAMPLE PROBLEMS

INTRODUCTION

Ten test runs of EXTRAN are described in this report. (Additional examples are included on the program distribution disks.) They will demonstrate how to set up the input data sets for each of the flow diversions included in the model. The complete or partial results of these runs have also been included as an example of typical output and an aid in interpreting EXTRAN results. (Complete sets of input and output files are included in the distribution disks for EXTRAN.) Output values for these examples differ slightly from SWMM Version 3 EXTRAN output (Roesner et al., 1981) due to slight changes in coefficients affecting upstream junctions during surcharging (see Section 5).

EXAMPLE 1: BASIC PIPE SYSTEM

Figure 3-1 shows a typical system of conduits and channels conveying stormwater flow. In this system, which is used in all the first seven example problems below, conduits are designated with four-digit numbers while junctions have been given five-digit numbers. There are three inflow hydrographs, which are input in data group K3, and one free outfall. Table 3-1 is the input data set for Example 1.

The complete output for Example 1 is found in Table 3-2. The first section is an echo of the input data and a listing of conduits created internally by EXTRAN to represent outfalls and diversions caused by weirs, orifices, and pumps.

The next section of the output is the intermediate printout. This lists system inflows as they are read by EXTRAN and gives the depth at each junction and flow in each conduit in the system at a user-input time interval. A junction in surcharge is indicated by printing an asterisk beside its depth. An asterisk beside a conduit flow indicates that the flow is set at the normal flow value for the conduit. The intermediate printout ends with the printing of a continuity balance of the water passing through the system during the simulation. Printed outflows from junctions not designated as outfalls in the input data set are junctions which have flooded.

The final section of the output gives the time history of depths and flows for those junctions and conduits input by the user, as well as a summary for all junctions and conduits in the system. The output ends with the user-requested plots of junction heads and conduit flows.

EXAMPLE 2: TIDE GATE

Figure 3-2 shows the system simulated in Example 2, which is the basic pipe system with a tide gate at the outfall and constant receiving water depth of 94.4 feet. Two changes to the input data set, shown in Table 3-3, are required for this situation. These, shown in Table 3-3, are:

1. placing the outfall junction number (10208) in data group I1, and
2. changing NTIDE in data group J1 to 2 and inputting A1 = 94.4.

The summary statistics for this run are in Table 3-4.

EXAMPLE 3: SUMP ORIFICE DIVERSION

Example 3 uses a 2-foot diameter sump orifice to divert flow to junction 15009 in order to relieve the flooding upstream of junction 82309. A free outfall is also used in this example. Table 3-5 indicates that the sump orifice is inserted simply by changing data group D1 as shown. A summary of the results from this example is found in Table 3-6.

EXAMPLE 4: WEIR DIVERSION

A weir can also be used as a diversion structure to relieve the flooding upstream of junction 82309, as shown in Figure 3-4. Data group G1 has been revised as shown in Table 3-7 in order to input the specifications for this weir. Summary results are shown in Table 3-8.

EXAMPLE 5: STORAGE FACILITY WITH SIDE OUTLET ORIFICE

Inclusion of a storage facility requires several changes to the basic pipe system. Figure 3-5 shows that a new junction, 82308, has been inserted to receive the outflow from the orifice in the storage facility. Table 3-9 shows that this requires a new junction in data group D1, the invert of which is set to that of conduit 1602. This change, however, also requires that the invert of junction 82309 be raised to that of conduit 8060. Table 3-1 shows that, for the basic pipe system, conduit 8060 is 2.2 feet (ZP(N,2)) above the invert of junction 82309. Thus, the invert of 82308 is set at 112.3 feet (the original elevation of 82309), the invert of 82309 is 114.5 feet, and ZP(N,2) for 8060 is 0.0. Data group E1 is revised to show the size of the storage facility, and data group F1 is changed to show the specifications of the 2-foot diameter orifice. Table 3-10 gives the results of this example.

EXAMPLE 6: OFF-LINE PUMP STATION

Inclusion of an off-line pump station requires the addition of a junction to represent the wet-well and a conduit to divert the flow to it, as Figure 3-6 demonstrates. Examination of data groups C1 and D1 in Table 3-11 shows the specifications for conduit 8061 and junction 82310. However, the length and Manning's n of conduit 8061 shown here have been altered for stability purposes to those of a pipe equivalent to the actual 8061, the real dimension of which is 20 feet long with an n of .015. Section 2 gives the details of the equivalent pipe transformation. Also, data group H1 now includes a line giving the pump specifications. Results from this example are found in Table 3-12.

EXAMPLE 7: IN-LINE PUMP STATION

The pump in Example 6 can be moved to junction 82309 to simulate an in-line pump station. Figure 3-7 shows that this requires no alteration to the basic pipe system of Example 1. The only change to the input data set, shown in Table 3-13, is the pump data in group H1. It should be noted, though, that the VWELL variables are now water elevations at junction 82309 rather than the volume of a wet-well. Results are found in Table 3-14.

EXAMPLE 8: DEMONSTRATION OF ALL CONDUIT TYPES

All eight conduit types are illustrated in Example 8, the schematic of which is shown in Figure 3-8. Two natural channels are placed at the down-stream end of the system to represent a "natural" receiving stream.

In order to produce an initial flow of 20 cfs in the natural channels, the "hot start" mechanism is used. A first run is made with the only inflow being a constant flow of 20 cfs to junction 30081 (input data are shown in Table 3-15). At the end of the 1-hr simulation, the flow is approximately 20 cfs in channels 10081 and 10082 (Table 3-16). A possibly unexpected result of the initialization run is that water flows upstream into channel 10006 since its downstream invert elevation is the same as channel 10081. The flow in channel 10006 tends to "surge" in positive and negative directions while filling.

Input data for the main simulation are shown in Table 3-17, and partial output is shown in Table 3-18. This run uses the previously generated file (EX8.HOT) to initialize heads, areas, flows and velocities. The natural channels produce additional output describing their geometric and hydraulic properties.

EXAMPLE 9: VARIABLE STORAGE AREA WITH METRIC EXTRAN

This example illustrates variable storage areas and metric conduit and junction values. A side outlet orifice connects variable storage junction 3001 and junction 3002 (see Figure 3-9). This problem was solved in Bedient and Huber (1988, p. 378) and the maximum depth in junction 3001 should be about 6.95 meters at 4 hours and the peak orifice flow should be 0.42 m^3/sec at 4 hours. The input data for this simulation are shown in Table 3-19 and a partial output listing is presented in Table 3-20.

EXAMPLE 10: THREE-POINT PUMP CURVE STATION

This example illustrates the third type of pump station in EXTRAN. Five pumps are used to pump water 50 feet up a hill from an upstream storage junction to a downstream storage junction (see Figure 3-10). Each pump has a different operating curve. The input data for this simulation are shown in Table 3-21 and a partial output listing is presented in Table 3-22.

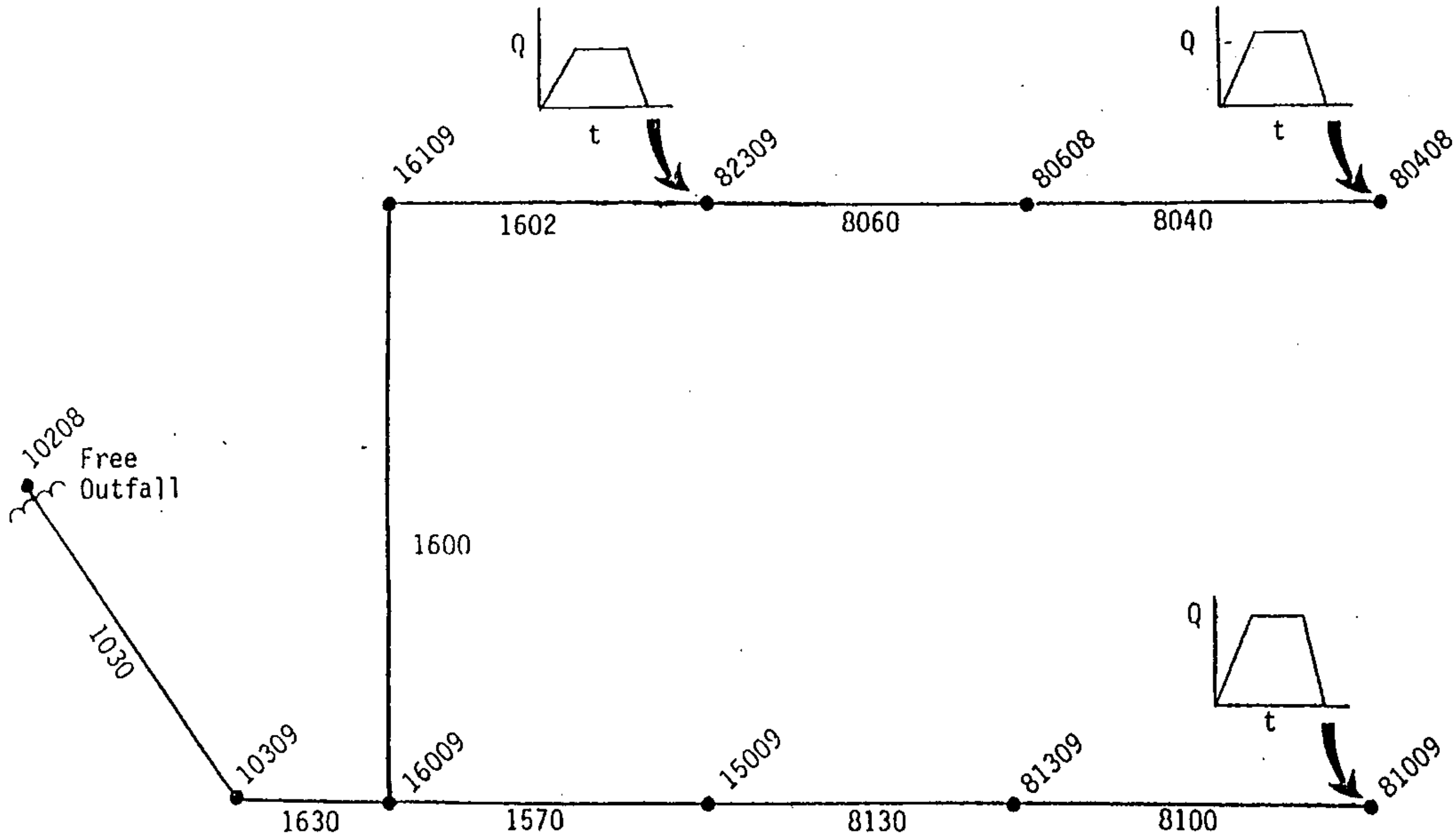

Figure 3-1. Basic System with Free Outfall.

Table 3-1. Input Data for Example 1.

```
SW  1  0  0
MM  3  10 11 12
$EXTRAN
A1  'EXTRAN USER''S MANUAL EXAMPLE 1'
A1  ' BASIC PIPE SYSTEM FROM FIGURE 3-1'
*   NTCYC DELT TZERO NSTART INTER JNTER REDO
B1 1440  20.0  0.0  45       45    45    0
*   METRIC NEQUAL  AMEN ITMAX SURTOL
B2     0    0       0.0   30  0.05
* NHPRT NQPRT NPLT LPLT NJSW
B3   6    6    6    6    3
*   PRINT HEADS
B4  80608 16009 16109 15009 82309 80408
*   PRINT FLOWS
B5  1030 1630 1600 1602 1570 8130
*   PLOT HEADS
B6  80608 16009 16109 15009 82309 80408
*   PLOT FLOWS
B7  1030 1630 1600 1602 1570 8130
*   CONDUIT DATA
C1  8040 80408 80608 0.0 1 0.0 4.0 0.0 1800.  0.0  0.0  0.015 0.0 0.0
C1  8060 80608 82309 0.0 1 0.0 4.0 0.0 2075.  0.0  2.2  0.015 0.0 0.0
C1  8100 81009 81309 0.0 1 0.0 4.5 0.0 5100.  0.0  0.0  0.015 0.0 0.0
C1  8130 81309 15009 0.0 1 0.0 4.5 0.0 3500.  0.0  0.0  0.015 0.0 0.0
C1  1030 10309 10208 0.0 6 0.0 9.0 0.0 4500.  0.0  0.0  0.016 3.0 3.0
C1  1570 15009 16009 0.0 1 0.0 5.5 0.0 5000.  0.0  0.0  .0154 0.0 0.0
C1  1600 16009 16109 0.0 1 0.0 6.0 0.0  500.  0.0  0.0  0.015 0.0 0.0
C1  1630 16009 10309 0.0 6 0.0 9.0 0.0  300.  0.0  0.0  0.015 3.0 3.0
C1  1602 82309 16109 0.0 1 0.0 5.0 0.0 5000.  0.0  0.0  0.034 0.0 0.0
*    JUNCTION DATA
D1   80408  138.0 124.6 0.0 0.0
D1   80608  135.0 118.3 0.0 0.0
D1   81009  137.0 128.2 0.0 0.0
D1   81309  130.0 117.5 0.0 0.0
D1   82309  155.0 112.3 0.0 0.0
D1   10208  100.0  89.9 0.0 0.0
D1   10309  111.0 101.6 0.0 0.0
D1   15009  125.0 111.5 0.0 0.0
D1   16009  120.0 102.0 0.0 0.0
D1   16109  125.0 102.8 0.0 0.0
I1  10208 1
J1  1
K1  3
K2 82309 80408 81009
K3  0.0  0.0  0.0  0.0
K3 0.25  40.0 45.0 50.0
K3  3.0  40.0 45.0 50.0
K3 3.25  0.0  0.0  0.0
K3 12.0  0.0  0.0  0.0
$ENDPROGRAM
```

Table 3-2. Output for Example 1.

```
**********************************************
*     ENVIRONMENTAL PROTECTION AGENCY        *
*       STORM WATER MANAGEMENT MODEL         *
*              VERSION 4.03                  *
**********************************************

              DEVELOPED BY

**********************************************
*          METCALF & EDDY, INC.              *
*          UNIVERSITY OF FLORIDA             *
*     WATER RESOURCES ENGINEERS, INC.        *
*             SEPTEMBER 1970                 *
**********************************************

               UPDATED BY

**********************************************
*          UNIVERSITY OF FLORIDA             *
*       CAMP DRESSER & MCKEE, INC.           *
*                                            *
*  MARCH     1975          NOVEMBER  1977    *
*  NOVEMBER  1981          JANUARY   1989    *
**********************************************

**********************************************
*   THIS IS A NEW RELEASE OF SWMM.  IF ANY   *
*   PROBLEMS OCCUR IN RUNNING THIS MODEL     *
*          CONTACT WAYNE HUBER               *
*         UNIVERSITY OF FLORIDA              *
*         PHONE 1-904-392-0846               *
**********************************************

**********************************************
* THIS IS AN IMPLEMENTATION OF EPA SWMM 4.03 *
* "NATURE IS FULL OF INFINITE CAUSES WHICH   *
*  HAVE NEVER OCCURED IN EXPERIENCE" da Vinci *
**********************************************

**********************************************
*     DISK OR TAPE ASSIGNMENTS BY BLOCK      *
*       JIN  -> INPUT TO A BLOCK             *
*       JOUT -> OUTPUT FROM A BLOCK          *
**********************************************

 BLOCK( 1)      JIN( 1)  0      JOUT( 1)  9
```

```
*************************************************
*             SCRATCH DISKS OR TAPES            *
*         THESE CAN BE USED BY ANY BLOCK        *
*************************************************

NSCRAT(1) NCSRAT(2) NSCRAT(3) NSCRAT(4) NSCRAT(5) NSCRAT(6) NSCRAT(7)
   10        11        12

*************************************************
*    PARAMETER VALUES ON THE TAPES COMMON BLOCK  *
*************************************************

NUMBER OF SUBCATCHMENTS IN THE RUNOFF BLOCK (NW)....  150
NUMBER OF CHANNEL/PIPES IN THE RUNOFF BLOCK (NG)....  150
NUMBER OF ELEMENTS IN THE TRANSPORT BLOCK (NET).....  175
NUMBER OF INPUT HYDROGRAPHS IN TRANSPORT (NTH)......   80
NUMBER OF ELEMENTS IN THE EXTRAN BLOCK (NEE)........  175
NUMBER OF GROUNDWATER SUBCATCHMENTS IN RUNOFF (NGW).  100
NUMBER OF INTERFACE LOCATIONS FOR ALL BLOCKS (NIE)..  175
NUMBER OF PUMPS IN EXTRAN (NEP).....................   20
NUMBER OF ORIFICES IN EXTRAN (NEO)..................   60
NUMBER OF TIDE GATES/FREE OUTFALLS IN EXTRAN (NTG)..   25
NUMBER OF EXTRAN WEIRS (NEW)........................   60
NUMBER OF EXTRAN PRINTOUT LOCATIONS (NPO)...........   30
NUMBER OF TIDE ELEMENTS IN EXTRAN (NTE).............   20
NUMBER OF NATURAL CHANNELS (NNC)....................   50
NUMBER OF STORAGE JUNCTIONS IN EXTRAN (NVSE)........   20
NUMBER OF DATA POINTS FOR VARIABLE STORAGE ELEMENTS
IN THE EXTRAN BLOCK (NVST)..........................   30
NUMBER OF INPUT HYDROGRAPHS IN EXTRAN (NEH).........   65

*****************************************************
* ENTRY MADE TO EXTENDED TRANSPORT MODEL (EXTRAN)    *
* UPDATED BY THE UNIVERSITY OF FLORIDA (UF) AND      *
* CAMP DRESSER AND MCKEE INC. (CDM), JANUARY, 1989.  *
*                                                   *
* "Smooth runs the water where the brook is deep."  *
*                  Shakespeare, Henry VI, II, III, 1 *
*****************************************************
```

CONTROL INFORMATION FOR SIMULATION

```
INTEGRATION CYCLES................. 1440

LENGTH OF INTEGRATION STEP IS......   20. SECONDS

DO NOT CREATE EQUIV. PIPES(NEQUAL).    0

USE U.S. CUSTOMARY UNITS FOR I/O...    0

PRINTING STARTS IN CYCLE...........   45

INTERMEDIATE PRINTOUT INTERVALS OF.   45 CYCLES

SUMMARY PRINTOUT INTERVALS OF......   45 CYCLES

HOT START FILE MANIPULATION(REDO)..    0

INITIAL TIME...................... 0.00 HOURS

ITERATION VARIABLES: ITMAX.........   30
                     SURTOL........0.0500

DEFAULT SURFACE AREA OF JUNCTIONS.. 12.57 CUB FT.

EXTRAN VERSION 3.3 SOLUTION. (ISOL = 0).
SUM OF JUNCTION FLOW IS ZERO DURING SURCHARGE.

NORMAL FLOW OPTION WHEN THE WATER
SURFACE SLOPE IS LESS THAN THE
GROUND SURFACE SLOPE (KSUPER=0)....

NJSW INPUT HYDROGRAPH JUNCTIONS....    7

PRINTED OUTPUT FOR THE FOLLOWING  6 JUNCTIONS

        80608    16009    16109    15009    82309    80408

PRINTED OUTPUT FOR THE FOLLOWING  6 CONDUITS

         1030     1630     1600     1602     1570     8130

WATER SURFACE ELEVATIONS WILL BE PLOTTED FOR THE FOLLOWING   6 JUNCTIONS

        80608    16009    16109    15009    82309    80408

FLOW RATE WILL BE PLOTTED FOR THE FOLLOWING   6 CONDUITS

         1030     1630     1600     1602     1570     8130
```

EXTRAN USER'S MANUAL EXAMPLE PROBLEM 1
BASIC PIPE SYSTEM FROM FIGURE 3-1

```
**************************************************
*                   CONDUIT DATA                 *
**************************************************
```

INP NUM	CONDUIT NUMBER	LENGTH (FT)	CONDUIT CLASS	AREA (SQ FT)	MANNING COEF.	MAX WIDTH (FT)	DEPTH (FT)	JUNCTIONS AT THE ENDS		INVERT HEIGHT ABOVE JUNCTIONS		TRAPEZOID SIDE SLOPES	
1	8040	1800.	CIRCULAR	12.57	0.01500	4.00	4.00	80408	80608				
2	8060	2075.	CIRCULAR	12.57	0.01500	4.00	4.00	80608	82309	0.00	2.20		
3	8100	5100.	CIRCULAR	15.90	0.01500	4.50	4.50	81009	81309				
4	8130	3500.	CIRCULAR	15.90	0.01500	4.50	4.50	81309	15009				
5	1030	4500.	TRAPEZOID	243.00	0.01600	0.01	9.00	10309	10208			3.00	3.00
6	1570	5000.	CIRCULAR	23.76	0.01540	5.50	5.50	15009	16009				
7	1600	500.	CIRCULAR	28.27	0.01500	6.00	6.00	16009	16109				
8	1630	300.	TRAPEZOID	243.00	0.01500	0.01	9.00	16009	10309			3.00	3.00
9	1602	5000.	CIRCULAR	19.63	0.03400	5.00	5.00	82309	16109				

===> WARNING !! THE UPSTREAM AND DOWNSTREAM JUNCTIONS FOR THE FOLLOWING CONDUITS HAVE BEEN REVERSED TO CORRESPOND TO THE POSITIVE FLOW AND DECREASING SLOPE EXTRAN CONVENTION. A NEGATIVE FLOW IN THE OUTPUT THUS MEANS THE FLOW WAS FROM YOUR ORIGINAL UPSTREAM JUNCTION TO YOUR ORIGINAL DOWNSTREAM JUNCTION. ANY INITIAL FLOW HAS BEEN MULTIPLIED BY -1.

1. CONDUIT #... 1600 HAS BEEN CHANGED.

```
**************************************************
*                  JUNCTION DATA                 *
**************************************************
```

INP NUM	JUNCTION NUMBER	GROUND ELEV.	CROWN ELEV.	INVERT ELEV.	QINST CFS	INITIAL DEPTH(FT)	CONNECTING CONDUITS		
1	80408	138.00	128.60	124.60	0.00	0.00	8040		
2	80608	135.00	122.30	118.30	0.00	0.00	8040	8060	
3	81009	137.00	132.70	128.20	0.00	0.00	8100		
4	81309	130.00	122.00	117.50	0.00	0.00	8100	8130	
5	82309	155.00	118.50	112.30	0.00	0.00	8060	1602	
6	10208	100.00	98.90	89.90	0.00	0.00	1030		
7	10309	111.00	110.60	101.60	0.00	0.00	1030	1630	
8	15009	125.00	117.00	111.50	0.00	0.00	8130	1570	
9	16009	120.00	111.00	102.00	0.00	0.00	1570	1600	1630
10	16109	125.00	108.80	102.80	0.00	0.00	1600	1602	

```
************************************************
*        FREE OUTFALL DATA (DATA GROUP I1)     *
*       BOUNDARY CONDITION ON DATA GROUP J1    *
************************************************

OUTFALL AT JUNCTION....   10208 HAS BOUNDARY CONDITION NUMBER...     1


************************************************
*       INTERNAL CONNECTIVITY INFORMATION      *
************************************************

        CONDUIT    JUNCTION    JUNCTION
        -------    --------    --------
        90010       10208          0

***************************************************
*       BOUNDARY CONDITON INFORMATION             *
*                DATA GROUPS J1-J4                *
***************************************************


BC NUMBER..       1 HAS NO CONTROL WATER SURFACE.


*********************************
*   INITIAL MODEL CONDITION     *
* INITIAL TIME =      0.00 HOURS *
*********************************

JUNCTION / DEPTH  / ELEVATION    ===> "*" JUNCTION IS SURCHARGED.
   80408/  0.00 /  124.60    80608/  0.00 /  118.30    81009/  0.00 /  128.20
   81309/  0.00 /  117.50    82309/  0.00 /  112.30    10208/  0.00 /   89.90
   10309/  0.00 /  101.60    15009/  0.00 /  111.50    16009/  0.00 /  102.00
   16109/  0.00 /  102.80

 CONDUIT/      FLOW   ===> "*" CONDUIT USES THE NORMAL FLOW OPTION.
    8040/      0.00      8060/      0.00      8100/      0.00      8130/      0.00
    1030/      0.00      1570/      0.00      1600/      0.00      1630/      0.00
    1602/      0.00     90010/      0.00

 CONDUIT/  VELOCITY
    8040/      0.00      8060/      0.00      8100/      0.00      8130/      0.00
    1030/      0.00      1570/      0.00      1600/      0.00      1630/      0.00
    1602/      0.00
```

```
-------------------------------------------------------------------------
===> SYSTEM INFLOWS (DATA GROUP K3) AT     0.00 HOURS ( JUNCTION / INFLOW,CFS )

   82309/ 0.0E-01     80408/ 0.0E-01     81009/ 0.0E-01
-------------------------------------------------------------------------
===> SYSTEM INFLOWS (DATA GROUP K3) AT     0.25 HOURS ( JUNCTION / INFLOW,CFS )

   82309/ 4.0E+01     80408/ 4.5E+01     81009/ 5.0E+01
-------------------------------------------------------------------------

CYCLE    45      TIME    0 HRS - 15.00 MIN

JUNCTION / DEPTH  / ELEVATION    ===> "*" JUNCTION IS SURCHARGED.
   80408/   2.87 /   127.47     80608/   1.26 /   119.56     81009/   2.27 /   130.47
   81309/   0.35 /   117.85     82309/   2.12 /   114.42     10208/   0.00 /    89.90
   10309/   0.00 /   101.60     15009/   0.00 /   111.50     16009/   0.00 /   102.00
   16109/   0.16 /   102.96

 CONDUIT/       FLOW   ===> "*" CONDUIT USES THE NORMAL FLOW OPTION.
    8040/      39.98        8060/       8.63      8100/      15.77       8130/        0.25
    1030/       0.00        1570/       0.00      1600/       0.08       1630/        0.00
    1602/       5.76       90010/       0.00
-------------------------------------------------------------------------
===> SYSTEM INFLOWS (DATA GROUP K3) AT     3.00 HOURS ( JUNCTION / INFLOW,CFS )

   82309/ 4.0E+01     80408/ 4.5E+01     81009/ 5.0E+01
-------------------------------------------------------------------------

CYCLE    90      TIME    0 HRS - 30.00 MIN

JUNCTION / DEPTH  / ELEVATION    ===> "*" JUNCTION IS SURCHARGED.
   80408/   2.26 /   126.86     80608/   2.78 /   121.08     81009/   3.32 /   131.52
   81309/   2.12 /   119.62     82309/   6.00 /   118.30     10208/   0.00 /    89.90
   10309/   0.05 /   101.65     15009/   0.37 /   111.87     16009/   0.42 /   102.42
   16109/   1.57 /   104.37

 CONDUIT/       FLOW   ===> "*" CONDUIT USES THE NORMAL FLOW OPTION.
    8040/      45.09*       8060/      44.05*     8100/      54.59       8130/       13.31
    1030/       0.00        1570/       1.08*     1600/      11.87       1630/        0.23
    1602/      38.51       90010/       0.00

CYCLE   135      TIME    0 HRS - 45.00 MIN

JUNCTION / DEPTH  / ELEVATION    ===> "*" JUNCTION IS SURCHARGED.
   80408/  12.75*/   137.35     80608/  16.70*/   135.00     81009/   2.72 /   130.92
   81309/   3.47 /   120.97     82309/  21.66*/   133.96     10208/   1.30 /    91.20
   10309/   1.59 /   103.19     15009/   1.47 /   112.97     16009/   2.75 /   104.75
   16109/   2.87 /   105.67
```

```
 CONDUIT/      FLOW   ===> "*" CONDUIT USES THE NORMAL FLOW OPTION.
   8040/      45.00      8060/     28.00      8100/     52.99*     8130/      44.21
   1030/      23.88      1570/     19.12*     1600/     70.31      1630/      74.78
   1602/      68.00     90010/     23.88

CUMULATIVE OVERFLOW VOLUME FROM NODE    80608  1.03E+04 CU.FT.  FLOOD FLOW =       17.0 CFS AT HOUR   0.75

CYCLE   180       TIME    1 HRS -  0.00 MIN

JUNCTION / DEPTH  / ELEVATION    ===>  "*" JUNCTION IS SURCHARGED.
  80408/  12.75*/   137.35     80608/  16.70*/   135.00     81009/   2.63 /   130.83
  81309/   3.47 /   120.97     82309/  21.66*/   133.96     10208/   2.27 /    92.17
  10309/   2.61 /   104.21     15009/   2.27 /   113.77     16009/   2.85 /   104.85
  16109/   2.86 /   105.66

 CONDUIT/      FLOW   ===> "*" CONDUIT USES THE NORMAL FLOW OPTION.
   8040/      45.00      8060/     27.93      8100/     50.24*     8130/      54.59
   1030/      94.58      1570/     43.75*     1600/     67.93      1630/     109.42
   1602/      67.93     90010/     94.58

CUMULATIVE OVERFLOW VOLUME FROM NODE    80608  2.57E+04 CU.FT.  FLOOD FLOW =       17.1 CFS AT HOUR   1.00

CYCLE   225       TIME    1 HRS - 15.00 MIN

JUNCTION / DEPTH  / ELEVATION    ===>  "*" JUNCTION IS SURCHARGED.
  80408/  12.75*/   137.35     80608/  16.70*/   135.00     81009/   2.62 /   130.82
  81309/   3.25 /   120.75     82309/  21.65*/   133.95     10208/   2.46 /    92.36
  10309/   2.80 /   104.40     15009/   2.49 /   113.99     16009/   2.94 /   104.94
  16109/   2.88 /   105.68

 CONDUIT/      FLOW   ===> "*" CONDUIT USES THE NORMAL FLOW OPTION.
   8040/      45.00      8060/     28.01      8100/     50.02*     8130/      53.77
   1030/     115.37      1570/     52.14*     1600/     67.86      1630/     119.11
   1602/      68.01     90010/    115.37

CUMULATIVE OVERFLOW VOLUME FROM NODE    80608  4.10E+04 CU.FT.  FLOOD FLOW =       17.0 CFS AT HOUR   1.25

CYCLE   270       TIME    1 HRS - 30.00 MIN

JUNCTION / DEPTH  / ELEVATION    ===>  "*" JUNCTION IS SURCHARGED.
  80408/  12.75*/   137.35     80608/  16.70*/   135.00     81009/   2.62 /   130.82
  81309/   3.11 /   120.61     82309/  21.65*/   133.95     10208/   2.51 /    92.41
  10309/   2.84 /   104.44     15009/   2.50 /   114.00     16009/   2.95 /   104.95
  16109/   2.89 /   105.69

 CONDUIT/      FLOW   ===> "*" CONDUIT USES THE NORMAL FLOW OPTION.
   8040/      45.00      8060/     28.06      8100/     50.00*     8130/      51.71
   1030/     120.11      1570/     52.38*     1600/     68.04      1630/     120.49
   1602/      68.06     90010/    120.11
```

```
CUMULATIVE OVERFLOW VOLUME FROM NODE     80608  5.63E+04 CU.FT.  FLOOD FLOW =       16.9 CFS AT HOUR   1.50

CYCLE   315       TIME    1 HRS - 45.00 MIN

JUNCTION / DEPTH  / ELEVATION    ===>  "*" JUNCTION IS SURCHARGED.
    80408/  12.75*/   137.35     80608/  16.70*/   135.00     81009/   2.62 /   130.82
    81309/   3.06 /   120.56     82309/  21.65*/   133.95     10208/   2.50 /    92.40
    10309/   2.84 /   104.44     15009/   2.47 /   113.97     16009/   2.94 /   104.94
    16109/   2.88 /   105.68

  CONDUIT/       FLOW   ===> "*" CONDUIT USES THE NORMAL FLOW OPTION.
     8040/      45.00        8060/      28.05      8100/      50.00*      8130/      50.54
     1030/     119.81        1570/      51.23*     1600/      68.07       1630/     119.49
     1602/      68.05       90010/     119.81

CUMULATIVE OVERFLOW VOLUME FROM NODE     80608  7.16E+04 CU.FT.  FLOOD FLOW =       16.9 CFS AT HOUR   1.75

CYCLE   360       TIME    2 HRS -  0.00 MIN

JUNCTION / DEPTH  / ELEVATION    ===>  "*" JUNCTION IS SURCHARGED.
    80408/  12.75*/   137.35     80608/  16.70*/   135.00     81009/   2.62 /   130.82
    81309/   3.05 /   120.55     82309/  21.65*/   133.95     10208/   2.50 /    92.40
    10309/   2.83 /   104.43     15009/   2.45 /   113.95     16009/   2.94 /   104.94
    16109/   2.88 /   105.68

  CONDUIT/       FLOW   ===> "*" CONDUIT USES THE NORMAL FLOW OPTION.
     8040/      45.00        8060/      28.04      8100/      50.00*      8130/      50.09
     1030/     118.88        1570/      50.43*     1600/      68.06       1630/     118.61
     1602/      68.04       90010/     118.88

CUMULATIVE OVERFLOW VOLUME FROM NODE     80608  8.68E+04 CU.FT.  FLOOD FLOW =       17.0 CFS AT HOUR   2.00

CYCLE   405       TIME    2 HRS - 15.00 MIN

JUNCTION / DEPTH  / ELEVATION    ===>  "*" JUNCTION IS SURCHARGED.
    80408/  12.75*/   137.35     80608/  16.70*/   135.00     81009/   2.62 /   130.82
    81309/   3.05 /   120.55     82309/  21.65*/   133.95     10208/   2.49 /    92.39
    10309/   2.83 /   104.43     15009/   2.44 /   113.94     16009/   2.93 /   104.93
    16109/   2.88 /   105.68

  CONDUIT/       FLOW   ===> "*" CONDUIT USES THE NORMAL FLOW OPTION.
     8040/      45.00        8060/      28.04      8100/      50.00*      8130/      49.97
     1030/     118.31        1570/      50.09*     1600/      68.04       1630/     118.18
     1602/      68.04       90010/     118.31
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CUMULATIVE OVERFLOW VOLUME FROM NODE     80608  1.02E+05 CU.FT.  FLOOD FLOW =       17.0 CFS AT HOUR   2.25

CYCLE  450      TIME    2 HRS - 30.00 MIN

JUNCTION / DEPTH  / ELEVATION    ===)  "*" JUNCTION IS SURCHARGED.
   80408/  12.75*/   137.35     80608/  16.70*/   135.00     81009/   2.62 /   130.82
   81309/   3.05 /   120.55     82309/  21.65*/   133.95     10208/   2.49 /    92.39
   10309/   2.83 /   104.43     15009/   2.44 /   113.94     16009/   2.93 /   104.93
   16109/   2.88 /   105.68

  CONDUIT/       FLOW   ===) "*" CONDUIT USES THE NORMAL FLOW OPTION.
    8040/      45.00       8060/       28.03       8100/      50.00*      8130/       49.97
    1030/     118.08       1570/       49.99*      1600/      68.04       1630/      118.04
    1602/      68.03      90010/      118.08

CUMULATIVE OVERFLOW VOLUME FROM NODE     80608  1.17E+05 CU.FT.  FLOOD FLOW =       17.0 CFS AT HOUR   2.50

CYCLE  495      TIME    2 HRS - 45.00 MIN

JUNCTION / DEPTH  / ELEVATION    ===)  "*" JUNCTION IS SURCHARGED.
   80408/  12.75*/   137.35     80608/  16.70*/   135.00     81009/   2.62 /   130.82
   81309/   3.05 /   120.55     82309/  21.65*/   133.95     10208/   2.49 /    92.39
   10309/   2.83 /   104.43     15009/   2.44 /   113.94     16009/   2.93 /   104.93
   16109/   2.88 /   105.68

  CONDUIT/       FLOW   ===) "*" CONDUIT USES THE NORMAL FLOW OPTION.
    8040/      45.00       8060/       28.03       8100/      50.00*      8130/       49.98
    1030/     118.02       1570/       49.98*      1600/      68.03       1630/      118.02
    1602/      68.03      90010/      118.02

CUMULATIVE OVERFLOW VOLUME FROM NODE     80608  1.33E+05 CU.FT.  FLOOD FLOW =       17.0 CFS AT HOUR   2.75

CYCLE  540      TIME    3 HRS -  0.00 MIN

JUNCTION / DEPTH  / ELEVATION    ===)  "*" JUNCTION IS SURCHARGED.
   80408/  12.75*/   137.35     80608/  16.70*/   135.00     81009/   2.62 /   130.82
   81309/   3.05 /   120.55     82309/  21.65*/   133.95     10208/   2.49 /    92.39
   10309/   2.83 /   104.43     15009/   2.44 /   113.94     16009/   2.93 /   104.93
   16109/   2.88 /   105.68

  CONDUIT/       FLOW   ===) "*" CONDUIT USES THE NORMAL FLOW OPTION.
    8040/      45.00       8060/       28.03       8100/      50.00*      8130/       49.99
    1030/     118.02       1570/       49.99*      1600/      68.03       1630/      118.02
    1602/      68.03      90010/      118.02

CUMULATIVE OVERFLOW VOLUME FROM NODE     80608  1.48E+05 CU.FT.  FLOOD FLOW =       17.0 CFS AT HOUR   3.00
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
===) SYSTEM INFLOWS (DATA GROUP K3) AT     3.25 HOURS ( JUNCTION / INFLOW,CFS )

   82309/ 0.0E-01     80408/ 0.0E-01     81009/ 0.0E-01
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
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CYCLE  585      TIME    3 HRS - 15.00 MIN

JUNCTION / DEPTH  / ELEVATION    ===> "*" JUNCTION IS SURCHARGED.
   80408/  0.90 /  125.50     80608/  2.70 /  121.00     81009/  1.56 /  129.76
   81309/  2.61 /  120.11     82309/  5.94 /  118.24     10208/  2.40 /   92.30
   10309/  2.76 /  104.36     15009/  2.36 /  113.86     16009/  2.77 /  104.77
   16109/  2.46 /  105.26

 CONDUIT/       FLOW  ===> "*" CONDUIT USES THE NORMAL FLOW OPTION.
   8040/       8.69*      8060/      39.71      8100/      20.52*     8130/      41.94
   1030/     108.62       1570/      47.46*     1600/      48.69      1630/     100.63
   1602/      43.67      90010/     108.62
---------------------------------------
===> SYSTEM INFLOWS (DATA GROUP K3) AT    12.00 HOURS ( JUNCTION / INFLOW,CFS )

   82309/ 0.0E-01     80408/ 0.0E-01     81009/ 0.0E-01
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CYCLE  630      TIME    3 HRS - 30.00 MIN

JUNCTION / DEPTH  / ELEVATION    ===> "*" JUNCTION IS SURCHARGED.
   80408/  0.22 /  124.82     80608/  0.85 /  119.15     81009/  0.71 /  128.91
   81309/  1.61 /  119.11     82309/  4.11 /  116.41     10208/  2.20 /   92.10
   10309/  2.55 /  104.15     15009/  1.93 /  113.43     16009/  2.52 /  104.52
   16109/  2.16 /  104.96

 CONDUIT/       FLOW  ===> "*" CONDUIT USES THE NORMAL FLOW OPTION.
   8040/       0.44*      8060/       5.32*     8100/       4.32*     8130/      19.62*
   1030/      87.33       1570/      32.77*     1600/      38.47      1630/      77.33
   1602/      32.86      90010/      87.33

CYCLE  675      TIME    3 HRS - 45.00 MIN

JUNCTION / DEPTH  / ELEVATION    ===> "*" JUNCTION IS SURCHARGED.
   80408/  0.11 /  124.71     80608/  0.44 /  118.74     81009/  0.44 /  128.64
   81309/  1.06 /  118.56     82309/  2.79 /  115.09     10208/  1.91 /   91.81
   10309/  2.26 /  103.86     15009/  1.42 /  112.92     16009/  2.17 /  104.17
   16109/  1.74 /  104.54

 CONDUIT/       FLOW  ===> "*" CONDUIT USES THE NORMAL FLOW OPTION.
   8040/       0.12*      8060/       1.37*     8100/       1.55*     8130/       8.63*
   1030/      61.59       1570/      18.10*     1600/      25.65      1630/      50.47
   1602/      19.04      90010/      61.59

CYCLE  720      TIME    4 HRS -  0.00 MIN

JUNCTION / DEPTH  / ELEVATION    ===> "*" JUNCTION IS SURCHARGED.
   80408/  0.06 /  124.66     80608/  0.33 /  118.63     81009/  0.30 /  128.50
   81309/  0.75 /  118.25     82309/  1.87 /  114.17     10208/  1.60 /   91.50
   10309/  1.94 /  103.54     15009/  1.06 /  112.56     16009/  1.82 /  103.82
   16109/  1.32 /  104.12
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 CONDUIT/       FLOW   ===> "*" CONDUIT USES THE NORMAL FLOW OPTION.
   8040/        0.05*       8060/       0.45       8100/       0.72*       8130/       4.33*
   1030/       40.05        1570/      10.11*      1600/      15.36        1630/      31.17
   1602/        9.80       90010/      40.05

CYCLE  765      TIME    4 HRS - 15.00 MIN

JUNCTION / DEPTH  / ELEVATION    ===>  "*" JUNCTION IS SURCHARGED.
   80408/   0.04 /   124.64      80608/   0.27 /   118.57      81009/   0.22 /   128.42
   81309/   0.57 /   118.07      82309/   1.33 /   113.63      10208/   1.33 /    91.23
   10309/   1.66 /   103.26      15009/   0.82 /   112.32      16009/   1.51 /   103.51
   16109/   0.98 /   103.78

 CONDUIT/       FLOW   ===> "*" CONDUIT USES THE NORMAL FLOW OPTION.
   8040/        0.03*       8060/       0.32       8100/       0.38*       8130/       2.42*
   1030/       25.53        1570/       6.00*      1600/       8.60*       1630/      19.08
   1602/        5.19       90010/      25.53

CYCLE  810      TIME    4 HRS - 30.00 MIN

JUNCTION / DEPTH  / ELEVATION    ===>  "*" JUNCTION IS SURCHARGED.
   80408/   0.03 /   124.63      80608/   0.23 /   118.53      81009/   0.17 /   128.37
   81309/   0.45 /   117.95      82309/   1.01 /   113.31      10208/   1.13 /    91.03
   10309/   1.42 /   103.02      15009/   0.66 /   112.16      16009/   1.26 /   103.26
   16109/   0.76 /   103.56

 CONDUIT/       FLOW   ===> "*" CONDUIT USES THE NORMAL FLOW OPTION.
   8040/        0.01*       8060/       0.19       8100/       0.22*       8130/       1.47*
   1030/       16.76        1570/       3.75*      1600/       5.07*       1630/      12.04
   1602/        3.00       90010/      16.76

CYCLE  855      TIME    4 HRS - 45.00 MIN

JUNCTION / DEPTH  / ELEVATION    ===>  "*" JUNCTION IS SURCHARGED.
   80408/   0.02 /   124.62      80608/   0.21 /   118.51      81009/   0.14 /   128.34
   81309/   0.36 /   117.86      82309/   0.79 /   113.09      10208/   0.94 /    90.84
   10309/   1.23 /   102.83      15009/   0.54 /   112.04      16009/   1.07 /   103.07
   16109/   0.61 /   103.41

 CONDUIT/       FLOW   ===> "*" CONDUIT USES THE NORMAL FLOW OPTION.
   8040/        0.01*       8060/       0.14       8100/       0.16*       8130/       0.94*
   1030/       10.91        1570/       2.50*      1600/       3.20*       1630/       8.00
   1602/        1.86       90010/      10.91

CYCLE  900      TIME    5 HRS -  0.00 MIN

JUNCTION / DEPTH  / ELEVATION    ===>  "*" JUNCTION IS SURCHARGED.
   80408/   0.01 /   124.61      80608/   0.19 /   118.49      81009/   0.12 /   128.32
   81309/   0.30 /   117.80      82309/   0.65 /   112.95      10208/   0.81 /    90.71
   10309/   1.09 /   102.69      15009/   0.45 /   111.95      16009/   0.93 /   102.93
   16109/   0.50 /   103.30
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 CONDUIT/      FLOW   ===> "*" CONDUIT USES THE NORMAL FLOW OPTION.
    8040/      0.01*      8060/      0.11      8100/      0.12*      8130/      0.66*
    1030/      7.67       1570/      1.71*     1600/      2.10*      1630/      5.44*
    1602/      1.23      90010/      7.67

CYCLE  945     TIME    5 HRS - 15.00 MIN

JUNCTION / DEPTH  / ELEVATION    ===>  "*" JUNCTION IS SURCHARGED.
    80408/  0.01 /  124.61     80608/  0.17 /  118.47     81009/  0.10 /  128.30
    81309/  0.26 /  117.76     82309/  0.54 /  112.84     10208/  0.73 /   90.63
    10309/  0.96 /  102.56     15009/  0.39 /  111.89     16009/  0.82 /  102.82
    16109/  0.42 /  103.22

 CONDUIT/      FLOW   ===> "*" CONDUIT USES THE NORMAL FLOW OPTION.
    8040/      0.00*      8060/      0.09      8100/      0.09*      8130/      0.47*
    1030/      5.62       1570/      1.25*     1600/      1.47*      1630/      3.88*
    1602/      0.85      90010/      5.62

CYCLE  990     TIME    5 HRS - 30.00 MIN

JUNCTION / DEPTH  / ELEVATION    ===>  "*" JUNCTION IS SURCHARGED.
    80408/  0.01 /  124.61     80608/  0.16 /  118.46     81009/  0.08 /  128.28
    81309/  0.22 /  117.72     82309/  0.46 /  112.76     10208/  0.60 /   90.50
    10309/  0.86 /  102.46     15009/  0.33 /  111.83     16009/  0.73 /  102.73
    16109/  0.36 /  103.16

 CONDUIT/      FLOW   ===> "*" CONDUIT USES THE NORMAL FLOW OPTION.
    8040/      0.00*      8060/      0.07      8100/      0.07*      8130/      0.34*
    1030/      3.85       1570/      0.93*     1600/      1.06*      1630/      2.88*
    1602/      0.60      90010/      3.85

CYCLE  1035    TIME    5 HRS - 45.00 MIN

JUNCTION / DEPTH  / ELEVATION    ===>  "*" JUNCTION IS SURCHARGED.
    80408/  0.01 /  124.61     80608/  0.14 /  118.44     81009/  0.07 /  128.27
    81309/  0.20 /  117.70     82309/  0.40 /  112.70     10208/  0.52 /   90.42
    10309/  0.79 /  102.39     15009/  0.29 /  111.79     16009/  0.66 /  102.66
    16109/  0.31 /  103.11

 CONDUIT/      FLOW   ===> "*" CONDUIT USES THE NORMAL FLOW OPTION.
    8040/      0.00*      8060/      0.06      8100/      0.05*      8130/      0.26*
    1030/      2.94       1570/      0.70*     1600/      0.78*      1630/      2.19*
    1602/      0.45      90010/      2.94

CYCLE  1080    TIME    6 HRS -  0.00 MIN

JUNCTION / DEPTH  / ELEVATION    ===>  "*" JUNCTION IS SURCHARGED.
    80408/  0.01 /  124.61     80608/  0.13 /  118.43     81009/  0.06 /  128.26
    81309/  0.18 /  117.68     82309/  0.35 /  112.65     10208/  0.47 /   90.37
    10309/  0.73 /  102.33     15009/  0.26 /  111.76     16009/  0.60 /  102.60
    16109/  0.27 /  103.07
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  CONDUIT/      FLOW   ===> "*" CONDUIT USES THE NORMAL FLOW OPTION.
    8040/       0.00*     8060/       0.05      8100/       0.04*      8130/       0.20*
    1030/       2.33      1570/       0.53*     1600/       0.58*      1630/       1.69*
    1602/       0.35     90010/       2.33

CYCLE  1125       TIME    6 HRS - 15.00 MIN

JUNCTION / DEPTH  / ELEVATION    ===>  "*" JUNCTION IS SURCHARGED.
   80408/   0.00 /   124.60     80608/   0.12 /   118.42     81009/   0.05 /   128.25
   81309/   0.16 /   117.66     82309/   0.32 /   112.62     10208/   0.44 /    90.34
   10309/   0.68 /   102.28     15009/   0.23 /   111.73     16009/   0.55 /   102.55
   16109/   0.24 /   103.04

  CONDUIT/      FLOW   ===> "*" CONDUIT USES THE NORMAL FLOW OPTION.
    8040/       0.00*     8060/       0.05      8100/       0.03*      8130/       0.17*
    1030/       1.88      1570/       0.42*     1600/       0.45*      1630/       1.33*
    1602/       0.27     90010/       1.88

CYCLE  1170       TIME    6 HRS - 30.00 MIN

JUNCTION / DEPTH  / ELEVATION    ===>  "*" JUNCTION IS SURCHARGED.
   80408/   0.00 /   124.60     80608/   0.11 /   118.41     81009/   0.05 /   128.25
   81309/   0.14 /   117.64     82309/   0.28 /   112.58     10208/   0.41 /    90.31
   10309/   0.62 /   102.22     15009/   0.21 /   111.71     16009/   0.50 /   102.50
   16109/   0.22 /   103.02

  CONDUIT/      FLOW   ===> "*" CONDUIT USES THE NORMAL FLOW OPTION.
    8040/       0.00*     8060/       0.04      8100/       0.03*      8130/       0.15*
    1030/       1.53      1570/       0.34*     1600/       0.37*      1630/       1.07*
    1602/       0.22     90010/       1.53

CYCLE  1215       TIME    6 HRS - 45.00 MIN

JUNCTION / DEPTH  / ELEVATION    ===>  "*" JUNCTION IS SURCHARGED.
   80408/   0.00 /   124.60     80608/   0.11 /   118.41     81009/   0.04 /   128.24
   81309/   0.13 /   117.63     82309/   0.26 /   112.56     10208/   0.39 /    90.29
   10309/   0.58 /   102.18     15009/   0.19 /   111.69     16009/   0.47 /   102.47
   16109/   0.19 /   102.99

  CONDUIT/      FLOW   ===> "*" CONDUIT USES THE NORMAL FLOW OPTION.
    8040/       0.00*     8060/       0.04      8100/       0.02*      8130/       0.13*
    1030/       1.27      1570/       0.30*     1600/       0.31*      1630/       0.89*
    1602/       0.17     90010/       1.27

CYCLE  1260       TIME    7 HRS -  0.00 MIN

JUNCTION / DEPTH  / ELEVATION    ===>  "*" JUNCTION IS SURCHARGED.
   80408/   0.00 /   124.60     80608/   0.10 /   118.40     81009/   0.04 /   128.24
   81309/   0.12 /   117.62     82309/   0.24 /   112.54     10208/   0.37 /    90.27
   10309/   0.53 /   102.13     15009/   0.18 /   111.68     16009/   0.44 /   102.44
   16109/   0.17 /   102.97
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CONDUIT/      FLOW   ===> "*" CONDUIT USES THE NORMAL FLOW OPTION.
   8040/      0.00*     8060/      0.03      8100/      0.02*     8130/      0.11*
   1030/      1.07      1570/      0.26*     1600/      0.26*     1630/      0.76*
   1602/      0.14     90010/      1.07

CYCLE  1305      TIME    7 HRS - 15.00 MIN

JUNCTION / DEPTH  / ELEVATION    ===>  "*" JUNCTION IS SURCHARGED.
   80408/   0.00 /   124.60     80608/   0.09 /   118.39     81009/   0.03 /   128.23
   81309/   0.11 /   117.61     82309/   0.22 /   112.52     10208/   0.29 /    90.19
   10309/   0.50 /   102.10     15009/   0.16 /   111.66     16009/   0.42 /   102.42
   16109/   0.16 /   102.96

CONDUIT/      FLOW   ===> "*" CONDUIT USES THE NORMAL FLOW OPTION.
   8040/      0.00*     8060/      0.03      8100/      0.02*     8130/      0.09*
   1030/      0.76      1570/      0.23*     1600/      0.22*     1630/      0.65*
   1602/      0.12     90010/      0.76

CYCLE  1350      TIME    7 HRS - 30.00 MIN

JUNCTION / DEPTH  / ELEVATION    ===>  "*" JUNCTION IS SURCHARGED.
   80408/   0.00 /   124.60     80608/   0.09 /   118.39     81009/   0.03 /   128.23
   81309/   0.10 /   117.60     82309/   0.20 /   112.50     10208/   0.24 /    90.14
   10309/   0.49 /   102.09     15009/   0.15 /   111.65     16009/   0.39 /   102.39
   16109/   0.14 /   102.94

CONDUIT/      FLOW   ===> "*" CONDUIT USES THE NORMAL FLOW OPTION.
   8040/      0.00*     8060/      0.03      8100/      0.01*     8130/      0.08*
   1030/      0.63      1570/      0.20*     1600/      0.19*     1630/      0.56*
   1602/      0.10     90010/      0.63

CYCLE  1395      TIME    7 HRS - 45.00 MIN

JUNCTION / DEPTH  / ELEVATION    ===>  "*" JUNCTION IS SURCHARGED.
   80408/   0.00 /   124.60     80608/   0.08 /   118.38     81009/   0.03 /   128.23
   81309/   0.09 /   117.59     82309/   0.19 /   112.49     10208/   0.21 /    90.11
   10309/   0.48 /   102.08     15009/   0.14 /   111.64     16009/   0.38 /   102.38
   16109/   0.13 /   102.93

CONDUIT/      FLOW   ===> "*" CONDUIT USES THE NORMAL FLOW OPTION.
   8040/      0.00*     8060/      0.03      8100/      0.01*     8130/      0.07*
   1030/      0.55      1570/      0.18*     1600/      0.16*     1630/      0.49*
   1602/      0.09     90010/      0.55

CYCLE  1440      TIME    8 HRS -  0.00 MIN

JUNCTION / DEPTH  / ELEVATION    ===>  "*" JUNCTION IS SURCHARGED.
   80408/   0.00 /   124.60     80608/   0.08 /   118.38     81009/   0.02 /   128.22
   81309/   0.09 /   117.59     82309/   0.18 /   112.48     10208/   0.19 /    90.09
   10309/   0.47 /   102.07     15009/   0.13 /   111.63     16009/   0.36 /   102.36
   16109/   0.12 /   102.92
```

```
 CONDUIT/       FLOW   ===> "*" CONDUIT USES THE NORMAL FLOW OPTION.
   8040/        0.00*       8060/       0.02       8100/       0.01*      8130/        0.07*
   1030/        0.49        1570/       0.16*      1600/       0.14*      1630/        0.43*
   1602/        0.08       90010/       0.49

********************************
*     FINAL MODEL CONDITION     *
*  FINAL TIME =      8.00 HOURS *
********************************

JUNCTION / DEPTH  / ELEVATION     ===>  "*" JUNCTION IS SURCHARGED.
   80408/   0.00 /   124.60      80608/   0.08 /   118.38      81009/   0.02 /   128.22
   81309/   0.09 /   117.59      82309/   0.18 /   112.48      10208/   0.19 /    90.09
   10309/   0.47 /   102.07      15009/   0.13 /   111.63      16009/   0.36 /   102.36
   16109/   0.12 /   102.92

 CONDUIT/       FLOW   ===> "*" CONDUIT USES THE NORMAL FLOW OPTION.
   8040/        0.00*       8060/       0.02       8100/       0.01*      8130/        0.07*
   1030/        0.49        1570/       0.16*      1600/       0.14*      1630/        0.43*
   1602/        0.08       90010/       0.49

 CONDUIT/   VELOCITY
   8040/        0.01        8060/       0.48       8100/       0.17       8130/        0.52
   1030/       -1.39        1570/       0.39       1600/       0.34       1630/        0.83
   1602/        0.41

 CONDUIT/ CROSS SECTIONAL AREA
   8040/        0.04        8060/       0.05       8100/       0.07       8130/        0.13
   1030/        0.36        1570/       0.40       1600/       0.41       1630/        0.52
   1602/        0.20

 CONDUIT/ HYDRAULIC RADIUS
   8040/        0.03        8060/       0.04       8100/       0.04       8130/        0.07
   1030/        0.16        1570/       0.16       1600/       0.16       1630/        0.20
   1602/        0.10

 CONDUIT/ UPSTREAM/ DOWNSTREAM ELEVATION
   8040/  124.60/  118.38     8060/  118.38/  114.51     8100/  128.22/  117.59
   8130/  117.59/  111.63     1030/  102.07/   90.09     1570/  111.63/  102.36
   1600/  102.92/  102.36     1630/  102.36/  102.07     1602/  112.48/  102.92
```

```
*****************************************************
*            SURCHARGE ITERATION SUMMARY            *
*****************************************************

MAXIMUM NUMBER OF ITERATIONS IN A TIME STEP.....       31
TOTAL NUMBER OF ITERATIONS IN THE SIMULATION....     3009
AVERAGE NUMBER OF ITERATIONS DURING SIMULATION..     2.09
SURCHARGE ITERATIONS DURING THE SIMULATION......      129
MAXIMUM SURCHARGE FLOW ERROR DURING SIMULATION.. 2.95E+00 CFS
TOTAL NUMBER OF TIME STEPS DURING SIMULATION....     1440
```

```
1
************************************************
*       CONDUIT COURANT CONDITION SUMMARY      *
* TIME IN MINUTES DELT > COURANT TIME STEP     *
************************************************
* SEE BELOW FOR EXPLANATION OF COURANT TIME STEP. *
* THIS TIME DOES NOT INCLUDE TIME THE CONDUIT IS  *
*     SURCHARGED OR USING THE NORMAL FLOW OPTION.*
************************************************
```

