USER'SGUIDE
PC-ROUTE SPREADSHEET
October 2020

1. Introduction PC-ROUTE is a spreadsheet which performs flood routing for inflow hydrographs through a stormwater detention / retention facility (facility). The spreadsheet was developed by the District for general distribution, without charge. Input includes the inflow hydrographs, facility geometry and outlet configuration. Output includes outflow hydrographs, peak outflow rate with time & stage. The spreadsheet is distributed as PC-Route-XX.xls, where XX represents the current version. As of this writing, XX is 08. The spreadsheet, which does not contain macros, will execute under Microsoft Excel 2003, 2007, 2010 and 2016. PC-Route is available for download at: www.rfcd.pima.gov/software/. Comments should be directed to andy.seiger@pima.gov.

2. Capabilities of and Background for PC-Route The spreadsheet consists of a number of worksheets (tabs) each dedicated to a separate subtask of the flood routing. The spreadsheet also has several information tabs, including **Intro** and **Chron**. The **Intro** tab contains brief application guidelines and pertinent application notes and warnings. A new user should review the **Intro** tab prior to use of the spreadsheet, as this may conserve the user's time and effort. The **Chron** tab documents the sequence of corrections, bug fixes and enhancements. A list of all the tabs currently incorporated into the spreadsheet, along with a brief description of each tab function, is listed in the Description of Worksheets (Tabs) Table.

The facility geometry may be varied to suit the topography of the site, property boundary limitations, stormwater storage characteristics, or other factors. The geometry is provided to the spreadsheet as a collection of data pairs which are input in the **Stage Vol** tab. The data pairs may be either stage – area, or stage – volume. For either pair, the facility characteristics must begin at a stage of zero and cumulative volume of zero. Up to 26 data pairs may be input into the spreadsheet. Additional data pairs may be accommodated by modification of the spreadsheet. If stage – area data pairs are provided, the spreadsheet calculates incremental volume at each stage by the conic projection method; this method is illustrated in the **Conic Proj** tab. Data pairs for a simple rectangular or circular facility may be developed with the aid if the **Facility Geometry** tab, and then cut and pasted into the **Stage Vol** tab.

Several outflow elements may be combined in the **Vol Outflow** tab to design the outlet works for the facility. These elements include an unlimited number of identical orifice plates, a triangular-crest weir, a box and circular culvert, and up to 3 horizontal-crest weirs. The vertical placement and dimensions (rise, span, diameter, length, and/or side slope) may be varied to change the outflow characteristics of the outlet works. Identification of these characteristics is shown on the **Out Elements** tab. The **Orifice**, **RCBC**, and **RCP** tabs develop the rating curves for an orifice plate, box culvert, and circular culvert, respectively as they operate under either unsubmerged or submerged inlet conditions. Circular culvert (RCP) capacity can be limited by either inlet control or outlet control; box culvert capacity is limited by inlet control only. Calculations within these tabs are automatically activated by incorporating an orifice plate, circular pipe and/or a box culvert into the outlet works.

Description of Worksheets (Tabs) Contained in the PC-Route Spreadsheet

Tab Name	Full Name	Tab Function
Intro	Introduction	Application notes and warnings
Chron	Chronology	Sequential tabulation of improvements, corrections, bug fixes to the PC-Route Spreadsheet
PC-Hydro Info	PC-Hydro Input	Paste hydrographs from PC-Hydro
Inflow HG	Inflow and Outflow Hydrographs	Enter inflow hydrographs for up to 3 frequencies and display outflow hydrographs. This tab will autopopulate based on the PC-Hydro Input tab, if used.
Table 4.7	SMDDFM Table 4.7	Produce an inflow hydrograph per Sec. 4.5 of the SMDDFM. Copy and paste these results to Inflow HG
Stage Vol	Stage – Volume Characteristics	Enter stage – volume characteristics for facility
Vol Outflow	Stage – Outflow Characteristics	Enter characteristics of outflow elements for facility to develop stage – outflow characteristics
SO Working Curve	Storage – Outflow Working Curve	Develops the Storage – Outflow working curve from the stage – volume and the volume – outflow information
Summary	Output Summary	Summation of input and output information in report format on a single sheet
Out Elements	Outflow Element Informational Graphic	Graphic illustration of outflow element characteristics
Conic Proj	Conic Projection Informational Graphic	Graphic illustration of facility volume calculation by conic projection method
Facility Geometry	Depth – Area – Change in Volume	Develops depth, area and volume curves for simple rectangular & circular facilities
RCBC	Box Culvert	Develops outflow characteristics for box culvert flowing under inlet control
Orifice	Circular Section Critical Depth	Develops stage – discharge for unsubmerged & submerged orifice
RCP	Circular Culvert	Develops outflow characteristics for circular culvert flowing under inlet or outlet control
Ke	Entrance Loss Coefficients	Table of entrance loss coefficients for outlet control calculations for RCP
RCP Verfication	HEC5 Table 8 Comparison	Comparison of spreadsheet results to Table 8 from HEC5 to document accurate calculation of inlet and outlet control for provided example of a 48-inch dia. RCP

