USER'S MANUAL

Water Surface Pressure Gradient Package

PROGRAM "WSPGW"

Version 14.10

(909) 885-3806
234 N. Arrowhead Ave. San Bernardino, Ca 92408

http://www.civildesign.com

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****************THE WSPGW PROGRAM*************

After evaluating the runoff from an area or basin, the design or analysis of the storm drain is necessary. It is not enough to simply determine the normal flow depths in a channel. Often, the normal depth is not attained in a channel reach because of either a backwater caused by downstream restrictions, or the depth is lower than normal because of changes in downstream slopes.

This program is designed to assist the engineer in designing or evaluating storm drains or channels. The program package was originally written by the Los Angeles County Flood Control District as a main frame program called F0515P. With the advent of modern personal computers, extensive modifications and enhancements have been made possible for the program, including the ability to automatically create precision plan and profile drawing file of the channel, hydraulic data and results.

The program computes and plots uniform and non-uniform steady flow water surface profiles and pressure gradients in open channels or closed conduits with regular or irregular cross sections. The flow may alternate between super critical, sub-critical and pressure flow in any sequence. The program will analyze natural river channels with up to 35 cross section data points, although the principal use of the program is intended for determining profiles in improved flood control systems.

****************GENERAL PROGRAM DESCRIPTION*************

Basic Theory:

The computational procedure is based on solving Bernoulli's equation for the total energy at each section and Manning's formula for the friction loss between the sections in a reach. The open channel flow procedure uses the standard step method. Confluences and bridge piers are analyzed using pressure and momentum theory. The program uses basic mathematical and hydraulic principals to calculate all such data as cross sectional area, wetted perimeter, normal depth, critical depth, pressure and momentum. The water surface super-elevation caused by channel curves are calculated and plotted using the equations and methods listed in the Los Angeles County Flood Control District Design Manual, Hydraulic. See Appendix A for equations used by the program.

Computational Procedure:

The channel or conduit system is divided into the following elements: system outlet, reach, transition, junction, bridge exit, bridge entrance, wall entrance (sudden contraction), wall exit (sudden expansion), and system headworks. Each element is internally assigned a number and the user provides the station and invert elevation for each element. The program determines the distance between elements by the difference between stations. Additional intermediate "points" between elements are internally set by the program whenever the velocity head between to points exceeds 10 percent. Up to 200 additional points may be set between elements. The input data must consist of at least three elements (system outlet, any other element with distance, and the system headworks). A maximum of 200 elements is allowed. A greater number of elements requires the user to make separate data files for the analysis.

Flow Rates:

The starting flow rate is input by the user for the system headworks. The flow rate is increased at desired locations by specifying junction elements. Up to two lateral channels may enter a junction at angles varying from + - 0.1 to + - 90 degrees from the main channel flow.

NOTE: A Warning will be printed if the lateral flows exceed the up- stream flow rate.

Multiple profiles:

To obtain additional water surface or pressure gradient profiles for different flow rates in the same system, additional profiles (up to 5) may be specified. When added profiles are requested, the program will ask for a Q factor which is a number used to multiply times the lateral flow rates entering a junction. In this way, you may adjust both the system headworks flow and the flow rates specified in the junctions. NOTE: The .DXF drawing file is only made for the last profile computed, however, the printed output file contains results for all profiles.

Manning's "N":

The program uses the Manning formula for friction loss in all types of channels. The program uses only one "N" value per element, however, the "N" value may be changed at any reach, transition or junction element. The default "N" value is 0.14 for open improved channels, .013 for covered improved channels, and, .03 for irregular shaped channels. The user should change these values to the appropriate calue for the actual channel or conduit being used. A channel section with different roughness coefficients should be entered using a hand calculated "N" value based on the estimated depth of flow.

Water Surface Controls:

Water surface elevations at the system outlet and system headworks are optional input values. If the water surface elevation is not given, the program uses critical depth controls. If a water surface is given at the system outlet, the program will use it only if the energy grade line of the computed channel analysis channel is less than the water surface elevation given.

Critical and Normal Depths:

Critical depth is computed for every section with the given Q using the "Specific Energy Equation". Normal depth is computed in every reach element with a positive slope for the given flow rate.

The velocity head (Hv) is computed using the mean velocity of sections. This may not be accurate in the case of a complex section such as one with shallow flow in the horizontal over-bank area where the velocity distribution is not uniform. If the program is used in this situation, the user should be aware some error may be introduced into the results.

Water Surface Stages:

Phase I, downstream direction, the lower stage water surface profile, or defined as upstream control, begins at the system headworks and ends in the system outlet. The computation will proceed downstream in every consecutive element as long as the energy is available to maintain flow in the super critical stage. When energy is insufficient, the program will discontinue computations at that point to the downstream end of that element. Then, computation will resume in the next element with critical depth control until the system outlet is analyzed.

Phase II, upstream direction, upper stage water surface profile, or defined as downstream control, begins at the system outlet and ends at the system headworks. Computation proceeds upstream in every element as long as the water surface at the dowstream end of any two adjacent "points" can support the moving mass of water to flow at the critical or sub-critical depth. Otherwise, computation will be suspended from the downstream point to the upstream end of the next element. Then computation resumes at the downstream end of the next element with critical depth control, provided no depth less than critical depth has been calclated at that point during Phase I, and proceeds upstream until the system headworks has been analyzed. If the computed depth is greater than the user specified channel height in open channel flow, the program will add up to 10 units of additional channel height to continue calculations. If the depth of flow is greater than 10 units over the given channel height, computation stops.

Note: If depth of flow is greater than maximum height of channel, the program extends channel up to 10 units above maximum channel height.

Phase III, a composite profile, or hydraulic jump routine, analyzes Phases I and II, beginning at the system outlet to the system head works. It searches the lower stage and upper stage profiles for points of equal energy. If a hydraulic jump or a hydraulic drop is encountered, it is approximately located; and the data on either the upper stage or lower stage not consistent with the greater energy theory will be deleted from appropriate elements.

The final profile will be a composite of upper stage and lower stage with hydraulics jumps or hydraulic drops in between if the water elevation passed through critical depth in the system.

************** *PROGRAM INSTALLATION* *****************

The package may be installed on only one PC with Windows 95/98 or Windows NT/2000. To install the programs, place the disk in the CD drive, the installation should start. If not, run the "SETUP.EXE" program using the Windows run option, or, by clicking on the SETUP.EXE file in your floppy drive using Windows Explorer. The setup program will create a directory named C:\Program Files\CIVILD on your computer and copy the program files to that directory. (During setup, you may change this directory location if desired.) The program will run only through Windows 95/98 or Windows NT/2000, and you may create a "shortcut" to the program using the Window Explorer by "dragging" the WSPGW icon from the C:\Program Files\CIVILD directory to the computer DeskTop.

After running the setup program, the first time you run the program you need to contact CivilDesign Corporation at (909) 885-3806, FAX (909) 381-1721, or e-mail us at info@civildesign.com to obtain authorization numbers to encode the program to your computer. After this first run, you no longer have to use the floppy or CD Rom, store it in a safe place and keep it for backup purposes. When encoding the computer the first time - keep a record of the Authorization Codes, they may be used again on the same computer again if the C: drive has not been changed.

Changing Computers/ Removing Software:

Because the software "locks" on only one computer, at a later date you may wish to move the programs to another computer. To do this, run the Windows Settings (Add/Remove Programs Options). Insert the original floppy disk into the A: or B: drive, and again, call CivilDesign Corporation for a new authorization Code to install the software as described above.

Printing Output Data Files: The program produces 132 character width EDIT(study name.EDT), and OUTPUT (study name.OUT) data files. These files may be sent to the computer disk or to the printer by the program. Because the normal page width is 80 characters, you must adjust the font size to print these files on normal letter size paper. Most ink jet printers have a DOS "compressed font" setting on the printer which will set the font to the correct size. Laser jet printers have a procedure spelled out in the printer's manual to reduce the character size. If all else fails, you may send the output files to your computer's disk and in Windows 95/98/NT open the file using the Wordpad program. Select the edit function, select edit "all", change the font size to 7, and print the files to your printer.

Multiple Installations: If you purchased multiple copies of the WSPGW program, make a list of the Computer ID numbers you have received when running the program on each work station the first time, and Call or FAX , or e-mail CivilDesign Corporation for the Authorization Numbers for each separate computer.

***************** *MAIN MENU* *******************

Operation:

Basically, there are four program modules included in the package. The first three consist of (1) Creating, building or correcting an input data file; (2) Editing the data file and creating an edit report; (3) Computing the results and printing an output data file.

The fourth (4) module reads the output data file and creates a .DXF* drawing exchange file which is a plan and a profile drawing of the channel with water surface, with a text listing of channel data and hydraulic results, and, optional cross-section views of the channel.

Main Menu:

To start the program, use either the Windows DOS prompt, and type the name of the program "WSPGW", or, create a "shortcut" to the WSPGW program using the Windows Explorer. The program runs in the Windows environment, and the menu items may be selected by using either the computer "mouse" or "tab key".

After entering the program, The following menu will appear:

GENERAL DATA ENTRY:
WATER SURFACE PROFILE PROGRAM OPTIONS:
1 - BUILD New File
2 - RUN Data File
3 - CORRECT Data File
4 - ADD to End of Data File
5 - Write ".DXF" File of Program Results
6 - Explain Program Methodology
7 - EXIT PROGRAM

Enter program option desired in the edit box.

Item 1 of the menu is for creation of a new input data file. If item 1 is selected, additional menus appear to receive the input data.

Item 2 of the menu, first calls the edit program, which edits the input file and prints an edit report (name.edt), and prepares additional files for the main program to run. If the edit program is successful, another sub-menu appears with run time printout options for the final output file (name.out).

Item 3 of the menu is used to make corrections or additions to the input data file.

Item 4 allows addition to a data file from the last station.

*************** *PROGRAM DATA REQUIREMENTS* ******************

Description of Input Data Elements:

The storm drain system consists of one stream from the system outlet up to a system headworks. The system may be defined as open channels or closed conduits, or any combination of the two. Junctions may be placed in the system, however, the program only calculates the water surface or pressure inside the junction. Separate systems or data files must be prepared to analyze the lateral channel(s) entering a junction once the water surface at the lateral outlet (main junction) is determined.

As previously stated, the input data is based on elements. Element number one is the system outlet. The program internally numbers successive elements as 2, 3 ... up to the system headworks.

Elements with length:

All elements are entered with a station and elevation. Stations must increase going upstream. Element length is measured from the previous element entered to the present element. A reach (R), transition (TS), and junction (JX), are all considered to have some length. Therefore, the station of these elements should be greater than the previous station entered. The station and elevation for these elements are considered to be the upstream end of the element. The program first requires the Station Entry, then computes an invert elevation based upon the previous channel slope, if this is incorrect the user enters the correct invert elevation by over-writing the default value.

Zero Length Elements:

Zero length elements area the system outlet (SO), bridge exit (BX), bridge entrance (BE), wall exit (WE), wall entrance (WE), and system headworks (SH). The station and elevation of zero length elements are also considered to be the upstream end of the element. Except for the system outlet (SO), the station and elevation of these elements must be the same as the previous element (reach, transition, or junction).