CONDUIT #	TIME(MN)	CONDUIT #	TIME(MN)	CONDUIT #	TIME(MN)	CONDUIT #	TIME(MN)
8040	0.33	8060	0.00	8100	0.33	8130	0.00
1030	0.00	1570	0.00	1600	0.00	1630	0.00
1602	0.33						

```
1
**********************************************
*       CONDUIT COURANT CONDITION SUMMARY    *
**********************************************
* COURANT   =            CONDUIT LENGTH      *
* TIME STEP = ------------------------------ *
*           VELOCITY + SQRT(GRVT*AREA/WIDTH) *
**********************************************
* AVERAGE COURANT CONDITION TIME STEP(SECONDS) *
**********************************************
```

CONDUIT #	TIME(SEC)	CONDUIT #	TIME(SEC)	CONDUIT #	TIME(SEC)	CONDUIT #	TIME(SEC)
8040	494.92	8060	473.58	8100	1169.55	8130	717.09
1030	658.86	1570	906.64	1600	85.41	1630	54.27
1602	751.78						

```
***************************************************
* EXTRAN CONTINUITY BALANCE AT THE LAST TIME STEP *
***************************************************

**********************************************
* JUNCTION INFLOW, OUTFLOW OR STREET FLOODING *
**********************************************

  JUNCTION   INFLOW, FT3
  --------   -----------
    80408    4.8600E+05
    81009    5.4000E+05
    82309    4.3200E+05

  JUNCTION   OUTFLOW, FT3
  --------   -----------
    80408    5.7476E+02
    80608    1.4951E+05
    10208    1.3037E+06

*****************************************************
* INITIAL SYSTEM VOLUME       =   2.7775E+00 CU FT *
* TOTAL SYSTEM INFLOW VOLUME  =   1.4580E+06 CU FT *
* INFLOW + INITIAL VOLUME     =   1.4580E+06 CU FT *
*****************************************************
* TOTAL SYSTEM OUTFLOW        =   1.4537E+06 CU FT *
* VOLUME LEFT IN SYSTEM       =   6.2006E+03 CU FT *
* OUTFLOW + FINAL VOLUME      =   1.4599E+06 CU FT *
*****************************************************
* ERROR IN CONTINUITY, PERCENT =       -0.13       *
*****************************************************

**********************************************************
*   J U N C T I O N   S U M M A R Y   S T A T I S T I C S *
**********************************************************
```

JUNCTION NUMBER	GROUND ELEVATION (FT)	UPPERMOST PIPE CROWN ELEVATION (FT)	MEAN JUNCTION DEPTH (FT)	JUNCTION DEPTH COEF. VAR	MAXIMUM JUNCTION DEPTH (FT)	TIME OF OCCURENCE HR.	MIN.	FEET OF SURCHARGE AT MAX DEPTH	FEET MAX. DEPTH IS BELOW GROUND ELEVATION	LENGTH OF SURCHARGE (MIN)	LENGTH OF FLOODING (MIN)	MAXIMUM JUNCTION AREA (SQ.FT)
80408	138.00	128.60	4.21	1.38	13.40	0	34	9.40	0.00	151.0	1.3	2.497E+04
80608	135.00	122.30	5.64	1.34	16.70	0	33	12.70	0.00	157.0	149.0	1.049E+05
81009	137.00	132.70	1.13	1.08	3.36	0	27	0.00	5.44	0.0	0.0	1.143E+04
81309	130.00	122.00	1.36	0.99	3.55	0	51	0.00	8.95	0.0	0.0	1.923E+04
82309	155.00	118.50	7.83	1.22	21.68	0	35	15.48	21.02	164.0	0.0	1.916E+05
10208	100.00	98.90	1.27	0.75	2.51	1	34	0.00	7.59	0.0	0.0	7.005E+04
10309	111.00	110.60	1.54	0.66	2.84	1	34	0.00	6.56	0.0	0.0	3.989E+04
15009	125.00	117.00	1.11	0.88	2.51	1	22	0.00	10.99	0.0	0.0	2.152E+04
16009	120.00	111.00	1.55	0.71	2.95	1	28	0.00	15.05	0.0	0.0	1.787E+04
16109	125.00	106.80	1.37	0.86	3.01	0	39	0.00	19.19	0.0	0.0	3.268E+05

```
*****************************************************
* T I M E  H I S T O R Y  O F  T H E  H. G. L. ( Feet) *
*****************************************************
```

EXTRAN USER'S MANUAL EXAMPLE PROBLEM 1
BASIC PIPE SYSTEM FROM FIGURE 3-1

TIME HR:MIN	JUNCTION GRND ELEV	80608 135.00 DEPTH	JUNCTION GRND ELEV	16009 120.00 DEPTH	JUNCTION GRND ELEV	16109 125.00 DEPTH	JUNCTION GRND ELEV	15009 125.00 DEPTH	JUNCTION GRND ELEV	82309 155.00 DEPTH.
0:15	119.56	1.26	102.00	0.00	102.96	0.16	111.50	0.00	114.42	2.12
0:30	121.08	2.78	102.42	0.42	104.37	1.57	111.87	0.37	118.30	6.00
0:45	135.00	16.70	104.75	2.75	105.67	2.87	112.97	1.47	133.96	21.66
1: 0	135.00	16.70	104.85	2.85	105.66	2.86	113.77	2.27	133.96	21.66
1:15	135.00	16.70	104.94	2.94	105.68	2.88	113.99	2.49	133.95	21.65
1:30	135.00	16.70	104.95	2.95	105.69	2.89	114.00	2.50	133.95	21.65
1:45	135.00	16.70	104.94	2.94	105.68	2.88	113.97	2.47	133.95	21.65
2: 0	135.00	16.70	104.94	2.94	105.68	2.88	113.95	2.45	133.95	21.65
2:15	135.00	16.70	104.93	2.93	105.68	2.88	113.94	2.44	133.95	21.65
2:30	135.00	16.70	104.93	2.93	105.68	2.88	113.94	2.44	133.95	21.65
2:45	135.00	16.70	104.93	2.93	105.68	2.88	113.94	2.44	133.95	21.65
3: 0	135.00	16.70	104.93	2.93	105.68	2.88	113.94	2.44	133.95	21.65
3:15	121.00	2.70	104.77	2.77	105.26	2.46	113.86	2.36	118.24	5.94
3:30	119.15	0.85	104.52	2.52	104.96	2.16	113.43	1.93	116.41	4.11
3:45	118.74	0.44	104.17	2.17	104.54	1.74	112.92	1.42	115.09	2.79
4: 0	118.63	0.33	103.82	1.82	104.12	1.32	112.56	1.06	114.17	1.87
4:15	118.57	0.27	103.51	1.51	103.78	0.98	112.32	0.82	113.63	1.33
4:30	118.53	0.23	103.26	1.26	103.56	0.76	112.16	0.66	113.31	1.01
4:45	118.51	0.21	103.07	1.07	103.41	0.61	112.04	0.54	113.09	0.79
5: 0	118.49	0.19	102.93	0.93	103.30	0.50	111.95	0.45	112.95	0.65
5:15	118.47	0.17	102.82	0.82	103.22	0.42	111.89	0.39	112.84	0.54
5:30	118.46	0.16	102.73	0.73	103.16	0.36	111.83	0.33	112.76	0.46
5:45	118.44	0.14	102.66	0.66	103.11	0.31	111.79	0.29	112.70	0.40
6: 0	118.43	0.13	102.60	0.60	103.07	0.27	111.76	0.26	112.65	0.35
6:15	118.42	0.12	102.55	0.55	103.04	0.24	111.73	0.23	112.62	0.32
6:30	118.41	0.11	102.50	0.50	103.02	0.22	111.71	0.21	112.58	0.28
6:45	118.41	0.11	102.47	0.47	102.99	0.19	111.69	0.19	112.56	0.26
7: 0	118.40	0.10	102.44	0.44	102.97	0.17	111.68	0.18	112.54	0.24
7:15	118.39	0.09	102.42	0.42	102.96	0.16	111.66	0.16	112.52	0.22
7:30	118.39	0.09	102.39	0.39	102.94	0.14	111.65	0.15	112.50	0.20
7:45	118.38	0.08	102.38	0.38	102.93	0.13	111.64	0.14	112.49	0.19
8: 0	118.38	0.08	102.36	0.36	102.92	0.12	111.63	0.13	112.48	0.18
MEAN	123.94	5.64	103.55	1.55	104.17	1.37	112.61	1.11	120.13	7.83
MAXIMUM	135.00	16.70	104.95	2.95	105.81	3.01	114.01	2.51	133.98	21.68
MINIMUM	118.30	0.00	102.00	0.00	102.80	0.00	111.50	0.00	112.30	0.00

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*********************************************
*   TIME HISTORY OF FLOW AND VELOCITY      *
*    Q(CFS), VEL(FPS), TOTAL(CUBIC FEET)    *
*********************************************
```

EXTRAN USER'S MANUAL EXAMPLE PROBLEM 1
BASIC PIPE SYSTEM FROM FIGURE 3-1

TIME HR:MIN	CONDUIT FLOW	1030 VELOC.	CONDUIT FLOW	1630 VELOC.	CONDUIT FLOW	1600 VELOC.	CONDUIT FLOW	1602 VELOC.	CONDUIT FLOW	1570 VELOC.
0:15	0.00	0.00	0.00	0.00	0.08	0.63	5.76	1.51	0.00	0.25
0:30	0.00	0.23	0.23	1.01	11.87	3.57	38.51	2.69	1.08	1.37
0:45	23.88	3.70	74.78	5.08	70.31	5.45	68.00	3.85	19.12	2.22
1: 0	94.58	5.26	109.42	4.89	67.93	5.13	67.93	3.85	43.75	4.02
1:15	115.37	5.52	119.11	4.81	67.86	5.00	68.01	3.85	52.14	4.46
1:30	120.11	5.58	120.49	4.78	68.04	4.99	68.06	3.85	52.38	4.46
1:45	119.81	5.57	119.49	4.75	68.07	5.00	68.05	3.85	51.23	4.40
2: 0	118.88	5.56	118.61	4.74	68.06	5.01	68.04	3.85	50.43	4.36
2:15	118.31	5.55	118.18	4.74	68.04	5.01	68.04	3.85	50.09	4.35
2:30	118.08	5.55	118.04	4.74	68.04	5.01	68.03	3.85	49.99	4.34
2:45	118.02	5.55	118.02	4.74	68.03	5.01	68.03	3.85	49.98	4.34
3: 0	118.02	5.55	118.02	4.74	68.03	5.01	68.03	3.85	49.99	4.34
3:15	108.62	5.43	100.63	4.39	48.69	4.13	43.67	2.67	47.46	4.37
3:30	87.33	5.15	77.33	4.02	38.47	3.77	32.86	2.57	32.77	3.66
3:45	61.59	4.72	50.47	3.44	25.65	3.22	19.04	2.21	18.10	2.70
4: 0	40.05	4.24	31.17	2.95	15.36	2.62	9.80	1.82	10.11	2.04
4:15	25.53	3.79	19.08	2.54	8.60	2.02	5.19	1.51	6.00	1.62
4:30	16.76	3.41	12.04	2.22	5.07	1.60	3.00	1.28	3.75	1.33
4:45	10.91	3.06	8.00	2.00	3.20	1.31	1.86	1.11	2.50	1.14
5: 0	7.67	2.80	5.44	1.78	2.10	1.09	1.23	0.98	1.71	0.98
5:15	5.62	2.59	3.88	1.63	1.47	0.93	0.85	0.87	1.25	0.86
5:30	3.85	2.36	2.88	1.50	1.06	0.81	0.60	0.79	0.93	0.76
5:45	2.94	2.20	2.19	1.37	0.78	0.71	0.45	0.72	0.70	0.68
6: 0	2.33	2.08	1.69	1.26	0.58	0.61	0.35	0.66	0.53	0.60
6:15	1.88	1.97	1.33	1.18	0.45	0.54	0.27	0.61	0.42	0.54
6:30	1.53	1.87	1.07	1.11	0.37	0.51	0.22	0.57	0.34	0.50
6:45	1.27	1.78	0.89	1.07	0.31	0.48	0.17	0.53	0.30	0.48
7: 0	1.07	1.71	0.76	1.05	0.26	0.44	0.14	0.50	0.26	0.46
7:15	0.76	1.56	0.65	1.02	0.22	0.41	0.12	0.48	0.23	0.44
7:30	0.63	1.48	0.56	0.95	0.19	0.39	0.10	0.45	0.20	0.42
7:45	0.55	1.43	0.49	0.88	0.16	0.36	0.09	0.43	0.18	0.40
8: 0	0.49	1.39	0.43	0.83	0.14	0.34	0.08	0.41	0.16	0.39
MEAN	45.27	3.37	45.34	2.68	26.72	2.55	26.62	2.27	18.69	2.09
MAXIMUM	120.24	5.58	120.56	5.20	72.67	6.03	68.74	383.08	52.70	4.48
MINIMUM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	1.30E+06		1.31E+06		7.70E+05		7.67E+05		5.38E+05	

y

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*******************************************************
*  C O N D U I T   S U M M A R Y   S T A T I S T I C S  *
*******************************************************
```

EXTRAN USER'S MANUAL EXAMPLE PROBLEM 1
BASIC PIPE SYSTEM FROM FIGURE 3-1

CONDUIT NUMBER	DESIGN FLOW (CFS)	DESIGN VELOCITY (FPS)	CONDUIT VERTICAL DEPTH (IN)	MAXIMUM COMPUTED FLOW (CFS)	TIME OF OCCURENCE HR.	MIN.	MAXIMUM COMPUTED VELOCITY (FPS)	TIME OF OCCURENCE HR.	MIN.	RATIO OF MAX. TO DESIGN FLOW	MAXIMUM DEPTH ABOVE INV. AT CONDUIT ENDS UPSTREAM (FT)	DOWNSTREAM (FT)	LENGTH OF SPC FLOW (MIN)	CONDUIT SLOPE (FT/FT)
8040	7.36E+01	5.86	48.00	5.10E+01	0	22	341.87	0	0	0.69	13.40	16.70	299.7	0.00350
8060	5.33E+01	4.24	48.00	4.42E+01	0	26	4.82	0	27	0.83	16.70	19.46	35.3	0.00183
8100	7.81E+01	4.91	54.00	6.11E+01	0	37	503.99	0	0	0.78	3.36	3.55	442.7	0.00210
8130	7.06E+01	4.44	54.00	5.49E+01	1	3	5.14	0	56	0.78	3.55	2.51	279.3	0.00171
1030	3.03E+03	12.46	108.00	1.20E+02	1	34	5.58	1	34	0.04	2.84	2.51	0.0	0.00260
1570	1.24E+02	5.20	66.00	5.27E+01	1	22	4.48	1	21	0.43	2.51	2.95	451.7	0.00190
1600	1.47E+02	5.19	72.00	7.27E+01	0	42	6.03	0	39	0.49	3.01	2.95	240.3	0.00160
1630	2.31E+03	9.52	108.00	1.21E+02	1	26	5.20	0	48	0.05	2.95	2.84	192.7	0.00133
1602	4.34E+01	2.21	60.00	6.87E+01	0	39	383.08	0	0	1.58	21.66	3.01	0.0	0.00190
90010	UNDEF	UNDEF	UNDEF	1.20E+02	1	34								

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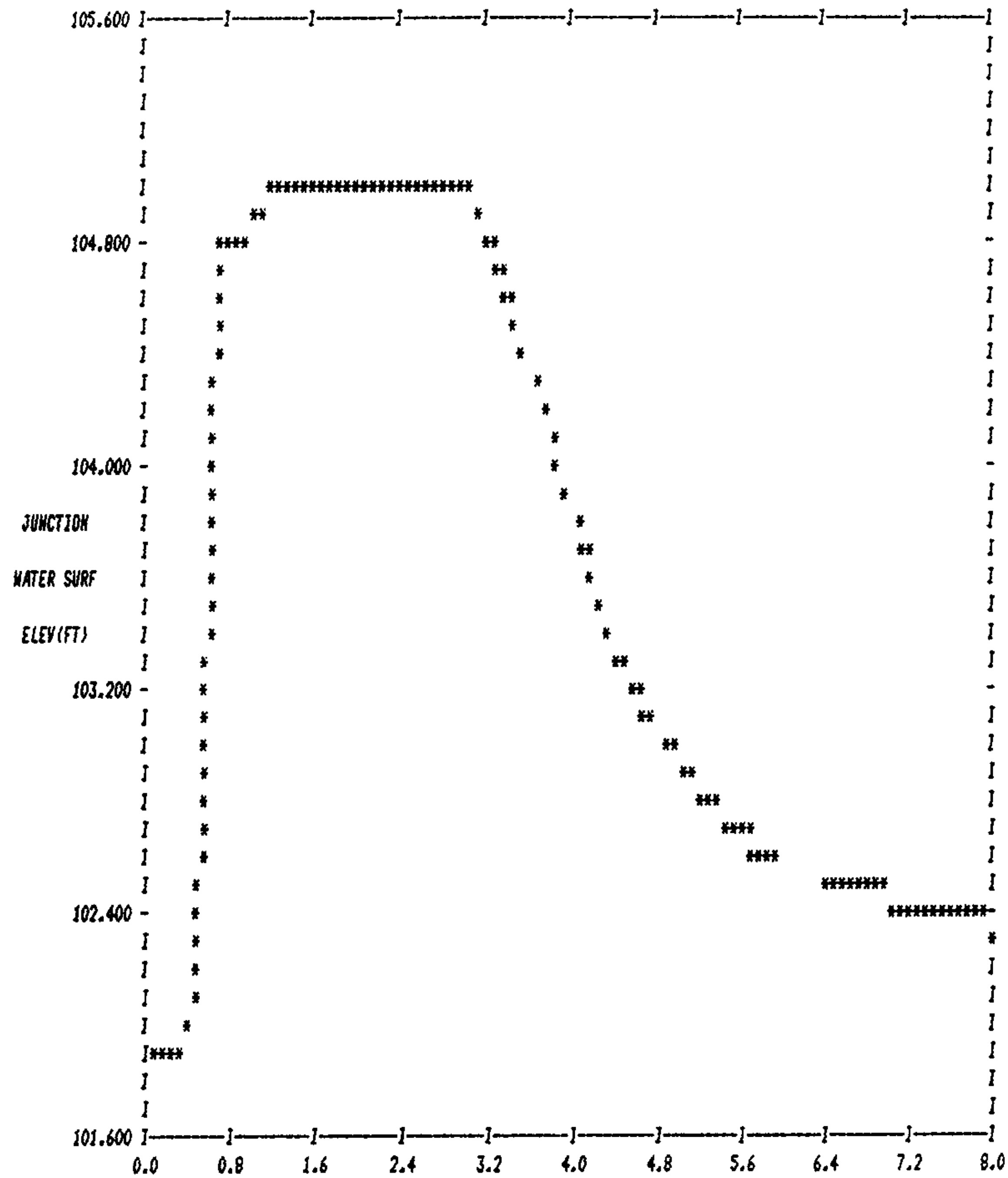
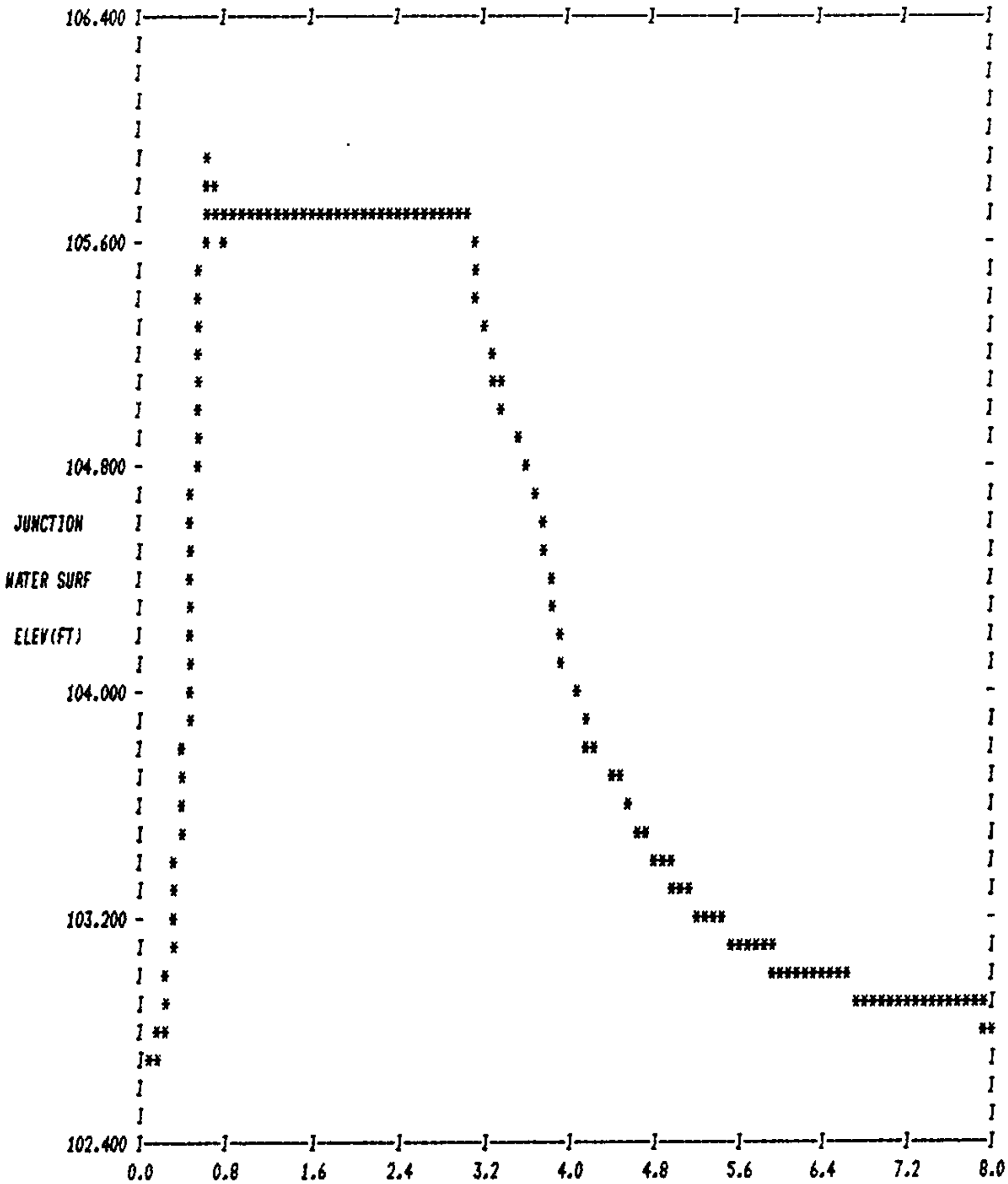
************************************************
* SUBCRITICAL AND CRITICAL FLOW ASSUMPTIONS FROM *
* SUBROUTINE HEAD.  SEE FIGURE 5-4 IN THE EXTRAN *
*       MANUAL FOR FURTHER INFORMATION.          *
************************************************
```

CONDUIT NUMBER	LENGTH OF DRY FLOW(MIN)	LENGTH OF SUBCRITICAL FLOW(MIN)	LENGTH OF UPSTR. CRITICAL FLOW(MIN)	LENGTH OF DOWNSTR. CRITICAL FLOW(MIN)	MEAN FLOW (CFS)	FLOW (CV)	TOTAL FLOW CUBIC FT	MAXIMUM HYDRAULIC RADIUS(FT)	MAXIMUM CROSS SECT AREA(FT2)
8040	0.00	480.00	0.00	0.00	16.86	1.26	4.8562E+05	1.1669	12.5664
8060	0.33	206.00	0.00	273.67	11.36	1.22	3.2703E+05	1.2040	12.5664
8100	0.00	480.00	0.00	0.00	18.84	1.25	5.4272E+05	1.3165	11.6707
8130	0.33	479.67	0.00	0.00	18.78	1.22	5.4080E+05	1.2784	10.7617
1030	26.33	453.67	0.00	0.00	45.27	1.12	1.3037E+06	1.2704	21.5588
1570	8.33	471.67	0.00	0.00	18.69	1.18	5.3828E+05	1.3653	11.7694
1600	0.33	479.67	0.00	0.00	26.72	1.13	7.6951E+05	1.4726	13.6490
1630	8.67	471.33	0.00	0.00	45.34	1.14	1.3057E+06	1.3755	25.2293
1602	0.00	480.00	0.00	0.00	26.62	1.14	7.6673E+05	1.3951	17.8158
90010	UNDEFINED	UNDEFINED	UNDEFINED	UNDEFINED	45.27	1.12	1.3037E+06		



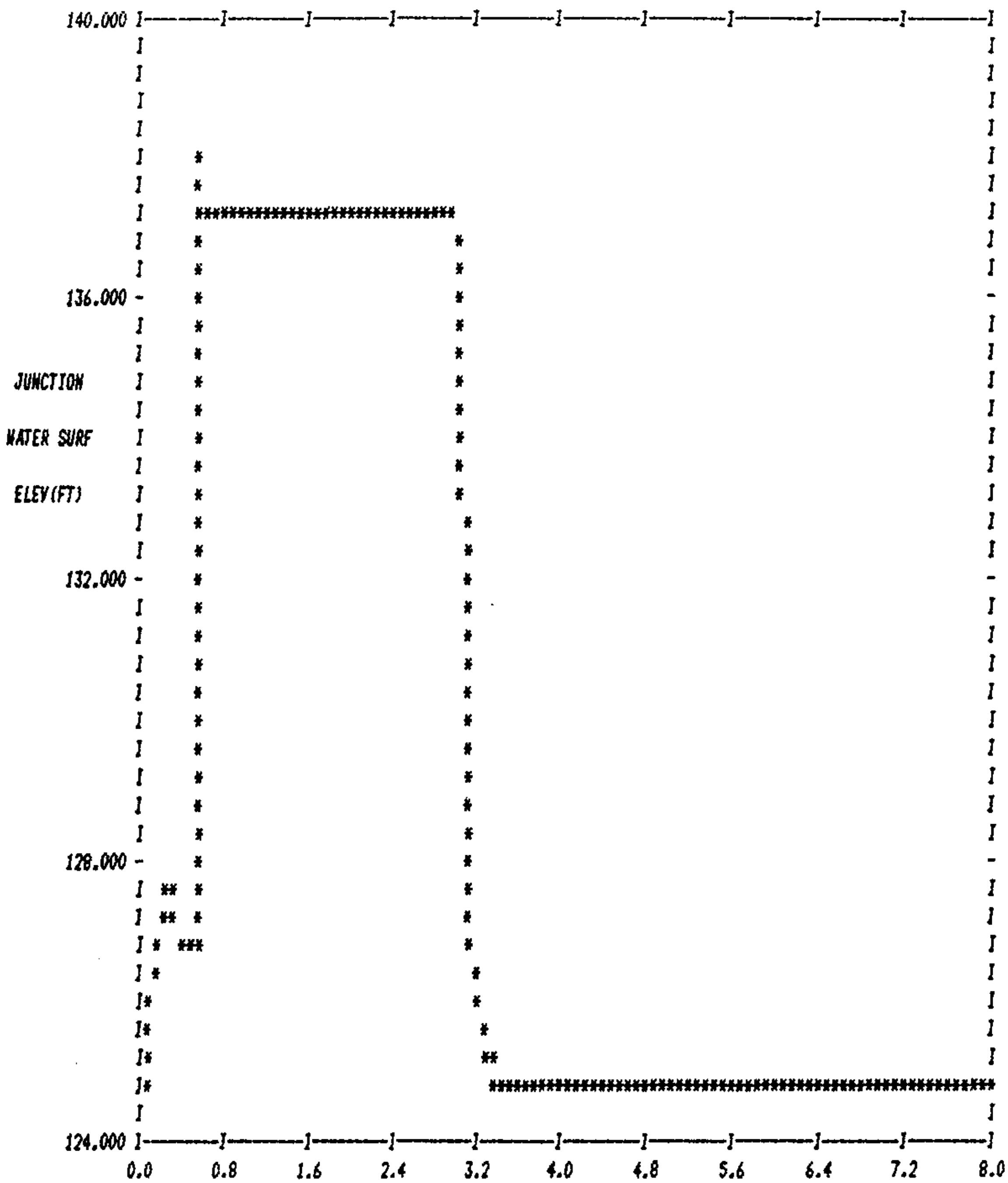
LOCATION NO. : 16009 CLOCK TIME IN HOURS. PLOT OF JUNCTION ELEVATION

INVERT ELEV - 102.00 FEET
CROWN ELEV - 111.00 FEET
GROUND ELEV - 120.00 FEET



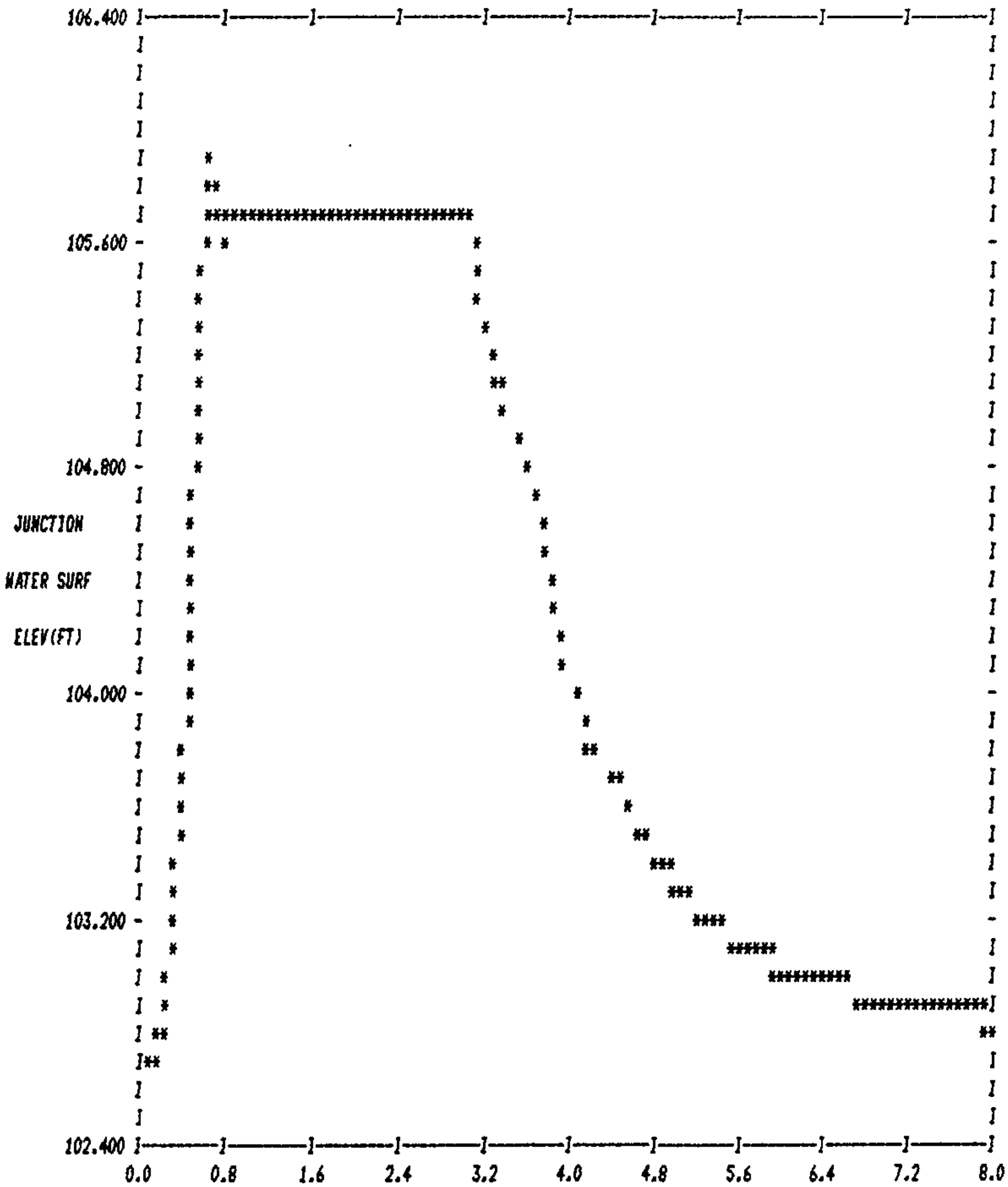
LOCATION NO. : 16109 CLOCK TIME IN HOURS. PLOT OF JUNCTION ELEVATION

INVERT ELEV - 102.80 FEET
CROWN ELEV - 108.80 FEET
GROUND ELEV - 125.00 FEET



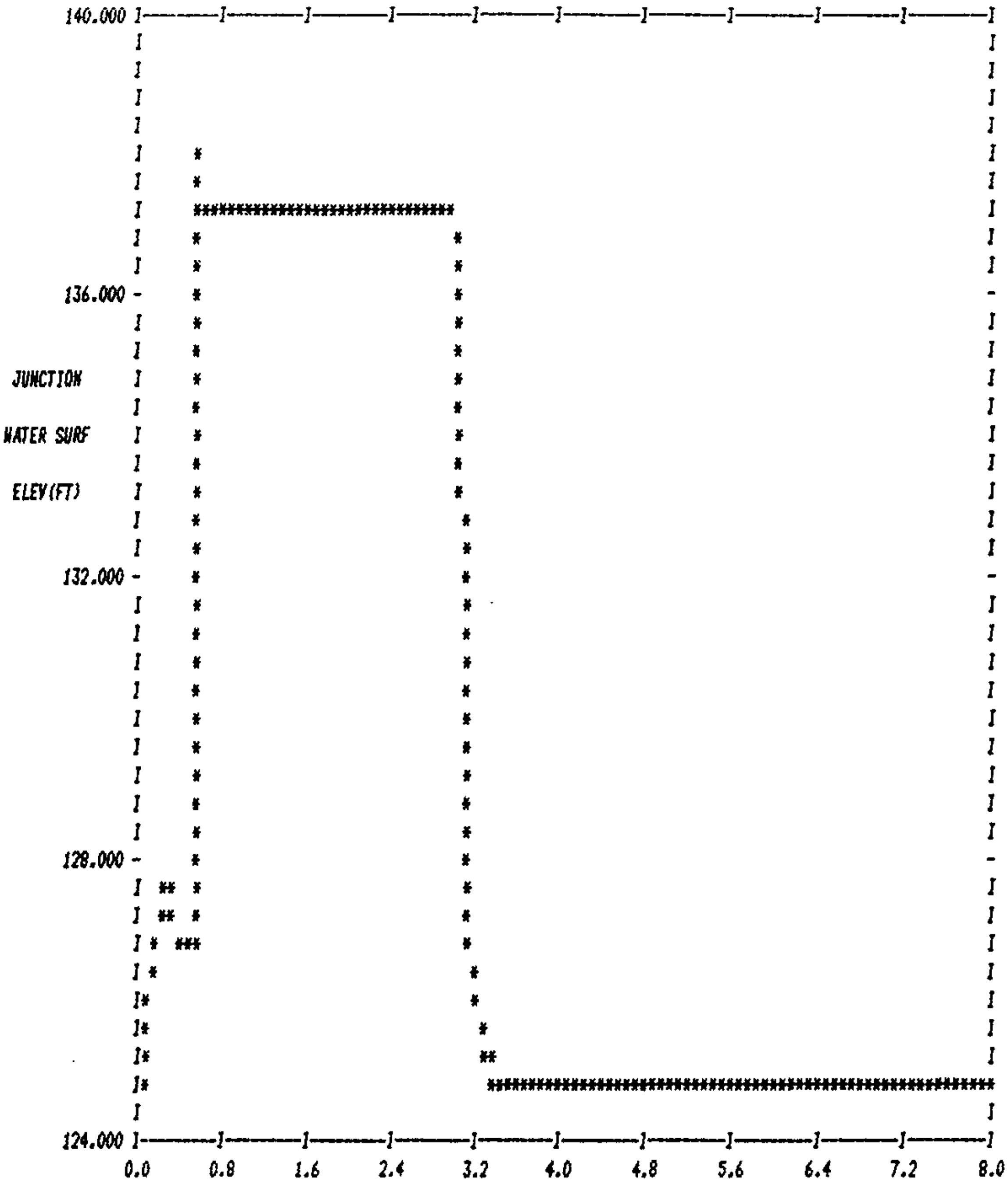
LOCATION NO. : 80408 CLOCK TIME IN HOURS. PLOT OF JUNCTION ELEVATION

INVERT ELEV - 124.60 FEET
CROWN ELEV - 128.60 FEET
GROUND ELEV - 138.00 FEET



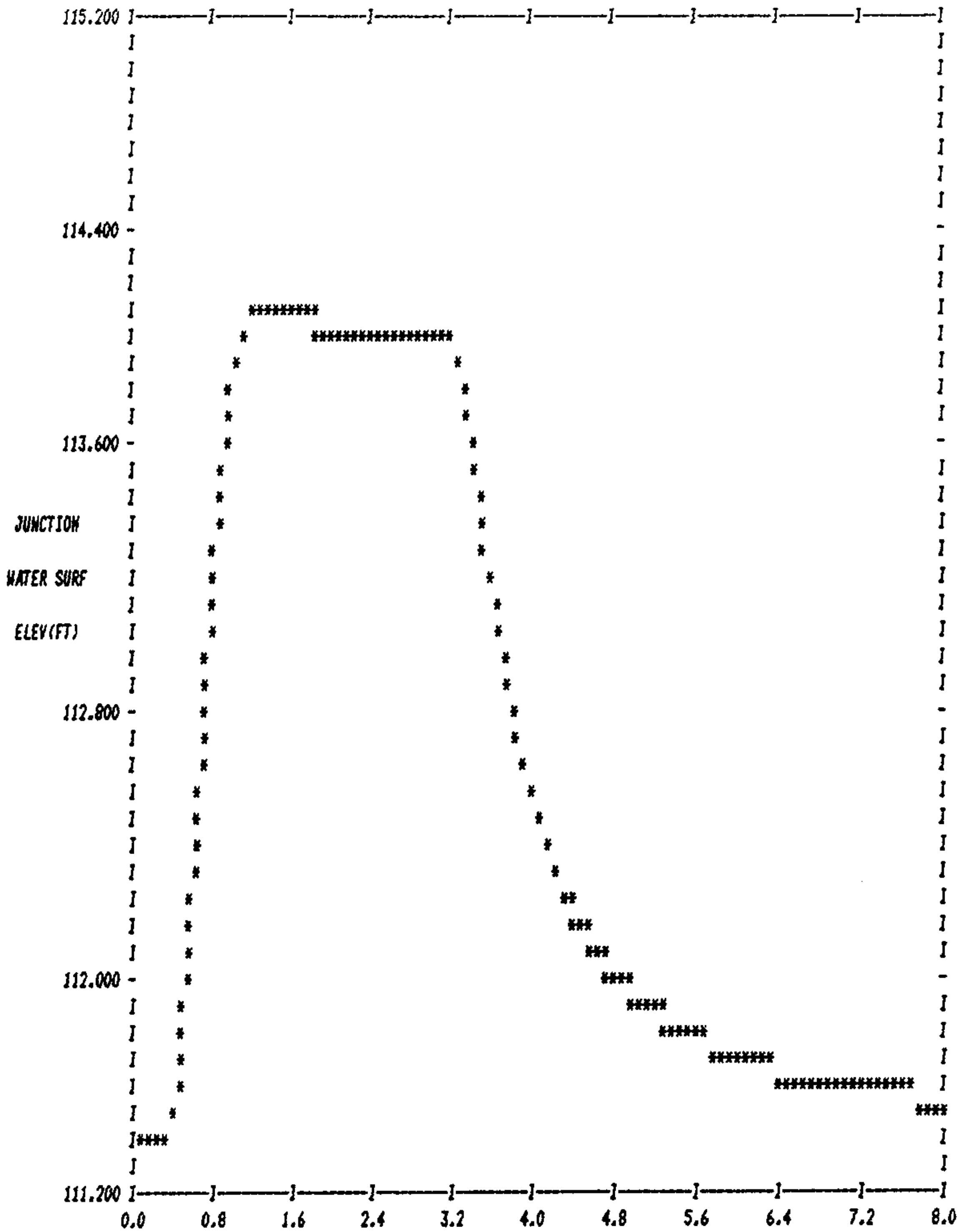
LOCATION NO. : 16109 CLOCK TIME IN HOURS. PLOT OF JUNCTION ELEVATION

INVERT ELEV - 102.80 FEET
CROWN ELEV - 108.80 FEET
GROUND ELEV - 125.00 FEET



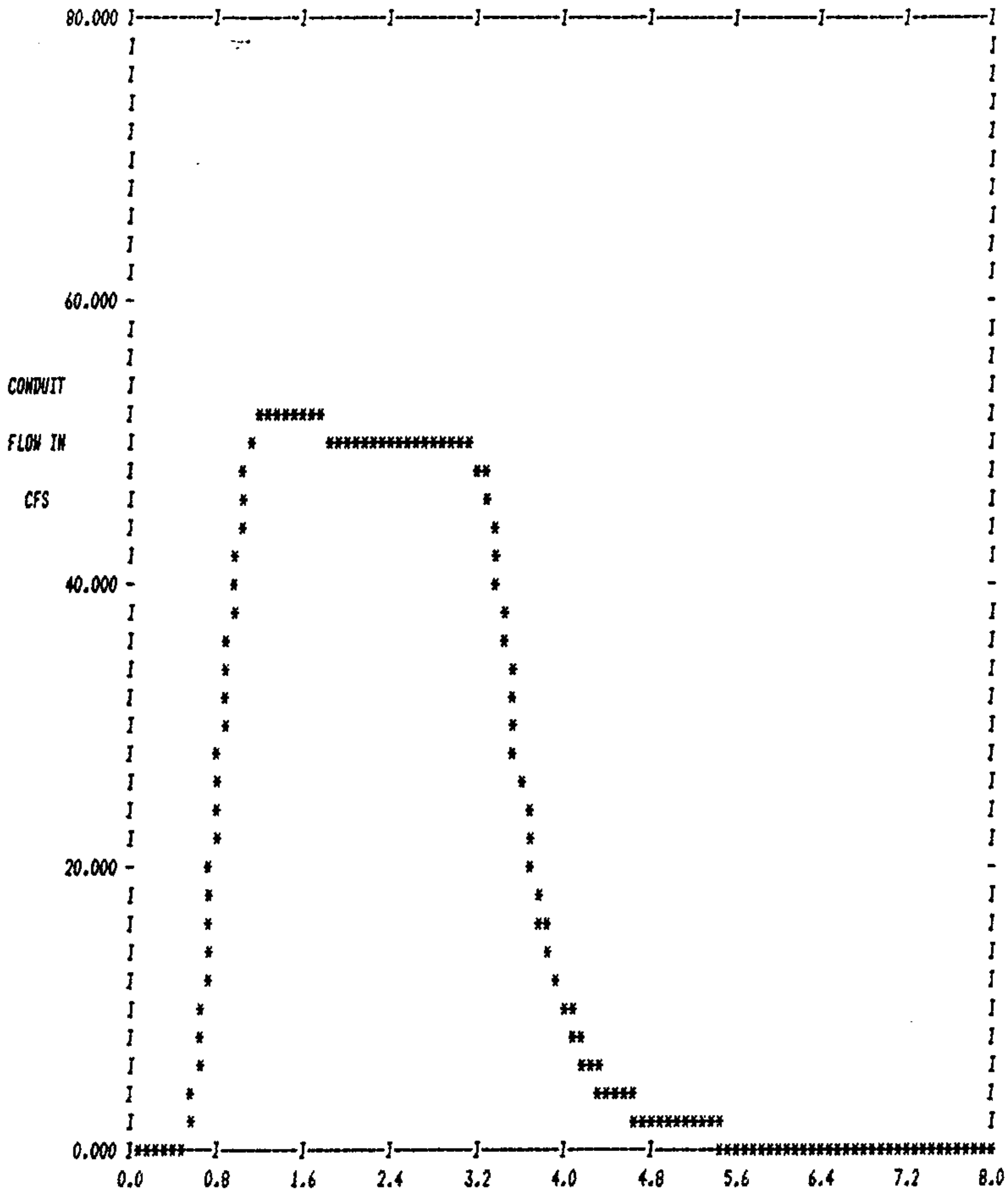
LOCATION NO. : 80408 CLOCK TIME IN HOURS. PLOT OF JUNCTION ELEVATION

INVERT ELEV - 124.60 FEET
CROWN ELEV - 128.60 FEET
GROUND ELEV - 138.00 FEET

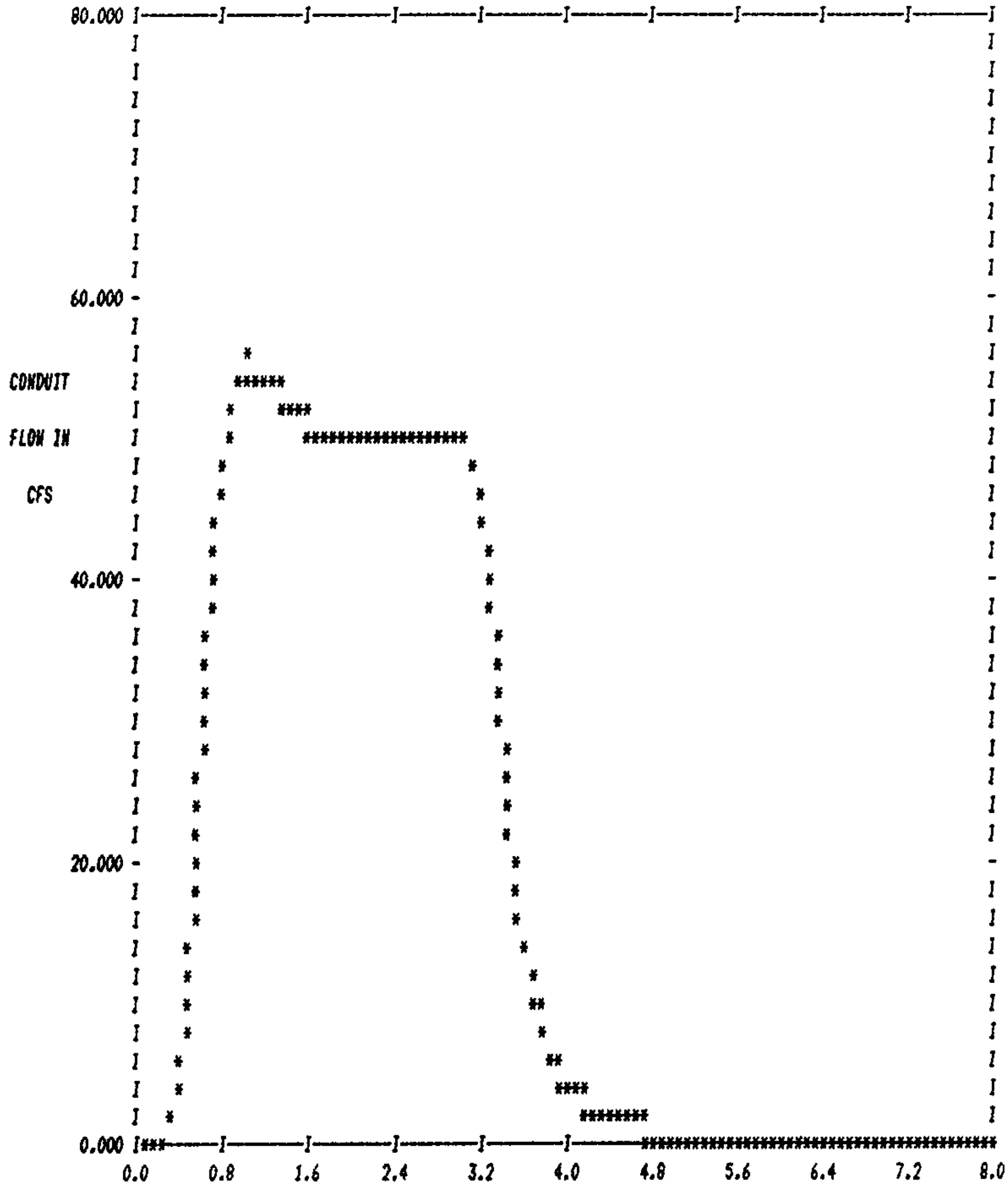


LOCATION NO. :   15009   CLOCK TIME IN HOURS. PLOT OF JUNCTION ELEVATION

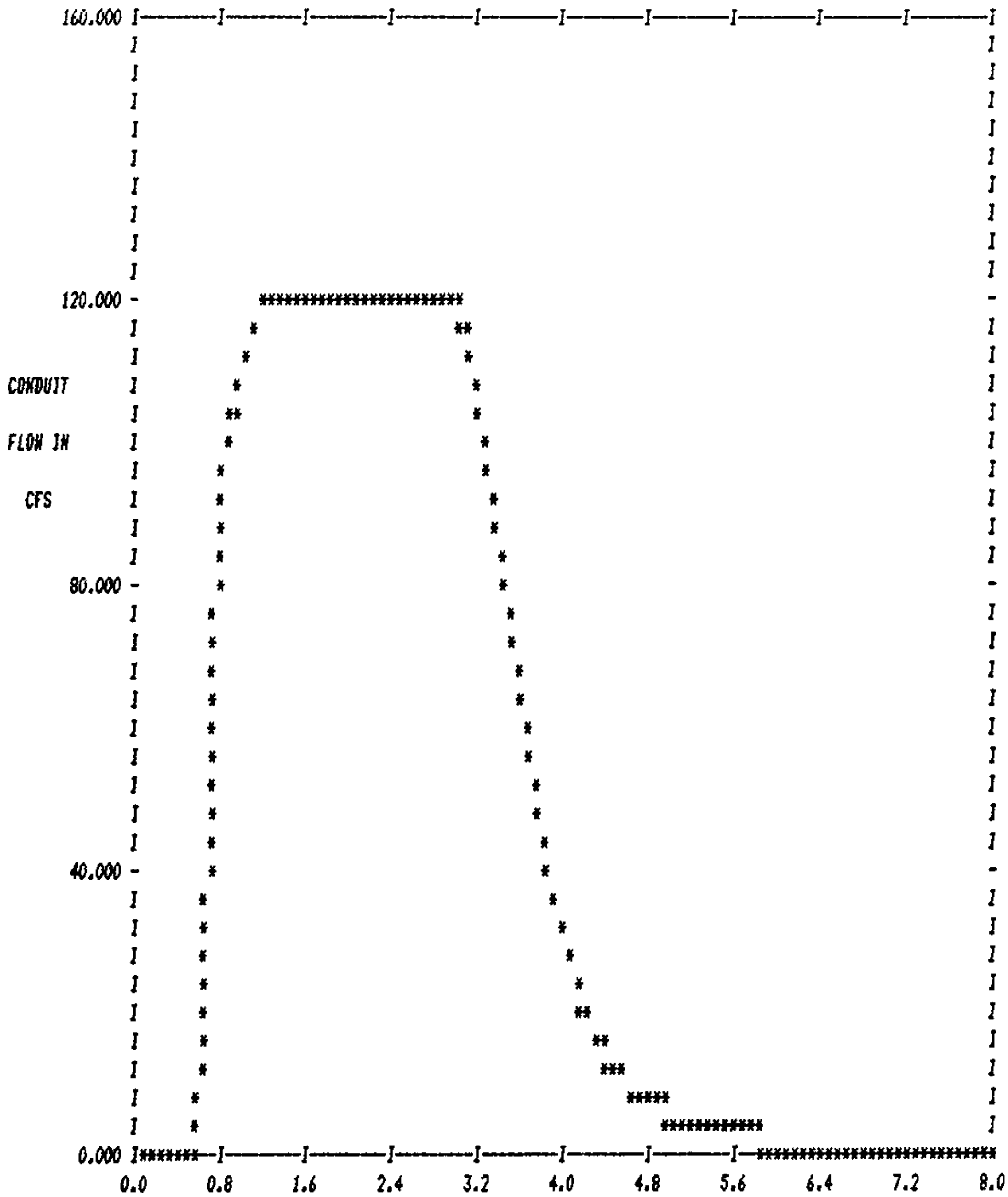
INVERT ELEV - 111.50 FEET
CROWN ELEV - 117.00 FEET
GROUND ELEV - 125.00 FEET



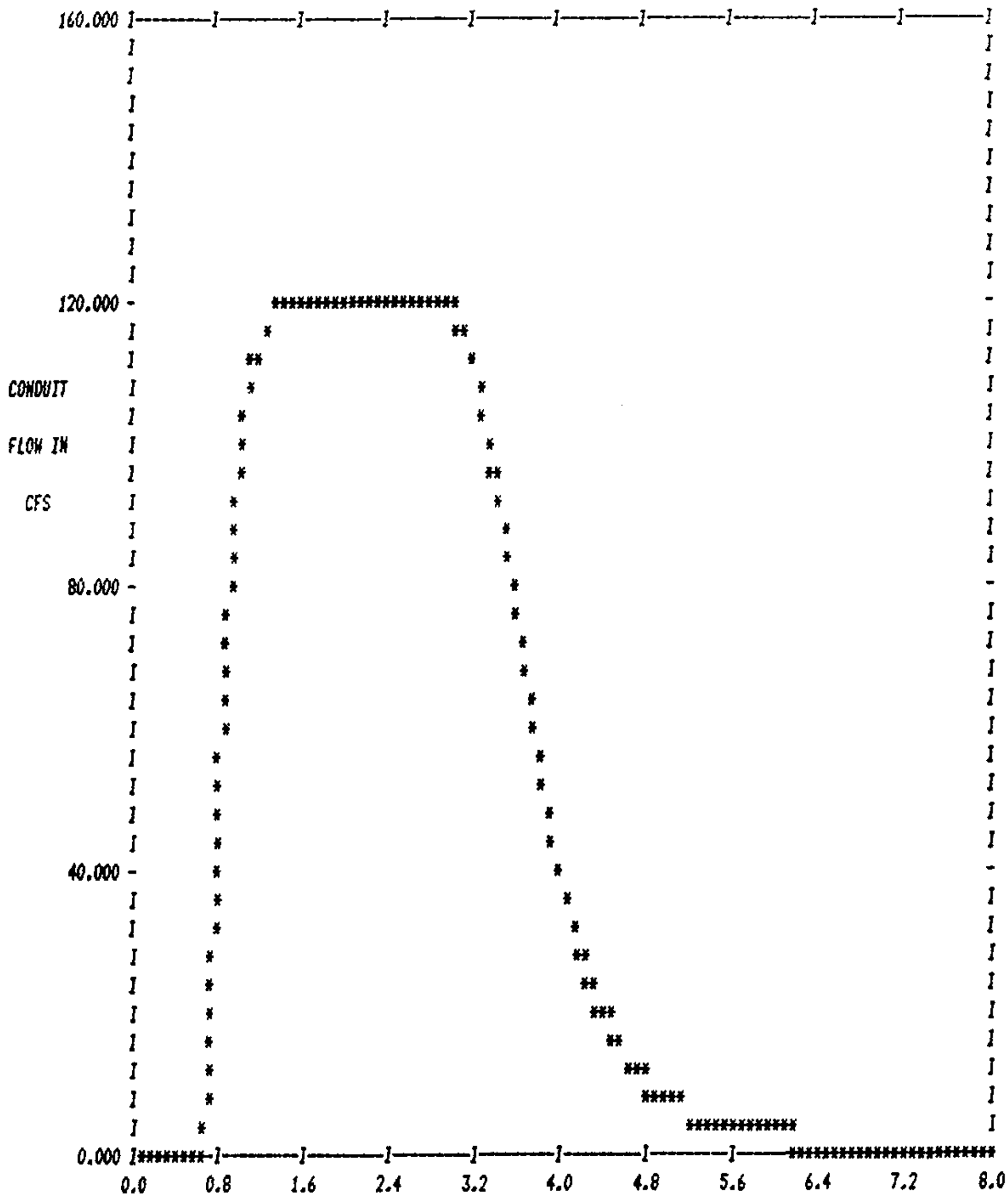
LOCATION NO. : 1570 CLOCK TIME IN HOURS. PLOT OF CONDUIT FLOW



LOCATION NO. : 8130 CLOCK TIME IN HOURS. PLOT OF CONDUIT FLOW



LOCATION NO. : 1630 CLOCK TIME IN HOURS. PLOT OF CONDUIT FLOW



LOCATION NO. : 1030 CLOCK TIME IN HOURS. PLOT OF CONDUIT FLOW

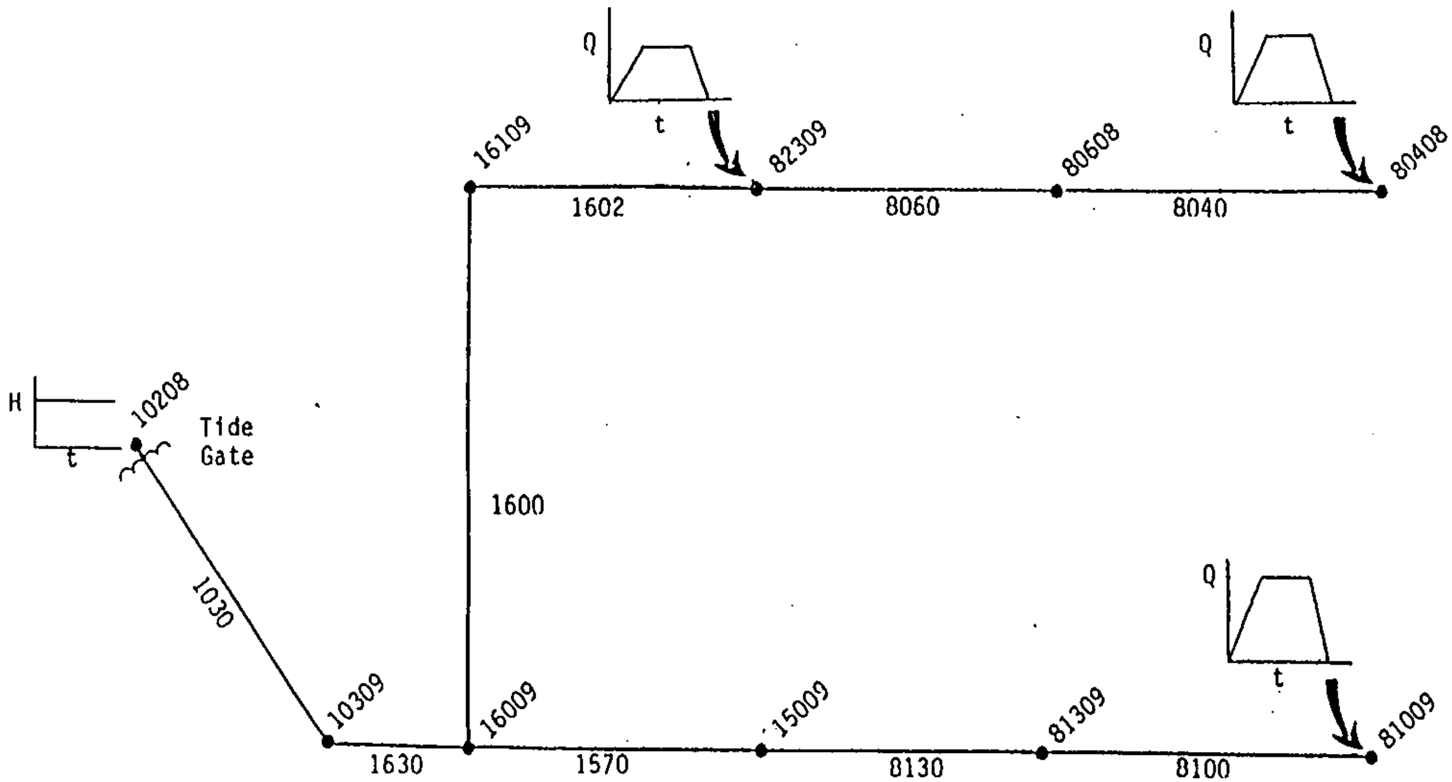


Figure 3-2. Basic System with Tide Gate.

Table 3-3. Input Data for Example 2.