The spreadsheet will route inflow hydrographs for up to three storm frequencies through the facility. The hydrographs are provided to the spreadsheet via the **Inflow HG** tab by entering a single constant time increment, and up to 200 discharges for each hydrograph. Longer hydrographs may be accommodated by modification of the spreadsheet. Use of a variable time increment is not supported. Inflow hydrographs can either be pasted into the **PC-Hydro** tab or entered directly into the **Inflo HG** tab. The three events typically represent important storm frequencies (i.e., 2-year, 10-year, and 100-year) for the design of the facility, and the **Summary** tab is set up to interpret the routing results accordingly. Input data for a routing may be documented by saving an electronic copy of the spreadsheet containing all input data, with appropriate identifiers appended to the file name. Documentation may also be accomplished by printing out a hard-copy of the individual worksheets. These printouts may be included in the design report for the facility.

Inflow hydrographs are routed through the facility by the modified puls method. This method assumes a level pool, and a time increment for the inflow hydrographs which is less than the wave travel time through the facility. The method is a statement of conservation of mass, where over each time increment the outflow volume minus the inflow volume equals the change in storage within the facility. This is expressed in the following equation:

$$\tfrac{1}{2} * (I_1 + I_2) * \Delta t - \tfrac{1}{2} * (O_1 + O_2) * \Delta t = S_2 - S_1$$

Where: Subscript 1 signifies the first time step;
Subscript 2 signifies the second time step;
I = inflow, cfs;
O = outflow, cfs;
S = stormwater storage in the facility, cubic feet; and
Δt = constant time increment = $t_2 - t_1$, seconds.

Isolating the variables known at the first time step on the left side of the equation, and dividing by Δt produces the form which is used in the spreadsheet:

$$\tfrac{1}{2} * (I1 + I2) + S1 /\Delta t - \tfrac{1}{2} * O1 = S2 /\Delta t + \tfrac{1}{2}*O2$$

At the first time step, I1 , I2 , and Δt are known from the inflow hydrograph, and both S1 and O1 are zero (because the facility is initially empty). Substituting these values allows evaluation of the left side of the above equation. Given a graphical relationship between ($S/\Delta t + \tfrac{1}{2}*O$) and O, the evaluated left side of the equation is equated to $S2 /\Delta t + \tfrac{1}{2}*O2$, and from the graphical relationship yields O2 . S2 is calculated by back substitution of O2 into $S2 /\Delta t + \tfrac{1}{2}*O2$. For the second time step, I2 , O2 , and S2 evaluated for the first step become I1 , O1 , and S1 for the second iteration, while I2 and Δt are known from the inflow hydrograph, and the process is repeated. By iteratively applying the equation in this fashion, the entire outflow hydrograph is obtained.

The graphical relationship between ($S/\Delta t + \tfrac{1}{2}*O$) and O is developed within the **SO Working Curve** tab. In developing this relationship, the spreadsheet automatically interacts with the **Stage Vol** and **Vol Outflow** tabs. Conceptually, this interaction is as follows: A value for stage is selected, and from the **Stage Vol** tab, the corresponding storage is obtained. This same stage is provided to the **Vol Outflow** tab to determine the corresponding outflow. Having S, Δt and O, the data pair (($S/\Delta t + \tfrac{1}{2}*O$) , O) is calculated, to provide one point on the graphical relationship. A second, higher, stage is then selected, and the calculations are repeated. This proceeds until the selected stage exceeds the depth of the facility, and the resulting data pairs compose the necessary graphical relationship.

