PIPEFLOW Version 5.0 Users Guide

Introduction

PIPEFLOW is a Microsoft (MS) Excel® spreadsheet developed using MS Visual Basic for Applications® (VBA) to determine the flow hydraulics for pipe structures with risers. The spreadsheet will calculate the discharge for pipe structures with four types of riser structures: (1) full-round risers, (2) half-round risers with flashboards, (3) rectangular risers, or (4) rectangular risers with slots. The spreadsheet is applicable to structures for water control, pond principal spillways, grade stabilization structures or similar type structures.

Spreadsheet Purpose and Description

The user enters the structure dimensions and appropriate hydraulic coefficients, planned elevations and required discharge or drainage area and drainage coefficient. The spreadsheet computes the flow capacity of the planned pipe and riser. The spreadsheet is designed for the pipe to flow full and not be restricted by the riser size. If the pipe discharge is restricted by the riser size or planned elevations, a warning is given with a notation of the condition restricting full pipe flow. **The spreadsheet is not designed for partial pipe flow.** If partial pipe flow occurs a different program or procedure must be used.

The spreadsheet calculates pipe flow and pipe orifice flow for a given pipe diameter and elevations and the riser weir and riser orifice flow for the given riser type, size, and elevations. The spreadsheet plots pipe flow, pipe orifice flow, riser weir flow, and riser orifice flow for the planned pipe diameter, riser size, ballast sized design, and planned elevations. The flows are plotted at the increment specified by the user.

The spreadsheet has macros written in MS VBA® embedded in the spreadsheet. All programming codes are locked, and can not be accessed without the password. All cells in the spreadsheet which are not used for data entry are locked from the user and can not be modified without the password.

Running the Spreadsheet

To run PIPEFLOW, start MS Excel, and open the file <pipeflow.xls>. The MS Excel® spreadsheet asks if you want to enable, or disable macros, be sure to click <Enable Macros>. The spreadsheet will not run properly without the macros enabled. A screen appears asking for a password. The spreadsheet is password protected ands the user should click on <Read Only>. See Figure1 and Figure 2.

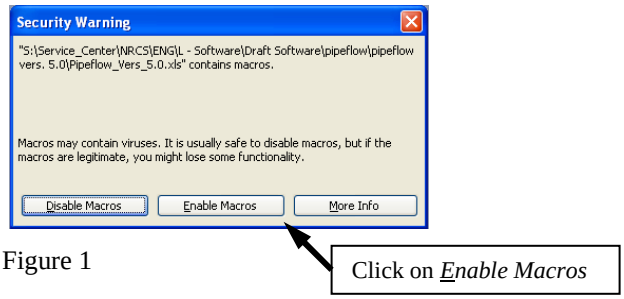

Figure 1

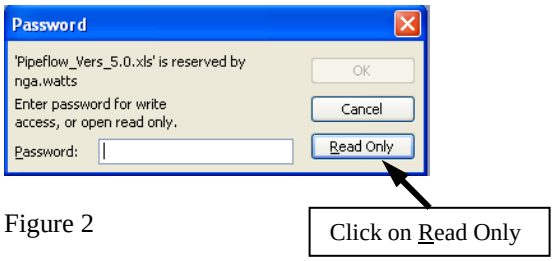

Figure 2

Go to <Tools>, <Options>, choose <Edit> tab, turn off <Enable AutoComplete for cell values>, and click on <OK>. This is to keep the auto complete from occurring when hooded inlet selection is made. See Figure 3 and Figure 4.