```
SW  1  0  0
MM  3  10 11 12
$EXTRAN
A1  'EXTRAN USER''S MANUAL EXAMPLE 2'
A1  ' BASIC PIPE SYSTEM WITH TIDE GATE FROM FIGURE 3-2'
*   NTCYC DELT TZERO NSTART INTER JNTER REDO
B1 1440  20.0  0.0     45    500    45    0
*   METRIC NEQUAL  AMEN ITMAX SURTOL
B2      0     0       0.0   30  0.05
* NHPRT NQPRT NPLT LPLT NJSW
B3   1     1     1     1    3
*   PRINT HEADS
B4  80608 16009 16109 15009 82309 80408
*   PRINT FLOWS
B5  1030 1630 1600 1602 1570 8130
*   PLOT HEADS
B6  80608 16009 16109 15009 82309 80408
*   PLOT FLOWS
B7  1030 1630 1600 1602 1570 8130
*   CONDUIT DATA
C1  8040 80408 80608 0.0 1 0.0 4.0 0.0 1800.  0.0   0.0   0.015 0.0 0.0
C1  8060 80608 82309 0.0 1 0.0 4.0 0.0 2075.  0.0   2.2   0.015 0.0 0.0
C1  8100 81009 81309 0.0 1 0.0 4.5 0.0 5100.  0.0   0.0   0.015 0.0 0.0
C1  8130 81309 15009 0.0 1 0.0 4.5 0.0 3500.  0.0   0.0   0.015 0.0 0.0
C1  1030 10309 10208 0.0 6 0.0 9.0 0.0 4500.  0.0   0.0   0.016 3.0 3.0
C1  1570 15009 16009 0.0 1 0.0 5.5 0.0 5000.  0.0   0.0   .0154 0.0 0.0
C1  1600 16009 16109 0.0 1 0.0 6.0 0.0  500.  0.0   0.0   0.015 0.0 0.0
C1  1630 16009 10309 0.0 6 0.0 9.0 0.0  300.  0.0   0.0   0.015 3.0 3.0
C1  1602 82309 16109 0.0 1 0.0 5.0 0.0 5000.  0.0   0.0   0.034 0.0 0.0
*    JUNCTION DATA
D1   80408  138.0 124.6 0.0 0.0
D1   80608  135.0 118.3 0.0 0.0
D1   81009  137.0 128.2 0.0 0.0
D1   81309  130.0 117.5 0.0 0.0
D1   82309  155.0 112.3 0.0 0.0
D1   10208  100.0  89.9 0.0 0.0
D1   10309  111.0 101.6 0.0 0.0
D1   15009  125.0 111.5 0.0 0.0
D1   16009  120.0 102.0 0.0 0.0
D1   16109  125.0 102.8 0.0 0.0
I2  10208 1
J1  2
J2  94.4
K1  3
K2 82309 80408 81009
K3  0.0   0.0   0.0   0.0
K3 0.25  40.0 45.0 50.0
K3  3.0  40.0 45.0 50.0
K3 3.25  0.0   0.0   0.0
K3 12.0  0.0   0.0   0.0
$ENDPROGRAM
```

Table 3-4. Partial Output for Example 2.

```
************************************************************
* J U N C T I O N   S U M M A R Y   S T A T I S T I C S *
************************************************************
```

JUNCTION NUMBER	GROUND ELEVATION (FT)	UPPERMOST PIPE CROWN ELEVATION (FT)	MEAN JUNCTION DEPTH (FT)	JUNCTION DEPTH COEF. VAR	MAXIMUM JUNCTION DEPTH (FT)	TIME OF OCCURENCE HR.	MIN.	FEET OF SURCHARGE AT MAX DEPTH	FEET MAX. DEPTH IS BELOW GROUND ELEVATION	LENGTH OF SURCHARGE (MIN)	LENGTH OF FLOODING (MIN)	MAXIMUM JUNCTION AREA (SQ.FT)
80408	138.00	128.60	4.21	1.38	13.40	0	34	9.40	0.00	151.0	1.3	2.500E+04
80608	135.00	122.30	5.64	1.34	16.70	0	33	12.70	0.00	157.0	149.0	1.050E+05
81009	137.00	132.70	1.13	1.08	3.36	0	27	0.00	5.44	0.0	0.0	1.143E+04
81309	130.00	122.00	1.36	0.99	3.56	0	51	0.00	8.94	0.0	0.0	1.923E+04
82309	155.00	118.50	7.83	1.22	21.68	0	35	15.48	21.02	164.0	0.0	1.916E+05
10208	100.00	98.90	4.25	0.24	4.50	0	26	0.00	5.60	0.0	0.0	1.093E+05
10309	111.00	110.60	1.42	0.68	2.68	1	34	0.00	6.72	0.0	0.0	4.487E+04
15009	125.00	117.00	1.11	0.88	2.51	1	22	0.00	10.99	0.0	0.0	2.152E+04
16009	120.00	111.00	1.56	0.71	3.12	0	50	0.00	14.88	0.0	0.0	1.783E+04
16109	125.00	108.80	1.38	0.86	3.00	0	39	0.00	19.20	0.0	0.0	3.268E+05

```
************************************************************
* C O N D U I T   S U M M A R Y   S T A T I S T I C S *
************************************************************
```

CONDUIT NUMBER	DESIGN FLOW (CFS)	DESIGN VELOCITY (FPS)	CONDUIT VERTICAL DEPTH (IN)	MAXIMUM COMPUTED FLOW (CFS)	TIME OF OCCURENCE HR.	MIN.	MAXIMUM COMPUTED VELOCITY (FPS)	TIME OF OCCURENCE HR.	MIN.	RATIO OF MAX. TO DESIGN FLOW	MAXIMUM DEPTH ABOVE INV. AT CONDUIT ENDS UPSTREAM (FT)	DOWNSTREAM (FT)	LENGTH OF SPC FLOW (MIN)	CONDUIT SLOPE (FT/FT)
8040	7.36E+01	5.86	48.00	5.10E+01	0	22	50.00	0	0	0.69	13.40	16.70	299.7	0.00350
8060	5.33E+01	4.24	48.00	4.42E+01	0	26	4.82	0	27	0.83	16.70	19.47	35.3	0.00183
8100	7.81E+01	4.91	54.00	6.11E+01	0	37	50.00	0	0	0.78	3.36	3.56	442.7	0.00210
8130	7.06E+01	4.44	54.00	5.49E+01	1	3	5.14	0	56	0.78	3.56	2.51	279.3	0.00171
1030	3.03E+03	12.46	108.00	1.20E+02	1	34	3.01	1	35	0.04	2.68	4.50	453.7	0.00260
1570	1.24E+02	5.20	66.00	5.27E+01	1	22	4.46	1	22	0.43	2.51	3.12	451.7	0.00190
1600	1.47E+02	5.19	72.00	7.33E+01	0	41	6.02	0	39	0.50	3.00	3.12	241.3	0.00160
1630	2.31E+03	9.52	108.00	1.21E+02	1	25	5.51	0	52	0.05	3.12	2.68	207.0	0.00133
1602	4.34E+01	2.21	60.00	6.87E+01	0	39	50.00	0	0	1.58	21.67	3.00	0.0	0.00190
90010	UNDEF	UNDEF	UNDEF	1.20E+02	1	34								

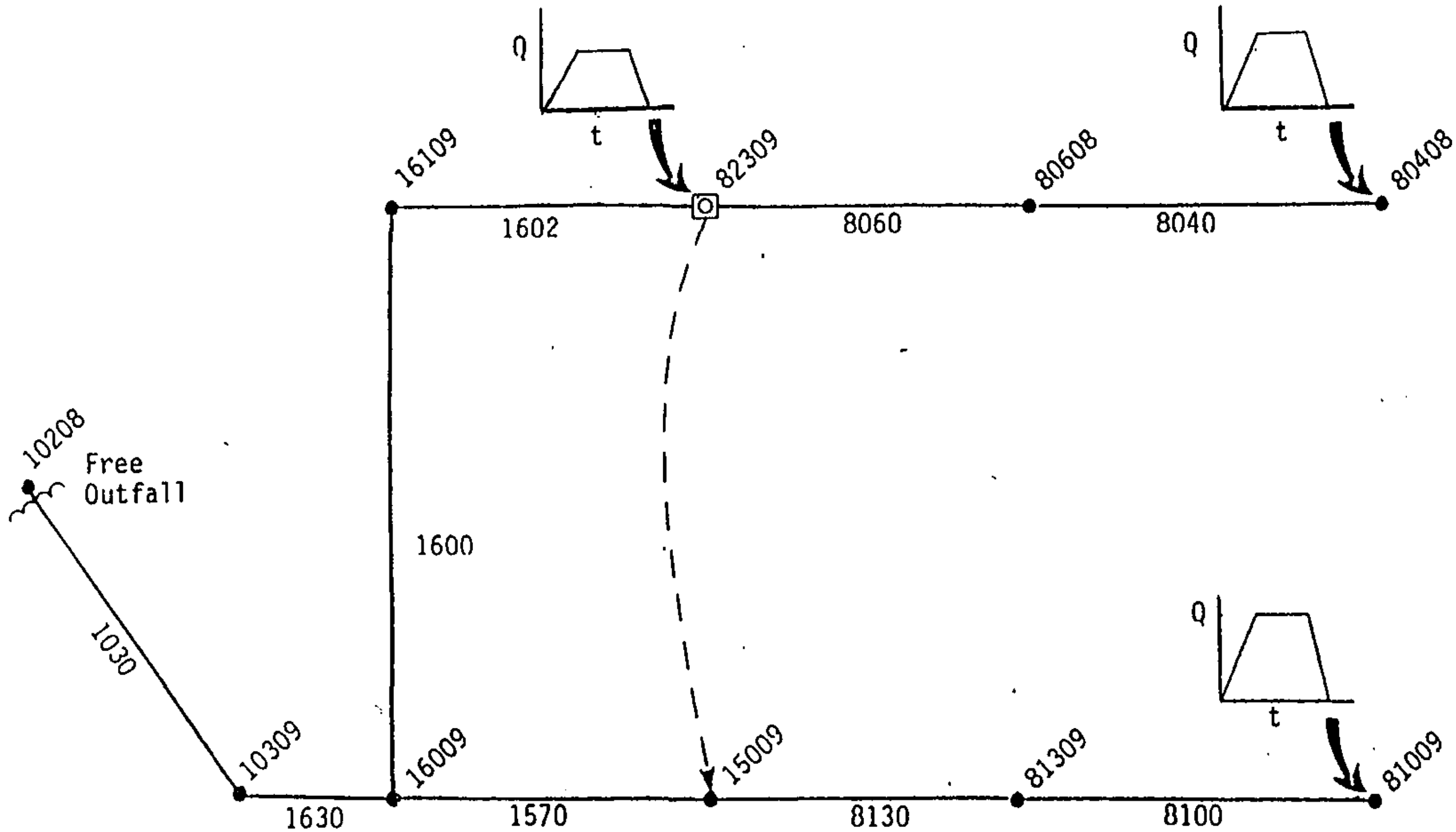


Figure 3-3. Sump Orifice at Junction 82309.

Table 3-5. Input Data for Example 3.

```
SW  1  0  0
MM  3  10 11 12
$EXTRAN
A1  'EXTRAN USER''S MANUAL EXAMPLE 3'
A1  ' BASIC PIPE SYSTEM WITH SUMP ORIFICE AT JUNCTION 82309 FROM FIG 3-3'
*   NTCYC DELT TZERO NSTART INTER JNTER REDO
B1 1440  20.0  0.0  45       45    45     0
*   METRIC NEQUAL  AMEN ITMAX SURTOL
B2     0     0       0.0   30  0.05
* NHPRT NQPRT NPLT LPLT NJSW
B3   6     6     6     6     3
*   PRINT HEADS
B4  80608 16009 16109 15009 82309 80408
*   PRINT FLOWS
B5  1030 1630 1600 1602 1570 8130
*   PLOT HEADS
B6  80608 16009 16109 15009 82309 80408
*   PLOT FLOWS
B7  1030 1630 1600 1602 1570 8130
*   CONDUIT DATA
C1  8040 80408 80608 0.0 1 0.0 4.0 0.0 1800.  0.0   0.0   0.015 0.0 0.0
C1  8060 80608 82309 0.0 1 0.0 4.0 0.0 2075.  0.0   2.2   0.015 0.0 0.0
C1  8100 81009 81309 0.0 1 0.0 4.5 0.0 5100.  0.0   0.0   0.015 0.0 0.0
C1  8130 81309 15009 0.0 1 0.0 4.5 0.0 3500.  0.0   0.0   0.015 0.0 0.0
C1  1030 10309 10208 0.0 6 0.0 9.0 0.0 4500.  0.0   0.0   0.016 3.0 3.0
C1  1570 15009 16009 0.0 1 0.0 5.5 0.0 5000.  0.0   0.0   .0154 0.0 0.0
C1  1600 16009 16109 0.0 1 0.0 6.0 0.0  500.  0.0   0.0   0.015 0.0 0.0
C1  1630 16009 10309 0.0 6 0.0 9.0 0.0  300.  0.0   0.0   0.015 3.0 3.0
C1  1602 82309 16109 0.0 1 0.0 5.0 0.0 5000.  0.0   0.0   0.034 0.0 0.0
*    JUNCTION DATA
D1   80408  138.0 124.6 0.0 0.0
D1   80608  135.0 118.3 0.0 0.0
D1   81009  137.0 128.2 0.0 0.0
D1   81309  130.0 117.5 0.0 0.0
D1   82309  155.0 112.3 0.0 0.0
D1   10208  100.0  89.9 0.0 0.0
D1   10309  111.0 101.6 0.0 0.0
D1   15009  125.0 111.5 0.0 0.0
D1   16009  120.0 102.0 0.0 0.0
D1   16109  125.0 102.8 0.0 0.0
*    SUMP ORIFICE AT JUNCTION 82309
F1  82309   15009 2 3.14 .85 0.0
I1  10208 1
J1  1
K1  3
K2 82309 80408 81009
K3  0.0  0.0  0.0  0.0
K3 0.25  40.0 45.0 50.0
K3  3.0  40.0 45.0 50.0
K3 3.25  0.0  0.0  0.0
K3 12.0  0.0  0.0  0.0
$ENDPROGRAM
```

Table 3-6. Partial Output for Example 3.

```
**********************************************************
*   J U N C T I O N   S U M M A R Y   S T A T I S T I C S   *
**********************************************************
```

EXTRAN USER'S MANUAL EXAMPLE 3
BASIC PIPE SYSTEM WITH SUMP ORIFICE AT JUNCTION 82309 FROM FIG 3-3

JUNCTION NUMBER	GROUND ELEVATION (FT)	UPPERMOST PIPE CROWN ELEVATION (FT)	MEAN JUNCTION DEPTH (FT)	JUNCTION DEPTH COEF. VAR	MAXIMUM JUNCTION DEPTH (FT)	TIME OF OCCURENCE HR.	MIN.	FEET OF SURCHARGE AT MAX DEPTH	FEET MAX. DEPTH IS BELOW GROUND ELEVATION	LENGTH OF SURCHARGE (MIN)	LENGTH OF FLOODING (MIN)	MAXIMUM JUNCTION AREA (SQ.FT)
80408	138.00	128.60	0.91	1.19	2.93	0	16	0.00	10.47	0.0	0.0	3.592E+03
80608	135.00	122.30	1.23	1.02	3.19	0	42	0.00	13.51	0.0	0.0	6.164E+04
81009	137.00	132.70	1.15	1.09	3.48	0	29	0.00	5.32	0.0	0.0	1.146E+04
81309	130.00	122.00	1.22	0.96	2.86	0	58	0.00	9.64	0.0	0.0	1.919E+04
82309	155.00	118.50	4.02	0.73	8.17	2	50	0.05	36.45	111.7	0.0	1.182E+05
10208	100.00	98.90	1.29	0.79	2.62	1	58	0.00	7.48	0.0	0.0	7.318E+04
10309	111.00	110.60	1.57	0.69	2.97	2	0	0.00	6.43	0.0	0.0	4.165E+04
15009	125.00	117.00	1.71	0.89	3.75	1	30	0.00	9.75	0.0	0.0	2.155E+04
16009	120.00	111.00	1.59	0.74	3.08	1	51	0.00	14.92	0.0	0.0	1.781E+04
16109	125.00	108.80	1.09	1.01	2.58	1	56	0.00	19.62	0.0	0.0	1.827E+05

```
**********************************************************
*   C O N D U I T   S U M M A R Y   S T A T I S T I C S   *
**********************************************************
```

CONDUIT NUMBER	DESIGN FLOW (CFS)	DESIGN VELOCITY (FPS)	CONDUIT VERTICAL DEPTH (IN)	MAXIMUM COMPUTED FLOW (CFS)	TIME OF OCCURENCE HR.	MIN.	MAXIMUM COMPUTED VELOCITY (FPS)	TIME OF OCCURENCE HR.	MIN.	RATIO OF MAX. TO DESIGN FLOW	MAXIMUM DEPTH ABOVE INV. AT CONDUIT ENDS UPSTREAM (FT)	DOWNSTREAM (FT)	LENGTH OF SPC FLOW (MIN)	CONDUIT SLOPE (FT/FT)
8040	7.36E+01	5.86	48.00	5.10E+01	0	22	6.42	0	20	0.69	2.93	3.19	457.3	0.00350
8060	5.33E+01	4.24	48.00	5.08E+01	0	44	5.04	0	41	0.95	3.19	4.05	34.7	0.00183
8100	7.81E+01	4.91	54.00	5.72E+01	0	41	5.45	0	37	0.73	3.48	2.86	429.3	0.00210
8130	7.06E+01	4.44	54.00	5.16E+01	0	58	4.34	0	51	0.73	2.86	3.75	478.0	0.00171
1030	3.03E+03	12.46	108.00	1.35E+02	1	58	5.74	1	59	0.04	2.97	2.62	0.0	0.00260
1570	1.24E+02	5.20	66.00	8.91E+01	1	34	5.75	1	29	0.72	3.75	3.08	271.7	0.00190
1600	1.47E+02	5.19	72.00	4.61E+01	2	8	3.51	2	37	0.31	2.58	3.08	243.3	0.00160
1630	2.31E+03	9.52	108.00	1.35E+02	1	47	5.22	0	53	0.06	3.08	2.97	196.7	0.00133
1602	4.34E+01	2.21	60.00	4.60E+01	2	17	31.28	0	5	1.06	6.25	2.58	269.3	0.00190
90010	3.03E+01	0.68	23.99	3.90E+01	3	0	12.41	3	0	1.29	8.17	4.88	0.7	0.00003
90011	UNDEF	UNDEF	UNDEF	1.35E+02	1	58								

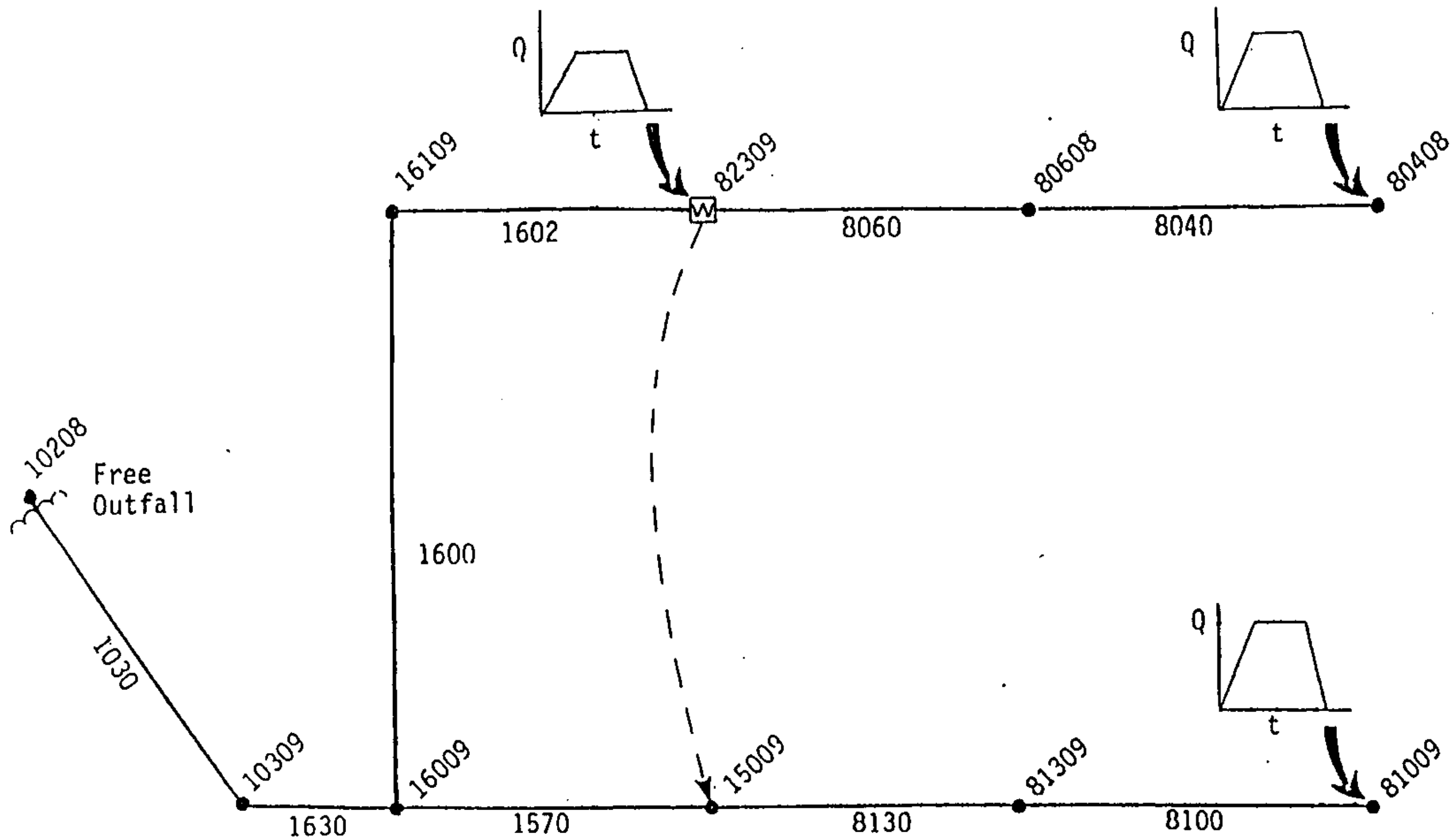


Figure 3-4. Weir at Junction 82309.

Table 3-7. Input Data for Example 4.

```
SW  1  0  0
MM  3  10 11 12
$EXTRAN
A1  'EXTRAN USER''S MANUAL EXAMPLE 4'
A1  ' BASIC PIPE SYSTEM WITH A WEIR AT JUNCTION 82309 FROM FIG 3-4'
*   NTCYC DELT TZERO NSTART INTER JNTER REDO
B1 1440  20.0  0.0    45     500    45    0
*   METRIC NEQUAL  AMEN ITMAX SURTOL
B2     0     0      0.0   30  0.05
* NHPRT NQPRT NPLT LPLT NJSW
B3   1     1     1     1    3
*   PRINT HEADS
B4  80608 16009 16109 15009 82309 80408
*   PRINT FLOWS
B5  1030 1630 1600 1602 1570 8130
*   PLOT HEADS
B6  80608 16009 16109 15009 82309 80408
*   PLOT FLOWS
B7  1030 1630 1600 1602 1570 8130
*   CONDUIT DATA
C1  8040 80408 80608 0.0 1 0.0 4.0 0.0 1800.  0.0  0.0  0.015 0.0 0.0
C1  8060 80608 82309 0.0 1 0.0 4.0 0.0 2075.  0.0  2.2  0.015 0.0 0.0
C1  8100 81009 81309 0.0 1 0.0 4.5 0.0 5100.  0.0  0.0  0.015 0.0 0.0
C1  8130 81309 15009 0.0 1 0.0 4.5 0.0 3500.  0.0  0.0  0.015 0.0 0.0
C1  1030 10309 10208 0.0 6 0.0 9.0 0.0 4500.  0.0  0.0  0.016 3.0 3.0
C1  1570 15009 16009 0.0 1 0.0 5.5 0.0 5000.  0.0  0.0  .0154 0.0 0.0
C1  1600 16009 16109 0.0 1 0.0 6.0 0.0  500.  0.0  0.0  0.015 0.0 0.0
C1  1630 16009 10309 0.0 6 0.0 9.0 0.0  300.  0.0  0.0  0.015 3.0 3.0
C1  1602 82309 16109 0.0 1 0.0 5.0 0.0 5000.  0.0  0.0  0.034 0.0 0.0
*    JUNCTION DATA
D1   80408  138.0 124.6 0.0 0.0
D1   80608  135.0 118.3 0.0 0.0
D1   81009  137.0 128.2 0.0 0.0
D1   81309  130.0 117.5 0.0 0.0
D1   82309  155.0 112.3 0.0 0.0
D1   10208  100.0  89.9 0.0 0.0
D1   10309  111.0 101.6 0.0 0.0
D1   15009  125.0 111.5 0.0 0.0
D1   16009  120.0 102.0 0.0 0.0
D1   16109  125.0 102.8 0.0 0.0
*   TRANVERSE WEIR AT JUNCTION 82309
G1  82309 15009 1 3.0 6.0 3.0 0.80
I1  10208 1
J1  1
K1  3
K2 82309 80408 81009
K3  0.0  0.0  0.0  0.0
K3 0.25  40.0 45.0 50.0
K3  3.0  40.0 45.0 50.0
K3 3.25  0.0  0.0  0.0
K3 12.0  0.0  0.0  0.0
$ENDPROGRAM
```

Table 3-8. Partial Output for Example 4.

