K. A. Brewer
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Multiplan Spreadsheets for Highway and Hydraulic Engineering Computations in County Engineering Offices

July 1987

Iowa DOT Project HR-284

ERI Project 1844

ISU-ERI-Ames-88402

Final Report

Sponsored by the Iowa Department of Transportation, Highway Division, and the Iowa Highway Research Board.

Department of Civil and Construction Engineering,
Civil Engineering Extension Program, and

Engineering Research Institute

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LIST OF FIGURES

Figure:	Title:	Page:
1	Input template for VERTCURV	30
2	Schematic of a vertical curve	31
3	Input form for example problem	32
4	Example problem template	33
5	Input template for HORIZCRV	41
6	Schematic of a horizontal circular curve	42
7	Input form for example problem	43
8	Example problem template	44
9	Input template for MAXTANG	52
10	Schematic of a horizontal circular curve	53
11	Input form for example problem	54
12	Example problem template	55
13	Input template for EARTHWKS	65
14	Input template for SUPERE	78
15	Schematic of a superelevated horizontal curve	79
16	Input form for example problem	80
17	Example problem template	81
18	Form of SIGNINV	96
19	Form of MAINTREC	102
20	Input template for Manning's equation - open channel geometric section	113
21	Description of input variables for channel cross-section	114
22	Cross section for the three example problems	114
23	Input form for DITCHFL	115

24	Example problem 1 template	117
25	Example problem 2 template	118
26	Example problem 3 template	119
27	Location of input data for RUNOFF	131
28	Input template with error message for RUNOFF	132
29	Hydrologic regions of Iowa	133
30	Input form for RUNOFF	134
31	RUNOFF completed	135
32	Leftover input in RUNOFF	136
33	RUNOFF example - Bulletin 11, Region II	137
34	Input template for WSGEOM (part 1)	148
35	Description of input variables for channel cross-section	149
36	Input template for WSGEOM	150
37	Plane view for example problem	151
38	Input form for WSGEOM	152
39	Input form continuation for WSGEOM	153
40	Example problem template for first cross-section	154
41	Output for example problem (for first cross-section)	155
42	Output for example problem (for second cross-section)	155
43	Location of descriptive input data in CULVERT spreadsheet	170
44	Location of culvert input data in the CULVERT spreadsheet	171
45	Definition of the variables in site data for CULVERT	172
46	Display of informative record portion of CULVERT spreadsheet	173

47	Example problem site description	174
48	Results from the RUNOFF spreadsheet used in the CULVERT spreadsheet example	175
49	Input data form for use with CULVERT spreadsheet	176
50	Total output from the example problem for CULVERT spreadsheet	177
51	Data input for XSECT example problem	185
52	Example when inputting overbank data in XSECT	187
53	XSECT example cross-section	188
54	VAL program data input form	189
55	Output table from XSECT spreadsheet	190
56	VAL program output	191
57	Input of administrative data for WSNAT	207
58	Example cross-section	208
59	WSNAT spreadsheet format	209
60	WSNAT iteration illustration	211
61	Example output summary of WSNAT	212

LIST OF TABLES

Table:	Title:	Page:
1	Input for example problem	112
2	Values for LF	123
3	Limits on variables for RUNOFF	127
4	Various values for the energy coefficient (according to finding of Chow, 1959)	142
5	Culvert types available	169
6	Various values for the energy coefficient (after Chow, 1959)	199

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TABLE OF CONTENTS

	Page
LIST OF FIGURES	ii
LIST OF TABLES	v
ACKNOWLEDGEMENTS	vi

Research and Development of Spreadsheets

1. Introduction	1
1.1 Perceived Need	1
1.2 Identification of Initial Problem Set	2
1.3 Objectives of Project	3
2. Development of Spreadsheets	4
2.1 Selection of the Base Spreadsheet Program	4
2.2 Development Sources	4
2.3 Development Process	6
2.4 System Compatibility Difficulties	6
2.5 Computer to Computer Communication Solution	7
2.6 Spreadsheets Developed	8
2.7 Recommendations for Further Development and Refinements	12
2.8 Development Dissemination Workshops	13
2.9 Suggestions for Using Applications Manual	14

Applications Manual

1. Multiplan Orientation	17
1.1 Starting With MULTIPLAN Initially	17

Disk 18

1.3 Saving a Computation Result 20

1.4 Contacts for Problems in Using MULTIPLAN 21

2. Spreadsheet User Instructions 23

2.1 Highway Engineering Spreadsheets 24

2.1.1 VERTCURV (calculating elevations on a vertical curve) 25

2.1.1.1. Introduction 26

2.1.1.2. Using the Spreadsheet 26

2.1.1.3. Example Problem 28

2.1.2 HORIZCRV (calculating the elements for locating a horizontal curve from known PI, known DELTA and known degree of curvature) 36

2.1.2.1. Introduction 37

2.1.2.2. Using the Spreadsheet 38

2.1.2.3. Example Problem 39

2.1.3 MAXTANG (calculating the elements for locating a horizontal curve from a known PI, known DELTA and maximum allowable tangent) 49

2.1.3.1. Introduction 50

2.1.3.2. Example Problem 50

2.1.4 EARTHWKS (calculating mass diagram ordinates from cut and fill of cross sections) 60

2.1.4.1. Introduction 61

2.1.4.2. Using the Spreadsheet 62

2.1.4.3. Example Problem 63

2.1.5 SUPERE (calculating field staking instructions for a superelevated transition to a horizontal curve) 71

2.1.5.1. Introduction 72

2.1.5.2. Using the spreadsheet 73

2.1.5.3. Example porblem 75

2.1.6 SIGNINV (illustration of using a spreadsheet for an sign inventory) and MAINTREC (illustration of using a spreadsheet for a sign maintenance record associated with an inventory) 88

2.1.6.1. Introduction to SIGNINV 89

2.1.6.2. Introduction to MAINTREC 90

2.1.6.3. General introduction 91

2.1.6.4. Using the spreadsheets 92

2.1.6.5. SIGNINV 93

2.1.6.6. MAINTREC 94

2.1.6.7. Example problem 95

2.2 Hydraulic Engineering Spreadsheets 106

2.2.1 DITCHFL (calculation of flow in a regular shape section ditch based on Manning's equation) 107

2.2.1.1. Introduction 108

2.2.1.2. Using the spreadsheet 108

2.2.1.3. Example probelm 110

2.2.2 RUNOFF (estimation of the water running off an Iowa watershed) 120
2.2.2.1. Introduction 121
2.2.2.2. Using the spreadsheet 121
2.2.2.3. Iowa Runoff Chart 123
2.2.2.4. Bulletin 11 124
2.2.2.5. Rounding the output 126
2.2.2.6. Example problem 128
2.2.3 WSGEOM (calculation of water depth along a trapezoidal channel) 138
2.2.3.1. Introduction 139
2.2.3.2. Using the spreadsheet 140
2.2.3.3. Example problem 145
2.2.3.4. References 146
2.2.4 CULVERT (determination of culvert size and type for roadway design) 156
2.2.4.1. Introduction 157
2.2.4.2. Using the spreadsheet 158
2.2.4.3. Example problem 166
2.2.5 XSECT (calculation of stage discharge curve across natural reach of stream) 179
2.2.5.1. Introduction 180
2.2.5.2. Using the spreadsheet 180
2.2.5.3. Example problem 184
2.2.6 WSNAT (calculation of water depth in natural cross sections) 196

in natural cross sections) 196

2.2.6.1. Introduction 196

2.2.6.2. Using the spreadsheet 198

2.2.6.3. Reference 206

APPENDIX

User Reference Instructions for KERMIT 213

Research and Development of Spreadsheets

1. INTRODUCTION

1.1. Perceived Need

Beginning in 1983 the Civil Engineering Department, through its research and extension role, began providing assistance to the practicing engineering profession in making the transition from programmable calculator applications in engineering to the use of microcomputer applications. The early work with the engineering profession concentrated on hardware systems and commercially available software. Eventually the evaluation process identified a need to develop some specific software applications that civil engineering offices could make direct application with limited hands-on training. Educational research had identified the microcomputer spreadsheet as the coming general purpose programming environment for small scale computational work and routine accounting system work in a microcomputer environment. Computer industry reports also indicated that the general purpose programmable calculator was merging into the briefcase-sized microcomputer which typically has, among others, a spreadsheet program installed on an internal chip.

County engineering offices have made extensive use of programmable calculators in their engineering operations and have had some difficulty incorporating microcomputers into their operations. Combining the utility of a spreadsheet program with the need for county engineering offices to build a bridge between programmable calculator applications and microcomputers in the technological transition seemed the natural way to respond to the need. Applications in highway and hydraulic computations were selected as the specific application areas after conducting a survey of all 99 counties for priority preferences, should such a project be undertaken.

1.2. Identification of Initial Problem Set

The results of the preproject survey of all Iowa counties for priorities in application areas was presented to an advisory committee at the Hilton Inn in Des Moines on October 16, 1985. It was recommended that short-term priority should be given to developing spreadsheets for

* computing flow in ditches
* calculating vertical curve elevations
* determining bridge waterway opening
* determining the size of culverts in design

and that long-term priority should be assigned to

* computing earthworks with an attempt to plot mass

diagram

* computing backwater analysis from drainage structures.

The advisory committee suggested a modular design on the spreadsheet programs with instructions on how to link these together.

1.3. Objective of the Project

The project had as a central objective development of Multiplan spreadsheets for a set of hydraulic and highway engineering computations of common interest to county engineers and to make these available to the various counties through a series of one-day workshops. This report is also one of the dissemination devices intended in the project objective.

2. DEVELOPMENT OF SPREADSHEETS

2.1. Selection of the Base Spreadsheet Program

Several surveys have been done regarding the variety of microcomputer hardware available in the 99 Iowa counties. Those surveys and the survey work of the project staff in the preproject stage convinced the project staff that the most appropriate spreadsheet program to use was Multiplan by Microsoft Corporation. This was based on the fact that it was available in versions that operated on the widest variety of hardware brands and models, and that, it was moderately priced for counties just beginning to acquire software. High cost software places a temptation to acquire pirate software or places an undue burden on the budget to make a trial installation. Multiplan seemed to offer the greatest potential to be low cost, widely implementable and flexible enough in structure to accomodate the range of computational needs. Subsequent research by the project staff identified that Multiplan had the most powerful equation capability which was critical in some of the hydraulic engineering spreadsheets.

2.2. Development Sources

Sources used as the basis of developing these spreadsheets were those that are either expected to be in most engineering offices desiring to use the particular spreadsheet or be readily available in a cooperating office. The highway engineering computation spreadsheets utilized equation relationships and table lookup materials from two primary sources:

* A Policy on Geometric Design of Highways and Streets, 1984, American Association of State Highway and Transportation Officials.
* Route Location and Design, Fifth Edition, Thomas F. Hickerson, McGraw-Hill, 1964.

The hydraulic engineering spreadsheets were based on a variety of sources. Among those were:

* Hydraulic Design of Highway Culverts, Report FHWA-IP-85-15, Federal Highway Administration, September 1985.
* VAL program on DOT T50, Iowa Department of Transportation.
* Open Channel Hydraulics, Ven Te Chow, McGraw-Hill, Inc., New York, 1959, pp 27-28, 249-289.
* "Federal Highway Administration Calculator Series for Hydraulics for the TI-55" equation was used for the critical depth for outlet control for culverts

Other sources include consultations with Mr. Phillip Thompson of the Federal Highway Administration in

Washington, DC, and staff personnel of the Iowa Department of Transportation Office of Preliminary Bridge Design.

NOTE: For culvert design and analysis, full flow was assumed in all cases with velocity defined by the ratio of flow to cross-sectional area of a culvert.

2.3. Development Process

The spreadsheets were developed by first laying out the computational process an engineer typically uses with a paper-pencil-calculator method. Then information was organized into an input screen which became a home base for the spreadsheet. The required computations were organized in a linear flow pattern since a spreadsheet calculates down and to the right unless special instructions are included. Then an output screen was organized into which the computational answers were placed. Testing with a known result example then followed. Modifications to the spreadsheet to enhance user understanding, add flexibility in use, and clarify results created several versions for some spreadsheets.

2.4. System Compatibility Difficulties

It was determined after testing thoroughly that

Multiplan versions were available for almost all microcomputers in use. One exception is the Hewlett-Packard 80 series. Furthermore, consultation with the Iowa State University Microcomputer Products Center and the Engineering Research Institute Electronics Laboratory resulted in a combined hardware-software method for transfering spreadsheets between MS-DOS based hardware and the various Apple microcomputers. One problem never fully resolved was the difficulty of interacting with the Burroughs B-20 series microcomputers.

2.5 Computer to Computer Communication Solution

With the assistance of the Iowa State University Computation Center Microcomputer Products Center it was determined that by connecting between two serial ports on any two computers for which a valid Multiplan program exists, it was possible to transmit spreadsheets between the two computers. A software communication program must exist in common for both computers. KERMIT is a public domain program to public agencies so that ISU can furnish a copy to a public agency (it can be purchased for $40 by for profit organizations). KERMIT is available for a wide range of microcomputers. Using KERMIT permits the transmission of a Multiplan spreadsheet in the SYMBOLIC format code between, for example, IBM computers and APPLE

computers. Similarly, a county engineering office with a modem can use such a communication program to transmit a Multiplan spreadsheet to another office having a modem on a microcomputer. Interchange of spreadsheets can be made in this fashion between computer systems which cannot directly read each others disks.

2.6. Spreadsheets Developed

The following spreadsheets were developed to assist in highway engineering computations:

A. HORIZCRV is a spreadsheet to permit entry of basic roadway design parameters for width of pavement and related facts, entry of PI station, the DELTA angle at the PI, and the design degree of curvature and the spreadsheet will compute the necessary information to locate the curve on the ground. It will also provide the typical design detail information to be included on a plan and profile sheet.

B. VERTCURV is a spreadsheet to permit entry of vertical profile design information such as the VPI station and elevation, the grade entering and leaving the VPI and the distance between desired elevations along a vertical curve to compute vertical curve elevations. AASHTO criteria is used to determine the required length of vertical curve to be input. The spreadsheet will then calculate the vertical profile elevations.

A separate portion of the spreadsheet allows calculations at odd stations for driveways or similar points requiring profile elevations.

C. SUPERE is a spreadsheet to utilize AASHTO criteria to define the centerline, left and right edge of pavement profile for a superelevation transition to a circular curve. The transition can be either tangent or spiral curve. If other than AASHTO criteria are desired, those can be specified.

D. MAXTANG is a spreadsheet to permit an engineer to define a maximum length of tangent that can be accepted in a curve relocation as curve design control. The spreadsheet will then compute the curve which can be placed in the restricted geometry.

E. EARTHWKS is a spreadsheet to permit entering cut and fill data from a series of cross-sections and then compute the mass diagram ordinates. It was hoped that this approach could lead to a quick method for entering limited cross section information resulting in a calculation of the cut and fill, definition of the mass diagram and a character plot of a mass diagram for preliminary adjustment of the design gradeline. This effort was not very successful.

F. SIGNINV and MAINTREC are two spreadsheets included in this project report which were completed under a student special topic effort rather than this contract

effort. The student effort was coordinated with this project so that the inclusion of these two can be provided as an illustration of how a spreadsheet program can be used to perform an inventory and record keeping function. Some offices may not be interested in devoting the time needed to learn a microcomputer data base, which is better suited to this type task, and may find these spreadsheets a useful aid in developing other similar applications.

The following hydraulic engineering spreadsheets were developed:

A. DITCHFL is a spreadsheet to compute flow in a regular section (trapezoid, V-bottom, rectangular, etc.) ditch from Manning's equation. The computation is often used for trapezoidal cross section roadside ditches and for lined channels were the depth of flow is not critical.

B. RUNOFF is a spreadsheet developed to calculate the runoff flow from an Iowa watershed drainage area to yield a design flow for hydraulic structures. The hydrologic bases of this spreadsheet are the Iowa runoff chart and the current version of Bulletin 11. Bulletin 11 is being updated as of this report date. When the new version of Bulletin 11, upon which this spreadsheet was partially based, is issued, the spreadsheet can be updated to reflect any changes and a new spreadsheet revision issued.

C. WSGEOM is a spreadsheet developed to calculate the water surface profile along a section of a trapezoidal channel. If the trapezoid is defined with a zero bottom width it becomes a V-bottom ditch. This is for use in estimating the backwater effects due to ponding by a culvert under the roadway at a downstream location.

D. CULVERT is a spreadsheet developed to perform the necessary steps to size a culvert at a site. The program is less data intensive than the FHWA program and focuses on parameters with which county engineers are expected to be more familiar. The significant advantage of this spreadsheet over the FHWA program is that in the FHWA program all initial data must be reentered each time a single design trial revision is made. In the spreadsheet, only the design parameters the engineer wishes to change are modified to develop a new or alternate solution.

E. XSECT is a spreadsheet developed to permit entry of elevations and distances across the natural reach of a stream to obtain the stage discharge curve. It was created and tested to conform to the Iowa Department of Transportation VAL program for the DOT T50. It provides a useful illustration of the degree to which computational activities can be made to reproduce a high level computer language program in a microcomputer spreadsheet.

F. WSNAT-1 and WSNAT-2 are two spreadsheets which compute the water surface profile for natural cross section channels much like WSGEOM does for a geometric cross section channel. Because of the complexity of the computation layout for the natural cross section channel, only three cross sections can be computed along the channel in WSNAT-1 (plus a data transfer cell area). If the channel under consideration requires more than three cross sections, then the Multiplan "external copy" function can transfer the transitional information to WSNAT-2 to continue computations for three more cross sections. If more cross sections are anticipated, the engineer can create multiple copies of WSNAT-2 under the names of WSNAT-3, WSNAT-4, etc., and continue using the "external copy" function to extend the computation as far as needed. The project staff did not expect most county engineering applications to require such analysis for an extensive distance due to the nature of most county projects.

2.7 Recommendations for Further Developments and Refinements

The project staff is of the professional opinion that coordination of interests in refinements and additional developments using Multiplan (or Lotus 1-2-3 for that

matter) can be conducted satisfactorily for the needs of public agencies in Iowa through the academic activities of the Center for Transportation and Public Works at Iowa State University. Many bright capable students in civil engineering are most interested in developing a program solution to a real world engineering need for laboratory credit. Modifications that might be pursued along this path include continued investigation of ways by which a mass diagram plot can be generated from a spreadsheet column of mass ordinates; methods of entering directly cross section elevations to compute cuts and fill areas for mass diagram computations; updating the hydrologic analysis curves and tables associated with revised reports; developing equipment analysis procedures on spreadsheets. Updates and revisions pursued in this manner should be relatively low cost (or no cost if done completely in an academic assignment context). for example, a student could prepare a horizontal curve calculation spreadsheet to make the necessary computations for spiraled circular curves.

2.8. Development Dissemination Workshops

Workshops were conducted on November 25, 1986, January 6, January 7, and February 13, 1987 to a total of 76 participants. At these workshops the participants were

briefed on the project. They were introduced to using Multiplan as a spreadsheet program. Participants were given detailed instruction in the use of one highway engineering spreadsheet and one hydraulic engineering spreadsheet. They were guided in a self-practice exercise in one additional spreadsheet in each of the highway and hydraulic engineering areas. Participants were briefly introduced to the other spreadsheets developed. All participants were given an opportunity to make suggestions and requests for changes or revisions in the spreadsheets. These suggestions and requests were used to modify the spreadsheets and documents between and after workshops.

Not all persons eligible to participate in the workshops chose to attend. It is suggested that the Civil Engineering Extension Program at Iowa State University conduct a workshop fall 1987 as a part of its regular program to enable additional interested persons to become familiar with the use of these spreadsheets.

2.9 Suggestions for Using Applications Manual

The project staff suggests that users of the Applications Manual (later portions of this report) make changes and modifications in it as needed for most efficient user operation. When a person first starts using these Multiplan spreadsheets it is anticipated that

an individual will follow the instructions closely. With a little familiarity with the spreadsheet, the developers anticipate that most of the user cues will be taken from the screen with only occasional reference to the Applications Manual. In that type of operation, it is suggested that copies be made of the sheets deemed critical to recalling steps needed to use the spreadsheet. This will produce a "quick reference guide" to each spreadsheet. Because it was not possible for the project staff to know what most people will need for quick reference, no such guide was developed in this contract. Again, if comments about the needs along this line are forwarded to the Center for Transportation and Public Works at the Civil & Construction Engineering Department of Iowa State University, some academic project may be able to develop a quick reference guide based on user input.

It has been assumed by the project staff that persons using this Applications Manual have worked with Multiplan enough to be aware of a few basic spreadsheet program operations. These include:

A. Entering a label as alphabetic information in a cell.

B. Entering a number (value) in a cell for computational purposes.

C. Transfering a spreadsheet file from a disk into computer memory.

D. Saving a spreadsheet from computer memory onto disk as

a file.

E. Creating a window of row and column titles for maintaining headings while scrolling through a spreadsheet.

F. Inserting rows or columns in a spreadsheet.

G. Deleting rows or columns from a spreadsheet.

H. Copying information from one row or column or cell to another.

I. Using the options function to turn the recalculation and iteration functions off and on.

J. Printing a spreadsheet out on a printer, setting the print ranges and print margins.

K. Changing the format code of the spreadsheet from/to symbolic format and normal format.

Applications Manual

1. MULTIPLAN ORIENTATION

1.1 Starting With MULTIPLAN Initially

This project assumes some limited familiarity with Multiplan to be prepared to use these spreadsheets. The project staff considers it neither ethical nor prudent use of any computer software package to use it in an engineering design, analysis or management context without first gaining some minimal awareness of the capabilities and limitations of the software package. Microsoft Corporation has provided that for persons who are not interested in experimenting with work not of a critical nature in a learning mode. Microsoft documentation for Multiplan provides a very thorough and well written tutorial which it is suggested that the novice user complete before beginning use of these spreadsheets.

It is advisable to have several blank disks available which have been formatted in MS-DOS before beginning operations with these spreadsheets. The project staff suggests that two or more spare formatted empty disks are available at all times. That way if a person ever attempts to SAVE a spreadsheet file from computer memory

onto disk and the "disk full" message appears, the spreadsheet can be immediately re-SAVEd on one of the spare formatted disks. Note that when a disk full error is encountered in the process of saving a spreadsheet, there is no assurance that all the spreadsheet was saved, thus, the spreadsheet partially saved creating the "disk full" error should be DELETEd from the "full" disk. ALWAYS SAVE A SPREADSHEET TO TWO SEPARATE DISKS TO CREATE A WORKING COPY AND A BACKUP COPY.

When and if these spreadsheets begin to be used with any degree of frequency, all design and analysis spreadsheets should be dated when they are saved. This will enable the user to maintain only the most current version of solutions when "cleaning" files.

1.2. Transfering the SYMBOLIC Format Dissemination Disk

The disk issued as a portion of the dissemination documents has the spreadsheets stored on it in Symbolic Format. There several reasons for this. First, any MS-DOS computer or other computer which can read the disk will be able to read the symbolic format spreadsheet. Second, since a user will almost always want to load and save spreadsheets in a Normal Format for speed of operations, there is limited potential to erroneously use the dissemination disk as a regular working disk, thereby, altering or destroying the spreadsheets

furnished.

Because using spreadsheets in the symbolic format requires a long disk access time, it is suggested that the very first operation required is to transfer the spreadsheets furnished onto another formatted disk in normal format. The steps to follow are:

1. Prepare several formatted data disks.
2. Boot Multiplan on your computer.
3. Assuming a two floppy disk drive computer configuration, insert the dissemination disk in Drive B (#2).
4. ALWAYS CLEAR THE SCREEN AND CLEAR COMPUTER MEMORY BY USING THE COMMAND Transfer ClearBEFORE LOADING A Symbolic File TO AVOID ADDING THE FILE TO UNWANTED MATERIAL. Enter the command Transfer, then Options, and "space" over to highlight Symbolic as the "mode". If desired, "tab" to the "setup" and identify the drive of the data disk. Press "Return" key.
5. Enter the command Transfer, then Load. When asked for a file name enter VERTCURV.MPS (preceding it by drive designation such as B: if the setup has not been specified for the data disk drive).
6. After several minutes of disk drive operation, the spreadsheet will come up on the screen of your computer. Now enter the command Transfer, then Options, and change the mode back to Normal.

7. Remove the dissemination disk from the data disk drive and insert a new formatted data disk in the drive.
8. Enter the command Transfer, then Save. When asked for a file name, the program will retain the name VERTCURV.MPS. Change the name to VERTCURV deleting the extension MPS which stands for Multiplan Symbolic. That way there will be no confusion about the contents of the disk.
9. Repeat the steps 4 through 8 above until all the spreadsheet files on the dissemination disk have been converted from Symbolic mode to Normal mode and saved on a new data disk.
10. Repeat steps 4 through 8 above for the hydraulic engineering spreadsheets disk.

1.3 Saving a Computation Result

It is expected that when spreadsheets begin to be used commonly for engineering computations the program's power to recalculate alternative solutions immediately upon entering a changed design parameter will cause a person to test a wide range of alternatives. This suggests that a person may want to keep a large number of intermediate solutions before selecting the one to be incorporated in the final design. That suggests that a user should keep several formatted blank disks available upon which the

spreadsheet can be quickly saved before a parameter is changed to generate another solution. When a final solution is reached, a decision can be made about whether to obtain a printed record of any or all of the intermediate solutions for the project file and all but selected solutions can be erased from the data disk(s). Two things to bear in mind for efficient and effective use to spreadsheets. First, it is much faster to save a spreadsheet to disk in normal mode than it is to print a spreadsheet out on paper. Second, keeping unnecessary spreadsheets on disk file will quickly create a disk storage problem so that it is necessary to exercise some filing control.

1.4. Contacts for Problems in Using Multiplan

The Civil and Construction Engineering Department at Iowa State Uinversity maintains a commitment to service to the profession through the Extension and Research role. Persons in the Department who are knowledgable about Multiplan (and spreadsheets in general) include:

Charles S. Oulman (515) 294-6734

Edward J. Kannel (515) 294-6777

Kenneth A. Brewer (515) 294-6777

It is also appropriate to address an inquiry to the Manager, Center for Transportation and Public Works, Civil and Construction Engineering Department, Iowa State

University, Ames, Iowa 50011, to gain possible access to a knowledgable student advanced in the intracies of Multiplan. It would also be appropriate to inquire with either the Civil Engineering Extenstion Program Leader or the Technology Transfer Program Leader, Civil and Construction Engineering Department, Iowa State University, Ames, Iowa 50011.

2. SPREADSHEET USER INSTRUCTIONS

2.1 Highway Engineering Spreadsheets

2.1.1 VERTCURV

VERTCURV

2.1.1.1. Introduction

VERTCURV is a spreadsheet developed to layout a vertical curve. The spreadsheet will calculate the data required to layout a vertical curve onto plan and profile sheets.

The input data include: point of vertical intersection (V.P.I.), grade into and out of the V.P.I., elevation of the V.P.I., length of the vertical curve and station increment.

The output generated inlcudes:

curve data:

point of vertical curvature (V.P.C.), point of vertical tangency (V.P.T.), elevations of the V.P.C. and V.P.T., and location and elevation of the crest or sag;

curve layout data:

extended tangent elevation, curve profile elevation, curve gradient, and odd station curve elevations.

2.1.1.2. Using the spreadsheet

The best way to begin using a spreadsheet is to obtain all pertinent data, record the data in a form that is

easily transferred to the spreadsheet, and then input the data onto the spreadsheet. The data obtained from preliminary roadway layouts and design manuals can be transferred to an input form. Once this is done, the user can proceed to use the spreadsheet.

The first step is to load the file from the disk to Multiplan. These instructions assume the file has been stored on disk in Normal Format (transferred from Symbolic Format) under the name VERTCURV.MP. Once the spreadsheet has been loaded into your computer the initial screen will appear. Select the Options command and set Recalculation to OFF to enter the initial data. Input the informative data in rows 13-16 of the spreadsheet (see Figure 1). These data include the project number, project name, preparer, checker and dates the project was prepared and checked.

Once the informative data are input, the user then should input the point of vertical intersection (V.P.I.), elevation of the V.P.I., length of the vertical curve, and station increment into rows 23-28 in column 4 (see Figure 1). The point of vertical intersection, grades into and out of the V.P.I., and elevation of the V.P.I. can be obtained from the preliminary plans for the project (see Figure 2). The length of the vertical curve and station increment are determined using the AASHTO Green Book or the Iowa Department of Transportation Design Procedure Manual. The station increment is chosen

according to the policy used in the engineer's office. These are all the data that are required to be input on this spreadsheet. Before viewing the ouptut data generated by spreadsheet, remember to turn the Recalculation Mode back to the ON status by selecting the Options command again. (The spreadsheet will not produce any results unless the recalculation function is on.) After viewing the output data, the spreadsheet should be saved with a filename solely characteristic of the vertical curve and project for the purpose of reuse and editing. Do not save it under the same name that your blank master spreadsheet has in the disk directory or you will overwrite your master spreadsheet with one containing project data.

2.1.1.3. Example Problem

The following is an example application of the spreadsheet described above.

A farm-to-market paved county highway is to be designed and constructed in rural Iowa. From the preliminary plans, the point of vertical intersection is 107 + 78.50. The grades into and out of the V.P.I. are 6% and -4%, respectively. The elevation of the V.P.I. is 900 feet above sea level. The length of the vertical curve is set at 1000 feet by the engineer. The station increment is chosen as 100 feet. Several odd stations

were required to be found and are included in the output (see Figure 4).

The data are first entered on an input form. An example of the filled in input form is shown in Figure 3. Transferring information from the data entry form to the spreadsheet completed the process. Persons experienced with using the spreadsheet will probably bypass the data entry form and enter data directly into the spreadsheet.

The completed spreadsheet is shown in figure 4. The total output is contained on 3 pages, all of which are required when laying out the curve on the plan and profile sheets.

Figure 1. Input Template for VERTCURV

```
         1                 2                 3                 4                 5
 1 ***************************************************************************
 2                        VERTICAL CURVE COMPUTATIONS
 3 ***************************************************************************
 4
 5        ++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 6        +  Multiplan Microcomputer Spreadsheets for County    +
 7        +   Hydraulic and Highway Engineering Computations    +
 8        +          Copyright by Kent L. Ahrenholtz            +
 9        +                    Version 1.0                      +
10        +                        1986                         +
11        ++++++++++++++++++++++++++++++++++++++++++++++++++++++++
12
13 Project Number:
14 Project Name:
15 Prepared By:                                  Date:
16 Checked By:                                   Date:
17
18 ---------------------------------------------------------------------------
19
20 CURVE INPUT DATA:
21 ~~~~~~~~~~~~~~~~~
22                 Point of vertical
23                         intersection, V.P.I. =    0.0000 stations
24                 Grade into V.P.I., G1        =      0.00 percent
25                 Grade out of V.P.I., G2      =      0.00 percent
26                 Elevation of the V.P.I.      =      0.00 feet
27                 Length of the vertical curve =      0.00 feet
28                 Station increment            =       100 feet
29
30 ---------------------------------------------------------------------------
31
32 CURVE OUTPUT DATA:
33 ~~~~~~~~~~~~~~~~~~
34                 Point of vertical
35                           curvature, V.P.C. =    0.0000 stations
36                 Elevation of the, V.P.C.     =      0.00 feet
37
38                 Point of vertical
39                             tangency, V.P.T. =    0.0000 stations
40
41                 Location of the crest        = #DIV/0!  stations
42                 Elevation of the crest       = #VALUE!  feet
43
44                 Last even station
45                           before the V.P.C. =    0.0000 stations
46                 First even incremental
47                    station beyond the V.P.C. =    1.0000 stations
48
49 ---------------------------------------------------------------------------
```

Figure 2. Schematic of a Vertical Curve

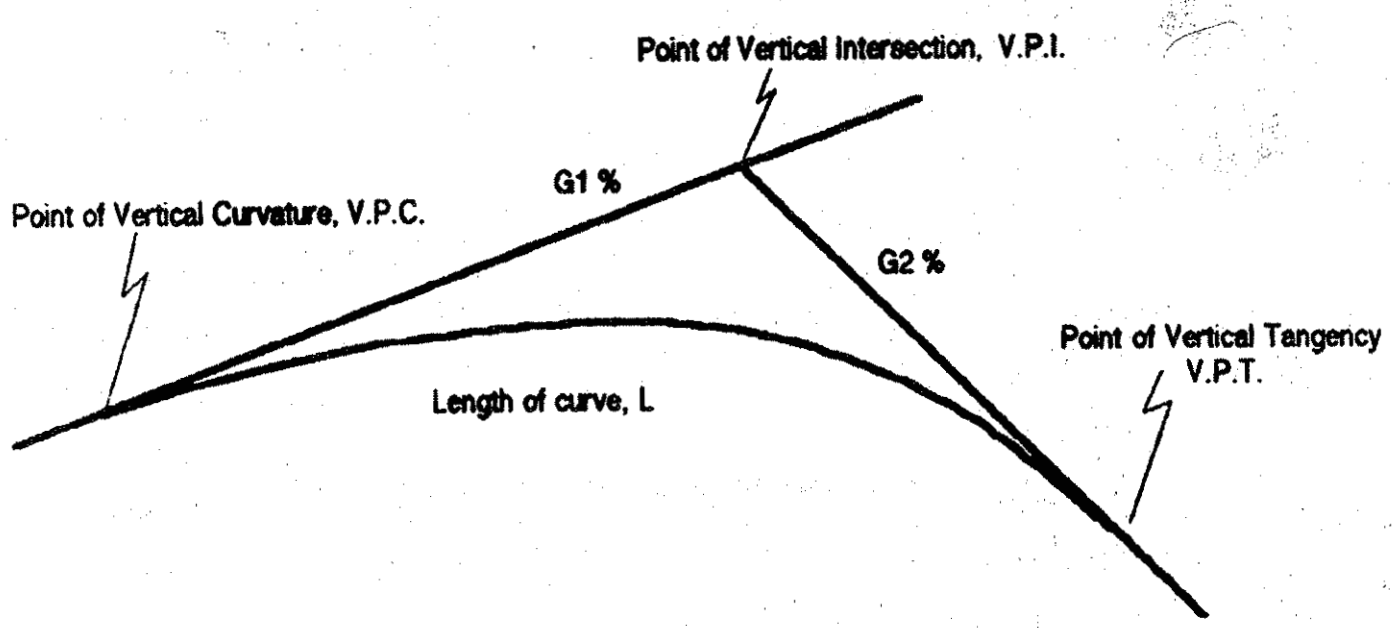

Figure 3. Input form for Example Problem

****

VERTICAL CURVE INPUT WORKSHEET

****

Project Number: 87-1

Project Name: Story Co. E57

Prepared By: Ahrenholtz Date: 03-19-87

Checked By: Brewer Date: 03-20-87

CURVE INPUT DATA:

Point of Vertical Intersection, V.P.I.	=	107.7850	stations
Grade into the V.P.I., G1	=	+6	percent
Grade out of the V.P.I., G2	=	-4	percent
Elevation of the V.P.I.	=	900	feet
Length of the Vertical Curve	=	1000	feet
Station Increment	=	100.00	feet

Figure 4. Example Problem Template

```
*****************************************************************
                    VERTICAL CURVE COMPUTATIONS
*****************************************************************

      ++++++++++++++++++++++++++++++++++++++++++++++++++++++
      +  Multiplan Microcomputer Spreadsheets for County   +
      +   Hydraulic and Highway Engineering Computations   +
      +          Copyright by Kent L. Ahrenholtz           +
      +                   Version 1.0                      +
      +                      1986                          +
      ++++++++++++++++++++++++++++++++++++++++++++++++++++++

Project Number:
Project Name:
Prepared By:                              Date:
Checked By:                               Date:

-----------------------------------------------------------------

CURVE INPUT DATA:
~~~~~~~~~~~~~~~~~

              Point of vertical
                     intersection, V.P.I. = 107.7850 stations
              Grade into V.P.I., G1       =     6.00 percent
              Grade out of V.P.I., G2     =    -4.00 percent
              Elevation of the V.P.I.     =   900.00 feet
              Length of the vertical curve =  1000.00 feet
              Station increment           =      100 feet

-----------------------------------------------------------------

CURVE OUTPUT DATA:
~~~~~~~~~~~~~~~~~~

              Point of vertical
                       curvature, V.P.C. = 102.7850 stations
              Elevation of the, V.P.C.   =   870.00 feet

              Point of vertical
                        tangency, V.P.T. = 112.7850 stations

              Location of the crest      = 108.7850 stations
              Elevation of the crest     =   888.00 feet

              Last even station
                       before the V.P.C. = 102.0000 stations
              First even incremental
                 station beyond the V.P.C. = 103.0000 stations

-----------------------------------------------------------------
```

Figure 4. (continued)

CURVE LAYOUT DATA:

	Station	Distance from V.P.C. (in feet)	Extended Tangent Elevation (in feet)	Curve Profile Elevation (in feet)	Curve Gradient (in percent)
V.P.C.	102.7850	0.00	870.00	870.00	6.00
	103.0000	21.50	871.29	871.27	5.78
	104.0000	121.50	877.29	876.55	4.78
	105.0000	221.50	883.29	880.84	3.78
	106.0000	321.50	889.29	884.12	2.78
	107.0000	421.50	895.29	886.41	1.78
	108.0000	521.50	901.29	887.69	0.78
	109.0000	621.50	907.29	887.98	-0.22
	110.0000	721.50	913.29	887.26	-1.22
	111.0000	821.50	919.29	885.55	-2.22
	112.0000	921.50	925.29	882.83	-3.22
V.P.T.	112.7850	1000.00	930.00	880.00	-4.00
	0.0000	0.00	0.00	0.00	0.00
	0.0000	0.00	0.00	0.00	0.00
	0.0000	0.00	0.00	0.00	0.00
	0.0000	0.00	0.00	0.00	0.00
	0.0000	0.00	0.00	0.00	0.00
	0.0000	0.00	0.00	0.00	0.00
	0.0000	0.00	0.00	0.00	0.00
	0.0000	0.00	0.00	0.00	0.00
	0.0000	0.00	0.00	0.00	0.00
	0.0000	0.00	0.00	0.00	0.00
	0.0000	0.00	0.00	0.00	0.00
	0.0000	0.00	0.00	0.00	0.00
	0.0000	0.00	0.00	0.00	0.00
	0.0000	0.00	0.00	0.00	0.00
	0.0000	0.00	0.00	0.00	0.00
	0.0000	0.00	0.00	0.00	0.00
	0.0000	0.00	0.00	0.00	0.00
	0.0000	0.00	0.00	0.00	0.00
	0.0000	0.00	0.00	0.00	0.00
	0.0000	0.00	0.00	0.00	0.00
	0.0000	0.00	0.00	0.00	0.00
	0.0000	0.00	0.00	0.00	0.00
	0.0000	0.00	0.00	0.00	0.00
	0.0000	0.00	0.00	0.00	0.00
	0.0000	0.00	0.00	0.00	0.00
	0.0000	0.00	0.00	0.00	0.00
	0.0000	0.00	0.00	0.00	0.00
	0.0000	0.00	0.00	0.00	0.00
	0.0000	0.00	0.00	0.00	0.00
	0.0000	0.00	0.00	0.00	0.00
	0.0000	0.00	0.00	0.00	0.00
	0.0000	0.00	0.00	0.00	0.00
	0.0000	0.00	0.00	0.00	0.00
	0.0000	0.00	0.00	0.00	0.00
	0.0000	0.00	0.00	0.00	0.00

Figure 4. (continued)

ODD STATIONS:

Description	Station	Curve Elevation (in feet)
FARM ENTRANCE	104.2500	877.72
CMP	106.7540	885.94
INTERSECTION	110.5000	886.53
FIELD ENTRANCE	112.5000	881.10
		0.00
		0.00
		0.00
		0.00
		0.00
		0.00
		0.00
		0.00
		0.00
		0.00
		0.00
		0.00
		0.00
		0.00
		0.00
		0.00

2.1.2 HORIZCRV

HORIZCRV

2.1.2.1. Introduction

HORIZCRV is a spreadsheet to layout a horizontal circular curve. The spreadsheet will calculate the surveying data required to layout a horizontal curve onto plan sheets and in the field.