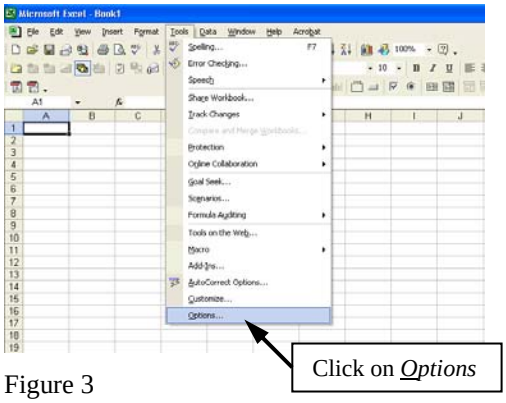

Figure 3

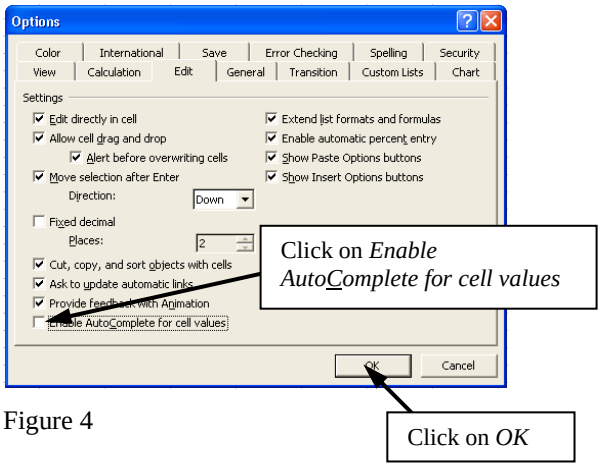

Figure 4

The spreadsheet consists of seven worksheets: (1) "Structure Graphic Input", (2) "Input and Calculate", (3) "Graph of Flow", (4) "Stage Discharge Curve", (5) "Ballast Calculations", (6) "Manning's Roughness Value "n"", and (7) "Instructions". Data is entered in the "Structure Graphic Input" and "Input and Calculate" worksheets. The "Input and Calculate" worksheet computes pipe flow, pipe orifice flow, riser weir flow, and riser orifice flow for a given pipe diameter, riser size, and structure elevations. Worksheet "Graph of Flow" plots the four flows from the "Input and Calculate" worksheet at the increment specified by the user. Worksheet "Stage Discharge Curve" plots the actual flow of the structure. Worksheet "Ballast Calculations" computes the amount of ballast required for the structure. Manning's n is provided in the "Manning's Roughness Value "n"" worksheet. The "Instructions" worksheet contains a link to the program documentation and instructions.

Data Entry

First enter data on the "Structure Graphic Input" worksheet. Begin by entering the county, field office, conservation district, plan ID, landowner, project name, structure number, and the designer's name. Then enter data in the shaded areas of the worksheet. Finally choose a riser type and enter the riser data. Be sure to enter data for only one type of riser. Indicate "Y" or "N" in the appropriate cell if the pipe has a hooded inlet for the round riser or rectangular riser. Then go to the "Input and Calculate" worksheet.

On the "Input and Calculate" worksheet, begin by entering the drainage area and drainage coefficient. This will be used to compute the discharge (Q) required. If the user has a specific design Q for the structure, then enter "0" for the drainage coefficient. This will allow a design Q to be entered. The spreadsheet will not accept a negative value for "C". The typical range for "C" is between 15 and 50. For more information on drainage coefficients, see Chapter 5 of National Engineering Handbook (NEH) Part 624, Drainage (formerly NEH 16).

Enter data into the remaining shaded cells. These cells include riser type, plotting increment, Manning's n, entrance coefficient (Ke), and riser weir coefficient.

The following is a list of the required data:

(a) "Structure Graphic Input" Worksheet

Note: All dimensions entered are in feet unless otherwise noted. All values entered in the "Structure Graphic Input" worksheet are automatically linked to the "Input and Calculation" worksheet.