```
************************************************************
*  J U N C T I O N   S U M M A R Y   S T A T I S T I C S  *
************************************************************
```

EXTRAN USER'S MANUAL EXAMPLE 4
BASIC PIPE SYSTEM WITH A WEIR AT JUNCTION 82309 FROM FIG 3-4

JUNCTION NUMBER	GROUND ELEVATION (FT)	UPPERMOST PIPE CROWN ELEVATION (FT)	MEAN JUNCTION DEPTH (FT)	JUNCTION DEPTH COEF. VAR	MAXIMUM JUNCTION DEPTH (FT)	TIME OF OCCURENCE HR.	MIN.	FEET OF SURCHARGE AT MAX DEPTH	FEET MAX. DEPTH IS BELOW GROUND ELEVATION	LENGTH OF SURCHARGE (MIN)	LENGTH OF FLOODING (MIN)	MAXIMUM JUNCTION AREA (SQ.FT)
80408	138.00	128.60	2.76	1.36	10.40	0	40	6.40	3.00	142.0	0.0	2.512E+04
80608	135.00	122.30	4.13	1.33	13.46	0	40	9.46	3.24	151.0	0.0	6.535E+04
81009	137.00	132.70	1.13	1.08	3.36	0	27	0.00	5.44	0.0	0.0	1.146E+04
81309	130.00	122.00	1.26	0.97	3.19	0	46	0.00	9.31	0.0	0.0	1.924E+04
82309	155.00	118.50	5.75	1.17	16.67	0	41	10.47	26.03	159.7	0.0	1.220E+05
10208	100.00	98.90	1.30	0.77	2.63	1	33	0.00	7.47	0.0	0.0	7.338E+04
10309	111.00	110.60	1.58	0.68	2.98	1	33	0.00	6.42	0.0	0.0	4.176E+04
15009	125.00	117.00	1.35	0.94	3.17	1	16	0.00	10.33	0.0	0.0	2.157E+04
16009	120.00	111.00	1.59	0.73	3.09	1	25	0.00	14.91	0.0	0.0	1.791E+04
16109	125.00	108.80	1.32	0.86	2.78	1	28	0.00	19.42	0.0	0.0	2.099E+05

```
************************************************************
*  C O N D U I T   S U M M A R Y   S T A T I S T I C S  *
************************************************************
```

CONDUIT NUMBER	DESIGN FLOW (CFS)	DESIGN VELOCITY (FPS)	CONDUIT VERTICAL DEPTH (IN)	MAXIMUM COMPUTED FLOW (CFS)	TIME OF OCCURENCE HR.	MIN.	MAXIMUM COMPUTED VELOCITY (FPS)	TIME OF OCCURENCE HR.	MIN.	RATIO OF MAX. TO DESIGN FLOW	MAXIMUM DEPTH ABOVE INV. AT CONDUIT ENDS UPSTREAM (FT)	DOWNSTREAM (FT)	LENGTH OF SPC FLOW (MIN)	CONDUIT SLOPE (FT/FT)
8040	7.36E+01	5.86	48.00	5.10E+01	0	22	50.00	0	0	0.69	10.28	13.47	305.7	0.00350
8060	5.33E+01	4.24	48.00	4.65E+01	0	41	4.82	0	27	0.87	13.47	14.49	33.0	0.00183
8100	7.81E+01	4.91	54.00	5.99E+01	0	38	50.00	0	0	0.77	3.36	3.19	441.7	0.00210
8130	7.06E+01	4.44	54.00	5.62E+01	0	56	5.05	0	48	0.80	3.19	3.17	421.3	0.00171
1030	3.03E+03	12.46	108.00	1.36E+02	1	33	5.75	1	32	0.04	2.98	2.63	0.0	0.00260
1570	1.24E+02	5.20	66.00	7.66E+01	1	17	5.49	1	16	0.62	3.17	3.09	315.0	0.00190
1600	1.47E+02	5.19	72.00	6.02E+01	0	42	5.52	0	39	0.41	2.78	3.09	237.7	0.00160
1630	2.31E+03	9.52	108.00	1.36E+02	1	22	5.41	0	50	0.06	3.09	2.98	195.0	0.00133
1602	4.34E+01	2.21	60.00	6.01E+01	0	41	50.00	0	0	1.38	16.69	2.78	0.0	0.00190
90010	UNDEF	UNDEF	UNDEF	2.61E+01	0	41								
90011	UNDEF	UNDEF	UNDEF	1.36E+02	1	33								

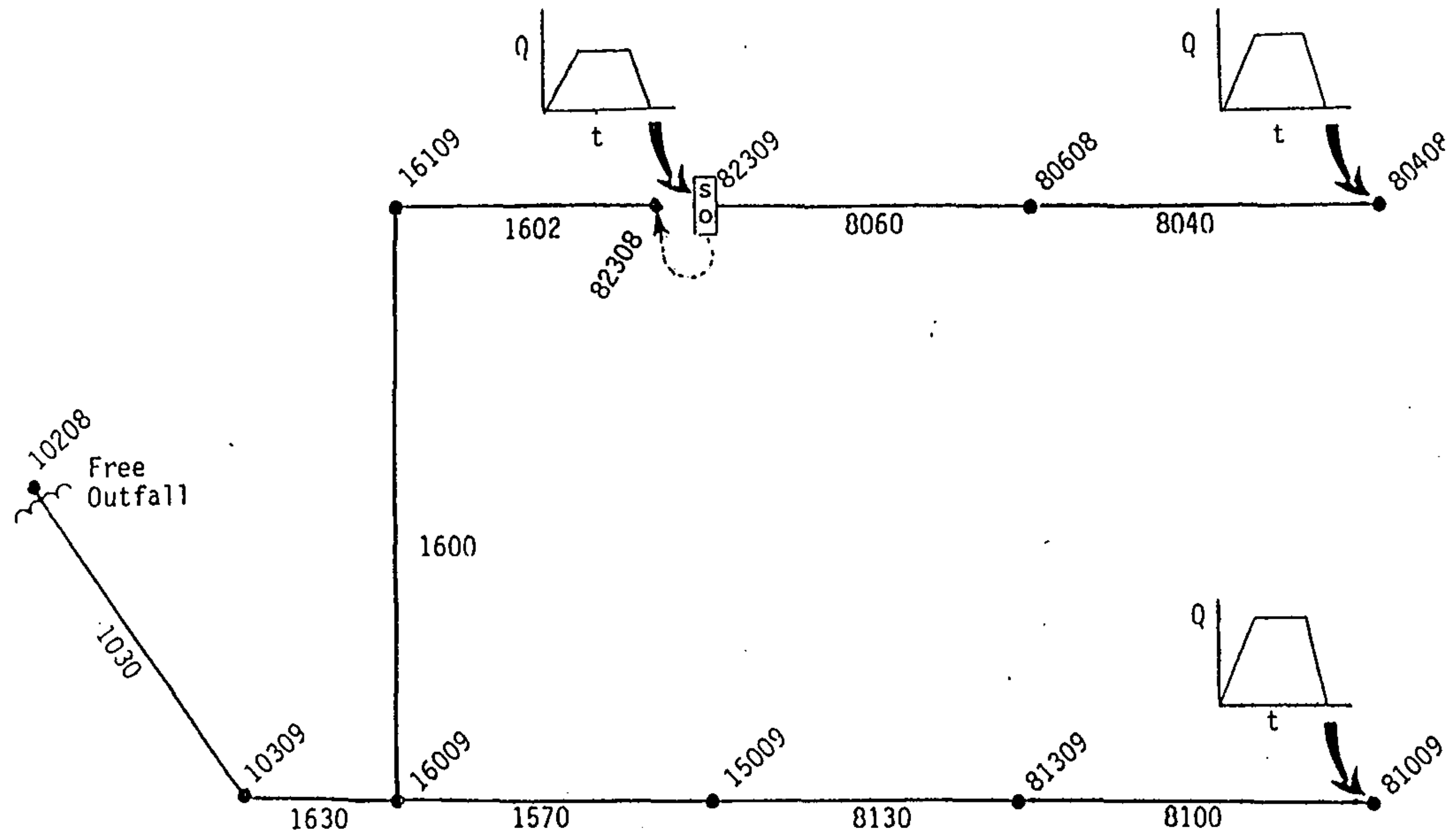


Figure 3-5. Storage Facility and Side Outlet Orifice at Junction 82309.

Table 3-9. Input Data for Example 5.

```
SW  1  0  0
MM  3  10 11 12
$EXTRAN
A1  'EXTRAN USER''S MANUAL EXAMPLE 5'
A1  ' STORAGE FACILITY AND SIDE OUTLET ORIFICE AT JUNCTION 82309, FIG 3-5'
*   NTCYC DELT TZERO NSTART INTER JNTER REDO
B1 1440  20.0  0.0  45       45    45    0
*   METRIC NEQUAL  AMEN ITMAX SURTOL
B2     0     0      0.0   30  0.05
* NHPRT NQPRT NPLT LPLT NJSW
B3   6    6    6    6    3
*   PRINT HEADS
B4  80608 16009 16109 15009 82309 80408
*   PRINT FLOWS
B5  1030 1630 1600 1602 1570 8130
*   PLOT HEADS
B6  80608 16009 16109 15009 82309 80408
*   PLOT FLOWS
B7  1030 1630 1600 1602 1570 8130
*   CONDUIT DATA
C1  8040 80408 80608 0.0 1 0.0 4.0 0.0 1800.  0.0   0.0   0.015 0.0 0.0
C1  8060 80608 82309 0.0 1 0.0 4.0 0.0 2075.  0.0   2.2   0.015 0.0 0.0
C1  8100 81009 81309 0.0 1 0.0 4.5 0.0 5100.  0.0   0.0   0.015 0.0 0.0
C1  8130 81309 15009 0.0 1 0.0 4.5 0.0 3500.  0.0   0.0   0.015 0.0 0.0
C1  1030 10309 10208 0.0 6 0.0 9.0 0.0 4500.  0.0   0.0   0.016 3.0 3.0
C1  1570 15009 16009 0.0 1 0.0 5.5 0.0 5000.  0.0   0.0   .0154 0.0 0.0
C1  1600 16009 16109 0.0 1 0.0 6.0 0.0  500.  0.0   0.0   0.015 0.0 0.0
C1  1630 16009 10309 0.0 6 0.0 9.0 0.0  300.  0.0   0.0   0.015 3.0 3.0
*  NOTE, PIPE 1602 NOW CONNECTS TO JUNCTION 82308
C1  1602 82308 16109 0.0 1 0.0 5.0 0.0 5000.  0.0   0.0   0.034 0.0 0.0
*    JUNCTION DATA
D1    80408   138.0 124.6 0.0 0.0
D1    80608   135.0 118.3 0.0 0.0
D1    81009   137.0 128.2 0.0 0.0
D1    81309   130.0 117.5 0.0 0.0
D1    82309   155.0 114.5 0.0 0.0
*  NEW JUNCTION FOR ORIFICE CONNECTION
D1    82308   155.0 112.3 0.0 0.0
D1    10208   100.0  89.9 0.0 0.0
D1    10309   111.0 101.6 0.0 0.0
D1    15009   125.0 111.5 0.0 0.0
D1    16009   120.0 102.0 0.0 0.0
D1    16109   125.0 102.8 0.0 0.0
* STORAGE JUNCTION AT JUNCTION 82309
E1    82309   155.0  800.0  0
*     SIDE-OUTLET ORIFICE AT JUNCTION 82309
F1  82309    82308  1  3.14 0.85 0.0
I1  10208 1
J1  1
K1  3
K2 82309 80408 81009
K3  0.0   0.0   0.0   0.0
K3 0.25  40.0 45.0 50.0
K3  3.0  40.0 45.0 50.0
K3 3.25   0.0  0.0   0.0
K3 12.0   0.0  0.0   0.0
$ENDPROGRAM
```

Table 3-10. Partial Output for Example 5.

```
************************************************************
*  J U N C T I O N   S U M M A R Y   S T A T I S T I C S  *
************************************************************
```

EXTRAN USER'S MANUAL EXAMPLE 5
STORAGE FACILITY AND SIDE OUTLET ORIFICE AT JUNCTION 82309, FIG 3-5

JUNCTION NUMBER	GROUND ELEVATION (FT)	UPPERMOST PIPE CROWN ELEVATION (FT)	MEAN JUNCTION DEPTH (FT)	JUNCTION DEPTH COEF. VAR	MAXIMUM JUNCTION DEPTH (FT)	TIME OF OCCURENCE HR.	MIN.	FEET OF SURCHARGE AT MAX DEPTH	FEET MAX. DEPTH IS BELOW GROUND ELEVATION	LENGTH OF SURCHARGE (MIN)	LENGTH OF FLOODING (MIN)	MAXIMUM JUNCTION AREA (SQ.FT)
80408	138.00	128.60	4.43	1.32	12.93	0	33	8.93	0.47	164.3	0.0	2.368E+04
80608	135.00	122.30	5.99	1.28	16.70	0	33	12.70	0.00	173.0	152.7	1.314E+04
81009	137.00	132.70	1.13	1.08	3.36	0	27	0.00	5.44	0.0	0.0	1.143E+04
81309	130.00	122.00	1.36	0.99	3.53	0	51	0.00	8.97	0.0	0.0	1.923E+04
82309	155.00	155.00	7.45	1.22	21.03	0	35	0.00	19.47	0.0	0.0	5.279E+03
82308	155.00	117.30	5.73	1.13	16.03	0	35	11.03	26.67	165.7	0.0	1.127E+05
10208	100.00	98.90	1.24	0.73	2.42	1	35	0.00	7.68	0.0	0.0	6.763E+04
10309	111.00	110.60	1.51	0.65	2.76	1	36	0.00	6.64	0.0	0.0	3.869E+04
15009	125.00	117.00	1.11	0.88	2.51	1	22	0.00	10.99	0.0	0.0	2.152E+04
16009	120.00	111.00	1.53	0.70	2.86	1	28	0.00	15.14	0.0	0.0	1.780E+04
16109	125.00	108.80	1.31	0.83	2.90	0	40	0.00	19.30	0.0	0.0	1.672E+05

```
************************************************************
*  C O N D U I T   S U M M A R Y   S T A T I S T I C S    *
************************************************************
```

CONDUIT NUMBER	DESIGN FLOW (CFS)	DESIGN VELOCITY (FPS)	CONDUIT VERTICAL DEPTH (IN)	MAXIMUM COMPUTED FLOW (CFS)	TIME OF OCCURENCE HR.	MIN.	MAXIMUM COMPUTED VELOCITY (FPS)	TIME OF OCCURENCE HR.	MIN.	RATIO OF MAX. TO DESIGN FLOW	MAXIMUM DEPTH ABOVE INV. AT CONDUIT ENDS UPSTREAM (FT)	DOWNSTREAM (FT)	LENGTH OF SPC FLOW (MIN)	CONDUIT SLOPE (FT/FT)
8040	7.36E+01	5.86	48.00	5.25E+01	0	19	50.00	0	0	0.71	12.90	16.70	288.3	0.00350
8060	5.33E+01	4.24	48.00	4.63E+01	0	27	3.69	0	27	0.87	16.70	21.04	294.0	0.00183
8100	7.81E+01	4.91	54.00	6.10E+01	0	37	50.00	0	0	0.78	3.36	3.53	442.7	0.00210
8130	7.06E+01	4.44	54.00	5.46E+01	1	3	5.13	0	56	0.77	3.53	2.51	279.3	0.00171
1030	3.03E+03	12.46	108.00	1.10E+02	1	35	5.46	1	35	0.04	2.76	2.42	0.0	0.00260
1570	1.24E+02	5.20	66.00	5.26E+01	1	22	4.57	1	21	0.43	2.51	2.86	443.0	0.00190
1600	1.47E+02	5.19	72.00	6.54E+01	0	43	5.89	0	41	0.45	2.90	2.86	240.7	0.00160
1630	2.31E+03	9.52	108.00	1.11E+02	1	26	5.15	0	51	0.05	2.86	2.76	189.7	0.00133
1602	4.34E+01	2.21	60.00	6.10E+01	0	31	3.94	0	32	1.41	16.03	2.90	0.0	0.00190
90010	3.03E+01	0.68	23.99	7.69E+01	0	31	24.48	0	31	2.54	21.04	13.84	0.0	0.00003
90011	UNDEF	UNDEF	UNDEF	1.10E+02	1	35								

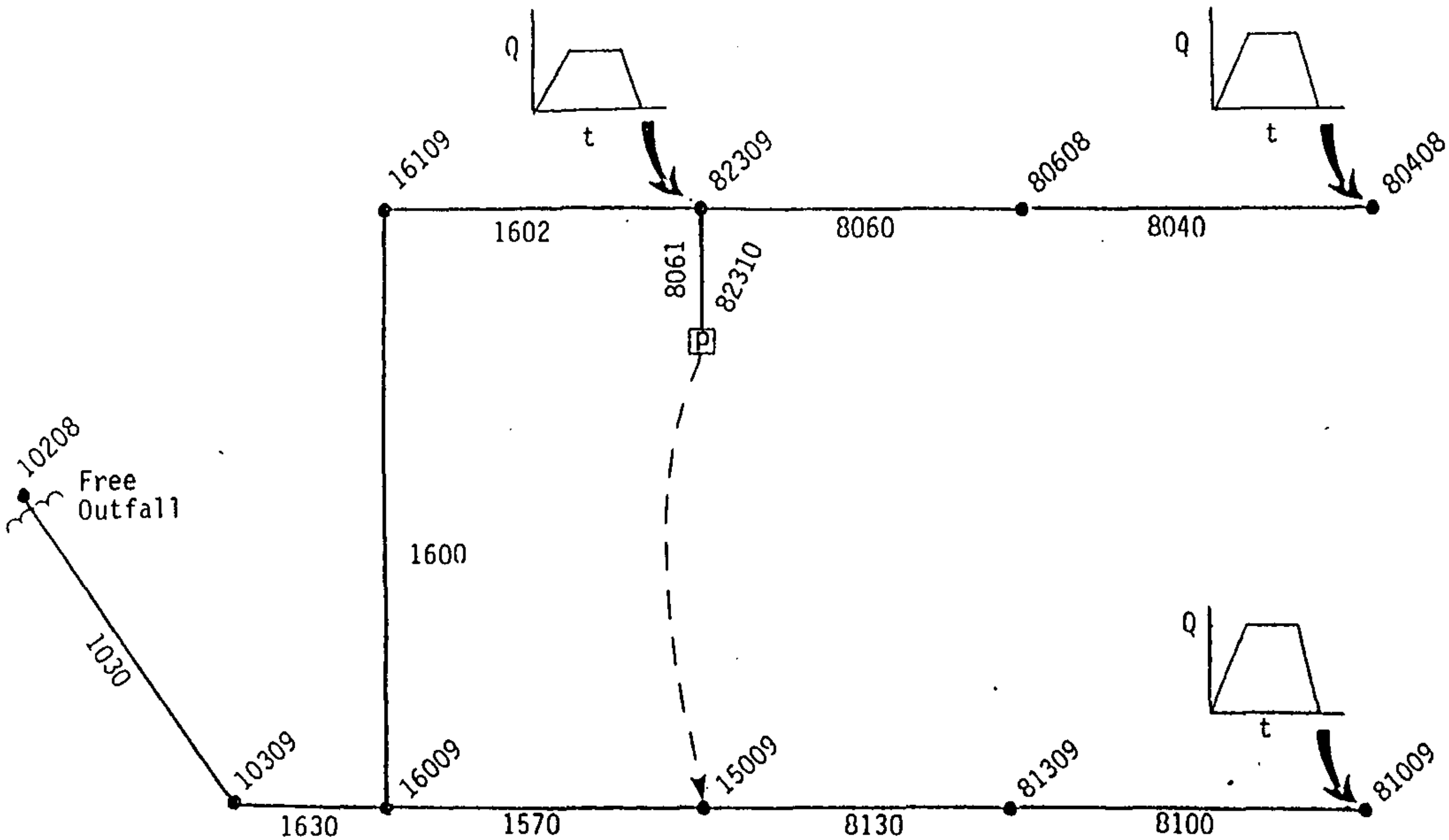


Figure 3-6. Off-line Pump Station (Activated by Wet Well Volume) at Junction 82310.

Table 3-11. Input Data for Example 6.

```
SW  1  0  0
MM  3  10 11 12
$EXTRAN
A1  'EXTRAN USER''S MANUAL EXAMPLE 6'
A1  ' OFF-LINE PUMP STATION AT JUNCTION 82310 FROM FIGURE 3-6'
*   NTCYC DELT TZERO NSTART INTER JNTER REDO
B1 1440  20.0  0.0  45       45     45     0
*   METRIC NEQUAL  AMEN ITMAX SURTOL
B2     0     0       0.0   30  0.05
* NHPRT NQPRT NPLT LPLT NJSW
B3   6     6     6     6     3
*   PRINT HEADS
B4  80608 16009 16109 15009 82309 80408
*   PRINT FLOWS
B5  1030 1630 1600 1602 1570 8130
*   PLOT HEADS
B6  80608 16009 16109 15009 82309 80408
*   PLOT FLOWS
B7  1030 1630 1600 1602 1570 8130
*   CONDUIT DATA
C1  8040 80408 80608 0.0 1 0.0 4.0 0.0 1800.  0.0  0.0  0.015 0.0 0.0
C1  8060 80608 82309 0.0 1 0.0 4.0 0.0 2075.  0.0  2.2  0.015 0.0 0.0
C1  8100 81009 81309 0.0 1 0.0 4.5 0.0 5100.  0.0  0.0  0.015 0.0 0.0
*  EXTRA PIPE FOR PUMP
C1  8061 82309 82310 0.0 1 0.0 4.0 0.0  300.  0.0  0.0  0.004 0.0 0.0
C1  8130 81309 15009 0.0 1 0.0 4.5 0.0 3500.  0.0  0.0  0.015 0.0 0.0
C1  1030 10309 10208 0.0 6 0.0 9.0 0.0 4500.  0.0  0.0  0.016 3.0 3.0
C1  1570 15009 16009 0.0 1 0.0 5.5 0.0 5000.  0.0  0.0  .0154 0.0 0.0
C1  1600 16009 16109 0.0 1 0.0 6.0 0.0  500.  0.0  0.0  0.015 0.0 0.0
C1  1630 16009 10309 0.0 6 0.0 9.0 0.0  300.  0.0  0.0  0.015 3.0 3.0
C1  1602 82309 16109 0.0 1 0.0 5.0 0.0 5000.  0.0  0.0  0.034 0.0 0.0
*    JUNCTION DATA
D1   80408   138.0 124.6 0.0 0.0
*  EXTRA JUNCTION FOR PUMP
D1   82310   155.0 112.3 0.0 0.0
D1   80608   135.0 118.3 0.0 0.0
D1   81009   137.0 128.2 0.0 0.0
D1   81309   130.0 117.5 0.0 0.0
D1   82309   155.0 112.3 0.0 0.0
D1   10208   100.0  89.9 0.0 0.0
D1   10309   111.0 101.6 0.0 0.0
D1   15009   125.0 111.5 0.0 0.0
D1   16009   120.0 102.0 0.0 0.0
D1   16109   125.0 102.8 0.0 0.0
* OFF-LINE PUMP
* IPTYP NJUNC1 NJUNC2 PRATE1 - PRATE3 VRATE1   -   VRATE3  VWELL
H1  1  82310  15009  5.0  10.0  20.0  200.0  600.0  1200.0  60.0
I1  10208 1
J1  1
K1  3
K2 82309 80408 81009
K3  0.0  0.0  0.0  0.0
K3 0.25  40.0 45.0 50.0
K3  3.0  40.0 45.0 50.0
K3 3.25  0.0  0.0  0.0
K3 12.0  0.0  0.0  0.0
$ENDPROGRAM
```

Table 3-12. Partial Output for Example 6.

```
***********************************************************
*  J U N C T I O N   S U M M A R Y   S T A T I S T I C S  *
***********************************************************
```

EXTRAN USER'S MANUAL EXAMPLE 6
OFF-LINE PUMP STATION AT JUNCTION 82310 FROM FIGURE 3-6

JUNCTION NUMBER	GROUND ELEVATION (FT)	UPPERMOST PIPE CROWN ELEVATION (FT)	MEAN JUNCTION DEPTH (FT)	JUNCTION DEPTH COEF. VAR	MAXIMUM JUNCTION DEPTH (FT)	TIME OF OCCURENCE HR.	TIME OF OCCURENCE MIN.	FEET OF SURCHARGE AT MAX DEPTH	FEET MAX. DEPTH IS BELOW GROUND ELEVATION	LENGTH OF SURCHARGE (MIN)	LENGTH OF FLOODING (MIN)	MAXIMUM JUNCTION AREA (SQ.FT)
80408	138.00	128.60	3.65	1.44	12.65	0	48	8.65	0.75	134.0	0.0	5.847E+04
82310	155.00	116.30	1.59	1.11	4.00	0	40	0.00	251.00	0.0	0.0	1.257E+01
80608	135.00	122.30	4.98	1.39	16.33	0	52	12.33	0.37	142.0	0.0	8.615E+04
81009	137.00	132.70	1.14	1.09	3.46	0	29	0.00	5.34	0.0	0.0	1.146E+04
81309	130.00	122.00	1.22	0.96	2.86	0	58	0.00	9.64	0.0	0.0	1.923E+04
82309	155.00	118.50	6.25	1.33	19.61	0	52	13.41	23.09	149.0	0.0	1.963E+05
10208	100.00	98.90	1.29	0.79	2.62	1	36	0.00	7.48	0.0	0.0	7.323E+04
10309	111.00	110.60	1.57	0.69	2.97	1	37	0.00	6.43	0.0	0.0	4.168E+04
15009	125.00	117.00	1.43	0.84	2.98	1	19	0.00	10.52	0.0	0.0	2.157E+04
16009	120.00	111.00	1.58	0.74	3.08	1	28	0.00	14.92	0.0	0.0	1.792E+04
16109	125.00	108.80	1.22	0.98	2.87	1	31	0.00	19.33	0.0	0.0	3.167E+05

```
***********************************************************
*  C O N D U I T   S U M M A R Y   S T A T I S T I C S    *
***********************************************************
```

CONDUIT NUMBER	DESIGN FLOW (CFS)	DESIGN VELOCITY (FPS)	CONDUIT VERTICAL DEPTH (IN)	MAXIMUM COMPUTED FLOW (CFS)	TIME OF OCCURENCE HR.	TIME OF OCCURENCE MIN.	MAXIMUM COMPUTED VELOCITY (FPS)	TIME OF OCCURENCE HR.	TIME OF OCCURENCE MIN.	RATIO OF MAX. TO DESIGN FLOW	MAXIMUM DEPTH ABOVE INV. AT CONDUIT ENDS UPSTREAM (FT)	MAXIMUM DEPTH ABOVE INV. AT CONDUIT ENDS DOWNSTREAM (FT)	LENGTH OF SPC FLOW (MIN)	CONDUIT SLOPE (FT/FT)
8040	7.36E+01	5.86	48.00	5.10E+01	0	22	50.00	0	0	0.69	12.52	16.33	314.7	0.00350
8060	5.33E+01	4.24	48.00	5.03E+01	0	37	4.97	0	34	0.94	16.33	17.41	20.0	0.00183
8100	7.81E+01	4.91	54.00	5.71E+01	0	41	50.00	0	0	0.73	3.46	2.86	429.7	0.00210
8061	2.70E+01	0.00	48.00	1.15E+02	3	9	9.49	3	10	4.28	19.61	1.58	0.3	0.00000
8130	7.06E+01	4.44	54.00	5.16E+01	0	55	4.85	0	55	0.73	2.86	2.98	460.7	0.00171
1030	3.03E+03	12.46	108.00	1.35E+02	1	36	5.74	1	36	0.04	2.97	2.62	0.0	0.00260
1570	1.24E+02	5.20	66.00	7.05E+01	1	19	5.31	3	10	0.57	2.98	3.08	440.7	0.00190
1600	1.47E+02	5.19	72.00	6.51E+01	1	2	4.69	1	2	0.44	2.87	3.08	228.0	0.00160
1630	2.31E+03	9.52	108.00	1.35E+02	1	24	5.39	0	53	0.06	3.08	2.97	194.7	0.00133
1602	4.34E+01	2.21	60.00	6.52E+01	0	56	50.00	0	0	1.50	19.61	2.87	160.7	0.00190
90011	UNDEF	UNDEF	UNDEF	2.00E+01	0	13								
90012	UNDEF	UNDEF	UNDEF	1.35E+02	1	36								

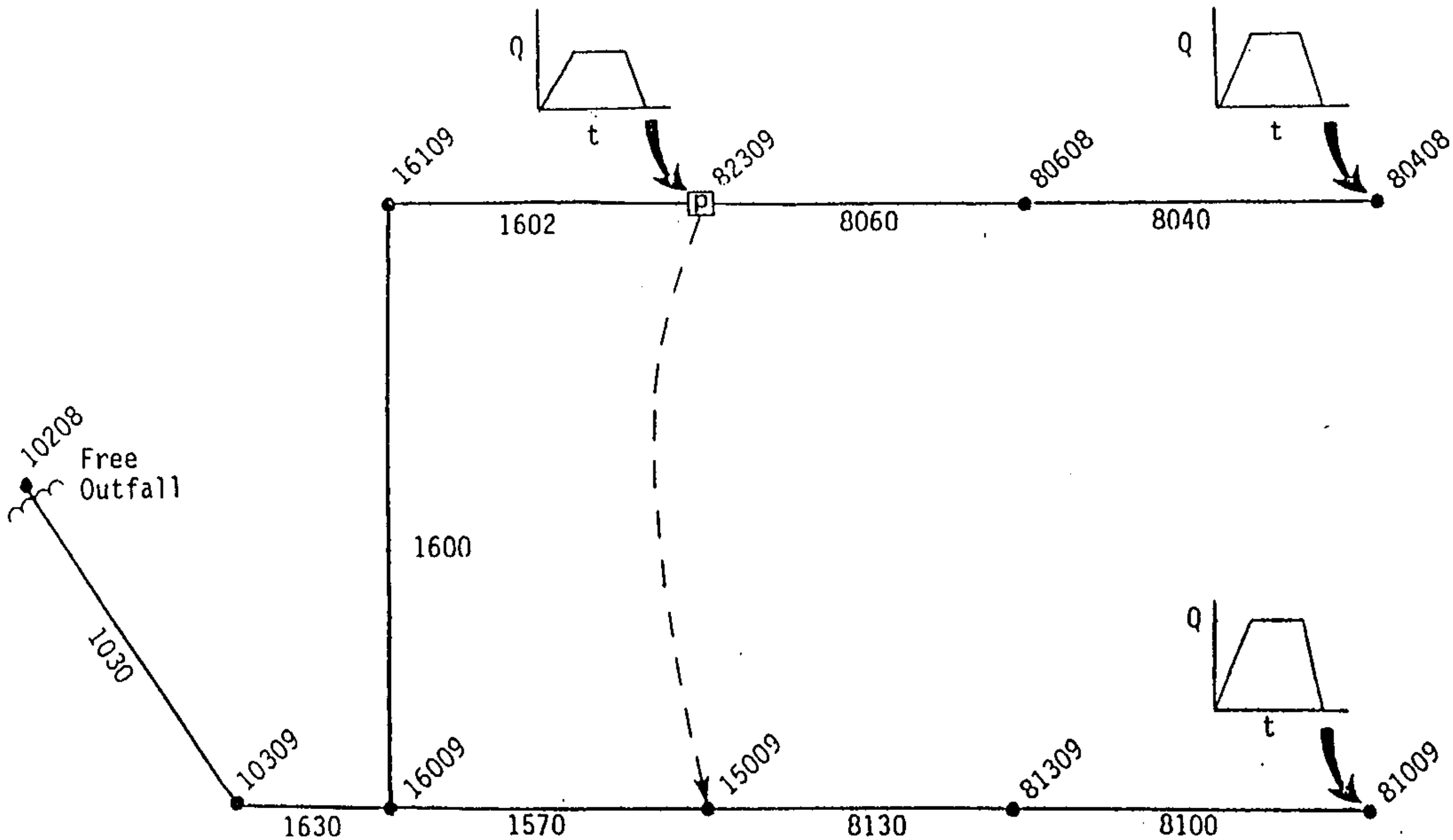


Figure 3-7. In-line Pump (Stage Activated) at Junction 82309.

Table 3-13. Input Data for Example 7.

```
SW  1  0  0
MM  3  10 11 12
$EXTRAN
A1  'EXTRAN USER''S MANUAL EXAMPLE 7'
A1  ' IN-LINE PUMP STATION AT JUNCTION 82309 FROM FIGURE 3-7'
*   NTCYC DELT TZERO NSTART INTER JNTER REDO
B1 1440  20.0  0.0  45       45    45    0
*   METRIC NEQUAL  AMEN ITMAX SURTOL
B2     0    0       0.0   30  0.05
* NHPRT NQPRT NPLT LPLT NJSW
B3   6    6    6    6    3
*   PRINT HEADS
B4  80608 16009 16109 15009 82309 80408
*   PRINT FLOWS
B5  1030 1630 1600 1602 1570 8130
*   PLOT HEADS
B6  80608 16009 16109 15009 82309 80408
*   PLOT FLOWS
B7  1030 1630 1600 1602 1570 8130
*   CONDUIT DATA
C1  8040 80408 80608 0.0 1 0.0 4.0 0.0 1800.  0.0  0.0  0.015 0.0 0.0
C1  8060 80608 82309 0.0 1 0.0 4.0 0.0 2075.  0.0  2.2  0.015 0.0 0.0
C1  8100 81009 81309 0.0 1 0.0 4.5 0.0 5100.  0.0  0.0  0.015 0.0 0.0
C1  8130 81309 15009 0.0 1 0.0 4.5 0.0 3500.  0.0  0.0  0.015 0.0 0.0
C1  1030 10309 10208 0.0 6 0.0 9.0 0.0 4500.  0.0  0.0  0.016 3.0 3.0
C1  1570 15009 16009 0.0 1 0.0 5.5 0.0 5000.  0.0  0.0  .0154 0.0 0.0
C1  1600 16009 16109 0.0 1 0.0 6.0 0.0  500.  0.0  0.0  0.015 0.0 0.0
C1  1630 16009 10309 0.0 6 0.0 9.0 0.0  300.  0.0  0.0  0.015 3.0 3.0
C1  1602 82309 16109 0.0 1 0.0 5.0 0.0 5000.  0.0  0.0  0.034 0.0 0.0
*    JUNCTION DATA
D1   80408  138.0 124.6 0.0 0.0
D1   80608  135.0 118.3 0.0 0.0
D1   81009  137.0 128.2 0.0 0.0
D1   81309  130.0 117.5 0.0 0.0
D1   82309  155.0 112.3 0.0 0.0
D1   10208  100.0  89.9 0.0 0.0
D1   10309  111.0 101.6 0.0 0.0
D1   15009  125.0 111.5 0.0 0.0
D1   16009  120.0 102.0 0.0 0.0
D1   16109  125.0 102.8 0.0 0.0
* IPTYP NJUNC1 NJUNC2 PRATE1 - PRATE3 VRATE1   -   VRATE3  VWELL
H1  2  82309  15009  5.0  10.0  20.0    8.0   25.0   0.0    0.0
I1  10208 1
J1  1
K1  3
K2 82309 80408 81009
K3  0.0  0.0  0.0  0.0
K3 0.25  40.0 45.0 50.0
K3  3.0  40.0 45.0 50.0
K3 3.25  0.0  0.0  0.0
K3 12.0  0.0  0.0  0.0
$ENDPROGRAM
```

Table 3-14. Partial Output for Example 7.

```
*********************************************************
*  J U N C T I O N   S U M M A R Y   S T A T I S T I C S *
*********************************************************
```

EXTRAN USER'S MANUAL EXAMPLE 7
IN-LINE PUMP STATION AT JUNCTION 82309 FROM FIGURE 3-7

JUNCTION NUMBER	GROUND ELEVATION (FT)	UPPERMOST PIPE CROWN ELEVATION (FT)	MEAN JUNCTION DEPTH (FT)	JUNCTION DEPTH COEF. VAR	MAXIMUM JUNCTION DEPTH (FT)	TIME OF OCCURENCE HR.	MIN.	FEET OF SURCHARGE AT MAX DEPTH	FEET MAX. DEPTH IS BELOW GROUND ELEVATION	LENGTH OF SURCHARGE (MIN)	LENGTH OF FLOODING (MIN)	MAXIMUM JUNCTION AREA (SQ.FT)
80408	138.00	128.60	4.15	1.39	13.40	0	36	9.40	0.00	148.7	1.3	2.010E+04
80608	135.00	122.30	5.57	1.35	16.70	0	35	12.70	0.00	155.0	146.0	1.090E+05
81009	137.00	132.70	1.14	1.08	3.43	0	28	0.00	5.37	0.0	0.0	1.146E+04
81309	130.00	122.00	1.27	0.97	3.17	0	52	0.00	9.33	0.0	0.0	1.926E+04
82309	155.00	118.50	7.26	1.29	22.96	0	37	16.76	19.74	162.0	0.0	1.958E+05
10208	100.00	98.90	1.28	0.78	2.57	1	35	0.00	7.53	0.0	0.0	7.183E+04
10309	111.00	110.60	1.55	0.68	2.92	1	35	0.00	6.48	0.0	0.0	4.089E+04
15009	125.00	117.00	1.29	0.82	2.75	1	21	0.00	10.75	0.0	0.0	2.157E+04
16009	120.00	111.00	1.57	0.74	3.03	1	27	0.00	14.97	0.0	0.0	1.791E+04
16109	125.00	108.80	1.27	0.98	2.89	1	32	0.00	19.31	0.0	0.0	3.269E+05

```
*********************************************************
*  C O N D U I T   S U M M A R Y   S T A T I S T I C S  *
*********************************************************
```

CONDUIT NUMBER	DESIGN FLOW (CFS)	DESIGN VELOCITY (FPS)	CONDUIT VERTICAL DEPTH (IN)	MAXIMUM COMPUTED FLOW (CFS)	TIME OF OCCURENCE HR.	MIN.	MAXIMUM COMPUTED VELOCITY (FPS)	TIME OF OCCURENCE HR.	MIN.	RATIO OF MAX. TO DESIGN FLOW	MAXIMUM DEPTH ABOVE INV. AT CONDUIT ENDS UPSTREAM (FT)	DOWNSTREAM (FT)	LENGTH OF SPC FLOW (MIN)	CONDUIT SLOPE (FT/FT)
8040	7.36E+01	5.86	48.00	5.10E+01	0	22	50.00	0	0	0.69	13.40	16.70	302.3	0.00350
8060	5.33E+01	4.24	48.00	4.62E+01	0	29	4.82	0	29	0.87	16.70	20.76	28.3	0.00183
8100	7.81E+01	4.91	54.00	5.94E+01	0	40	50.00	0	0	0.76	3.43	3.17	438.0	0.00210
8130	7.06E+01	4.44	54.00	5.34E+01	1	3	5.01	0	54	0.76	3.17	2.75	305.3	0.00171
1030	3.03E+03	12.46	108.00	1.29E+02	1	35	5.67	1	34	0.04	2.92	2.57	0.0	0.00260
1570	1.24E+02	5.20	66.00	6.19E+01	1	21	4.89	1	20	0.50	2.75	3.03	443.0	0.00190
1600	1.47E+02	5.19	72.00	6.71E+01	1	42	5.61	0	40	0.46	2.89	3.03	209.3	0.00160
1630	2.31E+03	9.52	108.00	1.29E+02	1	25	5.37	0	49	0.06	3.03	2.92	188.3	0.00133
1602	4.34E+01	2.21	60.00	6.84E+01	0	41	3.98	0	32	1.58	22.96	2.89	237.0	0.00190
90010	UNDEF	UNDEF	UNDEF	1.00E+01	0	32								
90011	UNDEF	UNDEF	UNDEF	1.29E+02	1	35								

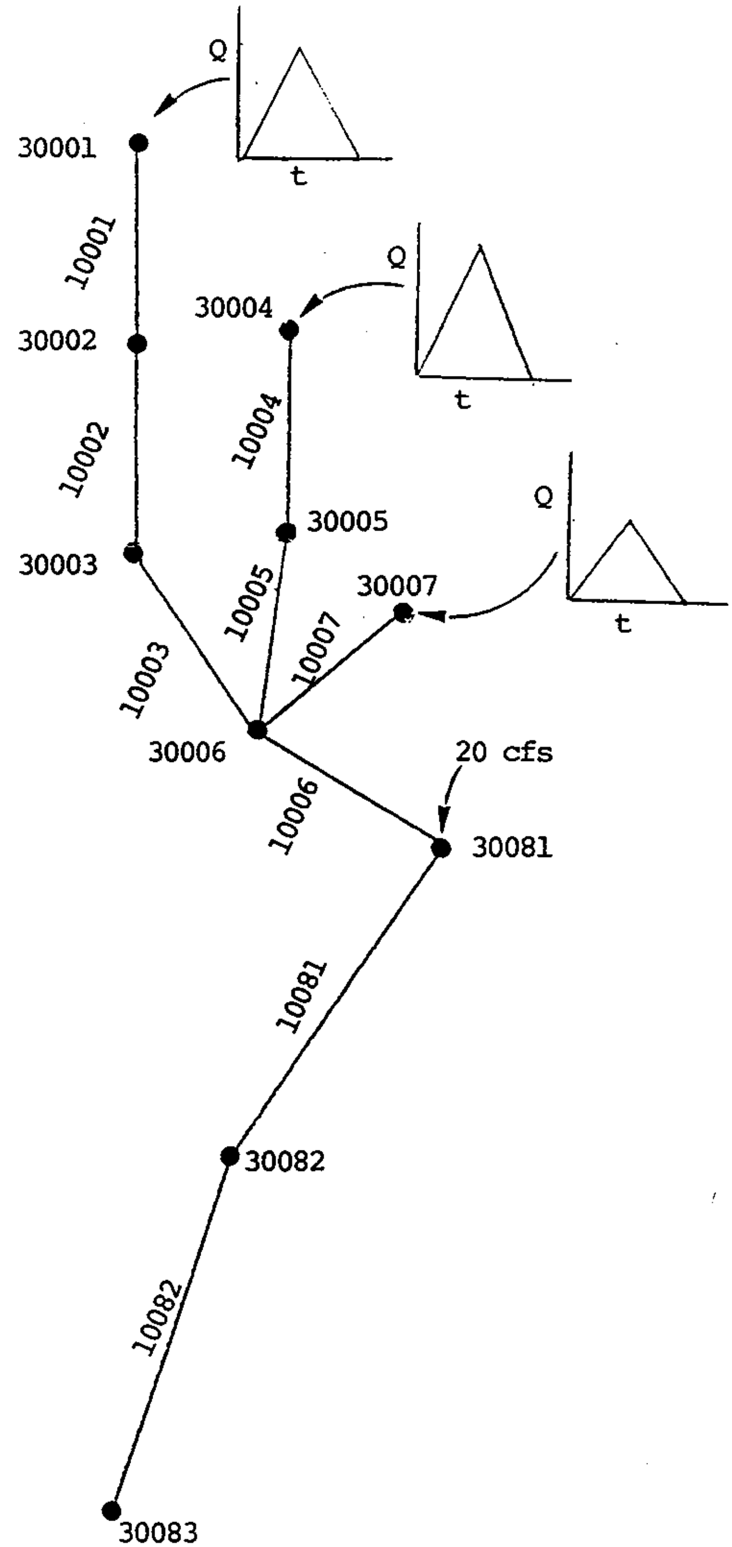


Figure 3-8. Schematic for Example 8.

Table 3-15. Input Data for Example 8. Generation of Hot Start File.

```
SW 1 0 0
MM 3 10 11 12
* MUST SAVE NSCRAT2 FOR FUTURE HOT START.
@  11 'EX8.HOT'
$EXTRAN
A1 'EXTRAN EXAMPLE SHOWING MOST CONDUIT AND DIVERSION TYPES'
A1 'INCLUDE IN USER''S MANUAL AS EXAMPLE 8'
*  RUN FOR 1 HR TO USE AS HOT START FOR NEXT RUN.
*   NTCYC DELT TZERO NSTART INTER JNTER REDO
B1 180    20.0  0.0    2      1    10    2
B2 0 0 0.0 30 0.05
B3 10 9 2 2 4
B4 30001 30002 30003 30004 30005 30006 30007 30081 30082 30083
B5 10001 10002 10003 10004 10005 10006 10007 10081 10082
B6 30081 30082
B7 10081 10082
* CONDUIT DATA
C1 10001 30001 30002 0.0 1 0.0   3.0 0.0  510. 0.0 0.0 0.015 0.0 0.0
C1 10002 30002 30003 0.0 2 0.0   3.0 3.5  520. 0.0 0.0 0.015 0.0 0.0
* GEOMETRIC PROPERTIES OF HORSESHOE, EGG AND BASKET-HANDLE ARE IN
*  SECTION 6 OF MAIN SWMM MANUAL.
C1 10003 30003 30006 0.0 3 13.26 4.0 4.0  530. 0.0 0.0 0.015 0.0 0.0
C1 10004 30004 30005 0.0 4 8.17  4.0 2.67 540. 0.0 0.0 0.015 0.0 0.0
C1 10005 30005 30006 0.0 5 12.58 4.0 3.78 550. 0.0 1.0 0.015 0.0 0.0
C1 10007 30007 30006 0.0 7 0.0   3.0 4.0  570. 0.0 2.0 0.018 0.0 0.0
C1 10006 30006 30081 0.0 6 0.0   5.0 8.0  560. 0.0 0.0 0.020 0.25 0.25
C1 10081 30081 30082 20. 8 0.0   5.0 0.0  1000. 0.0 0.0 0.00 91 0.001
C1 10082 30082 30083 20. 8 0.0   5.0 0.0  1000. 0.0 0.0 0.00 92 0.002
* DATA FOR IRREGULAR (NATURAL CHANNEL) CROSS-SECTIONS
*    XNL   XNR   XNCH
C2  0.04  0.04   0.04
* SECNO NUMST STCHL STCHR XLOBL XLOBR LEN PXCECR PSXECE
C3 91    6    50.0  110.0  0.0   0.0  1000. 0.0   799.0
* EL1  STA1  EL2  STA2  EL3  STA3  EL4  STA4   EL5  STA5
C4 5.0  0.0   4.0  50.0  1.0  55.0  0.0  100.0  3.0  110.0
* EL6  STA6
C4 5.0  150.0
*
C3 92    6    55.0  115.0  0.0   0.0  1000. 0.0   798.0
C4 5.0  0.0   4.5  55.0  0.0  60.0  2.0  95.0   4.0  115.0
C4 6.0  160.0
```

Table 3-15(Continued). Input Data for Example 8, Generation of Hot Start File.