Stationing and Boundary Lines:

All elements are bounded on the upstream end by Section 1 and on the downstream end by Section 2 except the System Outlet (SO) , and System Headworks (SH) which only have Section 1. (See Fig. 5-1, next page). The user inputs channel definition data such as base width, conduit height, etc. for Section 1 of every element. The data for Section 2 for every element is taken by the program from the upstream Section 1 of the adjacent downstream element. The elements are input sequentially from downstream to upstream, and the distance between elements is taken from the station data, increasing in an upstream direction. If, for some reason, the stationing of the channel on the map decreases in an upstream direction, then the user may input the map stations as "negative numbers", and the program will still realize increasing stations from downstream to upstream. If the station values on your map change, ie., the system changes one station, example Sta 13+97.50 equals Station 5+00.00, the program allows you to enter a "station equation"or EQ line where the new stationing value is entered at the upstream end.

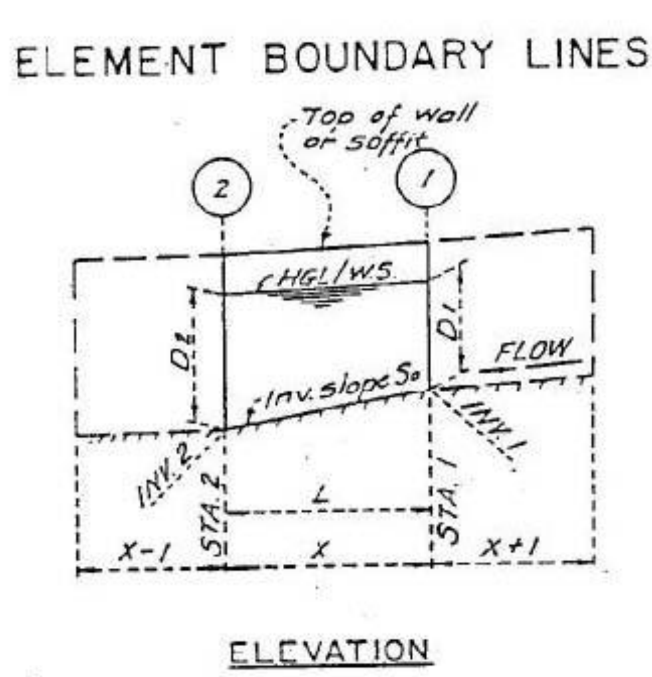


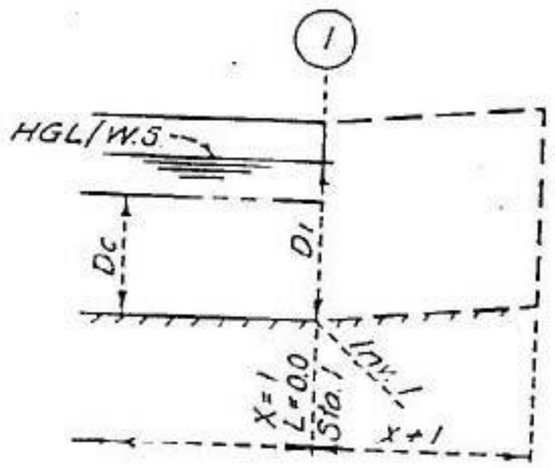
FIG. 5 - 1

L = Length of Element (Reaches may have considerable length)
X = Number of Element under Consideration
X+1 = Adjacent Upstream Element
X-1 = Adjacent Downstream Element

Elevations:

Normally elevations of a storm drain channel increase from the system outlet. However, the program allows for decreases in elevations proceeding upstream provided the energy and/or the open channel height of the system can support the flow.

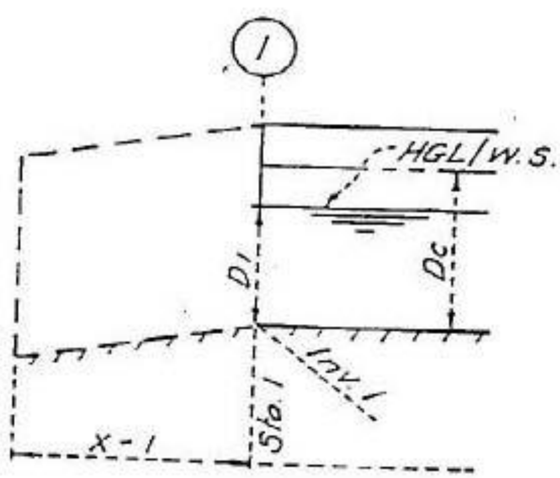
SYSTEM OUTLET



ELEVATION

FIG. 5-2

SYSTEM HEADWORKS



ELEVATION

FIG. 5-3

System Outlet (SO):

The system outlet (SO) element entry requires the station, invert elevation, water surface elevation, and channel cross-section (CD) description and identification number (IDNO). The water surface elevation defaults to the invert elevation, and, if so, the program starts calculations assuming critical depth at the system outlet. As previously stated, the user may enter another water surface elevation which will be accepted by the program. The final program results are the depth determined using the energy at the outlet. If the energy grade line is higher than a user input depth, or critical depth, then the program sets the depth of flow to that depth calculated using energy. The system outlet is a zero length element.

System headworks (SH)

The last element entered is the system headworks (SH), a zero length element at the upstream terminus of the system. The previous element's station, elevation and channel type must be used. The program asks for a water surface elevation, and uses the elevation it if the depth is greater than the invert elevation. If a depth greater than the critical depth is entered, the program will use that elevation if it is supported by energy calculations downstream of the System Headworks. If not, the program starts with critical depth at the upstream end.

REACH

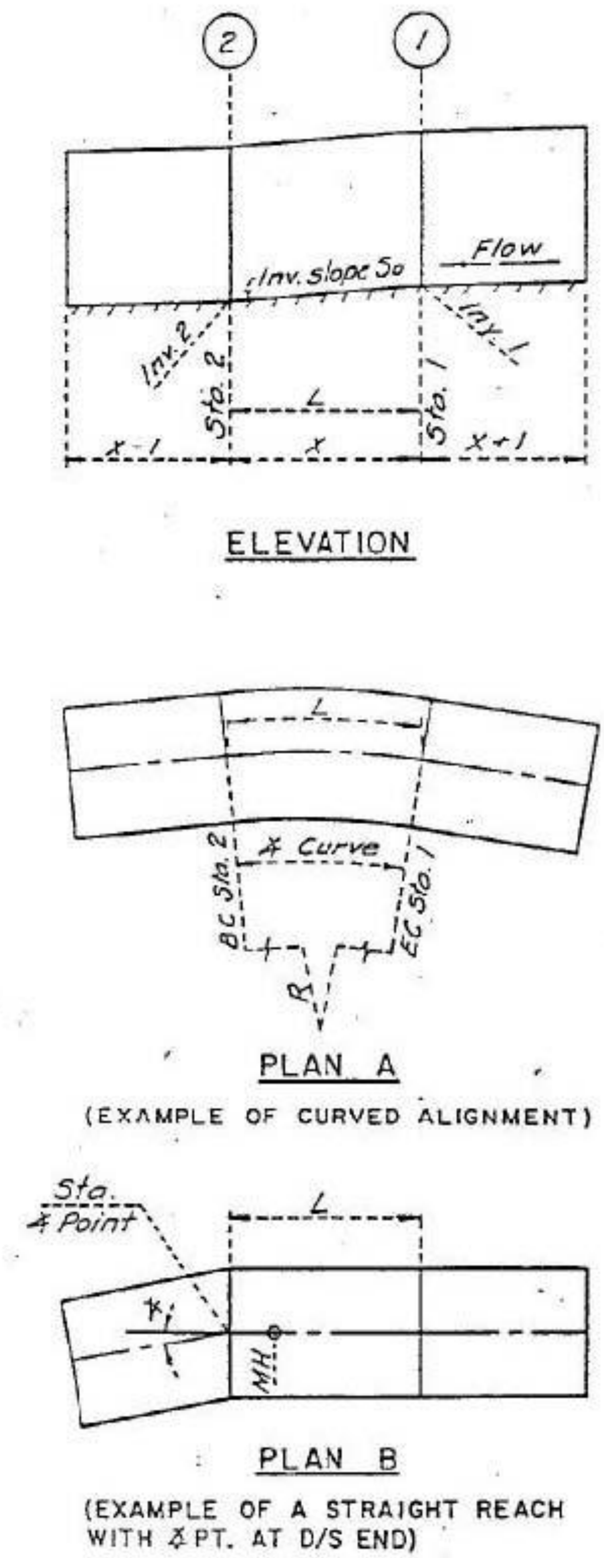
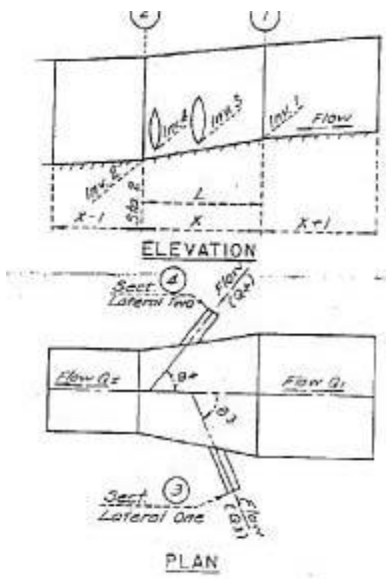


FIG. 5-4

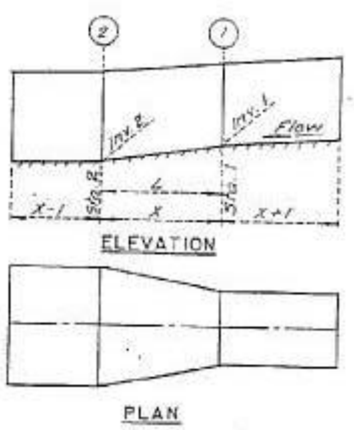
Reach element (R):

The reach (R) element is a length of channel with a constant Q, slope, channel cross section, and Mannings "N". A reach may have a straight or curving horizontal alignment. If the reach has a curving alignment, the angle of curve is required by the program. This is the total change in channel alignment from the start to the end of the reach. An angle point may be specified in place of a curve. If an angle point is specified, it is assumed to occur at the upstream end of the reach element. An angle point is a zero length change in channel direction and should only be used in closed or covered channels. The maximum recommended angle point in channel design is 15 degrees. Again, the reach element requires a cross section description and IDNO. Normally, a reach element should use the previously defined channel description. If a change in channel description is made, the user should select either a Wall Exit (WX), Wall Entrance (WE), Bridge Exit (BX), Bridge Entrance (BE), or a Transition Structure (TS) to account for losses when changing channel types or sizes. See Appendix A regarding when manhole, bend, or angle point losses are applied to a reach.



JUNCTION

FIG. 5-5



TRANSITION

FIG. 5-6

Junction Structure (JX):

A junction structure is a length of the system channel with either the same or a different channel cross section at the upstream end. The downstream end of the junction uses the previously entered element description and IDNO. Normally, a junction element is used where there is lateral inflow into the system. The junction analysis uses the momentum equation (See Appendix A) to analyze losses in this element. The program allows the entire junction structure to have a curving horizontal alignment. In addition, the angles of joining lateral channels are required. For example, an angle of 90 degrees specifies lateral flow entering from the right; looking upstream along the main channel, and entering the main channel perpendicular to the main channel flow. An angle of -45 would enter the main channel from the left, looking upstream and turning left 45 degrees. Angles greater than 90 degrees are not permitted. The flow rate may also be reduced along the main channel by specifying negative flow rates to the laterals in a junction element. However, no losses are computed for negative flow rates. Note: A Warning will be printed if a junction has different channel types from the upstream to the downstream end , or is an irregular channel, or, has greater lateral flow than the upstream end. These warnings reflect limitations of the Thompson Delta-Y junction analysis method.