3. Data Input for PC-Route Within the spreadsheet, a color-coding scheme is applied to assist with data entry. This scheme is described on the **Intro** tab, and is repeated here:

Calc Notes:	
	• blue shaded cells are for input data.
	• purple shaded cells are for optional input data.
	• brown shaded cells are autopopulated from other worksheets.
	• green shaded cells are intermediate calculation work areas.
	• yellow shaded cells are for final calculated output.

Data input occurs only in the blue or purple cells. All other cells are locked and are unavailable for input. Within the blue or purple cells, data may be input by direct typing from the keyboard or other input device, or by the cut-and-paste method. Cut-and-paste is convenient for inputting the inflow hydrographs, since they usually involve entry of many numbers which are produced by other software such as PC-Hydro or HEC-HMS. Cut-and-paste may also be convenient if the relationships coded into the **Facility Geometry** tab is used to develop the Stage-Volume characteristics for the facility or if the inflow hydrograph is developed from Tr/Qp via the **Table 4.7** tab. All other information is typically provided from the keyboard.

Note that the purple cells contain default equations which may be overwritten by input data if the user decides the default equations do not adequately describe the desired relationship or method of data input. Within the spreadsheet these purple cells occur within the **Vol Outflow** tab, where they are used to specify the rating curve for various outflow elements, within the **Stage Vol** tab, where they implement the conic projection method of volume calculation, and within the **Inflow HG tab**, where they copy PC-Hydro results from the **PC-Hydro Info** tab. Inputting data into these cells overwrites the default equations, and if the user later decides to return to the default equations, then the equations must be restored to these cells for proper operation. Restoration involves copying the equation(s) from an unmodified purple cell within each column.

Often, all of the blue or purple cells are not needed to input all the available data. In this case, the unused purple cells must remain unmodified, or must be cleared of all entries. Clearing is accomplished by highlighting the unused cells, right-clicking, and selecting "Clear Contents".

Project Identification: Identification of the project and the designer is accomplished within the Inflow HG tab, and this information is then automatically copied onto all other pertinent tabs within the spreadsheet. A run date and program file name are also automatically entered in this area; these fields are shaded green, indicating that they cannot be changed by the user:

Example for PC-Route Manual	**Project Address**
RFCD	**Designer**
Thursday, October 22, 2020	**Run Date**
PC-ROUTE_07_Example.xls	**Program File Name**

Target Discharge: A primary function of the facility is to accomplish reduction of the peak inflow rate. The minimum amount of reduction is established by policy, and minimum reduced peak inflow rate may be entered within the **Inflow HG** tab, as illustrated below. This information is then automatically copied onto all other pertinent tabs. The target discharges entered are not involved in any calculations, but are entered in order to document the minimim required performance of the facility.

target ** discharge		* Max Design Stage =	2.80	ft
25.5	cfs	NOTE: IF H > MAX DESIGN STAGE, EXTEND STAGE-VOL DATA TO A HIGHER STAGE		
10.2	csf			
3.8	cfs	** target discharges not used in calculations; for informational use only		

Inflow Hydrograph: For each of three return frequencies, enter the discharge values in cfs, and the constant time increment in minutes, into the appropriate purple cells on the **Inflow HG** tab, as illustrated below for a portion of the three inflow hydrographs. Note that zero discharge values preceding or proceeding the inflow hydrographs are allowed. Note also that the constant time increment applies to all three hydrographs.

Dt = 1.00 min 0.0167 hr inflow hydrograph time interval

	100-Year			10-Year		2-Year	
index count	Inflow I, cfs	time t, hr	S/Δt+O/2 cfs	Inflow I, cfs	S/Δt+O/2 cfs	Inflow I, cfs	S/Δt+O/2 cfs
0	0.00	0.0000	0.00	0.00	0.00	0.00	0.00
1	1.01	0.0167	0.51	0.37	0.19	0.12	0.06
2	2.98	0.0333	2.50	1.00	0.87	0.28	0.26
3	5.61	0.0500	6.80	1.91	2.33	0.57	0.69
4	8.56	0.0667	13.88	2.98	4.77	0.88	1.41

Importing PC-Hydro Hydrograph: To import hydrograph from PC-Hydro, select "Generate Hydrograph" from the Output tab at the top of the PC-Hydro web page. Select the ".XLSX (Excel/ PC-Route" Output Format, "Cubic Feet" for Volume Units, enter a Hydrograph Increment and click on "Generate Hydrograph". The last tab on the generated spreadsheet is called **PC-ROUTE_LID Export**. Copy all of the cells in this tab, and paste them into the **PC-Hydro Info** tab of the PC-Route Spreadsheet, at cell A1. The **Inflow HG** tab will automatically read this data.