```
* JUNCTION DATA
D1 30001 810.0 802.0 0.0 0.0
D1 30002 810.0 801.0 0.0 0.0
D1 30003 810.0 800.5 0.0 0.0
D1 30004 810.0 802.5 0.0 0.0
D1 30005 810.0 801.5 0.0 0.0
D1 30007 806.0 803.0 0.0 0.0
D1 30006 806.0 800.0 0.0 0.0
* INPUT 20 CFS AT BEGINNING OF NATURAL CHANNELS (E.G., RECEIVING STREAM)
*  BUT DO THIS IN HYDROGRAPH INPUT LINES.
D1 30081 806.0 799.0 20.0 0.0
D1 30082 806.0 798.0  0.0 0.0
D1 30083 806.0 796.0  0.0 2.0
* FREE OUTFALL TO CONSTANT HEAD AT DOWNSTREAM END
I1 30083 1
J1 2
J2 798.0
* INPUT TRIANGULAR HYDROGRAPHS AT THREE UPSTREAM ENDS OF SEWERS
K1 4
K2 30001 30004 30007 30081
*  FEED IN ZERO FLOWS FOR HOT START FILE CREATION.
*   JUST USE CONSTANT INFLOW OF 20 CFS AT JUNCTION 30081.
K3 0.0  0.0  0.0  0.0   0.0
K3 0.5  0.0  0.0  0.0   0.0
K3 1.0  0.0  0.0  0.0   0.0
$ENDPROGRAM
```

Table 3-16. Partial Output from Example 8. Generation of Hot Start File

```
**************************************************
* EXTRAN CONTINUITY BALANCE AT THE LAST TIME STEP *
**************************************************

***********************************************
* JUNCTION INFLOW, OUTFLOW OR STREET FLOODING *
***********************************************

   JUNCTION   INFLOW, FT3
   --------   -----------
      30081    7.2200E+04

   JUNCTION   OUTFLOW, FT3
   --------   ------------
      30083    5.5461E+04

******************************************************
* INITIAL SYSTEM VOLUME      =    4.5781E+04 CU FT *
* TOTAL SYSTEM INFLOW VOLUME =    7.2200E+04 CU FT *
* INFLOW + INITIAL VOLUME    =    1.1798E+05 CU FT *
******************************************************
* TOTAL SYSTEM OUTFLOW       =    5.5461E+04 CU FT *
* VOLUME LEFT IN SYSTEM      =    6.1049E+04 CU FT *
* OUTFLOW + FINAL VOLUME     =    1.1651E+05 CU FT *
******************************************************
* ERROR IN CONTINUITY, PERCENT =          1.25      *
******************************************************


***********************************************************
*   J U N C T I O N   S U M M A R Y   S T A T I S T I C S *
***********************************************************
```

JUNCTION NUMBER	GROUND ELEVATION (FT)	UPPERMOST PIPE CROWN ELEVATION (FT)	MEAN JUNCTION DEPTH (FT)	JUNCTION DEPTH COEF. VAR	MAXIMUM JUNCTION DEPTH (FT)	TIME OF OCCURENCE HR.	MIN.	FEET OF SURCHARGE AT MAX DEPTH	FEET MAX. DEPTH IS BELOW GROUND ELEVATION	LENGTH OF SURCHARGE (MIN)	LENGTH OF FLOODING (MIN)	MAXIMUM JUNCTION AREA (SQ.FT)
30001	810.00	805.00	0.00	0.00	0.00	0	0	0.00	8.00	0.0	0.0	7.819E+03
30002	810.00	804.00	0.00	0.00	0.00	0	0	0.00	9.00	0.0	0.0	1.578E+04
30003	810.00	804.50	0.00	0.00	0.00	0	0	0.00	9.50	0.0	0.0	1.550E+04
30004	810.00	806.50	0.00	0.00	0.00	0	0	0.00	7.50	0.0	0.0	7.979E+03
30005	810.00	805.50	0.00	0.00	0.00	0	0	0.00	8.50	0.0	0.0	1.609E+04
30007	806.00	806.00	0.00	0.00	0.00	0	0	0.00	3.00	0.0	0.0	8.422E+03
30006	806.00	805.00	0.02	0.93	0.04	0	58	0.00	5.96	0.0	0.0	2.660E+04
30081	806.00	804.00	0.96	0.12	1.04	1	0	0.00	5.96	0.0	0.0	2.678E+04
30082	806.00	803.00	1.19	0.06	1.29	1	0	0.00	6.71	0.0	0.0	3.840E+04
30083	806.00	801.00	2.00	0.00	2.00	0	0	0.00	8.00	0.0	0.0	3.393E+04

TIME HR:MIN	CONDUIT FLOW	10006 VELOC.	CONDUIT FLOW	10007 VELOC.	CONDUIT FLOW	10081 VELOC.	CONDUIT FLOW	10082 VELOC.
0: 3	0.00	0.00	0.00	0.00	6.15	0.29	13.21	0.56
0: 6	0.00	0.00	0.00	0.00	9.21	0.42	12.33	0.53
0:10	0.00	0.00	0.00	0.00	12.01	0.51	12.05	0.52
0:13	0.00	0.00	0.00	0.00	14.21	0.58	12.21	0.52
0:16	0.00	0.00	0.00	0.00	15.83	0.61	12.63	0.54
0:20	0.00	0.00	0.00	0.00	17.01	0.63	13.21	0.56
0:23	0.00	0.00	0.00	0.00	17.86	0.64	13.87	0.58
0:26	-0.29	-0.06	0.00	0.00	18.60	0.65	14.56	0.60
0:30	-0.33	-0.08	0.00	0.00	18.99	0.65	15.23	0.62
0:33	-0.02	-0.01	0.00	0.00	19.30	0.65	15.88	0.64
0:36	0.06	0.02	0.00	0.00	19.58	0.65	16.53	0.66
0:40	-0.08	-0.02	0.00	0.00	19.74	0.64	17.10	0.68
0:43	-0.12	-0.03	0.00	0.00	19.79	0.64	17.59	0.69
0:46	0.03	0.00	0.00	0.00	19.85	0.63	18.00	0.71
0:50	0.07	0.02	0.00	0.00	19.93	0.63	18.35	0.72
0:53	-0.07	-0.01	0.00	0.00	19.96	0.63	18.65	0.73
0:56	-0.07	-0.02	0.00	0.00	19.94	0.62	18.89	0.73
1: 0	0.06	0.01	0.00	0.00	19.96	0.62	19.09	0.74
MEAN	-0.04	-0.01	0.00	0.00	16.70	0.59	15.41	0.63
MAXIMUM	0.09	0.02	0.00	0.00	19.96	1.08	19.09	0.83
MINIMUM	-0.38	-0.09	0.00	0.00	3.33	0.18	12.05	0.52
TOTAL	-1.58E+02		0.00E-01		6.01E+04		5.55E+04	

****

* C O N D U I T   S U M M A R Y   S T A T I S T I C S *

****

CONDUIT NUMBER	DESIGN FLOW (CFS)	DESIGN VELOCITY (FPS)	CONDUIT VERTICAL DEPTH (IN)	MAXIMUM COMPUTED FLOW (CFS)	TIME OF OCCURENCE HR.	MIN.	MAXIMUM COMPUTED VELOCITY (FPS)	TIME OF OCCURENCE HR.	MIN.	RATIO OF MAX. TO DESIGN FLOW	MAXIMUM DEPTH ABOVE INV. AT CONDUIT ENDS UPSTREAM (FT)	DOWNSTREAM (FT)	LENGTH OF SPC FLOW (MIN)	CONDUIT SLOPE (FT/FT)
10001	2.56E+01	3.62	36.00	0.00E-01	0	0	0.00	0	0	0.00	-1.00	0.00	0.0	0.00196
10002	2.80E+01	2.66	36.00	0.00E-01	0	0	0.00	0	0	0.00	-0.50	0.00	0.0	0.00096
10003	4.08E+01	3.07	48.00	0.00E-01	0	0	0.00	0	0	0.00	-0.46	0.04	0.0	0.00094
10004	2.93E+01	3.59	48.00	0.00E-01	0	0	0.00	0	0	0.00	-1.00	0.00	0.0	0.00185
10005	4.13E+01	3.28	48.00	0.00E-01	0	0	0.00	0	0	0.00	-1.46	-0.96	0.0	0.00091
10007	2.88E+01	3.60	36.00	0.00E-01	0	0	0.00	0	0	0.00	-2.96	-1.96	0.0	0.00175
10006	2.69E+02	5.82	60.00	-3.76E-01	0	28	-0.09	0	28	0.00	0.04	1.04	1.7	0.00179
10081	8.30E+02	2.64	60.00	2.00E+01	1	0	1.08	0	0	0.02	1.04	1.29	60.0	0.00100
10082	7.48E+02	3.42	60.00	1.91E+01	1	0	0.83	0	0	0.03	1.29	2.00	60.0	0.00200
90010	UNDEF	UNDEF	UNDEF	1.91E+01	1	0								

Table 3-17. Input Data for Example 8. Use of Hot Start File.

```
SW 2 0 0 0 0
MM 3 10 11 12
* USE HOTSTART FILE FOR INITIAL CONDITIONS OF 20 CFS IN NATURAL CHANNELS.
@  11 'EX8.HOT'
$EXTRAN
A1 'EXTRAN EXAMPLE SHOWING MOST CONDUIT AND DIVERSION TYPES'
A1 'USE HOT START FILE FOR INITIAL 20 CFS IN TWO NATURAL CHANNELS'
*
*   NTCYC DELT TZERO NSTART INTER JNTER REDO
B1  360   20.0   0.0     1    100  100   1
*   METRIC NEQUAL  AMEN ITMAX SURTOL
B2     0      0     0.0   30    0.05
* NHPRT NQPRT NPLT LPLT NJSW
B3   2    2    2    2    3
B4 30001 30002 30003 30004 30005 30006 30007 30081 30082 30083
B5 10001 10002 10003 10004 10005 10006 10007 10081 10082
B6 30001 30003 30005 30006 30081 30082
B7 10081 10082 10006 10007 10081 10082
* CONDUIT DATA
*   NCOND NJ1 NJ2    QO  NKLASS AFULL DEEP WIDE   LEN  ZP1 ZP2 ROUGH STHETA SPHI
C1 10001 30001 30002  0.   1     0.0   3.0  0.0   510.  0.0 0.0 0.015  0.0   0.0
C1 10002 30002 30003  0.   2     0.0   3.0  3.5   520.  0.0 0.0 0.015  0.0   0.0
* GEOMETRIC PROPERTIES OF HORSESHOE, EGG AND BASKET-HANDLE ARE IN
*  SECTION 6 OF MAIN SWMM MANUAL.
C1 10003 30003 30006  0.   3   13.26  4.0 4.0  530. 0.0 0.0 0.015 0.0 0.0
C1 10004 30004 30005  0.   4    8.17  4.0 2.67 540. 0.0 0.0 0.015 0.0 0.0
C1 10005 30005 30006  0.   5   12.58  4.0 3.78 550. 0.0 1.0 0.015 0.0 0.0
C1 10007 30007 30006  0.   7    0.0   3.0 4.0  570. 0.0 2.0 0.018 0.0 0.0
C1 10006 30006 30081  0.   6    0.0   5.0 8.0  560. 0.0 0.0 0.020 0.25 0.25
*  Conduit 10081 uses data from section 91
C1 10081 30081 30082 20.   8    0.0   5.0 0.0  1000. 0.0 0.0 0.0 91 0.001
*  Conduit 10082 uses data from section 92
*          A negative STHETA stops the printout of the
*             normalized curves for a natural channel.
C1 10082 30082 30083 20.   8    0.0   5.0 0.0  1000. 0.0 0.0 0.0 92 0.002
* DATA FOR IRREGULAR (NATURAL CHANNEL) CROSS-SECTION
*    XNL   XNR   XNCH
C2  0.08  0.08   0.03
* SECNO NUMST STCHL STCHR XLOBL XLOBR LEN PXCECR PSXECE
C3 91     6    50.0  110.0  0.0   0.0  1000. 0.0   799.0
*  EL1  STA1  EL2  STA2  EL3  STA3  EL4  STA4   EL5  STA5
C4 5.0  0.0   4.0  50.0  1.0  55.0  0.0  100.0  3.0  110.0
*  EL6  STA6
C4 5.0  150.0
*  OTHER NATURAL CHANNEL
C3 92     6    55.0  115.0  0.0   0.0  1000. 0.0   798.0
C4 5.0  0.0   4.5  55.0  0.0  60.0  2.0  95.0   4.0  115.0
C4 6.0  160.0
```

Table 3-17(Continued). Input Data for Example 8. Use of Hot Start File.

```
*    JUNCTION DATA
*    JUN    GRELEV   Z    QINST  Y
D1 30001   810.0  802.0  0.0  0.0
D1 30002   810.0  801.0  0.0  0.0
D1 30003   810.0  800.5  0.0  0.0
D1 30004   810.0  802.5  0.0  0.0
D1 30005   810.0  801.5  0.0  0.0
D1 30007   806.0  803.0  0.0  0.0
D1 30006   806.0  800.0  0.0  0.0
* INPUT 20 CFS AT BEGINNING OF NATURAL CHANNELS (E.G., RECEIVING STREAM)
D1 30081    806.0 799.0  20.  0.0
D1 30082    806.0 798.0  0.0  0.0
* INITIAL CONDITION OF 2 FT DEPTH AT DOWNSTREAM END (CONSTANT HEAD)
D1 30083    806.0 796.0  0.0  2.0
* FREE OUTFALL TO CONSTANT HEAD AT DOWNSTREAM END
I1 30083 1
J1 2
J2 798.0
* INPUT TRIANGULAR HYDROGRAPHS AT THREE UPSTREAM ENDS OF SEWERS
K1 3
K2      30001  30004  30007
K3 0.0   0.0    0.0    0.0
K3 0.5  15.0   18.0    9.0
K3 1.1   0.0    0.0    0.0
K3 3.0   0.0    0.0    0.0
$ENDPROGRAM
```

Table 3-18. Partial Output for Example 8. Use of Hot Start File.

```
EXTRAN EXAMPLE SHOWING MOST CONDUIT AND DIVERSION TYPES
USE HOT START FILE FOR INITIAL 20 CFS IN TWO NATURAL CHANNELS

CONTROL INFORMATION FOR SIMULATION
----------------------------------

INTEGRATION CYCLES.................  360

LENGTH OF INTEGRATION STEP IS......   20. SECONDS

DO NOT CREATE EQUIV. PIPES(NEQUAL).    0

USE U.S. CUSTOMARY UNITS FOR I/O...    0

PRINTING STARTS IN CYCLE...........    1

INTERMEDIATE PRINTOUT INTERVALS OF.  100 CYCLES

SUMMARY PRINTOUT INTERVALS OF......  100 CYCLES

HOT START FILE MANIPULATION(REDO)..    1

INITIAL TIME....................... 0.00 HOURS

ITERATION VARIABLES: ITMAX.........   30
                     SURTOL........0.0500

DEFAULT SURFACE AREA OF JUNCTIONS.. 12.57 CUB FT.

EXTRAN VERSION 3.3 SOLUTION. (ISOL = 0).
SUM OF JUNCTION FLOW IS ZERO DURING SURCHARGE.

NORMAL FLOW OPTION WHEN THE WATER
SURFACE SLOPE IS LESS THAN THE
GROUND SURFACE SLOPE (KSUPER=0)....

NJSW INPUT HYDROGRAPH JUNCTIONS....    3

PRINTED OUTPUT FOR THE FOLLOWING  2 JUNCTIONS

       30001    30002

PRINTED OUTPUT FOR THE FOLLOWING  2 CONDUITS

       10001    10002
```

POWER FUNCTION CROSS-SECTION INFORMATION FOR CHANNEL 10007
==

LENGTH	:	570.0 FEET.
EXPONENT OF CHANNEL	:	2.000
MAXIMUM DEPTH	:	3.00 FEET.
MANNING N	:	0.018
MAXIMUM SECTION AREA	:	8.00 SQ. FT.
MAXIMUM HYDRAULIC RADIUS	:	1.06 FEET.
MAXIMUM TOP WIDTH	:	4.00 FEET.

CROSS-SECTION DIMENSIONLESS CURVES
NORMALIZED BY DEPTH

POINT NO.	HYDRAULIC RADIUS	DEPTH	TOPWIDTH	POINT NO.	HYDRAULIC RADIUS	DEPTH	TOPWIDTH	POINT NO.	HYDRAULIC RADIUS	DEPTH	TOPWIDTH
1	0.0000	0.0000	0.2000	10	0.8058	0.3600	0.6000	19	0.9439	0.7200	0.8485
2	0.3593	0.0400	0.2000	11	0.8282	0.4000	0.6325	20	0.9536	0.7600	0.8718
3	0.4827	0.0800	0.2828	12	0.8480	0.4400	0.6633	21	0.9627	0.8000	0.8944
4	0.5655	0.1200	0.3464	13	0.8659	0.4800	0.6928	22	0.9711	0.8400	0.9165
5	0.6276	0.1600	0.4000	14	0.8819	0.5200	0.7211	23	0.9790	0.8800	0.9381
6	0.6768	0.2000	0.4472	15	0.8966	0.5600	0.7483	24	0.9864	0.9200	0.9592
7	0.7172	0.2400	0.4899	16	0.9099	0.6000	0.7746	25	0.9934	0.9600	0.9798
8	0.7512	0.2800	0.5292	17	0.9222	0.6400	0.8000	26	1.0000	1.0000	1.0000
9	0.7804	0.3200	0.5657	18	0.9335	0.6800	0.8246				

NATURAL CROSS-SECTION INFORMATION FOR CHANNEL 10081
==
CROSS-SECTION ID (FROM X1 CARD) : 91.0

LENGTH	:	1000.0 FT	MAXIMUM ELEVATION	:	804.00 FT.
SLOPE	:	0.0010 FT/FT	MAXIMUM DEPTH	:	5.00 FT.
MANNING N	:	0.080 TO STATION 50.0	MAXIMUM SECTION AREA	:	315.00 SQ. FT.
" "	:	0.030 IN MAIN CHANNEL	MAXIMUM HYDRAULIC RADIUS	:	3.12 FT.
" "	:	0.080 BEYOND STATION 110.0	MAX TOPWIDTH	:	150.00 FT.
			MAXIMUM UNIFORM FLOW	:	708.28 CFS.

CROSS-SECTION POINTS

THE FOLLOWING 6 STATIONS WERE READ AND ADJUSTED 799.000 FT VERTICALLY AND HORIZONTALLY BY A RATIO OF 1.000

ELEVATION FT	STATION FT	ELEVATION FT	STATION FT	ELEVATION FT	STATION FT	ELEVATION FT	STATION FT	ELEVATION FT	STATION FT
804.00	0.00	803.00	50.00	800.00	55.00	799.00	100.00	802.00	110.00
804.00	150.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

CROSS-SECTION DIMENSIONLESS CURVES
NORMALIZED BY DEPTH

POINT NO.	HYDRAULIC RADIUS	DEPTH	TOPWIDTH	POINT NO.	HYDRAULIC RADIUS	DEPTH	TOPWIDTH	POINT NO.	HYDRAULIC RADIUS	DEPTH	TOPWIDTH
1	0.0000	0.0000	0.0644	10	0.4017	0.2045	0.3489	19	0.8966	0.5388	0.4756
2	0.0320	0.0031	0.0644	11	0.4604	0.2381	0.3556	20	0.9370	0.5855	0.5044
3	0.0640	0.0123	0.1289	12	0.5185	0.2723	0.3622	21	0.9733	0.6349	0.5333
4	0.0960	0.0276	0.1933	13	0.5759	0.3071	0.3689	22	1.0007	0.6902	0.6267
5	0.1280	0.0491	0.2578	14	0.6328	0.3425	0.3756	23	1.0139	0.7543	0.7200
6	0.1600	0.0767	0.3222	15	0.6890	0.3786	0.3822	24	1.0163	0.8273	0.8133
7	0.2215	0.1077	0.3289	16	0.7447	0.4153	0.3889	25	1.0108	0.9092	0.9067
8	0.2822	0.1394	0.3356	17	0.8011	0.4538	0.4178	26	1.0000	1.0000	1.0000
9	0.3423	0.1716	0.3422	18	0.8515	0.4949	0.4467				

NATURAL CROSS-SECTION INFORMATION FOR CHANNEL 10082
==
CROSS-SECTION ID (FROM X1 CARD) : 92.0

LENGTH	:	1000.0 FT		MAXIMUM ELEVATION	:	803.00 FT.
SLOPE	:	0.0020 FT/FT		MAXIMUM DEPTH	:	5.00 FT.
MANNING N	:	0.080 TO STATION	55.0	MAXIMUM SECTION AREA	:	218.75 SQ. FT.
" "	:	0.030 IN MAIN CHANNEL		MAXIMUM HYDRAULIC RADIUS	:	2.88 FT.
" "	:	0.080 BEYOND STATION	115.0	MAX TOPWIDTH	:	137.50 FT.
				MAXIMUM UNIFORM FLOW	:	659.68 CFS.

CROSS-SECTION POINTS

THE FOLLOWING 6 STATIONS WERE READ AND ADJUSTED 798.000 FT VERTICALLY AND HORIZONTALLY BY A RATIO OF 1.000

ELEVATION FT	STATION FT	ELEVATION FT	STATION FT	ELEVATION FT	STATION FT	ELEVATION FT	STATION FT	ELEVATION FT	STATION FT
803.00	0.00	802.50	55.00	798.00	60.00	800.00	95.00	802.00	115.00
804.00	160.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

```
**************************************************
*                  CONDUIT DATA                  *
**************************************************
```

INP NUM	CONDUIT NUMBER	LENGTH (FT)	CONDUIT CLASS	AREA (SQ FT)	MANNING COEF.	MAX WIDTH (FT)	DEPTH (FT)	JUNCTIONS AT THE ENDS		INVERT HEIGHT ABOVE JUNCTIONS		TRAPEZOID SIDE SLOPES	
1	10001	510.	CIRCULAR	7.07	0.01500	3.00	3.00	30001	30002				
2	10002	520.	RECTANGLE	10.50	0.01500	3.50	3.00	30002	30003				
3	10003	530.	HORSESHOE	13.26	0.01500	4.00	4.00	30003	30006				
4	10004	540.	EGG-SHAPE	8.17	0.01500	2.67	4.00	30004	30005				
5	10005	550.	BASKET	12.58	0.01500	3.78	4.00	30005	30006	0.00	1.00		
6	10007	570.	NATURAL	8.00	0.01800	4.00	3.00	30007	30006	0.00	2.00		
7	10006	560.	TRAPEZOID	46.25	0.02000	8.00	5.00	30006	30081			0.25	0.25
8	10081	1000.	NATURAL	315.00	0.03000	150.00	5.00	30081	30082				
9	10082	1000.	NATURAL	218.75	0.03000	137.50	5.00	30082	30083				

```
**************************************************
*                 JUNCTION DATA                  *
**************************************************
```

INP NUM	JUNCTION NUMBER	GROUND ELEV.	CROWN ELEV.	INVERT ELEV.	QINST CFS	INITIAL DEPTH(FT)	CONNECTING CONDUITS			
1	30001	810.00	805.00	802.00	0.00	0.00	10001			
2	30002	810.00	804.00	801.00	0.00	0.00	10001	10002		
3	30003	810.00	804.50	800.50	0.00	0.00	10002	10003		
4	30004	810.00	806.50	802.50	0.00	0.00	10004			
5	30005	810.00	805.50	801.50	0.00	0.00	10004	10005		
6	30007	806.00	806.00	803.00	0.00	0.00	10007			
7	30006	806.00	805.00	800.00	0.00	0.00	10003	10005	10007	10006
8	30081	806.00	804.00	799.00	20.00	0.00	10006	10081		
9	30082	806.00	803.00	798.00	0.00	0.00	10081	10082		
10	30083	806.00	801.00	796.00	0.00	2.00	10082			

```
************************************************
*       FREE OUTFALL DATA (DATA GROUP I1)      *
*     BOUNDARY CONDITION ON DATA GROUP J1      *
************************************************
```

OUTFALL AT JUNCTION.... 30083 HAS BOUNDARY CONDITION NUMBER... 1

```
**************************************************
*      BOUNDARY CONDITON INFORMATION             *
*              DATA GROUPS J1-J4                 *
**************************************************
```

BC NUMBER.. 1 CONTROL WATER SURFACE ELEVATION IS.. 798.00 FEET.

```
*********************************************
*        CONDUIT COURANT CONDITION SUMMARY   *
*********************************************
* COURANT   =             CONDUIT LENGTH     *
* TIME STEP = ------------------------------ *
*           VELOCITY + SQRT(GRVT*AREA/WIDTH) *
*********************************************
* AVERAGE COURANT CONDITION TIME STEP(SECONDS) *
*********************************************
```

CONDUIT #	TIME(SEC)	CONDUIT #	TIME(SEC)	CONDUIT #	TIME(SEC)	CONDUIT #	TIME(SEC)
10001	201.22	10002	162.30	10003	114.57	10004	118.09
10005	185.94	10007	284.41	10006	101.03	10081	177.90
10082	155.89						

```
***********************************************
* EXTRAN CONTINUITY BALANCE AT THE LAST TIME STEP *
***********************************************

*********************************************
* JUNCTION INFLOW, OUTFLOW OR STREET FLOODING *
*********************************************
```

JUNCTION	INFLOW, FT3
30001	2.9700E+04
30004	3.5640E+04
30007	1.7820E+04
30081	1.4400E+05

JUNCTION	OUTFLOW, FT3
30083	2.3275E+05

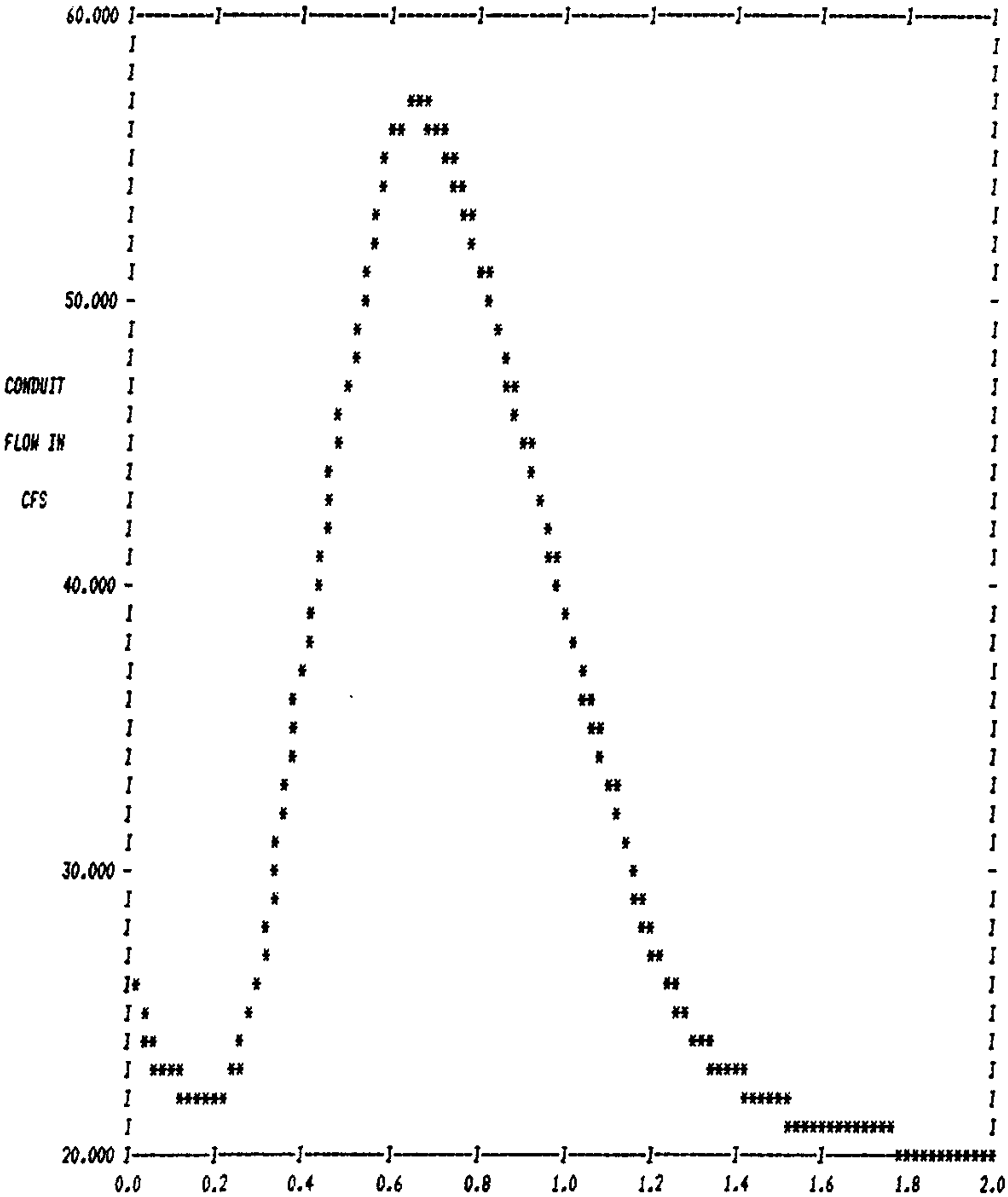
```
*****************************************************
* INITIAL SYSTEM VOLUME        =   6.1049E+04 CU FT *
* TOTAL SYSTEM INFLOW VOLUME   =   2.2716E+05 CU FT *
* INFLOW + INITIAL VOLUME      =   2.8821E+05 CU FT *
*****************************************************
* TOTAL SYSTEM OUTFLOW         =   2.3275E+05 CU FT *
* VOLUME LEFT IN SYSTEM        =   5.5583E+04 CU FT *
* OUTFLOW + FINAL VOLUME       =   2.8833E+05 CU FT *
*****************************************************
* ERROR IN CONTINUITY, PERCENT =       -0.04        *
*****************************************************
```

JUNCTION NUMBER	GROUND ELEVATION (FT)	UPPERMOST PIPE CROWN ELEVATION (FT)	MEAN JUNCTION DEPTH (FT)	JUNCTION DEPTH COEF. VAR	MAXIMUM JUNCTION DEPTH (FT)	TIME OF OCCURENCE HR.	MIN.	FEET OF SURCHARGE AT MAX DEPTH	FEET MAX. DEPTH IS BELOW GROUND ELEVATION	LENGTH OF SURCHARGE (MIN)	LENGTH OF FLOODING (MIN)	MAXIMUM JUNCTION AREA (SQ.FT)
30001	810.00	805.00	0.64	0.96	1.68	0	30	0.00	6.32	0.0	0.0	7.770E+02
30002	810.00	804.00	0.53	1.00	1.50	0	32	0.00	7.50	0.0	0.0	1.687E+03
30003	810.00	804.50	0.63	0.79	1.49	0	34	0.00	8.01	0.0	0.0	1.950E+03
30004	810.00	806.50	1.00	0.97	2.62	0	30	0.00	4.88	0.0	0.0	7.192E+02
30005	810.00	805.50	0.74	0.77	1.71	0	33	0.00	6.79	0.0	0.0	2.736E+03
30007	806.00	806.00	0.42	1.05	1.22	0	32	0.00	1.78	0.0	0.0	1.368E+03
30006	806.00	805.00	0.53	0.91	1.43	0	34	0.00	4.57	0.0	0.0	3.474E+03
30081	806.00	804.00	1.08	0.13	1.34	0	39	0.00	5.66	0.0	0.0	2.765E+04
30082	806.00	803.00	1.40	0.12	1.68	0	48	0.00	6.32	0.0	0.0	4.202E+04
30083	806.00	801.00	2.00	0.00	2.00	0	0	0.00	8.00	0.0	0.0	3.575E+04

```
*****************************************************
* C O N D U I T   S U M M A R Y   S T A T I S T I C S *
*****************************************************
```

CONDUIT NUMBER	DESIGN FLOW (CFS)	DESIGN VELOCITY (FPS)	CONDUIT VERTICAL DEPTH (IN)	MAXIMUM COMPUTED FLOW (CFS)	TIME OF OCCURENCE HR.	MIN.	MAXIMUM COMPUTED VELOCITY (FPS)	TIME OF OCCURENCE HR.	MIN.	RATIO OF MAX. TO DESIGN FLOW	MAXIMUM DEPTH ABOVE INV. AT CONDUIT ENDS UPSTREAM (FT)	DOWNSTREAM (FT)	LENGTH OF SPC FLOW (MIN)	CONDUIT SLOPE (FT/FT)
10001	2.56E+01	3.62	36.00	1.48E+01	0	30	3.96	0	30	0.58	1.68	1.50	53.7	0.00196
10002	2.80E+01	2.66	36.00	1.43E+01	0	32	2.77	0	32	0.51	1.50	1.49	57.3	0.00096
10003	4.08E+01	3.07	48.00	1.38E+01	0	34	2.87	0	33	0.34	1.49	1.43	8.3	0.00094
10004	2.93E+01	3.59	48.00	1.77E+01	0	31	4.41	0	30	0.60	2.62	1.71	57.0	0.00185
10005	4.13E+01	3.28	48.00	1.70E+01	0	33	3.76	0	33	0.41	1.71	1.05	0.0	0.00091
10007	2.88E+01	3.60	36.00	8.52E+00	0	31	3.51	0	31	0.30	1.22	0.60	0.0	0.00175
10006	2.69E+02	5.82	60.00	3.89E+01	0	35	3.39	0	34	0.14	1.43	1.34	107.0	0.00179
10081	1.05E+03	3.34	60.00	5.68E+01	0	39	1.20	0	36	0.05	1.34	1.68	119.7	0.00100
10082	9.80E+02	4.48	60.00	5.14E+01	0	48	1.62	0	48	0.05	1.68	2.00	120.0	0.00200
90010	UNDEF	UNDEF	UNDEF	5.14E+01	0	48								

CONDUIT NUMBER	LENGTH OF DRY FLOW(MIN)	LENGTH OF SUBCRITICAL FLOW(MIN)	LENGTH OF UPSTR. CRITICAL FLOW(MIN)	LENGTH OF DOWNSTR. CRITICAL FLOW(MIN)	MEAN FLOW (CFS)	FLOW (CV)	TOTAL FLOW CUBIC FT	MAXIMUM HYDRAULIC RADIUS(FT)	MAXIMUM CROSS SECT AREA(FT2)
10001	0.00	120.00	0.00	0.00	4.13	1.20	2.9755E+04	0.7718	3.7593
10002	1.00	119.00	0.00	0.00	4.12	1.18	2.9680E+04	0.8044	5.2105
10003	4.00	116.00	0.00	0.00	4.09	1.17	2.9475E+04	0.8460	4.8249
10004	0.00	120.00	0.00	0.00	4.96	1.19	3.5738E+04	0.7450	4.0203
10005	0.67	0.00	0.00	119.33	4.93	1.17	3.5485E+04	0.9016	4.5222
10007	0.00	0.00	0.00	120.00	2.47	1.18	1.7816E+04	0.8085	2.4270
10006	0.00	120.00	0.00	0.00	11.50	1.16	8.2767E+04	1.0596	11.4851
10081	0.00	120.00	0.00	0.00	31.86	0.39	2.2940E+05	0.9696	48.8641
10082	0.00	120.00	0.00	0.00	32.33	0.32	2.3275E+05	0.9039	31.6818
90010	UNDEFINED	UNDEFINED	UNDEFINED	UNDEFINED	32.33	0.32	2.3275E+05		



LOCATION NO. : 10081 CLOCK TIME IN HOURS. PLOT OF CONDUIT FLOW

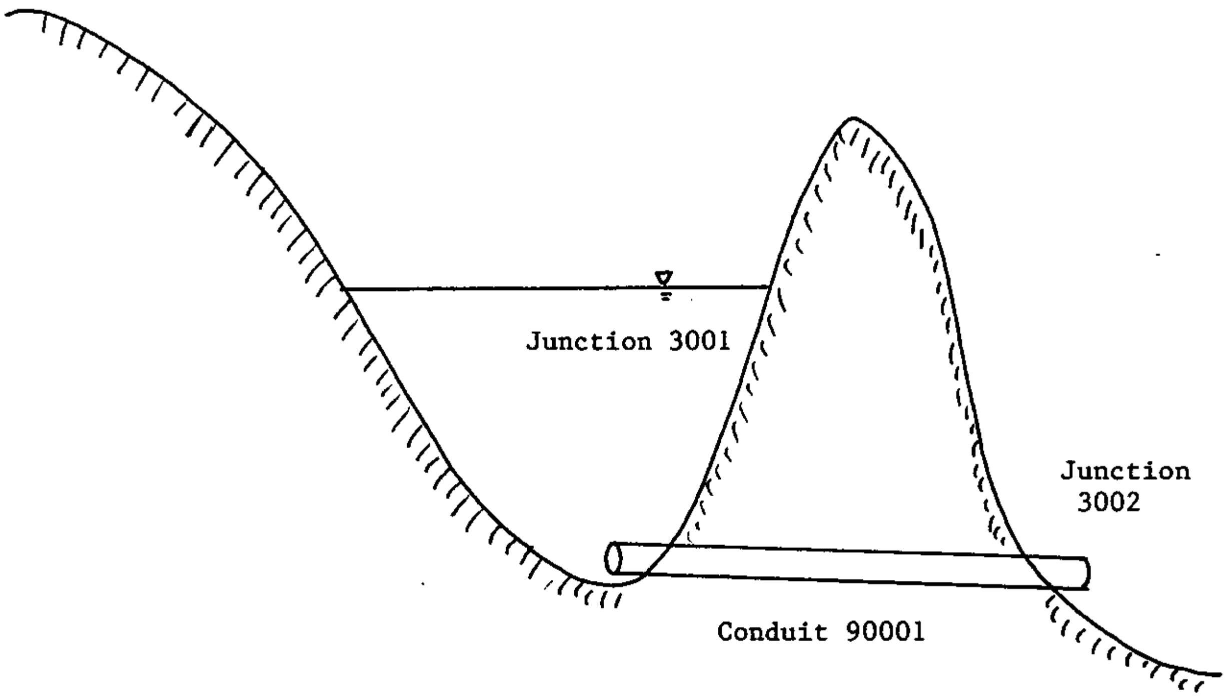


Figure 3-9. Use of Variable Storage Areas.

Table 3-19. Input Data for Example 9. Use of Variable Storage Areas.

```
SW 1 0 0
MM 3 10 11 12
$EXTRAN
A1 'EXTRAN EXAMPLE 9. FLOW ROUTING THROUGH A DETENTION POND.'
A1 'USE THE BEDIENT-HUBER EXAMPLE 6.10 ON PAGE 378.'
*
* OPTIONAL SOLUTION TECHNIQUES
* B0 LINE IS COMPLETELY OPTIONAL
*                   ISOL = 0 --> EXPLICIT EXTRAN SOLUTION
*                   ISOL = 1 --> SEMI-IMPLICIT SOLUTION
*                   ISOL = 2 --> ITERATIVE EXTRAN SOLUTION
* ISOL KSUPER
B0 1    0
*  NTCYC DELT  TZERO NSTART INTER JNTER REDO
B1 120   300.0  0.0    1     10    10    0
*  METRIC NEQUAL  AMEN ITMAX SURTOL
B2   1     0       0.0  10   0.01
* NHPRT NQPRT NPLT LPLT NJSW
B3  2    1     1   1    1
B4 30001 30002
B5 90001
B6 30001
B7 90001
* NO CONDUIT DATA
*
* JUNCTION IS VARIABLE-AREA STORAGE JUNCTION
*    JUN   GRELEV   Z  QINST  Y
D1 30001   10.0    0.0 0.0   0.5
D1 30002   10.0   -1.0 0.0   0.0
* STORAGE JUNCTION DATA
* JSTORE   GELEV   ASTORE NUMST
E1  30001    10.0    -1.0    23
E2 .013 0. .0246 0.2 .034 0.5 .04     0.8 .053    1.0 .065    1.5 .076 2.0
   .086 2.5 .096 3.0 .106 3.5 .114633 4.0 .123407 4.5 .131921 5.0 .140 5.5
   .148 6.0 .156 6.5 .164 7.0 .171    7.5 .179    8.0 .186    8.5 .193 9.0
   .200 9.5 .200 10.0
* OUTFLOW BY CULVERT TREATED AS ORIFICE
F1 30001 30002  1  0.03976  0.9  0.0
I1 30002 1
J1 1
K1 1
K2 30001
* TRIANGULAR INPUT HYDROGRAPH
K3 0.0  0.0
K3 2.0  1.2
K3 5.0  0.0
K3 10.  0.0
$ENDPROGRAM
```

Table 3-20. Partial Output for Example 9. Use of Variable Storage Area.

ENVIRONMENTAL PROTECTION AGENCY	**** EXTENDED TRANSPORT PROGRAM ****	WATER RESOURCES DIVISION
WASHINGTON, D.C.	**** ****	CAMP DRESSER & MCKEE INC.
	**** ANALYSIS MODULE ****	ANNANDALE, VIRGINIA

EXTRAN EXAMPLE 9. FLOW ROUTING THROUGH A DETENTION POND.
USE THE BEDIENT-HUBER EXAMPLE 6.10 ON PAGE 378.

```
*****************************************************
*                  JUNCTION DATA                    *
*****************************************************
```

INP NUM	JUNCTION NUMBER	GROUND ELEV.	CROWN ELEV.	INVERT ELEV.	QINST CMS	INITIAL DEPTH(M)	CONNECTING CONDUITS
1	30001	10.00	0.00	0.00	0.00	0.50	
2	30002	10.00	-1.00	-1.00	0.00	0.00	

```
*****************************************************
*              STORAGE JUNCTION DATA                *
*****************************************************
```

STORAGE JUNCTION NUMBER OR NAME	JUNCTION TYPE	MAXIMUM OR CONSTANT SURFACE AREA (M2)	PEAK OR CONSTANT VOLUME (CUBIC MET.)	CROWN ELEVATION (M)
30001	VARIABLE	12641.81	12641.81	10.000

```
*******************************************
*              ORIFICE DATA               *
*******************************************
```

FROM JUNCTION	TO JUNCTION	TYPE	AREA (MET2)	DISCHARGE COEFFICIENT	HEIGHT ABOVE JUNCTION (M)
30001	30002	1	0.04	0.900	0.000

```
====> EQUIVALENT PIPE INFORMATION FOR ORIFICE #      1
      CONDUIT NUMBER..........................   90001
      PIPE DIAMETER........................       0.22
      PIPE LENGTH..........................     891.22
      MANNINGS ROUGHNESS...................     0.0012
      INVERT ELEVATION AT UPSTREAM END.....     0.0000
      INVERT ELEVATION AT DOWNSTREAM END...    -0.0030
```

```
**********************************************
* JUNCTION INFLOW, OUTFLOW OR STREET FLOODING *
**********************************************
```

JUNCTION	INFLOW, CU M
30001	1.0800E+04

JUNCTION	OUTFLOW, CU M
30002	1.0648E+04

```
****************************************************
* INITIAL SYSTEM VOLUME       =    1.4387E+02 CU M *
* TOTAL SYSTEM INFLOW VOLUME  =    1.0800E+04 CU M *
* INFLOW + INITIAL VOLUME     =    1.0944E+04 CU M *
*************************************************
* TOTAL SYSTEM OUTFLOW        =    1.0648E+04 CU M *
* VOLUME LEFT IN SYSTEM       =    4.8340E+02 CU M *
* OUTFLOW + FINAL VOLUME      =    1.1131E+04 CU M *
*************************************************
* ERROR IN CONTINUITY, PERCENT =        -1.71      *
****************************************************
```

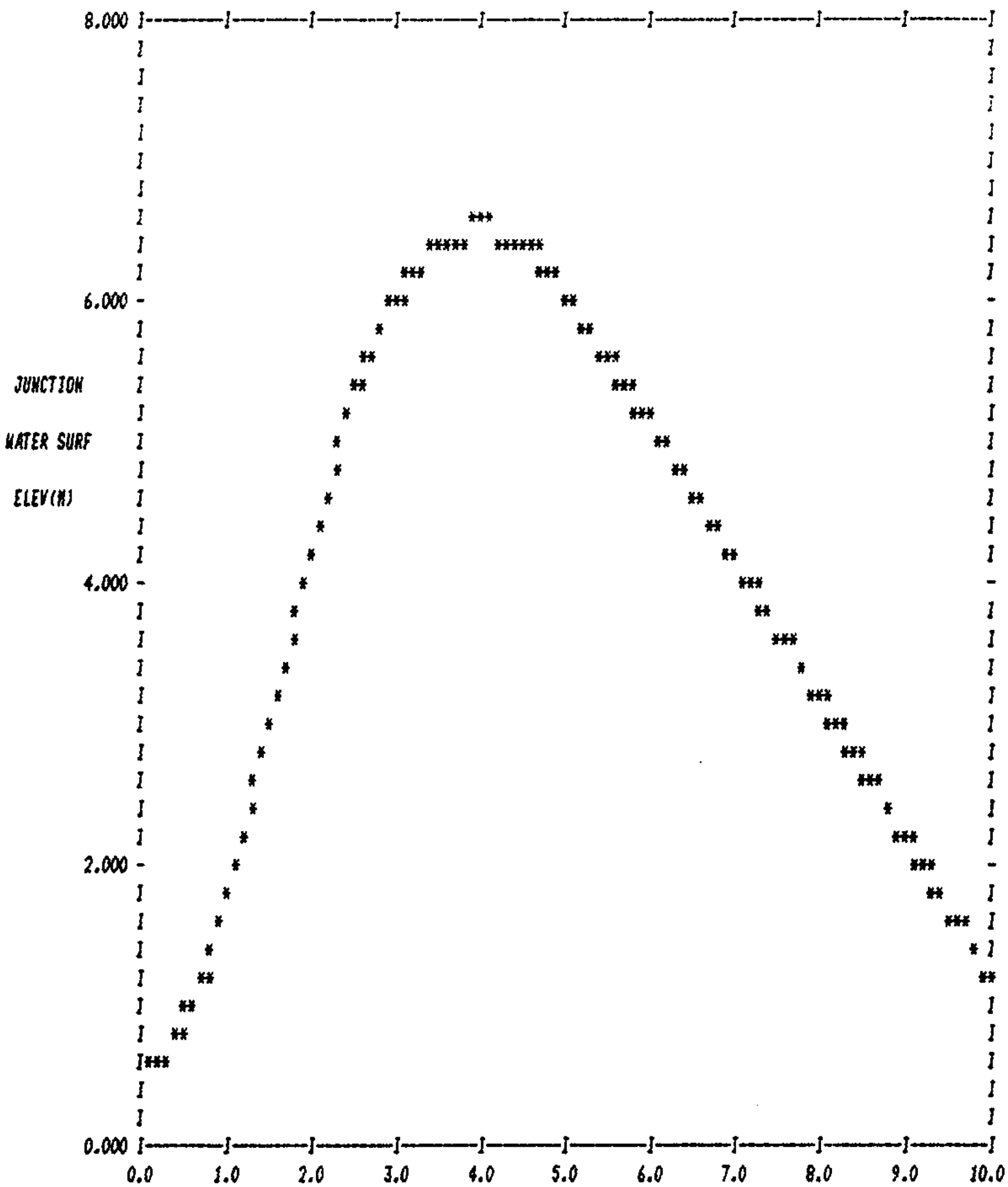
```
**********************************************************
*   J U N C T I O N   S U M M A R Y   S T A T I S T I C S *
**********************************************************
```

EXTRAN EXAMPLE 9. FLOW ROUTING THROUGH A DETENTION POND.
USE THE BEDIENT-HUBER EXAMPLE 6.10 ON PAGE 378.

JUNCTION NUMBER	GROUND ELEVATION (M)	UPPERMOST PIPE CROWN ELEVATION (M)	MEAN JUNCTION DEPTH (M)	JUNCTION DEPTH COEF. VAR	MAXIMUM JUNCTION DEPTH (M)	TIME OF OCCURENCE HR.	MIN.	FEET OF SURCHARGE AT MAX DEPTH	FEET MAX. DEPTH IS BELOW GROUND ELEVATION	LENGTH OF SURCHARGE (MIN)	LENGTH OF FLOODING (MIN)	MAXIMUM JUNCTION AREA (SQ.MET)
30001	10.00	10.00	4.03	0.46	6.51	4	0	0.00	3.49	0.0	0.0	1.562E+03
30002	10.00	-1.00	1.00	0.00	1.00	0	5	1.00	10.00	600.0	0.0	1.220E+00

```
**********************************************************
*   C O N D U I T   S U M M A R Y   S T A T I S T I C S  *
**********************************************************
```

CONDUIT NUMBER	DESIGN FLOW (CMS)	DESIGN VELOCITY (M/S)	CONDUIT VERTICAL DEPTH (MM)	MAXIMUM COMPUTED FLOW (CMS)	TIME OF OCCURENCE HR.	MIN.	MAXIMUM COMPUTED VELOCITY (MPS)	TIME OF OCCURENCE HR.	MIN.	RATIO OF MAX. TO DESIGN FLOW	MAXIMUM DEPTH ABOVE INV. AT CONDUIT ENDS UPSTREAM (M)	DOWNSTREAM (M)	LENGTH OF SPC FLOW (MIN)	CONDUIT SLOPE (M/M)
90001	7.52E-02	0.22	22.50	3.97E-01	4	5	9.99	4	10	5.28	6.51	0.22	0.0	0.00000
90002	UNDEF	UNDEF	UNDEF	3.97E-01	4	5								



LOCATION NO. : 30001 CLOCK TIME IN HOURS. PLOT OF JUNCTION ELEVATION

INVERT ELEV - 0.00 METERS
CROWN ELEV - 10.00 METERS
GROUND ELEV - 10.00 METERS

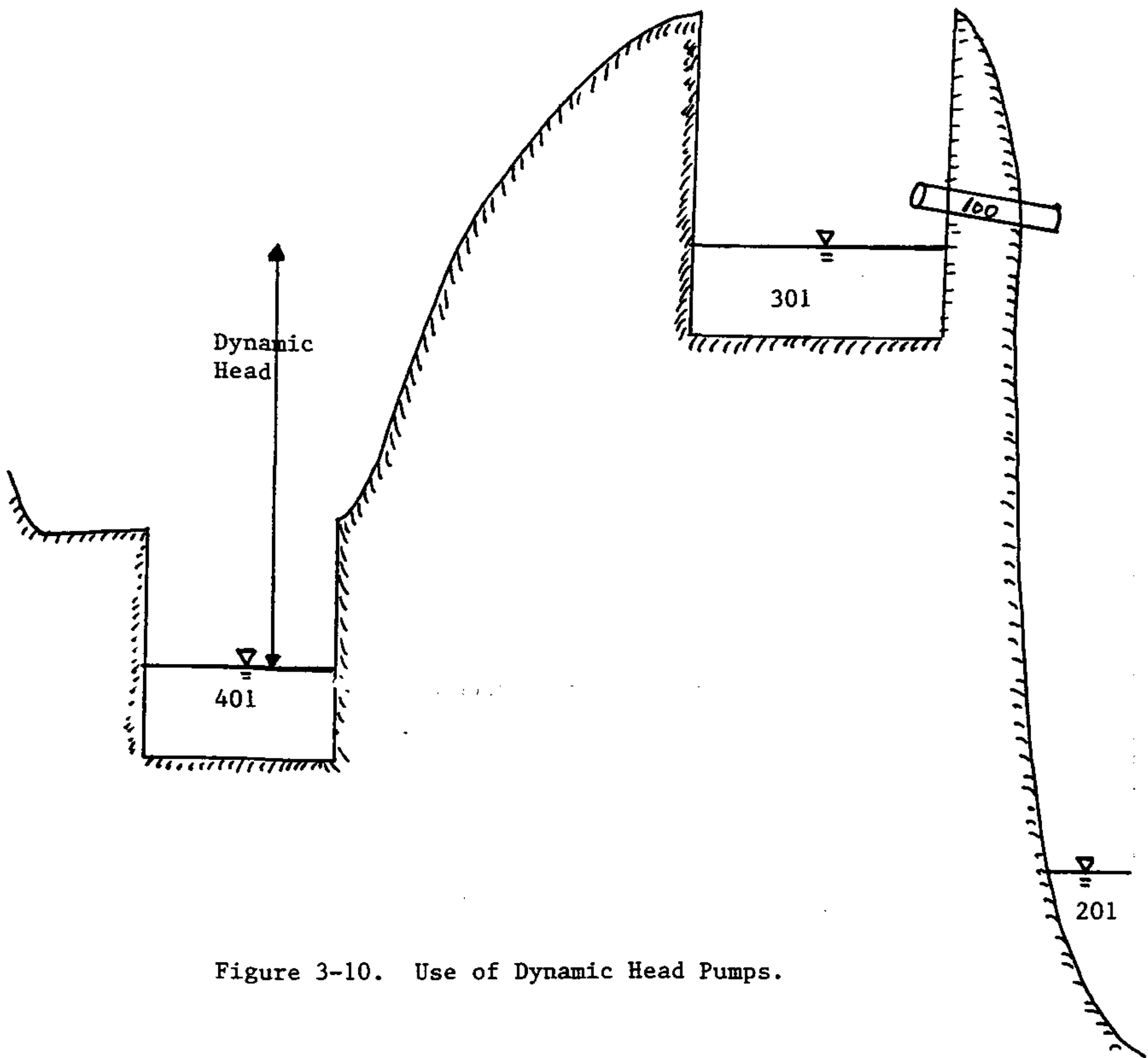


Figure 3-10. Use of Dynamic Head Pumps.

Table 3-21. Input for Example 10. Use of Dynamic Head Pumps.