1. "Design Headwater Elevation:"
2. "Top of Riser Elevation:"
3. "Top of Embankment Elevation:"
4. "Pipe Diameter (in):" Pipe diameter in inches.
5. "Tailwater (TW) Elev.:" Water surface elevation at the structure outlet. See the "Spreadsheet Formulas" section of this document for details on how the tailwater elevation is used in pipe flow calculations.
6. "Min. H(o) Elev.:" Enter the fraction of the pipe diameter to be used (between 0.50 pipe diameter (d) and 0.75 d) in calculating the head when the tailwater elevation is below the pipe outlet invert.
7. "Pipe Inlet Invert Elev.:"
8. "Pipe Length:"
9. "Embankment Top Width:"
10. "Side Slope:" Slope of the embankment. This is used to calculate required pipe length.
11. "Pipe Outlet Invert Elev.:"
12. "Type of pipe:" Choose between corrugated or smooth. This is used to compute the minimum surcharge head required for full pipe flow.
13. "Type of Riser:" enter "1" for full-round, "2" for half-round, "3" for rectangular, or "4" for slotted.
14. "Riser Diameter (in):" Riser diameter in inches. (Round and half-round risers only)
15. "Number of Braces:" Number of braces used to support the riser not including the front cross-member. (Half-round risers only)
16. Brace Width (in.):" Width of the support braces in inches. (Half-round risers only)
17. "Flashboard Elev.:" (only used with half-round risers) Any value from the pipe inlet invert (plus half the pipe diameter) to the riser crest is acceptable.
18. "Hooded Inlet? (Y/N):" Enter "Y" if the pipe has a hooded inlet and "N" if the pipe does not have a hooded inlet. For hooded inlet implications see calculations portion of this document. (Round and Rectangular risers only).
19. "Riser Length (in)" Riser length in inches (Rectangular and slotted risers only).
20. "Riser Width (in)" Riser width in inches (Rectangular and slotted risers only).
21. Check sides that will contribute to weir flow (Rectangular riser only).

22. Check sides with slots “Slot #1” or “Slot #2” (Slotted risers only). At least one slot must be checked for the program to compute.

23. “Slot #1 Elev” Enter the inlet elevation of slot number 1, same for slot #2 elev if applicable (Slotted risers only).

24. “Slot #1 Width (in)” Enter the width of slot number 1 in inches, same for slot #2 width if applicable (Slotted risers only).

25. “Grate?” Enter Y or N whether the slotted riser has a grate on top. If yes, enter values for 23 and 24.

26. “Grate Open Area (ft^2)” Enter the open area of the grate in ft^2. The open area must be less than the total area of the top of the riser.

27. “% of Grate Blocked by Trash” Enter the percent of the grate open area that will normally be blocked by trash. This will reduce the effective open area of the grate by this percentage.

(b) “Input and Calculate” worksheet

1. “Plotting Increment:” The plotting increment is the elevation increment between the elevations at which discharges are computed in Table 1 - Flow at Incremental Head Water Elevations on the “Input and Calculate” worksheet and plotted on the graph of flow vs. water elevation on the “Graph of Flow” worksheet. Typical increment ranges are from 0.05 to 0.5. This will determine the range of flows that will be plotted. The larger the plotting increment, the larger the plotting range.

2. “Manning’s n:” Enter a value between 0.009 and 0.030. The default value is 0.025. See NEH Part 650, Engineering Field Handbook, Chapter 3 Florida Supplement for values.

3. “Ke:” Pipe entrance coefficient. Enter a value between 0.2 and 1.5. The default value is 1.0. See NEH Part 650, Engineering Field Handbook, Chapter 3 for values.

4. “Riser Weir Coefficient:” Enter a value between 2.8 and 3.6. The default value is 3.33.

(c) “Ballast Calculations” worksheet

1. This worksheet will calculate the necessary depth of a ballast on the selected riser.

2. Select a value from the given drop-down menu, depending on whether a ballast in the riser or a ballast around the riser is needed.

3. If necessary, enter a length and width dimensions for ballasts around the riser.

4. The required depth of concrete for the ballast will be highlighted in yellow.

5. Refer to National Engineering Field Handbook Chapter 3 for method to calculate buoyancy and flotation.

(d) Calculations

After all the data is entered, click on the “Calculate!” button on the “Input and Calculate” worksheet to review the flows calculated by the spreadsheet. The discharges are displayed in Table 1 on the “Input and Calculate” worksheet beginning at the tailwater elevation and at additional elevations based on the plotting increment entered by the user. Table 1 is limited to 40 increments. Depending on the plotting increment chosen, Table 1 may not include calculations to the top of the head water. Table 2 - Discharge at Design Head Water does contain the calculated flow for all flow conditions at the design head water elevation.

For hooded inlets, when the depth over the inlet equals to or is greater than 1.8 times the pipe diameter, pipe orifice is not in effect and “N/A” is printed in Table 1.