The input data include: total deflection angle (delta) at the point of intersection (P.I.), degree of curvature, point of intersection station, station increment along the circular curve, lane width of finished roadway cross section, and shoulder width (if area of pavement and area of shoulder along the curve is desired).

The output generated includes:

curve data:

radius of curvature, tangent distance, length of curve, external distance, long chord, and middle ordinate;

stationing information:

point of curvature (P.C.) and point of tangency (P.T.);

curve layout data:

deflection angles, chord distances, offset distance both from curve to tangent and from tangent to curve, and areas of pavement and shoulder per station.

2.1.2.2. Using the spreadsheet

The best way to begin using a spreadsheet is to obtain all pertinent data, record the data in a form that is easily transferred to the spreadsheet, and then input the data onto the spreadsheet. The data obtained from preliminary roadway layouts and design manuals can be transferred to an input form. Once this is done, the user can proceed to use the spreadsheet.

The first step is to load the file from the disk to Multiplan. The file is assumed in this discussion to be stored a disk in Normal Format under the name HORIZCRV.MP. Once the program is loaded, turn Recalculation OFF by selecting the Options command and then input the informative data in rows 13-16 (see Figure 5). These data inclue the project number, project name, preparer, checker, and dates the project was prepared and checked.

Once the informative data are input, the user should then input the total deflection angle, degree of curvature, point of intersection station, curve station increment, lane width and shoulder width (lane and shoulder width needed only if pavement areas desired) into rows 19-26 in column 4 (see Figure 5). The deflection angle and point of intersection can be obtained from the preliminary plans for the project (see

Figure 6). The degree of curvature, station increment, lane width and shoulder width are all determined by the engineer. For the degree of curvature, a maximum value can be obtained from the AASHTO Green Book or the Iowa Department of Transportation Design Procedures Manual using the design speed, but the value used should be chosen by a knowledgable engineer. The other values are chosen according to the policy used in the engineer's office. These data complete the input portion of the spreadsheet. Before the output data generated by the spreadsheet can be viewed the Recalculation function must be turned on by entering the Options command again. After viewing the the output data, the spreadsheet should be saved with a filename solely characteristic of the horizontal curve and the project for purposes of editing and reuse.

2.1.2.3. Example Problem

The following is an example application of the spreadsheet described above.

A farm-to-market paved county highway is to be designed and constructed in rural Iowa. From the preliminary plans, the total deflection angle is found to be 54 degrees 30 minutes and the station of the point of intersection is found to be 105 + 35.40. The engineer has set the degree of curvature at 3 degrees. The

station increment along the circular curve is chosen as 100 feet. Enginering criteria call for a lane width of 12 feet and a shoulder width of 10 feet for this particular roadway.

The data are first entered on an input form. An example of the completed input form is shown in Figure 7. Data entry to the spreadsheet is completed using this form.

The completed spreadsheet is shown in Figure 8. The total output of the spreadsheet is contained on 5 pages, but for layout of the curve onto plan sheets or layout in the field, only the second and third pages are needed.

Figure 5. Input Template for HORIZCRV

```
         1                 2                 3                 4                 5
 1 ***********************************************************************
 2                 HORIZONTAL CIRCULAR CURVE COMPUTATIONS
 3 ***********************************************************************
 4
 5       ++++++++++++++++++++++++++++++++++++++++++++++++++++++
 6       +  Multiplan Microcomputer Spreadsheets for County   +
 7       +   Hydraulic and Highway Engineering Computations   +
 8       +           Copyright by Kent L. Ahrenholtz          +
 9       +              All Rights Reserved, 1986             +
10       +                     Version 2.0                    +
11       ++++++++++++++++++++++++++++++++++++++++++++++++++++++
12
13 Project Number:
14 Project Name  :
15 Prepared By   :                          Date:
16 Checked By    :                          Date:
17 -----------------------------------------------------------------------
18
19 CURVE INPUT DATA:  Deflection angle, Delta  =      0.00 degrees
20 ~~~~~~~~~~~~~~~~~~                          =      0.00 radians
21                    Degree of curvature, D   =      0.00 degrees
22                                             =      0.00 radians
23                    Point of Intersection, PI=   0.0000 stations
24                    Station increment        =       100 feet
25                    Lane width, L.W.         =      0.00 feet
26                    Shoulder width, Sh.W.    =      0.00 feet
27 -----------------------------------------------------------------------
28
29 CURVE OUTPUT DATA:
30 ~~~~~~~~~~~~~~~~~~
31                 CURVE DATA:
32                    Radius of curve, R       = #DIV/0!  feet
33                    Tangent distance, T      = #VALUE!  feet
34                    Length of curve, L       =      0.00 feet
35                    External distance, E     = #VALUE!  feet
36                    Long chord, C            = #VALUE!  feet
37                    Middle ordinate, M       = #VALUE!  feet
38
39                 STATIONING INFORMATION:
40                    Point of Curvature, PC   = #VALUE!
41                    Point of Tangency, PT    = #VALUE!
42 -----------------------------------------------------------------------
43
44 CURVE LAYOUT DATA:
45 ~~~~~~~~~~~~~~~~~~ Chord length, c           = #VALUE!  feet
46                    Increment Angles,       d =      0.00 degrees
47                                              =      0.00 radians
48                                             d1= #VALUE!  minutes
49                                              = #VALUE!  degrees
50                                              = #VALUE!  radians
51                                             d2= #VALUE!  minutes
52                                              = #VALUE!  degrees
53                                              = #VALUE!  radians
54 -----------------------------------------------------------------------
```

Figure 6. **Schematic of a Horizontal Circular Curve**

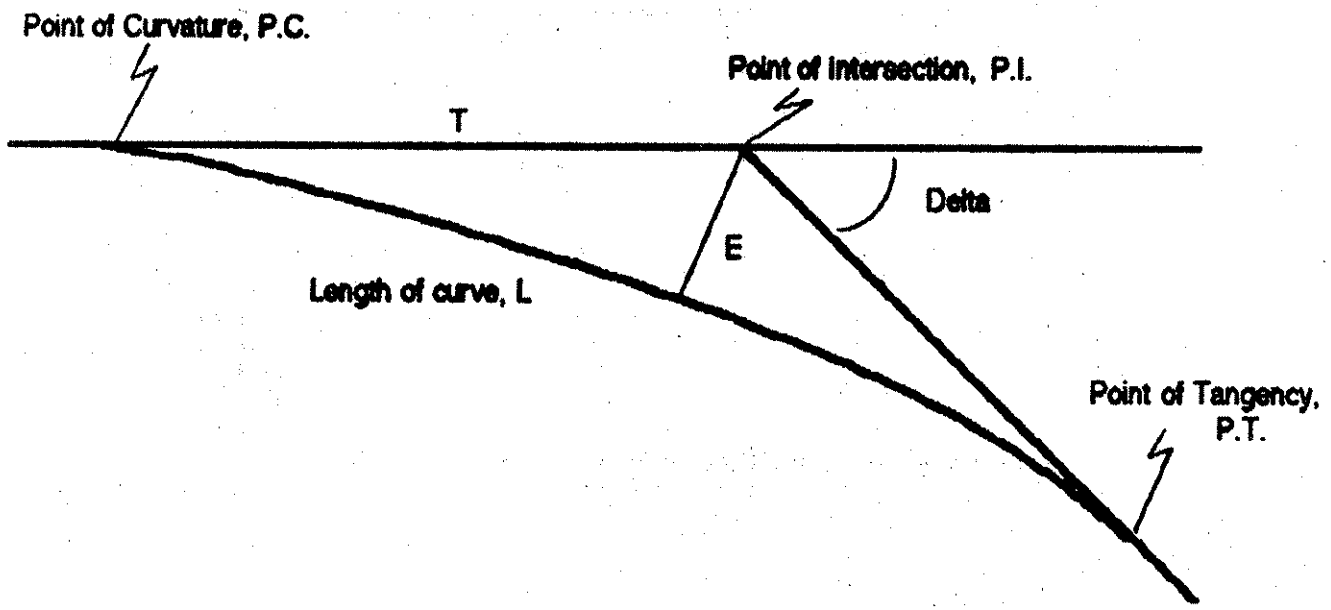

Figure 7. Input form for Example Problem

****

HORIZONTAL CURVE INPUT WORKSHEET

****

Project Number: 87-1

Project Name: Story Co. E57

Prepared By: Ahrenholtz Date: 03-20-87

Checked By: Brewer Date: 03-22-87

CURVE INPUT DATA:

Deflection Angle, Delta	=	54.5	degrees
Degree of Curvature, D	=	3.0	degrees
Point of Intersection, PI	=	105.3540	stations
Station Increment	=	100.00	feet
Lane Width	=	12.0	feet
Shoulder Width	=	10.0	feet

Figure 8. Example Problem Template

```
         1                 2                 3                 4                 5
 1 ***********************************************************************************
 2                    HORIZONTAL CIRCULAR CURVE COMPUTATIONS
 3 ***********************************************************************************
 4
 5        ++++++++++++++++++++++++++++++++++++++++++++++++++++++
 6        +  Multiplan Microcomputer Spreadsheets for County   +
 7        +   Hydraulic and Highway Engineering Computations   +
 8        +            Copyright by Kent L. Ahrenholtz         +
 9        +               All Rights Reserved, 1986            +
10        +                      Version 2.0                   +
11        ++++++++++++++++++++++++++++++++++++++++++++++++++++++
12
13 Project Number:  87-1
14 Project Name  : Story Co. E57
15 Prepared By   :Ahrenholtz                    Date:03-19-87
16 Checked By    :Brewer                        Date:03-20-87
17 -----------------------------------------------------------------------------------
18
19 CURVE INPUT DATA:  Deflection angle, Delta  =    54.50 degrees
20 ~~~~~~~~~~~~~~~~~~                          =     0.95 radians
21                    Degree of curvature, D   =     3.00 degrees
22                                             =     0.05 radians
23                    Point of Intersection, PI= 105.3540 stations
24                    Station increment        =      100 feet
25                    Lane width, L.W.         =    12.00 feet
26                    Shoulder width, Sh.W.    =    10.00 feet
27 -----------------------------------------------------------------------------------
28
29 CURVE OUTPUT DATA:
30 ~~~~~~~~~~~~~~~~~~
31                 CURVE DATA:
32                    Radius of curve, R       =  1909.86 feet
33                    Tangent distance, T      =   983.64 feet
34                    Length of curve, L       =  1816.67 feet
35                    External distance, E     =   238.42 feet
36                    Long chord, C            =  1748.95 feet
37                    Middle ordinate, M       =   211.96 feet
38
39                 STATIONING INFORMATION:
40                    Point of Curvature, PC   =  95.5176
41                    Point of Tangency, PT    = 113.6842
42 -----------------------------------------------------------------------------------
43
44 CURVE LAYOUT DATA:
45 ~~~~~~~~~~~~~~~~~~ Chord length, c          =    99.99 feet
46                    Increment Angles,      d =     1.50 degrees
47                                             =     0.03 radians
48                                            d1=    43.42 minutes
49                                             =     0.72 degrees
50                                             =     0.01 radians
51                                            d2=    61.58 minutes
52                                             =     1.03 degrees
53                                             =     0.02 radians
54 -----------------------------------------------------------------------------------
```

Figure 8. (continued)

6 7 8 9 10 11 12 13 14 15

CURVE LAYOUT DATA:(continued)

	Station	Deflection Angle from PC: Turning Right (deg	min	sec)	Turning Left (deg	min	sec)	Chord Distance from PC (in feet)	from PT
P.C.	95.5176	0	0	0	360	0	0	0.00	1748.95
	96.0000	0	43	25	359	16	35	48.24	1705.92
	97.0000	2	13	25	357	46	35	148.20	1615.88
	98.0000	3	43	25	356	16	35	248.07	1524.72
	99.0000	5	13	25	354	46	35	347.76	1432.52
	100.0000	6	43	25	353	16	35	447.21	1339.34
	101.0000	8	13	25	351	46	35	546.36	1245.24
	102.0000	9	43	25	350	16	35	645.13	1150.29
	103.0000	11	13	25	348	46	35	743.47	1054.55
	104.0000	12	43	25	347	16	35	841.29	958.08
	105.0000	14	13	25	345	46	35	938.53	860.96
	106.0000	15	43	25	344	16	35	1035.13	763.25
	107.0000	17	13	25	342	46	35	1131.03	665.02
	108.0000	18	43	25	341	16	35	1226.14	566.33
	109.0000	20	13	25	339	46	35	1320.42	467.25
	110.0000	21	43	25	338	16	35	1413.79	367.85
	111.0000	23	13	25	336	46	35	1506.20	268.20
	112.0000	24	43	25	335	16	35	1597.57	168.37
	113.0000	26	13	25	333	46	35	1687.84	68.42
P.T.	113.6842	27	15	0	332	45	0	1748.95	0.00
	0.0000	0	0	0	0	0	0	0.00	0.00
	0.0000	0	0	0	0	0	0	0.00	0.00
	0.0000	0	0	0	0	0	0	0.00	0.00
	0.0000	0	0	0	0	0	0	0.00	0.00
	0.0000	0	0	0	0	0	0	0.00	0.00
	0.0000	0	0	0	0	0	0	0.00	0.00
	0.0000	0	0	0	0	0	0	0.00	0.00
	0.0000	0	0	0	0	0	0	0.00	0.00
	0.0000	0	0	0	0	0	0	0.00	0.00
	0.0000	0	0	0	0	0	0	0.00	0.00
	0.0000	0	0	0	0	0	0	0.00	0.00
	0.0000	0	0	0	0	0	0	0.00	0.00
	0.0000	0	0	0	0	0	0	0.00	0.00
	0.0000	0	0	0	0	0	0	0.00	0.00
	0.0000	0	0	0	0	0	0	0.00	0.00
	0.0000	0	0	0	0	0	0	0.00	0.00
	0.0000	0	0	0	0	0	0	0.00	0.00
	0.0000	0	0	0	0	0	0	0.00	0.00
	0.0000	0	0	0	0	0	0	0.00	0.00
	0.0000	0	0	0	0	0	0	0.00	0.00
	0.0000	0	0	0	0	0	0	0.00	0.00
	0.0000	0	0	0	0	0	0	0.00	0.00
	0.0000	0	0	0	0	0	0	0.00	0.00
	0.0000	0	0	0	0	0	0	0.00	0.00
	0.0000	0	0	0	0	0	0	0.00	0.00
	0.0000	0	0	0	0	0	0	0.00	0.00

Figure 8. (continued)

16 17 18 19 20 21 22 23

CURVE LAYOUT DATA: (continued)

		MEASURED FROM					
		Curve to Tangent			Tangent to Curve		
	Curve Station	Offset Distance (in feet)	Tangent Station		Tangent Station	Offset Distance (in feet)	Curve Station
P.C.	95.5176	0.00	95.5176	¦	95.5176	0.00	95.5176
	96.0000	0.61	96.0000	¦	96.0000	0.61	96.0001
	97.0000	5.75	97.0007	¦	97.0000	5.76	97.0015
	98.0000	16.14	98.0035	¦	98.0000	16.20	98.0070
	99.0000	31.79	99.0097	¦	99.0000	32.02	99.0196
	100.0000	52.72	100.0207	¦	100.0000	53.35	100.0422
	101.0000	78.96	101.0380	¦	101.0000	80.38	101.0782
	102.0000	110.55	102.0630	¦	102.0000	113.38	102.1314
	103.0000	147.53	103.0972	¦	103.0000	152.68	103.2060
	104.0000	189.96	104.1422	¦	104.0000	198.71	104.3070
	105.0000	237.90	105.1997	¦	105.0000	252.03	105.4404
	106.0000	155.65	107.4008	¦	106.0000	235.67	104.0961
	107.0000	117.58	108.4371	¦	107.0000	184.54	105.2194
	108.0000	84.90	109.4638	¦	108.0000	140.53	106.3121
	109.0000	57.59	110.4826	¦	109.0000	103.11	107.3800
	110.0000	35.59	111.4947	¦	110.0000	71.88	108.4277
	111.0000	18.88	112.5017	¦	111.0000	46.54	109.4595
	112.0000	7.43	113.5051	¦	112.0000	26.84	110.4788
	113.0000	1.23	114.5061	¦	113.0000	12.60	111.4890
P.T.	113.6842	0.00	115.1904	¦	114.0000	3.71	112.4931
	0.0000	0.00	0.0000	¦	115.0000	0.09	113.4938
	0.0000	0.00	0.0000	¦	115.1904	0.00	113.6842
	0.0000	0.00	0.0000	¦	0.0000	0.00	0.0000
	0.0000	0.00	0.0000	¦	0.0000	0.00	0.0000
	0.0000	0.00	0.0000	¦	0.0000	0.00	0.0000
	0.0000	0.00	0.0000	¦	0.0000	0.00	0.0000
	0.0000	0.00	0.0000	¦	0.0000	0.00	0.0000
	0.0000	0.00	0.0000	¦	0.0000	0.00	0.0000
	0.0000	0.00	0.0000	¦	0.0000	0.00	0.0000
	0.0000	0.00	0.0000	¦	0.0000	0.00	0.0000
	0.0000	0.00	0.0000	¦	0.0000	0.00	0.0000
	0.0000	0.00	0.0000	¦	0.0000	0.00	0.0000
	0.0000	0.00	0.0000	¦	0.0000	0.00	0.0000
	0.0000	0.00	0.0000	¦	0.0000	0.00	0.0000
	0.0000	0.00	0.0000	¦	0.0000	0.00	0.0000
	0.0000	0.00	0.0000	¦	0.0000	0.00	0.0000
	0.0000	0.00	0.0000	¦	0.0000	0.00	0.0000
	0.0000	0.00	0.0000	¦	0.0000	0.00	0.0000
	0.0000	0.00	0.0000	¦	0.0000	0.00	0.0000
	0.0000	0.00	0.0000	¦	0.0000	0.00	0.0000
	0.0000	0.00	0.0000	¦	0.0000	0.00	0.0000
	0.0000	0.00	0.0000	¦	0.0000	0.00	0.0000
	0.0000	0.00	0.0000	¦	0.0000	0.00	0.0000

Figure 8. (continued)

CURVE LAYOUT DATA: (continued)

24	25 Curve Station	26 Area of Pavement per Station (in sq. ft.)	27 Area of Shoulder per Station (in sq. ft.)
P.C.	95.5176	0.00	0.00
	96.0000	1157.81	964.84
	97.0000	2400.00	2000.00
	98.0000	2400.00	2000.00
	99.0000	2400.00	2000.00
	100.0000	2400.00	2000.00
	101.0000	2400.00	2000.00
	102.0000	2400.00	2000.00
	103.0000	2400.00	2000.00
	104.0000	2400.00	2000.00
	105.0000	2400.00	2000.00
	106.0000	2400.00	2000.00
	107.0000	2400.00	2000.00
	108.0000	2400.00	2000.00
	109.0000	2400.00	2000.00
	110.0000	2400.00	2000.00
	111.0000	2400.00	2000.00
	112.0000	2400.00	2000.00
	113.0000	2400.00	2000.00
P.T.	113.6842	1642.19	1368.49
	0.0000	0.00	0.00
	0.0000	0.00	0.00
	0.0000	0.00	0.00
	0.0000	0.00	0.00
	0.0000	0.00	0.00
	0.0000	0.00	0.00
	0.0000	0.00	0.00
	0.0000	0.00	0.00
	0.0000	0.00	0.00
	0.0000	0.00	0.00
	0.0000	0.00	0.00
	0.0000	0.00	0.00
	0.0000	0.00	0.00
	0.0000	0.00	0.00
	0.0000	0.00	0.00
	0.0000	0.00	0.00
	0.0000	0.00	0.00
	0.0000	0.00	0.00
	0.0000	0.00	0.00
	0.0000	0.00	0.00
	0.0000	0.00	0.00
	0.0000	0.00	0.00
	0.0000	0.00	0.00
TOTAL AREAS(sq.ft.)=		43600.00	36333.33

(Columns 28–30)

Pavement Char.

r1 = R + L.W.
= 1921.86

r2 = R - L.W.
= 1897.86

Shoulder Char.

First set:
r1 =R +LW +ShW
= 1931.86

r2 = R + LW
= 1921.86

r1 + r2
= 3853.72
r1 - r2
= 10.00

Second set:
r1 = R - LW
= 1897.86

r2 =R -LW -ShW
= 1887.86

r1 + r2
= 3785.72
r1 - r2
= 10.00

Figure 8. (continued)

TANGENT TO CURVE COMPUTATIONS

t/R	Theta	Arc Length
0.00	0.00	0.00
0.03	1.45	48.25
0.08	4.45	148.39
0.13	7.47	248.95
0.18	10.51	350.20
0.23	13.57	452.46
0.29	16.68	556.07
0.34	19.84	661.38
0.39	23.07	768.84
0.44	26.37	878.94
0.50	29.77	992.29
0.48	28.76	958.81
0.43	25.39	846.49
0.38	22.12	737.21
0.32	18.91	630.43
0.27	15.77	525.65
0.22	12.67	422.48
0.17	9.62	320.54
0.11	6.59	219.53
0.06	3.57	119.12
0.01	0.57	19.04
0.00	0.00	0.00
0.00	0.00	0.00
0.00	0.00	0.00
0.00	0.00	0.00
0.00	0.00	0.00
0.00	0.00	0.00
0.00	0.00	0.00
0.00	0.00	0.00
0.00	0.00	0.00
0.00	0.00	0.00
0.00	0.00	0.00
0.00	0.00	0.00
0.00	0.00	0.00
0.00	0.00	0.00
0.00	0.00	0.00
0.00	0.00	0.00
0.00	0.00	0.00
0.00	0.00	0.00
0.00	0.00	0.00
0.00	0.00	0.00
0.00	0.00	0.00
0.00	0.00	0.00
0.00	0.00	0.00

2.1.3. MAXTANG

2.1.3.1. Introduction

MAXTANG is a spreadsheet to calculate the elements of a horizontal curve for alignment purposes for which the field location has a restriction on the length of tangent that is permitted between the point of intersection and either the point of curvature or the point of tangency. The spreadsheet operates in the same form and manner as HORIZCRV. Thus, it is suggested that the user become familiar with HORIZCRV first. Then review Figures 9 through 12 on the following pages and proceed to use the spreadsheet in a manner similar to HORIZCRV.

2.1.3.2. Example Problem

The following is an example application of the spreadsheet MAXTANG.

A rural county highway in Iowa is to be paved. At one point in the route the existing aggregate surfaced roadway has a sharp curve that has several farmstead driveways near it. The engineer desires to keep these driveways on the tangent alignment rather than be located in the curved portion of the new paved highway. The engineer does, however, wish to use the longest and most

gentle curve possible at this location. Field survey measurements indicate that the longest permissible tangent length from the point of intersection to keep the closest farmstead driveway in the tangent is 650.00 feet. The total deflection angle, delta, was found to be 54 degrees and 30 minutes. The station of the point of intersection is 105 + 35.40. The stationing increment around the curve will be 100.00 feet. The paved roadway cross section will have 12.00 feet wide lanes and 10.00 feet wide shoulders.

The data may be entered on an input form. This example is shown in such a form in Figure 11. From this form the spreadsheet is then completed.

The completed spreadsheet for this example is shown in Figure 12. As before with HORIZCRV, the total output is contained in several pages but for layout of the curve in the field or on plans, only the first few pages are needed.

Figure 9. Input Template for MAXTANG

```
         1                 2                 3                 4                 5
 1 ***********************************************************************************
 2  HORIZONTAL CIRCULAR CURVE COMPUTATIONS Given MAXIMUM TANGENT LENGTHS
 3 ***********************************************************************************
 4
 5        ++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 6        +  Multiplan Microcomputer Spreadsheets for County    +
 7        +   Hydraulic and Highway Engineering Computations    +
 8        +          Copyright by Kent L. Ahrenholtz            +
 9        +              All Rights Reserved, 1986              +
10        +                     Version 1.0                     +
11        ++++++++++++++++++++++++++++++++++++++++++++++++++++++++
12
13 Project Number:
14 Project Name   :
15 Prepared By    :                                Date:
16 Checked By     :                                Date:
17 ---------------------------------------------------------------------------------
18
19 CURVE INPUT DATA:   Deflection angle, Delta  =      0.00 degrees
20 ~~~~~~~~~~~~~~~~~~                           =      0.00 radians
21                     Tangent distance, T      =      0.00 feet
22                     Point of Intersection, PI=   0.0000 stations
23                     Station increment        =       100 feet
24                     Lane width, L.W.         =      0.00 feet
25                     Shoulder width, Sh.W.    =      0.00 feet
26 ---------------------------------------------------------------------------------
27
28 CURVE OUTPUT DATA:
29 ~~~~~~~~~~~~~~~~~~
30                  CURVE DATA:
31                     Radius of curve, R       =      0.00 feet
32                     Degree of curvature, D   = #DIV/0!   degrees
33                                                #VALUE!   radians
34                     Length of curve, L       = #DIV/0!   feet
35                     External distance, E     =      0.00 feet
36                     Long chord, C            =      0.00 feet
37                     Middle ordinate, M       =      0.00 feet
38
39                  STATIONING INFORMATION:
40                     Point of Curvature, PC   =    0.0000
41                     Point of Tangency, PT    = #VALUE!
42 ---------------------------------------------------------------------------------
43
44 CURVE LAYOUT DATA:
45 ~~~~~~~~~~~~~~~~~~  Chord length, c            = #VALUE!   feet
46                     Increment Angles,       d = #VALUE!   degrees
47                                               = #VALUE!   radians
48                                             d1= #DIV/0!   minutes
49                                               = #VALUE!   degrees
50                                               = #VALUE!   radians
51                                             d2= #VALUE!   minutes
52                                               = #VALUE!   degrees
53                                               = #VALUE!   radians
54 ---------------------------------------------------------------------------------
```

Figure 10. Schematic of a Horizontal Circular Curve

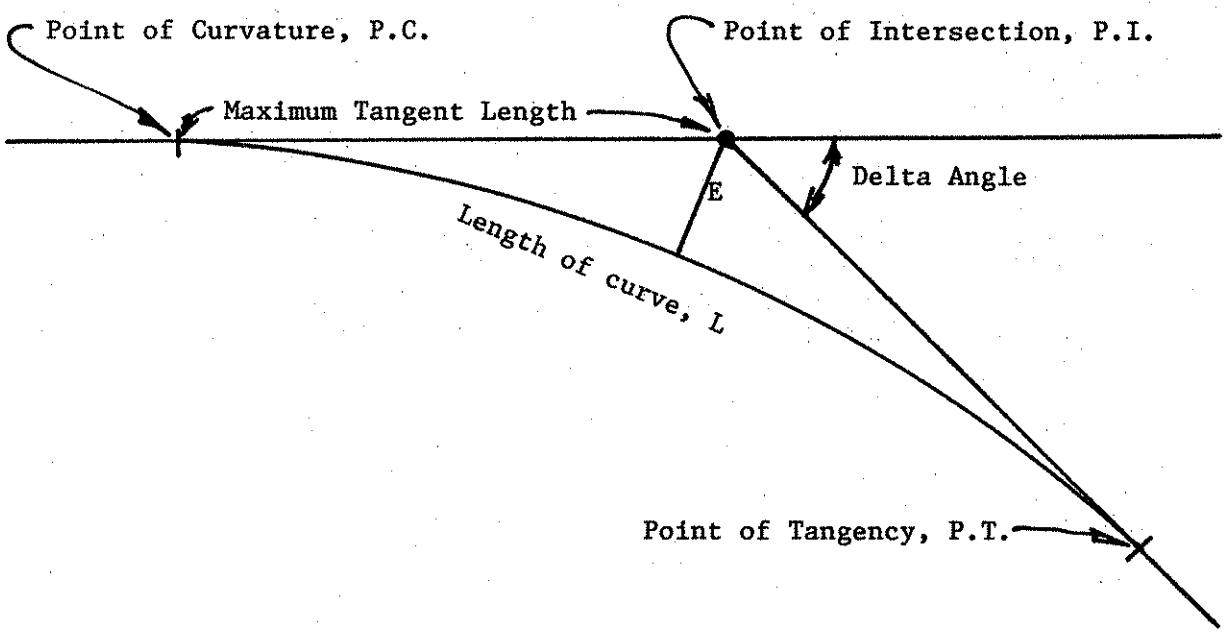

Figure 11. Input form for Example Problem

****

HORIZONTAL CURVE INPUT WORKSHEET Given MAXIMUM TANGENT LENGTHS

****

Project Number: 87-2

Project Name: Story Co. E57

Prepared By: Ahrenholtz Date: 06-11-87

Checked By: Brewer Date: 06-11-87

CURVE INPUT DATA:

Deflection Angle, Delta	= 54.5	degrees
Tangent Distance, T	= 650.00	feet
Point of Intersection, PI	= 105.3540	stations
Station Increment	= 100	feet
Lane Width	= 12	feet
Shoulder Width	= 10	feet

Figure 12. Example Problem Template

```
         1                 2                 3                 4                 5
 1 ***********************************************************************
 2  HORIZONTAL CIRCULAR CURVE COMPUTATIONS Given MAXIMUM TANGENT LENGTHS
 3 ***********************************************************************
 4
 5        ++++++++++++++++++++++++++++++++++++++++++++++++++++++
 6        +  Multiplan Microcomputer Spreadsheets for County   +
 7        +   Hydraulic and Highway Engineering Computations   +
 8        +           Copyright by Kent L. Ahrenholtz          +
 9        +              All Rights Reserved, 1986             +
10        +                     Version 1.0                    +
11        ++++++++++++++++++++++++++++++++++++++++++++++++++++++
12
13 Project Number:  87-2
14 Project Name   :  Story Co. E57
15 Prepared By    :Ahrenholtz                 Date: 06-11-87
16 Checked By     :Brewer                     Date: 06-11-87
17 ---------------------------------------------------------------------
18
19 CURVE INPUT DATA:  Deflection angle, Delta  =    54.50 degrees
20 ~~~~~~~~~~~~~~~~~~                          =     0.95 radians
21                    Tangent distance, T      =   650.00 feet
22                    Point of Intersection, PI= 105.3540 stations
23                    Station increment        =      100 feet
24                    Lane width, L.W.         =    12.00 feet
25                    Shoulder width, Sh.W.    =    10.00 feet
26 ---------------------------------------------------------------------
27
28 CURVE OUTPUT DATA:
29 ~~~~~~~~~~~~~~~~~~
30                 CURVE DATA:
31                    Radius of curve, R       =  1262.05 feet
32                    Degree of curvature, D   =     4.54 degrees
33                                             =     0.08 radians
34                    Length of curve, L       =  1200.47 feet
35                    External distance, E     =   157.55 feet
36                    Long chord, C            =  1155.72 feet
37                    Middle ordinate, M       =   140.07 feet
38
39                 STATIONING INFORMATION:
40                    Point of Curvature, PC   =  98.8540
41                    Point of Tangency, PT    = 110.8587
42 ---------------------------------------------------------------------
43
44 CURVE LAYOUT DATA:
45 ~~~~~~~~~~~~~~~~~~  Chord length, c          =    99.97 feet
46                    Increment Angles,      d =     2.27 degrees
47                                             =     0.04 radians
48                                            d1=    19.88 minutes
49                                             =     0.33 degrees
50                                             =     0.01 radians
51                                            d2=   116.95 minutes
52                                             =     1.95 degrees
53                                             =     0.03 radians
54 ---------------------------------------------------------------------
```

Figure 12. (continued)

6 7 8 9 10 11 12 13 14 15

CURVE LAYOUT DATA: (continued)

	Station	Deflection Angle from PC: Turning Right (deg	min	sec)	Turning Left (deg	min	sec)	Chord Distance from PC (in feet)	from PT (in feet)
P.C.	98.8540	0	0	0	360	0	0	0.00	1155.72
	99.0000	0	19	53	359	40	7	14.60	1142.72
	100.0000	2	36	5	357	23	55	114.56	1052.68
	101.0000	4	52	17	355	7	43	214.34	960.99
	102.0000	7	8	28	352	51	32	313.79	867.80
	103.0000	9	24	40	350	35	20	412.74	773.24
	104.0000	11	40	52	348	19	8	511.04	677.46
	105.0000	13	57	4	346	2	56	608.54	580.62
	106.0000	16	13	16	343	46	44	705.09	482.88
	107.0000	18	29	27	341	30	33	800.53	384.37
	108.0000	20	45	39	339	14	21	894.72	285.26
	109.0000	23	1	51	336	58	9	987.50	185.70
	110.0000	25	18	3	334	41	57	1078.73	85.85
P.T.	110.8587	27	15	0	332	45	0	1155.72	0.00
	0.0000	0	0	0	0	0	0	0.00	0.00
	0.0000	0	0	0	0	0	0	0.00	0.00
	0.0000	0	0	0	0	0	0	0.00	0.00
	0.0000	0	0	0	0	0	0	0.00	0.00
	0.0000	0	0	0	0	0	0	0.00	0.00
	0.0000	0	0	0	0	0	0	0.00	0.00
	0.0000	0	0	0	0	0	0	0.00	0.00
	0.0000	0	0	0	0	0	0	0.00	0.00
	0.0000	0	0	0	0	0	0	0.00	0.00
	0.0000	0	0	0	0	0	0	0.00	0.00
	0.0000	0	0	0	0	0	0	0.00	0.00
	0.0000	0	0	0	0	0	0	0.00	0.00
	0.0000	0	0	0	0	0	0	0.00	0.00
	0.0000	0	0	0	0	0	0	0.00	0.00
	0.0000	0	0	0	0	0	0	0.00	0.00
	0.0000	0	0	0	0	0	0	0.00	0.00
	0.0000	0	0	0	0	0	0	0.00	0.00
	0.0000	0	0	0	0	0	0	0.00	0.00
	0.0000	0	0	0	0	0	0	0.00	0.00
	0.0000	0	0	0	0	0	0	0.00	0.00
	0.0000	0	0	0	0	0	0	0.00	0.00
	0.0000	0	0	0	0	0	0	0.00	0.00
	0.0000	0	0	0	0	0	0	0.00	0.00
	0.0000	0	0	0	0	0	0	0.00	0.00
	0.0000	0	0	0	0	0	0	0.00	0.00
	0.0000	0	0	0	0	0	0	0.00	0.00
	0.0000	0	0	0	0	0	0	0.00	0.00
	0.0000	0	0	0	0	0	0	0.00	0.00
	0.0000	0	0	0	0	0	0	0.00	0.00

Figure 12. (continued)

16 17 18 19 20 21 22 23

CURVE LAYOUT DATA: (continued)

		MEASURED FROM					
		Curve to Tangent			Tangent to Curve		
	Curve Station	Offset Distance (in feet)	Tangent Station		Tangent Station	Offset Distance (in feet)	Curve Station
P.C.	98.8540	0.00	98.8540	!	98.8540	0.00	98.8540
	99.0000	0.08	92.5836	!	99.0000	0.08	99.0000
	100.0000	5.20	93.8172	!	100.0000	5.21	100.0016
	101.0000	18.27	95.0068	!	101.0000	18.38	101.0105
	102.0000	39.31	96.1581	!	102.0000	39.84	102.0335
	103.0000	68.41	97.2765	!	103.0000	70.04	103.0784
	104.0000	105.66	98.3667	!	104.0000	109.68	104.1545
	105.0000	151.18	99.4332	!	105.0000	159.76	105.2732
	106.0000	94.11	100.4798	!	106.0000	143.98	104.7714
	107.0000	59.22	101.5104	!	107.0000	97.08	105.8763
	108.0000	32.45	102.5284	!	108.0000	60.29	106.9421
	109.0000	13.70	103.5373	!	109.0000	32.69	107.9798
	110.0000	2.92	104.5404	!	110.0000	13.69	108.9980
P.T.	110.8587	0.00	105.3994	!	111.0000	2.89	110.0041
	0.0000	0.00	0.0000	!	111.8540	0.00	110.8587
	0.0000	0.00	0.0000	!	0.0000	0.00	0.0000
	0.0000	0.00	0.0000	!	0.0000	0.00	0.0000
	0.0000	0.00	0.0000	!	0.0000	0.00	0.0000
	0.0000	0.00	0.0000	!	0.0000	0.00	0.0000
	0.0000	0.00	0.0000	!	0.0000	0.00	0.0000
	0.0000	0.00	0.0000	!	0.0000	0.00	0.0000
	0.0000	0.00	0.0000	!	0.0000	0.00	0.0000
	0.0000	0.00	0.0000	!	0.0000	0.00	0.0000
	0.0000	0.00	0.0000	!	0.0000	0.00	0.0000
	0.0000	0.00	0.0000	!	0.0000	0.00	0.0000
	0.0000	0.00	0.0000	!	0.0000	0.00	0.0000
	0.0000	0.00	0.0000	!	0.0000	0.00	0.0000
	0.0000	0.00	0.0000	!	0.0000	0.00	0.0000
	0.0000	0.00	0.0000	!	0.0000	0.00	0.0000
	0.0000	0.00	0.0000	!	0.0000	0.00	0.0000
	0.0000	0.00	0.0000	!	0.0000	0.00	0.0000
	0.0000	0.00	0.0000	!	0.0000	0.00	0.0000
	0.0000	0.00	0.0000	!	0.0000	0.00	0.0000
	0.0000	0.00	0.0000	!	0.0000	0.00	0.0000
	0.0000	0.00	0.0000	!	0.0000	0.00	0.0000
	0.0000	0.00	0.0000	!	0.0000	0.00	0.0000
	0.0000	0.00	0.0000	!	0.0000	0.00	0.0000
	0.0000	0.00	0.0000	!	0.0000	0.00	0.0000
	0.0000	0.00	0.0000	!	0.0000	0.00	0.0000
	0.0000	0.00	0.0000	!	0.0000	0.00	0.0000
	0.0000	0.00	0.0000	!	0.0000	0.00	0.0000
	0.0000	0.00	0.0000	!	0.0000	0.00	0.0000
	0.0000	0.00	0.0000	!	0.0000	0.00	0.0000

Figure 12. (continued)

CURVE LAYOUT DATA: (continued)

	Curve Station	Area of Pavement per Station (in sq. ft.)	Area of Shoulder per Station (in sq. ft.)
P.C.	98.8540	0.00	0.00
	99.0000	350.40	292.00
	100.0000	2400.00	2000.00
	101.0000	2400.00	2000.00
	102.0000	2400.00	2000.00
	103.0000	2400.00	2000.00
	104.0000	2400.00	2000.00
	105.0000	2400.00	2000.00
	106.0000	2400.00	2000.00
	107.0000	2400.00	2000.00
	108.0000	2400.00	2000.00
	109.0000	2400.00	2000.00
	110.0000	2400.00	2000.00
P.T.	110.8587	2060.89	1717.41
	0.0000	0.00	0.00
	0.0000	0.00	0.00
	0.0000	0.00	0.00
	0.0000	0.00	0.00
	0.0000	0.00	0.00
	0.0000	0.00	0.00
	0.0000	0.00	0.00
	0.0000	0.00	0.00
	0.0000	0.00	0.00
	0.0000	0.00	0.00
	0.0000	0.00	0.00
	0.0000	0.00	0.00
	0.0000	0.00	0.00
	0.0000	0.00	0.00
	0.0000	0.00	0.00
	0.0000	0.00	0.00
	0.0000	0.00	0.00
	0.0000	0.00	0.00
	0.0000	0.00	0.00
	0.0000	0.00	0.00
	0.0000	0.00	0.00
	0.0000	0.00	0.00
	0.0000	0.00	0.00
	0.0000	0.00	0.00
	0.0000	0.00	0.00
	0.0000	0.00	0.00
	0.0000	0.00	0.00
	0.0000	0.00	0.00
	0.0000	0.00	0.00
TOTAL AREAS(sq.ft.)=		28811.29	24009.41

Pavement Char.

r1 = R + L.W.
= 1274.05

r2 = R - L.W.
= 1250.05

Shoulder Char.