Stage – Volume Relationship: This data is entered into the blue or purple cells of the **Stage Vol** tab. Data pairs must either be (stage in feet, area in acre-feet) or (stage in feet, Δ volume in acre-feet). Stage is entered in the first column (blue cells). Associated area in acre-feet is entered in the second column (blue cells), or Δ volume in acre-feet, in the third column (purple cells). Entering data into the purple cells overwrites the default equations in these cells. Regardless of the identity of the data pairs, the data set must begin at a stage and cumulative volume of zero, and must be entered in ascending order. Blue cells below the entered data must remain empty (highlight, right-click, clear contents). Unused purple cells beyond the data pairs are acceptable. A portion of the facility geometry input area within the **Stage Vol** tab is shown below:

			for information only				
stage H, ft	area A, ac	volume ΔV, af	area A, ft^2	volume ΔV, ft^3	Σ ΔV S, ft^3	Σ ΔV S, af	index for interpolation
0.00	0.19931	0	8682	0	0	0	1
0.10	0.21885	0.021	9533	910	910	0.02090	2
0.20	0.23836	0.023	10383	996	1906	0.04375	3
0.30	0.25790	0.025	11234	1081	2986	0.06856	4
0.40	0.27741	0.027	12084	1166	4152	0.09532	5

Volume-Outflow Relationship: The volume-outflow relationship for the facility is developed within the **Vol Outflow** tab by selecting the desired outflow elements, and specifying the geometry and hydraulic characteristics for each. Geometry and characteristics are entered into the blue cells as shown:

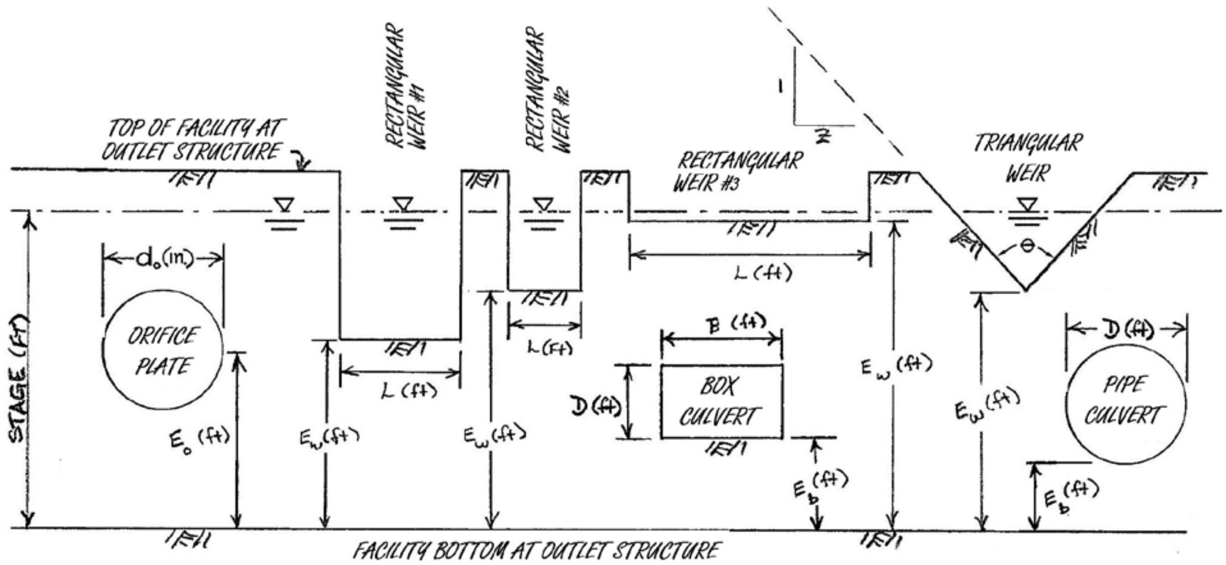
ORIFICE PLATE OUTFLOW ELEMENT				
d_o (in) =		diameter	area (ft^2) =	0.000
C =		disch coefficient		
E_o (ft) =		stage @ orifice center	inv (in) =	0.00
N =		nbr identical openings	inv (ft) =	0.000