If the headwater elevation is greater than embankment elevation, “*” is printed in Table 1 to indicate flow over the embankment.

If the head water elevation is not above the top of the pipe, values are not computed and “***” is printed in Table 1. If the head water elevation is not above the top of riser, slots, or the flashboard, values are not computed and “****” is printed in Table 1.

If the head water elevation is above the riser and there is a grate over the slotted riser, “NOTE” will be in Table 1 and Table 2 for Qw. This is to alert the user that Qw was not calculated and another method to computer Qw is required.

If the head water elevation does not meet the minimum surcharge head for the designed Q an error box appears on the “Input and Calculate” worksheet. Surcharge head is considered only for the designed Q at the designed head water elevation. Refer to NEH Part 650, Engineering Field Handbook, Chapter 14 Appendix 14B for explanation of minimum surcharge head for full pipe flow.

The “Graph of Flow” worksheet provides a graphical presentation of the flows and allows the user to determine the controlling flow at any of the plotted elevations. The elevation chosen as the “Design Headwater Elevation” is plotted as a vertical line on the graph. If the flows at the

design headwater are not acceptable, the user should change the appropriate values on the "Structure Graphic Input" and "Input and Calculate" worksheets. After changing the values, always click on the "Calculate!" button to re-compute the flows.

The "Stage Discharge Curve" worksheet provides a graphical presentation of the actual flow that occurred for the structure.

(e) Printing

After all data is correctly entered and is acceptable and the flow rates are acceptable, the worksheets can be printed. To print the current worksheet, either click on the printer icon on the toolbar, or go to the "File" menu and select "Print". The worksheets are formatted such that by default, the worksheet will fit on one page. The printed worksheets should be checked and initialed by someone with appropriate engineering job approval authority.

(f) Saving

The spreadsheet may be saved for documentation. To save the spreadsheet go to the MS Excel File menu and click on <Save As…>, then save the file as a name other than <pipeflow.xls>. It is recommended to save the spreadsheet as a filename such as <landowner_structure_no.xls>.

Checks, Warnings and Limitations

The spreadsheet has several error checks and warnings. The spreadsheet checks to determine if the input values are within an acceptable range.

(a) Input Restrictions

1. Entrance Coefficient Ke must be between 0.2 and 1.5, If the entered value is not in this range, the user is prompted to enter a new value. The default value is 1.0. The spreadsheet automatically recalculates using the new input value.
2. Riser Weir Coefficient must be between 2.8 and 3.6. If the entered value is not in this range, the user is prompted to enter a new value. The default value is 3.33. The spreadsheet automatically recalculates using the new input value.
3. Drainage Coefficient must be greater than 0 and less than 100. If 0 is entered, a design Q will need to be entered to continue. The spreadsheet automatically recalculates using the new input value.
4. Manning's "n" must be between 0.009 and 0.030. If the entered value is not in this range, the user is prompted to enter a new value. The default value is 0.025. The spreadsheet automatically recalculates using the new input value.
5. If a rectangular or slotted riser is selected, the input wall width must be greater than or equal to six inches.

(b) Headwater Elevation Restrictions

1. The headwater elevation must be greater than the top of the riser elevation for full-round risers and rectangular risers. If this condition is not met, the spreadsheet stops and allows the user to enter either a new riser elevation or a new design headwater elevation. The user then must click on the "Calculate!" button to continue.
2. The headwater elevation must be greater than flashboard elevation for half-round risers or the lowest slot elevation for slotted risers. If this condition is not met, the spreadsheet stops and allows the user to enter either a new flashboard (or slot) elevation or a new design headwater elevation. The user then must click on the "Calculate!" button to continue.
3. The headwater elevation must be higher than the tailwater elevation. The design tailwater elevation is used for all the pipe flow calculations. This value is the higher of either the tailwater elevation entered in the "Structure Graphic Input" worksheet or the pipe outlet invert elevation plus (0.50 - 0.75 as specified by the user) times the pipe diameter. If the headwater elevation is not higher than the tailwater elevation, the spreadsheet stops and asks the user to enter a new headwater elevation. The user then must click the "Calculate!" button to continue.
4. The headwater elevation must be above the top of the pipe. If the headwater elevation is below the top of the pipe, the spreadsheet stops and asks the user to enter a new headwater elevation or use a different method of calculating pipe flow. The user then must click the "Calculate!" button to continue.
5. The headwater elevation has to have a minimum surcharge head above the top of the pipe for full pipe flow. If the headwater elevation is below the minimum surcharge head required, the spreadsheet will not calculate Q for pipe flow. The user must increase the headwater elevation and click "Calculate!" button to continue.