First set:
r1 =R +LW +ShW
= 1284.05

r2 = R + LW
= 1274.05

r1 + r2
= 2558.11
r1 - r2
= 10.00

Second set:
r1 = R - LW
= 1250.05

r2 =R -LW -ShW
= 1240.05

r1 + r2
= 2490.11
r1 - r2
= 10.00

Figure 12. (continued)

	31	32	33	34	35	36	37
1							
2							
3		DEFLECTION					
4		ANGLES					
5					TANGENT TO CURVE COMPUTATIONS		
6	Turning		Turning				
7	Right		Left				Arc
8	(degrees)	(radians)	(degrees)		t/R	Theta	Length
9							
10	0.00	0.000	360.00		0.00	0.00	0.00
11	0.33	0.006	359.67		0.01	0.66	14.60
12	2.60	0.045	357.40		0.09	5.21	114.76
13	4.87	0.085	355.13		0.17	9.79	215.65
14	7.14	0.125	352.86		0.25	14.43	317.95
15	9.41	0.164	350.59		0.33	19.18	422.44
16	11.68	0.204	348.32		0.41	24.06	530.05
17	13.95	0.243	346.05		0.49	29.14	641.92
18	16.22	0.283	343.78		0.46	27.64	608.73
19	18.49	0.323	341.51		0.38	22.62	498.24
20	20.76	0.362	339.24		0.31	17.78	391.66
21	23.03	0.402	336.97		0.23	13.07	287.89
22	25.30	0.442	334.70		0.15	8.45	186.07
23	27.25	0.476	332.75		0.07	3.88	85.47
24	0.00	0.000	0.00		0.00	0.00	0.00
25	0.00	0.000	0.00		0.00	0.00	0.00
26	0.00	0.000	0.00		0.00	0.00	0.00
27	0.00	0.000	0.00		0.00	0.00	0.00
28	0.00	0.000	0.00		0.00	0.00	0.00
29	0.00	0.000	0.00		0.00	0.00	0.00
30	0.00	0.000	0.00		0.00	0.00	0.00
31	0.00	0.000	0.00		0.00	0.00	0.00
32	0.00	0.000	0.00		0.00	0.00	0.00
33	0.00	0.000	0.00		0.00	0.00	0.00
34	0.00	0.000	0.00		0.00	0.00	0.00
35	0.00	0.000	0.00		0.00	0.00	0.00
36	0.00	0.000	0.00		0.00	0.00	0.00
37	0.00	0.000	0.00		0.00	0.00	0.00
38	0.00	0.000	0.00		0.00	0.00	0.00
39	0.00	0.000	0.00		0.00	0.00	0.00
40	0.00	0.000	0.00		0.00	0.00	0.00
41	0.00	0.000	0.00		0.00	0.00	0.00
42	0.00	0.000	0.00		0.00	0.00	0.00
43	0.00	0.000	0.00		0.00	0.00	0.00
44	0.00	0.000	0.00		0.00	0.00	0.00
45	0.00	0.000	0.00		0.00	0.00	0.00
46	0.00	0.000	0.00		0.00	0.00	0.00
47	0.00	0.000	0.00		0.00	0.00	0.00
48	0.00	0.000	0.00		0.00	0.00	0.00
49	0.00	0.000	0.00		0.00	0.00	0.00
50	0.00	0.000	0.00		0.00	0.00	0.00
51	0.00	0.000	0.00		0.00	0.00	0.00
52	0.00	0.000	0.00		0.00	0.00	0.00
53	0.00	0.000	0.00		0.00	0.00	0.00
54	0.00	0.000	0.00		0.00	0.00	0.00

2.1.4. EARTHWKS

EARTHWKS

2.1.4.1. Introduction

EARTHWKS is a spreadsheet developed to calculate the mass diagram ordinate using the cut and fill quantities obtained from roadway cross sections. The original objective was to create a spreadsheet that would provide a dot-matrix printer plot of the mass diagram from the results of this spreadsheet. Another design objective for this spreadsheet was to have one variation which permitted the entry of ground elevations of the cross section with the specified finished profile cross section, then the spreadsheet would compute the cuts and fills for each cross section. While both of these are possible, it proved unwieldy and cumbersome such that both these objectives were abandoned. It is anticipated that programs to do these tasks and that can also interface with this spreadsheet will be developed in the future.

The input data include: station, template cut and fill per station, additional cut and fill per station, cut and fill required to rebuild embankment, cut and fill related to removal of pavement, unsuitable cut, and percent shrinkage.

The output generated includes: adjusted cut and fill

per station, adjusted fill + shrinkage, and mass diagram ordinate.

2.1.4.2. Using the Spreadsheet

The best way to begin using a spreadsheet is to obtain all pertinent data, record the data in a form that is easily transferred to the spreadsheet, and then input the data onto the spreadsheet. The data obtained from preliminary cross sections can be transferred to an input form. In this way this spreadsheet may be a useful tool in the early stages of design to determine what major vertical profile adjustments may be required to achieve earthworks balance before going to a computer generated set of cross sections for a final design. Once this input form record of the data is made, the user can proceed to use the spreadsheet.

The first step is to load the file from the disk to Multiplan. The master spreadsheet file is assumed to be stored on disk in a Normal Mode under the name EARTHWKS.MP. Once the master spreadsheet is loaded into the computer, turn the Recalculation option OFF (select Options command, then "tab key" to Recalc and highlight "off"). Then input the information in rows 13-14 (see Figure 13). These data include the project number, project name, preparer, checker, and dates the project was prepared and checked. Once the informative data are

input, the user then should input the station, template cut and fill per station, additional cut and fill per station, cut and fill required to rebuild embankment, cut and fill related to pavement removal, unsuitable cut, and percent shrinkage. All input data except the percent shrinkage can be obtained from the preliminary cross sections. The percent shrinkage (row 13 column 19, see Figure 13) is chosen according to the policy used in the engineer's office for the anticipated soil conditions and construction practices. All of these data are input for each station. Before viewing the output data generated by the spreadsheet, REMEMBER TO TURN THE RECALCULATION MODE OF SPREADSHEET OPERATION BACK TO "ON". After viewing the output data, the spreadsheet should be saved with a file name solely characteristic of the project for the purpose of reuse and later editing.

If the project has more stations than are provided by the spreadsheet, the user should insert additional rows just above the "Totals" line in the spreadsheet. The equations for adjusted cut and fill, adjusted fill + shrinkage, station (column 21, see Figure 13), mass diagram ordinate, and the section dividers should also be copied dowm into the inserted additional rows of the expanded spreadsheet.

2.1.4.3. Example Problem

There is not a readily adaptable example that can be shown in the space of this manual. To begin use, and as a check, the user should calculate the mass diagram ordinates for a project both by hand and using the spreadsheet the first time he or she uses this spreadsheet. In this way, the user can verify that the spreadsheet is working properly.

Figure 13. Input Template for EARTHWKS

```
         1         2         3         4         5         6         7
1 ***********************************************************************
2                    ROADWAY EARTHWORK COMPUTATIONS
3 ***********************************************************************
4
5       ++++++++++++++++++++++++++++++++++++++++++++++++++++++
6       +  Multiplan Microcomputer Spreadsheets for County   +
7       +   Hydraulic and Highway Engineering Computations   +
8       +          Copyright by Kent L. Ahrenholtz           +
9       +                   Version 1.0                      +
10      +                   1986                             +
11      ++++++++++++++++++++++++++++++++++++++++++++++++++++++
12
13 Project Number:          Prepared By:                  Date:
14 Project Name:            Checked By:                   Date:
15 -----------------------------------------------------------------------
16                                          Addit.     Rebuild  Pavement
17                                Template  Quant.     Embank.   Removal
18 Description      Station        Cut      +C          +C        -C
19 ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
20                  0.0000 |        0        0         0         0
21                         |
22                         |
23                         |
24                         |
25                         |
26                         |
27                         |
28                         |
29                         |
30                         |
31                         |
32                         |
33                         |
34                         |
35                         |
36                         |
37                         |
38                         |
39                         |
40                         |
41                         |
42                         |
43                         |
44                         |
45                         |
46                         |
47                         |
48                         |
49                         |
50                         |
51                         |
52                         |
53                         |
54                         |
```

Figure 13. (continued)

	1	2	3	4	5	6	7
55							
56							
57							
58							
59							
60							
61							
62							
63							
64							
65							
66							
67							
68							
69							
70							
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79							
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92							
93							
94							
95							
96							
97							
98							
99							
100							
101							
102							
103							
104							
105							
106							
107							
108		TOTALS ==>		0	0	0	0

Figure 13. (continued)

```
        8         9        10        11        12        13        14        15
 1 ***********************************************************************************
 2                        ROADWAY EARTHWORK COMPUTATIONS
 3 ***********************************************************************************
 4
 5
 6
 7
 8
 9
10
11
12
13
14
15
16   Addit.    Adjusted   Unsuit.   Unsuit.                    Addit.     Subt.
17   Quant.     Earth      C-3       C-5          Template     Quant.     Quant.
18    -C         Cut                              Fill         +F         -F
19 ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
20          0        XXX         0         0  |        0         0         0
21                    0                       |
22                    0                       |
23                    0                       |
24                    0                       |
25                    0                       |
26                    0                       |
27                    0                       |
28                    0                       |
29                    0                       |
30                    0                       |
31                    0                       |
32                    0                       |
33                    0                       |
34                    0                       |
35                    0                       |
36                    0                       |
37                    0                       |
38                    0                       |
39                    0                       |
40                    0                       |
41                    0                       |
42                    0                       |
43                    0                       |
44                    0                       |
45                    0                       |
46                    0                       |
47                    0                       |
48                    0                       |
49                    0                       |
50                    0                       |
51                    0                       |
52                    0                       |
53                    0                       |
54                    0                       |
```

Figure 13. (continued)

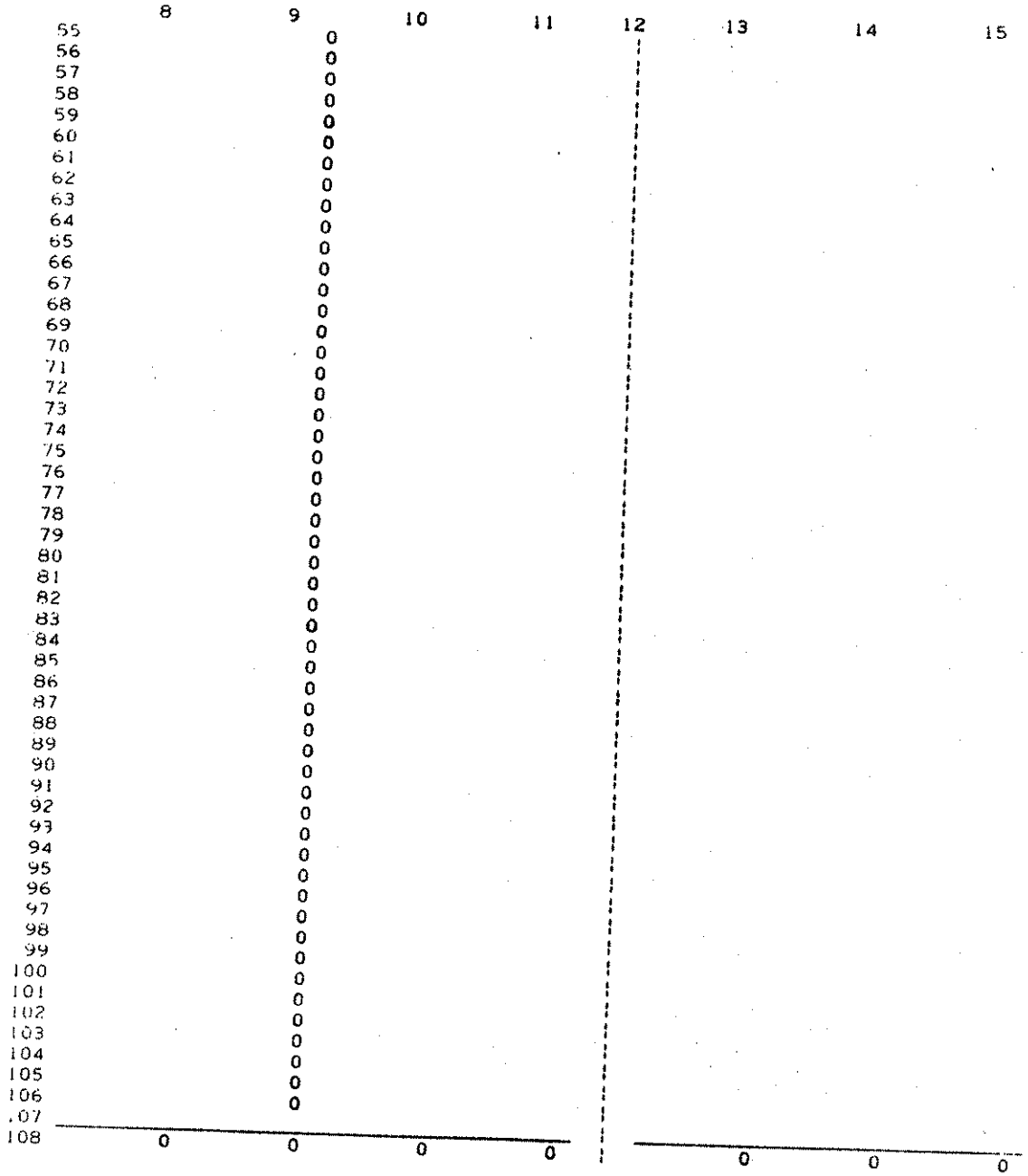

Figure 13. (continued)

```
     16         17         18         19      20       21         22
1 ***************************************************************************
2            ROADWAY EARTHWORK COMPUTATIONS
3 ***************************************************************************
4
5
6
7
8
9
10
11
12          ----------------------------------------
13          | Percent shrinkage =            percent |
14          ----------------------------------------
15
16   Rebuild  Pavement                Adjusted                          Mass
17   Embank.   Removal   Adjusted     Fill +                          Diagram
18     +F        +F        Fill     Shrinkage        Station        Ordinate
19 ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
20          0         0       XXX        XXX   |     0.0000            0
21                              0          0   |     0.0000            0
22                              0          0   |     0.0000            0
23                              0          0   |     0.0000            0
24                              0          0   |     0.0000            0
25                              0          0   |     0.0000            0
26                              0          0   |     0.0000            0
27                              0          0   |     0.0000            0
28                              0          0   |     0.0000            0
29                              0          0   |     0.0000            0
30                              0          0   |     0.0000            0
31                              0          0   |     0.0000            0
32                              0          0   |     0.0000            0
33                              0          0   |     0.0000            0
34                              0          0   |     0.0000            0
35                              0          0   |     0.0000            0
36                              0          0   |     0.0000            0
37                              0          0   |     0.0000            0
38                              0          0   |     0.0000            0
39                              0          0   |     0.0000            0
40                              0          0   |     0.0000            0
41                              0          0   |     0.0000            0
42                              0          0   |     0.0000            0
43                              0          0   |     0.0000            0
44                              0          0   |     0.0000            0
45                              0          0   |     0.0000            0
46                              0          0   |     0.0000            0
47                              0          0   |     0.0000            0
48                              0          0   |     0.0000            0
49                              0          0   |     0.0000            0
50                              0          0   |     0.0000            0
51                              0          0   |     0.0000            0
52                              0          0   |     0.0000            0
53                              0          0   |     0.0000            0
54                              0          0   |     0.0000            0
```

Figure 13. (continued)

	16	17	18	19	20	21	22
55			0	0		0.0000	0
56			0	0		0.0000	0
57			0	0		0.0000	0
58			0	0		0.0000	0
59			0	0		0.0000	0
60			0	0		0.0000	0
61			0	0		0.0000	0
62			0	0		0.0000	0
63			0	0		0.0000	0
64			0	0		0.0000	0
65			0	0		0.0000	0
66			0	0		0.0000	0
67			0	0		0.0000	0
68			0	0		0.0000	0
69			0	0		0.0000	0
70			0	0		0.0000	0
71			0	0		0.0000	0
72			0	0		0.0000	0
73			0	0		0.0000	0
74			0	0		0.0000	0
75			0	0		0.0000	0
76			0	0		0.0000	0
77			0	0		0.0000	0
78			0	0		0.0000	0
79			0	0		0.0000	0
80			0	0		0.0000	0
81			0	0		0.0000	0
82			0	0		0.0000	0
83			0	0		0.0000	0
84			0	0		0.0000	0
85			0	0		0.0000	0
86			0	0		0.0000	0
87			0	0		0.0000	0
88			0	0		0.0000	0
89			0	0		0.0000	0
90			0	0		0.0000	0
91			0	0		0.0000	0
92			0	0		0.0000	0
93			0	0		0.0000	0
94			0	0		0.0000	0
95			0	0		0.0000	0
96			0	0		0.0000	0
97			0	0		0.0000	0
98			0	0		0.0000	0
99			0	0		0.0000	0
100			0	0		0.0000	0
101			0	0		0.0000	0
102			0	0		0.0000	0
103			0	0		0.0000	0
104			0	0		0.0000	0
105			0	0		0.0000	0
106			0	0		0.0000	0
107			0	0		0.0000	0
108	0	0	0	0			

2.1.5. SUPERE

SUPERE

2.1.5.1. Introduction

SUPERE is a spreadsheet developed to establish superelevation for a horizontal curve. The spreadsheet will calculate the surveying data required to layout a superelevated horizontal curve in the field.

The input data include: design speed, lane width, rates of normal crown and superelevation, point of curvature, point of tangency, centerline grades at the P.C. and P.T., elevation of the P.C. and P.T., station increment, and desired length of runoff.

The output generated includes:

runoff data:

minimum length of runoff to establish superelevation,

actual design slope,

distance X required to raise outside edge of pavement to centerline elevation,

distance Y required to raise outside edge of pavement to a constant slope equal to the normal crown rate,

70% of runoff distance;

layout data:

centerline elevation,

difference in elevation from centerline, elevation, and cross slope for both outside and inside of curve pavement edges at beginning and end of curve;

stationing details:

beginning of superelevation runoff,

station at a distance X from the beginning of runoff,

station at a distance Y from the beginning of runoff, and

end of runoff.

2.1.5.2. Using the Spreadsheet

The best way to begin using a spreadsheet is to obtain all pertinent data, to record the data in a form that is easily transferred to the spreadsheet, and then input the data into the spreadsheet. The data obtained from preliminary roadway layouts and design manuals can be transferred to an input form. Once this is done, the user can proceed to use the spreadsheet.

The first step is to load the file from the disk to Multiplan. The master spreadsheet is assumed to be stored on disk as a file in Normal Mode under the name SUPERE.MP. Once the empty master spreadsheet is loaded, turn the Recalculation OFF by using the Options command. Then input the informative data in rows 12-15 (see Figure 14). These data include the project number, project

name, preparer, checker, and the dates the project was prepared and checked.

Once the informative data are input, the user should then input the design speed, pavement lane width, rates of normal crown and superelevation, centerline grades at the P.C. and P.T., point of curvature station, point of tangency station, P.C. and P.T. elevations, and station increment into rows 17-27 in column 4 (see Figure 14). The point of curvature, point of tangency, centerline grades at the P.C. and P.T., and P.C. and P.T. elevations can be obtained from the plan and profile sheets (see Figure 15). The design speed, lane width, rates of normal crown and superelevation, and station increment are determined by or under the supervision of a qualified engineer. The values for these data are all chosen according to the highway design policy in practice in the engineer's office. Before proceeding, the user should turn the Recalculation Mode of operation back to ON (reenter the Options command).

When the spreadsheet has been recalculated by the computer, the user should examine the output value for the "Minimum length of runoff to establish superelevation" (row 32 column 4, see Figure 14). The engineer should determine if this is the value the engineer wants to use for length of runoff. If Tables III-7 to III-11 from the AASHTO Green Book or comparable tables from the Iowa Department of Transportation Design

Procedures Manual are used to obtain a value for the length of runoff, the distance X (row 46, column 4, see Figure 14) needs to be added to the value for length of runoff taken from the book tables. This is necessary in order to compare the table values with those computed by the spreadsheet.

If the value the engineer chooses for length of runoff differs from that given by the program, the user needs to input the preferred value in space beside the question: "If not, what length of runoff do you wish to use?" (row 39, column 4, see Figure 14). If the engineer wishes to use the length of runoff computed by the spreadsheet, he or she needs to be sure that the cell described above (row 39, column 4) is empty. This is done by moving the cell pointer (illuminated block) to the cell in question (R39C4) and selecting the Blank command in the Multiplan command menu. These are all the required input data. The Recalculation Mode of operation should be in the ON status (go to the Options command to check), therefore, the output data is ready for viewing. After viewing the output data, the spreadsheet should be saved with a filename solely characteristic of the superelevated horizontal curve and project for the purpose of reuse and later editing.

2.1.5.3. Example Problem

The following is an example application of the spreadsheet previously described.

A farm-to-market paved county highway is to be designed and constructed in rural Iowa. From the plan and profile sheets, the point of curvature and point of tnagency are found to be 100 + 00.00 and 110 + 00.00, respectively. The P.C. is 900.00 feet above sea level and the P.T. is 890.00 feet above sea level. The centerline grades are 1% and -2% at the P.C. and the P.T., respectively. The design speed is 60 miles per hour. The pavement lane width is 12 feet. The rates of normal crown and the superelevation rate are selected as 2% and 8%, respectively, and the station increment is 25 feet.

The data are first entered on an input form. An example of one such input form with the example information entered is shown in Figure 16. After these data were entered into the spreadsheet and the Recalculation turned ON, the minimum length of runoff required to establish superelevation was found to be 266.4 feet. Assume the engineer wanted to use a value which was a multiple of the station increment, so the desired length of runoff of 275 feet was entered into the appropriate spreadsheet cell.

The completed spreadsheet is shown in Figure 17. The total output of the spreadsheet requires seven pages, but for layout of the curve in the field, only pages 3

through 6 are needed.

Figure 14. Input Template for SUPERE

```
         1                 2                 3                 4          5
 1 ***************************************************************************
 2          SUPERELEVATION COMPUTATIONS for HORIZONTAL CURVES
 3 ***************************************************************************
 4        ++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 5        +  Multiplan Microcomputer Spreadsheets for County    +
 6        +   Hydraulic and Highway Engineering Computations    +
 7        +          Copyright by Kent L. Ahrenholtz            +
 8        +                    Version 1.0                      +
 9        +                        1986                         +
10        ++++++++++++++++++++++++++++++++++++++++++++++++++++++++
11
12 Project Number:
13 Project Name:
14 Prepared By:                                  Date:
15 Checked By:                                   Date:
16 ---------------------------------------------------------------------------
17 INPUT DATA:     Design speed, V                  =         0 miles/hour
18 ~~~~~~~~~~~     Lane width                       =       0.0 feet
19                 Rate of normal crown             =       0.0 percent
20                 Rate of superelevation, e        =       0.0 percent
21                 Centerline grade, g (at P.C.)=       0.00 percent
22                                   g (at P.T.)=       0.00 percent
23                 Point of curvature, PC           =    0.0000 stations
24                 P.C. elevation                   =      0.00 feet
25                 Point of Tangency, PT            =    0.0000 stations
26                 P.T. elevation                   =      0.00 feet
27                 Station increment                =        25 feet
28 ---------------------------------------------------------------------------
29 RUNOFF DATA:    Maximum relative design
30 ~~~~~~~~~~~         slope for given design speed   =  1:#N/A
31                 Minimum length of runoff to
32                     establish superelevation =   #N/A   feet
33               ++++++++++++++++++++++++++++++++++++++++++++++++++
34               + Do you wish to use this value                   +
35               +        for runoff, YES or NO ?   YES            +
36               +                                                 +
37               + If not, what length of                          +
38               +    runoff do you wish to use ?           feet   +
39               ++++++++++++++++++++++++++++++++++++++++++++++++++
40 ---------------------------------------------------------------------------
41 OUTPUT DATA:    Runoff distance, S               =   #N/A   feet
42 ~~~~~~~~~~~     Actual design slope          = 1:#N/A
43                                              =       #N/A   percent
44                 Distance 'X' required to
45                     raise outside edge to
46                       centerline elevation   =   #N/A   feet
47
48                 Distance 'Y' required to
49                   raise outside edge to
50                    a constant slope equal
51                     to the normal crown rate =   #N/A   feet
52
53                 70% of superelevation runoff =   #N/A   feet
54 ---------------------------------------------------------------------------
```

Figure 15. Schematic of a Superelevated Horizontal Curve

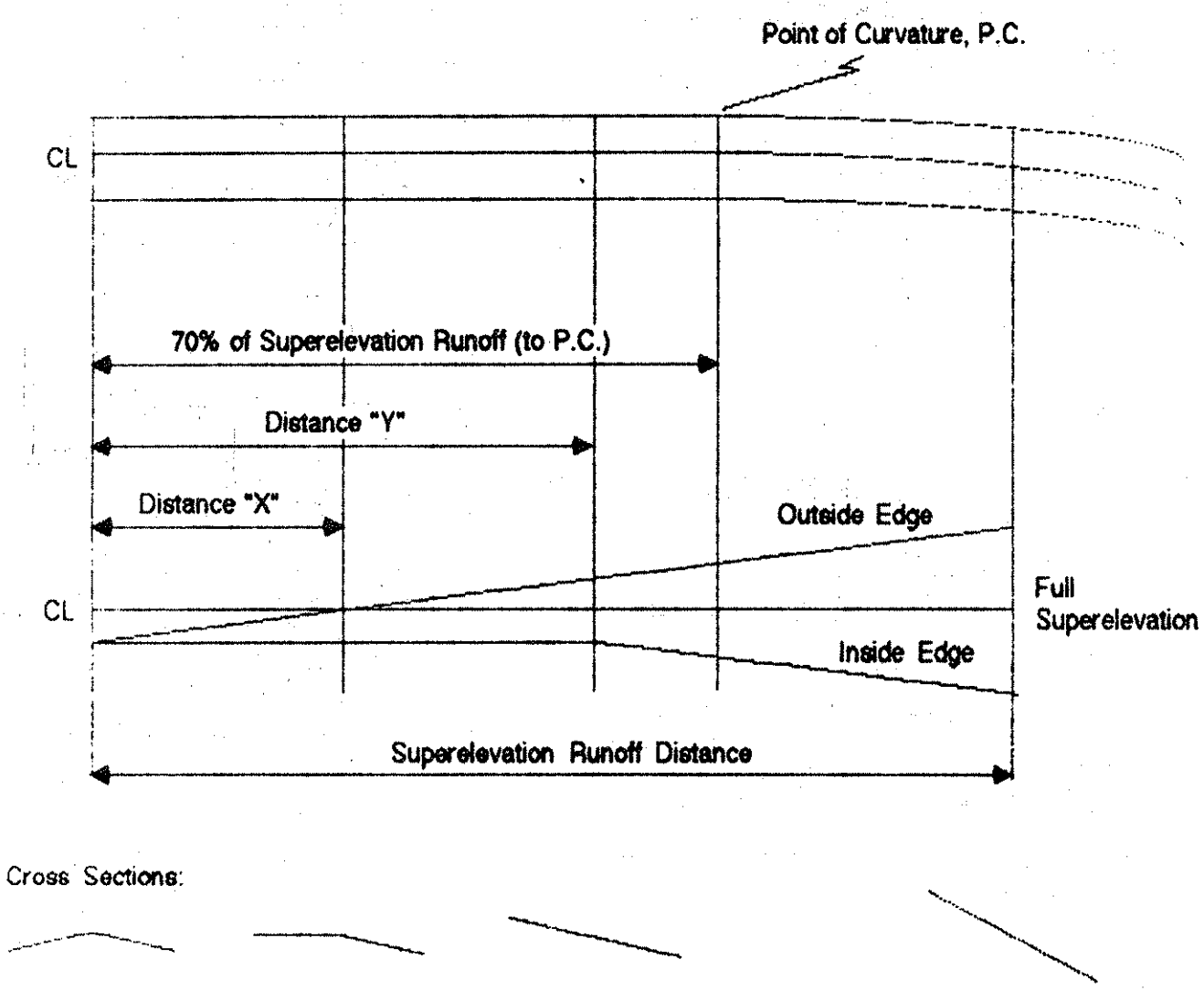

Figure 16. Input Form for Example Problem

****

SUPERELEVATION INPUT WORKSHEET

****

Project Number: 87-2

Project Name: Story Co. E57

Prepared By: Ahrenholtz Date: 06-17-87

Checked By: Brewer Date: 06-18-87

INPUT DATA:

Design Speed, V	=	60	miles/hr
Lane Width	=	12	feet
Rate of Normal Crown	=	2	percent
Rate of Superelevation, e	=	8	percent
Centerline Grade (at PC)	=	+1	percent
(at PT)	=	-2	percent
Point of Curvature, PC	=	100.0000	stations
P.C. Elevation	=	900.00	feet
Point of Tangency, PT	=	110.0000	stations
P.T. Elevation	=	890.00	feet
Station Increment	=	25	feet

* Be sure to check the length of the runoff after you have input the values above so it is the length you wish to use.

Figure 17. Example Problem Template

```
*****************************************************************
        SUPERELEVATION COMPUTATIONS for HORIZONTAL CURVES
*****************************************************************
      ++++++++++++++++++++++++++++++++++++++++++++++++++++
      +  Multiplan Microcomputer Spreadsheets for County   +
      +   Hydraulic and Highway Engineering Computations   +
      +          Copyright by Kent L. Ahrenholtz           +
      +                    Version 1.0                     +
      +                       1986                         +
      ++++++++++++++++++++++++++++++++++++++++++++++++++++

Project Number:
Project Name:
Prepared By:                                Date:
Checked By:                                 Date:
-----------------------------------------------------------------
INPUT DATA:     Design speed, V                =        60 miles/hour
~~~~~~~~~~~     Lane width                     =      12.0 feet
                Rate of normal crown           =       2.0 percent
                Rate of superelevation, e      =       8.0 percent
                Centerline grade, g (at P.C.)=      1.00 percent
                                  g (at P.T.)=     -2.00 percent
                Point of curvature, PC         = 100.0000 stations
                P.C. elevation                 =    900.00 feet
                Point of Tangency, PT          = 110.0000 stations
                P.T. elevation                 =    890.00 feet
                Station increment              =        25 feet
-----------------------------------------------------------------
RUNOFF DATA:    Maximum relative design
~~~~~~~~~~~         slope for given design speed   =  1:222
                Minimum length of runoff to
                    establish superelevation =    266.4 feet
              ++++++++++++++++++++++++++++++++++++++++++++++
              + Do you wish to use this value               +
              +        for runoff, YES or NO ?   YES        +
              +                                             +
              + If not, what length of                      +
              +    runoff do you wish to use ?          feet +
              ++++++++++++++++++++++++++++++++++++++++++++++
-----------------------------------------------------------------
OUTPUT DATA:    Runoff distance, S             =    266.4 feet
~~~~~~~~~~~     Actual design slope          = 1:222
                                             =      0.45    percent
                Distance 'X' required to
                    raise outside edge to
                      centerline elevation   =    53.28 feet

                Distance 'Y' required to
                  raise outside edge to
                   a constant slope equal
                    to the normal crown rate =   106.56 feet