TRIANGULAR WEIR OUTFLOW ELEMENT		
Z =		side slope
E_w (ft) =		stage at crest
C_1 =		disch coefficient
Θ (deg) =		notch angle

RECTANGULAR WEIR OUTFLOW ELEMENT(S)				
	rect 1	rect 2	rect 3	
L (ft) =				crest length
C =				disch coefficient
E_w (ft) =				stage at crest

BOX or ROUND CULVERT OUTFLOW ELEMENT			
	circ pipe	RCBC	
D (ft) =			barrel rise, dia
B (ft) =			barrel span
E_b (ft) =			barrel invert
n (dim) =			Manning's coef
S (ft/ft) =			barrel slope
L (ft) =			barrel length
K_e (dim)=			ent loss coef
TW (ft) =			tailwater depth

An outflow element is selected by entering the required characteristics for the element in the appropriate blue cells. Outflow from any particular element may be disabled by completely removing the element's characteristics from the blue cells (select, right-click, clear contents), by placing the element above the maximum facility stage (triangular weir, orifice plate, horizontal weir, RCBC, RCP), by specifying zero cross sectional area (orifice plate, RCBC, RCP), or zero crest length (horizontal weir). Once the outflow elements are selected, the **Vol Outflow** tab divides the maximum facility stage into 100 equal stage increments, calculates discharge through each selected outflow element at each stage increment, then totals the discharge from all selected elements at each stage increment. The maximum facility stage is read from the **Stage Vol** tab. Do not add rows to this worksheet; it must contain the specified 100 rows of stage data. A graphic presented in the **Out Elements** tab may assist with identifying the various characteristics of the outflow elements. This graphic is also presented here:



Incorporation of an outflow element which is not among the available elements can be accomplished by developing the stage – discharge characteristics outside the spreadsheet using the stage increments presented in column 1 of the worksheet, and then entering these calculated discharges into one of the unused purple columns, at rows corresponding to each basin stage presented in column 1. This will overwrite the default equations behind the purple cells, shown below:

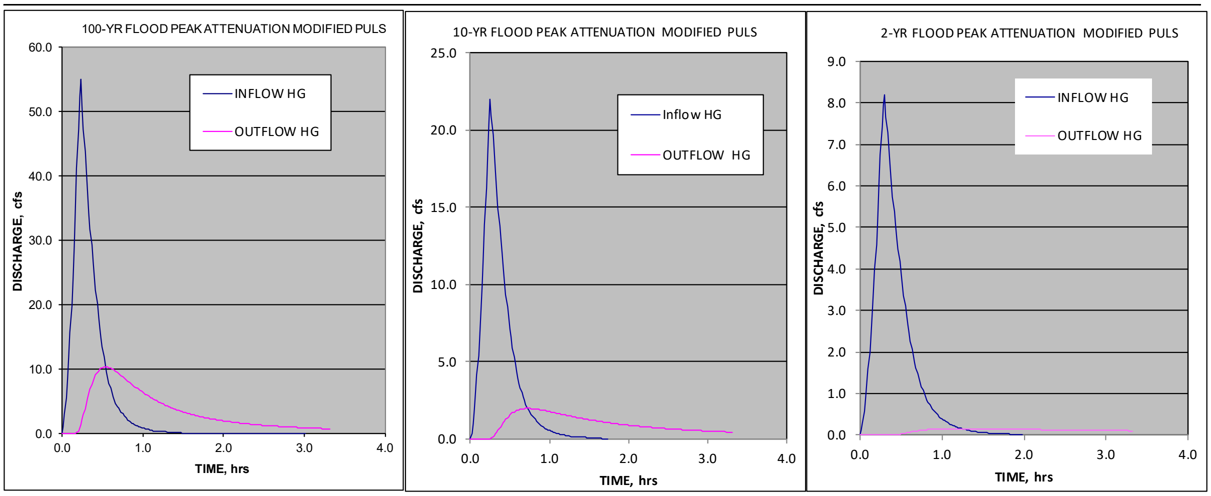
	Orifice	Weir Element(s)							
Stage	Plate	Triang 1	Rect 1	Rect 2	Rect 3	RCP	RCBC	Outflow	Σ vol
H, ft	Q, cfs	Q, cfs	Q, cfs	Q, cfs	Q, cfs	Q, cfs	Q, cfs	O, cfs	S, af
0.0000								0.00	0.00000
0.0280								0.00	0.00585
0.0560								0.00	0.01170
0.0840								0.00	0.01756