Transition Structure (TS):

A transition structure is a length of the main channel where a gradual change in the channel cross section is taking place. The downstream end of the transition uses the previously entered channel description and IDNO. The upstream end of the channel is described by entering a new channel description. Transition element structures are normally used in place of reach element structures when describing irregular or natural channels to the program. Another example would be to describe an approach to a bridge entrance or exit, or, a bell mouth entrance into a pipe. Head loss in a transition structure varies depending upon the angle of convergence or divergence in the channel. See Appendix A for this information.

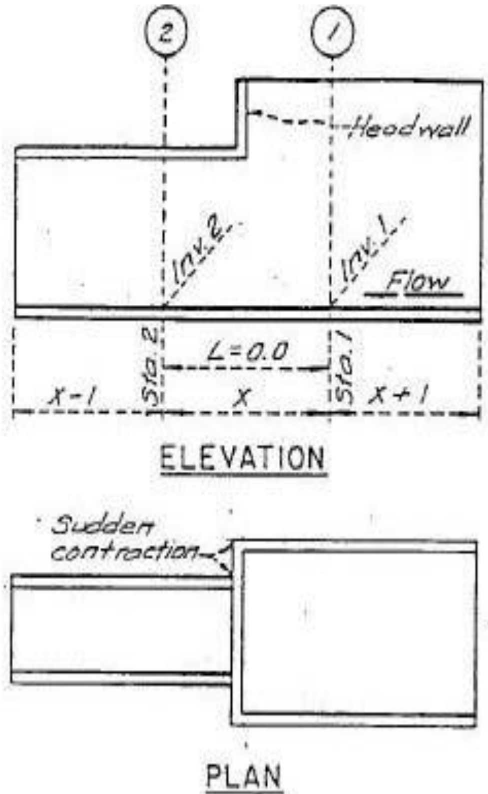


FIG. 5-9

WALL EXIT / SUDDEN EXPANSION

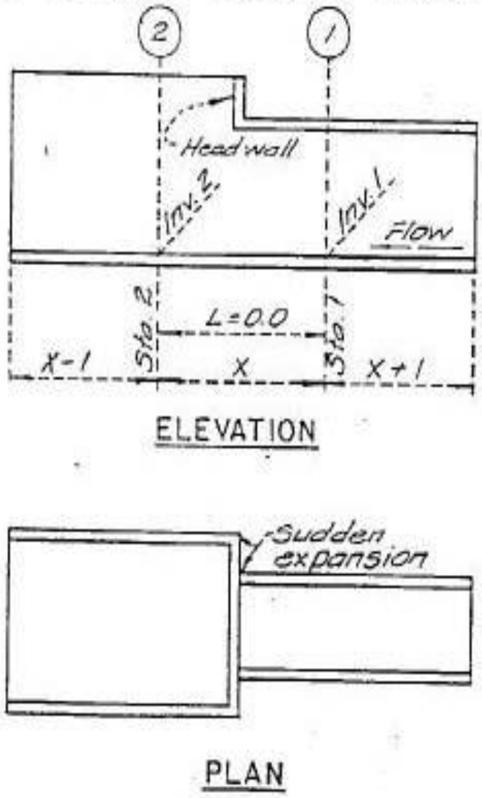


FIG. 5-10

Wall Entrance (WE):

This element is used where there is a sudden contraction in channel size from upstream to downstream, such as a headwall. This is a zero length element. Under pressure flow downstream control conditions, the program applies a minor loss factor Kc to the losses. The default Kc factor is 0.5 and may be changed by the user. Under upstream control, pressure or non-pressure, and downstream control non-pressure, the program uses the momentum equation to solve for losses; the Kc factor is not applied. See Appendix A for equations used. Note: The element upstream of a Wall Entrance may not have piers, if it does, use a Bridge Exit.

Wall Exit (WX):

This element is used where there is a sudden expansion from a smaller to a larger channel. This element is considered to have zero length. The upstream element above a Wall Exit may have piers. The downstream element may not have piers, of it does, use a Bridge Entrance.

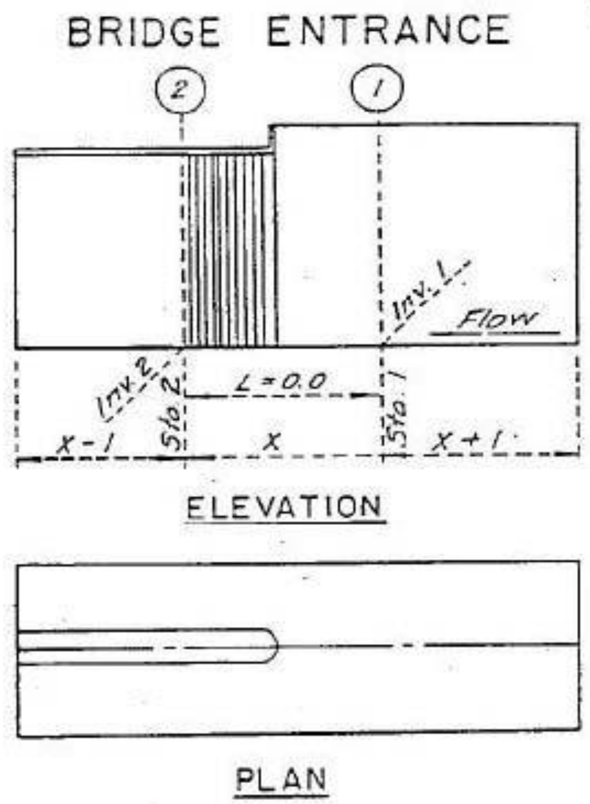


FIG. 5-7

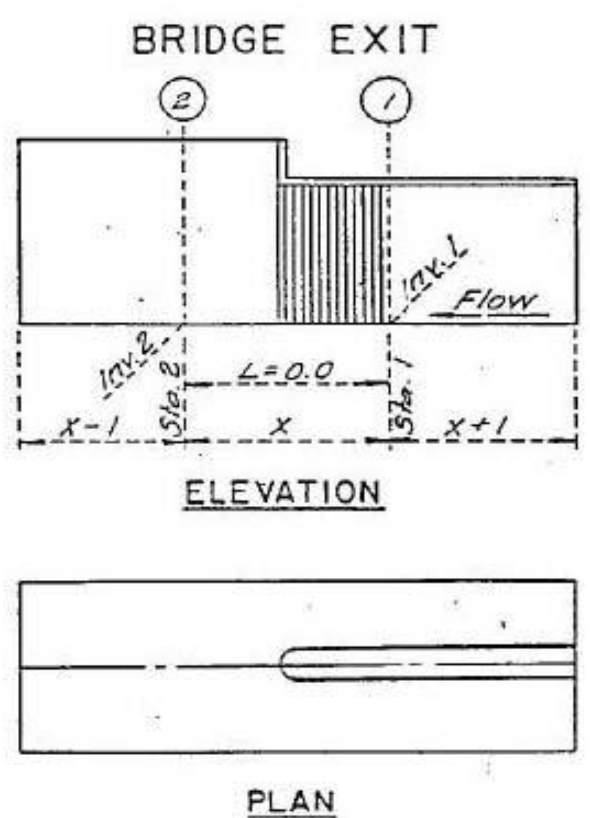


FIG. 5-8

Bridge Entrance (BE):

A Bridge Entrance element is used when flow enters from an element without piers to an element with piers. The base width and channel side slopes of the upstream and downstream elements must be the same. If irregular shaped cross sections are used they too must be identical with the upstream element having at least one pier below the water line. Normally a transition structure follows a Bridge Entrance. A Bridge Entrance is a zero length element even though the bridge nose pier may have a minor length.

Bridge Exit (BX):

The Bridge Exit element is also considered to have zero length. The upstream channel must have piers, the downstream channel must not have piers. The channel base width and side slopes must be the same on both sides of the bridge exit. If irregular shaped cross sections are used they too must be identical with the upstream element having at least one pier below the water line. Normally a Transition Structure is placed immediately downstream of a Bridge Exit.

******************* *INPUT OF DATA* ***********************

Data input into the program is simple once you understand the requirements of the program.

Whether building, editing, running, or plotting a data file; the program requires the study name (up to 26 characters). As shown in the program file listing, the program prepares several input and output files by applying file extensions to this name.

SEQUENCE OF INPUT:

Title Data (T1,T2,T3):

After supplying a study name, the program requires the title data if desired. You may enter up to 3 lines of title data which will be printed at the top of each page of the output file results.

English or Metric (SI) Units:

The program offers the option of using either English or Metric Units. If English units are used, stations, elevations and channel/pipe sizes are in feet, flow rates are in cubic feet per second. If Metric (SI) units are selected, length/size units are in meters, flow rates are in cubic meters per second. Output data files may be in either English or Metric (SI) units. For small systems the program offers the option of flow rates in GPM or L/S and pipe sizes in inches or centimeters.

Stationing:

All of the following element entries assume the station and elevation being entered is at the UPSTREAM end of the element. This means that an element with length actually starts at the previously entered station and is ending at the current station being entered.

Curve Angle, Radius of Curve, Angle Point:

All elements with length, the Reach (R), Transition Structure (TS), and Junction (JX), require an angle of curve. The angle of curve is used by the program for determining the curve radius for super-elevation calculations, and drawing the plan view of the channel. This angle is the number of degrees, and decimal degrees (3 places), that the channel changes direction, looking upstream, from the previously entered station to the station being entered. If the channel curves to the right, enter a positive(+) angle; to the left, enter a negative(-) angle. The program also permits use of positive (+) or negative (-) radius of curvature, and will calculate the + or - angle to be stored in the input data file. For hydraulic calculations, the program disregards the sign (+, or -) of the angle or radius. Separate reach or transition elements must be entered at the start and end of curves (even if they are elbows in a pipe).

If an angle point is used, the angle point change occurs at the upstream station being entered, to the right left using a positive +, or negative - angle point.