(c) Flashboard and Riser Restrictions

1. The flashboard elevation can not be higher than the top of the riser elevation for a half-round riser. If the flashboard elevation is higher, the spreadsheet

prompts the user to enter a new flashboard elevation and automatically recalculates using the new elevation.

2. The pipe diameter must be smaller than the riser diameter or the smallest dimension on a rectangular riser. The spreadsheet stops and allows the user to change either the riser or the pipe dimensions. The user then must click on the "Calculate!" button to continue.

3. The riser elevation must be higher than the pipe inlet invert. If the riser elevation is less than the pipe inlet invert, the spreadsheet prompts the user to enter a new riser elevation, then automatically recalculates using the new riser elevation.

4. A riser type must be selected. If the riser type is not selected as 1, 2, 3, or 4 the spreadsheet prompts the user to enter a new riser type, then recalculates using the selected riser type.

The Qro graph of flow might have a dip or a negative change in the flow. The program is written where different riser orifice flows are calculated and the lowest flow is graphed. For example, for the slotted riser, if there is trash rack and different slots, the program calculates riser orifice flow for the different slots and the trash rack, and the riser orifice flow at different head elevations. The program then plots the lowest value for riser orifice flow at different head elevations.

The spreadsheet checks whether the pipe length entered is long enough by comparing it with the horizontal distance of the embankment top width and side slopes. If the pipe is not long enough, an error will appear on the "Structure Graphic Input" worksheet. However, even with this error the spreadsheet will calculate the flow.

The spreadsheet does not calculate or plot values for elevations above the embankment elevation. Under these circumstances, a "*" will appear instead of a flow rate in Table 1.

The spreadsheet does not limit the riser size, but does limit the pipe diameter to 96 inches. The spreadsheet does not limit the drainage area, discharge, or embankment height. The user must stay within their engineering job approval authority when approving designs using this spreadsheet.

Spreadsheet Tips

After changing any input value, always click the "Calculate" button on the "Input and Calculate" worksheet before printing or analyzing the data. If data for more than one kind of riser is entered, the data for the riser that is not used in the calculations is deleted upon pressing the "Calculate" button. A particular set of data can be saved by going to the "save as" option under the file menu. Be sure to change the name of the worksheet when you save it to ensure the original spreadsheet is not overwritten.

Spreadsheet Formulas

The spreadsheet uses the following formulas to calculate discharges:

(a) Pipe Flow

$$Q_p = a\sqrt{\frac{2gh}{1+K_e+K_cL}}$$

where: Q_p = pipe discharge, cfs

a = cross sectional area of the pipe, ft^2

g = gravitational constant (32.2 ft/s^2)

h = head on pipe, ft

K_e = entrance coefficient

K_c = friction loss coefficient

L = length of pipe, ft

The head (h) for pipe flow is determined as follows:

If the tailwater elevation is greater than the minimum tailwater elevation (pipe outlet invert elevation plus 0.5 to 0.75 times the pipe diameter), the head (h) is determined by subtracting the tailwater elevation from the headwater elevation.

If the tailwater is less than the minimum tailwater elevation (pipe outlet invert elevation plus 0.5 to 0.75 times the pipe diameter), the head (h) is determined by subtracting the minimum tailwater elevation (pipe outlet invert elevation plus 0.5 to 0.75 times the pipe diameter) from the headwater elevation.

Surcharge Head for Pipe Flow

$h_1 = 0.022v^2$ for corrugated metal pipe

$h_1 = 0.017v^2$ for smooth pipe (concrete, PVC, etc.)

where: v = velocity of the flow through the pipe.