                70% of superelevation runoff =   186.48 feet
-----------------------------------------------------------------
```

Figure 17. (continued)

TABLE III-13 from the AASHTO Green Book

DESIGN SPEED V (mph)	MAXIMUM RELATIVE SLOPES FOR PROFILES BETWEEN THE EDGE OF TWO-LANE PAVEMENT AND THE CENTERLINE
20	1:133
30	1:150
40	1:175
50	1:200
60	1:222
65	1:244
70	1:250

Figure 17. (continued)

LAYOUT DATA:

	Station	Difference in elevation from centerline (in feet)	OUTSIDE EDGE Elevation	Cross Slope (in percent)
BEGINNING OF CURVE:				
Section from =>	98.1352	-0.240	897.90	-2.00
beginning to	98.2500	-0.188	898.06	-1.57
the station at	98.5000	-0.076	898.42	-0.63
a distance 'Y'	98.7500	0.037	898.79	0.31
	99.0000	0.150	899.15	1.25
	99.2008	0.240	899.44	2.00
	0.0000	0.000	0.00	0.00
	0.0000	0.000	0.00	0.00
Section from =>	99.2008	0.240	899.44	2.00
the station at	99.2500	0.262	899.51	2.18
a distance 'Y'	99.5000	0.375	899.87	3.12
to the P.C.	99.7500	0.487	900.24	4.06
	100.0000	0.600	900.60	5.00
	0.0000	0.000	0.00	0.00
	0.0000	0.000	0.00	0.00
	0.0000	0.000	0.00	0.00
	0.0000	0.000	0.00	0.00
	0.0000	0.000	0.00	0.00
Section from =>	100.0000	0.600	900.60	5.00
the P.C. to	100.2500	0.713	900.96	5.94
the end of	100.5000	0.825	901.33	6.88
the runoff	100.7500	0.938	901.69	7.82
	100.7992	0.960	901.76	8.00
	0.0000	0.000	0.00	0.00
	0.0000	0.000	0.00	0.00
	0.0000	0.000	0.00	0.00
	0.0000	0.000	0.00	0.00
	0.0000	0.000	0.00	0.00
END OF CURVE:				
Section from =>	109.2008	0.960	892.56	8.00
the beginning	109.2500	0.938	892.44	7.82
of the runoff	109.5000	0.825	891.83	6.88
to the P.T.	109.7500	0.713	891.21	5.94
	110.0000	0.600	890.60	5.00
	0.0000	0.000	0.00	0.00
	0.0000	0.000	0.00	0.00
	0.0000	0.000	0.00	0.00
	0.0000	0.000	0.00	0.00
	0.0000	0.000	0.00	0.00
	0.0000	0.000	0.00	0.00

Figure 17. (continued)

LAYOUT DATA: (continued)

			OUTSIDE EDGE	
	Station	Difference in elevation from centerline (in feet)	Elevation	Cross Slope (in percent)
Section from => the P.T. to the station at a distance 'Y'	110.0000	0.600	890.60	5.00
	110.2500	0.487	889.99	4.06
	110.5000	0.375	889.37	3.12
	110.7500	0.262	888.76	2.18
	110.7992	0.240	888.64	2.00
	0.0000	0.000	0.00	0.00
	0.0000	0.000	0.00	0.00
	0.0000	0.000	0.00	0.00
	0.0000	0.000	0.00	0.00
	0.0000	0.000	0.00	0.00
	0.0000	0.000	0.00	0.00
Section from => the station at a distance 'Y' to the end	110.7992	0.240	888.64	2.00
	111.0000	0.150	888.15	1.25
	111.2500	0.037	887.54	0.31
	111.5000	-0.076	886.92	-0.63
	111.7500	-0.188	886.31	-1.57
	111.8648	-0.240	886.03	-2.00
	0.0000	0.000	0.00	0.00
	0.0000	0.000	0.00	0.00
	0.0000	0.000	0.00	0.00

Figure 17. (continued)

LAYOUT DATA:(continued)

INSIDE EDGE

Station	Difference in elevation from centerline (in feet)	Elevation	Cross Slope (in percent)	CENTERLINE ELEVATION
98.1352	-0.240	897.90	-2.00	898.14
98.2500	-0.240	898.01	-2.00	898.25
98.5000	-0.240	898.26	-2.00	898.50
98.7500	-0.240	898.51	-2.00	898.75
99.0000	-0.240	898.76	-2.00	899.00
99.2008	-0.240	898.96	-2.00	899.20
0.0000	0.000	0.00	0.00	0.00
0.0000	0.000	0.00	0.00	0.00
99.2008	-0.240	898.96	-2.00	899.20
99.2500	-0.262	898.99	-2.18	899.25
99.5000	-0.375	899.13	-3.12	899.50
99.7500	-0.487	899.26	-4.06	899.75
100.0000	-0.600	899.40	-5.00	900.00
0.0000	0.000	0.00	0.00	0.00
0.0000	0.000	0.00	0.00	0.00
0.0000	0.000	0.00	0.00	0.00
0.0000	0.000	0.00	0.00	0.00
0.0000	0.000	0.00	0.00	0.00
100.0000	-0.600	899.40	-5.00	900.00
100.2500	-0.713	899.54	-5.94	900.25
100.5000	-0.825	899.67	-6.88	900.50
100.7500	-0.938	899.81	-7.82	900.75
100.7992	-0.960	899.84	-8.00	900.80
0.0000	0.000	0.00	0.00	0.00
0.0000	0.000	0.00	0.00	0.00
0.0000	0.000	0.00	0.00	0.00
0.0000	0.000	0.00	0.00	0.00
0.0000	0.000	0.00	0.00	0.00
109.2008	-0.960	890.64	-8.00	891.60
109.2500	-0.938	890.56	-7.82	891.50
109.5000	-0.825	890.17	-6.88	891.00
109.7500	-0.713	889.79	-5.94	890.50
110.0000	-0.600	889.40	-5.00	890.00
0.0000	0.000	0.00	0.00	0.00
0.0000	0.000	0.00	0.00	0.00
0.0000	0.000	0.00	0.00	0.00
0.0000	0.000	0.00	0.00	0.00
0.0000	0.000	0.00	0.00	0.00
0.0000	0.000	0.00	0.00	0.00

Figure 17. (continued)

LAYOUT DATA: (continued)

INSIDE EDGE

Station	Difference in elevation from centerline (in feet)	Elevation	Cross Slope (in percent)	CENTERLINE ELEVATION
110.0000	-0.600	889.40	-5.00	890.00
110.2500	-0.487	889.01	-4.06	889.50
110.5000	-0.375	888.63	-3.12	889.00
110.7500	-0.262	888.24	-2.18	888.50
110.7992	-0.240	888.16	-2.00	888.40
0.0000	0.000	0.00	0.00	0.00
0.0000	0.000	0.00	0.00	0.00
0.0000	0.000	0.00	0.00	0.00
0.0000	0.000	0.00	0.00	0.00
0.0000	0.000	0.00	0.00	0.00
0.0000	0.000	0.00	0.00	0.00
110.7992	-0.240	888.16	-2.00	888.40
111.0000	-0.240	887.76	-2.00	888.00
111.2500	-0.240	887.26	-2.00	887.50
111.5000	-0.240	886.76	-2.00	887.00
111.7500	-0.240	886.26	-2.00	886.50
111.8648	-0.240	886.03	-2.00	886.27
0.0000	0.000	0.00	0.00	0.00
0.0000	0.000	0.00	0.00	0.00
0.0000	0.000	0.00	0.00	0.00

Figure 17. (continued)

STATIONING DETAILS:

At the Beginning of the Curve:

* Beginning of superelevation runoff, P.C.- 70% of runoff = 98.1352

* Station at a distance 'X' from beginning of superelevation runoff = 98.6680

* Station at a distance 'Y' from beginning of superelevation runoff = 99.2008

* Point of Curvature, P.C. = 100.0000

* End of superelevation runoff, P.C.+ 30% of runoff = 100.7992

First even incremental station after beginning of superelevation runoff = 98.2500

First even incremental station after a distance 'Y' from the beginning = 99.2500

First even incremental station after the point of curvature, P.C. = 100.2500

At the End of the Curve:

* Beginning of superelevation runoff, P.T.- 30% of runoff = 109.2008

* Point of Tangency, P.T. = 110.0000

* Station at a distance 'Y' from end of superelevation runoff = 110.7992

* Station at a distance 'X' from end of superelevation runoff = 111.3320

* End of superelevation runoff, P.T.+ 70% of runoff = 111.8648

First even incremental station after beginning of superelevation runoff = 109.2500

First even incremental station after the point of tangency, P.T. = 110.2500

First even incremental station after a distance 'Y' from the beginning = 111.0000

2.1.6. SIGNINV and MAINTREC

SIGNINV and MAINTREC

2.1.6.1. Introduction to SIGNINV

SIGNINV is a spreadsheet illustrating one (of many) approach to creating a traffic control device inventory using a spreadsheet program. A microcomputer data base program will permit creation of a traffic control device inventory system with more flexibility in manipulating the information contained in the file. However, if the need is for a systematic record from which reports may be generated periodically, then it is possible to create a workable and effective inventory system with a spreadsheet program. This spreadsheet is organized with the various traffic control device parameters entered in columns across the table and each control device occupies a row. Thus, as many traffic control devices can be entered as there are rows in a spreadsheet. For the smallest versions of Multiplan that operate on an Apple IIe computer, the spreadsheet contains 254 rows. For the largest versions for MS-DOS computers the spreadsheet contains over 4000 rows. In a practical sense, the number of rows that may be filled is dependent upon the computer memory size installed and the efficiency of the computer in allocating memory. Therefore, in this and similar applications, the user should prepare a SIGNINV1,

SIGNINV2, etc., to handle any massive data base.

The user should change the column headings to suit his or her needs in identifying traffic control devices. This illustrative design resulted from several consultations with county offices, the Iowa Division of the Federal Highway Administration and the Iowa Department of Transportation Office of Local Systems. It is intended, however, to be a guide to assist the user in generating application concepts to move beyond the scope of this report in using Multiplan (or any spreadsheet).

2.1.6.2. Introduction to MAINTREC

MAINTREC is a spreadsheet designed to work with SIGNINV to establish a record of the maintenance history for a traffic control device. It is designed to have a particular traffic control device occupy an entire row in the table. Note that the column headings contain identification information in the first few columns which is to correspond to the sign identification in SIGNINV. Subsequent columns in the table are a repeating pattern of recording a notice of need for maintenance and action taken. This permits establishing a record base of the maintenance history of the traffic control device. There are sufficient columns in the spreadsheet to permit retaining what is expected to be about 10 years activity on a traffic control device.

There is an advantage to having something such as a maintenance record in a separate file from an inventory. The maintenance record in the case of traffic control devices may be considered a sensitive record. In this manner, it is possible to keep different security levels for the inventory and the maintenance record. Someone looking at the inventory will not immediately find the maintenance history. In fact, it may be desirable to have files such as these on two completely different disks. Access to data and file security is always a concern in computer systems. Planning for it should be considered at the time records are established.

2.1.6.3. General Introduction

SIGNINV and MAINTREC are two spreadsheets developed to be used as a traffic control device inventory. SIGNINV can be used to store the location, type, and condition of the traffic control devices within an engineer's jurisdiction. MAINTREC can be used to store a record of the maintenance performed on each traffic control device.

The input data for SIGNINV include: sign number, sign location (township number, range number, section number, township name, and the engineer's choice for the exact location of the sign), sign legend, MUTCD number, sign position (direction sign is facing, lateral position such

as distance from roadway and side of road), number in assembly, sign characteristics (shape, color, size in horizontal and vertical dimensions, height, sign condition, sign reflectivity, and sign visibility), post characteristics (post type and post condition), inventory direction, inventory date, last date checked, maintenance record sheet, and remarks.

The input data for MAINTREC include: sign number (same as in SIGNINV), date reported, sign condition, recommended improvements, and date installed/serviced for each time a sign is repaired.

These spreadsheets were developed using the Traffic Sign Inventory System developed for the Iowa Department of Transportation by Johnson, Brickell, Mulcahy and Associates as a reference and a guide. The spreadsheets are similar to the sign inventory and maintenance record forms included in this document.

2.1.6.4. Using the Spreadsheets

The best way to begin using a spreadsheet is to obtain all pertinent data, record the data in a form that is easily transferred onto the spreadsheet, and then input the data into the spreadsheet. The data obtained in the field should be collected on an input form. The form can be made up by the engineer or it can be similar to the examples in the Traffic Sign Inventory System document.

Once the data have been collected, the user can proceed to use the spreadsheet.

The first step is to load either file from the disk into the computer operating in Multiplan. The files are assumed to be stored on disk in Normal Mode as SIGNINV.MP and MAINTREC.MP, respectively. Once the spreadsheet to be used is loaded into the computer, the data can be input from the appropriate field input form (examples shown in Figure 18).

2.1.6.5. SIGNINV

Before entering data, the engineer should decide upon a method to be used for the exact location of the sign to put into columns 7 and 8 (see Figure 18). Some suggestions for this include references to section corners and quarter-section corners, reference to the Iowa Department of Transportation's road number system, the ALAS link-node indentification system used for accident location, or by route number and referenced to section lines. These are only a few of the possible methods. The engineer may have another one he or she prefers. The most important thing to remember is the system must be inderstood and applied by all personnel who are involved in the sign inventory.

Once the user is prepared to begin, he or she should then input the data into the spreadsheet. These data for

SIGNINV include the sign number, sign location, sign legend, MUTCD number, direction facing, lateral position, number in assembly, sign characteristics, post characteristics, inventory direction, inventory date, last date checked, maintenance record sheet number, and any remarks (see Figure 18). All of these data can be obtained in a field inspection of traffic control devices, except for the MUTCD number which can be obtained from the Manual on Uniform Traffic Control Devices. Once the data have been entered, the spreadsheet should be saved with a filename characteristic of the position of the spreadsheet within the inventory (i.e., SIGNINV!, SIGNINV2, etc.).

One problem in using a spreadsheet to develop this inventory system is not being able to easily obtain a list of all signs of a specific type of a specific location unless the data is input in that fashion. This means, if the engineer wanted a list of all the STOP signs within his or her jurisdiction, it would be cumbersome to accomplish.

2.1.6.6. MAINTREC

When the user is prepared to begin using MAINTREC, the engineer should then input the data into the spreadsheet. These data include the sign number, date sign condition reported, condition, recommended improvements, and date

installed or repaired (see Figure 19). All of these data can be obtained from either a field inspection or a citizen callling in a problem with a sign. The sign number should be the same number as that used in SIGNINV for the sign in question. Once the data have been entered, the spreadsheet should be saved with a filename characteristic of the position of the spreadsheet within the inventory (i.e., MAINTREC1, MAINTREC2, etc.). The spreadsheet should also be labeled with a letter (i.e., A, B, C, etc.) in row 13 column 2 at the top of the sheet corresponding to its position in the inventory.

2.1.6.7. Example Problem

No example problem was developed for this spreadsheet due to the wide range of opinion on exactly how it should be applied.

Figure 18. Form of SIGNINV

```
     1    2    3    4    5              6                  7          8      9
 1 ***********************************************************************
 2                    TRAFFIC CONTROL DEVICE INVENTORY
 3 ***********************************************************************
 4
 5       ++++++++++++++++++++++++++++++++++++++++++++++++++++
 6       +  Multiplan Microcomputer Spreadsheets for County  +
 7       +   Hydraulic and Highway Engineering Computations  +
 8       +          Copyright by Kent L. Ahrenholtz          +
 9       +                     Version 1.0                   +
10       +                        1986                       +
11       ++++++++++++++++++++++++++++++++++++++++++++++++++++
12
13          ¦                    SIGN LOCATION                          ¦
14 SIGN     ¦                                                           ¦
15  NO.     ¦ Twns Range Sect   Township Name          ?          ?    ¦
16 ---------------------------------------------------------------------
17    1     ¦                                                           ¦
18    2     ¦                                                           ¦
19    3     ¦                                                           ¦
20    4     ¦                                                           ¦
21    5     ¦                                                           ¦
22    6     ¦                                                           ¦
23    7     ¦                                                           ¦
24    8     ¦                                                           ¦
25    9     ¦                                                           ¦
26   10     ¦                                                           ¦
27   11     ¦                                                           ¦
28   12     ¦                                                           ¦
29   13     ¦                                                           ¦
30   14     ¦                                                           ¦
31   15     ¦                                                           ¦
32   16     ¦                                                           ¦
33   17     ¦                                                           ¦
34   18     ¦                                                           ¦
35   19     ¦                                                           ¦
36   20     ¦                                                           ¦
37          ¦                                                           ¦
38          ¦                                                           ¦
39          ¦                                                           ¦
40          ¦                                                           ¦
41          ¦                                                           ¦
42          ¦                                                           ¦
43          ¦                                                           ¦
44          ¦                                                           ¦
45          ¦                                                           ¦
46          ¦                                                           ¦
47          ¦                                                           ¦
48          ¦                                                           ¦
49          ¦                                                           ¦
50          ¦                                                           ¦
51          ¦                                                           ¦
52          ¦                                                           ¦
53          ¦                                                           ¦
```

Figure 18. (continued)

```
         10              11              12          13          14
 1 ***********************************************************************
 2                    TRAFFIC CONTROL DEVICE INVENTORY
 3 ***********************************************************************
 4
 5
 6
 7
 8
 9
10
11
12
13                                                   LATERAL POSITION
14                                   DIRECTION    Distance   Side of
15   SIGN LEGEND    MUTCD NUMBER   SIGN FACING    (feet)      Road
16 -----------------------------------------------------------------------
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
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39
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41
42
43
44
45
46
47
48
49
50
51
52
53
```

Figure 18. (continued)

```
     15     16        17                  18           19   20      21
 1 ***********************************************************************
 2                              TRAFFIC CONTROL DEVICE INVENTORY
 3 ***********************************************************************
 4
 5
 6
 7
 8
 9
10
11
12
13                 |                  SIGN CHARACTERISTICS
14  NUMBER IN      |                                        Size
15   ASSEMBLY      |       Shape             Color        Horiz Vert  Height
16 ---------------------------------------------------------------------
17                 |
18                 |
19                 |
20                 |
21                 |
22                 |
23                 |
24                 |
25                 |
26                 |
27                 |
28                 |
29                 |
30                 |
31                 |
32                 |
33                 |
34                 |
35                 |
36                 |
37                 |
38                 |
39                 |
40                 |
41                 |
42                 |
43                 |
44                 |
45                 |
46                 |
47                 |
48                 |
49                 |
50                 |
51                 |
52                 |
53                 |
```

Figure 18. (continued)

```
          22                  23                  24
 1 ***********************************************************************
 2                    TRAFFIC CONTROL DEVICE INVENTORY
 3 ***********************************************************************
 4
 5
 6
 7
 8
 9
10
11
12
13                        SIGN CHARACTERISTICS
14
15   Sign Condition    Sign Reflectivity         Sign Visibility
16 -----------------------------------------------------------------------
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
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43
44
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46
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48
49
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53
```

Figure 18. (continued)

```
   25          26                  27          28     29        30
 1 ***************************************************************
 2                 TRAFFIC CONTROL DEVICE INVENTORY
 3 ***************************************************************
 4
 5
 6
 7
 8
 9
10
11
12
13 |          POST CHARACTERISTICS                |
14 |                                              | INVENTORY INVENTORY
15 |      Post Type        Post Condition         | DIRECTION   DATE
16 ----------------------------------------------------------------
17 |                                              |
18 |                                              |
19 |                                              |
20 |                                              |
21 |                                              |
22 |                                              |
23 |                                              |
24 |                                              |
25 |                                              |
26 |                                              |
27 |                                              |
28 |                                              |
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41 |                                              |
42 |                                              |
43 |                                              |
44 |                                              |
45 |                                              |
46 |                                              |
47 |                                              |
48 |                                              |
49 |                                              |
50 |                                              |
51 |                                              |
52 |                                              |
53 |                                              |
```

Figure 18. (continued)

```
      31          32                    33
 1 ***************************************************
 2                    TRAFFIC CONTROL DEVICE INVENTORY
 3 ***************************************************
 4
 5
 6
 7
 8
 9
10
11
12
13             MAINTENANCE
14  LAST DATE   RECORD,
15   CHECKED     SHEET                 REMARKS
16 ---------------------------------------------------
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
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```

Figure 19. Form of MAINTREC

```
    1    2        3                    4                                  5
 1 ***************************************************************************
 2                 TRAFFIC CONTROL DEVICE MAINTENANCE RECORD
 3 ***************************************************************************
 4
 5       +++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 6       +  Multiplan Microcomputer Spreadsheets for County     +
 7       +   Hydraulic and Highway Engineering Computations     +
 8       +            Copyright by Kent L. Ahrenholtz           +
 9       +                      Version 1.0                     +
10       +                         1986                         +
11       +++++++++++++++++++++++++++++++++++++++++++++++++++++++++
12
13 SHEET A
14
15 SIGN   |    DATE                                          RECOMMENDED
16  NO.   |  REPORTED          CONDITION                      IMPROVEMENTS
17 ---------------------------------------------------------------------------
18    1   |
19    2   |
20    3   |
21    4   |
22    5   |
23    6   |
24    7   |
25    8   |
26    9   |
27   10   |
28   11   |
29   12   |
30   13   |
31   14   |
32   15   |
33   16   |
34   17   |
35   18   |
36   19   |
37   20   |
38        |
39        |
40        |
41        |
42        |
43        |
44        |
45        |
46        |
47        |
48        |
49        |
50        |
51        |
52        |
53        |
54        |
```

Figure 19. (continued)

```
        6       7       8                   9
 1 ********************************************
 2
 3 ********************************************
 4
 5
 6
 7
 8
 9
10
11
12
13
14
15    DATE      |    DATE
16 INSTALLED    |  REPORTED          CONDITION
17 ---------------------------------------------
18              |
19              |
20              |
21              |
22              |
23              |
24              |
25              |
26              |
27              |
28              |
29              |
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44              |
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47              |
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49              |
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51              |
52              |
53              |
54              |
```

Figure 19. (continued)

```
                10                  11      12      13
 1 ***************************************************
 2
 3 ***************************************************
 4
 5
 6
 7
 8
 9
10
11
12
13
14
15        RECOMMENDED          DATE      |   DATE
16         IMPROVEMENTS      INSTALLED    |  REPORTED
17 ---------------------------------------------------
18                                        |
19                                        |
20                                        |
21                                        |
22                                        |
23                                        |
24                                        |
25                                        |
26                                        |
27                                        |
28                                        |
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50                                        |
51                                        |
52                                        |
53                                        |
54                                        |
```

Figure 19. (continued)

```
                14                          15                  16     17
 1 ***************************************************************************
 2
 3 ***************************************************************************
 4
 5
 6
 7
 8
 9
10
11
12
13
14
15                                  RECOMMENDED          DATE
16          CONDITION               IMPROVEMENTS       INSTALLED
17 ---------------------------------------------------------------------------
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
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```

2.2. Hydraulic Engineering Spreadsheets

2.2.1. DITCHFL

DITCHFL

MANNING'S EQUATION - OPEN CHANNEL GEOMETRICAL SECTIONS

2.2.1.1. Introduction

The "Manning's Equation - Open Channel Geometrical Section" spreadsheet was developed to find the normal depth of water given various hydraulic conditions. The program uses the Iteration Mode of operation available in Multiplan to compare an entered initial specified design flow and one calculated by the spreadsheet.

The input data consists of the ditch bottom, foreslope, backslope, Manning's n, ditch slope, design flow, and initial trial depth. Once the initial data are entered, the Iteration option is invoked and depth of flow for a given design will be calculated. The output consist only of the calculated flow depth.

2.2.1.2. Using the Spreadsheet

The best way to begin using this or any spreadsheet template is to collect all the pertinent data, record the data in a form that is easily transferred into the spreadsheet, and then enter the data into the spreadsheet. The first step is, thus, to collect the data and record it onto an input form. Once this is

accomplished, a person can begin to use the spreadsheet template.

The first step after completing the input form is to load the spreadsheet into the computer. The master template is assumed to be stored on a disk in the Normal Mode under the filename DITCHFL.MP. Once the master template is loaded into the computer, use the Options command from the Multiplan menu to turn OFF both the Recalculation option and the Iteration option for initial data entry. At this time the user can enter the data for project number, project name, preparer, checker and dates prepared and checked. These entry lines are found in rows 14 through 17 (see Figure 20).

After items have been entered in rows 14 through 17, enter the design parameters located in column 6 in rows 23 through 29 (see Figure 20). These items include: the ditch bottom width, foreslope, backslope, Manning's n, ditch slope, design flow to be accommodated, and the initial trial depth.

The ditch bottom width is entered in feet. For triangular cross-sections, the ditch bottom width should be 0.0 feet. The foreslope is the slope from the ditch bottom to the edge of the roadway shoulder. The backslope is that from the ditch bottom to the interception of natural ground surface at the outer right of way edge. The backslope and the foreslope are entered in the form Z:1 where Z is a horizontal distance in feet

(see Figure 21). The ditch slope is the average slope at the location for which the data apply and is entered in feet per feet. Manning's n should be the one that is best suited at the channel location where the flow depth is to be calculated. The design flow is the flow for which the normal depth is to be calculated. Design flow is entered in cubic feet per second (cfs). The final input parameter is the initial trial depth. The spreadsheet will work for any initial trial depth that is less than or nearly equal to the final depth. A value of 0.10 feet is recommended as a starting value for most conditions.

Once all the data are entered, the Recalculation option and the Iteration option are turned ON. At this time the spreadsheet will begin the recalculation and iteration to converge on a flow depth. When the iteration is complete the results are found in row 33 (see Figure 20).

Before making changes to more than one cell in the spreadsheet, turn the Iteration and the Recalculation options OFF. After making the changes in design parameters, then turn Iteration and Recalculation back ON. IF ANY RESULTS OF AN ITERATION ARE NEEDED FOR LATER USE, BE CERTAIN TO SAVE THE SPREADSHEET ON DISK AT THAT POINT BEFORE MAKING FURTHER CHANGES.

2.2.1.3. Example Problem

A ditch located along a county road has deteriorated to the point where it needs to be regraded to adequately drain the water. The final ditch design is one which requires the road to be located five feet above the bottom of the ditch. Three alternative designs have been proposed. These are shown in Figure 22. Table 1 shows the design parameters for each cross-section. Which ditch design should be used so that the water depth remains below the elevation of the roadway for the 100-year storm?

The data are taken from Table 1 and recorded onto input forms. These completed forms are shown in Figure 23. From the input forms, the data are input into the spreadsheet template. The results of each of the three examples are shown in Figures 24, 25 and 26.

One can now look at and compare the results. From this example it appears that the only ditch that will give a water depth below the roadway surface is cross-section 1 which has a water depth of 4.8 feet. The water depths for cross-sections 2 and 3 are 5.4 feet and 6.8 feet respectively which exceeds the design specification of 5.0 feet maximum depth of flow.

Table 1. Input data for example problem

Design parmeter	Cross - section 1	2	3
Ditch bottom (ft)	30	20	0
Foreslope (ft:1)	1:1	2:1	4:1
Backslope (ft:1)	1:1	2:1	4:1
Manning's N	0.02	0.02	0.02
Ditch slope (ft/ft)	0.01	0.01	0.01
100-year design flow (cfs)	3000	3000	3000
Initial trial depth (ft)	0.1	0.1	0.1

Figure 20. Input Template for Manning's Equation - Open Channel Geometric Section

```
      1         2         3         4         5         6
 1 ************************************************************
 2           MANNING'S EQUATION - OPEN CHANNEL GEOMETRIC SECTIO
 3 ************************************************************
 4
 5           ++++++++++++++++++++++++++++++++++++++++++++++++
 6           +  Multiplan Applications in Civil Engineering   +
 7           +              November 21, 1984                 +
 8           +         Copyright by Kenneth A. Brewer         +
 9           +           All Rights Reserved, 1984            +
10           +                  Version 1.4                   +
11           +            Revised March 27, 1987              +
12           ++++++++++++++++++++++++++++++++++++++++++++++++
13
14 Project Number      :
15 Project Name        :
16 Prepared By         :                          Date:
17 Checked By          :                          Date:
18
19 ------------------------------------------------------------
20
21 INPUT - Design Parameters
22 ~~~~~~~~~~~~~~~~~~~~~~~~~~
23                     Ditch bottom (FT) ----------->
24                     Foreslope (FT:1) ------------->
25                     Backslope (FT:1) ------------->
26                     Manning's N ------------------>
27                     Ditch slope (FT/FT) --------->
28                     Design flow (cfs) ----------->
29                     Initial trial depth (FT) ---->
30
31 ------------------------------------------------------------
32 OUTPUT
33 ~~~~~~              Calculated Flow Depth (FT)   =   #VALUE!
34
35 ------------------------------------------------------------
36
37 CALCULATIONS
38 ~~~~~~~~~~~~
39                     1.486/Mannning's N           =   #DIV/0!
40                     Calculated Flow Depth (FT)   =   #VALUE!
41                     Flow Area (SQ FT)            =   #VALUE!
42                     Wetted Perimeter (FT)        =   #VALUE!
43                     Hydraulic Radius (FT)        =   #VALUE!
44                     Calculated Velocity (FPS)    =   #VALUE!
45                     Test to Design Flow (cfs)    =   #VALUE!
46                     Delta Flow (cfs)             =   #VALUE!
47                     Initial Delta                =
48                     Delta Change                 =   #VALUE!
49                     Delta Check to Stop          =   TRUE
50                     Test for end:        #VALUE!
51
52 ------------------------------------------------------------
53
54           ************************************************
55           *      COPYRIGHT 1984, 1985, BY K. A. BREWER     *
56           ************************************************
```

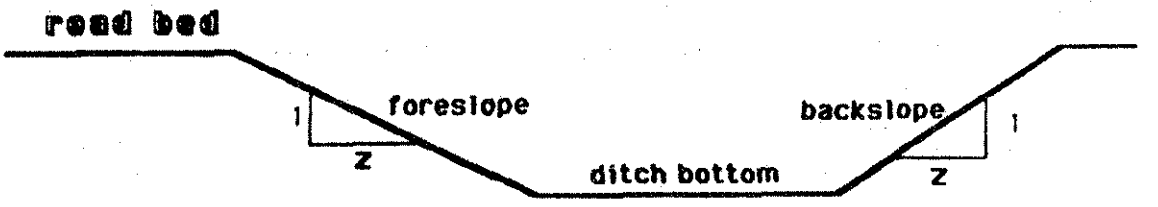


Figure 21. . Description of input varibles for channel cross-section

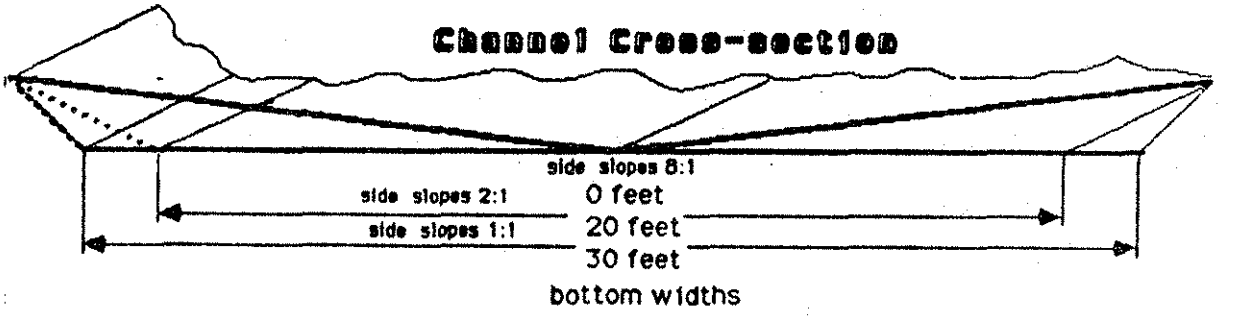


Figure 22. Cross-section for the three example problems.

Figure 23. Input Form for DITCHFL

INPUT FORM - Page 1

MANNING'S EQUATION - OPEN CHANNEL GEOMETRICAL SECTION

Project Number: _____

Project Name : _____

Prepared By : _____ Date: _____

Checked By : _____ Date: _____

****

INPUT - Design Parameters - Option 1

Ditch bottom ----------> 30 feet

Foreslope ----------> 1 ft:1

Backslope ----------> 1 ft:1

Manning's roughness coefficient (n) ---> 0.02

Ditch Slope ----------> 0.01 ft/ft

Design flow ----------> 3000 cfs

Initial trial depth ----------> 0.1 feet

****

INPUT - Design Parameters - Option 2

Ditch bottom ----------> _____ feet

Foreslope ----------> _____ ft:1

Backslope ----------> _____ ft:1

Manning's roughness coefficient (n) ---> _____

Ditch Slope ----------> _____ ft/ft

Design flow ----------> _____ cfs

Initial trial depth ----------> _____ feet

Figure 23. (continued)

INPUT FORM - (continued) - Page ____ of ____

MANNING'S EQUATION - OPEN CHANNEL GEOMETRICAL SECTION

Input Design Parameters - Option ____

Ditch bottom ----------> _____ feet

Foreslope ----------> _____ ft:1

Backslope ----------> _____ ft:1

Manning's roughness coefficient (n) ---> _____

Ditch Slope ----------> _____ ft/ft

Design flow ----------> _____ cfs

Initial trial depth ----------> _____ feet

****

INPUT - Design Parameters - Option ____

Ditch bottom ----------> _____ feet

Foreslope ----------> _____ ft:1

Backslope ----------> _____ ft:1

Manning's roughness coefficient (n) ---> _____

Ditch Slope ----------> _____ ft/ft

Design flow ----------> _____ cfs

Initial trial depth ----------> _____ feet

****

INPUT - Design Parameters - Option ____

Ditch bottom ----------> _____ feet

Foreslope ----------> _____ ft:1

Backslope ----------> _____ ft:1

Manning's roughness coefficient (n) ---> _____

Ditch Slope ----------> _____ ft/ft

Design flow ----------> _____ cfs

Initial trial depth ----------> _____ feet

Figure 24. Example Problem 1 Template

```
*****************************************************************
        MANNING'S EQUATION - OPEN CHANNEL TRAPEZOIDAL SECTION
*****************************************************************

          ++++++++++++++++++++++++++++++++++++++++++++++++
          +  Multiplan Applications in Civil Engineering   +
          +              November 21, 1984                 +
          +         Copywrite by Kenneth A. Brewer         +
          +                  Version 1.2                   +
          +            Revised August 19, 1986             +
          ++++++++++++++++++++++++++++++++++++++++++++++++

Project Number      :        1
Project Name        :Example problem 1
Prepared By         :Rocky Keehn                Date:9/9/86
Checked By          :Rocky Keehn                Date:9/9/86

-----------------------------------------------------------------

INPUT - Design Parameters
~~~~~~~~~~~~~~~~~~~~~~~~~
                    Ditch bottom (FT) ----------->       30
                    Foreslope (FT:1) ------------>        1
                    Backslope (FT:1) ------------>        1
                    Manning's N ----------------->     0.02
                    Ditch slope (FT/FT) --------->     0.01
                    Design flow (cfs) ----------->     3000
                    Initial trial depth (FT) ---->     0.10

-----------------------------------------------------------------

CALCULATIONS
~~~~~~~~~~~~
                    1.486/Mannning's N          =    74.30
                    Calculated Flow Depth (FT)  =     4.76
                    Flow Area (SQ FT)           =   165.45
                    Wetted Perimeter (FT)       =    43.46
                    Hydraulic Radius (FT)       =     3.81
                    Calculated Velocity (FPS)   =    18.12
                    Test to Design Flow (cfs)   =  2998.41
                    Delta Flow (cfs)            =   1.5896
                    Initial Delta               =
                    Delta Change                =     0.00
                    Delta Check to Stop         =    TRUE
                    Test for end:       CONTINUE ITERATION

-----------------------------------------------------------------

OUTPUT
~~~~~~
                    Calculated Flow Depth (FT)  =     4.76

-----------------------------------------------------------------

          ***********************************************
          *      COPYRIGHT 1984, 1985, BY K. A. BREWER  *
          ***********************************************
```

Figure 25. Example Problem 2 Template

```
*****************************************************************
          MANNING'S EQUATION - OPEN CHANNEL TRAPEZOIDAL SECTION
*****************************************************************

          +++++++++++++++++++++++++++++++++++++++++++++++++
          +  Multiplan Applications in Civil Engineering   +
          +              November 21, 1984                 +
          +         Copywrite by Kenneth A. Brewer         +
          +                  Version 1.2                   +
          +            Revised August 19, 1986             +
          +++++++++++++++++++++++++++++++++++++++++++++++++

Project Number      :        1
Project Name        :Example problem 2
Prepared By         :Rocky Keehn                Date:9/9/86
Checked By          :Rocky Keehn                Date:9/9/86

-----------------------------------------------------------------

INPUT - Design Parameters
~~~~~~~~~~~~~~~~~~~~~~~~~
                    Ditch bottom (FT) ----------->        20
                    Foreslope (FT:1) ------------>         2
                    Backslope (FT:1) ------------>         2
                    Manning's N ----------------->      0.02
                    Ditch slope (FT/FT) --------->      0.01
                    Design flow (cfs) ----------->      3000
                    Initial trial depth (FT) ---->      0.10

-----------------------------------------------------------------

CALCULATIONS
~~~~~~~~~~~~
                    1.486/Mannning's N            =    74.30
                    Calculated Flow Depth (FT)    =     5.40
                    Flow Area (SQ FT)             =   166.52
                    Wetted Perimeter (FT)         =    44.17
                    Hydraulic Radius (FT)         =     3.77
                    Calculated Velocity (FPS)     =    18.01
                    Test to Design Flow (cfs)     =  2998.26
                    Delta Flow (cfs)              =   1.7379
                    Initial Delta                 =
                    Delta Change                  =     0.00
                    Delta Check to Stop           =   TRUE
                    Test for end:       CONTINUE ITERATION

-----------------------------------------------------------------

OUTPUT
~~~~~~
                    Calculated Flow Depth (FT)    =     5.40

-----------------------------------------------------------------

          ***************************************************
          *      COPYRIGHT 1984, 1985, BY K. A. BREWER      *
          ***************************************************
```

Figure 26. Example Problem 3 Template

```
*****************************************************************
          MANNING'S EQUATION - OPEN CHANNEL TRAPEZOIDAL SECTION
*****************************************************************

          +++++++++++++++++++++++++++++++++++++++++++++++++
          +  Multiplan Applications in Civil Engineering   +
          +              November 21, 1984                 +
          +          Copywrite by Kenneth A. Brewer        +
          +                  Version 1.2                   +
          +            Revised August 19, 1986             +
          +++++++++++++++++++++++++++++++++++++++++++++++++

Project Number      :        1
Project Name        :Example problem 3
Prepared By         :Rocky Keehn              Date:9/9/86
Checked By          :Rocky Keehn              Date:9/9/86

-----------------------------------------------------------------

INPUT - Design Parameters
~~~~~~~~~~~~~~~~~~~~~~~~~
                    Ditch bottom (FT) ----------->        0
                    Foreslope (FT:1) ------------>        4
                    Backslope (FT:1) ------------>        4
                    Manning's N ----------------->     0.02
                    Ditch slope (FT/FT) --------->     0.01
                    Design flow (cfs) ----------->     3000
                    Initial trial depth (FT) ---->     0.10

-----------------------------------------------------------------

CALCULATIONS
~~~~~~~~~~~~
                    1.486/Mannning's N            =    74.30
                    Calculated Flow Depth (FT)    =     6.76
                    Flow Area (SQ FT)             =   182.79
                    Wetted Perimeter (FT)         =    55.74
                    Hydraulic Radius (FT)         =     3.28
                    Calculated Velocity (FPS)     =    16.41
                    Test to Design Flow (cfs)     =  2998.74
                    Delta Flow (cfs)              =   1.2565
                    Initial Delta                 =
                    Delta Change                  =     0.00
                    Delta Check to Stop           =   TRUE
                    Test for end:        CONTINUE ITERATION

-----------------------------------------------------------------

OUTPUT
~~~~~~              Calculated Flow Depth (FT)    =     6.76

-----------------------------------------------------------------

          ***********************************************
          *      COPYRIGHT 1984, 1985, BY K. A. BREWER  *
          ***********************************************
```

2.2.2. RUNOFF

RUNOFF

2.2.2.1. Introduction

RUNOFF is a spreadsheet developed to estimate the amount of runoff from most all watersheds in Iowa. The spreadsheet can be used to calculate runoff based on the "Iowa Runoff Chart" and the "Iowa Natural Resources Council Bulletin Number 11".

Input for the Iowa Runoff Chart consist of the drainage area and the land use factor (LF). For Bulletin 11, a person needs to input the drainage area, the Iowa hydrologic region in which the watershed is located, model number if the watershed is in Region I, and slope if the watershed is in Region I and Model 2 is used.

The output generated for both methods is the peak discharges for the 2-, 5-, 10-, 25-, 50-, 100-, and 500-year recurrence intervals for storms.

2.2.2.2. Using the Spreadsheet

The best way to begin using a spreadsheet is to obtain all pertinent data, record the data in a form that is easily transferred into the spreadsheet, and then input the data into the spreadsheet. The data obtained in the field, from topographic maps, and engineering principles

can be transferred to an input form. Once this is done, a person can proceed to use the spreadsheet.

The first step in spreadsheet use is to load the master spreadsheet as a file from a disk drive to place it under the control of the Multiplan program. Assume the spreadsheet is stored on disk in the Normal Mode and is named RUNOFF.MP. Once the spreadsheet is loaded into the computer, enter the Multiplan command menu Options command and turn the Recalculation option OFF. Then enter the informative data in rows 13 through 16 (see Figure 27). This data includes the project number, project name, preparer, checker, and dates the project was prepared and checked.

Once the informative data are input, the user needs to enter the method to be used by the spreadsheet and the units of the drainage area as it is tabulated. The first choice the user must make is whether to use the Iowa Runoff Chart (input a number 1), Bulletin 11 (input a number 2), or both (input a number 3) to calculate the peak rate of runoff. The input for this choice is located in row 23, column 5 (see Figure 27). After the method(s) are chosen, the user must enter the units for the drainage area datum. If the area is to entered as square miles, put a number 1 in row 35, column 6 (see Figure 27). If the area is in acres, enter a number 2 in row 35, column 6. Once these two steps are complete, enter the Multiplan command for Options and turn

Recalculation ON. Wait until the computer has recalculated the spreadsheet, and then enter the drainage area in row 41, column 6 (see Figure 27).

2.2.2.3. Iowa Runoff Chart

If the user selects choice 1 or 3 in row 35, column 6 he or she can find the peak discharges using the Iowa Runoff Chart. The only datum the user needs to enter is the land use factor (LF) in row 67, column 2 (see Figure 27). The user can "unlock" cell R36C1 if he or she wishes to enter a description of the land use for later reference.

The values for LF can be found in one of three sources. These are: the original paper, Table 2, and by entering "IOWA" in the Goto Name command in the Multiplan command menu.

Table 2. Values for LF

	Land Description				
Land Use	Very Hilly	Hilly	Rolling	Flat	Very Flat No Ponds
Mixed Cover	1.00	0.80	0.60	0.40	0.20
Permanent Pasture	0.60	0.50	0.40	0.20	0.10
Permanent Woods	0.30	0.25	0.20	0.10	0.05

Once the LF factor has been entered, the results for

several recurrence intervals are calculated. All the results are based on the equation for a direct calculation of a peak Q except the 2-year and the 500-year interval which are based on a linear regression equation developed from the other recurrence intervals.

If the user specifies using only the Iowa Runoff Chart, the output data can be examined beginning in row 74, column 2. If Bulletin 11 output is also desired, then the user should now enter the data for this method of calculation. If only the Iowa Runoff Chart is to be used, the spreadsheet results should now be saved with a filename solely characteristic of the watershed, for later use and reference in design.