System Outlet (SO):

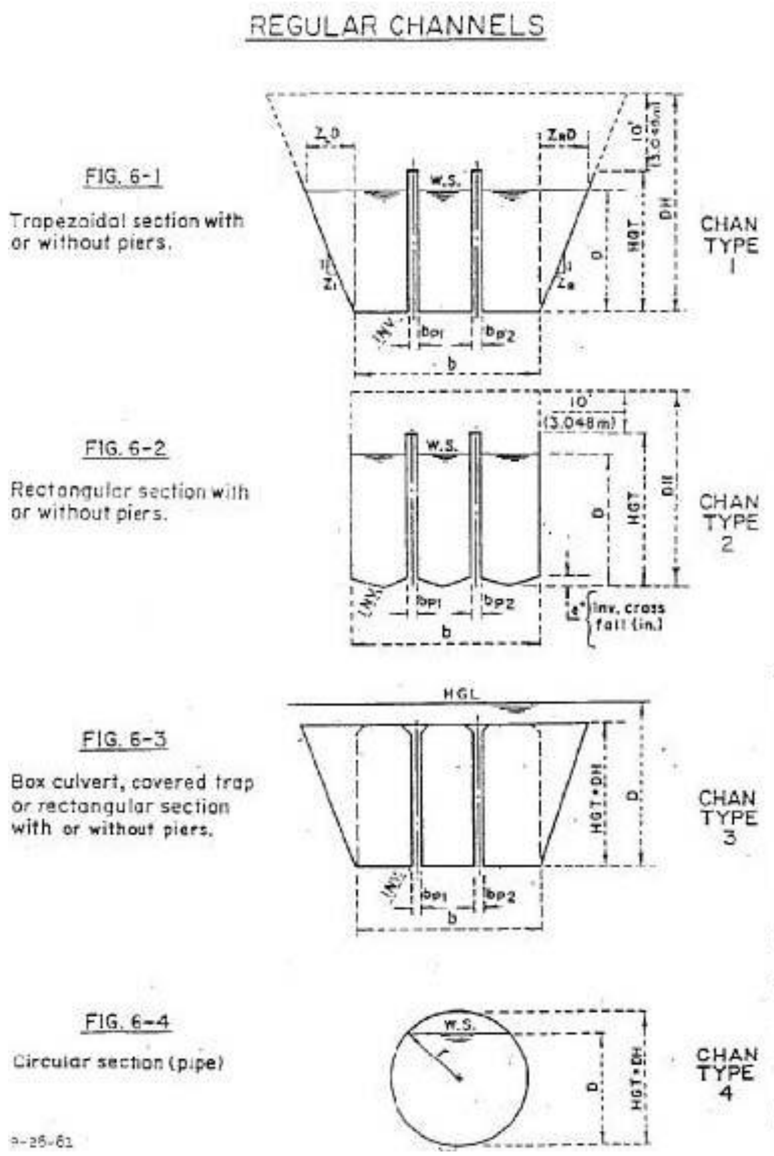
Next the program requires the station, invert elevation, and water surface elevation (if known) of the System Outlet (SO). The default value of these numbers is zero (0.0). Therefore, if you simply entered "Enter", without entering numbers, the program would start you out at station 0, elevation 0, and a water surface assumed to be 0 which, since it is the same as the invert elevation, starts the program computations at critical depth control. Following input of this data, the channel cross section data (CD) at the System Outlet is required.

Channel Data (CD):

As previously stated, a channel cross section description and identification number (IDNO) for that description is used by the program to define what type of channel exists at the upstream end of each element. The program internally assigns IDNO 1 to the first channel type you enter, 2 to the second, etc. Up to 200 types and numbers may be entered, however, this is not usually necessary because previously entered channel descriptions may be used over and over again.

Regular or irregular shaped channels may be used. A type number as follows tells the program which type of channel is assigned to the IDNO:

Channel Type	Description
1	Trapezoidal open top, with or without piers.
2	Rectangular open top, with or without piers.
3	Box or covered trapezoidal, with or without piers.
4	Pipe, or parallel pipes of the same size.
5	Irregular, open top, with or without piers, described by entering (x,y) cross-section points (positive values less than 1000, the lowest y values reset to invert elevation) Pier data, up to 10, entered separately.
6	Irregular, covered top, with or without piers, entered the same as channel type 5, except program internally assumes last (x,y) point entered is connected to the first (x,y) point entered, thereby covering the channel.



Pier data includes the number of piers and the average pier width. Up to 10 piers are allowed. If piers are used in an irregular channel, the reference (x,y) axis must be the same at that used to describe the channel. In regular shaped channel sections, piers are assumed to have the pier bases attached to the bottom of the channel. In irregular sections, the pier bases correspond to the elevation of the channel at the (x,y) point entered in the channel description.

Invert cross fall is an option used in regular rectangular or trapezoidal channels. This is the distance, in inches, the bottom center of the channel is depressed from where the channel walls intersect the bottom. A negative (-) number entry is required in either inches or millimeters. Another words, the channel has a "V" shaped bottom, which is so many inches deep. Note: The depth of flow results include this depressed area and uses the bottom of the "V" as the invert.

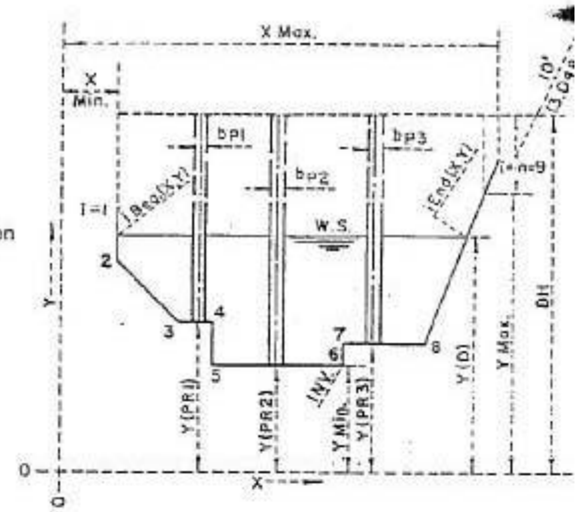
Pipe(s) may be entered either as a single pipe, or multiple pipes of the same size in parallel.

Channel side slopes, ZL and ZR, are the side slope of the channel. A value of zero, 0, is a vertical wall. Higher values are the horizontal distance divided by the vertical distance of the side wall. If a new type of channel is to be entered, the program asks the appropriate questions about the channel dimensions, number of piers, and, in the case of irregular sections, the (x,y) cross section data points.

IRREGULAR CHANNELS

FIG. 6-5

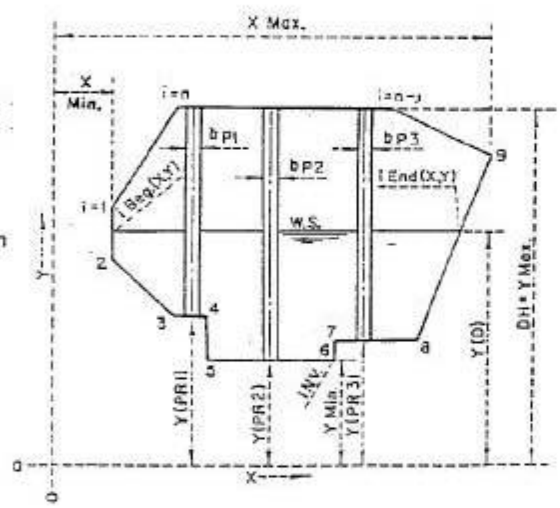
Irregular open top section with or without piers.



If the channel is *irregular open*, the channel type is 5. It is not necessary to enter the actual ground elevations of the cross section because the program internally resets the X-Y elevations. Therefore, the lowest elevation entered is set to the invert elevation of the channel at the element station / elevation entered. The (x,y) data points are related only to the lowest elevation or "y" value entered. All (x,y) data points must be equal or greater than zero (0.0). A maximum of 35 data points are allowed, and the largest value must be less than 1000.

FIG. 6-6

Irregular covered section with or without piers.



If the channel is *irregular covered*, the channel type is 6. The x-y points are entered in a counter-clockwise direction, beginning at the lowest x-value. It is not necessary to enter the first point twice, because the program considers the channel to be closed from the last point entered to the first point entered.

ELEMENTS WITH LENGTH:

Reach (R):

Data entry for this element requires the station, invert elevation, Manning's N, type of channel used, and angle or angle point of curve. A reach assumes the channel definition (CD) remains the same as from the previously entered channel, therefore a new type should not be defined. When entering reach elements, the program will automatically default to the last channel definition and IDNO entered. Simply press "Enter" to use the channel again.

A reach is entered when the channel slope, curve radius, and channel definition (CD) do not change. In some cases the reach may be of considerable length provided the conditions remain constant.

If a covered channel, pipe, or box is being used, the program will also account for manhole losses in a reach. Up to 99 manholes may be entered. It should be noted however, that manhole losses are only accounted for if the channel is under pressure flow (See Appendix A). The program only prints the water surface out at the station of elements entered, and at intermediate points when the velocity head changes by more than 10%. Therefore, if you wish to know the water surface at an exact point, say a manhole, enter a reach to that point and you will receive the results.

Transition Structure (TS):

Data entry for this element requires the station, invert elevation, Manning's N, type of channel used, and angle or angle point of curve. A transition assumes the channel gradually changes from the previously entered channel to the new type being defined.

Junction Structure (JX):

As a reminder, the station and elevation entered here is the upstream side or end of a junction. The previously entered station is considered the start of the junction. Junctions must have a length, at least that of the width of the lateral channels entering the main channel.

Data entry for this element also includes the angle of curve from the downstream end to the present upstream station being entered, and the Manning "N" value inside the junction.

The program requires the channel definitions for the upstream end of the junction, and for each lateral channel entering the junction. The channel definition for the upstream end may be the same as the downstream end, if it is, you may use the "previously entered channel" option 7, of the program.

In addition, the program requires the lateral channel flow rates, invert elevations, and the angle(s) which they are joining the main channel. These angles are defined as looking upstream from the centerline of the junction and then turning right (positive +) or left (negative -). The invert elevations are of the lateral outlets entering the main channel.

ZERO LENGTH ELEMENTS:

In addition to the system outlet (SO) and system headworks (SH), the program has the Wall Entrance (WE) and Exit (WX), and Bridge Entrance (BE) and Exit(BX) to describe abrupt changes in the in the channel type.

Because the elements are zero length, the program defaults to the last station and invert elevation entered. However, you must enter the new upstream channel definition (CD) when entering a zero length element.

See the Program Data Requirement section for additional data about zero length elements.

REMARKS ENTRY:

The program allows Remarks Line Entries (REM) at any point in the input data file between the System Outlet (SO) and System Headworks (SH) entries. These remarks will be printed in the Edit program .EDT output file, and, have no effect on the computations.

*********** *PROGRAM WORKING DIRECTORY* ************

When starting the program, you must specify which directory on your computer the input and output files are to be stored. The default directory is the current directory where the program WSPGW.EXE is located. This may be changed by entering another existing directory, for example; "C:\MYJOB".

************** *PROGRAM WORKING FILES* ****************

Files Used by the Program:

The user specifies a STUDY NAME (up to 26 characters), and the program applies the following file name extensions to the name for operating files:

File Extension	Purpose of File
.WSW	Input Data File (Formatted ASCII)
.EDT	Edit Output File
.OUT	Final Output File
.SEC	Cross section data (Random Access)
.PWS	Data for preparing a DXF file
.DXF	DXF file (Formatted ASCII)

Definitions:

Definitions:

Several other files named ELEM.DAT and TEXT.DAT are written by the program for use in computations and preparation of a .DXF file. Also, temporary .DAT files are written and erased when the program computes the resulting edit and output files.

The input data file, .WSW, is a standard ASCII data file prepared the program. The file consists of lines of data, the first two characters in each line describe what type of element is being used. After a data file has been prepared, the file may be changed by either using the program, or, using a text file editor. If a text file editor is used, do not change the location of the number fields or decimal point positions, however, the numbers themselves may be changed. In element data lines, the first number field is the station, the second is the elevation, the third is the channel identification number, The remaining fields are variable depending on the type of element and have such data as Manning's N, angle of curve, minor loss values for entrances, lateral data for junctions, etc. Following the last element, the system headworks (SH) line, channel definition (CD) lines appear with the channel identification number (IDNO), type of channel, 1-6, and channel dimensions, number of piers/pipes, etc. If irregular shaped channel are used, both a CD line and PTS lines will appear. Following the channel data lines a Q line will be written, if multiple profiles are called for, multiple Q lines will appear.