One additional set of calculations is accomplished within the **Vol Outflow** tab, in order to facilitate development of the Storage-Outflow Working Curve. These calculations are automatic and determine the storage associated with each stage increment used in the **Vol Outflow** tab. Storage at each stage is calculated by referencing the stage versus storage results contained within the **Stage Vol** tab. During this referencing, if the stage increment from the **Vol Outflow** tab falls between stage values presented in the **Stage Vol** tab, the basin storage at the stage increment is determined by linear interpolation.

Storage-Outflow Working Curve for the Facility: The Storage – Outflow Working Curve is developed within the **SO Working Curve** tab. No input data is required on this tab; calculations are performed automatically. With completion of the storage-outflow working curve, the routing will automatically proceed. One particular note is important: Through the sequence of the routing calculations, the value of $S_2/\Delta t + \frac{1}{2} * O_2$ (function value) is periodically passed to the **SO Working Curve** tab to determine the corresponding value of O_2. If the function value passed to the tab does not exactly match a function value for one of the calculated data pairs which compose the working curve and which were calculated within the **SO Working Curve** tab, then linear interpolation is used to derive the corresponding value of O_2.

4. Viewing Results from PC-Route:

Routing results produced by the spreadsheet include the outflow hydrographs from the facility, and a few associated characteristics of the hydrographs and of the facility operation. The outflow



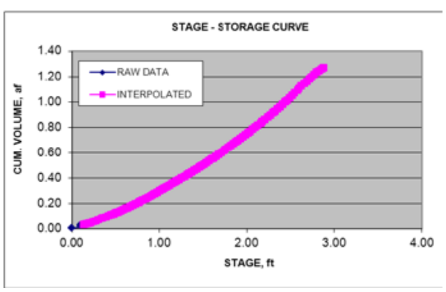
hydrographs are graphically presented along with the inflow hydrographs for comparison, on both the **Inflow HG** tab and the **Summary** tab. A sample of this output as shown on the **Inflow HG** tab is repeated above. These same tabs also present summary information, consisting of maximum inflow and outflow in cfs, the volume of stormwater runoff contained in the inflow hydrograph (cubic feet & acre-feet), the facility stage at maximum outflow in feet, and the time of occurrence of maximum outflow in minutes. Both tabs also present the maximum facility stage (copied from the **Stage Vol** tab) to allow comparison with the calculated facility stage at maximum outflow. The user is cautioned that if this comparison shows the calculated stage at maximum outflow is equal to, or greater than, the maximum facility stage, then the stage – volume data presented on the **Stage Vol** tab must be extended to a higher stage in order to insure an accurate simulation. A sample of this summary information output is repeated here:

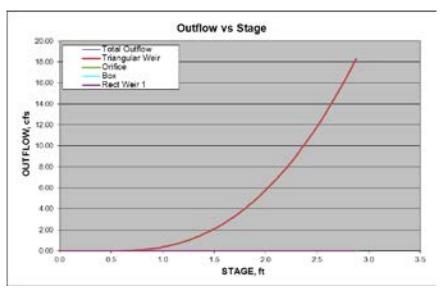
RESULTS:														
	max inflow		max outflow		total inflow volume				max stage (H) *			
100-Year	55.0	cfs	10.4	cfs	57150	ft^3	1.312	af	2.40	ft	32	min
10-Year	22.0	cfs	2.0	cfs	25190	ft^3	0.578	af	1.48	ft	44	min
2-Year	8.2	cfs	0.2	cfs	10958	ft^3	0.252	af	0.85	ft	75	min