```
SW  1   0  0
MM  3  10 11 12
$EXTRAN
A1  'EXTRAN USER''S MANUAL EXAMPLE PROBLEM 10. ISOL = 0 SOLUTION.'
A1  'PUMP OVER A HILL EXAMPLE FOR TYPE 3 DYNAMIC HEAD PUMPS'
*
*   NTCYC DELT  TZERO NSTART INTER JNTER REDO
B1  300    60.0   0.0   1     100   10      0
*   METRIC NEQUAL  AMEN ITMAX SURTOL
B2    0       0    0.0  10    0.0010
* NHPRT NQPRT NPLT LPLT NJSW
B3   3   2     2   2   1
*   PRINT HEADS
B4  401 301 201
*   PRINT FLOWS
B5  100 90002
*   PLOT HEADS
B6  401 301 201
*   PLOT FLOWS
B7  100 90006
*                            CONDUIT DATA
C1  100 301 201 0.0 1 0.0 4.0 0.0 1000. 20.0  0.0  0.015 0.0 0.0
*                            JUNCTION DATA
*   JUN    GRELEV       Z QINST   Y
D1  401      100.0    50.0  0.0  1.0
D1  301      150.0   100.0  0.0  1.0
D1  201      150.0   119.9  0.0  1.0
*                     Storage junctions
E1 401  90.0 2000. 0
E1 301 140.0 2000. 0
*
* IPTY NJUNC  NJUNC  PRATE1   PRATE2 PRATE3 VRATE1 VRATE2 VRATE3  VWELL  PON  POFF
H1 3    401    301   10.0      50.0   100.0   70.0   60.0  50.0   5.00  6.00  2.00
H1 3    401    301   10.0      50.0   100.0   70.0   60.0  50.0   5.00  7.00  3.00
H1 3    401    301   10.0      50.0   100.0   70.0   60.0  50.0   5.00  8.00  4.00
H1 3    401    301   10.0      50.0   100.0   70.0   60.0  50.0   5.00  9.00  5.00
H1 3    401    301   10.0      50.0   100.0   70.0   60.0  50.0   5.00 10.00  6.00
*
I1  201  1
J1    1
K1    1
K2  401
K3  0.0  0.0
K3 0.50  50.0
K3  1.0 100.0
K3  5.0 100.0
$ENDPROGRAM
```

Table 3-22. Partial Output from Example 10. Use of Dynamic Head Pumps.

EXTRAN USER'S MANUAL EXAMPLE PROBLEM 10. ISOL = 0 SOLUTION.
PUMP OVER A HILL EXAMPLE FOR TYPE 3 DYNAMIC HEAD PUMPS

```
****************************************************
*             STORAGE JUNCTION DATA                *
****************************************************
```

STORAGE JUNCTION NUMBER OR NAME	JUNCTION TYPE	MAXIMUM OR CONSTANT SURFACE AREA (FT2)	PEAK OR CONSTANT VOLUME (CUBIC FEET)	CROWN ELEVATION (FT)
401	CONSTANT	2000.00	80000.00	90.000
301	CONSTANT	2000.00	80000.00	140.000

```
*******************************************
*             PUMP CURVE DATA             *
*******************************************
```

	JUNCTIONS FROM	JUNCTIONS TO	INITIAL DEPTH IN WELL, FT	PUMP RATE, CFS 1	PUMP RATE, CFS 2	PUMP RATE, CFS 3	STAGES, FT 1	STAGES, FT 2	STAGES, FT 3	WET WELL DEPTH, FT ON	WET WELL DEPTH, FT OFF
1	401	301	5.0	10.0	50.0	100.0	70.0	60.0	50.0	6.0	2.0
2	401	301	5.0	10.0	50.0	100.0	70.0	60.0	50.0	7.0	3.0
3	401	301	5.0	10.0	50.0	100.0	70.0	60.0	50.0	8.0	4.0
4	401	301	5.0	10.0	50.0	100.0	70.0	60.0	50.0	9.0	5.0
5	401	301	5.0	10.0	50.0	100.0	70.0	60.0	50.0	10.0	6.0

```
***********************************************
*      FREE OUTFALL DATA (DATA GROUP I1)      *
*     BOUNDARY CONDITION ON DATA GROUP J1     *
***********************************************
```

OUTFALL AT JUNCTION....   201 HAS BOUNDARY CONDITION NUMBER...   1

```
***********************************************
*       INTERNAL CONNECTIVITY INFORMATION     *
***********************************************
```

CONDUIT	JUNCTION	JUNCTION
90002	401	301
90003	401	301
90004	401	301
90005	401	301
90006	401	301
90007	201	0

****
* T I M E H I S T O R Y O F T H E H. G. L. (Feet) *
****

TIME HR:MIN	JUNCTION GRND ELEV	401 100.00 DEPTH	JUNCTION GRND ELEV	301 150.00 DEPTH	JUNCTION GRND ELEV	201 150.00 DEPTH
0:10	53.48	3.48	101.00	1.00	119.90	0.00
0:20	52.05	2.05	107.39	7.39	119.90	0.00
0:30	53.87	3.87	115.03	15.03	119.90	0.00
0:40	58.05	8.05	122.93	22.93	121.38	1.48
0:50	59.26	9.26	126.44	26.44	122.39	2.49
1: 0	60.76	10.76	128.54	28.54	122.74	2.84
1: 9	61.95	11.95	129.53	29.53	122.87	2.97
1:20	62.32	12.32	129.85	29.85	122.91	3.01
1:30	62.44	12.44	129.95	29.95	122.92	3.02
1:39	62.47	12.47	129.98	29.98	122.93	3.03
1:50	62.49	12.49	129.99	29.99	122.93	3.03
2: 0	62.49	12.49	129.99	29.99	122.93	3.03
2:10	62.49	12.49	129.99	29.99	122.93	3.03
2:19	62.49	12.49	129.99	29.99	122.93	3.03
2:30	62.49	12.49	129.99	29.99	122.93	3.03
2:40	62.49	12.49	129.99	29.99	122.93	3.03
2:49	62.49	12.49	129.99	29.99	122.93	3.03
3: 0	62.49	12.49	129.99	29.99	122.93	3.03
3:10	62.49	12.49	129.99	29.99	122.93	3.03
3:19	62.49	12.49	129.99	29.99	122.93	3.03
3:30	62.49	12.49	129.99	29.99	122.93	3.03
3:40	62.49	12.49	129.99	29.99	122.93	3.03
3:49	62.49	12.49	129.99	29.99	122.93	3.03
4: 0	62.49	12.49	129.99	29.99	122.93	3.03
4: 9	62.49	12.49	129.99	29.99	122.93	3.03
4:20	62.49	12.49	129.99	29.99	122.93	3.03
4:30	62.49	12.49	129.99	29.99	122.93	3.03
4:39	62.49	12.49	129.99	29.99	122.93	3.03
4:50	62.49	12.49	129.99	29.99	122.93	3.03
5: 0	62.49	12.49	129.99	29.99	122.93	3.03
MEAN	61.12	11.12	126.86	26.86	122.50	2.60
MAXIMUM	62.49	12.49	129.99	29.99	122.93	3.03
MINIMUM	51.02	1.02	101.00	1.00	119.90	0.00

```
*********************************************
*  TIME HISTORY OF FLOW AND VELOCITY       *
*    Q(CFS), VEL(FPS), TOTAL(CUBIC FEET)   *
*********************************************
```

EXTRAN USER'S MANUAL EXAMPLE PROBLEM 10. ISOL = 0 SOLUTION.
PUMP OVER A HILL EXAMPLE FOR TYPE 3 DYNAMIC HEAD PUMPS

TIME HR:MIN	CONDUIT FLOW	90002 VELOC.	CONDUIT FLOW	90003 VELOC.	CONDUIT FLOW	90004 VELOC.	CONDUIT FLOW	90005 VELOC.	CONDUIT FLOW	90006 VELOC.
0:10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0:20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0:30	56.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0:40	32.33	0.00	28.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0:50	22.52	0.00	22.52	0.00	22.49	0.00	16.86	0.00	0.00	0.00
1: 0	18.29	0.00	18.29	0.00	18.29	0.00	18.29	0.00	17.98	0.00
1: 9	19.59	0.00	19.59	0.00	19.59	0.00	19.59	0.00	19.59	0.00
1:20	19.87	0.00	19.87	0.00	19.87	0.00	19.87	0.00	19.87	0.00
1:30	19.96	0.00	19.96	0.00	19.96	0.00	19.96	0.00	19.96	0.00
1:39	19.99	0.00	19.99	0.00	19.99	0.00	19.99	0.00	19.99	0.00
1:50	20.00	0.00	20.00	0.00	20.00	0.00	20.00	0.00	20.00	0.00
2: 0	20.00	0.00	20.00	0.00	20.00	0.00	20.00	0.00	20.00	0.00
2:10	20.00	0.00	20.00	0.00	20.00	0.00	20.00	0.00	20.00	0.00
2:19	20.00	0.00	20.00	0.00	20.00	0.00	20.00	0.00	20.00	0.00
2:30	20.00	0.00	20.00	0.00	20.00	0.00	20.00	0.00	20.00	0.00
2:40	20.00	0.00	20.00	0.00	20.00	0.00	20.00	0.00	20.00	0.00
2:49	20.00	0.00	20.00	0.00	20.00	0.00	20.00	0.00	20.00	0.00
3: 0	20.00	0.00	20.00	0.00	20.00	0.00	20.00	0.00	20.00	0.00
3:10	20.00	0.00	20.00	0.00	20.00	0.00	20.00	0.00	20.00	0.00
3:19	20.00	0.00	20.00	0.00	20.00	0.00	20.00	0.00	20.00	0.00
3:30	20.00	0.00	20.00	0.00	20.00	0.00	20.00	0.00	20.00	0.00
3:40	20.00	0.00	20.00	0.00	20.00	0.00	20.00	0.00	20.00	0.00
3:49	20.00	0.00	20.00	0.00	20.00	0.00	20.00	0.00	20.00	0.00
4: 0	20.00	0.00	20.00	0.00	20.00	0.00	20.00	0.00	20.00	0.00
4: 9	20.00	0.00	20.00	0.00	20.00	0.00	20.00	0.00	20.00	0.00
4:20	20.00	0.00	20.00	0.00	20.00	0.00	20.00	0.00	20.00	0.00
4:30	20.00	0.00	20.00	0.00	20.00	0.00	20.00	0.00	20.00	0.00
4:39	20.00	0.00	20.00	0.00	20.00	0.00	20.00	0.00	20.00	0.00
4:50	20.00	0.00	20.00	0.00	20.00	0.00	20.00	0.00	20.00	0.00
5: 0	20.00	0.00	20.00	0.00	20.00	0.00	20.00	0.00	20.00	0.00
MEAN	20.95	0.00	17.65	0.00	17.32	0.00	16.69	0.00	16.28	0.00
MAXIMUM	87.50	0.00	28.64	0.00	22.96	0.00	20.33	0.00	20.00	0.00
MINIMUM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	3.77E+05		3.18E+05		3.12E+05		3.00E+05		2.93E+05	

```
*******************************************************
*  C O N D U I T   S U M M A R Y   S T A T I S T I C S  *
*******************************************************
```

EXTRAN USER'S MANUAL EXAMPLE PROBLEM 10. ISOL = 0 SOLUTION.
PUMP OVER A HILL EXAMPLE FOR TYPE 3 DYNAMIC HEAD PUMPS

CONDUIT NUMBER	DESIGN FLOW (CFS)	DESIGN VELOCITY (FPS)	CONDUIT VERTICAL DEPTH (IN)	MAXIMUM COMPUTED FLOW (CFS)	TIME OF OCCURENCE HR.	MIN.	MAXIMUM COMPUTED VELOCITY (FPS)	TIME OF OCCURENCE HR.	MIN.	RATIO OF MAX. TO DESIGN FLOW	MAXIMUM DEPTH ABOVE INV. AT CONDUIT ENDS UPSTREAM (FT)	DOWNSTREAM (FT)	LENGTH OF SPC FLOW (MIN)	CONDUIT SLOPE (FT/FT)
100	1.24E+01	0.99	48.00	1.00E+02	2	58	8.35	2	52	8.03	9.99	3.03	0.0	0.00010
90002	UNDEF	UNDEF	UNDEF	8.75E+01	0	17								
90003	UNDEF	UNDEF	UNDEF	2.86E+01	0	41								
90004	UNDEF	UNDEF	UNDEF	2.30E+01	0	49								
90005	UNDEF	UNDEF	UNDEF	2.03E+01	0	55								
90006	UNDEF	UNDEF	UNDEF	2.00E+01	2	42								
90007	UNDEF	UNDEF	UNDEF	1.00E+02	2	58								