APPENDIX A - EQUATIONS

File Extension	Purpose of File
.WSW	Input Data File (Formatted ASCII)
.EDT	Edit Output File
.OUT	Final Output File
.SEC	Cross section data (Random Access)
.PWS	Data for preparing a DXF file
.DXF	DXF file (Formatted ASCII)

Definitions:

Definitions:

Abbreviation	Meaning
A	Cross Sectional Area of Flow
Angp	Angle in pipe from intersection of water and pipe to intersection of water and pipe
Angle	Angle of Curve from one element to next element in degrees
Angpt	Angle point, abrupt angle change at upstream of element in degrees
At	Full Area of Closed Section
B	Base Width of Channel
Bnet	Base Width of Channel minus (-) Piers
Bp	Average Width of Piers
Const	Constant of 1.486 English Units, 1.000 SI units
CR	Curve radius between elements
d	delta, change in value from previous point
dYJ	Junction loss
D	Depth of Flow; if under pressure D = HGL - Inv
Dc	Critical Depth
Dh	Increase in Head, downstream to upstream
Diam	Pipe Diameter
Dn	Normal Depth
E	Specific Energy
Ec	Critical Energy
Egl	Energy Grade Line = D + Vh
G	Acceleration due to gravity (32.2 English, 9.81 SI)
F	Force
H	Height of Box Channel
HGL	Hydraulic Grade Line
HF	Friction Loss, Manning
HTS	Head Loss, Transition Structure
HJX	Head Loss Junction Structure
Hapt	Angle Point Loss, Minor
Hb	Bend Loss, Minor
Hmh	Manhole Loss, Minor
Hm	Total of minor losses
HT	Maximum Improved Channel Height
Inv	Invert Elevation
ICF	Invert Cross Fall, Inches a neg (-) value

Abbreviation	Meaning
Kc	Minor Loss factor, wall entrance
L	Length between sections, points
M	Momentum
N	Manning's N
NOP	Number of Piers
NPP	Number of Pipes
P	Hydrostatic Pressure
PI	3.14159265359
PW	Pier Width
Q	Flow Rate
R	Radius of Pipe
Rh	Hydraulic Radius
SE	Super Elevation of water, outside of curve
Sf	Friction Slope
Sfa	Average Friction Slope Between Sections
So	Actual slope of section (invert to invert)
TW	Top Width of open channel flow
V	Average Channel Velocity
Vh	Velocity Head = V^2 / (2 * G)
Vhc	Critical Depth Velocity Head
X(i)	Irregular Cross Section Horizontal Value
Y(i)	Irregular Cross Section Vertical/Elevation Value
Y(p)	Base Height of Pier in irregular channel
Ymax	Maximum Open Channel Depth of Irregular Channel
Yd	Depth of Flow in Irregular Channel
Yp	Height of Pier Bases
ZL	Left Channel Slope (Horiz / Vert)
ZR	Right Channel Slope (Horiz / Vert)
WP	Wetted Perimeter

The above variables may have one of two suffixes:

1: Identifies the variable at the upstream end of an element.

2: Identifies the variable at the downstream end of an element.

Example: V1: is the velocity at the upstream (U/S) end.
V2: is the velocity at the downstream (D/S) end.

Note: A ^ symbol in the following equations represents raising a Quantity to the power following the ^ symbol.

AREA OF FLOW (A)

Channel Type	Description, Equations
1	Trapezoidal, Open A = D * [Bnet + 0.5 * D * (ZL + ZR)]
2	Rectangular, Open

$$A = D * Bnet - ICF * Bnet / 2 * CONV$$

Where CONV = 12 for English units (In.), or 100 SI units (cm) to convert from either In to Ft., or CM to M

Note: The depth D is measured from the channel wall base, therefore, the invert cross fall ICF, is negative (-), and no positive values are allowed.

3 Trapezoidal, Covered

If D < HT use process 1 as in open trapezoidal channel

Otherwise;

A = HT [Bnet + 0.5 * HT * (ZL + ZR)]
A = A - ICF * Bnet / 2 * CONV

4 Pipe(s)

If open channel flow:

Angp = 2 * ArcCos(1 - 2 * D / Diam), in radians
A = NPP * (Diam * Diam / 8) * [Angp - Sin(Angp)]

If pressure flow, A = NPP * 2 * PI * R^2

Channel Type	Description, Equations
5	Open Irregular Shaped Channel
	A = sum of dX(i) * [Yd - Y(i)] + 0.5 * [dX(i) - dY(i)] (where i = 2 to n+1 , with n being number of (x,y) points) -sum of BP * [Yd - Y(p)] (where p = 1 to NOP)
	Depth of flow limited to 10 FT/M above top of channel (error noted)
6	Covered Irregular Shaped Channel

Same as process 5, except height cannot exceed soffit of channel.

WETTED PERIMETER

Wetted perimeter (WP) is a function of the depth of flow and the geometry of the channel, box or pipe section.

<u>Channel Type</u> <u>Description, Equations</u>

1 Trapezoidal, Open

WP = D * [(1 + ZL^2)^0.5 + (1 + ZR^2)^0.5 + 2 * NOP] + Bnet

2 Rectangular, Open

WP = 2 * D * (1 + NOP) + Bnet

3 Trapezoidal, Covered

If D < HT use process 1 as in open trapezoidal channel

Otherwise;

WP = D * [(1 + ZL^2)^0.5 + (1 + ZR^2)^0.5 + 2 * NOP]
+ 2 * Bnet + H * (ZL + ZR)

Note: A Warning will be printed if the depth of flow in a box structure is greater than 90% full, but less than pressure (full) conditions. Designers should be aware that the HGL will increase rapidly when a box structure enters pressure flow and the wetted perimeter of the top of the box is used.

4 Pipe(s)

If open channel flow:

WP = NPP * [PI * R / 90] * [ArcCos((R - D) / R)]

If pressure flow, WP = NPP * 2 * PI * R

5 Open Irregular Shaped Channel

WP = sum of [dX(i)^2 + dY(i)^2]^0.5
(where i = 2 to n with n being number of (x,y) points)
+ sum of 2 * [Yd - Y(p)] - Bp
(where p = 1 to NOP)

WETTED PERIMETER (Cont'd)

Channel Type	Description, Equations
6	Covered Irregular Shaped Channel

If open channel flow conditions same as process 5.

Otherwise;

WP = sum of [dX(i)^2 + dY(i)^2]^0.5
(where i = 2 to n + 1 with n being number of (x,y) points)
+ sum of 2 * [Yd - Y(p)] - Bp
(where p = 1 to NOP)

HYDROSTATIC PRESSURE

Pressure is a function of the depth of flow and the geometry of the channel, pipe or box.

Channel Type	Description, Equations
1	Trapezoidal, Open P = 0.5 * D^2 * [Bnet + D * (ZL + ZR) / 3]
2	Rectangular, Open P = 0.5 * D^2 * Bnet
3	Trapezoidal, Covered If D < HT use process 1 as in open trapezoidal channel Otherwise; P = 0.5 * D^2 * [Bnet + D * (ZL + ZR) / 3] -0.5 * (D - H)^2 * [(1/3) * (ZL + ZR) * (2H + D) + Bnet]
4	Pipe(s) If open channel flow, C = D /R and: P = NPP * (R^3 / 3) * { [C^2 - 2*C + 3] *(2 * C - C^2)*0.5 + [(PI/60) * (C-1)] * [90 + ArcSin(C - 1)] } If pressure flow, P = NPP * (D - R) * PI * R^2
5	Open Irregular Shaped Channel P = sum of 0.5 * { dX(i) * [D - Y(i)]^2 + dX(i) * dY(i) * [D - Y(i) + dY(i)/3] } (where i = 2 to n+1 with n being number of (x,y) points) -sum of 0.5 * Bp * [D - Y(p)] (where p = 1 to NOP)

HYDROSTATIC PRESSURE (Cont'd)

Channel Type	Description, Equations
6	Covered Irregular Shaped Channel If open channel flow conditions same as process 5. Otherwise; P = sum of 0.5 * { dX(i) * [D - Y(i)]^2 + 0.5 * dX(i) * dY(i) * [D - Y(i) + dY(i)/3] } (where i = 2 to n+1 with n being number of (x,y) points) - sum of 0.5 * Bp * [Ymax - Y(p)] * [D - 0.5 Ymax - 0.5 * Y(p)] (where p = 1 to NOP)

DEPTH OF FLOW (D)(Cont'd)

Channel Type 6	Description, EquationsCovered Irregular Shaped Channel

HYDROSTATIC PRESSURE (Cont’d)

Channel Type	Description, Equations
6	Covered Irregular Shaped Channel If open channel flow conditions same as process 5. Otherwise; P = sum of 0.5 * { dX(i) * [D - Y(i)]^2 + 0.5 * dX(i) * dY(i) * [D - Y(i) + dY(i)/3] } (where i = 2 to n+1 with n being number of (x,y) points) - sum of 0.5 * Bp * [Ymax - Y(p)] * [D - 0.5 Ymax - 0.5 * Y(p)] (where p = 1 to NOP)

DEPTH OF FLOW (D)

Depth computation when area of flow is known. Note At = the full area of a closed section.

Channel Type	Description, Equations
1	Trapezoidal, Open D = [1 / (ZL + ZR)] * { -Bnet + [Bnet^2 + 2 * (ZL + ZR) * A]^.5 }
2	Rectangular, Open D = (1 / Bnet) * A + (ICF * Bnet / 24)
3	Trapezoidal, Covered If A < At use process 1 as in open trapezoidal channel Otherwise; D = HGL - Inv
4	Pipe(s) If A < At open channel flow, find D by trial and error iteration from area of part full pipe. Otherwise; D = HGL - Inv
5	Open Irregular Shaped Channel Find D by trial and error from area of part full section.

DEPTH OF FLOW (D)(Cont’d)

Description, EquationsCovered Irregular Shaped

COMPUTATIONAL PROCEDURES

Assumptions are: Steady one dimensional flow using incompressible fluid - water.

BASIC EQUATIONS:

Equation of Continuity: A1 * V1 = A2 * V2 = Q

Manning's Formula (friction slope): Sf = { Q * N / [Const * A * (Rh)^(2/3)] }^2 Where Const = 1.486 English Units, or 1.0 SI Metric Units Bernoulli's Equation (open flow): D2 + Vh2 + dL * Sfa = D1 + Vh1 + dL * So

Bernoulli's Equation (pressure flow)

D2 + Vh2 + dL * Sfa + Hm = D1 + Vh1 + dL * So Where Hm is sum of minor losses

Bend Loss: Hb = 0.2 * Vh * [Angle / 90]^.5

Angle Point Loss: Hapt = 0.0033 * Angpt * Vh Note: A maximum of 6 degrees is recommended.

Manhole Loss: Hmh = 0.05 * Vh * (Number of Manholes in a reach)

Channel Type	Description, Equations
6	Covered Irregular Shaped Channel If open channel flow conditions same as process 5.