Required depth of concrete for Ballast Calculations

1. $V_1\rho_\omega = A_2\rho_c H_2$

where: V_1 = volume of the riser, (ft^3)

ρ_ω = density of water, (62.4 lb/ft^3)

A_2 = area of the ballast, (ft^2)

ρ_c = density of concrete, (150 lb/ft^3)

H_2 = depth of ballast before safety factor

2. $H_2X=H_3$

where: H_2 = depth of ballast before safety factor

X = recommended safety factor, (1.2)

H_3 = required depth of concrete ballast

Pipe Friction Loss Coefficient-Circular Pipe Flowing Full

$$K_c = \frac{5087n^2}{d_p^{4/3}}$$

where: K_c = pipe friction loss coefficient

n = Manning's friction loss factor

d_p = pipe diameter in inches

Pipe Orifice and Riser Orifice Flow

$$Q_{po}, Q_{ro} = ca\sqrt{2gh}$$

where: Q_{po},Q_{ro} = orifice flow, cfs

c = orifice coefficient (assumed to be 0.6)

a = cross sectional area of the orifice, ft^2

g = gravitational constant (32.2 ft/s^2)

h = water head on the orifice, ft

Before pipe orifice flow is calculated, s_n and s_o will be computed to determine if the pipe is inlet or outlet controlled. If the pipe is outlet controlled, pipe orifice flow will not be calculated. See Chapter 3 of the Part 650, National Engineering Field Handbook for explanation of inlet and outlet control of culverts.

$$s_o = \frac{\text{inlet invert elevation - outlet invert elevation}}{\text{pipe length}}$$

where: s_o = slope of pipe

$$s_n = \left[\frac{Q\,n}{(0.000614)(d_i)^{8/3}}\right]^2$$

where: s_n = neutral slope

Q = flow, cfs (this Q is calculated in this spreadsheet by using the pipe orifice equation above instead of using the actual measured flow as indicated in Chapter 3 of the Part 650, National Engineering Field Handbook)

d_i = diameter of pipe, inches

n = Manning's roughness coefficient

For pipe orifice flow, the head (h) is determined by subtracting the pipe inlet invert elevation plus 0.5 times the pipe diameter from the headwater elevation or headwater elevation minus tailwater elevation which ever is less. Pipe orifice flow will not be computed if the headwater elevation is less than the inlet invert plus 1/2 the diameter of the pipe or tailwater is greater than headwater. An orifice coefficient of 0.6 is used for this program. Actual values range from about 0.59 to 0.61. See the Brater and King "Handbook of Hydraulics" for more details. If a hooded inlet is specified, and the head water elevation is greater than 1.8 times the pipe diameter, then the flow will not be restricted by pipe orifice. For more information on hooded inlets, see Chapter 6 of the Part 650, National Engineering Field Handbook.

Riser orifice flow is not computed until the headwater elevation exceeds the top of the riser elevation. The riser orifice flow is computed using the cross-sectional area of the riser in all cases except half-round risers with support braces and slotted risers with a grate. For a half-round riser with braces, the length times width times the number of braces is subtracted from the cross-sectional area when computing orifice flow. For a slotted riser with a grate, the riser orifice flow is computed using the open area of the grate plus the area of the slot. The elevation used to compute the orifice flow for the slot area portion, is the elevation halfway from the slot elevation to the top of the riser.

An orifice coefficient of 0.6 is assumed in calculating both the riser orifice flow rate and the pipe orifice flow rate.

Riser Weir Flow

$$Q_w = CLH^{1.5}$$

where: Q_w = weir flow, cfs

C = riser weir coefficient, ft

L = length of weir, ft

H = water head above weir, ft

In computing the weir length for the half-round riser, when the flashboard elevation is below the top of the riser, 2 inches is subtracted from each side to account for the angle brackets that hold the flashboards in place. If braces are used, the brace width times the number of braces plus one (assuming all of the braces meet at one spot on the

front of the riser) is subtracted from the weir length. For a slotted riser, the inside dimensions of the box are added to the slot width to compute the weir length when the water elevation rises above the top of the riser.

Drainage Coefficient

$$C = 16.39 + 14.75Re$$

where: C = drainage coefficient

Re = 24 hour rainfall excess in inches

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