```
*************************************************
* SUBCRITICAL AND CRITICAL FLOW ASSUMPTIONS FROM *
* SUBROUTINE HEAD.  SEE FIGURE 5-4 IN THE EXTRAN *
*       MANUAL FOR FURTHER INFORMATION.          *
*************************************************
```

CONDUIT NUMBER	LENGTH OF DRY FLOW(MIN)	LENGTH OF SUBCRITICAL FLOW(MIN)	LENGTH OF UPSTR. CRITICAL FLOW(MIN)	LENGTH OF DOWNSTR. CRITICAL FLOW(MIN)	MEAN FLOW (CFS)	FLOW (CV)	TOTAL FLOW CUBIC FT	MAXIMUM HYDRAULIC RADIUS(FT)	MAXIMUM CROSS SECT AREA(FT2)
100	34.00	265.00	1.00	0.00	84.40	0.40	1.5191E+06	1.1164	11.9772
90002	UNDEFINED	UNDEFINED	UNDEFINED	UNDEFINED	20.95	0.53	3.7707E+05		
90003	UNDEFINED	UNDEFINED	UNDEFINED	UNDEFINED	17.65	0.38	3.1764E+05		
90004	UNDEFINED	UNDEFINED	UNDEFINED	UNDEFINED	17.32	0.39	3.1173E+05		
90005	UNDEFINED	UNDEFINED	UNDEFINED	UNDEFINED	16.69	0.44	3.0046E+05		
90006	UNDEFINED	UNDEFINED	UNDEFINED	UNDEFINED	16.28	0.47	2.9297E+05		
90007	UNDEFINED	UNDEFINED	UNDEFINED	UNDEFINED	84.40	0.40	1.5191E+06		

Pages 127 through 130 deliberately left blank.

SECTION 4

TIPS FOR TROUBLE-SHOOTING

INTRODUCTION

The preceding three chapters have described in detail the individual data input elements for EXTRAN. Careful study of the data input instructions together with the example problems of the last section will go a long way in answering the usual questions of "how to get started" in using a computerized stormwater model as intricate as this one.

Obviously, it is not possible to anticipate all problems in advance and therefore certain questions are bound to occur in the user's initial attempts at application. The purpose of this section is to offer a set of guidelines and recommendations for setting up EXTRAN which will help to reduce the number of problem areas and thereby alleviate frequently encountered start-up pains.

Most difficulties in using the EXTRAN MODEL arise from three sources: (1) improper selection of time step and incorrect specification of the total simulation period; (2) incorrect print and plot control variables; and (3) improper system connectivity in the model. These and other problems are discussed below:

STABILITY

Numerical stability constraints in the EXTRAN Model require that DELT, the time-step, be no longer than the time it takes for a dynamic wave to travel the length of the shortest conduit in the transport system (equation 2-1). A 10-second time-step is recommended for most wet-weather runs, while a 45-second step may be used satisfactorily for most dry weather conditions. The numerical stability criteria for the explicit finite-difference scheme used by the model are discussed in Section 2.

Numerical instability in the EXTRAN Block is signaled by the occurrence of the following hydraulic indicators:

1. Oscillations in flow and water surface elevation which are undampened in time are sure signs of numerical instability. Certain combinations of pipe and weir structures may cause temporary resonance, but this is normally short lived. The unstable pipe usually is short relative to other adjacent pipes and may be subject to backwater created by a downstream weir. The correction is a shorter time-step, a longer pipe length or combination of both. Neither of these should be applied until a careful check of system connections on all sides of the unstable pipe has been made as suggested below.

2. A second indicator of numerical instability is a node which continues to "dry up" on each time-step despite a constant or increasing inflow from upstream sources. The cause usually is too large a time-step and excessive discharges in adjacent downstream pipe elements which pull the upstream water surface down. The problem is related to items (1) and (3) and may usually be corrected by a smaller time-step.

3. Excessive velocities (over 20 ft/sec) and discharges which appear to grow without limit at some point in the simulation run are manifestations of an unstable pipe element in the transport system. The cause usually can be traced to the first source above and the corrections are normally applied, as suggested in item (1) above.

4. A large continuity error is a good indicator of either stability or other problems. A continuity check, which sums the volumes of inflow, outflow, and storage at the end of the simulation, is found at the end of the intermediary printout. If the continuity error exceeds ± 10%, the user should check the intermediate printout for pipes with zero flow or oscillating flow. These could be caused by stability or an improperly connected system.

SURCHARGE

Systems in surcharge require a special iteration loop, allowing the explicit solution scheme to account for the rapid changes in flows and heads during surcharge conditions. This iteration loop is controlled by two variables, ITMAX, the maximum number of iterations, and SURTOL, a fraction of the flow through the surcharged area. It is recommended that ITMAX and SURTOL be set initially at 30 and 0.05, respectively. The user can check the convergence of the iteration loop by examining the number of iterations actually required and the size of the net difference in the flows through the surcharged area, shown in the intermediate printout. These are significant since the iterations end when either SURTOL times the average flow through the surcharged area is less than the flow differential discussed above, or when the number of iterations exceeds ITMAX. If ITMAX is exceeded many times, leaving relatively large flow differentials, the user should increase ITMAX to improve the accuracy of the surcharge computation. If, on the other hand, the user finds that most or all of the iterations do converge, he may decrease ITMAX or increase SURTOL to decrease the run-time of the model and, consequently, the cost. The user should also keep an eye on the continuity error to insure that a large loss of water is not caused by the iterations.

In some large systems, more than one area may be in surcharge at the same time. If this occurs and the flows in these areas differ appreciably, those areas with the smallest flows may not converge, while areas with large flows will. This is because both the tolerance and flow differential are computed as sums of <u>all</u> flows in surcharge. It is possible, therefore, to assume convergence has occurred even when relatively large flow errors still exist in surcharge areas with small flows. If the user suspects this situation exists, he/she can compute a flow differential for any particular surcharge area by adding the differences between inflow to and outflow from each node in that surcharge area. Such information can be found in the intermediary printout.

Whenever the flow differential computed in this way is a significantly large fraction of the average flow in this area, inaccurate results may be expected. To correct this, SURTOL can be decreased until the flow differential for the area in question decreases to a small value over time. It should be noted, however, that large flow differentials for a short period of time are not unusual providing they decrease to near or below the established tolerance for most of the simulation.

SIMULATION LENGTH

The length of the simulation is defined by the product NTCYC x DELT (data group B1), that is, the product of the number of time-steps and length of time-step. This simulation period should be compatible with any inflow hydrographs on the SWMM interface file or else an end-of-file message may be encountered and execution stops. If this happens, the earlier block may be run again for a longer simulation time, or NTCYC may be reduced.

CONDUIT LENGTH

The length of all conduits in the transport system should be roughly constant and no less than about 100 ft (30 m). This constraint may be difficult to meet in the vicinity of weirs and abrupt changes in pipe configurations which must be represented in the model. However, the length of the shortest conduit does directly determine the maximum time step and the number of pipe elements, both of which in turn control the cost of simulation as indicated in Section 2. The use of longer pipes should be facilitated through use of equivalent sections and slopes in cases where significant changes in pipe shape, cross sectional area and gradient must be represented in the model. Bear in mind that very short, steep pipes have a negligible effect on routing (since water is transported through them almost "instantaneously" compared to the overall routing) and may ordinarily be omitted from the simulation or aggregated with other pipes.

PRELIMINARY SYSTEM CHECK

Prior to a lengthy run of EXTRAN for a new system, a short test run of perhaps five integration cycles should be made to confirm that the link-node model is properly connected and correctly represents the prototype. This check should be made on the echo of the input data, which show the connecting links at each node. The geometric-hydraulic data for each pipe and junction should also be confirmed. Particular attention should be paid to the nodal location of weirs, orifices, and outfalls to ensure that these conform to the prototype system. In addition, the total number of conduits and junctions, including internal links and nodes created for weirs, orifices, pumps and outfalls, can be determined from the Internal Connectivity Table. This information is necessary for proper specification of initial heads and flows at time zero in the simulation.

INVERT ELEVATIONS AT JUNCTIONS

The introduction of a ZP invert elevation difference for all pipes connecting a single junction will cause the junction invert elevation to be in-correctly specified. This, in turn, will create errors in hydraulic computation later in the simulation. The junction invert must be at the same elevation as the invert of the lowest pipe either entering or leaving the junction, otherwise it is improperly defined. This problem is readily corrected by checking the input conduit data lines (group C1) to determine where a non-zero ZP should be set to zero.

SECTION 5

FORMULATION OF EXTRAN

GENERAL

A conceptual overview of EXTRAN is shown in Figure 5-1. As shown here, the specific function of EXTRAN is to route inlet hydrographs through the network of pipes, junctions, and flow diversion structures of the main sewer system to the treatment plant interceptors and receiving water outfalls. It has been noted in Section 2 that the boundary between the Runoff (or Transport) and EXTRAN Blocks is dependent on the objectives of the simulation. EXTRAN must be used whenever it is important to represent severe backwater conditions and special flow devices such as weirs, orifices, pumps, storage basins, and tide gates. Normally, these conditions occur in the lower reaches of the drainage system when pipe diameters exceed roughly 20 inches (500 mm). The Runoff Block, on the other hand, is well suited for the simulation of overland and small pipe flow in the upper regions of the system where the non-linear reservoir assumptions of uniform flow hold.

As shown in Figure 5-1, EXTRAN simulates the following elements: pipes, manholes (pipe junctions), weirs, orifices, pumps, storage basins, and outfall structures. These elements and their associated properties are summarized in Tables 5-1 and 5-2. Output from EXTRAN takes the form of 1) discharge hydrographs and velocities in selected conduits in printed and plotted form, and 2) flow depths and water surface elevations at selected junctions in printed and plotted form. Hydrographs may be supplied to a subsequent block on the output interface file.

CONCEPTUAL REPRESENTATION OF THE TRANSPORT SYSTEM

EXTRAN uses a link-node description of the sewer system which facilitates the discrete representation of the physical prototype and the mathematical solution of the gradually-varied unsteady flow (St. Venant) equations which form the mathematical basis of the model.

As shown in Figure 5-2, the conduit system is idealized as a series of links or pipes which are connected at nodes or junctions. Links and nodes have well-defined properties which, taken together, permit representation of the entire pipe network. Moreover, the link-node concept is very useful in representing flow control devices. The specific properties of links and nodes are summarized in Table 5-2.

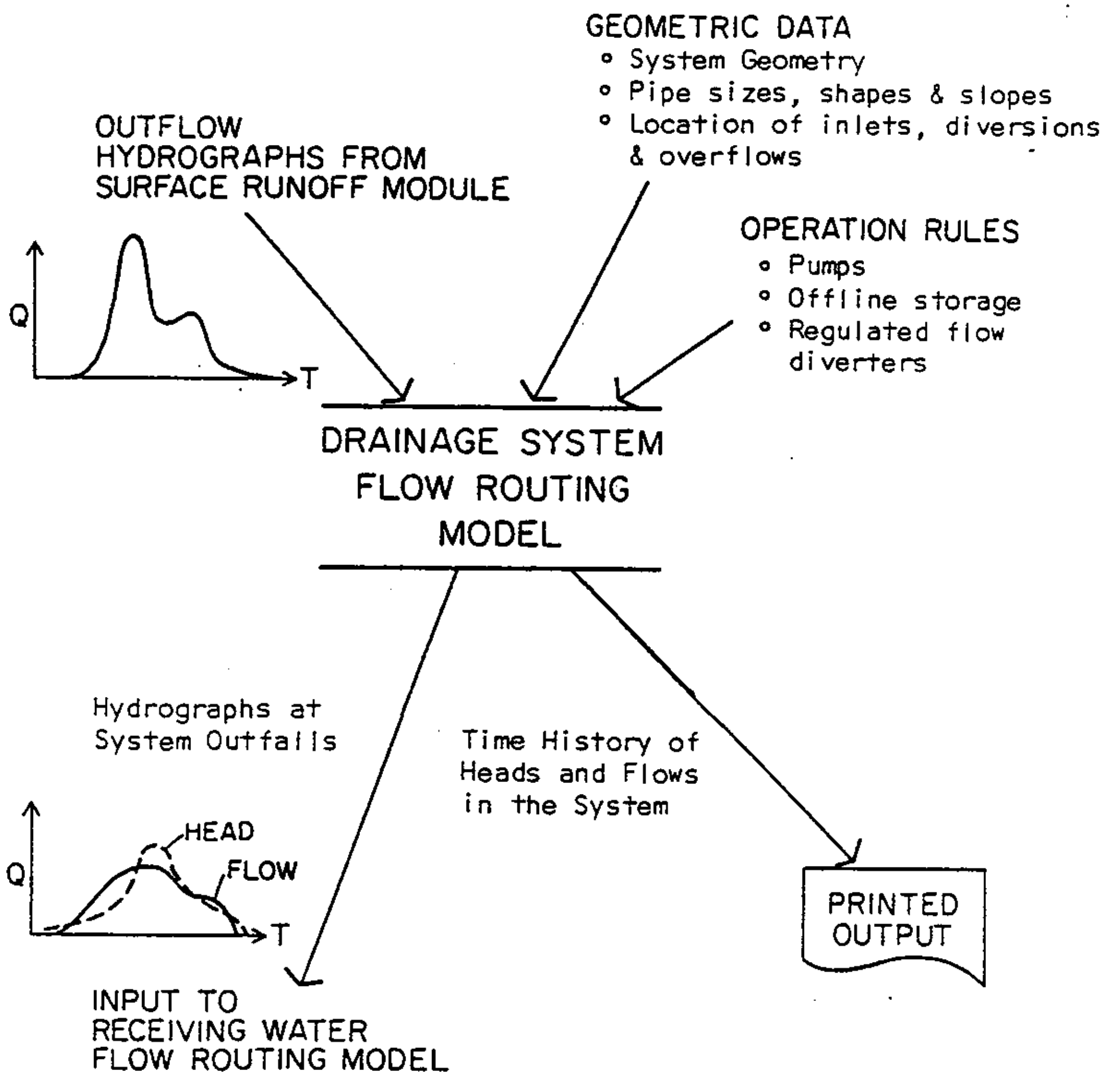


Figure 5-1. Schematic Illustration of EXTRAN.

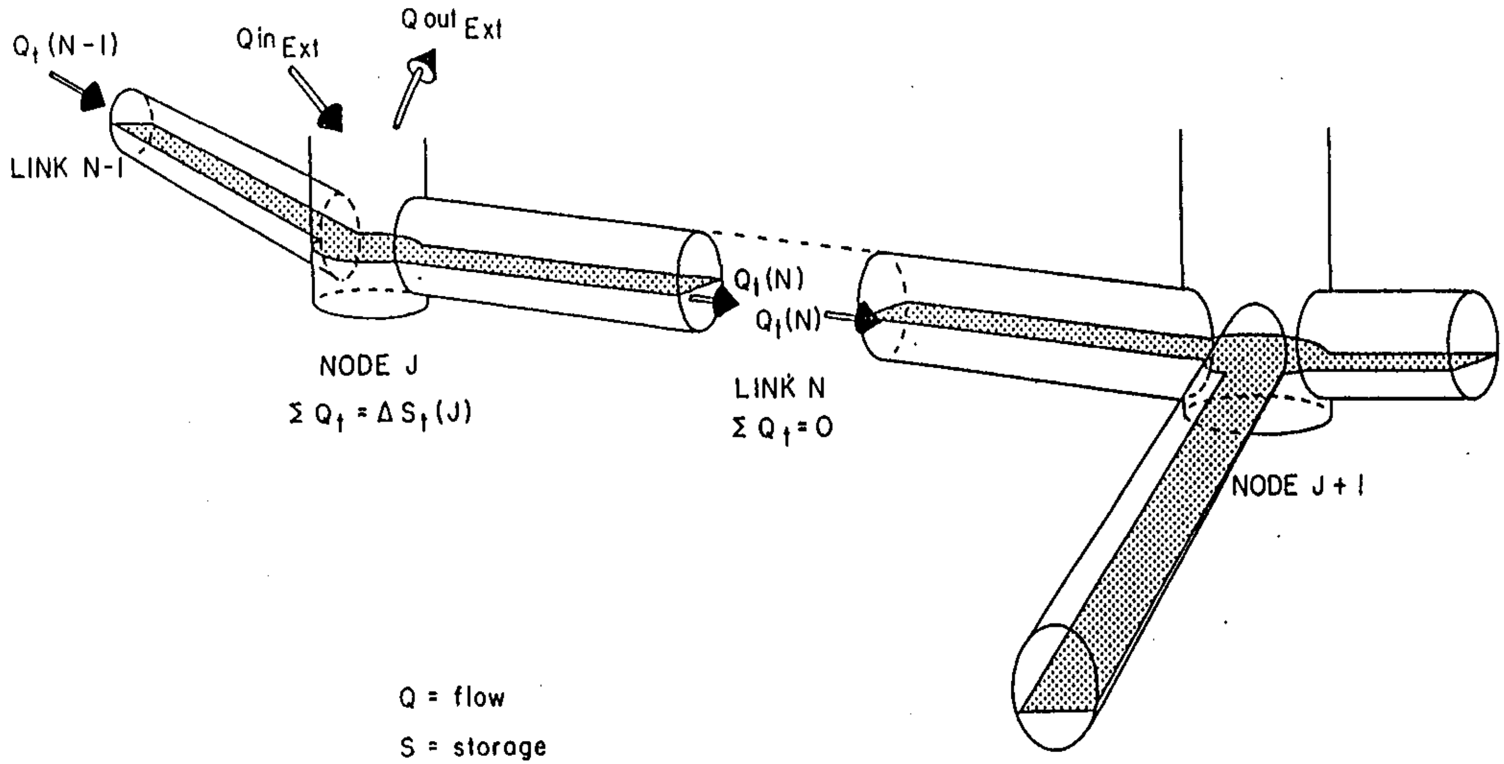


Figure 5-2. Conceptual Respresentation of the EXTRAN Model.

Table 5-1. Classes of Elements Included in EXTRAN.

Element Class	Types
Conduits or Links	Rectangular Circular Horseshoe Eggshape Baskethandle Trapezoid Power function Natural Channel (irregular cross section)
Junctions or Nodes (Manholes)	---------
Diversion Structures	Orifices Transverse weirs Side-flow Weirs
Pump Stations	On-line or off-line pump station
Storage Basins	On-line, enlarged pipes or tunnels On-line or off-line, arbitrary stage-area relationship
Outfall Structures	Transverse weir with tide gate Transverse weir without tide gate Side-flow weir with tide gate Side-flow weir without tide gate Outfall with tide gate Free outfall without tide gate

Links transmit flow from node to node. Properties associated with the links are roughness, length, cross-sectional area, hydraulic radius, and surface width. The last three properties are functions of the instantaneous depth of flow. The primary dependent variable in the links is the discharge, Q. The solution is for the average flow in each link, assumed to be constant over a time-step. Velocity and the cross-sectional area of flow, or depth, are variable in the link. In the early development of EXTRAN, a constant velocity approach was used, but this was later found to produce highly unstable solutions.

Table 5-2. Properties of Nodes and Links in EXTRAN.

		Properties and Constraints
NODES	Constraint	ΣQ = change in storage
	Properties computed at each time-step	Volume Surface area Head
	Constant Properties	Invert, crown, and ground elevations
LINKS	Constraint	$Q_{in} = Q_{out}$
	Properties computed at each time-step	Cross-sectional area Hydraulic radius Surface width Discharge Velocity of flow
	Constant Properties	Head loss coefficients Pipe shape, length, slope, roughness

Nodes are the storage elements of the system and correspond to manholes or pipe junctions in the physical system. The variables associated with a node are volume, head, and surface area. The primary dependent variable is the head, H (elevation to water surface = invert elevation plus water depth), which is assumed to be changing in time but constant throughout any one node. (A plot of head versus distance along the sewer network yields the hydraulic grade line, HGL.) Inflows, such as inlet hydrographs, and outflows, such as weir diversions, take place at the nodes of the idealized sewer system. The volume of the node at any time is equivalent to the water volume in the half-pipe lengths connected to any one node. The change in nodal volume during a given time step, Δt, forms the basis of head and discharge calculations as discussed below.

BASIC FLOW EQUATIONS

The basic differential equations for the sewer flow problem come from the gradually varied, one-dimensional unsteady flow equations for open channels, otherwise known as the St. Venant or shallow water equations (Lai, 1986). For use in EXTRAN, the momentum equation is combined with the continuity equation to yield an equation to be solved along each link at each time-step,

$$\partial Q/\partial t + gAS_f - 2V\partial A/\partial t - V^2\partial A/\partial x + gA\partial H/\partial x = 0 \qquad (5\text{-}1)$$

where Q = discharge through the conduit,
V = velocity in the conduit,
A = cross-sectional area of the flow,
H = hydraulic head (invert elevation plus water depth), and
S_f = friction slope.

The interested reader is referred to Appendix A for the equation derivation. Terms have their usual units. For example, when U.S. customary units are used, flow is in units of cfs. When metric units are used, flow is in m^3/sec. These units are carried through internal calculations as well as for input and output.

The friction slope is defined by Manning's equation, i.e.

$$S_f = \frac{k}{gAR^{4/3}} Q|V| \tag{5-2}$$

where $k = g(n/1.49)^2$ for U.S. customary units and gn^2 for metric units,
n = Mannings roughness coefficient,
g = gravitational acceleration (numerically different depending on units chosen), and
R = hydraulic radius.

Use of the absolute value sign on the velocity term makes S_f a directional quantity and ensures that the frictional force always opposes the flow. Substituting in equation 5-1 and expressing in finite difference form gives

$$Q_{t+\Delta t} = Q_t - \frac{k\Delta t}{R^{4/3}} |V_t| Q_{t+\Delta t} + 2V(\Delta A/\Delta t)_t \Delta t + V^2[(A_2-A_1)/L]\Delta t$$

$$- gA[(H_2-H_1)/L]\Delta t \tag{5-3}$$

where Δt = time-step, and
L = conduit length.

Solving equation 5-3 for $Q_{t+\Delta t}$ gives the final finite difference form of the dynamic flow equation,

$$Q_{t+\Delta t} = \frac{1}{1 + \frac{k\Delta t}{\bar{R}^{4/3}}|\bar{V}|}[\, Q_t + 2\bar{V}(\Delta A/\Delta t)_t \Delta t + \bar{V}^2[(A_2-A_1)/L]\Delta t$$

$$- g\bar{A}[(H_2-H_1)/L]\Delta t \,] \tag{5-4}$$

In equation 5-4, the values $\bar{V}$, $\bar{R}$, and $\bar{A}$ are weighted averages of the conduit end values at time t, and $(\Delta A/\Delta t)_t$ is the time derivative from the previous time step.

The basic unknowns in equation 5-4 are $Q_{t+\Delta t}$, H_2 and H_1. The variables

$\bar{V}$, $\bar{R}$, and $\bar{A}$ can all be related to Q and H. Therefore, another equation is required relating Q and H. This can be obtained by writing the continuity equation at a node,

$$\partial H/\partial t_t = \Sigma Q_t/A_{s_t} \tag{5-5}$$

or in finite difference form

$$H_{t+\Delta t} = H_t + \Sigma Q_t \Delta t/A_{s_t} \tag{5-6}$$

where A_s = surface area of node.

SOLUTION OF FLOW EQUATION BY MODIFIED EULER METHOD

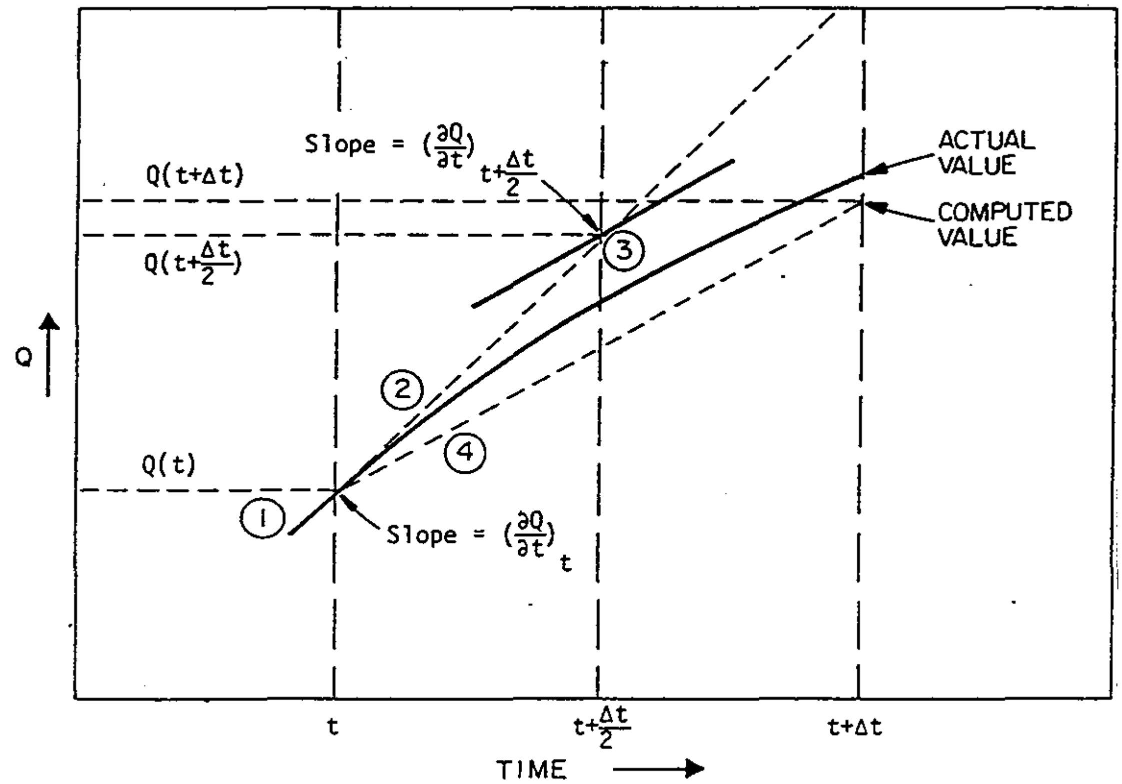
Equations 5-4 and 5-6 can be solved sequentially to determine discharge in each link and head at each node over a time-step Δt. The numerical integration of these two equations is accomplished by the improved polygon or modified Euler method. The results have proven to be relatively accurate and, when certain constraints are followed, stable. Figure 5-3 shows how the process would work if only the discharge equation were involved. The first three operations determine the slope $\partial Q/\partial t$ at the "half-step" value of discharge. In other words, it is assumed that the slope at time $t + \Delta t/2$ is the mean slope during the interval. The method is extended easily to more than one equation, although graphic representation is then very difficult. The corresponding half-step and full-step calculations of head are shown below:

Half-step at node j: Time $t + \Delta t/2$

$$H_j(t+\Delta t/2) = H_j(t) + (\Delta t/2)\{(1/2) \underbrace{\Sigma[Q(t)+Q(t+\Delta t/2)]}_{\text{conduits, surface runoff}} + \underbrace{\Sigma[Q(t+\Delta t/2)]}_{\text{diversions, pumps, outfalls}}\}/A_{s_j}(t) \tag{5-7}$$

Full-step at node j: Time $t + \Delta t$

$$H_j(t+\Delta t) = H_j(t) + \Delta t\{(1/2) \underbrace{\Sigma[Q(t)+Q(t+\Delta t)]}_{\text{conduits, surface runoff}} + \underbrace{\Sigma Q(t+\Delta t)}_{\text{diversions, pumps, outfalls}}\}/A_{s_j}(t) \tag{5-8}$$



1. Compute $(\frac{\partial Q}{\partial t})_t$ from properties of system at time t

2. Project $Q(t+\frac{\Delta t}{2})$ as $Q(t+\frac{\Delta t}{2}) = Q(t) + (\frac{\partial Q}{\partial t})_t \frac{\Delta t}{2}$

3. a. Compute system properties at $t+\frac{\Delta t}{2}$

   b. Form $(\frac{\partial Q}{\partial t})_{t+\frac{\Delta t}{2}}$ from properties of system at time $t+\frac{\Delta t}{2}$

4. Project $Q(t+\Delta t)$ as $Q(t+\Delta t) = Q(t) + (\frac{\partial Q}{\partial t})_{t+\frac{\Delta t}{2}} \Delta t$

Figure 5-3. Modified Euler Solution Method for Discharge Based on Half-step, Full-step Projection.

Note that the half-step computation of head uses the half-step computation of discharge in all connecting conduits. Similarly, the full-step computation requires the full-step discharge at time $t + \Delta t$ for all connecting pipes. In addition, the inflows to and diversions from each node by weirs, orifices, and pumps must be computed at each half and full-step. The total sequence of discharge computations in the links and head computations in the nodes can be summarized as:

1. Compute half-step discharge at $t + \Delta t/2$ in all links based on preceding full-step values of head at connecting junctions.

2. Compute half-step flow transfers by weirs, orifices, and pumps at time $t + \Delta t/2$ based on preceding full-step values of head at transfer junction.

3. Compute half-step head at all nodes at time $t + \Delta t/2$ based on average of preceding full-step and current half-step discharges in all connecting conduits, plus flow transfers at the current half-step.

4. Compute full-step discharge in all links at time $t + \Delta t$ based on half-step heads at all connecting nodes.

5. Compute full-step flow transfers between nodes at time $t + \Delta t$ based on current half-step heads at all weir, orifice, and pump nodes.

6. Compute full-step head at time $t + \Delta t$ for all nodes based on average of preceding full-step and current full-step discharges, plus flow transfers at the current full-step.

NUMERICAL STABILITY

Time-Step Restrictions

The modified Euler method yields a completely explicit solution in which the motion equation is applied to discharge in each link and the continuity equation to head at each node,with implicit coupling during the time-step. It is well known that explicit methods involve fairly simple arithmetic and require little storage space compared to implicit methods. However, they are generally less stable and often require very short time-steps. From a practical standpoint, experience with EXTRAN has indicated that the program is numerically stable when the following inequalities are met:

Conduits:

$$\Delta t \leq L/(gD)^{1/2} \tag{5-9}$$

where Δt = time-step, sec,
L = the pipe length, ft [m],
g = gravitational acceleration, 32.2 ft/sec^2 [9.8 m/sec^2], and
D = maximum pipe depth, ft [m].

This is recognized as a form of the Courant condition, in which the time step is limited to the time required by a dynamic wave to propagate the length of a conduit. A check is made at the beginning of the program to see if all conduits satisfy this condition (see discussion of equations 2-1 and 2-2).

Nodes:

$$\Delta t \leq C' A_s \Delta H_{max} / Q \qquad (5\text{-}10)$$

where C' = dimensionless constant, determined by experience to approximately equal 0.1,
ΔH_{max} = maximum water-surface rise during the time-step, Δt,
A_s = corresponding surface area of the node, and
ΣQ = net inflow to the node (junction).

Examination of inequalities 5-9 and 5-10 reveals that the maximum allowable time-step, Δt, will be determined by the shortest, smallest pipe having high inflows. Based on past experience with EXTRAN, a time-step of 10 seconds is nearly always sufficiently small enough to produce outflow hydrographs and stage-time traces which are free from spurious oscillations and also satisfy mass continuity under non-flooding conditions. If smaller time steps are necessary the user should eliminate or aggregate the offending small pipes or channels. In most applications, 15 to 30 second time-steps are adequate; occasionally time steps up to 60 seconds can be used.

Equivalent Pipes

An equivalent pipe is the computational substitution of an actual element of the drainage system by an imaginary conduit which is hydraulically identical to the element it replaces. Usually, an equivalent pipe is used when it is suspected that a numerical instability will be caused by the element of the drainage system being replaced in the computation. Short conduits and weirs are known at times to cause stability problems and thus occasionally need to be replaced by an equivalent pipe. (Orifices are automatically converted to equivalent pipes by the program; see the description below.)

The equivalent pipe substitution used by EXTRAN involves the following steps. First the flow equation for the element in question is set equal to the flow equation for an "equivalent pipe." This in effect, says that the head losses in the element and its equivalent pipe are the same. The length of the equivalent pipe is computed using the numerical stability equation 5-9. Then, after making any additional assumptions which may be required about the equivalent pipe's dimensions, a Manning's n is computed based on the equal head loss requirement. In the case of orifices, this conversion occurs internally in EXTRAN, but in those cases where short pipes and weirs are found to cause instabilities, the user must make the necessary conversion and revise the input data set. Section 2 of this report outlines the steps needed to make these conversions. The program will automatically adjust short pipes and weirs if parameter NEQUAL = 1 on data group B1.

SPECIAL PIPE FLOW CONSIDERATIONS

The solution technique discussed in the preceding paragraphs cannot be applied without modification to every conduit for the following reasons. First, the invert elevations of pipes which join at a node may be different since sewers are frequently built with invert discontinuities. Second, critical depth may occur in the conduit and thereby restrict the discharge. Third, normal depth may control. Finally, the pipe may be dry. In all of these cases, or combinations thereof, the flow must be computed by special techniques. Figure 5-4 shows each of the possibilities and describes the way in which surface area is assigned to the nodes. The options are:

1. Normal case. Flow computed from motion equation. Half of surface area assigned to each node.

2. Critical depth downstream. Use lesser of critical or normal depth downstream. Assign all surface area to upstream node.

3. Critical depth upstream. Use critical depth. Assign all surface area to downstream node.

4. Flow computed exceeds flow at critical depth. Set flow to normal value. Assign surface area in usual manner as in (1).

5. Dry pipe. Set flow to zero. If any surface area exists, assign to downstream node.

Once these depth and surface area corrections are applied, the computations of head and discharge can proceed in the normal way for the current time-step. Note that any of these special situations may begin and end at various times and places during simulation. EXTRAN detects these automatically.

EXTRAN now prints a summary of the special hydraulic cases illustrated in Figure 5-4. Subroutine OUTPUT prints the time in minutes that a conduit was: (1) dry (depth less than 0.0001 ft or m), (2) normal depth, (3) critical upstream, and (4) critical downstream. It should be noted that these designations refer strictly to the assignment of upstream and downstream nodal surface area.

During the calculation of conduit flow in Subroutine XROUTE another normal flow approximation is used when <u>all</u> of the following three conditions occur:

1. The flow is positive. Extran automatically designates the highest invert elevation as the upstream node and the lowest as the downstream node. This adjustment (if made) is now printed out by the model. Postive flow is from the upstream to the downstream node. Any initial flow entered by the user on data group C1 is multiplied by -1 if the upstream and downstream nodes are changed by

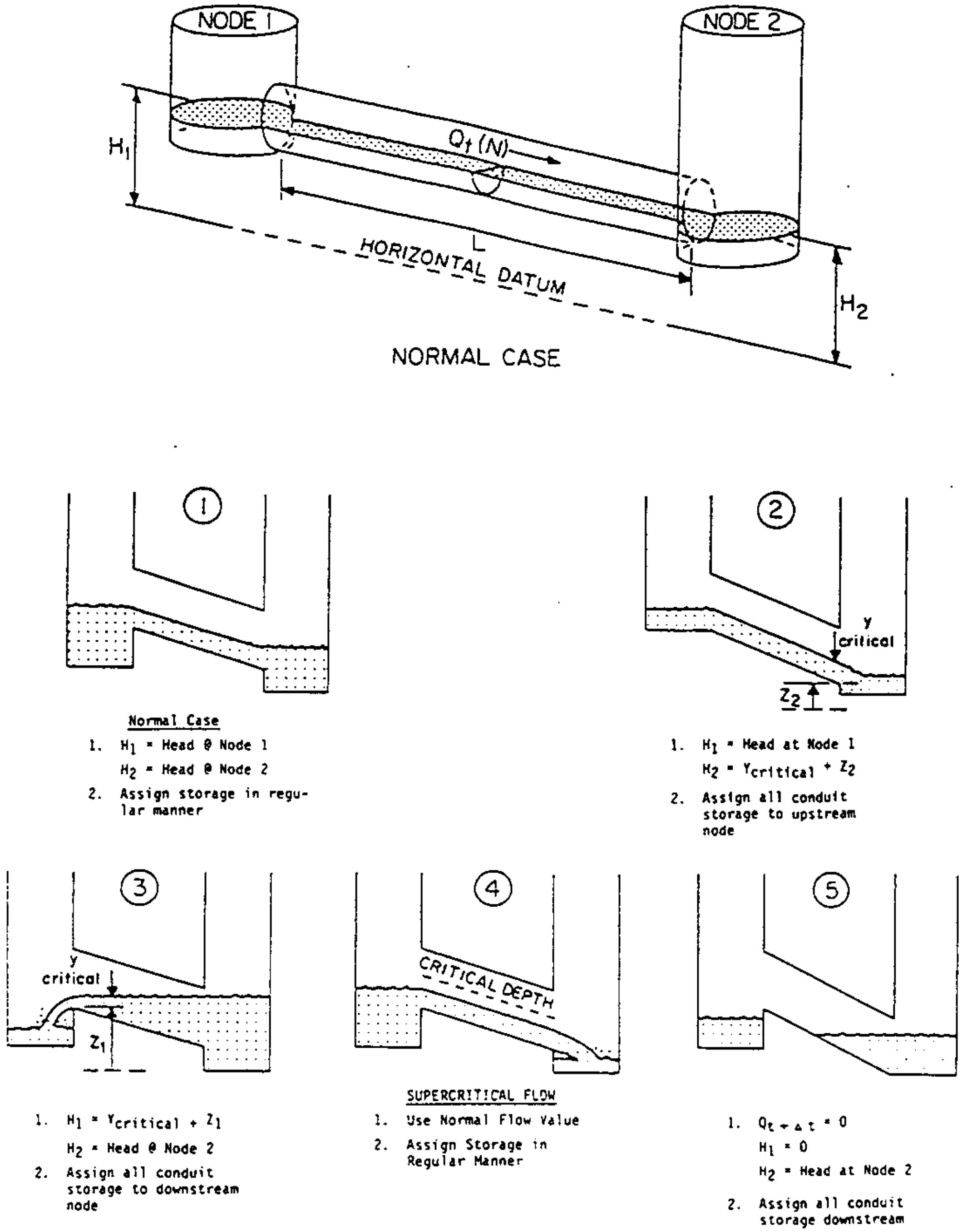


Figure 5-4. Special Hydraulic Cases in EXTRAN Flow Calculations.

the model.

2. The water surface slope in the conduit is less than the conduit slope. See Appendix C for more details.

3. The flow calculated from Manning's equation using the upstream cross-sectional area and hydraulic radius is less than the flow calculated by equation 5-4.

When all three conditions are met the flow the flow is "normal." Normal flow is labeled with an asterisk in the intermediate printout. The conduit summary lists the number of minutes the normal flow assumption is used for each conduit.

HEAD COMPUTATION DURING SURCHARGE AND FLOODING

Theory

Another hydraulic situation which requires special treatment is the occurrence of surcharge and flooding. Surcharge occurs when all pipes entering a node are full or when the water surface at the node lies between the crown of the highest entering pipe and the ground surface.

Flooding is a special case of surcharge which takes place when the hydraulic grade line breaks the ground surface and water is lost from the sewer node to the overlying surface system. While it would be possible to track the water lost to flooding by surface routing, this is not done automatically in EXTRAN. To track water on the surface the user must 1) simulate the surface pathways as conduits, and 2) simulate the vertical pathways through manholes or inlets as conduits also. Since a conduit cannot be absolutely vertical, equivalent pipes must be used.

During surcharge, the head calculation in equations 5-7 and 5-8 is no longer possible because the surface area of the surcharged node (area of manhole) is too small to be used as a divisor. Instead, the continuity equation for each node is equated to zero,

$$\Sigma\, Q(t) = 0 \tag{5-11}$$

where $\Sigma\, Q(t)$ is the sum of all inflows to and outflows from the node from surface runoff, conduits, diversion structures, pumps and outfalls.

Since the flow and continuity equations are not solved simultaneously in the model, the flows computed in the links connected to a node will not exactly satisfy equation 5-11. However, an iterative procedure is used in which head adjustments at each node are made on the basis of the relative changes in flow in each connecting link with respect to a change in head: $\partial Q/\partial H$. Expressing equation 5-11 in terms of the adjusted head at node j gives

$$\Sigma[Q(t) + (\partial Q(t)/\partial H_j)\Delta H_j(t)] = 0 \tag{5-12}$$

Solving for ΔH_j gives

$$\Delta H_j(t) = - \Sigma Q(t) \;/\; \Sigma \partial Q(t)/\partial H_j \qquad (5\text{-}13)$$

This adjustment is made by half-steps during surcharge so that the half-step correction is given as

$$\Delta H_j(t+\Delta t/2) = H_j(t) + k\ \Delta H_j(t+\Delta t/2) \qquad (5\text{-}14)$$

where $H_j(t+\Delta t/2)$ is given by equation 5-13 while the full-step head is computed as

$$H_j(t+\Delta t) = H_j(t+\Delta t/2) + k\ \Delta H_j(t) \qquad (5\text{-}15)$$

where $\Delta H_j(t)$ is computed from equation 5-11. The value of the constant k theoretically should be 1.0. However, it has been found that equation 5-12 tends to over-correct the head; therefore, a value of 0.5 is used for k in the half-step computation in order to improve the results. Unfortunately, this value was found to trigger oscillations at upstream terminal junctions. To eliminate the oscillations, values of 0.3 and 0.6 are automatically set for k in the half-step and full-step computations, respectively, at upstream terminal nodes.

The head correction derivatives are computed for conduits and system inflows as follows:

Conduits

$$\partial Q(t)/\partial H_j = [g/(1-K(t))]\ \Delta t\ (A(t)/L) \qquad (5\text{-}16)$$

where $$K(t) = -\ \Delta t\ [g\ n^2 \;/\; m^2\ R^{4/3}]\ |V(t)| \qquad (5\text{-}17)$$

- Δt = time-step,
- $A(t)$ = flow cross sectional area in the conduit,
- L = conduit length,
- n = Manning n,
- m = 1.49 for U.S. customary units and 1.0 for metric units,
- g = gravitational acceleration,
- R = hydraulic radius for the full conduit, and
- $V(t)$ = velocity in the conduit.

System Inflows

$$\partial Q(t)/\partial H_j = 0 \qquad (5\text{-}18)$$

Orifice, Weir, Pump and Outfall Diversions

Orifices are converted to equivalent pipes (see below); therefore, equation 5-16 is used to compute $\partial Q/\partial H$. For weirs, $\partial Q/\partial H$ in the weir link is taken as zero, i.e., the effect of the flow changes over the weir due to a change in head is ignored in adjusting the head at surcharged weir junctions. (The weir flow, of course, is computed in the next time-step on the basis of the adjusted head.) As a result, the solution may go unstable under surcharge conditions. If this occurs, the weir should be changed to an equivalent pipe as described in Section 2.

For pump junctions, $\partial Q/\partial H$ is also taken as zero. For off-line pumps (with a wet well), this is a valid statement since Q_{pump} is determined by the volume in the wet well, not the head at the junction. For in-line pumps, where the pump rate is determined by the water depth at the junction, a problem could occur if the pumping rate is not set at its maximum value at a depth less than surcharge depth at the junction. This situation should be avoided, if possible, because it could cause the solution to go unstable if a large step increase or decrease in pumping rate occurs while the pump junction is surcharged.

For all outfall pipes, the head adjustment at the outfall is treated as any other junction. Outfall weir junctions are treated the same as internal weir junctions ($\partial Q/\partial H$ for the weir link is taken as zero). Thus, unstable solutions can occur at these junctions also under surcharge conditions. Converting these weirs to equivalent pipes will eliminate the stability problem.

Because the head adjustments computed in equations 5-14 and 5-15 are approximations, the computed head has a tendency to "bounce" up and down when the conduit first surcharges. This bouncing can cause the solution to go unstable in some cases; therefore, a transition function is used to smooth the changeover from head computations by equations 5-7 and 5-8 to equations 5-14 and 5-15. The transition function used is

$$\Delta H_j(t) = \partial Q(t)/DENOM \qquad (5\text{-}19)$$

where DENOM is given by

$$DENOM = \partial Q(t)/\partial H_j + [A_{s_j}(t)/(\Delta t/2) - \partial Q(t)/\partial H_j] \exp[-15(y_j - D_j)/D_j] \qquad (5\text{-}20)$$

where D_j = pipe diameter,
y_j = water depth, and
A_{s_j} = nodal surface area at 0.96 of full depth.

The exponential function causes equation 5-20 to converge to within two percent of equation 5-13 by the time the water depth is 1.25 times the full-flow depth.

Surcharge in Multiple Adjacent Nodes

Use of $\partial Q(t)/\partial H_j$ in the manner explained above satisfies continuity at a single node, but may introduce a small continuity error when several consecutive nodes are surcharged. These small continuity errors combine to artificially attenuate the hydrograph in the surcharged area. Physically, inflows to all surcharged nodes must equal outflows during a time-step since no change in storage can occur during surcharge. In order to remove this artificial attenuation, the full-step computations of flow and head in surcharge areas are repeated in an iteration loop. The iterations for a particular time-step continue until one of the following two conditions is met:

1. The net difference of inflows to and outflows from all nodes in surcharge is less than a tolerance, computed every time-step, as a fraction of the average flow through the surcharged area. The fraction (SURTOL, data group B2) is input by the user.

2. The number of iterations exceeds a maximum set by the user (ITMAX, data group B2).

The iteration loop has been found to produce reasonably accurate results with little continuity error. The user may need to experiment somewhat with ITMAX and SURTOL in order to accurately simulate all surcharge points without incurring an unreasonably high computer cost due to extra iterations.

FLOW CONTROL DEVICES

Options

The link-node computations can be extended to include devices which divert sanitary sewage out of a combined sewer system or relieve the storm load on sanitary interceptors. In EXTRAN, all diversions are assumed to take place at a node and are handled as inter-nodal transfers. The special flow regulation devices treated by EXTRAN include: weirs (both side-flow and transverse), orifices, pumps, and outfalls. Each of these is discussed in the paragraphs below.

Storage Devices

In-line or off-line storage devices act as flow control devices by providing for storage of excessive upstream flows thereby attenuating and lagging the wet weather flow hydrograph from the upstream area. The conceptual representations of a storage junction and a regular junction are illustrated in Figure 5-5. Note that the only difference is that added surface area in the amount of ASTORE is added to that of the connecting pipes. Note also that ZCROWN(J) is set at the top of storage "tank." When the hydraulic head at junction J exceeds ZCROWN(J), the junction goes into surcharge.

An arbitrary stage-area-volume relationship may also be input (data group E2), e.g., to represent detention ponds. Routing is performed by ordinary level-surface reservoir methods. This type of storage facility is not allowed to surcharge.

Orifices

The purpose of the orifice generally is to divert sanitary wastewater out of the stormwater system during dry weather periods and to restrict the entry of stormwater into the sanitary interceptors during periods of runoff. The orifice may divert the flow to another pipe, a pumping station or an off-line storage tank.

Figure 5-6 shows two typical diversions: 1) a dropout or sump orifice, and 2) a side outlet orifice. EXTRAN simulates both types of orifice by con-

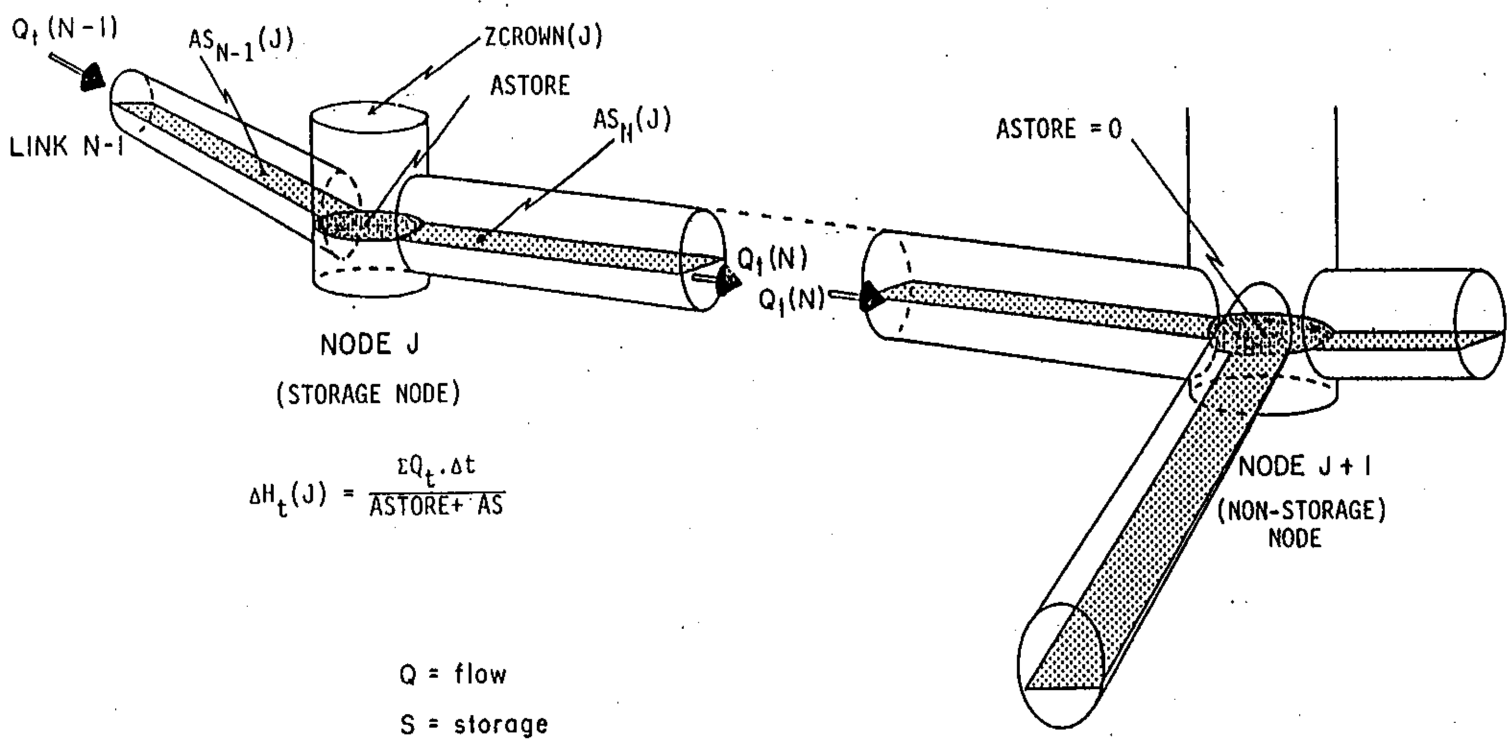


Figure 5-5. Conceptual Representation of a Storage Junction.

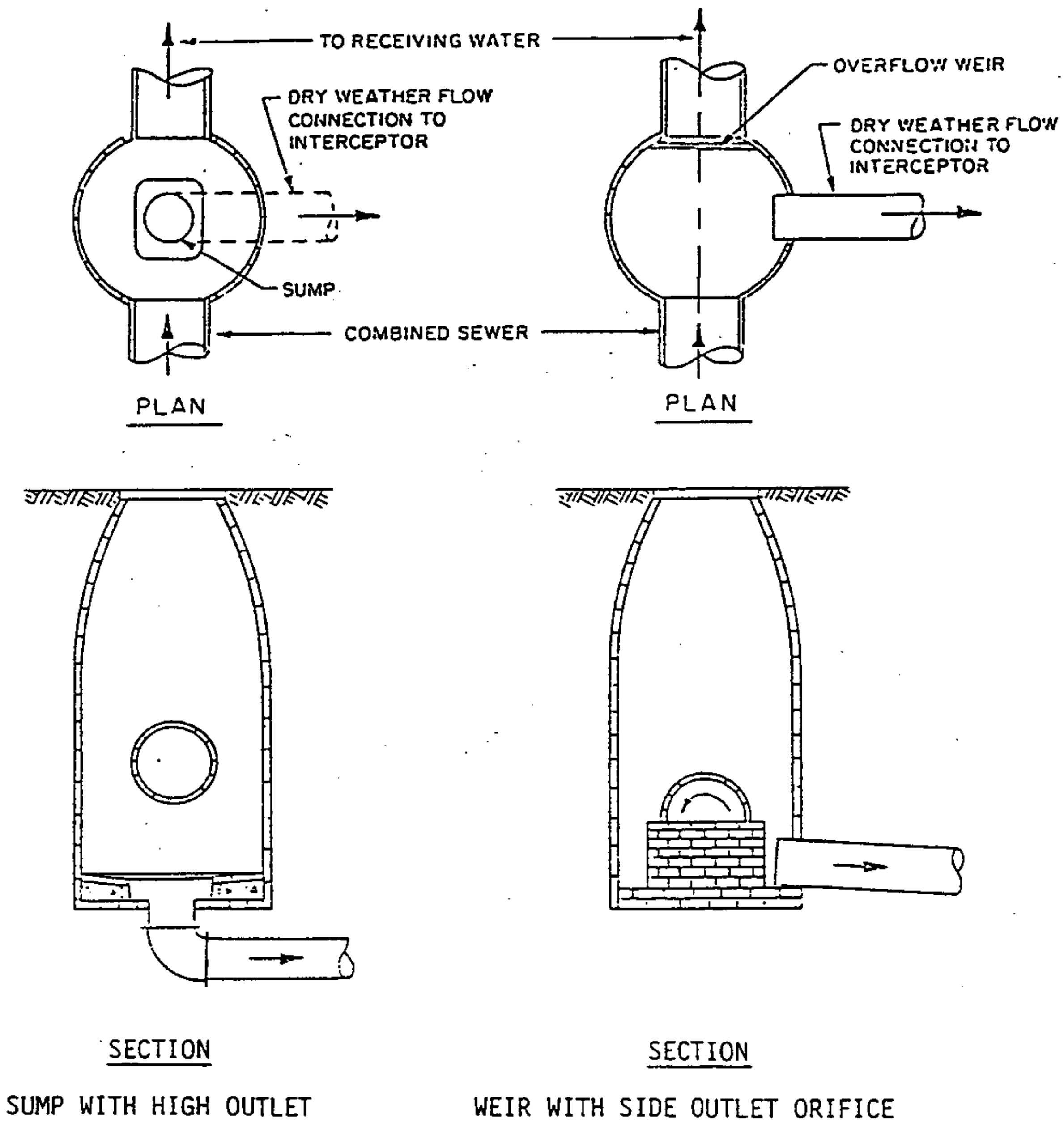


Figure 5-6. Typical Orifice Diversions.

verting the orifice to an equivalent pipe. The conversion is made as follows. The standard orifice equation is:

$$Q_o = C_o A \sqrt{2gh} \tag{5-21}$$

where C_o = discharge coefficient (a function of the type of opening and the length of the orifice tube),
A = cross-sectional area of the orifice,
g = gravitational acceleration, and
h = the hydraulic head on the orifice.

Values of C_o and A are specified by the user. To convert the orifice to a pipe, the program equates the orifice discharge equation and the Manning pipe flow equation, i.e.,

$$(m/n)\ AR^{2/3}\ S^{1/2} = C_o A \sqrt{2gh} \tag{5-22}$$

where m = 1.49 for U.S. customary units and 1.0 for metric units, and
S = slope of equivalent pipe.

The orifice pipe is assumed to have the same diameter, D, as the orifice and to be nearly flat, the invert on the discharge side being set 0.01 ft (3 mm) lower than the invert on the inlet side. In addition, for a sump orifice, the pipe invert is set by the program 0.96D below the junction invert so that the orifice pipe is flowing full before any outflow from the junction occurs in any other pipe. For side outlet orifices, the user specifies the height of the orifice invert above the junction floor.

If S is written as H_s/L where L is the pipe length, H_s will be identically equal to h when the orifice is submerged. When it is not submerged, h will be the height of the water surface above the orifice centerline while H_s will be the distance of the water surface above critical depth (which will occur at the discharge end) for the pipe. For practical purposes, it is assumed that H_s = h for this case also. Thus, letting S = h/L and substituting R = D/4 (where D is the orifice diameter) into equation 5-22 and simplifying gives,

$$n = \frac{m}{C_o\sqrt{2gL}}\ (D/4)^{2/3} \tag{5-23}$$

The length of the equivalent pipe is computed as the maximum of 200 feet (61 meters) or

$$L = 2\Delta t\sqrt{gD} \tag{5-24}$$

to ensure that the celerity (stability) criterion for the pipe is not violated. Manning's n is then computed according to equation 5-23. This algorithm produces a solution to the orifice diversion that is not only as accurate as the orifice equation but also much more stable when the orifice junction is surcharged.

Weirs

A schematic illustration of flow transfer by weir diversion between two nodes is shown in Figure 5-7. Weir diversions provide relief to the sanitary system during periods of storm runoff. Flow over a weir is computed by

$$Q_w = C_w L_w[(h+V^2/2g)^a - (V^2/2g)^a] \qquad (5\text{-}25)$$

where C_w = discharge coefficient,
L_w = weir length (transverse to overflow),
h = driving head on the weir,
V = approach velocity, and
a = weir exponent, 3/2 for transverse weirs and 5/3 for side-flow weirs.

Both C_w and L_w are input values for transverse weirs. For side-flow weirs, C_w should be a function of the approach velocity, but the program does not provide for this because of the difficulty in defining the approach velocity. For this same reason, V, which is programmed into the weir solution, is set to zero prior to computing Q_w.

Normally, the driving head on the weir is computed as the difference $h = Y_1 - Y_c$, where Y_1 is the water depth on the upstream side of the weir and Y_c is the height of the weir crest above the node invert. However, if the downstream depth Y_2 also exceeds the weir crest height, the weir is submerged and the flow is computed by

$$Q_w = C_{SUB}\, C_w L_w (Y_1 - Y_c)^{3/2} \qquad (5\text{-}26)$$

where C_{SUB} is a submergence coefficient representing the reduction in driving head, and all other variables are as defined above.

The submergence coefficient, C_{SUB}, is taken from Roessert's Handbook of Hydraulics (in German, reference unavailable) by interpolation from Table 5-3, where C_{RATIO} is defined as:

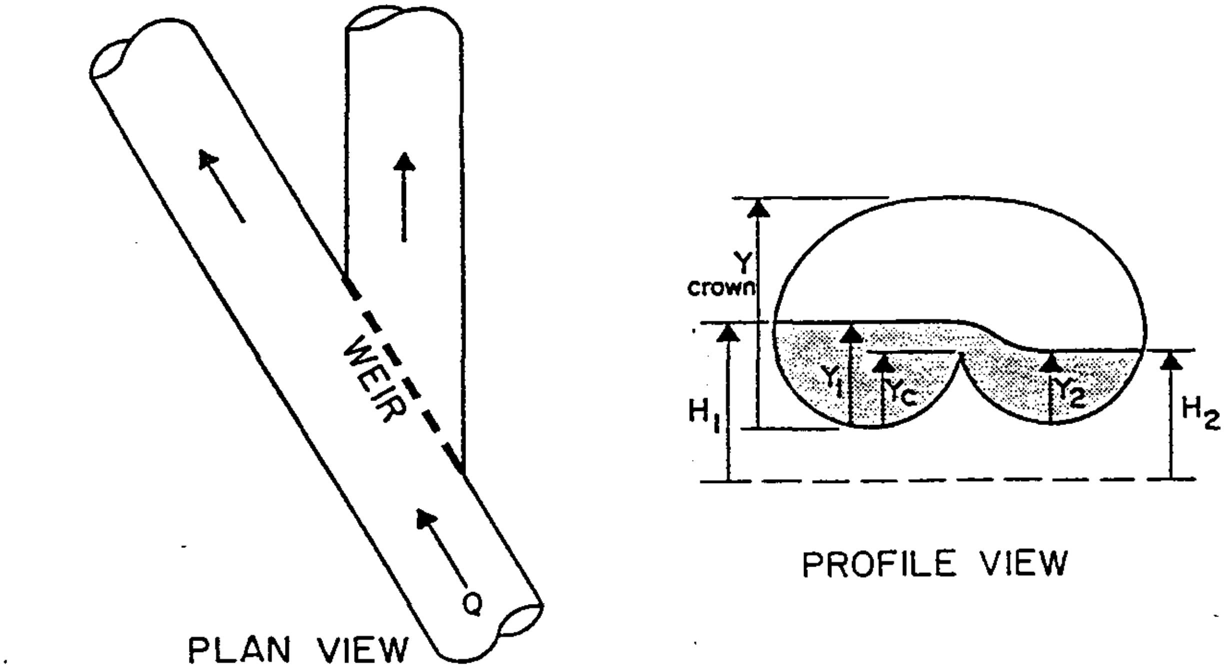
$$C_{RATIO} = (Y_2 - Y_c)/(Y_1 - Y_c) \qquad (5\text{-}27)$$

and all other variables are as previously defined. The values of C_{RATIO} and C_{SUB} are computed automatically by EXTRAN and no input data values are needed.

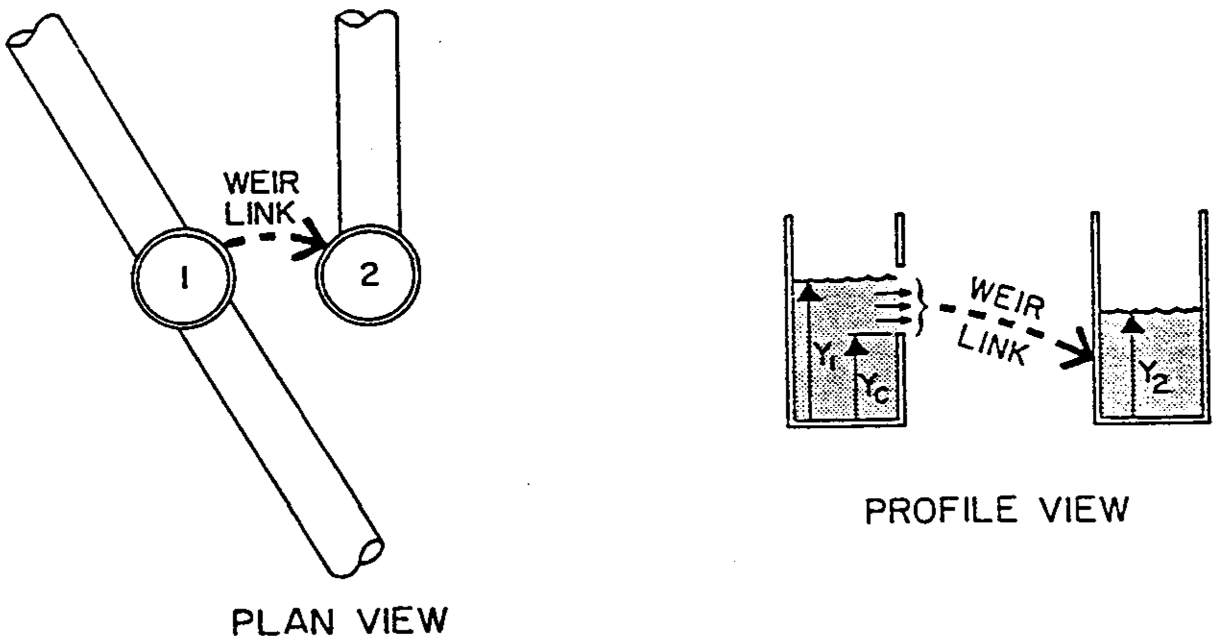
If the weir is surcharged it will behave as an orifice and the flow is computed as:

$$Q_w = C_{SUR}\, L_w\, (Y_{TOP} - Y_c)\sqrt{2gh'} \qquad (5\text{-}28)$$

where Y_{TOP} = distance to top of weir opening shown in Figure 2-7,
h' = Y_1 - maximum(Y_2, Y_c), and
C_{SUR} = weir surcharge coefficient.



Schematic of a Weir Diversion



Conceptual Representation of a Weir Diversion

Figure 5-7. Representation of Weir Diversions.

Table 5-3. Values of C_{SUB} as a Function of Degree of Weir Submergence.

C_{RATIO}	C_{SUB}
0.00	1.00
0.10	0.99
0.20	0.98
0.30	0.97
0.40	0.96
0.50	0.95
0.60	0.94
0.70	0.91
0.80	0.85
0.85	0.80
0.90	0.68
0.95	0.40
1.00	0.00

The weir surcharge coefficient, C_{SUR}, is computed automatically at the beginning of surcharge. At the point where weir surcharge is detected, the preceding weir discharge just prior to surcharge is equated to Q_w in equation 5-26, and equation 5-28 is then solved for the surcharge coefficient, C_{SUR}. Thus, no input coefficient for surcharged weirs is required.

Finally, EXTRAN detects flow reversals at weir nodes which cause the downstream water depth, Y_2, to exceed the upstream depth, Y_1. All equations in the weir section remain the same except that Y_1 and Y_2 are switched so that Y_1 remains as the "upstream" head. Also, flow reversal at a side-flow weir causes it to behave more like a transverse weir and consequently the exponent a in equation 5-25 is set to 1.5.

Weirs With Tide Gates

Frequently, weirs are installed together with a tide gate at points of overflow into the receiving waters. Flow across the weir is restricted by the tide gate, which may be partially closed at times. This is accounted for by reducing the effective driving head across the weir according to an empirical factor published by Armco (undated):

$$h' = h - (4/g)V^2 \exp(-1.15V/h^{1/2}) \tag{5-29}$$

where h is the previously computed head before correction for flap gate and V is the velocity of flow in the upstream conduit.

Pump Stations

A pump station is conceptually represented as either an in-line lift station or an off-line node representing a wet-well, from which the contents are pumped to another node in the system according to a programmed rule curve. Alternatively, either in-line or off-line pumps may use a three-point pump curve (head versus pumped outflow).

For an in-line lift station, the pump rate is based on the water depth, Y, at the pump junction. The step-function rule is as follows:

$$\begin{aligned} \text{Pump Rate} &= R_1 \quad \text{for } 0 < Y < Y_1 \\ &= R_2 \qquad\quad Y_1 \le Y < Y_2 \\ &= R_3 \qquad\quad Y_2 \le Y < Y_3 \end{aligned} \tag{5-30}$$

For Y = 0, the pump rate is the inflow rate to the pump junction.

Inflows to the off-line pump must be diverted from the main sewer system through an orifice, a weir, or a pipe. The influent to the wet-well node must be a free discharge regardless of the diversion structure. The pumping rule curve is based on the volume of water in the storage junction. A schematic presentation of the pump rule is shown in Figure 5-8. The step-function rule operates as follows:

1. Up to three wet-well volumes are prespecified as input data for each pump station: $V_1 < V_2 < V_3$, where V_3 is the maximum capacity of the wet well.

2. Three pumping rates are prespecified as input data for each station. The pump rate is selected automatically by EXTRAN depending on the volume, V, in the wet-well, as follows:

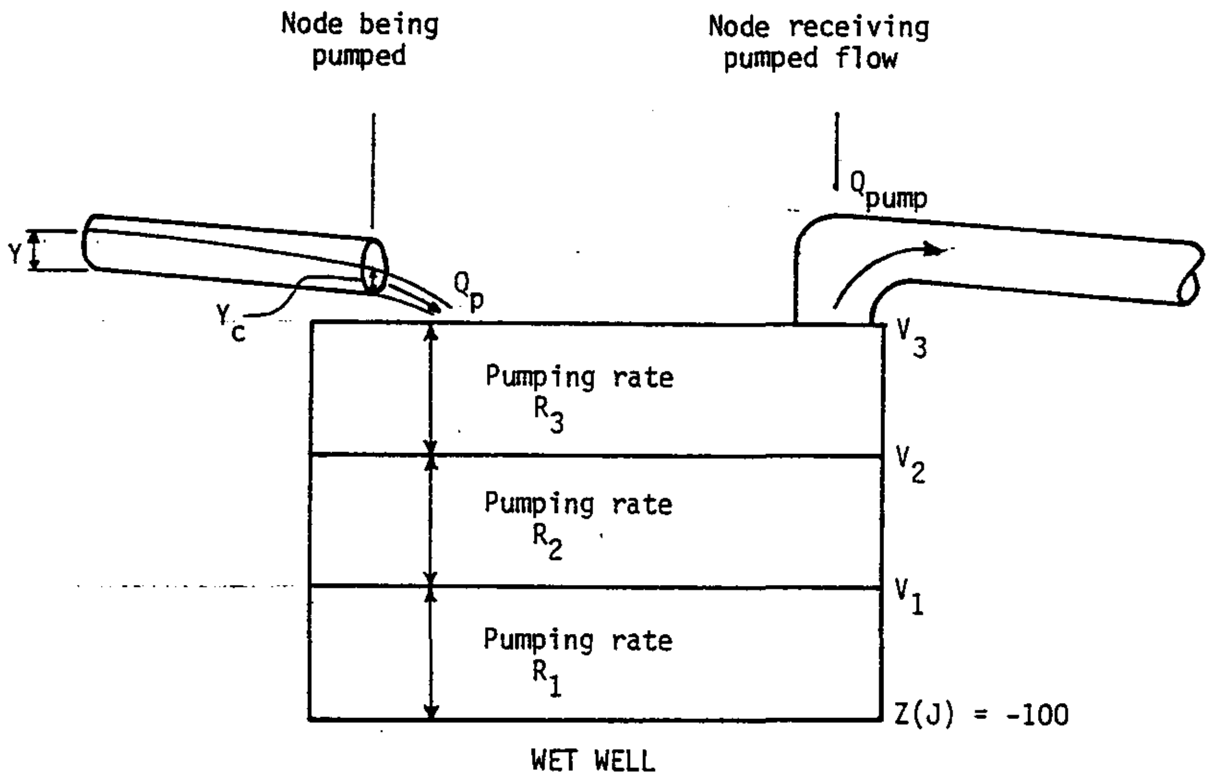
$$\begin{aligned} \text{Pump Rate} &= R_1 \quad \text{for } 0 < V < V_1 \\ &= R_2 \qquad\quad V_1 \le V < V_2 \\ &= R_3 \qquad\quad V_2 \le V < V_3 \end{aligned} \tag{5-31}$$

3. A mass balance of pumped outflow and inflow is performed in the wet-well during the model simulation period.

4. If the wet-well goes dry, the pump rate is reduced below rate R_1 until it just equals the inflow rate. When the inflow rate again equals or exceeds R_1, the pumping rate goes back to operating on the rule curve.

5. If V_3 is exceeded in the wet-well, the inflow to the storage node is reduced until it does not exceed the maximum pumped flow. When the inflow falls below the maximum pumped flow, the inflow "gates" are opened. The program automatically steps down the pumping rate by the operating rule of (2) as inflows and wet-well volume decrease.

A conceptual head-discharge curve for a pump is shown in Figure 2-10. When this method is used for either type of pump, an iteration is performed until the dynamic head difference between the upstream and downstream nodes on either side of the pump corresponds to the flow given on the pump curve. In other words, the pump curve replaces equation 5-4.



$$
\begin{aligned}
\text{Pumping rate} &= R_1 \text{ for } V < V_1 \\
&= R_2 \text{ for } V < V < V_2 \\
&= R_3 \text{ for } V < V < V_3
\end{aligned}
$$

V is volume in wet well

Figure 5-8. Schematic Presentation of Pump Diversion.

Outfall Structures

EXTRAN simulates both weir outfalls and free outfalls. Either type may be subject to a backwater condition and protected by a tide gate. A weir outfall is a weir which discharges directly to the receiving waters according to relationships given previously in the weir section. The free outfall is simply an outfall conduit which discharges to a receiving water body under given backwater conditions. The free outfall may be truly "free" if the elevation of the receiving waters is low enough (i.e., the end of the conduit is elevated over the receiving waters), or it may consist of a backwater condition. In the former case, the water surface at the free outfall is taken as critical or normal depth, whichever is less. If backwater exists, the receiving water elevation is taken as the water surface elevation at the free outfall.

Up to 20 different head versus time relationships can be used as boundary conditions. Any outfall junction can be assigned to any of the 20 boundary conditions.

When there is a tide gate on an outfall conduit, a check is made to see whether or not the hydraulic head at the upstream end of the outfall pipe exceeds that outside the gate. If it does not, the discharge through the outfall is equated to zero. If the driving head is positive, the water surface elevation at the outfall junction is set in the same manner as that for a free outfall subjected to a backwater condition. Note that even if the tide gate is closed, water can still enter and fill an empty outfall pipe as sometimes happens at the beginning of a simulation.

INITIAL CONDITIONS

Initial flows in conduits may be input by the user on data group C1. For each conduit, EXTRAN then computes the normal depth corresponding to the initial flow. Junction heads are then approximated as the average of the heads of adjacent conduits for purposes of beginning the computation sequence. The initial volume of water computed in this manner is included in the continuity check. A more accurate initial condition for any desired set of flows may be established by letting EXTRAN "warm up" with the initial inflows and restarted using the "hot start" feature explained in Section 2.

Initial heads at junctions may be input by the user on data group D1. The model does not estimate the initial conduit flow if the conduit flow is entered as zero on data group C1. Initial heads at junctions with a sump orifice are increased by 0.96 times the equivalent pipe diameter of the orifice at the start of the simulation.

SECTION 6

PROGRAM STRUCTURE OF EXTRAN

GENERAL

The EXTRAN Block is a set of computer subroutines which are organized to simulate the unsteady, gradually-varied movement of stormwater in a sewer network composed of conduits, pipe junctions, diversion structures, and free outfalls. A program flowchart for the major computational steps in the EXTRAN Block is presented in Figure 6-1. The complete Fortran code, together with key variable definitions, is contained on the SWMM4 program distribution disks or tape.

The EXTRAN Block contains 16 subroutines, in addition to the SWMM MAIN program which controls execution, and four line-printer graphing subroutines (CURVE, PPLOT, SCALE AND PINE). The organization of each subroutine and its relation to the main program has been diagrammed in the master flowchart of Figure 6-2. A description of each subroutine follows in the paragraphs below.

SUBROUTINE EXTRAN

EXTRAN is the executive subroutine of the Block. It sets the unit numbers of the device containing the input data and the device where printed output will be directed. The device numbers of the input and output hydrograph files, if used, are also set here. EXTRAN calls the three input data subroutines INDAT1, INDAT2 and INDAT3 for reading all input data groups defining the length of the transport simulation run, the physical data for the transport system, and the instructions for output processing.. The arrays in the common blocks of the Extran program are initialized in Subroutine EXTRAN. Various file manipulations are handled, including use of any "hot-start" files (i.e., restart from previous saved file), and then subroutine TRANSX is called to supervise the computations of the EXTRAN Block.

SUBROUTINE TRANSX

TRANSX is the main controlling subprogram of the EXTRAN Block which drives all other subprograms and effectively controls the execution of EXTRAN as it has been presented graphically in the flowchart of Figure 6-1. Principal steps in TRANSX are outlined below in the order of their execution:

1. Initialize the system flow properties and set time = TZERO.

2. Advance time = $t+\Delta t$ and begin main computation loop contained in steps 2 through 5 below.

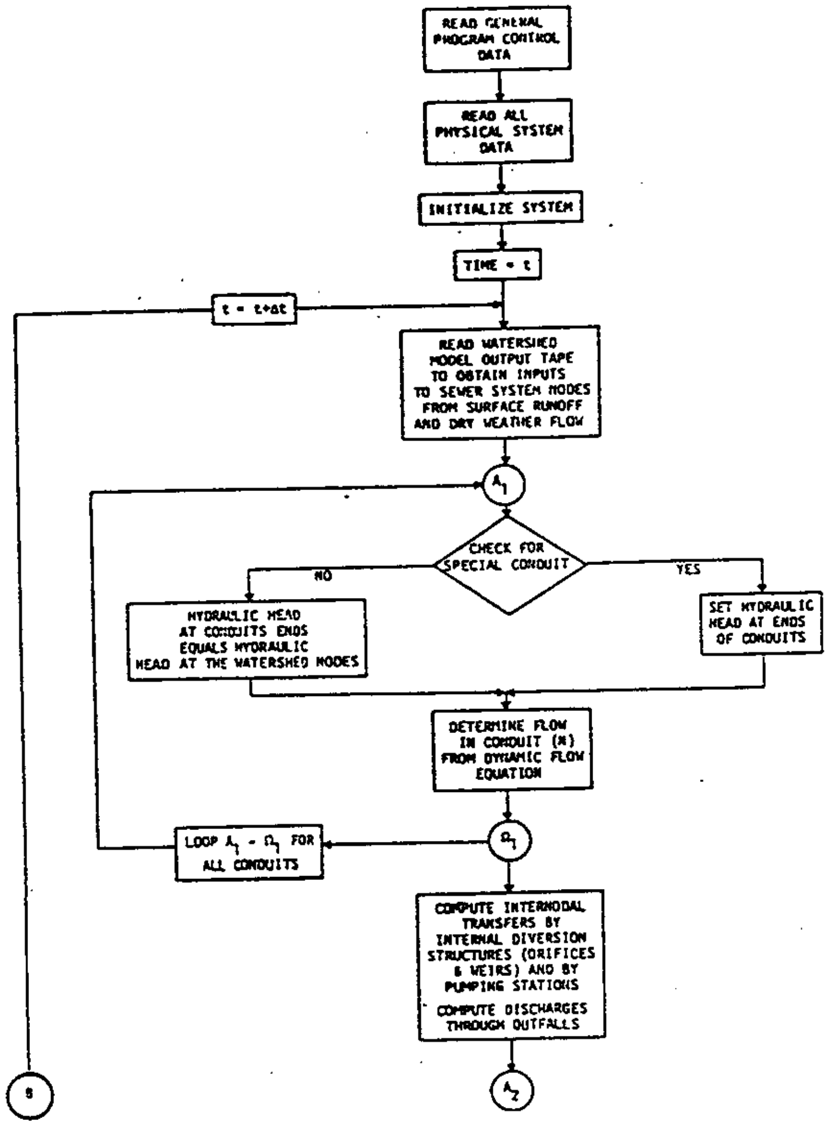


Figure 6-1. EXTRAN Block Program Flowchart.

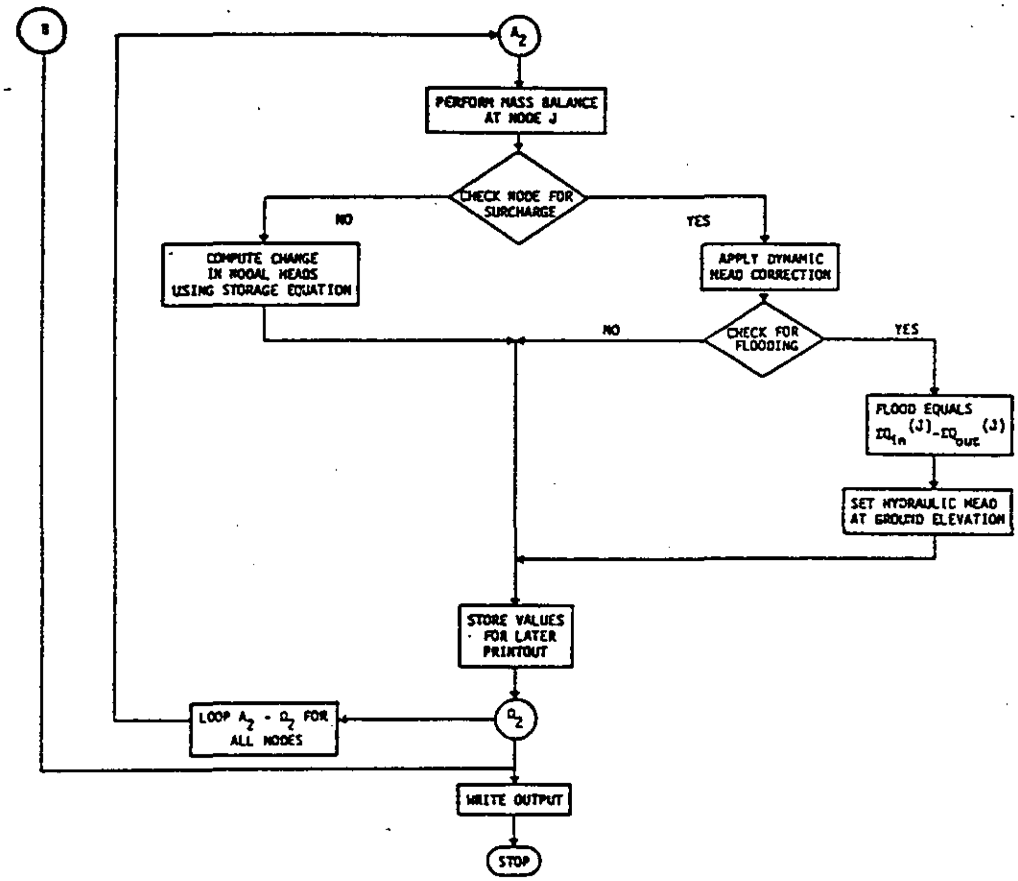


Figure 6-1. EXTRAN Block Program Flowchart.
(Continued)

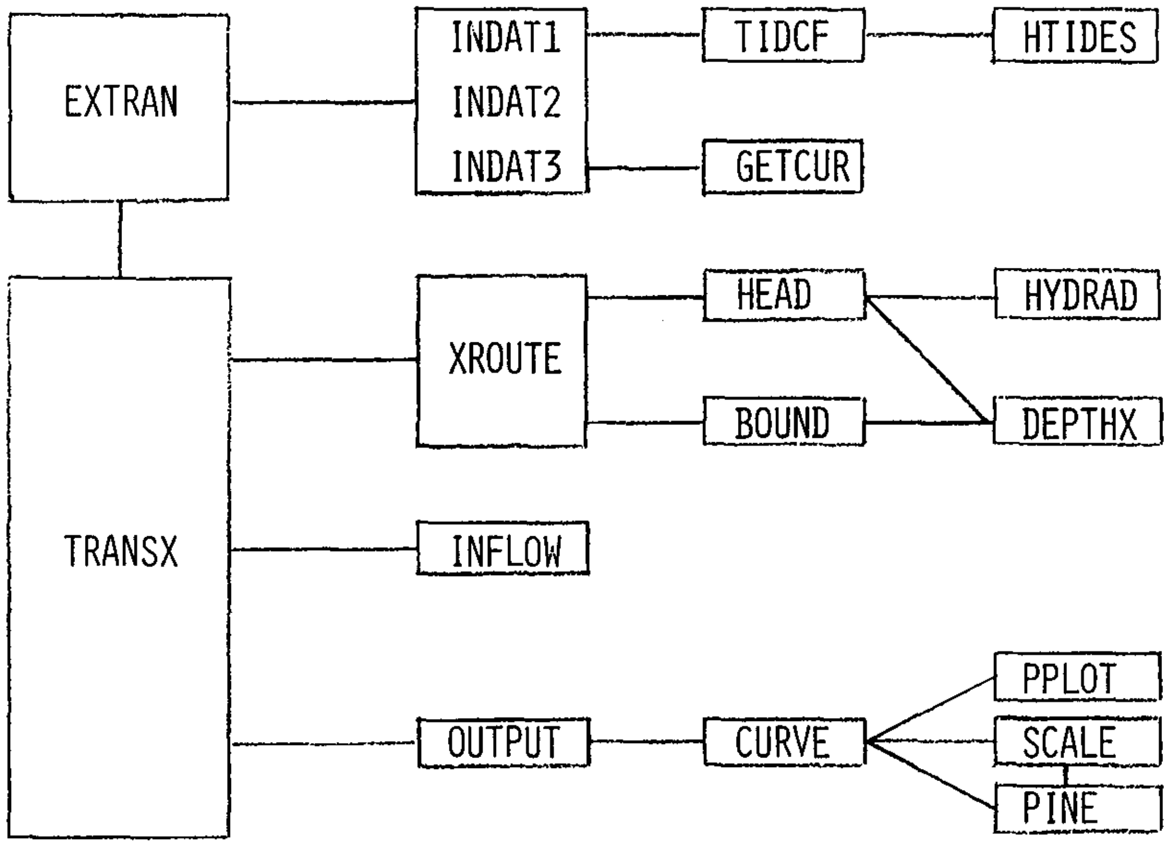


Figure 6-2. Master Flowchart for EXTRAN Block Subroutines. (Connection between BOUND and HTIDES not shown.)

3. Select current value of inflow hydrographs for all input nodes by call to INFLOW, which interpolates runoff hydrograph records either on device number N21 (interface file supplied by upstream block) or on data group K1 - K3.

4. Call subroutine XROUTE for the calculation of the transient properties of nodal depth and conduit flow.

5. Store nodal water depth and water surface on NSCRAT(1) to be used later by OUTPUT. Also, store conduit discharges and velocities for later printing. Print intermediate output.

6. Return to step 2 and repeat through step 5 until the transport simulation is complete for the entire period.

7. Call subroutine OUTPUT for printing and plotting of conduit flows and junction water surface elevations.

SUBROUTINE XROUTE

Subroutine XROUTE performs the numerical calculations for the open channel and surcharged flow equations used in EXTRAN. The solution uses the modified Euler method and a special iterative procedure for surcharged flow. The following principal steps are performed:

1. For all the physical conduits in the system, compute the following time-changing properties based on the last full-step values of depth and flow:

-- Hydraulic head at each conduit end.

-- Full-step values of cross-sectional area, velocity, hydraulic radius, and surface area corresponding to preceding full-step flow. This is done by calling subroutine HEAD.

-- Half-step value of discharge at time $t = t+\Delta t/2$ by modified Euler solution.

-- Check for normal flow, if appropriate. Normal flow is indicated by an asterisk in the intermediate printout.

-- Set system outflows and internal transfers at time $t+\Delta t/2$ by call to subroutine BOUND. BOUND computes the half-step flow transfers at all orifices, weirs, and pumps at time $t=t+\Delta t/2$. It also computes the current value of tidal stage and the half-step value of depth and discharge at all outfalls.

2. For all physical junctions in the system, compute the half-step depth at time $t=t+\Delta t/2$. This depth computation is based on the current net inflows to each node and the nodal surface areas computed previously in step 1. Check for surcharge and flooding at each node and compute water

depth accordingly.

3. For all physical conduits, compute the following properties based on the last half-step values of depth and flow (repeat step 1 for time $t+\Delta t/2$):

-- Hydraulic head at each pipe end.

-- Half-step values of pipe cross-sectional area, velocity, hydraulic radius, and surface are corresponding to preceding half-steep depth and discharge.

-- Full-step discharge at time $t+\Delta t$ by modified Euler solution.

-- Check for normal flow if appropriate.

-- Set system outflows and internal transfer at time $t+\Delta t$ by calling BOUND.

4. For all junctions, repeat the nodal head computation of step 6 for time $t+\Delta t$. Sum the differences between inflow and outflow for each junction in surcharge.

5. Repeat steps 3 and 4 for the surcharged links and nodes until the sum of the flow differences from step 4 is less than fraction SURTOL multiplied by the average flow through the surcharged area <u>or</u> the number of iterations exceeds parameter ITMAX.

6. Return to subroutine TRANSX for time and output data updates.

SUBROUTINE BOUND

The function of subroutine BOUND is to compute the half-step and full-step flow transfers by orifices, weirs, and pump stations. BOUND also computes the current level of receiving water backwater and determines discharge through system outfalls. A summary of principal calculations follows:

1. Compute current elevation of receiving water backwater. Depending on the tidal index, the backwater condition will be constant, tidal or below the system outfalls (effectively non-existent). The tidally-varied backwater condition is computed by a Fourier series about a mean time equal to the first coefficient, A1.

2. Compute the depth at orifice junctions for all sump orifices flowing less than full.

3. Compute discharge over transverse and side-flow weirs. Check for reverse flow, surcharge, and weir submergence. If the weir is surcharged, compute flow by orifice-type equation. If weir is submerged, compute the submergence coefficient and re-compute weir flow. If a tide gate is present at weir node, then compute head loss, reduce driving head on weir and re-compute weir discharge.

4. Compute pump discharges based on current junction or wet-well level and corresponding pump rate. If wet-well is flooded, set pump rate at maximum level and reduce inflow.

SUBROUTINE DEPTHX

Subroutine DEPTHX computes the critical and normal depths corresponding to a given discharge using the critical flow and Manning uniform flow equations, respectively. Tables of normalized values for the cross-sectional area, hydraulic radius and surface width of each pipe class are initialized in a Block Data subroutine to speed the computations of critical and normal depth. Subroutine DEPTHX is used by subroutines BOUND and HEAD.

SUBROUTINE HEAD

Subroutine HEAD is used to convert a nodal water depth to the depth of flow above the invert of a connecting pipe. Based on the depths of flow at each pipe end, HEAD computes the surface width and assigns surface area to the upstream and downstream node according to the following criteria:

1. For the normal situation in which both pipe inverts are submerged and the flow is sub-critical throughout the conduit, the surface area of that conduit is assigned equally to the two connecting junctions.

2. If a critical flow section is detected at the downstream end of a conduit, then surface area for that conduit is assigned to the upstream node.

3. If a critical section occurs at the upstream end, the conduit surface area is assigned to the downstream node.

4. For a dry pipe (pipe inverts unsubmerged), the surface area is zero. The velocity, cross-sectional area and hydraulic radius are set to zero for this case.

5. If the pipe is dry only at the upstream end, then all surface area for the conduit is assigned to the downstream junction.

Note that adverse flow in the absence of a critical section is treated as in (1) above. If a critical section occurs upstream, then all surface area for the adverse pipe is assigned downstream as in (3). The assignment of nodal surface area, based on the top width and length of conduit flow, is essential to the proper calculation of head changes computed at each node from mass continuity as discussed in Section 5. Following surface area assignment, HEAD computes the current weighted average values of cross-sectional area, flow velocity, and hydraulic radius for each pipe. Subroutine HEAD is called by subroutine XROUTE and in turn uses subroutines DEPTHX and HYDRAD in its surface area computations.

SUBROUTINE HYDRAD

The function of subroutine HYDRAD is to compute average values of hydraulic radius, cross-sectional area, and surface width for all conduits in the transport system. Based on the current water depth at the ends and midpoint of each conduit, HYDRAD computes from a table of normalized properties the current value of hydraulic radius, cross-sectional area, and surface width. HYDRAD is used by subroutine HEAD for computing nodal surface areas as described above. It is also called by BOUND for computing the cross-sectional area and average velocity of flow in the outfall pipe protected by a tide gate.

SUBROUTINES INDAT1, INDAT2 AND INDAT3

"Subroutine INDATA" really consists of three subroutines, INDATA1, INDAT2 and INDAT3, but will just be called "INDATA" in this discussion. INDATA is the principal input data subroutine for the EXTRAN Block; it is used once at the beginning of subroutine EXTRAN. Its primary function is to read all input data specifying the links, nodes, and special structures of the transport network. It also establishes transport system connectivity and sets up an internal numbering system for all transport elements by which the computations in XROUTE can be carried out. The principal operations of INDATA are listed below in the order they occur in the program:

1. Read first two title lines for output headings and run control data groups specifying the number of time-steps (integration cycles), the length of the time-step, DELT, and other parameters for output and run control.

2. Read external junction and conduit numbers for detailed printing and plotting of simulation output.

3. Read physical data for conduits and irregular (natural) channels and print a summary of all conduit data.

4. Read physical data for junctions and print summary of all junction data.

5. Set up internal numbering system for junctions and conduits and establish connectivity matrix. This matrix shows the connecting nodes at the end of each conduit and conversely the connecting links for each node in the transport system.

6. Read orifice input data and print summary. Assign internal link between orifice node and node to which it discharges.

7. Read weir input data and assign an internal link and node to each weir in the system. Print summary of all weir data.

8. Read pump data and assign an internal link number to each pump node. Print summary of all pumping input data. Set invert elevation and inflow index for pumped node.

9. Read free outfall data and print a data summary for outfalls, including which set of boundary condition data will be used. Assign an internal link for each free outfall in the internal numbering system.

10. Read tide-gated (non-weir) outfall data from cards and print a summary of tide gate data. Assign an internal link for each free outfall in the internal numbering system.

11. Print a summary of internal connectivity information showing the internal nodes and connecting links assigned to orifices, weirs, pumps, and free outfalls.

12. Read up to five sets of boundary condition input data. Depending on the tidal index, one of the following four boundary condition types will exist:

1) No control water surface at the system outfall.

2) Outfall control water surface at the same constant elevation, A1.

3) Tide coefficients are read on data group J2.

4) Tide coefficients A1 through A7 will be generated by TIDCF and are printed in subroutine TIDCF using data from data group J4.

Print summary of tidal boundary input data, including the tide coefficients generated (and printed) by TIDCF.

13. Set up print and plot arrays for output variables in the internal numbering system.

14. Initialize conduit conveyance factor in Manning equation.

15. Read in initial system information on file unit N21 generated by the block immediately preceding the EXTRAN Block, usually the Runoff Block.

16. Read first two hydrograph records either from file unit N21 and/or from data input lines (group K3).

17. Write out initial transport system information on interface file unit N22 (which equals Executive Block file JOUT) which will contain the hydrograph output from EXTRAN outfalls supplied as input to any subsequent block.

SUBROUTINE GETCUR

Subroutine GETCUR reads irregular cross-section and variable storage node data. For channels, GETCUR computes normalized values of cross-sectional area, hydraulic radius (with variable Manning's n), and top width. Interpolation of these curves during EXTRAN's simulation is identical to that performed for regular cross sections where the normalized curves have been predetermined and stored in Block Data.

SUBROUTINE INFLOW

Subroutine INFLOW is called from subroutine TRANSX at each time-step to compute the current value of hydrograph inflow to each input node in the sewer system. INFLOW reads current values of hydrograph ordinates from file unit N21 if the Runoff Block (or any other block) immediately precedes the EXTRAN Block, and/or from line input runoff hydrographs (data group K3). INFLOW performs a linear interpolation between hydrograph input points and computes the discharge at each input node at the half-step time, $t+\Delta t/2$.

SUBROUTINE TIDCF

Subroutine TIDCF is used once for each boundary condition type (if needed) by subroutine INDATA to compute seven tide coefficients, A1 through A7, which are used by subroutine BOUND to compute the current tide elevation according to the Fourier series:

$$H_{TIDE} = A_1 + A_2 \sin \omega t + A_3 \sin 2\omega t + A_4 \sin 3\omega t + A_5 \cos \omega t + A_6 \cos 5\omega t + A_7 \cos 6\omega t \qquad (6\text{-}1)$$

where t = current time, hours (units of seconds are used internally),
ω = 2 pi radians/W, hr^{-1}, and
W = tidal period, hours, entered in data group J2.

Typical tidal periods are 12.5 or 25 hours. The coefficients A_2 through A_7 are developed by an iterative technique in TIDCF in which a sinusoidal series is fit to the set of tidal stage-time points supplied as input data by subroutine INDATA (data groups J3 and J4).

FUNCTION HTIDES

HTIDES is merely a function that evaluates equation 6-1. It is called from TIDCF as part of the determination of the tidal coefficients and from BOUND during the simulation to determine the current tidal elevation for multiple boundary conditions.

SUBROUTINE OUTPUT

Subroutine OUTPUT is called by subroutine TRANSX at the end of the simulation run to print and plot the hydraulic output arrays generated by the EXTRAN Block. Printed output includes time histories of: 1) the water depths and water surface elevations at specified junctions, and 2) the discharge and flow velocity in specified conduits. In addition, there is a continuity check and summaries of stage and depth information at each node and flow and velocity information for every conduit. Surcharging, if any, is summarized in these tables.

The plotting of junction water surface elevation and conduit discharge is carried out by a line-printer plot package (subroutine CURVE of the Graph Block) which is called by OUTPUT after printed output is complete. Documentation of the graph routines may be found in the main SWMM User's Manual (Huber and Dickinson, 1988). The output is either in U.S. customary units or metric units depending on the value of parameter METRIC on data group B2.

User's of SWMM and EXTRAN on microcomputers may wish to use the superior graphics available with various software on those machines. Hydrographs stored on the SWMM interface file may be accessed for this purpose through a program written by the user or by conversion to an ASCII/text file by the Combine Block. EXTRAN will save all outfall hydrographs (i.e., from designated weirs or from outfalls identified in data groups I1 and I2) on SWMM interface file JOUT if JOUT > 0. The structure of this file is described in Appendix B and in Section 2 of the main SWMM User's Manual (Huber and Dickinson, 1988), from which a program may be written to access and plot the hydrographs. Similarly, this file structure must be followed if the user wishes to place onto an interface file arbitrary input hydrographs generated by a program external to SWMM.

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APPENDIX A

UNSTEADY FLOW EQUATIONS

The basic differential equations for the sewer flow problem come from the gradually varied, one-dimensional, unsteady flow equations for open channels, otherwise known as the St. Venant or shallow water equations. The unsteady flow continuity equation with no lateral inflow and with cross-sectional area and flow as dependent variables is (Yen, 1986; Lai, 1986):

$$\partial A/\partial t + \partial Q/\partial x = 0 \tag{A-1}$$

where
- A = cross sectional area,
- Q = conduit flow,
- x = distance along the conduit/channel, and
- t = time.

The momentum equation may be written in several forms depending on the choice of dependent variables. Using flow, Q, and hydraulic head (invert elevation plus water depth), H, the momentum equation is (Lai, 1986):

$$\partial Q/\partial t + \partial(Q^2/A)/\partial x + gA\partial H/\partial x + gAS_f = 0 \tag{A-2}$$

where
- g = gravitational constant,
- $H = z + h$ = hydraulic head,
- z = invert elevation,
- h = water depth, and
- S_f = friction (energy) slope.

(The bottom slope is incorporated into the gradient of H.)

EXTRAN uses the momentum equation in the links and a special lumped continuity equation for the nodes. Thus, momentum is conserved in the links and continuity in the nodes.

Equation A-2 is modified by substituting the following identities:

$$Q^2/A = V^2A \tag{A-3}$$

$$\partial(V^2A)/\partial x = 2AV\partial V/\partial x + V^2\partial A/\partial x \tag{A-4}$$

where V = conduit average velocity,

Substituting into equation A-2 leads to an equivalent form:

$$\partial Q/\partial t + 2AV\,\partial V/\partial x + V^2\,\partial A/\partial x + gA\,\partial H/\partial x + gAS_f = 0 \qquad \text{(A-5)}$$

This is the form of the momentum equation used by EXTRAN and it has the dependent variables Q, A, V, and H.

The continuity equation (A-1) may be manipulated to replace the second term of equation A-5, using $Q = AV$,

$$\partial A/\partial t + A\,\partial V/\partial x + V\,\partial A/\partial x = 0 \qquad \text{(A-6)}$$

or, rearranging terms and multiplying by V,

$$AV\,\partial V/\partial x = -V\,\partial A/\partial t - V^2\,\partial A/\partial x \qquad \text{(A-7)}$$

substituting equation A-7 into equation A-5 to eliminate the $\partial V/\partial x$ term leads to the equation solved along conduits by EXTRAN:

$$\partial Q/\partial t + gAS_f - 2V\partial A/\partial t - V^2\,\partial A/\partial x + gA\,\partial H/\partial x = 0 \qquad \text{(A-8)}$$

Equation A-8 is the same as equation 5-1, whose solution is discussed in detail in Section 5.

As discussed briefly in Table 2-1 and extensively in Appendix C, there are three Extran solutions (data group B0). Equation A-8 is the basis of the ISOL = 0 solution. The momentum equation for the ISOL = 1 and ISOL = 2 solutions are derived from equations A-1 and A-2 in the following manner. The $\partial(Q^2/A)/\partial x$ term in equation A-2 is expanded as the product of Q and Q/A instead of V^2/A as in the ISOL = 0 solution.

$$\partial(Q^2A)/\partial x = Q^2\,\partial(1/A)/\partial x + 2Q/A\,\partial Q/\partial x = Q^2\,\partial(1/A)/\partial x + 2V\,\partial Q/\partial x \qquad \text{(A-9)}$$

Again the continuity equation A-1 is used to substitute for the $\partial Q/\partial x$ term in equation A-9. This term is inadmissible in Extran since the flow is assumed constant in a link. The link momemtum equation used by the ISOL = 1 and ISOL = 2 solutions is presented in equation A-10.

$$\partial Q/\partial t + gAS_f - 2V\,\partial A/\partial t + Q^2\,\partial(1/A)/\partial x + gA\,\partial H/\partial x = 0 \qquad \text{(A-10)}$$

The solution techniques used to solve equation A-10 for the ISOL = 1 and ISOL = 2 solutions are discussed in Appendix C.

APPENDIX B

INTERFACING BETWEEN SWMM BLOCKS

Data may be transferred or interfaced from one block to another through the use of the file assignments on Executive Block data group SW. The interface file header consists of:

1) descriptive titles,
2) the simulation starting date and time,
3) the name of the block generating the interface file,
4) the total catchment or service area,
5) the number of hydrograph locations (inlets, outfalls, elements, etc.),
6) the number of pollutants found on the interface file,
7) the location identifiers for transferred flow and pollutant data,
8) the user-supplied pollutant and unit names,
9) the type of pollutant concentration units, and
10) flow conversion factor (conversion to internal SWMM units of cfs).

Following the file header are the flow and pollutant data for each time step for each of the specified locations. The detailed organization of the interface file is shown in Table B-1, and example Fortran statements that will write such a file are shown in Table B-2. These tables may be used as guidelines for users who may wish to write or read an interface file with a program of their own. Further information on required pollutant identifiers, etc. may be found in the Runoff Block input data descriptions, but these are not required for Extran.

The title and the values for the starting date and time from the first computational block are not altered by any subsequent block encountered by the Executive Block. All other data may (depending on the block) may be altered by subsequent blocks. The individual computational blocks also have limitations on what data they will accept from an upstream block and pass to a downstream block. These limitations are summarized in Table B-3. Detailed discussions for each block are presented in the user's manuals.

Block limitations can be adjusted upwards or downwards by the user by modifying the PARAMETER statement found in the include file TAPES.INC. Follow the instructions of Table B-4.

Table B-1. Detailed Organization of SWMM Interface File

	Variable Name	Description[a]
FROM FIRST COMPUTATIONAL BLOCK	TITLE(1)	First line of title from first block, maximum of 80 characters.
	TITLE(2)	Second line of title from first block, maximum of 80 characters.
	IDATEZ	Starting date; 5-digit number, 2-digit year plus Julian date within year, e.g. February 20, 1987 is 87051.
	TZERO	Starting time of day in seconds, e.g., 5:30 p.m. is 63000. This date and time should also be the first time step values found on the interface file.
FROM CURRENT INTERFACING BLOCK	TITLE(3)	First line of title from immediately prior block, maximum of 80 characters.
	TITLE(4)	Second line of title from immediately prior block, maximum of 80 characters.
	SOURCE	Name of immediately prior block, maximum of 20 characters.
	LOCATS	Number of locations (inlets, manholes,outfalls,etc.) on interface file.
	NPOLL	Number of pollutants on interface file.
	TRIBA	Tributary or service area, acres.
	(NLOC(K), K=1, LOCATS) or (KLOC(K), K=1, LOCATS)	Location numbers for which flow/pollutant data are found on interface file. These may be either numbers (JCE=0)[b], or alphanumeric names (JCE=1). NLOC array if numbers. KLOC if alphanumeric names area used.
	(PNAME(J),J=1,NPOLL)	NPOLL pollutant names, maximum of 8 characters for each.
	(PUNIT(J),J=1,NPOLL)	NPOLL pollutant units, e.g. mg/l, MPN/l, JTU, umho, etc., max. of 8 characters for each.
	(NDIM(J),J=1,NPOLL)	Parameter to indicate type of pollutant concentration units. =0, mg/l =1, "other quantity" per liter, e.g. for bacteria, units could be MPN/l.

Table B-1. Concluded.

	Variable Name	Description[a]
		=2, other concentration units, e.g., JTU, umho, °C, pH.
	QCONV	Conversion factor to obtain units of flow of cfs, (multiply values on interface file by QCONV to get cfs). All blocks assume inflow is in cfs and convert to m^3/sec if METRIC = 1.
FLOW AND POLLUTANT DATA FOR EACH LOCATION. REPEAT FOR EACH TIME STEP.	JULDAY	Starting date; 5-digit number, 2-digit year plus Julian date within year, e.g. February 20, 1987 is 87051.
	TIMDAY	Time of day in seconds at the beginning of the time step, e.g.,12:45 p.m. is 45900.
	DELTA	Step size in seconds for the <u>next</u> time step[c].
	(Q(K),(POLL(J,K),J=1,NPOLL),K=1,LOCATS)	Flow and pollutant loads for LOCATS locations at this time step. Q(K) must be the instantaneous flow at this time (i.e.,at end of time step) in units of volume/time. POLL(J,K) is the flow rate times the concentration (instantaneous value at end of time step) for Jth pollutant at Kth location, e.g.,units of cfs·mg/l or m^3/sec·JTU[d].

[a]Unformatted file. Use an integer or real value as indicated by the variable names. Integer variables begin with letters I through N.

[b]Parameter JCE indicates whether $ANUM has been invoked to use alphanumeric conduit and junction names and is included in COMMON/TAPES in each block.

[c]I.e., the next date/time encountered should be the current date/time plus DELTA.

[d]If units other than cfs are used for flow, this will be accounted for by multiplication by parameter QCONV.

Table B-2. FORTRAN Statements Required to Generate an Interface File

FILE HEADER	WRITE(NOUT)	TITLE(1),TITLE(2)
	WRITE(NOUT)	IDATEZ,TZERO
	WRITE(NOUT)	TITLE(3),TITLE(4)
	WRITE(NOUT)	SOURCE,LOCATS,NPOLL,TRIBA
	IF(JCE.EQ.0)WRITE(NOUT)	(NLOC(K),K=1,LOCATS)
	IF(JCE.EQ.1)WRITE(NOUT)	(KLOC(K),K=1,LOCATS)
	IF(NPOLL.GT.0)WRITE(NOUT)	((PNAME(L,J),L=1,2),J=1,NPOLL)
	IF(NPOLL.GT.0)WRITE(NOUT)	((PUNIT(L,J),L=1,2),J=1,NPOLL)
	IF(NPOLL.GT.0)WRITE(NOUT)	(NDIM(J),J=1,NPOLL)
	WRITE(NOUT)	QCONV
	NOUT is the interface file or logical unit number for output, e.g., NOUT = JOUT(1) for first computational block.	
FLOW AND POLLUTANT DATA FOR EACH LOCATION: REPEAT FOR EACH TIME STEP	See code below	