Specific Energy: E = D + Vh

Pressure - Momentum: P2 + M2 = P1 + M1 = F where; M = Q^2 / (A * G)

Critical Depth: Ec = Dc + Vhc

Normal Depth: Dn = depth of uniform flow and is found by iteration from Manning's formula: A * (Rh)^(2/3) = (Q * N) / (Const * So^0.5)

Super Elevation: Super elevation is calculated in any element which has a length (reach (R), transition (TS) or junction (JX)) and, in any type of channel which is under open channel flow conditions. The basic equation for the increase in depth on the outside of a curve in a subcritical flow channel is: SE = V^2 * TW / (2 * G * CR) where; CR (curve radius) = L / Angle = L (distance between stations) / Angle (curve angle in radians) For super-critical channel flow; SE = V^2 * TW / (G * CR) The program uses the above equation(s) for either supercritical or sub-critical flow and applies the following safety factors to the calculated SE

Note: The program printout, .OUT file, prints the above super-elevation values only when a curve is shown between two sections or points. However, the drawing file program, which writes a .DXF file, applies the following additional equations for plotting the super-elevation flow level lines:

X = Distance from the start of the circular curve to the point of the SE in feet or meters:

X = PI * TW * V / Beta where; Beta = Wave Front Angle = (12 * G * D)^0.5

X is also used in the program to determine the distance below the end of the curve to where the SE tapers to zero. This distance into the downstream tangent may or may not be accurate depending on the flow conditions, however, the presence of a super-elevation line alerts the channel designer that the super-elevated depth does not end immediately after the end of a curve.

REACH ANALYSIS

Open Channel Flow:

Intermediate points are computed on the water surface profile in a reach (R) using the standard step method. The difference in velocity head, Vh, between two adjacent points is held to a maximum of 10 percent. However, the maximum number of intermediate points between two user-input elements is limited to 100. If this number is exceeded, the program stops and the user must insert an element between the two elements of calculation. Minor losses are not a factor in open channel flow conditions.

dL = (E2 - E1) / (So - Sfa)

Pressure Flow:

Egl1 = Egl2 - + HF + Hm

D1 = Egl1 - Vh1 - Inv1

If the water surface profile rises to the soffit of a conduit before the end of a reach, or if the HGL breaks seal before the end of a reach, minor losses are adjusted to reflect only the portion of the reach under pressure.

TRANSITION ANALYSIS

If V2 is greater than V1 then;

HTS = 0.1 * (Vh2 - Vh1), or, angle of divergence or convergence > 5.75 deg. in regular channels HTS = (3.5/2.) * tan (theta/2)^1.22 *(Vh2 - Vh1)

Otherwise;

HTS = 0.2 * (Vh2 - Vh1), or, if angle of divergence or convergence > 5.75 deg. in regular channels HTS = (3.5) * tan (theta/2)^1.22 *(Vh2 - Vh1)

Note: The maximum multiplier is limited to 0.50 times (Vh2 - Vh1)

JUNCTION ANALYSIS dYJ = dL * Sfa + (1 / G) * [Q2 * V2 /

A2 - Q1 * V1 * Cos(Angle) / A1

-Q3 * V3 * Cos(T3) / A3 - Q4 * V4 * Cos(T4) / A4] where; Angle = angle of bend from downstream to

upstream

T3 = Angle of joining lateral # 1 T4 = Angle of joining lateral # 2 and dYJ = D1 + Dh - D2 HJX =

Dh + Vh1 - Vh2

WALL/BRIDGE ENTRANCE ANALYSIS (Sudden Contraction)

Lower Stage Profile (U/S Control): Find depth at the D/S end by iteration in the equation: M2 + P2 = M1 * [(A1 - A1wall) /A1] + P1 - P1wall Where A1wall is the area if the obstructed part of A1 and P1wall is the pressure on the obstructed part of

A1

Upper Stage Profile (D/S Control): If the control depth is less than the conduit height find the depth at the upstream end from: M2 + P2 = M1 * [(A1 - A1wall) /A1] + P1 - P1wall Otherwise find D1 by iteration from the following equation: D2 + Vh2 + Kc * ABS[Vh2 - Vh1] is the head loss at the wall entrance

ABS = absolute value

WALL/BRIDGE EXIT (Sudden Expansion) Energy loss in a wall exit = 1.0 ABS[Vh2 - Vh1] Find D1 or D2 by iteration in the following equation: D2 + Vh2 + 1.0 ABS[Vh2 - Vh1] = D1 + Vh1

APPENDIX B - ERROR AND WARNING MESSAGES

EDIT PROGRAM: After building the input data file, the program edits the file before the program run. If file errors are encountered, the program will not be able to run to compute the results. If warning messages are

encountered, the program writes these messages to the .EDT file and continues to run. The following error messages may occur when editing the input data file (before run): 1) THE ABOVE SYSTEM OUTLET WAS FOUND TO BE IN ERROR -

ELEMENT NOT EQUAL TO 001

The System Outlet) must be the first element to be processed. Check order of input to make sure the (System Outlet) line follows the Title lines. 2) THE ABOVE INPUT CARD DID NOT CONTAIN THE REQUIRED DATA XXX Check data on the input line with the input documentation for that element to make sure all the required

data is present. 3) THE ABOVE INPUT CARD CONTAINED AN INVALID ELEMENT NUMBER Invalid code in the element type field. 4) THE ABOVE INPUT CARD CONTAINED AN INVALID STATION Station is not in sequence with previous stations. Value is less than the station of the previous element. 6) DURING EDIT PHASE XXX ERRORS WERE ENCOUNTERED -PROCESSING WILL

NOT START

The number of errors in the edit phase is shown (XXX). Calculations will not begin until all edit errors are corrected. 7) NO EDIT ERRORS ENCOUNTERED - COMPUTATION IS NOW BEGINNING All data passes edit checks, and processing calculations will begin when user processes output file options. 8) A BLANK INVERT WAS GIVEN ON AN ELEMENT CARD Line requires an invert, but none was entered. 9) INVALID SECTION NUMBER ON ELEMENT CARD The section number must be between 1 and 200 10) SECTION NUMBER HAD NO DATA FOR CHANNEL DEFINITION

The section number on the element line refers to a section that was not defined, or that was labeled as being in error during editing of the channel lines.

11) SECTION NUMBER HAD NO DATA FOR CROSS SECTION

Same as Message #10, only for cross-section data instead of channel definition data.

12) THE CHANNEL DEFINITION REFERENCED DID NOT CONTAIN THE REQUIRED DATA TO BE USED IN THIS ELEMENT

There is a conflict between data in the channel definition used to describe this element, and the type of element being described. Check restrictions for this element and make sure the channel definition selected has applicable data.

13) THE PREVIOUS SECTION OR CHANNEL DEFINITION DID NOT COINCIDE WITH THE DATA UTILIZED IN THIS ELEMENT

There is a conflict between data in the channel definition of the previous element and the current element being used in the element being described. Check restrictions for this element type and the channel definition data used.

Warning Messages - Editing the 'Element Cards':

1) THE ABOVE ELEMENT CONTAINED AN INVERT ELEV WHICH WAS NOT GREATER THAN THE PREVIOUS INVERT ELEV

Check inverts on the preceding and the current elements to make sure they are what you want. Program assumes data is good and will continue.

2) WARNING - ADJACENT SECTIONS ARE NOT IDENTICAL -SEE SECTION NUMBERS AND CHANNEL DEFINITIONS

The two adjacent sections are supposed to be identical in a reach element, if the channel size is the same it is satisfactory. Check channel definitions to see if data is correct. Program assumes data is good and will continue.

3) WARNING - PREVIOUS SECTION NUMBER WAS INVALID OR 0 - SEE PREVIOUS DESCRIPTION

Previous element should have been flagged as being bad, so the data passed to this element is zeroes. Processing for the other elements continues.

Error Messages - Sequence Checking thru Channel Definition Data:

1) NO SYSTEM HEADWORKS CARD - CANNOT TELL WHERE THE START OF CHANNEL DEFINITION DATA IS - NO PROCESSING

There must be a System Headworks line at the end of the element lines, just preceding the channel definition lines.

2) CHANNEL DEFINITION DATA (CD) DID NOT FOLLOW THE SYSTEMS HEADWORKS

CARD - CONTINUING TO LOOK FOR CD OR PTS There must be at least one CD line following the System Headworks line, and all CD lines follow the System Headworks and come before the cross-section points (PTS) lines.

3) NO CHANNEL DEFINITION (CD) OR CROSS SECTION POINT CARDS (PTS)

WERE RECOGNIZED - CHECK DATA There must be at least one channel definition line following the System Headworks line. Check input data line code columns.

4) NO CHANNEL DEFINITION CARDS BEFORE CROSS SECTION POINT CARDS

CHECK DATA Check order of input lines. Element lines ending with System Headworks must be followed by at least one channel definition line. (CD) Cross-section point lines (PTS) follow the channel definition lines.

5) INVALID CHANNEL TYPE ON CHANNEL DEFINITION CARD - ITYPE = X SECT = XXX

ITYPE is the channel type requested and SECT is the section number the channel type is specified to define. Channel type must be a number between 1 and 6. 6) NO CROSS SECTION POINTS ENCOUNTERED - ASSUME NO IRREGULAR CHANNELS No irregular channels or cross-section points are indicated for this problem. This is a warning message.

Processing will continue. 7) INVALID CARD CODE ENCOUNTERED WHILE PROCESSING CD AND PTS CARDS CODE = XXX After the first CD line, a line was found which did not have a code of CD or PTS. CODE indicates the invalid line code which should be corrected or placed in the correct order.

8) NO SYSTEM HEADWORKS CARD BEFORE CHANNEL DEFINITION OR CROSS SECTION POINTS

The System Headworks) line was omitted or is out of sequence. It should be the last element line and should immediately precede the channel definition lines.

Error Messages - Sequence Checking Cross-section Points Cards: 1) INVALID OR MISSING NUMBER OF POINTS VALUE - MUST BE BETWEEN 3 AND 35 CODE = XXX ISECT = XXX NO PTS = XX The number of points value is in error, or the line is out of sequence. This is supposed to be the first

line of a cross-section for the section points. CODE is the line code. ISECT is the section number, and NO PTS is the number of points indicated. 2) INVALID CARD CODE FOR CROSS SECTION POINTS While processing PTS lines, a code not equal to PTS was found. Code is incorrect, or line is out of

sequence. 3) STARTED ANOTHER CROSS SECTION GROUP BEFORE PREVIOUS GROUP WAS COMPLETED A new cross-section group was indicated (number of points was given) before all the points indicated by

the previous number of points were read. Check line sequencing and make sure the number of points is only on the first line of a section, and is correct with the number of points to be read. 4) SECTION NUMBER IS INVALID OR MISSING - MUST BE BETWEEN 1 AND 200

CODE = XXX ISECT = XXX NO PTS = XXX

The section number entered is in error. CODE is the line code, ISECT is the invalid section number, and NO PTS is the number of points. 5) END OF FILE BEFORE ALL POINTS WERE READ ON LAST CROSS SECTION The last input line was read before all the points indicated to exist in the current cross-section were read.

Supply the remaining cross-section points lines to complete the section, or correct the number of points indicated to define the section. 6) END OF FILE ON CROSS SECTION POINTS The last cross-section points line was read and processing in this program is completed.