Since discharges are calculated by equations, there will always be results no matter what input is used. However, there are application limits to the variables. These limits are given in Table 3. If the drainage area or the LF factor does not fall within the specified limits, the output for the Iowa Runoff Chart will be suppressed. To warn users of problems with the input, special "flags" were included (see Figure 28).

2.2.2.4. Bulletin 11

If a value of 2 or 3 is entered in row 23, column 7, results from Bulletin 11 can be calculated. The data needed for Bulletin 11 may vary depending upon what part

of Iowa the drainage area is located, and whether the slope of the main channel can be calculated. The Bulletin 11 portion of the spreadsheet works better if the Recalculation option is ON at all times.

The segregation fo Iowa into regions for runoff analysis is depicted in Figure 29. The slashed area can be either in Region I or II. In the input box for "Region I(1) or II(2)" (in row 67, column 7), input either the number 1 for Region I or a number 2 for Region II (BE CERTAIN THAT THE RECALCULATION IS ON!). If Region II is used, the data inputs are complete. The results are then displayed beginning in row 74, columns 6 and 7.

If Region I contains the watershed, the spreadsheet will prompt the user for which model is to be used (row 68, column 7). Model 1 is to be used when a good determination of the main channel slope CANNOT be made, otherwise Model 2 is to be used. If Model 1 (input a number 1 when the spreadsheet prompts for selecting a model) is chosen, then the calculations will be complete at that point. The results may be reviewed beginning in row 74, column 6. If Model 2 is utilized, then one more item of information must be entered.

Once a number 2 is entered in response to "Model 1(1) or 2(2)" in row 68, column 7, the slope input will appear on the screen. The slope should be the 10/85 slope (refer to Bulletin 11, page 41, for the procedure to calculate the 10/85 slope) and it is input in feet per

mile. Once this item is entered, the computational results are again found in row 74, columns 6 and 7.

The output for this method includes an estimation for the 500-year storm. This value is based on a linear regression equation calculated from the other recurrence intervals. If the user is satisfied with the results, the spreadsheet should be saved on disk under a unique name for later reference.

As was the case with the Iowa Runoff Chart, limits are needed on the variables so that the equations are not misused. These limits are given in Table 3. If these limits are exceeded the spreadsheet will not display the output data for Bulletin 11 (except errors in the slope). If an error occurs, the user is warned and should then make the necessary adjustments (Figure 28 illustrates the error messages).

2.2.2.5. Rounding the Output

The output can be set to be rounded to a specified precision. The output data are broken into two sets. The first set consists of output values less than 1000. The second set consists of those values greater than or equal to 1000. The cells that contain the location for entering the rounding limits are located to the right of the final peak discharge output beginning in cell R74C11 and ending in cell R80C17.

The user specifies the range for rounding by entering a specific value in row 78, column 12 for number less than 1000 and row 79, column 12 for values greater than or equal to 1000. The following values can be entered:

0 for integer result,

-1 for rounding to tens,

-2 for rounding to hundreds, etc.

For example, if the calculated runoff was 4215.6 cfs, then a value of 0 would cause the output to report 4216 cfs, a value of -1 would result in an output of 4220 cfs, a value of -2 would yield an output of 4200 cfs, and a value of -3 would produce an output of 4000 cfs. It is recommended that a value of -1 be used for output of less than 1000 cfs and a value of -2 be entered for output greater than or equal to 1000 cfs.

Table 3. Limits on variables for RUNOFF

Variable	Range of values
Iowa Runoff Chart	
Recurrence intervals (years)	2*, 5, 10, 25, 50, 100, or 500*
Area (acres)	1 <= area <= 70,000
LF (unitless)	0.05 <= LF <= 1.00
Bulletin 11	
Recurrence intervals (years)	2, 5, 10, 25, 50, 100, or 500*
Area (square miles)	2 <= area <= 14,038
10/85 Slope (ft/mi)	1 <= slope <= 100

* Estimated by linear regression

2.2.2.6. Example Problem

One item that may concern or confuse the user is the numbers remaining in the spreadsheet from previous calculations. The best way to demonstrate this problem is by the following application example.

A culvert is to be constructed under a county highway in central Iowa. The drainage area is totally permanent pasture and is located in Story County (therefore, it is Region I or Region II) and has topography that can be described as rollling. The design storm is 50 years; the major storm is 100 years; the area is 10,000 acres (15.625 square miles); and the slope of the main channel is 9 feet per mile. Check the runoff for both Bulletin 11 and for the Iowa Runoff Chart.

Since the location of the watershed is in Region I and the slope of the main stream is known, Region I Model 2 is used for Bulletin 11. The data are first entered on an input form. An example of the input form is shown in Figure 30.

The completed spreadsheet is shown in Figure 31. After this computation, the user desired to check Region II results against those already calculated. Since the values for the Iowa Runoff Chart were already calculated, only Bulletin 11 data were input.

The number 2 is input in the cell to change the spreadsheet to output only data for Bulletin 11. Once this task is complete, the recalculation takes place. When the recalculation is complete, the number 2 is entered into the cell that contains the "region option". The results of this computation are shown in Figure 32.

The user can now see the extra values in the cells below where the region option is entered for Bulletin 11, and to the left of these cells, input leftover from applying the Iowa Runoff Chart. These data are from the previous computation using Bulletin 11 and the Iowa Runoff Chart. The numbers have no effect on the computational results (compare the results shown in Figures 32 and 33), but are a bit confusing as a person views the spreadsheet. To correct this confusion, a user needs to move the cell pointer to the cells in the spreadsheet containing the "extra or unnecessary" values and blank them out with the Blank command from the Multiplan menu. Figure 33 illustrates the spreadsheet after the "leftover" data are blanked out.

The results from the spreadsheet indicate that if the Iowa Runoff Chart is used to calculate the runoff, the design discharge is 1100 cfs and the major discharge is 1300 cfs. For Bulletin 11, Region II Model 2, the values are 3700 cfs for the design runoff and 4700 cfs for the major storm. And finally, for Bulletin 11, Region II the results are 1000 cfs for the design storm and 1200 cfs

for the major storm.

Figure 27. Location of Input Data for RUNOFF

```
         1         2         3         4         5         6         7         8
 1 ***************************************************************************
 2                                  RUNOFF
 3 ***************************************************************************
 4
 5        ++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 6        +  Multiplan Microcomputer Spreadsheets for County     +
 7        +   Hydraulic and Highway Engineering Computations     +
 8        +              Copyright by Rocky J. Keehn             +
 9        +                     Version 3.0                      +
10        +                        1986                          +
11        ++++++++++++++++++++++++++++++++++++++++++++++++++++++++
12
13 Project Number:1
14 Project Name   :Example Problem
15 Prepared By    :Rocky J. Keehn                        Date:11-15-86
16 Checked By     :Rocky J. Keehn                        Date:11-15-86
17
18 ---------------------------------------------------------------------------
19 INPUT
20 ~~~~~              ++++++++++++++++++++++++++++++++++++++++++++++++++++
21                    +    METHOD USED TO CALCULATE RUNOFF                +
22                    +    ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~               +
23                    +         Choose one from below (1-3) --->      3 +
24                    +         1 - Iowa Runoff Chart                    +
25                    +         2 - Bulletin No. 11                      +
26                    +         3 - both methods                         +
27                    + + + + + + + + + + + + + + + + + + + + + + + + + + +
28                    +     TO GET HELP                                  +
29                    +     ~~~~~~~~~~~                                  +
30                    +         For both methods                         +
31                    +        Goto IOWA OR BULL11                       +
32                    + + + + + + + + + + + + + + + + + + + + + + + + + + +
33                    +    UNITS USED WHEN INPUTTING THE AREA            +
34                    +    ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~            +
35                    +         Choose 1 or 2 --------->      2           +
36                    +             1 - square miles                     +
37                    +             2 - acres                            +
38                    + + + + + + + + + + + + + + + + + + + + + + + + + + +
39                    +     INPUT THE AREA                               +
40                    +     ~~~~~~~~~~~~~~                               +
41                    +         Area ------------------>  70000 acres    +
42                    +                                                  +
43                    +                                                  +
44                    +                                                  +
45                    +                                                  +
46                    +                                                  +
47                    +         --- Helpful Output ---                   +
48                    +         Area ------------------>109.375 sq mi    +
49                    +                                                  +
50                    ++++++++++++++++++++++++++++++++++++++++++++++++++++
51
52 ---------------------------------------------------------------------------
53 RESULTS
54 ~~~~~~~
55  + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + +
56 Project Number:1
57 Project Name   :Example Problem
58 Prepared By    :Rocky J. Keehn                        Date:11-15-86
59 Checked By     :Rocky J. Keehn                        Date:11-15-86
60
61  + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + +
62 *** IOWA RUNOFF CHART ***                  *** BULLETIN 11 ***
63  --- Helpful Output ---                  --- Helpful Output ---
64  Area (acres) >     70000                Area (sq mi) ---------->109.375
65
         1         2         3         4         5         6         7         8
66  --- Please input ---                   --- Please input ---
67  LF ---------->          1               Region I(1) OR II(2) ->       1
68                                          Model 1(1) OR 2(2) --->       2
69  Goto LF FOR HELP                        10/85 slope (ft/mi) -->     100
70
71
72
73  + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + +
```

Figure 28. Input Template with Error Message for RUNOFF

```
38                + + + + + + + + + + + + + + + + + + + + + + + + + + +
39                +     INPUT THE AREA                                +
40                +     ~~~~~~~~~~~~~~                                +
41                +         Area ------------------>  15001 sq mi    +
42                +                                                   +
43                +                                                   +
44                + NOTE: AREA TOO LARGE TO USE IOWA RUNOFF CHART     +
45                +                                                   +
46                + NOTE: AREA TOO LARGE TO USE BULLETIN 11           +
47                +         --- Helpful Output ---                    +
48                +         Area ------------------>  15001 sq mi    +
49                +                                                   +
50                +++++++++++++++++++++++++++++++++++++++++++++++++++++
```

```
          1            2      3         4          5     6        7     8
19 INPUT
20 ~~~~~          ++++++++++++++++++++++++++++++++++++++++++++++++++++
21                +    METHOD USED TO CALCULATE RUNOFF                +
22                +    ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~+
23                +         Choose one from below (1-3) --->      4 +
24                +         1 - Iowa Runoff Chart                   +
25                +         2 - Bulletin No. 11                     +
26                +         3 - both methods                        +
27                + + + + + + + + + + + + + + + + + + + + + + + + + + +
28                +    TO GET HELP                                  +
29                +    ~~~~~~~~~~~                                  +
30                +              ERROR - method used number incorrect+
31                +                      or area out-of-range        +
32                + + + + + + + + + + + + + + + + + + + + + + + + + + +
33                +    UNITS USED WHEN INPUTTING THE AREA           +
34                +    ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~+
35                +         Choose 1 or 2 --------->      2          +
36                +             1 - square miles                     +
37                +             2 - acres                            +
38                + + + + + + + + + + + + + + + + + + + + + + + + + + +
39                +    INPUT THE AREA                               +
40                +    ~~~~~~~~~~~~~~                               +
41                +         Area ------------------>      1 acres   +
42                +                                                  +
43                + NOTE: AREA TOO SMALL TO USE IOWA RUNOFF CHART    +
44                +                                                  +
45                + NOTE: AREA TOO SMALL TO USE BULLETIN 11          +
46                +                                                  +
47                +         --- Helpful Output ---                   +
48                +         Area ------------------>0.00156 sq mi   +
49                +                                                  +
50                ++++++++++++++++++++++++++++++++++++++++++++++++++++
61 + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + +
62 *** IOWA RUNOFF CHART ***                  *** BULLETIN 11 ***
63  --- Helpful Output ---                 --- Helpful Output ---
64  Area (acres) >    10000                Area (sq mi) ---------> 15.625
65
66  --- Please input ---                   --- Please input ---
67  LF ---------->      0.04               Region I(1) OR II(2) ->      1
68                                         Model 1(1) OR 2(2) --->      2
69  *** ERROR ***                          10/85 slope (ft/mi) -->    101
70 LF incorrect-Help at Goto LF            *** POSSIBLE ERROR ***
71                                         Check your Region number,
72                                         Model number, or slope value
73 + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + +
74                          *** PEAK DISCHARGES ***
75          IOWA RUNOFF CHART                                BULLETIN 11
76                                                           ~~~~~~~~~~~
77       NOT USED                                       Q2   ----->   2100 cfs
78                                                      Q5   ----->   3900 cfs
79                                                      Q10  ----->   5200 cfs
80                                                      Q25  ----->   7000 cfs
81                                                      Q50  ----->   8400 cfs
82                                                      Q100 ----->   9900 cfs
```

Figure 29. Hydrologic Regions of Iowa

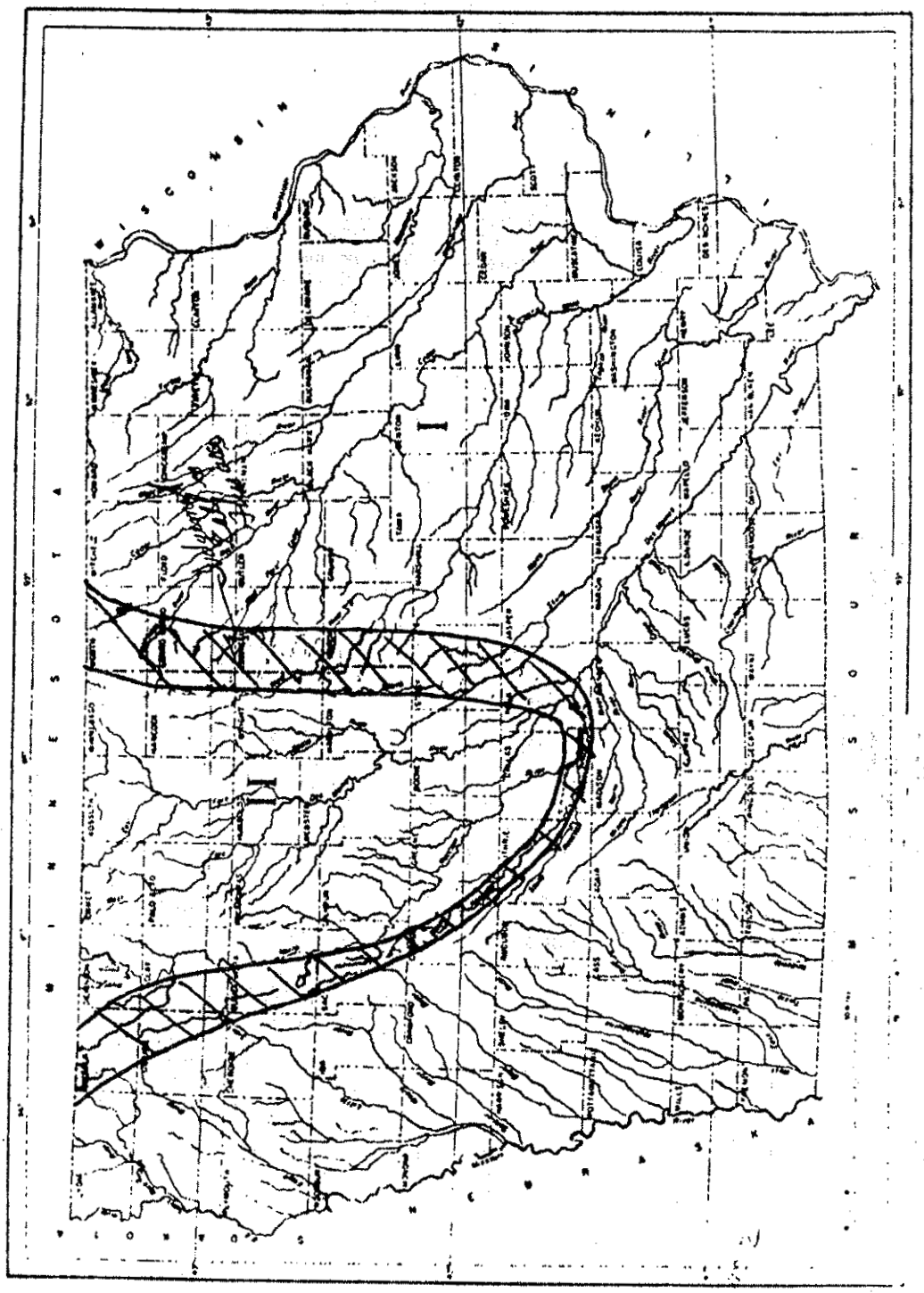


Figure 30. Input Form for RUNOFF

INPUT FORM - For RUNOFF

Project Number: _____

Project Name : _____

Prepared By : _____ Date: _____

Checked By : _____ Date: _____

****

METHOD: 1 = Iowa Runoff Chart, 2 = Bulletin 11, or 3 = Both

(Circle) 1, 2 or 3

****

AREA: Units 1 = square miles, 2 = acres; (Circle) 1 or 2

Area ----------> _____

****

METHOD 1: 1 - Iowa Runoff Chart

INPUT DATA: Land use (optional) _____

Topography (optional) _____

LF ----------> _____ unitless

****

METHOD 2: 2 - Bulletin 11 (Circle one)

INPUT DATA: Region I (1) or II (2) ----------> 1 or 2

Model 1 or 2 (if Region is I) ---> 1 or 2

Slope (if Model is 2) ----------> _____ ft/mi

Figure 31. RUNOFF Completed

```
          1            2      3         4         5     6       7     8
19 INPUT
20 ~~~~~
21                 ++++++++++++++++++++++++++++++++++++++++++++++++++++
22                 +    METHOD USED TO CALCULATE RUNOFF               +
23                 +    ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~+
24                 +         Choose one from below (1-3) --->      3 +
25                 +         1 - Iowa Runoff Chart                   +
26                 +         2 - Bulletin No. 11                     +
27                 +         3 - both methods                        +
28                 + + + + + + + + + + + + + + + + + + + + + + + + + +
29                 +     TO GET HELP                                 +
30                 +     ~~~~~~~~~~~                                 +
31                 +         For both methods                        +
32                 +        Goto IOWA OR BULL11                      +
33                 + + + + + + + + + + + + + + + + + + + + + + + + + +
34                 +    UNITS USED WHEN INPUTTING THE AREA           +
35                 +    ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~+
36                 +         Choose 1 or 2 --------->      2          +
37                 +             1 - square miles                    +
38                 +             2 - acres                           +
39                 + + + + + + + + + + + + + + + + + + + + + + + + + +
40                 +     INPUT THE AREA                              +
41                 +     ~~~~~~~~~~~~~~                              +
42                 +         Area ------------------>  10000 acres   +
43                 +                                                 +
44                 +                                                 +
45                 +                                                 +
46                 +                                                 +
47                 +                                                 +
48                 +         --- Helpful Output ---                  +
49                 +         Area ------------------> 15.625 sq mi   +
50                 +                                                 +
51                 ++++++++++++++++++++++++++++++++++++++++++++++++++++
52 ------------------------------------------------------------------------
53 RESULTS
54 ~~~~~~~
55  + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + +
56 Project Number:1
57 Project Name  :Example Problem
58 Prepared By   :Rocky J. Keehn                        Date:11-15-86
59 Checked By    :Rocky J. Keehn                        Date:11-15-86
60
61  + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + +
62 *** IOWA RUNOFF CHART ***                  *** BULLETIN 11 ***
63  --- Helpful Output ---              --- Helpful Output ---
64  Area (acres) >    10000             Area (sq mi) ---------> 15.625
65
66  --- Please input ---                --- Please input ---
67  LF ---------->      0.2             Region I(1) OR II(2) ->      1
68 Rolling pasture land                 Model 1(1) OR 2(2) --->      2
69  Goto LF FOR HELP                    10/85 slope (ft/mi) -->      9
70
71  + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + +
72                        *** PEAK DISCHARGES ***
73          IOWA RUNOFF CHART                          BULLETIN 11
74          ~~~~~~~~~~~~~~~~~                          ~~~~~~~~~~~
75        Q2   -->      360 cfs*                  Q2   ----->    630 cfs
76        Q5   -->      560 cfs                   Q5   ----->   1300 cfs
77        Q10  -->      780 cfs                   Q10  ----->   1900 cfs
78        Q25  -->      890 cfs                   Q25  ----->   2900 cfs
79        Q50  -->     1100 cfs                   Q50  ----->   3700 cfs
80        Q100 -->     1300 cfs                   Q100 ----->   4700 cfs
81        Q500 -->     1800 cfs*                  Q500 ----->   7800 cfs*
82                 * estimated by linear regression
```

Figure 32. Leftover Input in RUNOFF

```
83 ------------------------------------------------------------------------
          1          2      3         4         5     6       7     8
19 INPUT
20 ~~~~~          ++++++++++++++++++++++++++++++++++++++++++++++++++++
21                +    METHOD USED TO CALCULATE RUNOFF                +
22                +    ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~  +
23                +         Choose one from below (1-3) --->      2 +
24                +         1 - Iowa Runoff Chart                    +
25                +         2 - Bulletin No. 11                      +
26                +         3 - both methods                         +
27                + + + + + + + + + + + + + + + + + + + + + + + + + + +
28                +     TO GET HELP                                  +
29                +     ~~~~~~~~~~~                                  +
30                +         For Bulletin No. 11                      +
31                +        Goto BULL11                               +
32                + + + + + + + + + + + + + + + + + + + + + + + + + + +
33                +    UNITS USED WHEN INPUTTING THE AREA            +
34                +    ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~  +
35                +         Choose 1 or 2 --------->      2          +
36                +             1 - square miles                     +
37                +             2 - acres                            +
38                + + + + + + + + + + + + + + + + + + + + + + + + + + +
39                +     INPUT THE AREA                               +
40                +     ~~~~~~~~~~~~~~                               +
41                +         Area ------------------>  10000 acres   +
42                +                                                  +
43                +                                                  +
44                +                                                  +
45                +                                                  +
46                +                                                  +
47                +         --- Helpful Output ---                   +
48                +         Area ------------------> 15.625 sq mi   +
49                +                                                  +
50                ++++++++++++++++++++++++++++++++++++++++++++++++++++
51
52 ------------------------------------------------------------------------
53 RESULTS
54 ~~~~~~~
55  + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + +
56 Project Number:1
57 Project Name   :Example Problem
58 Prepared By    :Rocky J. Keehn                      Date:11-15-86
59 Checked By     :Rocky J. Keehn                      Date:11-15-86
60
61  + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + +
62                                        *** BULLETIN 11 ***
63                                  --- Helpful Output ---
64                                  Area (sq mi) ---------> 15.625
65
66                                  --- Please input ---
67                     0.2          Region I(1) OR II(2) ->      2
68 Rolling pasture land                                          2
69                                                               9
70
71  + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + +
72                          *** PEAK DISCHARGES ***
73          IOWA RUNOFF CHART                        BULLETIN 11
74                                                   ~~~~~~~~~~~
75       NOT USED                                 Q2   ----->    270 cfs
76                                                Q5   ----->    480 cfs
77                                                Q10  ----->    650 cfs
78                                                Q25  ----->    870 cfs
79                                                Q50  ----->   1000 cfs
80                                                Q100 ----->   1200 cfs
81                                                Q500 ----->   1800 cfs*
82                 * estimated by linear regression
```

Figure 33. RUNOFF Example - Bulletin 11, Region II

```
         1          2      3         4         5     6       7     8
INPUT
~~~~~
                +++++++++++++++++++++++++++++++++++++++++++++++++++++
                +    METHOD USED TO CALCULATE RUNOFF                +
                +    ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~  +
                +         Choose one from below (1-3) --->      2 +
                +         1 - Iowa Runoff Chart                   +
                +         2 - Bulletin No. 11                     +
                +         3 - both methods                        +
                + + + + + + + + + + + + + + + + + + + + + + + + + + +
                +     TO GET HELP                                 +
                +     ~~~~~~~~~~~                                 +
                +         For Bulletin No. 11                     +
                +        Goto BULL11                              +
                + + + + + + + + + + + + + + + + + + + + + + + + + + +
                +    UNITS USED WHEN INPUTTING THE AREA           +
                +    ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~ +
                +         Choose 1 or 2 --------->      2          +
                +             1 - square miles                    +
                +             2 - acres                           +
                + + + + + + + + + + + + + + + + + + + + + + + + + + +
                +     INPUT THE AREA                              +
                +     ~~~~~~~~~~~~~~                              +
                +         Area ------------------>  10000 acres   +
                +                                                 +
                +                                                 +
                +                                                 +
                +                                                 +
                +                                                 +
                +                                                 +
                +         --- Helpful Output ---                  +
                +         Area ------------------> 15.625 sq mi  +
                +                                                 +
                +++++++++++++++++++++++++++++++++++++++++++++++++++++

-----------------------------------------------------------------------
RESULTS
~~~~~~~
 + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + +
Project Number:1
Project Name   :Example Problem
Prepared By    :Rocky J. Keehn                        Date:11-15-86
Checked By     :Rocky J. Keehn                        Date:11-15-86

 + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + +
                                        *** BULLETIN 11 ***
                                  --- Helpful Output ---
                                  Area (sq mi) ---------> 15.625

                                  --- Please input ---
                                  Region I(1) OR II(2) ->      2


 + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + +
                         *** PEAK DISCHARGES ***
        IOWA RUNOFF CHART                          BULLETIN 11
        ~~~~~~~~~~~~~~~~                           ~~~~~~~~~~~
     NOT USED                                  Q2   ----->    270 cfs
                                               Q5   ----->    480 cfs
                                               Q10  ----->    650 cfs
                                               Q25  ----->    870 cfs
                                               Q50  ----->   1000 cfs
                                               Q100 ----->   1200 cfs
                                               Q500 ----->   1800 cfs*
              * estimated by linear regression
```

2.2.3. WSGEOM

WSGEOM

WATER SURFACE PROFILE

OPEN CHANNEL TRAPEZOIDAL SECTION

2.2.3.1. Introduction

The "Water Surface Profile - Open Channel Trapezoidal Section" spreadsheet was developoed to calculate the water depth along a section of a trapezoidal channel. This type of channel is typically located along a section of highway to drain water from the roadway and adjacent land.

This spreadsheet is very useful in answering "What if?" questions in regard to modifying the channel located next to the road. Various bottom widths, channel slopes, foreslopes and backslopes can be tried to obtain the optimal design.

The input consists of the water elevation at the last downstream cross-section (usually the design headwater depth at a culvert), design flow, channel bottom elevation at the last downstream cross-section, the energy coefficient, and cross-section data for up to 20 cross-sections. For each cross-section, a person needs to input the distance from the starting station, the width of the ditch bottom, foreslope, backslope, ditch or

channel slope, and Manning's roughness coefficient.

Once the data are input, the user must then iterate the water surface elevation at each cross-section. This is done by entering a trial depth, checking whether or not it is an acceptable value, if not, input a new elevation and recalculate at that station. If the trial depth is acceptable, then proceed to the next station for further calculation. The program contains a cell that informs the user whether to increase or decrease the elevation. A check value is also output for each iteration. This check value should approach 0,001 as the iterations are performed (seeking convergence).

Once all the cross-sections' water elevations have been interated by the user, the final output can be printed. Included in the output data are the channel bottom elevation, water surface elevation, energy line elevation, water depth, and friction loss. From this data, a water surface profile can be drawn and the water depths caused by the headwater can be observed. If the user has Microsoft Chart which is a companion software package to Microsoft Multiplan, this spreadsheet can be used as an input file to Chart and plot the water surface profile directly to the computer monitor screen or dump it out to a dot-matrix printer.

2.2.3.2. Using the Spreadsheet

The best way to begin using a spreadsheet is to obtain all pertinent data, record the data in a form that is easily transferred into the spreadsheet, and then input the data into the spreadsheet. The data obtained in the field, from topographic maps, and engineering principles can be transferred to an input form. Once this is finished, a user can begin to apply the spreadsheet.

The first step is to load the master spreadsheet file from the disk. It is assumed for discussion purposes here that the file is stored on disk in Normal Mode and is named WSGEOM.MP. Once the file has been loaded into the computer memory operating under the control of the Multiplan program, select the Options command from the Multiplan menu and turn the Recalculation OFF. Next enter the project number, project name, preparer, checker, and dates prepared and checked. These are located in rows 12-15 (see Figure 34). Once these entrie have been made, the constant variables in column 8, rows 21-24 (see Figure 34) are entered. These constant values should pertain to cross-section number 1 (the last downstream cross-section where the initial water depth is known). Typically, this initial water depth will be the headwater depth calculated during the analysis of a culvert or bridge located at this cross-section. Values for the energy coefficient, entered in row 22, column 8 (see Figure 34), are given in Table 4.

Table 4. Various values for the energy coefficient

(according to finding of Chow, 1959)

Channels	Value of the energy coeeficient		
	Minimum	Average	Maximum
Regular channels, flumes, spillways	1.10	1.15	1.20
Natural streams, and torrents	1.15	1.30	1.50
Rivers under ice cover	1.20	1.50	2.00
River valleys, overflooded	1.50	1.75	2.00

The next step is to enter the data for each cross-section. The maximum number of cross-sections is 20. The station distance from the starting cross-section should be entered in feet, not in stations. The ditch bottom width, foreslope, backslope, and Manning's roughness coefficient should be values that are associated with the cross-section under calculation consideration at the moment. The foreslope is the slope from the ditch bottom to the edge of the roadway shoulder. The backslope is the slope from the ditch bottom to the intercepted natural ground surface near the outer right of way boundary. The backslope and foreslope are entered as Z, where Z is the horizontal distance in the slope ration Z:1 (see Figure 35). The ditch slope is the average slope of the channel from the previous station cross-section to the current station

cross-section in feet per feet. For the initial station, enter the average slope at that station between an upstream and downstream location.

The six variables for each cross-section are entered in rows 31 through 36, beginning in column 8 for cross-section 1 and ending in column 31 for cross-section 20 (excluding columns 9, 11, 13, and 15). (Refer to Figure 36 which shows the template for cross-sections 1, 2, 3, and 4.) A person does not need to enter all 20 cross-sections for the spreadsheet to work. Once the cross-section data are entered, the user may begin iterating the water surface elevations. BEFORE BEGINNING THE ITERATIONS, ENTER THE MULTIPLAN COMMAND Options TO TURN Recalculation ON.

The water surface elevation for the first cross-section is automatically transferred from the constant variable previously entered in row 24, column 8 (see Figure 34). The user then begins the iteration process at cross-section 2. A person enters a trial depth in row 42, column 10 (see Figure 34). This depth should be slightly greater than the initial water surface elevation in column 8. Once a depth is entered, a "(+)" or a "(-)" will appear in row 46 below the water surface elevation number just entered. If it is a "(+)", then the water surface elevation should be INCREASED; if the spreadsheet displays a "(-)", then the water surface elevation should be decreased.

The method for finding the water surface is based on the standard step method presented by Chow (1959). This method utilizes the fact that the total head at the current cross-section is equal to the total head at the previous cross-section plus the friction head plus the eddy losses. For convenience of computation, the eddy losses can be considered part of the friction losses (Chow, 1959). The check value in row 47 is the difference between the total head at the current s cross-section and the total head plus the friction loss at the previous cross-section. As the check value becomes smaller, the precision of the method increases. For this spreadsheet, the recommended precision is such that the value in row 47 became 0.000.

Once the water surface depth is at a desirable precision, the user is to continue to cross-section 2 (row 42, column 12) and repeat the process. The user continues until all the cross-sections have been completed. USERS ARE TO REMEMBER THAT DATA CANNOT BE ENTERED IN COLUMNS 9, 11, 13, AND 15 IN ROW 42.

Once all the cross-sections have been entered, the output data can be reviewed in rows 69 through 96. The user can "jump" to this location within the spreadsheet by selecting the Goto command from the Multiplan command menu. The procedure is to select "Goto", then select the "Name" subcommand, then enter the word OUTPUT, and press the <return> key or the <enter> key. This will jump the

spreadsheet control directly to the output area.

At this time the spreadsheet should be saved for later revision and editing.

2.2.3.3. Example Problem

Figure 37 show a road section with a culvert located at station 0 + 00. The calculated headwater depth for the 50-year storm is five feet. The discharge in the ditch for this recurrence interval was 400 cfs. The road elevation at the culvert is 605.4 feet. The road elevation dips to 605.2 feet at station 6 + 79, which is located upstream from the culvert. In addition to stations 0 + 00 and 6 + 79, data were collected for stations 1 + 55, 3 + 18, and4 + 19. It was concluded that the channel is constructed such that the Z value for foreslope and backslope is 2; the ditch bottom is 20 feet; the channel slope is a constant 0.0016 feet per feet; and Manning's n is 0.025. These values pertain to all stations. The question is: Will the water flow over the road at station 6 + 79?

From the data given above, the input forms for the spreadsheet were completed using forms like those shown in Figure 38 and 39. Iteration and Recalculation were switched OFF by using the Multiplan command menu choice of Options. From an input form, the spreadsheet was filled in starting with lines 12 through 15; then lines

21 through 24 were completed (the energy coefficient was assumed to be 1.1). Finally, the cross-section data were entered in lines 31 through 36 starting in column 8. Figure 40 depicts the input template for this example problem.

Once the initial input was recorded, the Iteration and Recalculation functions were turned back ON. Following the closure of recalculation, an input is needed for row 42, column 10. This is the iteration cell to get the get the water surface elevation at cross-section 2. The iteration continued at this cross-section until the check value reached 0.000. Once this cross-section was complete, cross-section 3 was iterated; then cross-section 4; and finally, cross-section 5.

The output (see Figure 41) shows that the water surface elevation at cross-section 5 is 605.29 feet which is 0.09 feet above the road surface. To correct the problem, the engineer may decide to change the Z value in the foreslope and backslope to 1.0, and to change the ditch bottom to 30 feet. If these changes are made in the spreadsheet, the computational results would be those shown in Figure 42. The new water surface elevation at cross-section 5 would be 605.18 feet, which is 0.02 feet below the elevation of the road.

2.2.3.4. <u>References</u>

Chow, Ven Te, Open-Channel Hydraulics, McGraw-Hill, Inc., New York, 1959, pp. 27-28, 249-289.

Figure 34. Input Template for WSGEOM (Part 1)

```
        1         2     3     4   5    6   7      8      9      10
 1 ***********************************************************************
 2     WATER SURFACE PROFILE - OPEN CHANNEL TRAPEZOIDAL SECTION
 3 ***********************************************************************
 4       ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 5       +  Multiplan Microcomputer Spreadsheets for County    +
 6       +   Hydraulic and Highway Engineering Computations    +
 7       +            Copyright by Rocky J. Keehn              +
 8       +                   Version 1.0                       +
 9       +                    July, 1986                       +
10       ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
11
12 Project Number    :
13 Project Name      :
14 Prepared By       :                              Date:
15 Checked By        :                              Date:
16
17 ---------------------------------------------------------------------
18 INPUT - constant varibles
19 ~~~~~~~~~~~~~~~~~~~~~~~~~~
20           Elevation at
21                initial ditch bottom     =          feet
22           Energy coefficient            =
23           Design Flow                   =          cfs
24           Starting water depth elevation=          feet
25 ---------------------------------------------------------------------
```

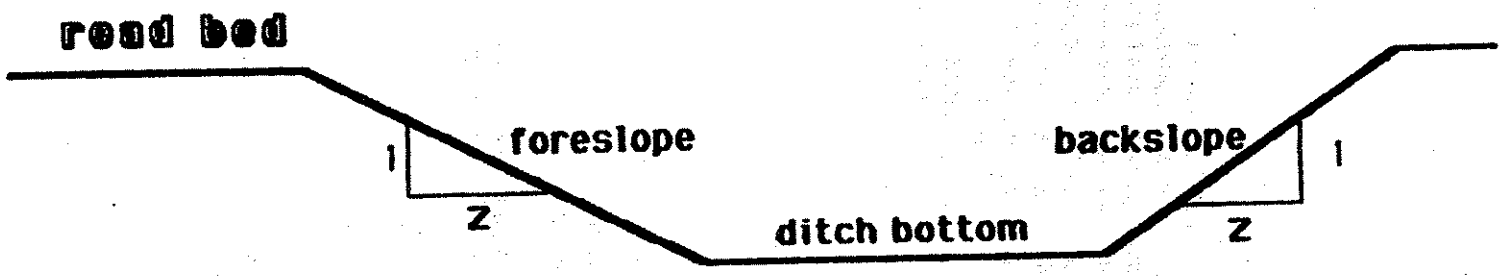


Figure 35. Description of input varibles for channel cross-section

Figure 36. Input Template for WSGEOM

```
      1        2    3    4  5   6  7     8      9      10     11     12    13     14
25 ---------------------------------------------------------------
26 INPUT - Cross-section data
27 ~~~~~~~~~~~~~~~~~~~~~~~~~~~~
28                 CROSS-SECTIONS ----->          1              2            3            4
29
30          Station distance from
31              starting point (feet)     =
32          Ditch bottom (ft)             =
33          Foreslope (ft:1)              =
34          Backslope (ft:1)              =
35          Ditch Slope (ft/ft)           =
36          Manning's n                   =
37 ------------------------------------------------------------------------------------------
38 INPUT - Self-interation
39 ~~~~~~~~~~~~~~~~~~~~~~~~~
40                 CROSS-SECTIONS ----->          1              2            3            4
41     ++ Input yourself ++
42          Water surface elevation (FT)  =       0
43
44     ++ Helpful Output ++
45          Increase (+) or decrease (-)
46               Water surface elev.      =   start at     #VALUE!      #VALUE!      #VALUE!
47          Check value (ok if (= +/-.001)=  X-section 2   #VALUE!      #VALUE!      #VALUE!
48
49 ------------------------------------------------------------------------------------------
50 CALCULATIONS
51 ~~~~~~~~~~~~~
52          Delta X (FT)                =     0.000        0.000        0.000        0.000
53          Length & Slope (FT)         =     0.000        0.000        0.000        0.000
54          Accumlative channel rise    =         0            0            0            0
55          Calculated Flow Depth (FT)  =     0.000        0.000        0.000        0.000
56          Flow Area (SQ FT)           =     0.000        0.000        0.000        0.000
57          Wetted Perimeter (FT)       =     0.000        0.000        0.000        0.000
58          Hydraulic Radius (FT)       =  #DIV/0!      #DIV/0!      #DIV/0!      #DIV/0!
59          Calculated Velocity (FPS)   =  #DIV/0!      #DIV/0!      #DIV/0!      #DIV/0!
60          alpha * V^2 / 2g            =  #VALUE!      #VALUE!      #VALUE!      #VALUE!
61          H1 elevation (FT)           =  #VALUE!      #VALUE!      #VALUE!      #VALUE!
62          Hydraulic Radius ^ 4/3      =  #VALUE!      #VALUE!      #VALUE!      #VALUE!
63          Friction Slope, Sf          =  #VALUE!      #VALUE!      #VALUE!      #VALUE!
64          Average Sf                  =  0.000000     #VALUE!      #VALUE!      #VALUE!
65          Friction head loss, hf (FT) =  0.000000     #VALUE!      #VALUE!      #VALUE!
66          H2 elevation (FT)           =  #VALUE!      #VALUE!      #VALUE!      #VALUE!
67
68 ------------------------------------------------------------------------------------------
```

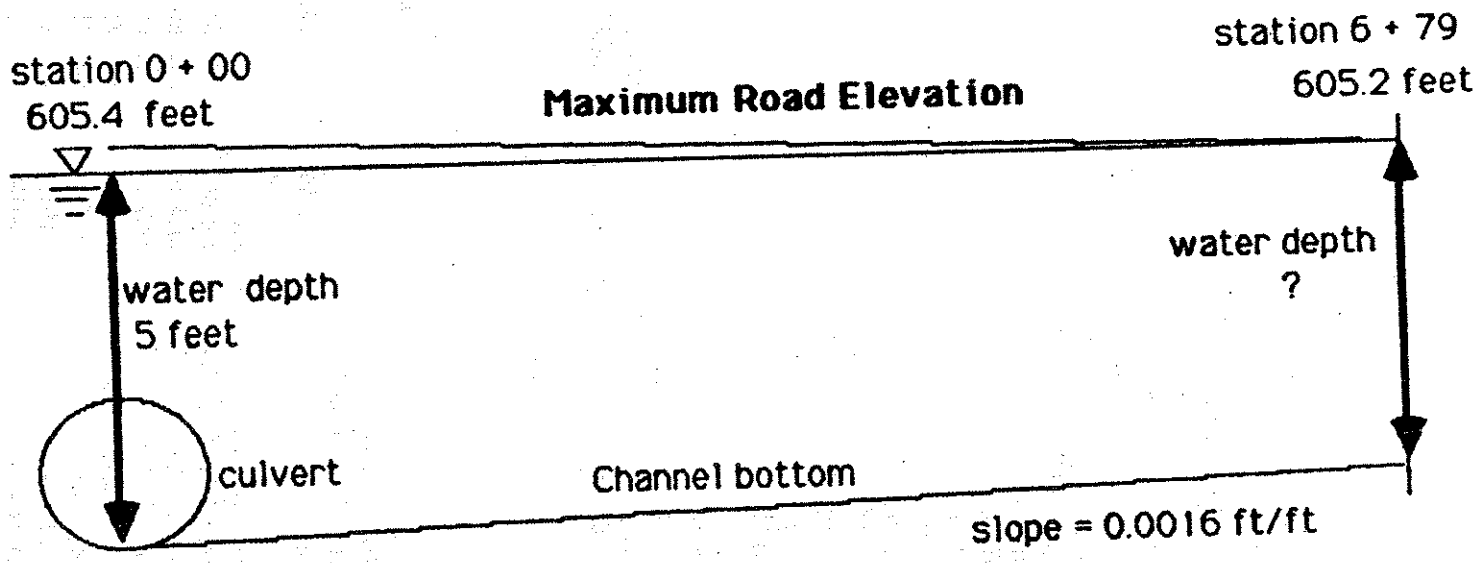


Figure 37. Plane view for example problem.