```
IF (NPOLL.GT.0) THEN
                WRITE(NOUT) JULDAY,TIMDAY,DELTA,(Q(K),
                (POLL(J,K),J=1,NPOLL),K=1,LOCATS)
                ELSE
                WRITE(NOUT) JULDAY,TIMDAY,DELTA,
                            (Q(K),K=1,LOCATS)
                ENDIF
```

Note 1: The interface file should be unformatted. The time step read/write statements must include IF statements to test for the appearance of pollutants.

Note 2: The interface file may be read by the Combine Block to produce an ASCII/text file which can be read by various microcomputer software.

Table B-3. Interface Limitations for Each Computational Block[a]

Block	Input	Output[b]
Runoff	--	150 elements (inlets), 10 pollutants
Transport	175 elements (inlets), 4 pollutants	175 elements (non-conduits), 4 pollutants
Extended Transport	175 elements (inlets), no pollutants (ignored if on the file)	175 junctions
Storage/ Treatment	10 elements (inlets or non-conduits), 3 pollutants	10 elements[c], 3 pollutants

[a]These limitations are based on the "vanilla" SWMM sent to the user. As explained in Table B-4, these limitations can easily be changed by the user by modifying the PARAMETER statement accompanying the file 'TAPES.INC'.

[b]The number of pollutants found on the output file from any block is the lesser of the number in the input file or that specified in the data for each block.

[c]Although the Storage/Treatment Block will read and write data for as many as 10 elements, the data for only one element pass through the storage/treatment plant; the rest are unchanged from the input file.

Table B-4. SWMM Parameter Statement Modification
This is file TAPES.INC in SWMM Fortran source code.

```
C=====================================================================
C     NW   = NUMBER OF SUBCATCHMENTS IN THE RUNOFF BLOCK
C     NG   = NUMBER OF GUTTER/PIPES IN THE RUNOFF BLOCK
C     NET  = NUMBER OF ELEMENTS IN THE TRANSPORT BLOCK
C     NTH  = NUMBER OF INPUT HYDROGRAPHS IN TRANSPORT
C     NEE  = NUMBER OF CONDUITS AND NUMBER OF JUNCTIONS IN EXTRAN BLOCK
C     NGW  = NUMBER OF SUBCATCHMENTS WITH GROUNDWATER
C                     COMPARTMENTS IN RUNOFF
C     NIE  = NUMBER OF INTERFACE LOCATIONS FOR ALL BLOCKS
C     NEP  = NUMBER OF EXTRAN PUMPS
C     NEO  = NUMBER OF EXTRAN ORIFICES
C     NTG  = NUMBER OF TIDE GATES OR FREE OUTFALLS IN EXTRAN
C     NEW  = NUMBER OF EXTRAN WEIRS
C     NPO  = NUMBER OF EXTRAN PRINTOUT LOCATIONS
C     NTE  = NUMBER OF DIFFERENT BOUNDARY CONDITIONS IN EXTRAN
C     NNC  = NUMBER OF NATURAL CHANNELS IN EXTRAN AND TRANSPORT
C     NVSE = NUMBER OF STORAGE JUNCTIONS IN EXTRAN
C     NVST = NUMBER OF DATA POINTS FOR VARIABLE STORAGE ELEMENTS
C            IN THE EXTRAN BLOCK
C     NEH  = NUMBER OF INPUT HYDROGRAPHS IN THE EXTRAN BLOCK
C
C     INSTRUCTIONS - INCREASE DIMENSIONS OF SUBCATCHMENTS ETC.
C                    BY MODIFYING THE PARAMETER STATEMENT
C                    AND RECOMPILING YOUR PROGRAM
C=====================================================================
      PARAMETER(NW=150,NG=150,NET=175,NEE=175,NGW=100,NTH=80,
     +          NIE=175,NTE=20,NEW=60,NEO=60,NEP=20,NTG=25,
     +          NPO=30,NVSE=20,NVST=30,NNC=50,NEH=65)
      CHARACTER*2 CC
      COMMON /TAPES/ INCNT,IOUTCT,JIN(25),JOUT(25),JCE,
     *               NSCRAT(7),N5,N6,CC,JKP(57),CMET(11,2)
C=====================================================================
```

APPENDIX C

ADDITIONAL EXTRAN SOLUTIONS

GENERAL

This release of Extran includes two additional solutions to the gradually varied, one-dimensional unsteady flow equations for open channels. These solutions are called using the ISOL parameter on data group B0. This appendix describes the the formulation of the ISOL = 1 and ISOL = 2 solutions and their weaknesses and strengths compared to the default solution described in Chapter 5 (ISOL = 0). For explanatory purposes the ISOL = 0 solution will henceforth be called the explicit method, the ISOL = 1 solution will be called the enhanced explicit method, and the ISOL = 2 solution will be called the iterative method.

The explicit method is solved by Subroutine XROUTE. Subroutine YROUTE solves the enhanced explicit method and Subroutine ZROUTE is the iterative method solution.

BASIC FLOW EQUATIONS

The basic differential equations for the sewer flow problem come from the gradually varied, one-dimensional unsteady flow equations for open channels, otherwise known as the St. Venant or shallow water equations (Lai, 1986). For use in EXTRAN, the momentum equation is combined with the continuity equation to yield an equation to be solved along each link at each time-step,

$$\partial Q/\partial t + gAS_f - 2V\partial A/\partial t + Q^2\partial Q/A/\partial x + gA\partial H/\partial x = 0 \qquad \text{(C-1)}$$

where
- Q = discharge through the conduit,
- V = velocity in the conduit,
- A = cross-sectional area of the flow,
- H = hydraulic head (invert elevation plus water depth), and
- S_f = friction slope.

The fourth term of equation C-1 is different from the term used in equation 5-1 of chapter 5. The interested reader is referred to Appendix A for the equation derivation and comparison to equation 5-1. The terms have their usual units. For example, when U.S. customary units are used, flow is in units of cfs. When metric units are used, flow is in m^3/sec. These units are carried through internal calculations as well as for input and output.

The friction slope is defined by Manning's equation, i.e.,

$$S_f = \frac{k}{gAR^{4/3}} Q|V| \qquad \text{(C-2)}$$

where $k = g(n/1.49)^2$ for U.S. customary units and gn^2 for metric units,
n = Mannings roughness coefficient,
g = gravitational acceleration (numerically different depending on units chosen), and
R = hydraulic radius.

Use of the absolute value sign on the velocity term makes S_f a directional quantity and ensures that the frictional force always opposes the flow.

SOLUTION OF FLOW EQUATION BY THE ENHANCED EXPLICIT METHOD

Substituting equation C-2 in equation C-1 and expressing in finite difference form gives

$$Q_{t+\Delta t} = Q_t - \frac{k\Delta t}{R^{4/3}} |V_t| Q_{t+\Delta t} + 2V(\Delta A/\Delta t)_t \Delta t - Q_{t+\Delta t} Q_t [(1/A_2 - 1/A_1)/L] \Delta t$$

$$- gA[(H_2 - H_1)/L] \Delta t \qquad \text{(C-3)}$$

where t = time-step, and
L = conduit length.

Solving equation C-3 for $Q_{t+\Delta t}$ gives the final finite difference form of the enhanced explicit dynamic flow equation,

$$Q_{t+\Delta t} = [\ Q_t + 2\bar{V}(\Delta A/\Delta t)_t \Delta t - g\bar{A}[(H_2 - H_1)/L] \Delta t\ ] \ /$$

$$[\ 1 + \frac{k\Delta t}{\bar{R}^{4/3}} |\bar{V}| + [Q_t (1/A_2 - 1/A_1)_t / L] \Delta t\ ] \qquad \text{(C-4)}$$

As in equation 5-4, the values $\bar{V}$, $\bar{R}$, and $\bar{A}$ in equation C-4 are weighted averages of the conduit upstream, middle and downstream values at time t, and $(\Delta A/\Delta t)_t$ is the average area time derivative from the previous half time step.

There are two significant differences between the explicit and enhanced explicit solutions as shown by equations 5-4 and C-4, respectively:

(1) The $\partial(Q^2/A)/\partial x$ term in the momentum equation has a different derivation, and

(2) An additional $Q_{t+\Delta t}$ is factored out of equation C-1.

The main consequence of these differences occurs during the rising and falling portions of the hydrograph. During steady flows the momentum equation reduces to a balance of the hydraulic head slope and friction slope. However, as the flow is increasing or decreasing the enhanced explicit solution allows substantially longer time steps than the explicit solution. Testing on 80

Extran examples indicates that a increase of 2 or 3 in the time step size is feasible. This does not apply to systems with many surcharged junctions. During surchage both solutions use the algorithm described in Chapter 5 and the same time step limitations apply.

The basic unknowns in equation C-4 are $Q_{t+\Delta t}$, H_2 and H_1. The variables $\bar{V}$, $\bar{R}$, and $\bar{A}$ can all be related to Q and H. The equation relating relating Q and H is the continuity equation at a node,

$$\partial H/\partial t_t = \Sigma Q_t/A_{s_t} \tag{C-5}$$

for the explicit and enhanced explicit solution.

where A_{s_t} = surface area of node at time t.

Equations C-4 and C-5 can be solved sequentially to determine the discharge in each link and the head at each node over a time-step Δt. The numerical integration of these two equations is accomplished by the modified Euler method, as described in chapter 5. The explicit and enhanced explicit solutions use the same numerical solution technique, but use different representations of the momentum equation: equation 5-4 for the explicit method versus equation C-4 for the enhanced explicit.

SOLUTION OF FLOW EQUATION BY THE ITERATIVE METHOD

Equation C-3 is the basis for the iterative method solution. Solving equation C-3 for $Q_{t+\Delta t}$ and using the appropriate weighting coefficients gives the following finite difference form for the iterative solution dynamic flow equation,

$$Q_{t+\Delta t} = \{ Q_t + (1-w)[-g\bar{A}[(H_2-H_1)/L]\Delta t + \frac{k\Delta t}{\bar{R}^{4/3}}|V| + [(Q/A_2-Q/A_1)/L]\Delta t]_t + w(- g\bar{A}[(H_2-H_1)/L]\Delta t\ ]_{t+\Delta t}) + V(\Delta A/\Delta t) \} / w[\frac{k\Delta t}{\bar{R}^{4/3}}|V| + [(Q/A_2-Q/A_1)/L]\Delta t\ ]_{t+\Delta t} \tag{C-6}$$

The values $\bar{V}$, $\bar{R}$, and $\bar{A}$ in equation C-6 are weighted averages of the conduit upstream, middle and downstream values at time t and/or t $+\Delta t$. The values at time $t+\Delta t$ are the values for the current iteration. At the first iteration they are equal to the previous time step's values. A_1, A_2, H_1, and H_2 are conduit cross sectional area and conduit depths at the upstream(1) and downstream(2) nodes. $V(\Delta A/\Delta t)$ is the conduit average area time derivative and conduit average velocity based on the average or difference of the previous time step and the current iteration. The time weighting factor (w) is 0.55.

The basic unknowns in equation C-6 are $Q_{t+\Delta t}$, H_2 and H_1. The variables

$\bar{V}$, $\bar{R}$, $\bar{A}$, A_1, and A_2 can all be related to Q and H. The equation relating relating Q and H is the continuity equation at a node,

$$\partial H/\partial t_t = \Sigma[Q_t + Q_{t+\Delta t}]/[A_{s_t} + A_{s_{t+\Delta t}}] \tag{C-7}$$

for the iterative solution (note that the 0.5 in the numerator and denominator of equation C-7 cancel).

where A_{s_t} = surface area of node at time t, and

$A_{s_{t+\Delta t}}$ = surface area of node at time $t+\Delta t$.

Equations C-6 and C-7 can be solved iteratively to determine the discharge in each link and the head at each node at the end of a time-step t. The numerical integration of these two equations is accomplished by using an underrelaxation iterative matrix solution. It should be noted that equation C-1 has been linearized by using the product of $Q_{t+\Delta t}$ and $(Q/A)_t$ and using equation C-2 for the S_f term.

The iterative method uses an underrelaxation factor of 0.75 for the first iteration and 0.50 for subsequent iterations. (These factors were found by trial and error.) Thus, the new estimate of $Q_{t+\Delta t}$ at each iteration is:

$$Q_{t+\Delta t} = (1-U_f)\,Q_j + U_f\,Q_{j+1} \tag{C-8}$$

where U_f = underrelaxation factor (0.75 or 0.50),

Q_j = conduit flow at iteration j, and

Q_{j+1} = conduit flow at iteration j+1.

Similarly, the estimated junction depth at each iteration is:

$$H_{t+\Delta t} = (1-U_f)\,H_j + U_f\,H_{j+1} \tag{C-9}$$

where U_f = underrelaxation factor (0.75 or 0.50),

H_j = junction depth at iteration j, and

H_{j+1} = junction depth at iteration j+1.

The new time step solution is found when <u>all</u> the estimated conduit flows and junction depths satisfy the convergence criterion (parameter SURTOL on data group B2). The convergence criteria for conduit flows and junction depths are:

$$|Q_{j+1} - Q_j|/Q_{full} \le \text{SURTOL} \tag{C-10}$$

$$|H_{j+1} - H_j|/H_{crown} \le \text{SURTOL} \tag{C-11}$$

where Q_{full} = the conduit design flow, and

H_{full} = distance between the junction invert and junction crown.

The design flow for conduit with a zero slope is based on an assumed difference of 0.01 (ft or m) between upstream and downstream nodes. Reasonable values for SURTOL are 0.0025 and 0.0010 for most simulations. If a conduit with an extremely large cross sectional area is used (> 10000 ft^2 or 1000 m^2) is connected to a small conduit smaller values of SURTOL will be required.

ITMAX iterations are allowed before convergence fails. When convergence fails the time step is halfed and Subroutine ZROUTE is called again with the old time step flows and heads. The recommended value for ITMAX is 10. Smaller values may cause the time step to change frequently and larger values may cause the program to waste time deciding that the time step failed to converge.

The iterative method uses a variable time step. The time step the user enters on data group B1 (DELT) is the <u>maximum allowable time step</u> the program should use during the simulation. NTCYC is the number of long time steps to use during the simulation. The program will select the current time step based on the smallest conduit Courant number at the beginning of each long time step (DELT). The model determines the number of equal length small time steps required to equal DELT.

The conduit Courant number is:

$$C\# = L \;/\; [V+(gD)^{1/2}] \tag{C-12}$$

for enclosed conduits, and

$$C\# = L \;/\; [V+(gA/T)^{1/2}] \tag{C-13}$$

for open channels.

where C# = Courant number for the conduit, seconds,
L = pipe length, ft [m],
g = gravitational acceleration, 32.2 ft/sec^2 [9.8 m/sec^2],
D = current pipe depth, ft [m],
V = average conduit velocity, ft/sec [m/sec],
A = conduit cross-sectional area, ft^2 [m^2], and
T = width of the conduit, ft [m].

If the smallest C# equals or exceeds DELT the program will use only one small time step. If the smallest C# is less than DELT the program will then compute the number of small time steps required to equal DELT. The procedure used is:

1. At the start of the simulation a time step of DELT/4.0 is used, or 4 small time steps.

2. Subsequently, the small time step is based on the current smallest conduit C# and the last time factor T_f. The starting T_f is 3.0. This means that a small time step of 3 times the minimum C# is selected.

3. When convergence fails T_f is reduced by 1.0. The minimum T_f is 0.5.

4. When the model converges within 2 iterations T_f is increased by 1.0. The maximum T_f is 3.0.

5. In summary, the model works between 0.5*min[C#] and 3.0*min[C#]. The number of small time steps is always a whole number.

The sequence of flow computations in the links and head calculations at the nodes can be summarized as:

1. Determine the next time step size. Find the new step based on the preceeding time step's conduit velocity and depth using equations C-12 or C-13. Find the number of time steps within this time step based on the calculated T_f*min[C#] and the DELT input on data group B1.

2. Compute the first iteration discharge at $t + \Delta t$ in all links based on preceding time step values of head at connecting junctions.

3. Compute first iteration flow transfers by weirs, orifices, and pumps at time $t + \Delta t$ based on preceding time step values of head at transfer junctions.

4. Compute first iteration head at all nodes at time $t + \Delta t$ based on the average of intial time step flow and first iteration flow in all connecting conduits, plus flow transfers at the current time step.

5. Repeat steps 2 thru 4 with new estimates for conduit flows and junction heads until <u>all</u> conduits and junctions converge. If iterations exceed ITMAX decrease the time step by 1/2. If convergence happens within 2 iterations increase the Courant number by 1.0.

TIME STEP CONSIDERATIONS

When using the iterative method a reasonable maximum time step is 60 seconds for most systems during a storm event. A longer maximum time step of 300 seconds can be used for systems with periods of extended steady flow (see EXTRAN examples 1 through 8).

An additional aid in the selection of an appropriate time step is the diagnostic conduit summary now printed at the end of an EXTRAN simulation. This summary can be used by all three solutions. This table lists the average C# time step for each conduit and the length of time in minutes DELT exceeded the C# for each conduit. Sensitive conduits will have the smallest time step and may be modified by using an equivalent pipe to enhance stability and increase the time step. Alternatively, the time step may be lowered to achieve the same ends.

SPECIAL PIPE FLOW CONSIDERATIONS

The solution techniques discussed in the preceding paragraphs cannot be applied without modification to every conduit for the following reasons:

1. The invert elevations of pipes which join at a node may be different since sewers are frequently built with invert discontinuities.

2. Critical depth may occur in the conduit and thereby restrict the discharge.

3. Normal depth may control.

4. The pipe may be dry.

In all of these cases, or combination of cases, the flow must be computed by special techniques. Figure 5-4 shows each of the possibilities and describes the way in which surface area is assigned to the nodes. The options are:

1. Normal case. Flow computed from motion equation. Half of surface area assigned to each node.

2. Critical depth downstream. Use lesser of critical or normal depth downstream. Assign all surface area to upstream node.

3. Critical depth upstream. Use critical depth. Assign all surface area to downstream node.

4. Flow computed exceeds flow at critical depth. Set flow to normal value. Assign surface area in usual manner as in (1).

5. Dry pipe. Set flow to zero. If any surface area exists, assign to downstream node.

Once these depth and surface area corrections are applied, the computations of head and discharge can proceed in the normal way for the current time-step. Note that any of these special situations may begin and end at various times and places during simulation. EXTRAN detects these automatically in Subroutine HEAD.

EXTRAN now prints a summary of the special hydraulic cases illustrated in Figure 5-4. Subroutine OUTPUT prints the time in minutes that a conduit was: (1) dry (depth less than 0.0001 (ft or m), (2) normal, (3) critical upstream, and (4) critical downstream. It should be noted that these designations refer strictly to the assignment of upstream and downstream nodal surface area and conduit depths.

Conduit normal or supercritical flow is controlled by parameter KSUPER on data group B0. If KSUPER equals 1 the Froude number of the conduit determines the switch to normal flow. When the Froude number exceeds 1.0 the conduit flow is calculated from the Manning's equation using the upstream cross-sectional area and hydraulic radius.

If KSUPER equals 0 (the EXTRAN default) the normal flow approximation is used when all of the following three conditions occur:

1. The flow is positive. Extran automatically designates the highest invert elevation as the upstream node and the lowest as the downstream node. This adjustment (if made) is now printed out by the model. Postive flow is from the upstream to the downstream node. Any initial flow entered by the user on data group C1 is multiplied by -1 if the upstream and downstream nodes are changed by the model.

2. The water surface slope in the conduit is less than the conduit slope.

3. The flow calculated from Manning's equation using the upstream cross-sectional area and hydraulic radius is less than the flow calculated by equation 5-4.

When all three conditions are met the flow the flow is "normal". Normal flow is labeled with an asterisk in the intermediate printout. The conduit summary lists the number of minutes the normal flow assumption is used for each conduit. The equation used for normal flow is:

$$Q_{norm} = (gS_o/k)^{1/2} A R^{2/3} \qquad \text{(C-14)}$$

where k = $g(n/1.49)^2$ for U.S. customary units and gn^2 for metric units,
n = Mannings roughness coefficient,
g = gravitational acceleration (numerically different depending on units chosen),
A = upstream cross-sectional area, and
R = upstream hydraulic radius.

HEAD COMPUTATION DURING SURCHARGE AND FLOODING

Theory for Conduits

During surcharge, the head calculation in equations C-5 and C-7 are modified because the surface area of the surcharged node (manhole area, AMEN) is negligible. The enhanced explicit method uses the same surcharge algorithm as the explicit method described in Chapter 5, except for the substitution of equation C-16 for equation 5-16 in the calculation of the head correction derivatives.

$$\partial Q(t)/\partial H_j = [g/(1+AKON)] \; \Delta t \; [A(t)/L] \qquad \text{(C-16)}$$

where Δt = time-step,
AKON = the denominator of equation C-6,
$A(t)$ = flow cross sectional area in the conduit,
L = conduit length, and
g = gravitational acceleration.

The iterative method avoids application of a different set of governing equations during surcharge by retaining a small pseudo-surface area for each conduit. A transition of conduit surface area is provided between the "almost full" conduit and a small "Priessmann slot" to maintain free-surface flow. The transition zone is from the 96 % conduit depth to a point 1.25 times conduit diameter above the top. The conduit width decreases quadratically from the conduit width at 0.96 * conduit depth to a width equal to 0.01 * conduit diameter at a depth of 1.25 diameters. The conduit cross sectional area increases but the hydraulic radius remains equal to R_{full}.

When the junction head is greater than 1.25 times the junction crown elevation the width stays constant at 1 % of the conduit diameter (or vertical dimension) allowing the same free-surface flow equations (C-6 and C-7) to be used. This "Priessmann slot" technique generates additional volume in the system and leads to somewhat lower (e.g., 10 %) surcharge heads than does the Q = 0 method used for ISOL = 0 and 1.

Orifice, Weir and Pump Diversions

Since orificies are treated as equivalent pipes, equation C-16 is used to compute $\partial Q/\partial H$. Weirs under surcharge are also converted to equivalent pipes and the surcharged weir is assumed to behave as an orifice:

$$Q_{wier} = C\ A\ (2gh)^{1/2} \qquad \text{(C-17)}$$

where C = calculated equivalent-roughness pipe coefficient,
A = cross-sectional area of equivalent pipe, and
h = driving head on the weir.

Equation C-17 is then differentiated with respect to head to give

$$\partial Q/\partial H = C\ A\ g\ /\ (2gh)^{1/2} \qquad \text{(C-18)}$$

$\partial Q/\partial H$ is zero for pump junctions. The use of the under-relaxation factor U_f may alleviate any instabilities caused by this assumption. Outfall junctions are treated the same as any other junction.