7) NO CHANNEL DEFINITION RECORD FOR THIS SECTION CODE - GOING ON TO NEXT CROSS SECTION SECT = XXX

There was no channel definition, or an invalid channel definition was given at the corresponding section number, so no processing was done on these cross-section points.

8) MISSING NUMBER OF POINTS FOR CODE XXX FOR SECTION XXX

The first line to describe the cross-section points of a section did not have the number of points value to indicate how many points are to be read to describe the channel. Make sure that this is supposed to be the first line of the section points, and that the correct number of points value for this section is entered. If it is not supposed to be the first line of the section points, put lines in proper sequence.

Error Messages - Channel Definition Processing: 1) SECTION NUMBER INVALID OR MISSING, DATA

CANNOT BE WRITTEN TO THE

OUTPUT FILE There is an invalid section number on a CD or PTS line. Section number must be

between 1 and 200. 2) INVALID VALUE FOR THE NUMBER OF PIERS - MUST BE BETWEEN 0 AND

10 IF GIVEN The number of piers on the CD line is invalid. Must be between zero and ten. 3) AVERAGE

WIDTH OF PIERS IS INVALID OR NOT GIVEN WHEN THERE IS A VALUE FOR

NUMBER OF PIERS IN THE CHANNEL.

When some number of piers is entered, a value for the average width of the piers must also be entered.

Correct either number of piers entry or average pier width entry. 4) CHANNEL HEIGHT IS INVALID OR

IS NOT GIVEN Correct height data entry in the channel definition. 5) CHANNEL DIAMETER IS

INVALID OR IS NOT GIVEN Correct the diameter data entry in the channel definition. 6) CHANNEL

WIDTH IS INVALID OR IS NOT GIVEN Correct the width data entry in the channel definition.

7) THERE IS A DIFFERENCE BETWEEN THE NO. OF PIERS AND THE NUMBER OF VALUES FOR PIER DEPTHS

If fewer depths are entered for piers in an irregular section than than the number of piers indicated, the remaining pier base values must be added, even if they are zero. If more depths are entered, only the amount up to the number of piers declared will be considered.

Error Messages - Cross-section Point Processing:

1) ENCOUNTERED A POINT WHERE X = 0 AND Y = 0 BEFORE ALL THE INDICATED POINTS WERE PROCESSED - ASSUMING ERROR

Only the first coordinate of the cross-section points can be 0, 0. Otherwise, the program cannot distinguish between blanks and zeros. If point desired is 0, 0 use .01, .01 for approximate data.

2) THE CROSS SECTION POINTS ARE OUT OF SEQUENCE FOR AN IRREGULAR OPEN SECTION - MUST BE COUNTERCLOCKWISE FROM MINIMUM X

Check the sequence of points on the cross-section point lines for the data which is out of order.

3) THE CROSS SECTION POINTS ARE OUT OF SEQUENCE FOR AN IRREGULAR SECTION - MUST BE COUNTERCLOCKWISE FROM MINIMUM X

Check the sequence of points on the cross-section point lines for data that is out of order. When maximum X is reached, the following X values must continually decrease.

4) MAXIMUM Y IS NOT AT EITHER SIDE OF AN OPEN IRREGULAR CHANNEL ASSUMED BAD DATA AND PROCESSING IS STOPPED

For some reason, maximum Y was not at the end of an open irregular channel. Check input data and correct.

COMPUTATIONAL ERROR / WARNING MESSAGES

COMPUTATIONAL PROGRAM:

After successfully editing the input data file, the program is ready to run and calculate the results. The following error and/or warning messages are printed in the .OUT file if required.

Note: If the program fails to produce an output data file, re-run the file and output to the CRT/SCREEN using the trace mode option. Then you can see what problem in the input data file is causing the error.

2) WATER SURFACE ELEVATION GIVEN IS LESS THAN OR EQUALS INVERT ELEVATION IN XXX, W.S. ELEV = INV + DC

The subroutine name is shown. This is a warning message that there was no water surface elevation entered for either the headworks or outlet, or that the water surface entered is less than the invert elevation causing DC to be the controlling depth. Processing continues.

3) WENTDS, NO AREA OF OBSTRUCTION IN ELEMENT XXX, A1 = XXX, A2 =XXX

The element number, area in the upstream end, and area in the downstream end (based on depth from the upstream end) are printed. The area in the upstream end must be greater than the area in the downstream end. Make sure this is supposed to be a Wall Entrance and that the channel sections are described properly. Processing is stopped.

4) W.S. ELEV IS 10 FEET OR MORE ABOVE OPEN CHANNEL WALLS IN XXX, STATION = XXX, D = XXX, DH = XXX

The subroutine, station, depth, and maximum open flow depth are shown. Open flow depth reached the maximum limit in the program. Raise the heights of the channel walls at this point and rerun. Processing is stopped.

5) OVER 100 RECORDS WRITTEN IN XXX. ELEMENT = XXX, STATION = XXX

The subroutine, element, and station are shown. The maximum number of 100 intermediate points in a Reach element have been processed. Divide this Reach element into two or more Reaches at the station shown, and rerun. Processing is stopped.

6) CANNOT SOLVE QUADRATIC FORMULA FOR START OF OPEN FLOW IN RCHUS, STATION = XXX

The station at the downstream end of the Reach is shown. The solution to solving the quadratic formula was negative for the length of Reach in pressure flow. There is no solution for this problem. This situation should not occur, but if it does, this element must be hand calculated, and the other elements can be run with the hand calculated control depths. Processing is stopped.

9) THE KNOWN DEPTH EQUALED THE NORMAL DEPTH IN BERNLI, DEPTH = XXX

The known depth is shown. This is a warning message that normal depth has already been reached. The depth at the end of the Reach is set equal to normal depth. Processing continues.

10) THE UPPER AND LOWER LIMIT VALUES CALCULATED IN BERNLI WERE THE SAME, LOWER LIMIT = XXX, UPPER LIMIT = XXX

The values from Bernoulli's Equation based on the lower and upper limit depths are shown. This is a warning message indicating that depth cannot be found by Bernoulli's Equation, and that the upper and lower limit depths are the same. The depth at the end of the Reach is set equal to the current known depth. Processing continues.

11) THE VALUE TO SOLVE FOR DEPTH IN BERNLI IS NOT BETWEEN THE UPPER AND LOWER VALUE LIMITS, DESIRED VALUE = XXX, UPPER LIMIT VALUE = XXX, LOWER LIMIT VALUE = XXX, UPPER LIMIT DEPTH = XXX, LOWER LIMIT DEPTH = XXX

The value needed to solve Bernoulli's Equation, the upper and lower limit values from Bernoulli's Equation, and the upper and lower limit depths are shown. This is a warning message indicating that depth to solve Bernoulli's Equation cannot be found between the limits where it is expected. Depth at the end of the Reach is set to the current known depth, or to normal depth depending on whether the desired value to solve Bernoulli's Equation is greater or less than the prescribed limits. Processing continues.

12) THE XX FILE DOES NOT HAVE DEPTH AT THE HYDRAULIC JUMP IN JUMPR

The upstream or downstream file is shown. The station of the hydraulic jump cannot be computed, although it is indicated to exist because the upstream and downstream force curves crossed. Processing is stopped.

13) NO INTERSECTION OF FORCE CURVES COULD BE FOUND FOR THE HYDRAULIC JUMP IN JUMPR

A hydraulic jump was indicated, but there was insufficient data in the upstream and downstream files to locate the point of intersection. Processing is stopped.

14) THE FORCE AT THE HYDRAULIC JUMP IS NOT BETWEEN THE FORCES FROM THE UPPER AND LOWER LIMIT DEPTHS. UPPER LIMIT DEPTH = XXX, LOWER LIMIT DEPTH = XXX, UPPER LIMIT FORCE = XXX, LOWER LIMIT FORCE = XXX, FORCE AT JUMP = XXX IN PPMDEP

The upper and lower limit depths (depth from either side of indicated hydraulic jump), the upper and lower limit forces, and the force at the hydraulic jump are shown. The force at the jump should be equal or between the forces on either side of the jump, but this was not the case. Either the force entered for the jump or the points entered from the upstream and downstream file adjacent to the jump are wrong. Check upstream and downstream files for valid data. Processing is stopped.

15) THE TEST DEPTH EXCEEDED THE UPPER LIMIT DEPTH BEFORE THE FORCE AT THE JUMP WAS REACHED. TEST DEPTH = XXX, UPPER LIMIT DEPTH = XXX, TEST FORCE = XXX, JUMP FORCE = XXX IN PPMDEP

The iterated depth, upper limit depth, iterated force, and force at the hydraulic jump are shown. The depth causing the force at the hydraulic jump should be equal or between the depths on either side of the jump, but this was not the case. Either the force entered for the jump or the points entered from the upstream and downstream file adjacent to the jump are wrong. Check the upstream and downstream files for valid data. Processing is stopped.

17) XXX ERRORS WERE ENCOUNTERED IN SETTING THE PRELIMINARY VALUES IN ELMCHG

The number of errors in analyzing adjacent elements and flow rates and computing critical and normal depths are shown. These errors must be corrected, and the program must be rerun before actual processing will start. Processing is stopped.

18) NO XX RECORDS EXISTED WHERE INDICATED - ELEMENT NO. XXX IN WRITEN

The upstream or downstream file and the element number are shown. The upstream or downstream processing code indicated the computation for the element was valid, but there were no records in that file for the element. Processing continues with the next element.

19) THERE WAS NO JUMP INDICATED WHEN BOTH U/S AND D/S RECORDS EXISTED FOR ELEMENT XXX IN WRITEN

The element number is shown. There was a problem in the jump processing for this element. Either one of the profiles should be deleted or a hydraulic jump should be indicated. Processing continues with the next element.

20) A JUMP WAS INDICATED BUT THERE WERE NOT RECORDS ON BOTH THE U/S AND D/S PROFILES FOR ELEMENT XXX IN WRITEN

The element number is shown. There was a problem in the jump processing for this element. If the entire upstream and downstream profile is deleted, then there cannot be a jump. If there is a jump, there must be upstream and downstream profile data. Processing continues with the next element.

21) THERE WERE NO RECORDS FOR ELEMENT XXX IN WRITEN

The element number is shown. This is a warning message to indicate that there was no upstream or downstream processing for this element. Check the upstream and downstream profiles to verify this. If there is data, there is an internal problem. If there is no data, check the construction of the element. Processing continues with the next element.

22) NO PLOT GENERATED, BAD DATA OR NOT ENOUGH POINTS, 3 OR LESS

If there are only three elements being run, no plot will be generated. Processing will continue.

23) ELEMENT NUMBER XXX HAS ADJACENT ELEMENTS WHICH ARE IN ERROR

The element number is shown. There is an error in the sequence of elements (such as Bridge Exits back to back), which are not allowed. Check sequence of the elements, correct the error, and rerun. Sequence checking will continue, but processing will be stopped.

24) XXX DEPTH COULD NOT BE FOUND IN ELEMENT XXX

Either normal or critical depth and element number are printed. There is either an error in function DCRIT or DNORM or there is a bad channel description. Hand calculate the value, and if it is valid for the channel, try rerunning the program. Elements will continue to be checked, but no processing will occur.