Figure 38. Input Form for WSGEOM

INPUT FORM - For WATER SURFACE PROFILE - OPEN CHANNEL
TRAPEZOIDAL SECTION

Project Number: _____

Project Name : _____

Prepared By : _____ Date: _____

Checked By : _____ Date: _____

****

INPUT - constant varibles

Elevation at initial ditch bottom -----> _____ feet

Energy coefficient ----------> _____

Design Flow ----------> _____ cfs

Starting water depth elevation --------> _____ feet

****

INPUT - Cross-section data for cross section number __1__

Station distance from startin point ---> _____ feet

Ditch bottom ----------> _____ feet

Foreslope ----------> _____ ft:1

Backslope ----------> _____ ft:1

Ditch Slope ----------> _____ ft/ft

Manning's roughness coefficient (n) ---> _____

****

INPUT - Cross-section data for cross section number __2__

Station distance from startin point ---> _____ feet

Ditch bottom ----------> _____ feet

Foreslope ----------> _____ ft:1

Backslope ----------> _____ ft:1

Ditch Slope ----------> _____ ft/ft

Manning's roughness coefficient (n) ---> _____

Figure 39. Input Form Continuation for WSGEOM

INPUT FORM - For WATER SURFACE PROFILE - OPEN CHANNEL
TRAPEZOIDAL SECTION

Project no. _____ Page ___ of___

INPUT - Cross-section data for cross section number _____

Station distance from startin point ---> _____ feet

Ditch bottom ----------> _____ feet

Foreslope ----------> _____ ft:1

Backslope ----------> _____ ft:1

Ditch Slope ----------> _____ ft/ft

Manning's roughness coefficient (n) ---> _____

****

INPUT - Cross-section data for cross section number _____

Station distance from startin point ---> _____ feet

Ditch bottom ----------> _____ feet

Foreslope ----------> _____ ft:1

Backslope ----------> _____ ft:1

Ditch Slope ----------> _____ ft/ft

Manning's roughness coefficient (n) ---> _____

****

INPUT - Cross-section data for cross section number _____

Station distance from startin point ---> _____ feet

Ditch bottom ----------> _____ feet

Foreslope ----------> _____ ft:1

Backslope ----------> _____ ft:1

Ditch Slope ----------> _____ ft/ft

Manning's roughness coefficient (n) ---> _____

Figure 40. Example Problem Template for First Cross Section

```
      1        2     3     4  5    6  7     8      9      10     11     12    13     14    15
 1 ****************************************************************
 2    WATER SURFACE PROFILE - OPEN CHANNEL TRAPEZOIDAL SECTION
 3 ****************************************************************
 4      ++++++++++++++++++++++++++++++++++++++++++++++++++++
 5      +  Multiplan Microcomputer Spreadsheets for County   +
 6      +   Hydraulic and Highway Engineering Computations   +
 7      +            Copyright by Rocky J. Keehn            +
 8      +                   Version 1.0                     +
 9      +                    July, 1986                     +
10      ++++++++++++++++++++++++++++++++++++++++++++++++++++
11
12 Project Number   :   1
13 Project Name     :Example problem
14 Prepared By      :Rocky Keehn                Date:9/9/86
15 Checked By       :Rocky Keehn                Date:9/9/86
16
17 ----------------------------------------------------------------
18 INPUT - constant varibles
19 ~~~~~~~~~~~~~~~~~~~~~~~~~~
20          Elevation at
21               initial ditch bottom     =     600 feet
22          Energy coefficient            =     1.1
23          Design Flow                   =     400 cfs
24          Starting water depth elevation=     605 feet
25 ----------------------------------------------------------------
26 INPUT - Cross-section data
27 ~~~~~~~~~~~~~~~~~~~~~~~~~~~
28                  CROSS-SECTIONS ----->          1            2            3            4
29
30          Station distance from
31              starting point (feet)     =       0          155          318          491
32          Ditch bottom (ft)             =      20           20           20           20
33          Foreslope (ft:1)              =       2            2            2            2
34          Backslope (ft:1)              =       2            2            2            2
35          Ditch Slope (ft/ft)           =  0.0016       0.0016       0.0016       0.0016
36          Manning's n                   =   0.025        0.025        0.025        0.025
37 ----------------------------------------------------------------------------------------
38 INPUT - Self-interation
39 ~~~~~~~~~~~~~~~~~~~~~~~~
40                  CROSS-SECTIONS ----->          1            2            3            4
41     ++ Input yourself ++
42          Water surface elevation (FT)  =     605        605.048      605.109      605.185
43
44     ++ Helpful Output ++
45          Increase (+) or decrease (-)
46               Water surface elev.      =  start at       (+)          (-)          (+)
47          Check value (ok if <= +/-.001)= X-section 2     0.000        0.000        0.000
48
49 ----------------------------------------------------------------------------------------
```

Figure 41. Output for Example Problem (for First Cross Section)

OUTPUT

** Results ** Cross-section number	Station	Channel Bottom Elevation (feet)	Water Surface Elevation (feet)	Energy Line Elevation (feet)	Water Depth (feet)	Friction Loss (feet)
1	0 + 0	600.00	605.00	605.12	5.00	0.000
2	1 + 55	600.25	605.05	605.18	4.80	0.062
3	3 + 18	600.51	605.11	605.26	4.60	0.077
4	4 + 91	600.79	605.18	605.36	4.40	0.095
5	6 + 79	601.09	605.29	605.48	4.20	0.123

Figure 42. Output for Example Problem (for Second Cross Section)

OUTPUT

** Results ** Cross-section number	Station	Channel Bottom Elevation (feet)	Water Surface Elevation (feet)	Energy Line Elevation (feet)	Water Depth (feet)	Friction Loss (feet)
1	0 + 0	600.00	605.00	605.09	5.00	0.000
2	1 + 55	600.25	605.03	605.13	4.78	0.040
3	3 + 18	600.51	605.07	605.18	4.56	0.048
4	4 + 91	600.79	605.11	605.24	4.33	0.061
5	6 + 79	601.09	605.18	605.32	4.09	0.079

2.2.4. CULVERT

CULVERT

2.2.4.1. Introduction

CULVERT is a spreadsheet developed to estimate the necessary size of a culvert used to convey a given amount of water. The spreadsheet has a menu of several box and pipe culverts from which the user can make a selection. The calculations are based on the Federal Highway Administration (FHWA) methodology.

Inputs for the spreadsheet consist of the site data, structure data, tailwater depth, and design flow rates. The site data include the roadway elevation or allowable headwater elevation for larger storm events, the allowable headwater for the design storm, pipe invert elevation at the inlet, elevation of the streambed at the pipe inlet, station distance at inlet, elevation of the pipe at the outlet invert, and station of the outlet invert.

The structure data needed are the structure type (selected from the menu of possible alternatives), diameter (or height) if it is a circular conduit, width and height if it is a rectangular box, number of barrels, whether or not the culvert has a mitered end, Manning's roughness coefficient, and the inlet loss coefficient (Ke). The tailwater depth is also entered. The final

items of information needed are the peak discharges for the design and major storms.

There are two sections of output in the culvert spreadsheet. The first section contains the culvert data inputs and outputs that are necessary to make initial checks of the headwater depths. In some cases, the pipe is in inlet control. When this occurs, the normal depth of water in the pipe needs to be found (if the pipe is not flowing full) so that an estimation of the outlet velocity can be calculated.

The normal depth is found by an interative process in which the user inputs an estimation of the water depth in the culvert. Based on this depth, the flow in the pipe is calculated. The design (or major) storm discharge is then compared against this calculated discharge. Once the two discharges are nearly equal, the outlet velocity due to normal depth can be estimated.

The second section of output comes from saving the data calculated in the first output section. The user can save up to six different culvert options in the second output section. The second output section of the spreadsheet includes all the information that is given on the FHWA input form for culvert analysis.

2.2.4.2. Using the Spreadsheet

The best way to begin using the spreadsheet is to

obtain all pertinent data, record the data in a form that is easily transferred into the spreadsheet, and then enter the data into the spreadsheet. The data obtained in the field, from topographic maps, and engineering principles can be transferred to an input form. Once this is done, a person can proceed to use the spreadsheet.

The first step is to load the file from the disk to the computer memory so that the spreadsheet will be operating under the control of Multiplan. For purposes of discussion here, assume the master spreadsheet is stored as a file on disk under the filename CULVERT.MP in Normal Mode. Once the program is loaded, turn the Recalculation and Iteration functions OFF by selecting the Options command from the Multiplan command menu, and then enter the informative data in rows 13 through 16 (see Figure 43). These data include the project number, project name, preparer, checker, and dates the project was prepared and checked.

Once all the informative data are input, the user needs to enter the site data. The site data begins in row 73, column 6, and continues to row 79, column 6 (see Figure 44). The roadway elevation is the minimum elevation of the roadway before overtopping occurs or is the maximum allowable headwater elevation for the major storm event. This elevation may be located at the point of the structure, or due to the geometrics of the

roadway, may be located a distance up the road (or down the road) from the structure. The allowable headwater is the maximum elevation the headwater can reach for the design storm. The rest of the entry information should be self-explanatory. Figure 45 in the report text or Figure 1 displayed in the spreadsheet may be helpful since both figures illustrate a culvert site and have labels for the location fo the various inputs.

The total number of barrels goes in cell R82C6. The methodology for this spreadsheet is such that the total flow is divided by the number of barrels. The design is then based on one culvert and this partial flow. In the final construction, a project designed with a 42 inch diameter pipe and two barrels would need two 42 inch pipes placed at the site

The user should now go to the structure data (which starts at row 88, column 18) and input the type of culvert that will be used in the initial calculation (see Figure 44 for the location of the inputs described hereafter). The cell for the culvert type is located in row 88, column 6. The user chooses one of the values (from 1 to 8 or from 20 to 37) as shown in Table 5 and enters it in the appropriate spreadsheet cell. Table 5 is also found in the spreadsheet starting in row 19 and ending in row 52. Once this selection is made, reenter the Options command in the Multiplan command menu and turn the Recalculation Mode back ON to let the program

recalculate all the spreadsheet cells. The user may hear a "BEEP!" and the message "Circular reference unresolved" may appear as a warning. Ignore this message; enter the Options command once more to turn OFF the Recalculation Mode; and continue entering your data.

If a circular pipe has been selected as the culvert structure, enter the height of the culvert in INCHES. This input goes into cell R91C6 (row 91, column 6). Cell R90C6 (above the cell where the culvert height was entered) can have any value since it is not used for circular pipes. If a box culvert has been selected, the user enters the width of the box in cell R90C6 and the height in cell R91C6. Both the width and the height of a box culvert are entered in FEET.

The tailwater elevation is entered in cell R100C6. If the pipe is mitered, enter a number 1 in cell R93C6, and if it is not mitered enter a number 2.

Manning's roughness coefficient and the entrance loss coefficient may or may not need to be entered. For both these variables default values have been established. If the user wishes to utilize the default values displayed in cells R95C8 and R96C8, enter a number 1 in the column 6 or each respective row (R95C6 and R96C6). If the user wants to enter his or her own value, enter the required value in place of the number 1 (i.e., in R95C6 and R96C6).

Once all pipe data have been entered, the user needs

to enter the design storm discharge and the major storm discharge. The design storm discharge is the one for which the structure is initially constructed. Depending upon the local design policy, this storm may be the 10-, 25-, or 50-year storm. The headwater for a major storm recurrence interval should also be examined to check for problems that may occur as a consequence of a large rainfall event. For example, a requirement may be that the design storm headwater be three feet below the centerline pavement elevation of the highway at the culvert station. However, for the major storm the required headwater must be such that overtopping of the highway does not occur. In this case, both discharges need to be checked. The CULVERT spreadsheet is designed to do both tasks.

Enter the design storm in cell R104C6 and enter the major storm in cell R105C6.

The final two entries are the storage location of the computed results and a cell to enter the description of the type of culvert being considered. The user needs to enter in cell R109C6 the location (designate the portion of the spreadsheet) where the ouptput is to be stored in the completed output form. A number from 2 to 6 can be used to specify which of five locations within the spreadsheet is to be used for storage of results. The engineer or analyst should be careful when using this cell, since whenever a number is entered, with the

Recalculation turned ON, all previous results (output data) stored in the block of spreadsheet cells designated by the selection of a number to be entered are lost and are replaced by the values of the most recent computation.

There is one way in which a spreadsheet user can store computational output from up to six different culvert analysis scenarios. If any number except 2, 3, 4, 5, or 6 is entered cell in R109C6, then the spreadsheet will place the current computation results in the first row of the final output data block and retain all previous results stored in the output data block. Thus, this retains up to six completed computations at once.

To aid in descriptive output, the type of culvert can be identified on the final output sheet. To reproduce any of the descriptions of culverts listed in Table 5, the user can type =CT? in cell R110C6. The ? is replaced by the structure type already entered in cell R90C2. For example, if a person used a CMP pipe with a headwall (option 4 from Table 5), the user could type =CT4 in cell R110C6 and "CMP pipe with a headwall" will appear in the output block of the spreadsheet. If the user types =CT6, the output would contain the message "CMP pipe projecting". If the user wishes to output his or her own description, it can be typed in cell R110C6 using the Alpha command from the Multiplan command menu. However, only part of it may be displayed due to the width of the

screen. It will all be printed out in the final spreadsheet display as long as it does not exceed 61 characters.

The input is now complete. The user should turn the Recalculation Mode back on by entering the Options command from the Multiplan command menu again. As was the case earlier, ignore the alerting "BEEP!" sounds and the error message "Circular references unresolved" which will be displayed at the bottom of the screen. Once the recalculation is complete, check the headwater elevations in cells R117C8 and R117C12. <u>If the values are not acceptable and the data does not need to be saved</u>, make the necessary changes to seek a better solution and check the results again. ***HELPFUL HINT: If only one cell needs to be changed (like the pipe diameter) it works fine to leave the Recalculation Mode ON. However, if several changes are to be made, the user should probably turn the Recalculation Mode OFF, make the changes, and then turn the Recalculation Mode back ON.*** If the results are acceptable and the culvert is in outlet control, turn the Iteration Mode of computation ON by entering the Options command from the Multiplan command menu. The operation of the spreadsheet is now complete and the user can try another alternative, save the spreadsheet for future reference, or print the results out on a printer for a paper record. If the culvert is under inlet control and the headwaters are acceptable,

the normal depth needs to be determined if the pipe is not running full. If the pipe is running full a message will appear in cell R135C8 for the design storm and in cell R135C12 for the major storm that displays "FULL%".

The normal depth is found by changing the water depths in cells R130C8 and R130C12 until the Design Discharge and the Calculated Discharge are close or match. It is recommended that depths be entered to the nearest one-tenth. This procedure calculates the outlet velocity for normal depth which is the maximum velocity possible in the pipe. Once the culvert inputs and the headwaters are acceptable, the user should enter the Options command in the Multiplan command menu to turn the Iteration Mode ON. When the iteration is completed the user can print out the spreadsheet results, save the spreadsheet as a data file on disk, or analyze another conduit.

If the user continues by analyzing another conduit, the user MUST reenter the Options command and turn OFF the Recalculation Mode and the Iteration Mode. After making these operational changes in the spreadsheet, move the cell pointer to the cells needing changed entries and enter the new values. MAKE CERTAIN THAT THE CELL THAT DETERMINES THE STORAGE LOCATION OF THE OUTPUT DATA IS CHANGED (i.e., cell R109C6). IF THIS CELL IS NOT CHANGED, THEN THE MOST RECENT OUTPUT DATA RESULTS WILL BE ERASED AND REPLACED BY THE RESULTS OF THE ANALYSIS UNDERWAY. Once the changes are completed, enter the

Options command once more and turn the Recalculation Mode back ON before checking the computational results.

When the user is ready to quit, the final results are tabulated starting in row 144, column 1, and continue to row 178, column 55. IT IS NOW A GOOD IDEA TO SAVE THE SPREADSHEET AS A DATA FILE IF NOT ALREADY DONE SO TO ENSURE THAT THE DATA ARE NOT ERASED AND LOST! Before printing, the user has the option of entering some informative data about the site beginning in cell R142C48 (see Figure 46). This includes such items as the drainage area, channel shape, routing, stream slope, and any other comments about the site. In addition to these information cells, comments about each scenario can be entered starting in cell R158C49 (see Figure 46).

Once all the information is entered, the Print command and its subcommands permit setting up the printed output to match the width and style of the printer available to produce printed records. The number of pages of output that are required is based on the printer capability and the style of print used. The user should utilize a set up with named grouping of cells to be printed out for minimum confusion during the printing process. (Consult the software manual for Microsoft Multiplan on how to Name cell blocks and on how to Print with the various options within the Print command.)

2.2.4.3. Example Problem

The highway plans are complete for a paved county road except for the design of a culvert which is to be placed under the road. The top of the roadway pavement elevation at the culvert location is 110.00 feet and the culvert inlet invert elevation is 100.00 feet. The pipe length needs to be approximately 100 feet long. The maximum allowable headwater elevation for the 25 year storm is 107 feet. For the 100-year storm the water cannot overtop the roadway. Due to the location of the structure, there is no tailwater.

The inlet invert will be put at 100 feet and the outlet invert at 94 feet elevations. The county has in it's maintenance and materials yard three 48 inch diameter CMP pipes, each 100 feet long. The county engineer has decided that, if possible, these pipes will be placed at the site with a headwall.

Two other options that are being considered are to place a square edged concrete pipe with a headwall and to construct a box culvert with no wingwall flares. In all cases the culverts will not be mitered, will be assumed to be 100 feet long, and cannot be over six feet high. An engineering sketch of the site conditions is shown in Figure 47.

The design and major storm discharges for this structure were found using the RUNOFF spreadsheet. The Iowa Runoff Chart was used with a drainage area of 2400

acres and an LF of 0.2. The discharge under these conditions was estimated at 350 cfs for the design storm (25-year) and 530 cfs for the major storm (100-year). The Iowa Runoff Chart results are shown in Figure 48.

Based on the site data and the calculated discharges, the input form was filled out. As was the case in the example problem and in almost all instances in culvert design, the heights and/or widths can only be estimated until the computations are performed. From the input form (see Figure 49) initial data was entered into the spreadsheet and the calculations completed.

The final results are shown in Figure 50. The portion of the output displayed in columns 1 through 22 contains a basic summary for comparing for adequate design flow while the output in columns 22 through 55 displays the computational details in the traditional format. It can be seen from this information that the 10 feet by 6 feet box culvert will work but that the other alternatives violate the minimum headwater depth requirement.

Table 5. Culvert Types Available

ID Number	Description
1	Concrete pipe - Square edge with headwall
2	Concrete pipe - Groove end with headwall
3	Concrete pipe - Groove end projecting
4	CMP * - Headwall
5	CMP - Mitered to slope
6	CMP - Projecting
7	Circular - Beveled ring, 45 degree bevels
8	Circular - Beveled ring, 33.7 degree bevels
20	RCB ** - 30 to 75 degree wingwall flares
21	RCB - 90 and 15 degree wingwall flares
22	RCB - 0 degree wingwall flares
23	RCB - 45 degree wingwall flare d=.043D
24	RCB - 18 to 33.7 degree wingwall flare d=.083D
25	RCB - 90 degree headwall with 3/4" chamfers
26	RCB - 90 degree headwall with 45 degree bevels
27	RCB - 90 degree headwall with 33.7 degree bevels
28	RCB - 3/4" chamfers; 45 degree shewed headwall
29	RCB - 3/4" chamfers; 30 degree shewed headwall
30	RCB - 3/4" chamfers; 15 degree shewed headwall
31	RCB - 45 degree bevels; 10 to 45 degree skewed headwall
32	RCB 3/4" chamfers - 45 degree non-offset wingwall flares
33	RCB 3/4" chamfers - 18.4 degree non-offset wingwall flares
34	RCB 3/4" chamfers - 18.4 degree non-offset wingwall flares 30 degree skewed barrel
35	RCB Top Bevels - 45 degree wingwall flares - offset
36	RCB Top Bevels - 45 degree wingwall flares - offset
37	RCB Top Bevels - 45 degree wingwall flares - offset

* CMP = Corrugated Metel Pipes
** RCB = Reinforced Concrete Box

```
   1       2      3     4    5      6     7      8     9    10   11    12    13     14
1 ***********************************************************************
2                          CULVERT ANALYSIS
3 ***********************************************************************
4
5      ++++++++++++++++++++++++++++++++++++++++++++++++++++++
6      +  Multiplan Microcomputer Spreadsheets for County   +
7      +   Hydraulic and Highway Engineering Computations   +
8      +             Copywrite by Rocky J. Keehn            +
9      +                    Version 2.1                     +
10     +                        1986                        +
11     ++++++++++++++++++++++++++++++++++++++++++++++++++++++
12
13 Project Number   :1
14 Project Name     :Example problem
15 Prepared by      :Rocky Keehn                    Date: 11/12/86
16 Checked By       :Rocky Keehn                    Date: 11/12/86
17
18 -----------------------------------------------------------------------
```

Figure 43. Location of Descriptive Input Data in CULVERT Spreadsheet

Figure 44. Location of the Culvert Input Data in the CULVERT Spreadsheet

```
     1      2      3    4   5     6    7     8    9   10  11   12   13    14
 63 ------------------------------------------------------------------------
 64 RESULTS:
 65 ~~~~~~~
 66 Project Number  :    0
 67 Project Name    :    0
 68 Prepared By     :    0                          Date:  0
 69 Checked By      :    0                          Date:  0
 70
 71 INPUT - SITE DATA (see Figure 1)
 72 ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
 73      Roadway Elevation -->     110 ft, or major storm headwater
 74      EL (hd) ------------>     107 ft, allowable headwater
 75
 76      EL (i) ------------->     100 ft, pipe invert elev. - inlet
 77      EL (i) station ----->       0 ft, pipe invert station - inlet
 78      ELo ---------------->      94 ft, pipe invert elev. - outlet
 79      ELo station -------->     100 ft, pipe invert station - outlet
 80
 81
 82      Number of barrels -->       1
 83
 84      El (sf) ------------>     100 ft, elev. of stream bed the inlet
 85
 86 INPUT - STRUCTURE DATA
 87 ~~~~~~~~~~~~~~~~~~~~~~~
 88      Type --------------->      22    See Table 1
 89
 90      Width -------------->      10 feet
 91      Height ------------->       6 feet
 92
 93      Mitered ? ---------->       2    1 = yes, 2 = no
 94
 95      Roughness (n) ------>       1      0.012 <- default value (if n=1)
 96      Entrance loss (Ke) ->       1        0.7 <- default value (if Ke=1)
 97
 98 INPUT TAILWATER DEPTH:
 99 ~~~~~~~~~~~~~~~~~~~~~~
100      Tailwater elevation >       0 ft
101
102 INPUT FLOW RATES:
103 ~~~~~~~~~~~~~~~~~
104      Design storm Q ---->      350 cfs        25-year
105      Major storm Q ----->      530 cfs        100-year
106
107 INPUT DATA STORAGE FOR SUMMARY TABLE:
108 ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
109      Store at (2-6) ----->       3
110      Label structure ---->RCB no wingwall flares (extension of sides)
111
112 ------------------------------------------------------------------------
113 OUTPUT:
114 ~~~~~~~
115                                 |      Design       |     Major
116                                 |      storm        |     storm
     ------------------------------------------------------------------
117      Headwater elevation        |   105.6 ft        |  108.0 ft
118      Control ?                  | Inlet             | Inlet
119      Below allowable ?          | Yes               | Yes
120      Maximum outlet velocity    |    35.0 ft/sec    |   40.8 ft/sec
121      ------------------------------------------------------------------

     1      2      3    4   5     6    7     8    9   10  11   12   13    14
122      ** If pipe is in inlet control need to find normal depth
123         below to get outlet velocity **
124 ------------------------------------------------------------------------
125 MANUAL INTERATION TO GET NORMAL DEPTH:
126 ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
127                                 |      Design       |     Major
128                                 |      storm        |     storm
     ------------------------------------------------------------------
129      INPUT: Water depth         |       1 ft        |    1.3 ft
130                                 |                   |
131      OUTPUT: Design dicharge    |   350.0 cfs       |  530.0 cfs
132              Calculated discharge |  352.9 cfs       |  520.8 cfs
133              Difference         |    -2.9 cfs       |    9.2 cfs
134              Error in percent   |     0.8 %         |   -1.7 %
135      ------------------------------------------------------------------
136      *** Needed to get outlet velocity when pipe is in inlet control ***
137
```

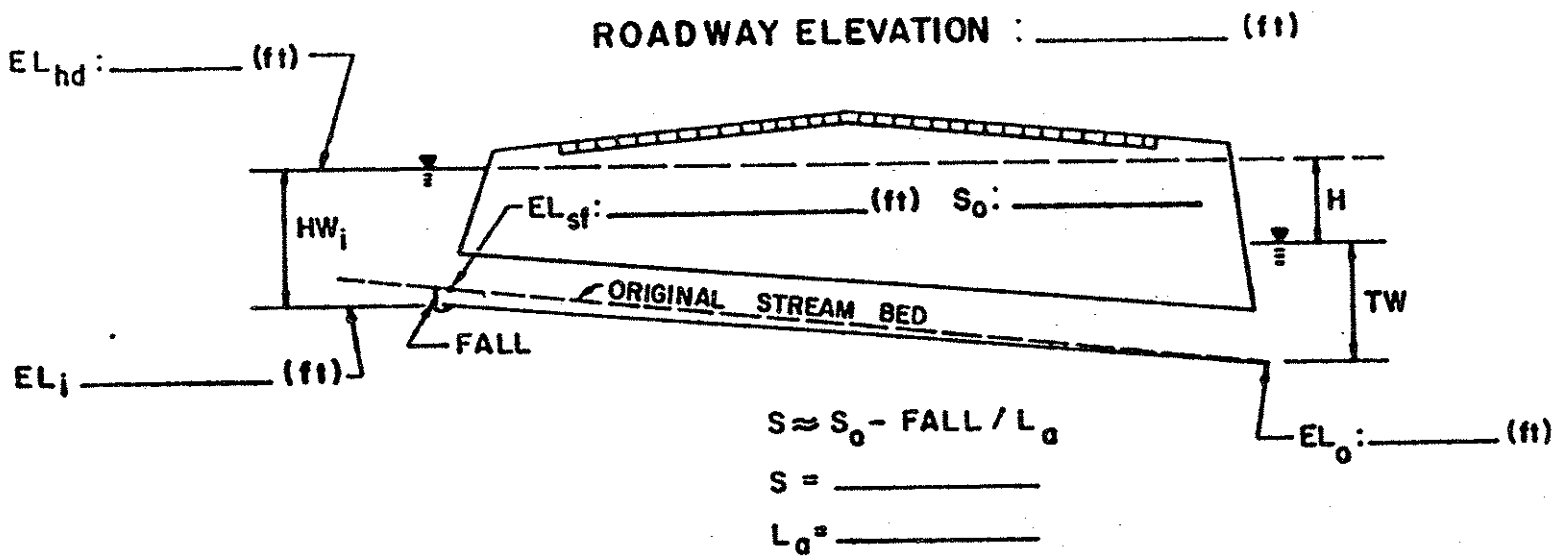
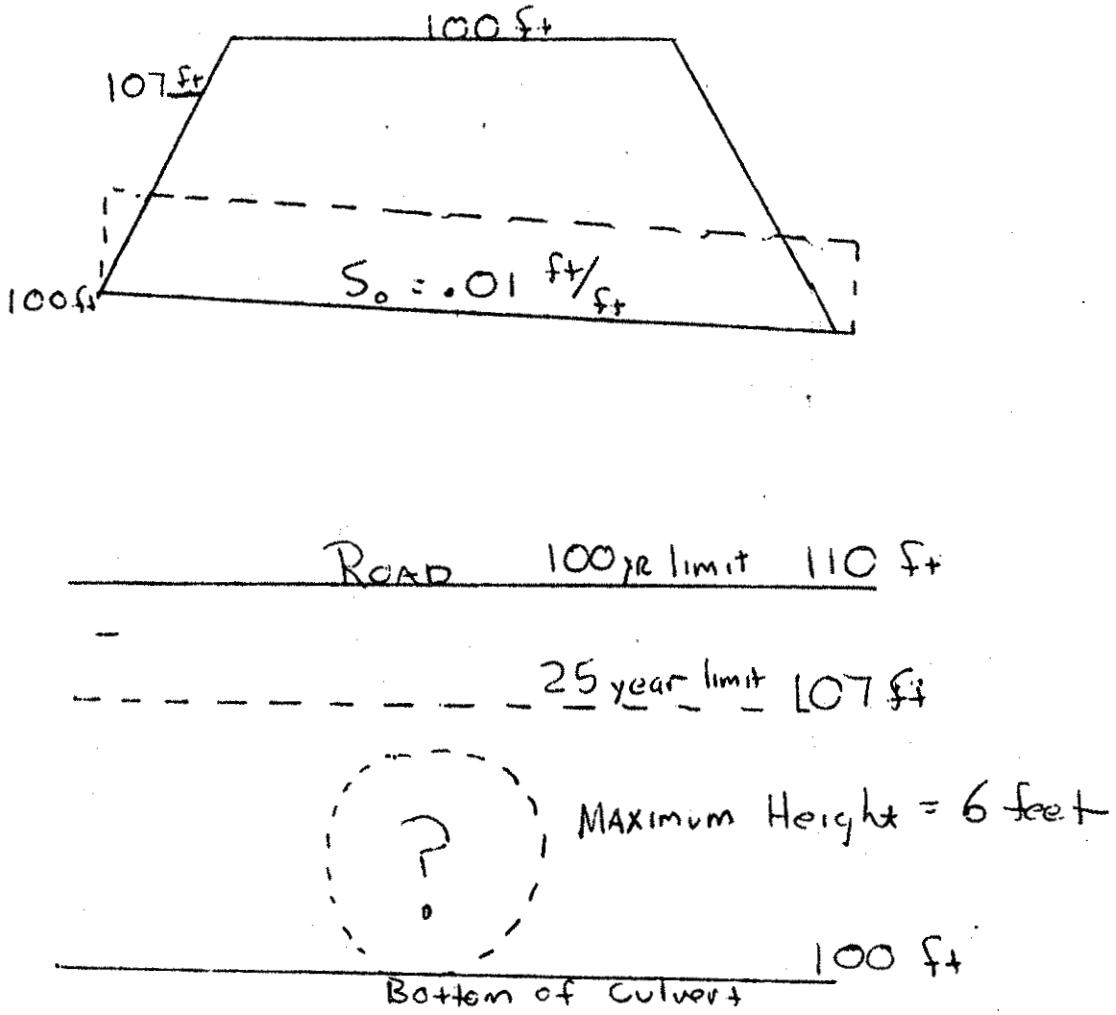


Figure 45. Definition of the Variables in Site Data for CULVERT

Figure 46. Display of Informative Record Portion of CULVERT Spreadsheet

```
     48        49          50     51      52        53     54   55
140
141 ------------------------------------------------------------ |
142  |       ** HYDROLOGICAL DATA (Optional input) **            |
143  |          Method:                                          |
144  | Drainage area: 2400 acres                                 |
145  | Channel shape: n/a                                        |
146  |        Routing: n/a                                       |
147  |  Stream slope: .01 ft/ft                                  |
148  |                                                           |
149  |                                                           |
150  |          Other:                                           |
151  |                                                           |
152  |                  ** SITE DATA OUTPUT **                   |
153  | Roadway Elev.:      10 ft    EL (hd):       1 ft         |
154  |        EL (i):      10 ft        ELo:       0 ft/ft      |
155  | EL(i) station:       0 ft    ELo sta:       0 ft         |
156  |   No. barrels:               EL (sf):                     |
157  | ------------------ ** COMMENTS ** ----------------------- |
158  |                                                           |
159  |                                                           |
160  |                                                           |
161  | larger pipe needed but due to 6 foot limit cannot         |
162  | increase pipe diameter                                    |
163  |                                                           |
164  | exceptable design                                         |
165  |                                                           |
166  |                                                           |
167  | try two pipes                                             |
168  |                                                           |
169  |                                                           |
170  | try three pipes                                           |
171  |                                                           |
172  |                                                           |
173  | pipes on hand will not work                               |
174  |                                                           |
```

Figure 47. Example Problem Site Description



```
         1              2       3          4          5      6        7      8
52 ------------------------------------------------------------------------------
53 RESULTS
54 ~~~~~~~
55  + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + +
56 Project Number:1
57 Project Name  :Example area for culvert example
58 Prepared By   :Rocky J. Keehn                        Date:11-15-86
59 Checked By    :Rocky J. Keehn                        Date:11-15-86
60
61  + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + +
62 *** IOWA RUNOFF CHART ***
63  --- Helpful Output ---
64  Area (acres) >     2400
65
66  --- Please input ---
67  LF ---------->      0.2
68
69  Goto LF FOR HELP
70
71
72
73  + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + +
74                          *** PEAK DISCHARGES ***
75          IOWA RUNOFF CHART                          BULLETIN 11
76          ~~~~~~~~~~~~~~~~                           ~~~~~~~~~~~
77        Q2   -->      140 cfs*                  NOT USED
78        Q5   -->      220 cfs
79        Q10  -->      310 cfs
80        Q25  -->      350 cfs
81        Q50  -->      440 cfs
82        Q100 -->      530 cfs
83        Q500 -->      720 cfs*
84                * estimated by linear regression
85 ------------------------------------------------------------------------------
```

Figure 48. Results from the RUNOFF Spreadsheet Used in the CULVERT Spreadsheet Example

Figure 49. Input Data Form for use with CULVERT Spreadsheet

INPUT FORM - For CULVERT - Page 1

Project Number: _____

Project Name : _____

Prepared By : _____ Date: _____

Checked By : _____ Date: _____

****

HYDROLOGICAL DATA (optional):

Method --------> _____

Drainage area -> _____

Channel shape -> _____

Routing -------> _____

Stream slope --> _____

Other ---------> _____

_____

****

SITE DATA:

Roadway elevation -> _____ ft

EL (hd) -----------> _____ ft - Allowable headwater

EL (i) ------------> _____ ft - Pipe invert elev. - inlet

EL (sf) -----------> _____ ft - Elev. stream bed at invert

So ----------------> _____ ft/ft - Pipe slope

****

DESIGN FLOW RATES:

	Recurrence interval	Peak Flow rate (Q)
Qdesign	_____ year	_____ cfs
Qmajor	_____ year	_____ cfs

***** More input data on additional page(s) *******

```
     1      2     3    4   5    6   7    8    9   10  11   12   13   14   15    16        17   18    19    20    21    22
120 ------------------------------------------------------------------------------------------------------------------------
121 RESULTS:
122 ********
123 Project Number  :1
124 Project Name    :Example problem
125 Prepared By     :Rocky Keehn                    Date:11/12/86
126 Checked By      :Rocky Keehn                    Date:11/12/86
127
128     !CULVERT DESCRIPTION                                                                                          !
129     !OUTPUT:                                                                                                      !
130     !Structure ! Size            ! Culvert description                                   ! Total     !  Flow       !
131     !type      ! Width  ! Height ! (design storm cell only)                              ! flow      !  per        !
132     !from      ! (B)    ! (D)    !                                                       !           !  barrel     !
133     !Table 1   ! feet   ! feet   !                                                       ! Q (cfs)   !  Q/N(1)     !
134     !--------- ! ------ ! ------- ! --------------- ---------------------------------------! ---------- ! ---------  !
135  ‡  !      22  !    10  !      6 ! RCB no wingwall flares (extension of sides)           !       350  !       350   !
136  ‡‡ !      22  !    10  !      6 ! RCB no wingwall flares (extension of sides)           !       530  !       530   !
137     !Choice 2  !        !        !                                                       !            !             !
138  ‡  !       1  !        !     72 ! Concrete pipe square edge with headwall               !       350  !       350   !
139  ‡‡ !       1  !        !     72 ! Concrete pipe square edge with headwall               !       530  !       530   !
140     !Choice 3  !        !        !                                                       !            !             !
141  ‡  !      22  !    10  !      6 ! RCB no wingwall flares (extension of sides)           !       350  !       350   !
142  ‡‡ !      22  !    10  !      6 ! RCB no wingwall flares (extension of sides)           !       530  !       530   !
143     !Choice 4  !        !        !                                                       !            !             !
144  ‡  !       4  !        !     48 ! CMP pipe with headwall                                !       350  !       350   !
145  ‡‡ !       4  !        !     48 ! CMP pipe with headwall                                !       530  !       530   !
146     !Choice 5  !        !        !                                                       !            !             !
147  ‡  !       4  !        !     48 ! CMP pipe with headwall                                !       350  !       175   !
148  ‡‡ !       4  !        !     48 ! CMP pipe with headwall                                !       530  !       265   !
149     !Choice 6  !        !        !                                                       !            !             !
150  ‡  !       4  !        !     48 ! CMP pipe with headwall                                !       350  !       117   !
151  ‡‡ !       4  !        !     48 ! CMP pipe with headwall                                !       530  !       177   !
152
153  ‡ Design storm recurrence interval
154 ‡‡ Major storm recurrence interval
```

Figure 50. Total Output from the Example Problem for CULVERT Spreadsheet

22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
Inlet Control								Outlet Control													
	HWi/D	HWi			Fall		EL-hi		TW		dc		(dc+D)/2		ho		ke		H		EL-ho
158	0.93	5.6			0.00		105.57		0.00		3.37		4.69		4.7		0.70		4.69		99.68
159	1.34	8.0			0.00		108.04		0.00		4.44		5.22		5.2		0.70		5.22		101.50
161	1.66	9.94			0.00		109.94		0.00		5.11		5.55		5.55		0.50		5.55		103.70
162	2.97	17.82			0.00		117.82		0.00		5.75		5.88		5.88		0.50		5.88		109.39
164	0.93	5.57			0.00		105.57		0.00		3.37		4.69		4.69		0.70		4.69		99.68
165	1.34	8.04			0.00		108.04		0.00		4.44		5.22		5.22		0.70		5.22		101.50
167	8.01	32.04			0.00		132.04		0.00		3.97		3.99		3.99		0.50		3.99		136.21
168	17.51	70.06			0.00		170.06		0.00		4.00		4.00		4.00		0.50		4.00		185.64
170	2.50	9.99			0.00		109.99		0.00		3.80		3.90		3.90		0.50		3.90		107.45
171	4.87	19.49			0.00		119.49		0.00		3.96		3.98		3.98		0.50		3.98		119.89
173	1.48	5.91			0.00		105.91		0.00		3.34		3.67		3.67		0.50		3.67		101.92
174	2.53	10.13			0.00		110.13		0.00		3.80		3.90		3.90		0.50		3.90		107.64

44	45	46	47	48	49	50	51	52	53	54	55
				** HYDROLOGICAL DATA (Optional input) **							
				Method: Iowa Runoff Chart							
				Drainage area: 2400 acres							
				Channel shape: n/a							
				Routing: n/a							
				Stream slope: .01 ft/ft							
				Other:							
	Control Headwater Elevation (feet)		Outlet Velocity (ft/sec)	** SITE DATA OUTPUT **							
				Roadway Elev.:	110 ft			EL (hd):	107 ft		
				EL (i):	100 ft			Elo:	94 ft		
				EL(i) station:	0 ft			Elo station:	100 ft		
				No. barrels:	1			EL (sf):	100		
				** COMMENTS **							
158	105.57		35.00								
159	108.04		40.77								
161	109.94		35.09	larger pipe needed but due to 6 foot limit cannot							
162	117.82		39.15	increase pipe diameter							
164	105.57		35.00	exceptable design							
165	108.04		40.77								
167	136.21		27.88	try two pipes							
168	185.64		42.18								
170	109.99		23.40	try three pipes							
171	119.89		21.13								
173	105.91		15.60	pipes on hand will not work							
174	110.13		18.11								

Figure 50. (Continued)

2.2.5. XSECT

XSECT

HYDRAULICS - STREAM CROSS-SECTIONS

2.2.5.1. Introduction

The "Hydraulics - Stream Cross-sections" spreadsheet was developed to give the same results as the Iowa Department of Transportation VAL program. The spreadsheet uses the iteration mode to give a discharge in a natural cross-section for each incremental depth. The spreadsheet will handle overbank flooding on one or both banks.