25) IRREGULAR XXX VALUES ARE ZERO OR NEGATIVE, SET XXX EQUAL TO ZERO, XXX = XXX, PIER XXX = XXX, IN XXX

Either force, area, or wetted perimeter values are shown from functions FORCEI, AREACI, or WETPI for irregular sections. The appropriate data could not be computed in this irregular section.

26) PIER WIDTH IS WIDER THAN CHANNEL WIDTH IN XXX, DEPTH = XXX, PIER WIDTH = XXX

Either force, area, or wetted perimeter, depth, and average pier width is shown. The width of the number of piers at the given depth is wider than the channel width at that depth. Correct the entered data and rerun.

27) DEPTH EXCEEDS XXX WITH FORCE TOO LOW IN FORCEM. TEST DEPTH = XXX, TEST FORCE = XXX, XXX = XXX, DESIRED FORCE = XXX

The iterated depth and force, the maximum or minimum depth, and the desired force value are shown. The desired force in the Bridge Exit could not be reached within the prescribed depth limits. The desired depth is set to zero and no processing is done in that end of the Bridge Exit. Processing continues with the next element.

28) DESIRED FORCE IS OUTSIDE THE RANGE OF DEPTHS IN FORCEF. TEST DEPTH = XXX, TEST FORCE = XXX, XXX = XXX, DESIRED FORCE = XXX

The iterated depth and force, the maximum or minimum depth, and the desired force are shown. In downstream processing the desired force in the downstream end of the Bridge Entrance could not be reached within the prescribed limits of depth, so the desired depth is set to zero and no computation is done in the downstream end. In upstream processing the Bridge Entrance was under pressure at the upstream end, so pressure flow calculations will be done. Processing is continued for pressure flow going upstream and in the next element going downstream.

29) DESIRED FORCE IS OUT THE RANGE OF DEPTHS IN FWALL. TEST DEPTH = XXX, TEST FORCE = XXX, MINIMUM DEPTH = XXX, DESIRED FORCE = XXX

Same as previous message, except for Wall Entrance rather than Bridge Entrance.

30) DEPTH IS OUTSIDE THE RANGE OF THE POINTS DESCRIBING THE CHANNEL IN XXX. DEPTH = XXX, YMIN = XXX, YMAX = XXX

Either force, area, or wetted perimeter values for depth and minimum and maximum Y values are shown. If the depth is not above maximum open flow depth, there is an internal error. If the depth exceeds maximum open flow depth, raise the channel walls. Processing will continue, but errors should be corrected and program rerun.

31) UNABLE TO CALCULATE FRICTION SLOPE WITH MANNINGS EQUATION IN SF. AREA = XXX, WETTED PERIMETER = XXX

The area and wetted perimeter are shown. Either the area or the wetted perimeter should be less than or equal to zero. Processing is stopped.

32) CRITICAL DEPTH MAY BE INACCURATE IN ELEMENT XXX. INCREMENT = XXX

The element number and increment value are shown. If the increment is large, then critical depth is probably above the top of the channel, but is set equal to the channel height. If the increment is small, critical depth is probably pretty accurate but for some reason cannot be computed precisely. Processing continues.

33) Q VALUES IN THE JUNCTION ARE INCORRECT FOR DEPSMP. Q1 = XXX, Q2 = XXX, Q3 = XXX, Q4 = XXX

The Q (flow) values for both upstream and downstream ends and for the laterals are shown. Q2 should equal the sum of the other Q's. If it does not, there is an internal program problem. If the Q values are in error, reenter Q values. Processing is stopped.

34) A LATERAL ANGLE OF CONFLUENCE IS GREATER THAN 90 DEGREES IN DEPSMP. FIRST ANGLE OF CONFLUENCE = XXX

The angles of the laterals are shown. Check the entered values for the lateral angles, and correct any errors. Angles must be in degrees. Processing is stopped.

36) MOMENTUM AND PRESSURE CURVES DID NOT CROSS IN DEPSMP, SETTING DEPTH EQUAL TO UPPER LIMIT DEPTH PLUS ONE FOOT. DEPTH = XXX

The depth is shown. The intersection of the pressure and momentum curves was above the maximum open flow depth. For a closed channel, pressure flow calculations will be executed. Otherwise, processing will stop because depth is too high in an open channel.

APPENDIX C - PLAN/PROFILE/X-SECTION DRAWING

After successfully running the WSPGW program, the results contained in the output files may be placed in a .DXF file for use in AutoCAD*, CIVILCADD, or other CAD drawing programs.

This drawing file contains various layers and pen colors and line types to separate various data types such as channel center line, channel banks, water lines, and super-elevated water lines.

The user must specify the horizontal and vertical scales, and text height for the drawing, and the blocks desired. Then the program reads the output and input data files and produces the drawing.

The drawing file consists of four parts or blocks:

(1) Plan View: First, a plan view of the channel system is drawn with the channel centerline, channel bottom, channel banks, water line(s), and super-elevated water line(s). A "tic mark" is placed on the channel centerline any time an element was written to the data file or any time an intermediate point was calculated by the program. If the text height and space permits, a number is also written by the tic mark. This number can be related to data contained in the profile and/or text drawing. Any significant event other than a reach is also written adjacent to the tic mark such as hydraulic jump, junction, transition, wall entrance, etc. Junctions are drawn with arrows indicating the joining laterals.

(2) Profile View: The profile view of the drawing contains a horizontal scale with stationing, and a vertical scale with elevations. The program uses the vertical scale specified by the user which is less than the horizontal scale so the elevations may be displayed in more detail. The channel invert elevation line, height or channel bank line, depth of flow line, critical depth line, and super-elevated water line are drawn along with text showing the station, flow rate, velocity and point number if space permits. If text information is missing, the user may specify a smaller text height and the program will write additional text data. A vertical line is drawn any time intermediate data is calculated by the program.

(3) Text Data: The drawing also has a column listing of all title data, and hydraulic data of the computational results. This text also has the point numbers at the start of each data line so the results may be compared to the plan and profile views. All intermediate points are written in the text block, so the user may find specific data about any tic mark on the plan view by counting upstream from the last number shown.

(4) Channel Cross Sections:

The program has an option to draw channel cross-sections either at all computed stations (this may result in a large size .DXF file), or only at the stations that were input into the input data file. The cross sections are plotted using the horizontal and vertical scales previously entered and show the channel cross section, stations from the left channel bank looking upstream, elevations at various points, the water surface and super-elevation lines, and some text data which gives the station, point number and hydraulic data. Depending on the text height selected, some or all of the elevation and station text may or may not be written.

The above items are inserted into the drawing file as “blocks”, and may easily be moved around as one entity.

Super-elevation:

The super-elevation data is further expanded and calculated by the drawing file program. The main program simply calculates the maximum super-elevation, with safety factors, at a specific point in the profile. The drawing program calculates the lead-in and taper of super-elevation using the formulas listed in Appendix A, under super-elevation. Therefore, in some cases, the drawing file will show super-elevation on both banks of a channel as in an "S-Curve". The program limitation on these super-elevation calculations is that the drawing file may only look at the stations and/or intermediate points produced by the computational program. Therefore, if the user is concerned about the exact effects of super-elevation, then when building the input data file, make sure additional intermediate points are specified, i.e. specify more intermediate reach or transition elements.

APPENDIX D - PROGRAM LIMITATIONS

Program Limitations: A maximum of 200 elements are allowed. A maximum of 100 intermediate points can be computed in a Reach (R) element. Critical depth cannot exceed 100 units (Ft. Or M). Program will produce a warning message in the water surface profile when the friction slope is at one or

greater.

Irregular channels may have a maximum of 35 (x,y) data points. Undulating bottoms cannot be calculated properly in an irregular section unless the depth of flow is above the undulations. Open channel processing is limited to a depth of 10 units(Ft. Or M) above the height of the described channel. Any time the depth is above the height of an open channel the results should be re-computed using a channel which will contain the flow without exceeding the height.

The program will not accept vertical drops in invert elevations. The invert-cross fall (ICF) may be used in rectangular or box or trapezoidal channels. The depth of flow shown in a channel with an ICF is the depth above the bottom of the ICF.

REFERENCES

1. Hydraulic Design Manual, L.A.C.F.C.D. (1970)

2. Handbook of Hydraulics, E. F. Brater and H. W. King

3. Hydraulic Analysis of Junctions, City of L.A. Office Std. No. 115 (1968)

4. Critical Water Surface by Minimum Specific Energy using the Parabolic Method, Hydrologic Engineering Center, U. S. Army Corps of Engineers, Eichert, Bill S.

COMMONLY ASKED QUESTIONS

1. WHY IS THE WATER SURFACE ELEVATION LOWER THAN WHAT I ENTERED AT THE SYSTEM OUTLET? ANS: If the energy grade line is greater than the standing water surface elevation at the system outlet, the program sets the water surface elevation according to the energy at the outlet. This commonly occurs if a steep conduit (closed channel) is the system outlet where the velocity head exceeds the water surface elevation you entered.

2. WHY DOES THE PROGRAM NOT MAKE AN OUTPUT DATA FILE AFTER IT SAID IT EDITED MY INPUT FILE O.K.? ANS: The edit program only checks the file format. Improper entry of stations and/or elevations, or lack of Manning's "N", or other data may cause the program to stop. To check the problem, re-run the file to the CRT screen using the "trace mode" or run option number 2. When the program stops, use the scroll bars to read the last entry, this will show you the data just before where the program stopped. The error is usually caused by the element data you entered immediately after this data. Take a look at this input data and correct the data entry.

3. THE PROGRAM ASSUMES CRITICAL DEPTH AT THE SYSTEM HEADWORKS, HOW MAY I CHANGE THIS? ANS: If you do not enter a water surface elevation at the system headworks, the program will assume critical depth, or, a depth great enough to force water into the system, whichever is greater. To over-ride this you may enter a known water surface elevation such as the normal depth if the channel continues upstream at the same slope. Some caution should be used here, because the program assumes you are entering an exact value, such as would occur if the water was existing a "gate opening" with the flow rate you have entered at the system headworks.

4. I HAVE PROBLEMS WITH THE PROGRAM PRINTING MY OUTPUT FILES, HOW MAY I CORRECT THIS? ANS: The program will send the output data files to the system default printer if you select that option. However, these files are ASCII text files with a width of 132 characters. The printer must be set up to accept this width. For example, the HP inkjet printers will work satisfactorily if the "compressed font" button is pressed before printing the files. Laser jet printers must be set up using the printer's manual with a small enough font to print the page on the paper size you are using. An alternate solution, is to have the WSPGW program prepare output files to the disk. Then, using Wordpad for Windows, you may (1) Open the (name).OUT or (name).EDT file, (2) Select EDIT, Select SELECT ALL, Select FORMAT, Select FONT, then, using your mouse, place the cursor in size, and enter the number 7. (3) Then print your output file, and it will now fit on a normal letter sized sheet. The only problem here is the page feeds may not be correct.

5. WHEN I USE AUTOCAD AND TRY TO "DXFIN" THE WSPGW DXF FILE, NOTHING HAPPENS.

ANS: You must begin a NEW drawing in AutoCAD, then the first command should be “DXFIN”. Users who have shell programs running AutoCAD should use the ACAD.EXE file and accomplish the same before starting the shell program. After creating the new drawing, you may, if you desire, insert it as a BLOCK drawing into existing drawings.
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