The input consists of the cross-section shots across the channel. The distance from the starting point, the elevation of the shot, and the Manning's n between the previous shot and the current shot are all input parameters. The user also enters the starting depth and incremental depths for which the depths are to be calculated. The output consists of the depth elevation, discharge, velocity, and conveyance.

2.2.5.2. Using the Spreadsheet

The best way to begin using this or any spreadsheet program is to collect all pertinent data, record the data

in a form that is easily transferred into the spreadsheet, and then to enter the data into the spreadsheet. The first step is, thus, to collect the data and record it onto an input form. Once this is done, a user can begin to manipulate the spreadsheet template.

The first step after completing the input form is to load the spreadsheet into the computer to operate it under the control of Microsoft Multiplan. Assume that this spreadsheet is stored on disk as a data file under the filename XSECT.MP in the Normal Mode. Once the program is loaded into the computer, turn both the Recalculation Mode and the Iteration Mode of operation OFF by selecting the Options command from the Multiplan command menu. Then the user enters the data for project number, project name, preparer name, checker name, and dates prepared and checked. The entry lines for these data are found in rows 12 through 15 (see Figure 51).

The user now enters the "Starting elevation of depth computations (ft)" (in R20C5), "Ending elevation of depth computations (ft)" (in R22C5), "Slope (ft/mi)" (in R23C5), and "Depth increment (ft)" (in R24C5). The spreadsheet can calculate up to 32 depth increments. The user can quickly check to see if all the points will be calculated by first subtracting the maximum depth from the minimum depth, and then, dividing by the depth increment.

The next step is to choose whether or not any bank overflow should be considered. If the option the user wants to choose is not already existing in cell R27C5, the value will need to be changed. Change the value in R27C5 (if needed) and turn the Recalculatin Mode ON by pressing the <shift> key and the <exclamation mark> key together (usually this is a SHIFT-1). After the recalculation begins, press the <ESC> key (escape key). This will cancel the recalculation so the user can continue to enter more data that is needed in order to complete the entire computation process.

If one or both bank overflows are desired, enter the shot distances and elevations for each overbank. The shot data for the left bank are entered in row 35, columns 5 and 6, and the data for the right bank is entered in row 36, columns 5 and 6 (see Figure 52). The banks are oriented as if the user is looking upstream for "left" and "right". An example of a stream cross-section is shown in Figure 53 with overbank shots labeled.

The next set of data to enter is the shot distances and elevations that describe the cross-section. Figure 52 shows a cross-section with these values.

The shot points are then entered beginning in R56C5 and R56C6. In R56C5 the first distance is entered (always should be 0.0). Cell R56C5 is the elevation of the first shot point. After the first shot is entered, the second shot is entered beginning with the Manning's

roughness coefficient between the first shot and the second shot in cell R57C4. The distance from the first shot to the second shot is entered in cell R57C5 and the corresponding elevation of the second shot entered in R57C6. The data for the third shot is then entered in row 58. Two things to remember for each shot are: (1) The distance is always that distance between the current shot and the first shot. (2) The Manning's n value describes the channel condition between the previous shot and the current one. A total of 24 shots can be input for each cross-section. The minimum number is 3 shots.

****** IMPORTANT NOTE: The spreadsheet has a problem when two successive shots have exactly the same elevation. To avoid this problem, enter one of the shots with a value slightly higher or lower than the other one. For example, if two successive shots have an elevation of 910.00, then one shot could be entered as 910.00 and the other could be entered as 910.001. This will have no effect on the accuracy of the results since the numbers are, for all practical purposes, equal. ******

Once this data is entered, a user can move down the spreadsheet to view the output beginning in row 84. Select the Options command from the Multiplan command menu and turn both the Recalculation Mode and the Iteration Mode ON for the results to be computed for

viewing.

2.2.5.3. Example Problem

To show how the program works, a sample problem given in an Iowa State University Short Course on the use of the VAL program at the Iowa Department of Transportation will be used. The input form is shown in Figure 54 that the Iowa Department of Transportation has a county engineer office submit when describing cross-sections. The data from this sheet is then entered into the spreadsheet and the results calculated. The input sheet is shown as Figure 51 and the output sheet is shown here as Figure 55. The output from the VAL program is also included as Figure 56.

Figure 51. Data Input for XSECT Example Problem

```
*************************************************************
                HYDRAULICS - STREAM CROSS-SECTIONS
*************************************************************
      ++++++++++++++++++++++++++++++++++++++++++++++++++++
      +  Multiplan Microcomputer Spreadsheets for County   +
      +   Hydraulic and Highway Engineering Computations   +
      +            Copyright by Rocky J. Keehn             +
      +                   Version 1.1                      +
      +                       1986                         +
      ++++++++++++++++++++++++++++++++++++++++++++++++++++

Project Number:                              Date:
Project Name  :                              Date:
Prepared By   :
Checked By    :
-------------------------------------------------------------
INPUT DATA
~~~~~~~~~~
          Starting elevation of
           depth computations (ft)=    987
          Ending elevation of
           depth computations (ft)=    997
          Slope (ft/mi)           =   4.75
          Depth increment (ft)    =      1

          Input one of the following options:
                  Input (0-3) ---->      0
               0 - no overbank flow
               1 - overbank flow both banks
               2 - overbank flow left bank
               3 - overbank flow right bank



-------------------------------------------------------------
OUTPUT:
~~~~~~~
          Slope                   = 0.0009 ft/ft
          Number of iterations    =      9
-------------------------------------------------------------
ITERATION:
~~~~~~~~~~
OUTPUT:
~~~~~~~
          Water depth             =   17.5 feet
          Water elevation         =    997 feet

INPUT - Cross-section information:                          |
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~                          |
                                        Distance  Elev      |
          Data                           (feet)  (feet)     |
                        Manning's n  ________  _______      |
          1 -->        ___________|       0   997.00       |
          2 -->               0.07       92   995.00       |
          3 -->               0.07      145   993.00       |
          4 -->               0.07      275   991.00       |
          5 -->               0.07      430   990.00       |
```

Figure 51. (Continued)

6 -->	0.03	462	982.50
7 -->	0.03	472	979.50
8 -->	0.03	487	982.50
9 -->	0.03	510	990.00
10 --	0.07	562	990.00
11 --	0.07	705	993.00
12 --	0.07	745	995.00
13 --	0.07	807	1000.90
14 --	0.07	900	1003.00
15 --			
16 --			
17 --			
18 --			
19 --			
20 --			
21 --			
22 --			
23 --			
24 --			
Sums:	---------->		

Figure 52. Example When Inputting Overbank Data in XSECT

```
        1       2      3          4           5        6          7
 1 ***************************************************************
 2                 HYDRAULICS - STREAM CROSS-SECTIONS
 3 ***************************************************************
 4       ++++++++++++++++++++++++++++++++++++++++++++++++++++++
 5       +  Multiplan Microcomputer Spreadsheets for County   +
 6       +   Hydraulic and Highway Engineering Computations   +
 7       +            Copyright by Rocky J. Keehn             +
 8       +                   Version 1.1                      +
 9       +                       1986                         +
10       ++++++++++++++++++++++++++++++++++++++++++++++++++++++
11
12 Project Number:                                Date:
13 Project Name  :                                Date:
14 Prepared By   :
15 Checked By    :
16 ---------------------------------------------------------------
17 INPUT DATA
18 ~~~~~~~~~~
19           Starting elevation of
20            depth computations (ft)=    987
21           Ending elevation of
22            depth computations (ft)=    997
23           Slope (ft/mi)           =   4.75
24           Depth increment (ft)    =      1
25
26           Input one of the following options:
27                   Input (0-3) ---->      1
28                0 - no overbank flow
29                1 - overbank flow both banks
30                2 - overbank flow left bank
31                3 - overbank flow right bank
32           Input location of overflow bank:
33                                        dist. elev.
34                                        (ft)  (ft)
35              Overflow left bank    =   220   994
36              Overflow right bank   =   600   996
37
38 ---------------------------------------------------------------
39 OUTPUT:
40 ~~~~~~~
41           Slope                   = 0.0009 ft/ft
42           Number of iterations    =      9
43 ---------------------------------------------------------------
44 ITERATION:
45 ~~~~~~~~~~
46 OUTPUT:
47 ~~~~~~~
48           Water depth             =    7.5 feet
49           Water elevation         =    987 feet
50
51 INPUT - Cross-section information:                          |
52 ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~                          |
53                                       Distance  Elev        |
54           Data                         (feet)  (feet)        |
55                        Manning's n  ________ _______        |
56           1 -->        __________|      0   997.00         |
57           2 -->              0.07      92   995.00         |
58           3 -->              0.07     145   993.00         |
59           4 -->              0.07     275   991.00         |
```

Figure 53. XSECT Example Cross-Section

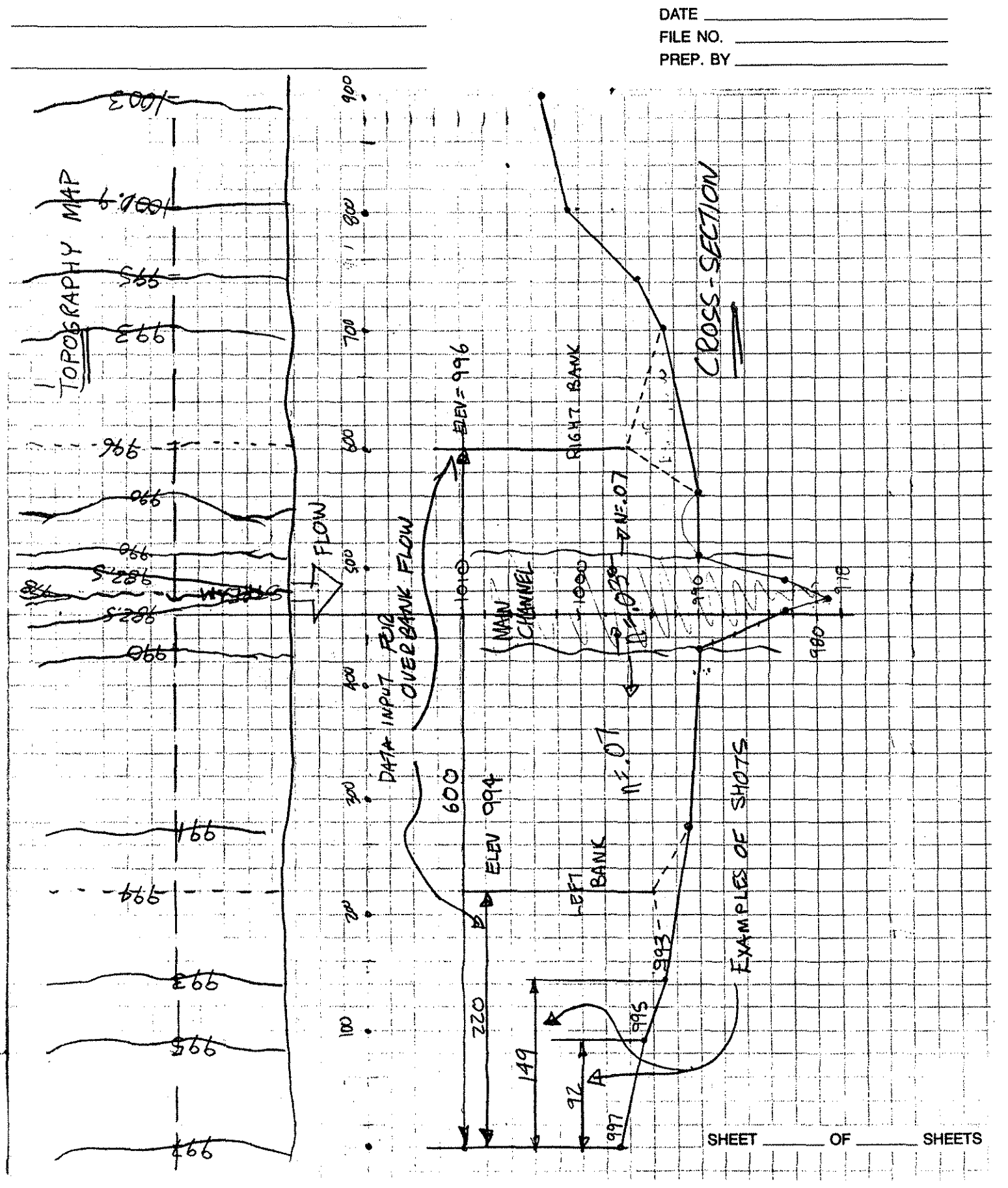


Figure 54. VAL Program Data Input Form

VALLEY CROSS SECTION DATA

The submittal of a bridge type structure will include a right angle valley section. This section should be taken downstream from the crossing. It shall be noted whether it is an average section or a control section. Enough ground shots will be taken to outline the valley to an elevation well above extreme highwater. Special care will be taken to accurately outline the main channel. Each shot should be identified; that is (FP) flood plain, (TB) top of bank, (ES) edge of stream, etc. Mannings equation roughness factors will be assigned each shot. Include site photos with this information.

REMARKS: Section taken 100' downstream from crossing. It is an average section. There are no control sections downstream from the bridge that effect the bridge hydraulics.

Distance	Elevation	(N) Roughness	Remarks	Distance	Elevation	(N) Roughness	Remarks
0	997.0	n=0.07	FP	807	1000.9	0.07	FP
92	995.0			900	1003.0	0.07	FP
145	993.0						
275	991.0						
430	990.0	n=0.07 n=0.03	EB				
462	982.5		ES				
472	979.5		℄ S				
487	982.5		ES				
510	990.0	n=0.03 n=0.07	TB				
562	990.0		FP				
705	993.0		FP				
745	995.0		FP				

PLAT OF DRAINAGE AREA

The drainage area is to be platted as completely and accurately as possible and to the largest practicable scale on a separate sheet. Use a definite scale, as 1" equals ¼, ½, 1 or 2 miles, and indicate what scale has been used. In addition to the outlines of the watershed, indicate the positions of the streams and, roughly, the character of the soil and the relative locations of the steep and flat portions. Whenever practicable, the above information should be secured by going over the area either on foot or in a car. For most watersheds the information may be secured from the best existing data, soil maps, U.S.G.S. maps and Bulletin No. 7-1.H.R.B. No plat is necessary if the area is listed in Bulletin Number 7.

REMARKS:

Give additional information by reference to marginal number on reverse side of this sheet.

Marginal No.	
5	Mr. Doe has been living in this area all his life (62 years.)

IMPORTANT NOTE

The information given on this form must in all cases be supplemented by complete plat and profile of the site, drawn to a convenient scale on a separate sheet.

The information as shown on this form is essential and must be supplied in detail before the plans can be prepared or approved. It will be necessary to return this form for correction unless the data supplied is complete.

Figure 55. Output Table from XSECT Spreadsheet

OUTPUT:

Data Point	Water Elev. (feet)	Water Depth (feet)	Q (cfs)	Velocity (ft/sec)	Conveyance (sq. ft.)
1	987	7.5	805	3.6	224
2	988	8.5	1114	3.9	286
3	989	9.5	1488	4.2	355
4	990	10.5	1930	4.5	431
5	991	11.5	2635	4.0	665
6	992	12.5	3613	3.4	1055
7	993	13.5	4890	3.1	1559
8	994	14.5	6566	3.1	2142
9	995	15.5	8557	3.1	2772
10	996	16.5	10835	3.1	3453
11	997	17.5	13442	3.2	4191

Figure 56. VAL Program Output

Instructions for using VAL program on DOT TSO

```
                    IOWA DEPARTMENT OF TRANSPORTATION
SYSTEM AVAILABILITY EXCEPT AS NOTED BELOW. 7 DAYS/WEEK, 24 HOURS/DAY
                FOR HELP, OR TO REPORT A TERMINAL PROBLEM:
              CALL D.O.T. NETWORK HELP DESK: 515-239-1075.
                          TERMINAL ID: DTIMF22
                   ------------- LOGON MENU -------------
SELECT ONE.  (REPLACE _ WITH ANY CHARACTER OR PRESS THE INDICATED PF KEY)
           _ (PF1/13) PROFESSIONAL OFFICE SYSTEM (PROFS)
           _ (PF2/14) TIME SHARING SYSTEM (TSO)
           _ (PF3/15) CUSTOMER INFORMATION CONTROL SYSTEM (CICS)
           _ (PF4/16) C.D.P. PROFS
           _ (PF5/17) C.D.P. OTHER APPLICATIONS
           _ (PF6/18) TEST C.I.C.S. -- I.S. INTERNAL USE ONLY ---
           _ (PF7/19) NCCF  --- FOR I.S. INTERNAL USE ONLY ---
           _ (PF8/20) DTACICST --- I.S. INTERNAL USE ONLY ---
```

Get Menu on Screen

Push [PF14] key

```
                 ENTER TSO USER INFO AND PRESS ENTER
                USERID: BR03 → PASSWORD: _____ → PROC: →
                ACCT   5320-211 (E)                SIZE:
          RECONNECT TO DISCONNECTED SESSION:   (Y OR LEAVE BLANK)
      IF YOU WISH TO RETURN TO THE DOT MENU PRESS ANY PF KEY
```

Key in information that is underlined Then Push [Enter] Key at each place you See (E) on this printout

Password will not show. It is your confidential number. Press → at these 3 locations. Use your numbers

```
BR03 LOGON IN PROGRESS AT 12:39:27 ON MARCH 15, 1985
NO BROADCAST MESSAGES
READY
VAL (E)
*******************************
*                             *
*  ARE YOU USING A CRT? (Y/N) *
*                             *
*******************************
=) Y (E)
ENTER JOB IDENTIFICATION.
MAXIMUM OF 63 CHARACTERS

58978 (E)
ANY CHANGES? ENTER Y OR N.  N (E)
ENTER NUMBER OF CROSS SECTION SHOTS.  14 (E)
ANY CHANGE?  N (E)
ENTER CROSS SECTION SHOTS, OFFSET FOLLOWED BY ELEV.
X( 1)  Y( 1)   0 997 (E)
X( 2)  Y( 2)   92 995 (E)
X( 3)  Y( 3)   145 993 (E)
X( 4)  Y( 4)   275 991 etc.
275 991 (Entered By Computer when screen was changed automatically)
X( 5)  Y( 5)   430 990
X( 6)  Y( 6)   462 982.5
X( 7)  Y( 7)   472 979.5
X( 8)  Y( 8)   487 982.5
X( 9)  Y( 9)   510 990
X( 10) Y( 10)  562 990
X( 11) Y( 11)  705 993
X( 12) Y( 12)  745 995
X( 13) Y( 13)  807 1000.9
X( 14) Y( 14)  900 1003
ANY CHANGES?  N (E)
ENTER SLOPE IN FT./MI.  4.75 (E)
ANY CHANGE? (Y OR N)  N (E)
ENTER NUMBER OF SECTIONS.  3 (E)
ANY CHANGE?  N (E)
ENTER SECTION DISTANCE AND N VALUE.
D( 1)  N( 1)   430 .07 (E)
D( 2)  N( 2)   510 .03 (E)
D( 3)  N( 3)   900 .07 (E)
ANY CHANGES?  N (E)
ENTER STAGE DATA. (HIGH ELEV, LOW ELEV, AND INCREMENT)
MAKE SURE HIGH ELEV IS LOWER THAN HIGHEST CROSS SECTION SHOTS.
*** (E)
997 987 1 (E)
ANY CHANGES?  N (E)
IS THERE A LOW POINT ON THE FLOOD PLAIN? (Y OR N)  N (E)
```

Key in Distance - Blank Space - Elevation for each shot

Key in Distance - Blank space - n Value for each Section

Key in High Elev., Space, Low Elev., Space, Increment

Computer puts 3 stars that require an (E) to shift screens.

```
      58978
      CROSS SECTION SHOTS
        NO.     X        Y
        1       0      997.0
        2      92      995.0
        3     145      993.0
        4     275      991.0
        5     430      990.0
        6     462      982.5
        7     472      979.5
        8     487      982.5
        9     510      990.0
```

Input

Output

Figure 56. (Continued)

```
      10     562      990.0
      11     705      993.0
*** (E)
      12     745      995.0
      13     807     1000.9
      14     900     1003.0
    SLOPE IN FEET/MILE .....  4.750
    SECTION  DIST.  N VALUE
       1     430   0.070
       2     510   0.030
       3     900   0.070
    STAGE DATA
     HIGH ELEV.  LOW ELEV. INCREMENT
        997.00     987.00    1.00
    58978
                          SECTION   DISCHARGE     VELOCITY        CONVEYANCE   N
VALUE
STAGE ELEV.  987.00
*** (E)
                            1          0 CFS      0.0 FPS         0 SQ. FT.
       0     0.0700
                            2        805 CFS      3.6 FPS       224 SQ. FT.
   26832     0.0300
                            3          0 CFS      0.0 FPS         0 SQ. FT.
       0     0.0700
                          TOTAL      805 CFS      3.6 FPS       224 SQ. FT.
   26832
STAGE ELEV.  988.00
                            1          0 CFS      0.0 FPS         0 SQ. FT.
       0     0.0700
                            2       1114 CFS      3.9 FPS       286 SQ. FT.
   37146     0.0300
                            3          0 CFS      0.0 FPS         0 SQ. FT.
       0     0.0700
                          TOTAL     1114 CFS      3.9 FPS       286 SQ. FT.
   37146
STAGE ELEV.  989.00
                            1          0 CFS      0.0 FPS         0 SQ. FT.
***(E)
       0     0.0700
                            2       1488 CFS      4.2 FPS       355 SQ. FT.
   49603     0.0300
                            3          0 CFS      0.0 FPS         0 SQ. FT.
       0     0.0700
                          TOTAL     1488 CFS      4.2 FPS       355 SQ. FT.
   49603
STAGE ELEV.  990.00
                            1          0 CFS      0.0 FPS         0 SQ. FT.
       0     0.0700
                            2       1930 CFS      4.5 FPS       431 SQ. FT.
   64358     0.0300
                            3          0 CFS      0.0 FPS         0 SQ. FT.
       0     0.0700
                          TOTAL     1930 CFS      4.5 FPS       431 SQ. FT.
   64358
STAGE ELEV.  991.00
                            1         31 CFS      0.4 FPS        77 SQ. FT.
    1039     0.0700
*** (E)
                            2       2563 CFS      5.0 FPS       511 SQ. FT.
   85463     0.0300
                            3         40 CFS      0.5 FPS        76 SQ. FT.
    1345     0.0700
                          TOTAL     2635 CFS      4.0 FPS       665 SQ. FT.
   87847
STAGE ELEV.  992.00
                            1        192 CFS      0.7 FPS       265 SQ. FT.
    6386     0.0700
                            2       3266 CFS      5.5 FPS       591 SQ. FT.
  108895     0.0300
                            3        156 CFS      0.8 FPS       199 SQ. FT.
    5190     0.0700
                          TOTAL     3613 CFS      3.4 FPS      1056 SQ. FT.
  120470
STAGE ELEV.  993.00
                            1        492 CFS      1.0 FPS       517 SQ. FT.
   16394     0.0700
                            2       4035 CFS      6.0 FPS       671 SQ. FT.
*** (E)
  134544     0.0300
                            3        363 CFS      1.0 FPS       370 SQ. FT.
   12097     0.0700
                          TOTAL     4890 CFS      3.1 FPS      1559 SQ. FT.
  163034
STAGE ELEV.  994.00
                            1        989 CFS      1.2 FPS       816 SQ. FT.
   32987     0.0700
                            2       4868 CFS      6.5 FPS       751 SQ. FT.
  162317     0.0300
                            3        708 CFS      1.2 FPS       575 SQ. FT.
   23612     0.0700
                          TOTAL     6566 CFS      3.1 FPS      2142 SQ. FT.
  218915
```

If no printer is available you should copy data before you change screens.(*** (E))

987 - 979.5

Figure 56. (Continued)

```
STAGE ELEV.  995.00
                          1        1638 CFS      1.4 FPS      1140 SQ. FT.
   54608     0.0700
                          2        5763 CFS      6.9 FPS       831 SQ. FT.
  192136     0.0300
*** E
                          3        1157 CFS      1.4 FPS       800 SQ. FT.
   38566     0.0700
                        TOTAL      8558 CFS      3.1 FPS      2772 SQ. FT.
  285310
STAGE ELEV.  996.00
                          1        2379 CFS      1.6 FPS      1501 SQ. FT.
   79315     0.0700
                          2        6717 CFS      7.4 FPS       911 SQ. FT.
  223934     0.0300
                          3        1740 CFS      1.7 FPS      1041 SQ. FT.
   58006     0.0700
                        TOTAL     10835 CFS      3.1 FPS      3453 SQ. FT.
  361255
STAGE ELEV.  997.00
                          1        3290 CFS      1.7 FPS      1908 SQ. FT.
  109701     0.0700
                          2        7728 CFS      7.8 FPS       991 SQ. FT.
  257649     0.0300
                          3        2424 CFS      1.9 FPS      1292 SQ. FT.
*** E
   80824     0.0700
                        TOTAL     13442 CFS      3.2 FPS      4191 SQ. FT.
  448174
IS DESIGN STAGE COMPUTATION DESIRED?  ENTER Y OR N : Y E
ENTER DESIGN DISCHARGE (IN CFS).  : 5200 E
ANY CHANGE?   N E
DESIGN DISCHAGRE    5200
STAGE ELEV.  993.21
                          1         584 CFS      1.0 FPS       578 SQ. FT.
   19481     0.0700
                          2        4207 CFS      6.1 FPS       688 SQ. FT.
  140250     0.0300
                          3         427 CFS      1.0 FPS       412 SQ. FT.
   14246     0.0700
                        TOTAL      5218 CFS      3.1 FPS      1679 SQ. FT.
  173977
*** E
IS DESIGN STAGE COMPUTATION DESIRED?  ENTER Y OR N : Y E
ENTER DESIGN DISCHARGE (IN CFS).  : 4200 E
ANY CHANGE?   N E
DESIGN DISCHAGRE    4200
STAGE ELEV.  992.50
                          1         324 CFS      0.8 FPS       384 SQ. FT.
   10791     0.0700
                          2        3645 CFS      5.8 FPS       631 SQ. FT.
  121509     0.0300
                          3         247 CFS      0.9 FPS       279 SQ. FT.
    8239     0.0700
                        TOTAL      4215 CFS      3.3 FPS      1295 SQ. FT.
  140539
IS DESIGN STAGE COMPUTATION DESIRED?  ENTER Y OR N : N E
DO YOU WANT TO CHANGE N VALUES?  ENTER Y OR N  : N E

ARE ADDITIONAL STAGES DESIRED?   N E
DO YOU WANT TO CHANGE THE SLOPE? (Y OR N)

N E
DO YOU WANT TO CHANGE ANY X-SECT. SHOTS? (Y OR N):  N E
DO YOU WANT TO RERUN FROM THE BEGINNING? :  N E
END OF JOB
** ENTER B IF YOU WISH TO BROWSE THE PRINT DATASET  **
** ENTER R IF YOU WISH TO RESTART AT THE BEGINNING  **
** ENTER P IF YOU WISH TO PRINT THE LISTING         **
** ENTER E IF YOU WISH TO END THE PROGRAM AND NOT   **
**         PRINT THE LISTING                        **
** P E
Logoff E
```

You could Browse By pushing B.

break

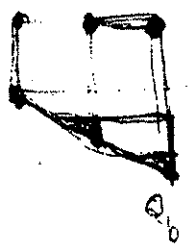


Figure 56. (Continued)

58978

CROSS SECTION SHOTS

NO.	X	Y
1	0	997.0
2	92	995.0
3	145	993.0
4	275	991.0
5	430	990.0
6	462	982.5
7	472	979.5
8	487	982.5
9	510	990.0
10	562	990.0
11	705	993.0
12	745	995.0
13	807	1000.9
14	900	1003.0

This is a listing if P is keyed and a printer is available.

SLOPE IN FEET/MILE 4.750

SECTION	DIST.	N VALUE
1	430	0.070
2	510	0.030
3	900	0.070

STAGE DATA

HIGH ELEV.	LOW ELEV.	INCREMENT
997.00	987.00	1.00

58978

	SECTION	DISCHARGE	VELOCITY	CONVEYANCE	N VALUE	
STAGE ELEV. 987.00						
	1	0 CFS	0.0 FPS	0 SQ. FT.	0	0.0700
	2	805 CFS	3.6 FPS	224 SQ. FT.	26832	0.0300
	3	0 CFS	0.0 FPS	0 SQ. FT.	0	0.0700
	TOTAL	805 CFS	3.6 FPS	224 SQ. FT.	26832	
STAGE ELEV. 988.00						
	1	0 CFS	0.0 FPS	0 SQ. FT.	0	0.0700
	2	1114 CFS	3.9 FPS	286 SQ. FT.	37146	0.0300
	3	0 CFS	0.0 FPS	0 SQ. FT.	0	0.0700
	TOTAL	1114 CFS	3.9 FPS	286 SQ. FT.	37146	
STAGE ELEV. 989.00						
	1	0 CFS	0.0 FPS	0 SQ. FT.	0	0.0700
	2	1488 CFS	4.2 FPS	355 SQ. FT.	49603	0.0300
	3	0 CFS	0.0 FPS	0 SQ. FT.	0	0.0700
	TOTAL	1488 CFS	4.2 FPS	355 SQ. FT.	49603	
STAGE ELEV. 990.00						
	1	0 CFS	0.0 FPS	0 SQ. FT.	0	0.0700
	2	1930 CFS	4.5 FPS	431 SQ. FT.	64358	0.0300
	3	0 CFS	0.0 FPS	0 SQ. FT.	0	0.0700
	TOTAL	1930 CFS	4.5 FPS	431 SQ. FT.	64358	
STAGE ELEV. 991.00						
	1	31 CFS	0.4 FPS	77 SQ. FT.	1039	0.0700
	2	2563 CFS	5.0 FPS	514 SQ. FT.	85463	0.0300
	3	40 CFS	0.5 FPS	76 SQ. FT.	1345	0.0700
	TOTAL	2635 CFS	4.0 FPS	665 SQ. FT.	87847	
STAGE ELEV. 992.00						
	1	192 CFS	0.7 FPS	265 SQ. FT.	6386	0.0700
	2	3266 CFS	5.5 FPS	591 SQ. FT.	108895	0.0300
	3	156 CFS	0.8 FPS	199 SQ. FT.	5190	0.0700
	TOTAL	3613 CFS	3.4 FPS	1056 SQ. FT.	120470	
STAGE ELEV. 993.00						
	1	492 CFS	1.0 FPS	517 SQ. FT.	16394	0.0700
	2	4035 CFS	6.0 FPS	671 SQ. FT.	134544	0.0300
	3	363 CFS	1.0 FPS	370 SQ. FT.	12097	0.0700
	TOTAL	4890 CFS	3.1 FPS	1559 SQ. FT.	163034	

Figure 56. (Continued)

1	492 CFS	1.0 FPS	517 SQ. FT.	16394	0.0700
2	4035 CFS	6.0 FPS	671 SQ. FT.	134544	0.0300
3	363 CFS	1.0 FPS	370 SQ. FT.	12097	0.0700
TOTAL	4890 CFS	3.1 FPS	1559 SQ. FT.	163034	

STAGE ELEV. 994.00

1	989 CFS	1.2 FPS	816 SQ. FT.	32987	0.0700
2	4868 CFS	6.5 FPS	751 SQ. FT.	162317	0.0300
3	708 CFS	1.2 FPS	575 SQ. FT.	23612	0.0700
TOTAL	6566 CFS	3.1 FPS	2142 SQ. FT.	218915	

STAGE ELEV. 995.00

1	1638 CFS	1.4 FPS	1140 SQ. FT.	54608	0.0700
2	5763 CFS	6.9 FPS	831 SQ. FT.	192136	0.0300
3	1157 CFS	1.4 FPS	800 SQ. FT.	38566	0.0700
TOTAL	8558 CFS	3.1 FPS	2772 SQ. FT.	285310	

STAGE ELEV. 996.00

1	2379 CFS	1.6 FPS	1501 SQ. FT.	79315	0.0700
2	6717 CFS	7.4 FPS	911 SQ. FT.	223934	0.0300
3	1740 CFS	1.7 FPS	1041 SQ. FT.	58006	0.0700
TOTAL	10835 CFS	3.1 FPS	3453 SQ. FT.	361255	

STAGE ELEV. 997.00

1	3290 CFS	1.7 FPS	1908 SQ. FT.	109701	0.0700
2	7728 CFS	7.8 FPS	991 SQ. FT.	257649	0.0300
3	2424 CFS	1.9 FPS	1292 SQ. FT.	80824	0.0700
TOTAL	13442 CFS	3.2 FPS	4191 SQ. FT.	448174	

DESIGN DISCHAGRE 5200
STAGE ELLV. 993.21

1	584 CFS	1.0 FPS	578 SQ. FT.	19481	0.0700
2	4207 CFS	6.1 FPS	688 SQ. FT.	140250	0.0300
3	427 CFS	1.0 FPS	412 SQ. FT.	14246	0.0700
TOTAL	5218 CFS	3.1 FPS	1679 SQ. FT.	173977	

DESIGN DISCHAGRE 4200
STAGE ELEV. 992.50

1	324 CFS	0.8 FPS	384 SQ. FT.	10791	0.0700
2	3645 CFS	5.8 FPS	631 SQ. FT.	121509	0.0300
3	247 CFS	0.9 FPS	279 SQ. FT.	8239	0.0700
TOTAL	4215 CFS	3.3 FPS	1295 SQ. FT.	140539	

2.2.6. WSNAT

WSNAT

WATER SURFACE PROFILES

NATURAL CHANNEL CROSS-SECTIONS

2.2.6.1. Introduction

The "Water Surface Profiles - Natural Channel Cross-section" spreadsheet was developed to calculate the water depth along a natural channel. This type of cross-section is normally associated with creeks, streams and rivers.

This spreadsheet allows the user to calculate the backwater effects of structures located along the channel reach. It permits the user to calculate the tailwater depths of upstream structures.

The initial input consists of the energy coefficient, design flow, and the starting water depth elevation. One also needs to input a description of the channel cross-section. This entry data includes: the station distance from the first station, minimum channel elevation, maximum channel elevation, whether or not there is overbanking (on the left bank, on the right bank or on both banks), distance and elevation of the overbanking from a datum (if overbanking exists), and values that outline the channel. The channel is described as starting at a point on the left bank, setting that distance equal to zero and recording the elevation at that point. There is no limit to the number of cross-sections permitted.

Once the data are entered, the user must then interate the water surface elevation at each cross-section. This is done by entering a trial depth and checking whether or not it is an acceptable value (if not acceptable then input a new elevation; if acceptable then go to next station). The spreadsheet contains a cell that tells the user whether to increase or decrease the elevation. A check value is also entered for each iteration. This check value should approach 0.001 as the iterations are performed.

After all the cross-sections' water elevations have been iterated by the user, the final output can be printed for a paper record. Included in the output data

are the channel bottom elevation, water surface elevation, energy line elevation, water depth, and friction loss. From these data a water surface profile can be drawn and the water depths caused by the headwater can be evaluated.

2.2.6.2. Using the Spreadsheet

The best way to begin using a spreadsheet is to obtain all pertinent data, record the data in a form that is easily transferred into the spreadsheet, and then input the data into the spreadsheet. The data obtained in the field, from topographic maps, and engineering principles can be transferred to an input form. Once this is done the user can begin to manipulate the spreadsheet.

The first step in using the spreadsheet is to load it into the computer memory so that it can be operated under the control of Microsoft Multiplan. Assume that this spreadsheet resides on disk as a data file under the filename of WSTRAP1.MP and has been saved to disk in the Normal Mode. Once the file has been loaded into the computer, select the Options command from the Multiplan command menu and turn the Recalculation Mode of operation OFF. Next enter the project number, project name, preparer's name, checker's name, and dates prepared and checked. These entry items are located in rows 13 through 16 (see Figure 57). Once these administrative

data have been entered, the constant values in column 8, rows 20 through 22 (see Figure 57) can be entered. Values for the energy coefficient, entered in row 20, column 7, (see Figure 57) are given in Table 6. The starting water depth is typically headwater depth of the structure located where the first cross-section is located.

Table 6. Various values for the energy coefficient (after Chow, 1959).

Channels	Value of the energy coefficient		
	Minimum	Average	Maximum
Regular channels, flumes, spillways	1.10	1.15	1.20
Natural streams, and torrents	1.15	1.30	1.50
Rivers under ice cover	1.20	1.50	2.00
River valleys overflooded	1.50	1.75	2.00

The next step is to input the data for each cross-section. The number of cross-sections are limitless. This is accomplished by allowing a newly created spreadsheet to copy data from a previous spreadsheet which contains the data from the previous downstream cross-section. Once a series of spreadsheets

have been created, the output from each is copied onto a summary output spreadsheet. The data needed to begin entering the cross-section is the cross-section shots.

An example of cross-section shots is depicted in Figure 58. The information therein illustrates how a person finds the offset and elevation at each shot. In addition to the elevation at each shot, a person needs to determine what is the Manning's roughness coefficient for each shot. The roughness coefficient is the one in the reach from the previous shot to the current shot. Besides the shot data, the user has to input the distance from the starting station to the station for which the data is being input, the minimum elevation of the channel cross-section, and the maximum elevation of the channel cross-section.

The input data for the station distance from the starting point, minimum elevation, maximum elevation for the first cross-section are input in column 6, rows 61, 62, 63 respectively (see Figure 59). The data for the cross-section shots begin in row 63, columns 11 and 12, and end at row 83, columns 10, 11, and 12. A Manning's roughness coefficient is not needed for the first shot.

If overbank flow is a problem, an additional item of information is needed. An example of what is meant by overbank flow is illustrated in Figure 58. Users need to specify whether the overbanking will not occur, will occur on the left bank only, will occur on the right

bank, or will occur on both banks. The overbanking condition is identified by entering a 0 for no overbanking, a 1 for overbank flow on both banks, a 2 for overbank flow on left bank only, or a 3 for overbank flow on right bank only. This "flag" is entered in row 68, column 6 (for cross-section 1 only). The orientation of left and right is based upon the user looking upstream of the flow.

The highest cross-section shot in the channel reach before overtopping can occur needs to be entered. This input data inlcudes the offset distance and elevation at the point of overtopping. The data input for cross-section 1 is entered in columns 6 and 7, rows 76 and 77.

Once all the data listed above have been entered for cross-section 1, repeat the input process for cross-section 2 (see Figure 59). The basic input is entered in rows 90 through 92, column 6. For the cross-section, begin entering data in row 92, columns 11 and 12. The overbanking entry begins in column 6, row 97. Once this process is complete for cross-section 2, proceed to cross-section 3. The data input for the third cross-section is located between rows 115 and 143 in a similar fashion to cross-section 2. (Additional cross-sections are entered by creating more spreadsheets, such as WSNAT2.MP, which can contain three more cross-sections each and continuing on with an "external

copy" capability. Consult the Microsoft Multiplan Manual.)

When all the cross-sections have been entered, the spreadsheet is ready for computation and the iteration process can begin. The water surface elevation for the first cross-section is automatically transferred from the constant value previously entered in row 22, coumn 8 (see Figure 57). The user then begins the iteration process at cross-section 2. A person first enters a trial water elevation in column 8, row 28 (see Figure 60). Once a water elevation is entered a "(+)" or a "(-)" will appear in row 31 below the water surface number just entered. If it is a "(+)" then the water surface elevation should be increased to achieve closure in the iteration process. If the indicator is a "(-)" then the water surface elevation should be decreased.

The method for finding the water surface is based on the standard step method presented by Chow (1959). This method is based on the fact that the total head at the current cross-section is equal to the total head at the previous cross-section plus the friction head plus the eddy losses. For convenience of computation, the eddy losses can be considered part of the friction loss (Chow, 1959). The check value in row 32 is the difference between the total head at the current cross-section and the total head plus the friction loss at the previous cross-section. As the check value becomes smaller, the

precision of the method increases. For this spreadsheet, the recommended precision is such that the value in row 47 becomes 0.000 or a very small minimum value.

Once the water surface elevation is at a satisfactory precision level, proceed to cross-section 3 (row 28, column 9) and repeat the process. For a problem encompassing three cross-sections, this would complete the spreadsheet. To continue on to more cross-sections beyond three, the user will have to use a second spreadsheet file, such as WSNAT2.MP, and employ the Multiplan "extenal copy" capability to bring the intermediate results from WSNAT1.MP into WSNAT2.MP. In this fashion, the process can be extended indefinitely. If only three cross-sections are needed to satisfy the hyraulic analysis for this project, the user can review the output at this time.

The output data for cross-sections 1, 2, and 3 can be found in rows 143 through 153. To "jump" to this portion of the spreadsheet, select the Goto command from the Multiplan command menu, then select the Name subcommand within the Goto command, and finally enter the name OUTPUT (press <return> or <enter> key to complete the command). This will move the cell pointer directly to the output area of the spreadsheet.

The spreadsheet should now be saved as a data file for later use. If additional cross-sections are to be incorporated in this analysis, name the spreadsheet when

saving it in some fashion that identifies the spreadsheet as containing cross-sections 1-3.

For purpose of explaining how to continue on to cross-sections 4 through 6, the data for the first three cross-sections will be assumed to be saved as EXAMPLE. The first step in continuing to cross-section 4 is to load the spreadsheet WSNAT2.MP into memory to bring it under the operational control of the Multiplan program. Once this is done, enter the identification data in rows 13 through 16. Then move to the cell located in row 26, column 7. This cell (R26C7) is located just below where the spreadsheet displays the message "Transfered Cells".

The user can now copy the necessary data from the spreadsheet template created for cross-sections 1 through 3. This is accomplished by using the XTERNAL/COPY command sequence from the Multiplan command menu. While the Multiplan command menu is displayed on the screen, press X or move the command cursor over to XTERNAL and press <return>. Multiplan will then display the subcommands under the XTERNAL command. One of these subcommands indicated will be COPY. As before, either press C or move the command cursor to COPY and press <return>. Multiplan will then bring up the prompts to identify from where the "external copying" is to be done. The user must enter the name of the spreadsheet from which the data is to be pulled and the name of the block of cells (or the row:column range) in which the data

resides.

It was assumed for this discussion that the first three cross-sections were saved as a data file named EXAMPLE. Thus, for naming the spreadsheet from which data is to be copied, the user would enter EXAMPLE if the file is stored in the default drive, enter B:EXAMPLE if the file is stored on a disk in Drive B, or enter pathname\EXAMPLE is the file is located in a hard disk directory. The name of the cells where the data to be copied is located has already been "named" TRANSFER, hence the user will always enter the name of the cells as TRANSFER to complete the "external" reference. Once this is done, tab twice to the "linked" subsubcommand prompt and set it to NO. This completes the set up for copying the previous output data as initial starting data into the continuation spreadsheet, so press <return> to begin the transfer of data from EXAMPLE into WSNAT2.MP.

Once the transfer is complete, the user then enters the cross-section data for the next three cross-sections. This data input begins in row 56. The input requirements and location of data entry is exactly the same as that for cross-sections 1 through 3, <u>except that one needs to enter the sequential cross-section number "Station distance from the starting station" in rows 58, 70, and 88</u>. When all the cross-sectional entries are complete go to row 27, column 8 and iterate the water surface elevation for each of the three cross-sections in this

spreadsheet. This procedure is the same as that which was employed for the first three cross-sections.

After completing the spreadsheet for cross-sections 4 through 6, the user should save the file. If additional cross-sections are to be analyzed, make a note of the filename (include a coded reference to sections 4-6), load a copy of WSNAT2.MP again to repeat the data entry process for cross-sections 7-9. Now the data is copied from the file containing cross-sections 4-6. In this manner the process can be extended indefinitely. An example of a spreadsheet created to provide the summary output is shown in Figure 61.

2.2.6.3. Reference

Chow, Ven Te, Open-Channel Hyraulics, McGraw-Hill, Inc. New York, 1959, pp. 27-28, 249-289.

Figure 57. Input of Administrative Data for WSNAT

```
        1         2         3   4     5         6         7         8
 1 ***********************************************************************
 2     WATER SURFACE PROFILES - NATURAL CHANNEL CROSS-SECTIONS
 3                              STARTER SHEET
 4 ***********************************************************************
 5        ++++++++++++++++++++++++++++++++++++++++++++++++++++++++
 6        +  Multiplan Microcomputer Spreadsheets for County    +
 7        +   Hydraulic and Highway Engineering Computations    +
 8        +              Copyright by Rocky J. Keehn            +
 9        +               All Rights Reserved, 1986             +
10        +                    Version 1.1                      +
11        ++++++++++++++++++++++++++++++++++++++++++++++++++++++++
12
13 Project Number:
14 Project Name  :
15 Prepared By   :                              Date:
16 Checked By    :                              Date:
17 ---------------------------------------------------------------------
18 INPUT - constant variables
19 ~~~~~~~~~~~~~~~~~~~~~~~~~~~~
20            Energy coefficient, unitless                =
21            Design flow, cfs                            =
22            Starting water depth elevation, feet        =
```

Figure 58. Example Cross-Section

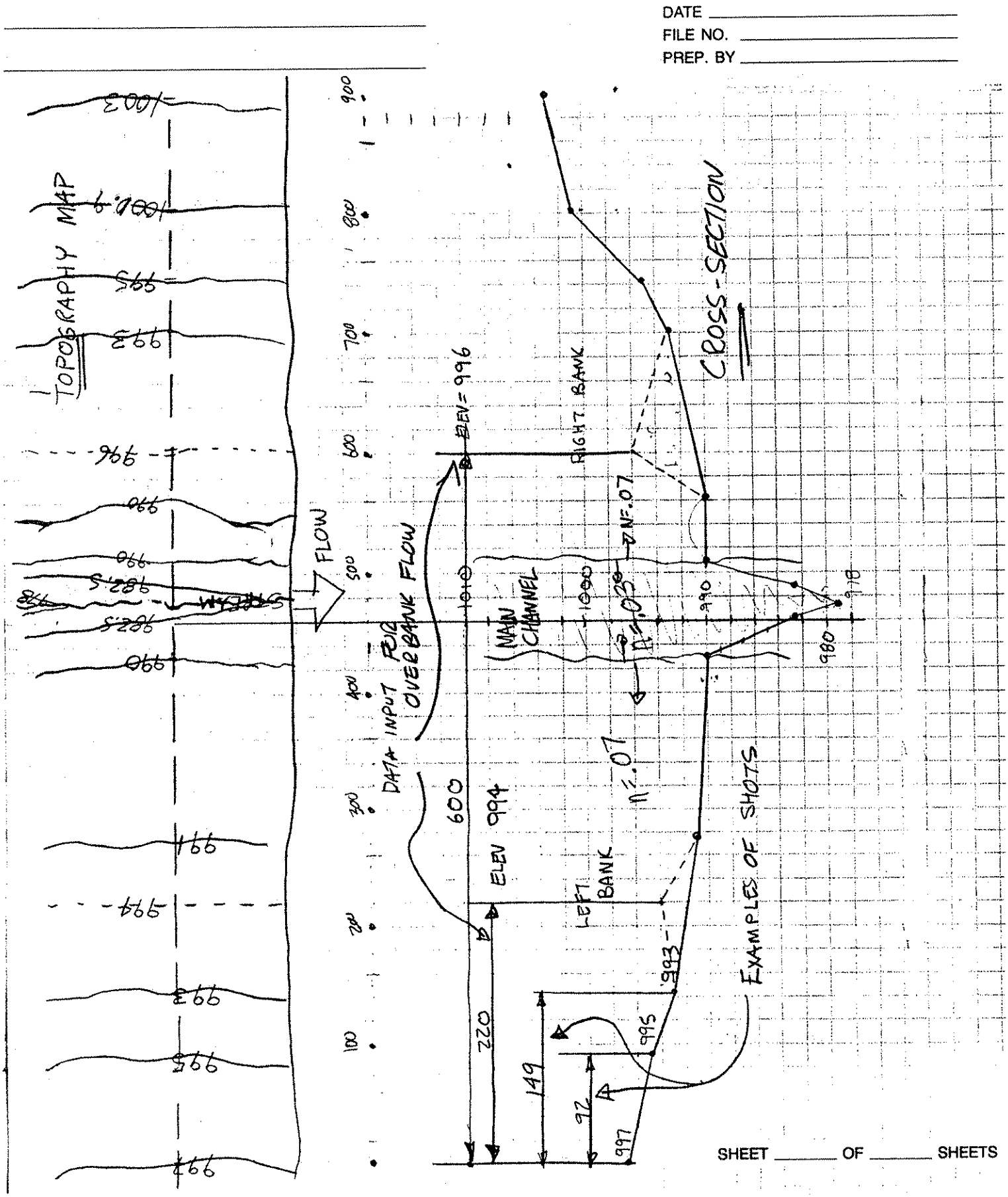


Figure 59. WSNAT Spreadsheet Format

```
      1       2       3  4     5        6        7        8        9       10       11       12       13
 56 ------------------------------------------------------------------------------------------------------------
 57 CROSS-SECTION 1                                  CROSS-SECTION 1
 58 INPUT DATA - BASIC'S                             INPUT - Cross-section inform                          ¦
 59 ^^^^^^^^^^^^^^^^^^^^                             ^^^^^^^^^^^^^^^^^^^^^^^^^^^^                          ¦
 60          Station distance from                                                   Distance   Elev        ¦
 61              starting point (ft) =     0                 Data point             (feet)   (feet)       ¦
 62          Minimum elevation (ft)  =   882                            Manning's_________ _______        ¦
 63          Maximum elevation (ft)  =   900                        1 -->  _______       0  900.00        ¦
 64          Slope (ft/mi)           =  42.24                       2 -->   0.03        20  890.00        ¦
 65                                                                 3 -->   0.03        80  882.00        ¦
 66                                                                 4 -->   0.03       220  890.00        ¦
 67          Input on of the following options:                     5 -->   0.03       270  900.00        ¦
 68                  Input (0-3) ---->     0                        6 -->                                  ¦
 69              0 - no overbank flow                               7 -->                                  ¦
 70              1 - overbank flow both banks                       8 -->                                  ¦
 71              2 - overbank flow left bank                        9 -->                                  ¦
 72              3 - overbank flow right bank                      10 -->                                  ¦
 73                                                                11 -->                                  ¦
 74                                                                12 -->                                  ¦
 75                                                                13 -->                                  ¦
 76                                                                14 -->                                  ¦
 77                                                                15 -->                                  ¦
 78 OUTPUT:                                                       16 -->                                  ¦
 79 ^^^^^^^                                                       17 -->                                  ¦
 80          Hydraulic radius        =    3.0 feet              18 -->                                  ¦
 81          Water depth             =    6.0 feet              19 -->                                  ¦
 82          Water elevation         =    888 feet              20 -->                                  ¦
 83          Slope                   =  0.008 ft/ft                                                      ¦
 84          Weighted Manning's n    =  0.030                 Sums:     ---------------------->          ¦
 85 ------------------------------------------------------------------------------------------------------------
 86 CROSS-SECTION 2                                  CROSS-SECTION 2
 87 INPUT DATA - BASIC'S                             INPUT - Cross-section inform                          ¦
 88 ^^^^^^^^^^^^^^^^^^^^                             ^^^^^^^^^^^^^^^^^^^^^^^^^^^^                          ¦
 89          Station distance from                                                   Distance   Elev        ¦
 90              starting point (ft) =   170                   Data point             (feet)   (feet)       ¦
 91          Minimum elevation (ft)  =   883                            Manning's_________ _______        ¦
 92          Maximum elevation (ft)  =   900                        1 -->  _______       0  900.00        ¦
 93                                                                 2 -->   0.03        20  890.00        ¦
 94                                                                 3 -->   0.03        55  883.00        ¦
 95                                                                 4 -->   0.03       150  890.00        ¦
 96          Input on of the following options:                     5 -->   0.03       200  900.00        ¦
 97                  Input (0-3) ---->     0                        6 -->                                  ¦
 98              0 - no overbank flow                               7 -->                                  ¦
 99              1 - overbank flow both banks                       8 -->                                  ¦
100              2 - overbank flow left bank                        9 -->                                  ¦
101              3 - overbank flow right bank                      10 -->                                  ¦
102                                                                11 -->                                  ¦
103                                                                12 -->                                  ¦
104                                                                13 -->                                  ¦
105                                                                14 -->                                  ¦
106                                                                15 -->                                  ¦
107 OUTPUT:                                                       16 -->                                  ¦
108 ^^^^^^^                                                       17 -->                                  ¦
109          Hydraulic radius        =    2.5 feet              18 -->                                  ¦
110          Water depth             =    5.0 feet              19 -->                                  ¦
111          Water elevation         =    888 feet              20 -->                                  ¦
112          Slope                   =0.00588 ft/ft                                                      ¦
113          Weighted Manning's n    =  0.030                 Sums:     ---------------------->          ¦
114 ------------------------------------------------------------------------------------------------------------
```

Figure 59. (Continued)

```
        1       2       3  4     5       6       7       8       9       10       11       12       13
115 CROSS-SECTION 3                                    CROSS-SECTION 3
116 INPUT DATA - BASIC'S                               INPUT - Cross-section inform                    |
117 ^^^^^^^^^^^^^^^^^^^^                               ^^^^^^^^^^^^^^^^^^^^^^^^^^^^                     |
118          Station distance from                                                Distance   Elev        |
119              starting point (ft) =    360                Data point          (feet)    (feet)      |
120          Minimum elevation (ft)  =    884                          Manning's_________ _______      |
121          Maximum elevation (ft)  =    890                     1 -->  _______       0   900.00      |
122                                                              2 -->   0.03        40   890.00      |
123                                                              3 -->   0.03        70   884.00      |
124                                                              4 -->   0.03       110   890.00      |
125          Input on of the following options:                  5 -->   0.03       170   900.00      |
126                  Input (0-3) ---->      0                    6 -->                                |
127              0 - no overbank flow                            7 -->                                |
128              1 - overbank flow both banks                    8 -->                                |
129              2 - overbank flow left bank                     9 -->                                |
130              3 - overbank flow right bank                   10 -->                                |
131                                                             11 -->                                |
132                                                             12 -->                                |
133                                                             13 -->                                |
134                                                             14 -->                                |
135                                                             15 -->                                |
136 OUTPUT:                                                     16 -->                                |
137 ^^^^^^^                                                     17 -->                                |
138          Hydraulic radius        =    1.7 feet              18 -->                                |
139          Water depth             =    3.4 feet              19 -->                                |
140          Water elevation         =  887.4 feet              20 -->                                |
141          Slope                   =0.00588 ft/ft                                                   |
142          Weighted Manning's n    =  0.030                Sums:    ---------------------)          |
```

Figure 60. WSNAT Iteration Illustration

```
     1        2        3  4     5        6       7        8        9       10        11
23 ------------------------------------------------------------------------------------------
24 INPUT - Self-interation                                                  :   Transfer
25 ~~~~~~~~~~~~~~~~~~~~~~                                                   :   Cells
26                                CROSS-SECTIONS --      1        2        3  :         3
27     ++ Input yourself ++                                                 :
28         Water surface elevation (FT)  =         888      888    887.4   :     887.4
29                                                                          :
30     ++ Helpful Output ++                                                 :
31         Increase (+) or decrease (-)                                     :
32             Water surface elev.       =  start at    (-)      (-)       :   (-)
33         Check value (ok if <= +/-.001)=  X-section   0.001    0.144    :   0.1436316
34                                                                          :
35 ------------------------------------------------------------------------ :   ----------
36 CALCULATIONS                                                             :
37 ~~~~~~~~~~~~                                                             :
38         X accumlative (FT)              =       0      170      360     :       360
39         Delta X (FT)                    =     0.0    170.0    190.0     :       190
40         Channel bottom elevation        = 882.000  883.000  884.000    :       884
41         Channel rise                    =   0.000    1.000    1.000    :         1
42         Accumlative channel rise        =   0.000    1.000    2.000    :         2
43         Average channel slope (ft/ft)   =  0.0059   0.0059   0.0053    :  0.0052632
44         Calculated Flow Depth (FT)      =    6.00     5.00     3.40    :       3.4
45         Flow area (sq. ft.)             =   450.0    232.1     67.4    :  67.433333
46         Hydraulic Radius (FT)           =     3.0      2.5      1.7    :  1.6750746
47         Calculated Velocity (FPS)       =     1.1      2.2      7.4    :  7.4147306
48         alpha * V^2 / 2g                =     0.0      0.1      0.9    :   0.939828
49         H1 elevation (FT)               = 888.021  888.079  888.340    :  888.33983
50         Hydraulic Radius ^ 4/3          =     4.3      3.4      2.0    :  1.9893545
51         Weighted Manning's n            =   0.030    0.030    0.030    :      0.03
52         Friction Slope, Sf              = 0.00012 0.000560 0.011204    :  0.0112039
53         Average Sf                      = 0.00012 0.000338 0.005882    :  0.0058818
54         Friction head loss, hf (FT)     =   0.000    0.057    0.118    :  0.1176357
55         H2 elevation (FT)               = 888.021  888.079  888.196    :   888.1962
56 ------------------------------------------------------------------------------------------
```

```
      1        2       3  4     5        6        7        8        9        10       11       12       13     14     15
143 ------------------------------------------------------------------------------------------------------------------------
144 OUTPUT
145 ******   ** RESULTS **            |  Channel    |  Water      |  Energy     |  Water    |  Friction
146          Cross-                   |  Bottom     |  Surface    |  Line       |  Depth    |  Loss
147          Sect.  Station           |  Elevation  |  Elevation  |  Elevation  |  (feet)   |  (feet)
148          Number                   |  (feet)     |  (feet)     |  (feet)     |           |
149          ------ -------- --------- |  --------   |  --------   |  --------   |  ------   |  --------
150              1     0  +     0.00  |    882.00   |    888.00   |    888.02   |  6.00     |  0.000
151              2     1  +    70.00  |    883.00   |    888.00   |    888.08   |  5.00     |  0.057
152              3     3  +    60.00  |    884.00   |    887.40   |    888.20   |  3.40     |  0.118
153 ------------------------------------------------------------------------------------------------------------------------
```

Figure 61. Example Output for Summary of WSNAT

APPENDIX

USER REFERENCE INSTRUCTIONS FOR KERMIT

Public Domain Communication Software

URM: USERS' REFERENCE MEMO

URM 142 *Using KERMIT*

March 1987 (revised)

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(Revised by Jeff Balvanz)

Overview

KERMIT is a communications protocol originally developed at Columbia University. This protocol has been incorporated into public domain communications programs for a wide variety of microcomputers, minicomputers, and mainframes. At ISU, versions of KERMIT are available for the NAS AS/9160, VAX, Apple //e, Zenith Z-100, IBM PC, TI PC, Commodore 64, and CP/M computers. Microcomputer versions may be acquired at the Microcomputer Product Center, 125 Computer Science. These diskettes include additional version-specific information which is not described in this publication.

KERMIT can be used as a terminal emulator allowing you to communicate with any host computer system. Two computers running KERMIT can exchange files over an RS-232 connection using an error-checking system. Such transfers are very reliable.

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Some material in this publication has been adapted from the KERMIT User's Guide prepared by Columbia University and the KERMIT-65 documentation prepared by Stevens Institute of Technology.

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1. GETTING STARTED

Note: All commands must be followed by pressing the <return> key.

To run KERMIT on your microcomputer, enter the following command(s):

CP/M or MS-DOS:	KERMIT
Apple][:	RUN KERMIT
Commodore 64:	LOAD "KERMIT",8 RUN

The prompt "KERMIT-xx>" will appear on the screen, where "xx" depends on the version of KERMIT you are running.

Version	Prompt
MS-DOS	KERMIT-MS
CP/M-80	KERMIT-80
Apple //e	KERMIT-65
Commodore 64	KERMIT-65

At this point you are in local mode. You can enter commands or enter "? <return>" for a command list. To get help with commands, enter a question mark at any point in the command. KERMIT will display the options available. Commands can be abbreviated to any prefix that is unique. (Example: DIR is a unique prefix, so it may be used instead of DIRECTORY in KERMIT commands.) Refer to the section entitled "KERMIT Commands" for details on commonly-used commands.

If you are going to log in to VAX or WYLBUR via a dialup or the ISN, you will have to enter the command:

SET PARITY NONE

before connecting to the remote computer. Without this step, file transfers will not work. MS-DOS users communicating with WYLBUR should enter the commands:

SET HANDSHAKE NONE
SET FLOW-CONTROL NONE

to get file transfers to work properly. KERMIT-MS allows you to put lists of commands into a TAKE file: see the KERMIT-MS documentation for more details.

To connect to VAX or WYLBUR, you must leave local mode and go into connect mode. To do this, enter CONNECT and press <return>. You can now dial the phone or give dialing commands to a direct-connect modem and log in as usual. For more details on logging in to WYLBUR or VAX, see *URM 39* "Login Procedure for VAX, EVAX and WYLBUR".

Before you can transfer files, you must leave connect mode. Do this by entering a special character called an escape character, followed by the letter C. The default escape characters are as follows (hold the control key down, then press the appropriate character):

MS-DOS:	<ctrl/]>
Apple CP/M:	<ctrl/]>
Other CP/M:	<ctrl/\>
Apple][:	<ctrl/@>
Commodore 64:	<ctrl/Y>

To leave connect mode on an MS-DOS machine, for example, you would press <ctrl/]>C. The escape character also performs other functions. To send a break, enter the escape character followed by the letter B. If you need to send the escape character to the remote computer, press the escape character twice.

2. TRANSFERRING FILES

To transfer files between two computers using KERMIT, both computers must be running a KERMIT program. There are two ways to transfer files. The first uses the SEND and RECEIVE commands, and the second uses the SERVER mode and the SEND and GET commands. Using the server mode is easier, but not all KERMITs can act as or work with a server.

2.1 Using KERMIT with the AS/9160 -- SEND and RECEIVE

KERMIT on the AS/9160 runs under the ORVYL file system. As a result, it cannot directly transfer WYLBUR edit format files, but can transfer ORVYL files and the active file. To run KERMIT on the AS/9160, enter:

KERMIT

which displays the "KERMIT-ORV>" prompt. You can still issue some WYLBUR commands by preceding the command with the word WYLBUR. To leave KERMIT and return to WYLBUR, enter EXIT.

Not all microcomputer files can be uploaded to WYLBUR. Files to be uploaded must have lines no more than 235 characters long. Also, ORVYL KERMIT cannot transfer non-text or binary files. **WARNING:** Because it runs under the ORVYL system, using ORVYL KERMIT is expensive. If there is another error-checking method of transferring files to WYLBUR available for your microcomputer (such as SAMSON) we recommend that you use it.

2.1.1 Downloading a WYLBUR File

To download a WYLBUR file, follow these steps:

1. Load the file to be downloaded into the WYLBUR active file by entering:

   WYLBUR USE filename CLEAR

where "filename" is the WYLBUR filename.

2. Enter the ORVYL KERMIT command:

   SEND filename

   where "filename" is the name that you want the file to be stored under on your microcomputer diskette. (It does not have to be the same as the WYLBUR filename.)

3. Return to local mode by entering the escape sequence for your version of KERMIT. Then enter:

   RECEIVE

   The status screen on your microcomputer will display information about the number of packets transferred.

4. When the transfer is completed, enter CONNECT to return to connect mode.

2.1.2 Transferring a Microcomputer File

To transfer a microcomputer file to the WYLBUR active file, follow these steps:

1. You should be in connect mode with ORVYL KERMIT running. Enter the command:

   WYLBUR CLEAR ACTIVE

   to clear the active file. If you don't clear the active file before the transfer begins, the information transferred will be added to whatever is currently in the active file. (This can be used effectively to combine several small microcomputer files into one WYLBUR file.)

2. Enter:

   RECEIVE

3. Exit to local mode and enter:

   SEND filename

   where "filename" is the name of the microcomputer file to be transferred. You will see the status screen display information about the packets being transferred.

4. When the transfer is completed, enter CONNECT to return to connect mode. The text is in the WYLBUR active file and may be SAVEd or PUT as usual.

2.1.3 Transferring ORVYL Files Directly

ORVYL KERMIT can be used to transfer ORVYL files directly. Give ORVYL KERMIT the command:

SET FILE-MODE ORVYL

Now the KERMIT-ORV command "SEND filename" can be used to transfer the ORVYL file named "filename". The RECEIVE command stores the file as an ORVYL file with the same name as the microcomputer file. If your microcomputer's KERMIT accepts wildcards in file specifications, you can use "SEND *.*" to transfer many files with only one RECEIVE command.

2.2 Using KERMIT with VAX -- SERVER Mode

On VAX, KERMIT is located in TESTLIB:. To run it, enter:

RUN TESTLIB:KERMIT

at the VAX "$" prompt. VAX KERMIT then displays the "KERMIT-32>" prompt. You can execute many VAX commands by preceding the command with the word "LOCAL". To leave KERMIT and return to VAX, enter EXIT.

WARNING: VAX KERMIT has not yet been updated to allow the extended filenames that can be used in VMS Version 4. As a result, files to be transmitted must have a filename no more than eight characters long and a file type no more than three characters long.

VAX KERMIT can act as a KERMIT server. You can SEND files to the server or GET files from the server without having to leave local mode. To activate VAX KERMIT's server mode, enter:

SERVER

at the "KERMIT-32>" prompt. Now you can return to local mode and use server commands. To send files to VAX, enter:

SEND filename

To transfer VAX files to your microcomputer, enter:

GET filename

When you are finished transferring files, enter the microcomputer KERMIT command: FINISH. CONNECTing now returns you to the KERMIT-32 command prompt. Enter the EXIT command to return to the VAX "$" prompt.

If your microcomputer's KERMIT is not capable of sending server commands, you can use SEND and RECEIVE commands to VAX KERMIT to transfer VAX files in the same way that ORVYL KERMIT transfers ORVYL files.

2.3 Microcomputer-to-Microcomputer Transfers

To send a file from one microcomputer to another, each must start in local mode. Issue the RECEIVE command at the receiving microcomputer. When the transfer status screen appears on the receiving computer, give the SEND command to the sending microcomputer by entering:

SEND filename

KERMIT displays a running total of the packets transferred along with any errors encountered. When the transfer is complete, both microcomputers return to local mode.

MS-DOS KERMIT can act as a server. Put KERMIT-MS into server mode by entering the SERVER command. You can then use the same commands to transfer files to and from that microcomputer that you would use with the VAX KERMIT server. You can either enter FINISH on the other microcomputer or press <ctrl/C> *on the MS-DOS microcomputer to end server mode.*

3. KERMIT COMMANDS

In addition to the commands discussed so far, other KERMIT commands can be used to set communications parameters or accomplish special tasks. The commands in the following list are some of the more useful KERMIT commands. They may not work on all versions of KERMIT. If you try to use commands that are not available, your KERMIT responds with "Illegal command" or "Not implemented." For a complete list of microcomputer KERMIT commands, see your microcomputer's KERMIT documentation.

- ***DIR [drive]***: Displays the directory of the diskette in "drive". This is not available in Apple KERMIT. In C-64 KERMIT, you must enter "DIR *".
- ***HELP***: Displays a summary of KERMIT commands.
- ***EXIT***: Exits from KERMIT to your operating system. QUIT is a synonym for EXIT.
- ***SET***: Modifies various file transfer and terminal parameters. The following parameters can be set:
  - ***DEFAULT-DISK parameter***: Tells KERMIT which disk drive should be used for file transfers. Apple KERMIT allows you to set default SLOT and DRIVE.
  - ***DEVICE-DRIVER parameter***: Tells Apple KERMIT-65 what type of communication card is being used. The following are valid parameters:

APPLE-COM-CARD	Apple communications card (or compatible)
DC-HAYES	D. C. Hayes Micromodem II
SUPER-SERIAL-CARD	Apple Super Serial Card

- ***FILE-BYTE-SIZE parameter***: Sets the byte size (SEVEN-BIT or EIGHT-BIT) for file transfers with KERMIT-65.

- ***FILE-TYPE parameter***: Tells KERMIT-65 what type of file is being transferred so it can do any character conversion necessary. Apple KERMIT accepts the following types:

TEXT	ASCII text file (the default)
APPLESOFT	Applesoft Basic program
INTEGER	Integer Basic program
BINARY	Binary image

C-64 KERMIT accepts the following types:

PETASCI	CBM ASCII file (the default)
ASCII	True ASCII file
SCRIPT	SpeedScript document file
BINARY	Program file (BASIC or machine language)

- ***FILE-WARNING ON or OFF***: Tells KERMIT whether or not to warn you when incoming filenames conflict with existing files. When FILE-WARNING is ON, KERMIT tries to change the filename slightly to avoid the conflict.

- ***DISPLAY parameter***: Tells Apple KERMIT-65 whether you have an Apple][+ (parameter = 2P) or Apple //e (parameter = 2E) monitor. Only the 40-column display is supported.

- ***KEYBOARD parameter***: Same as DISPLAY command above for the Apple keyboard.

- ***LOCAL-ECHO parameter***: Sets full duplex (LOCAL-ECHO ON) or half duplex (LOCAL-ECHO OFF).

- ***PARITY***: Sets parity to NONE, EVEN, ODD, MARK, or SPACE.

- ***RECEIVE***: Sets various parameters for receiving files.

- ***SEND***: Sets various parameters for sending files.

- ***SLOT parameter***: Tells Apple KERMIT-65 in which slot the communications card is located (normally 2). The range for the parameter is 1-7.

- ***SHOW parameter***: Examines the current parameter values. You can SHOW the value of any parameter which can be SET. In addition, SHOW ALL shows the current settings of all parameters in KERMIT-65.

- ***STATUS***: Gives statistics about the most recent file transfer (KERMIT-65), or shows the current parameter settings (MS-DOS).

4. HELP

Sometimes KERMIT doesn't work. If your KERMIT can time out automatically, you'll see the number of retries increasing on the screen as it tries to send to the remote KERMIT and can't get a response; or, as the remote KERMIT repeatedly sends what your local KERMIT thinks are bad packets. If your KERMIT can't automatically time out (KERMIT-65 is like this) then you'll see the screen appear to go dead--nothing will happen. Press <return> or <space> to manually time out the transmission; after 16 retries the local KERMIT gives up and returns you to local mode.

There are several reasons why KERMIT doesn't work. Following are a number of possibilities and how to correct each.

- ***Parity Set Incorrectly:***

  VAX KERMIT, ORVYL KERMIT, and most of the microcomputer KERMITs expect no parity by default. The ISN system is an eight-bit, no parity system, and this normally works fine. However, if you are communicating with some other system (over TELENET, for example) even parity may be imposed by the communications system. Try the command SET PARITY EVEN on both the receiving and sending computers. Even parity, by the way, should work even in a no-parity environment as long as both KERMITs agree to use it.

  Parity errors can also occur on micro-to-micro transfers (between two micro-computers), especially on KERMITs that cannot set parity and baud rates. In this case you must set the parity from the operating system; Apple and CP/M KERMITs are like this. Use SET PARITY to tell KERMIT about the parity the operating system has set.

- ***Broken Connections:***

  You must have good connections from serial port to modem to telephone, or between microcomputers. In a micro-to-micro transfer, be sure you have a null modem connector if your computers need one. It sounds like a silly error, but folks do trip over cords, and cables can be wired wrong. Check and be sure!

- ***Message Interference:***

  If an ISN, VAX or WYLBUR message is transmitted during a file transfer, the microcomputer KERMIT may get confused and terminate the transfer. There is not much you can do about this except start over.

  If an error occurs in VAX or ORVYL KERMIT, an error packet is transmitted to interrupt the transmission. Some microcomputer KERMITs know what to do with error packets and some don't. If you timeout manually and return to command mode, CONNECT and see if you receive the "KERMIT-xx>" prompt. If you do, this is what has happened. Entering STATUS displays a message telling you what happened.

- ***Transmission Delays:***

  Microcomputer KERMITs that timeout automatically may become impatient when VAX or WYLBUR is heavily loaded. If the microcomputer doesn't receive a packet in N seconds, it tells the host to resend the packet that hasn't been sent yet. This can confuse both sides and may result in termination. If this occurs, use SET DELAY on the microcomputer side to increase the time the local KERMIT will wait for the host to send a packet.

- ***Noise Corruption:***

  If your phone connection is very noisy, you may see KERMIT requesting a lot of retries, and it may abandon the transmission altogether. If this happens, first try dialing a new connection. If that doesn't help, use SET PACKET_LENGTH on the transmitting end to decrease the packet size (normally 80 characters) and SET RETRY on both ends to increase the number of times KERMIT will try to send a packet. If your KERMIT permits it, try switching to a two or three-character checksum with SET BLOCK_CHECK.

- ***Extra Characters at End of File:***

  On microcomputers with block-oriented disk structures (like CP/M), KERMIT sends whole blocks to the remote system, not recognizing an end-of-file character (<ctrl/z>). When this occurs you may see an extra line of garbled characters at the end of the file when you edit it on the remote system. Remove these from the file with an editor.