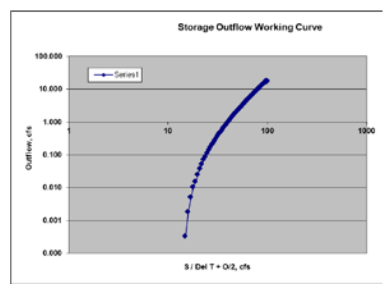
* Max Design Stage =	2.80	ft
NOTE: IF H > MAX DESIGN STAGE, EXTEND STAGE-VOL DATA TO A HIGHER STAGE		
** target discharges not used in calculations; for informational use only		

The summary information is also presented on the **Vol Outflow** tab, to facilitate design of the facility outlet works. In this way, from the **Vol Outflow** tab the user may vary the identity and characteristics of selected outflow elements and directly view the resulting change in the shape and timing of the outflow hydrographs. Note that the summary information throughout the spreadsheet is presented in yellow cells, indicating final calculated output in accordance with the color scheme presented in the **Intro** tab.

Graphs are provided throughout the spreadsheet, showing the results of subtasks of the routing. These graphs are useful in verifying proper data input, since an outlier in the input data will generally distort one of the graphs. The user is advised to inspect these graphs during data input to insure accuracy of the input, and after spreadsheet execution to insure proper operation of the spreadsheet. These graphs include the stage – volume relationship, the stage – outflow relationship, and the storage-outflow working curve:







5. Design Example

A facility is to be constructed within a critical watershed as part of a commercial development plan. Due to the location within a critical watershed, a 10% reduction in peak discharge is required for the 2-year, 10-year, and 100-year peak pre-project discharges. For this particular development plan, the watershed in which the facility is to be constructed has the following pre- and post-project (prior to construction of the facility) hydrologic characteristics:

Storm Frequency	Pre Project Peak Discharge, cfs	10% Reduction Required, cfs	Post Project Peak Discharge, cfs
2-Year	4.5	4.1	8.2
10-Year	12.0	10.8	22
100-Year	30.0	27.0	55

The facility is to be constructed with approximately 55,000 ft^3 (1.24 ac-ft) of storage, and will have a level bottom with an area of 8600 square feet. The facility is to provide 6-inches of stormwater harvesting for landscape irrigation. The outlet structure is a V-notch weir, with the bottom of the notch set 6-inches above the bottom of the facility. The depth of the notch is 2 feet, and the topwidth is 3-feet 4-inches. These dimensions will produce a V-notch with an interior angle of 80 degrees.

The inflow hydrographs to the facility are developed by application of PC Hydro to the developed watershed. The watershed area is 8.7 acres of which 20 % is impervious and the remaining area contains desert brush at a 30 % density. The desert brush is supported by Hydrologic Soils Group (HSG) type B soils. Due to proposed hydraulic structures which concentrate and direct surface runoff, a basin factor (n) of 0.022 was selected. The watercourse length is 1364 feet and the slope of the flow path is .0147 ft/ft. The 2-, 10-, &100-year post project inflow hydrographs, printed with a time increment of 1 minute in order to capture the peak discharges, are listed below:

INFLOW HYDROGRAPHS TO STORMWATER DETENTION FACILITY

Time min	2-yr cfs	10-yr cfs	100-yr cfs		Time min	2-yr cfs	10-yr cfs	100-yr cfs		Time min	2-yr cfs	10-yr cfs	100-yr cfs
0	0.0	0.0	0.0		34	2.9	4.9	8.7		68	0.2	0.3	0.4
1	0.1	0.4	1.0		35	2.7	4.4	7.8		69	0.2	0.3	0.4
2	0.3	1.0	3.0		36	2.5	3.9	7.0		70	0.2	0.3	0.4
3	0.6	1.9	5.6		37	2.3	3.6	6.4		71	0.2	0.3	0.4
4	0.9	3.0	8.6		38	2.1	3.3	5.7		72	0.2	0.2	0.4
5	1.2	4.1	11.9		39	1.9	3.0	5.2		73	0.2	0.2	0.4
6	1.6	5.4	15.7		40	1.8	2.7	4.7		74	0.2	0.2	0.3
7	2.0	6.9	19.9		41	1.6	2.5	4.2		75	0.2	0.2	0.3
8	2.5	8.4	24.1		42	1.5	2.2	3.9		76	0.1	0.2	0.3
9	3.0	9.9	29.1		43	1.4	2.1	3.6		77	0.1	0.2	0.3
10	3.5	11.8	34.8		44	1.3	1.9	3.4		78	0.1	0.2	0.3
11	4.0	13.9	41.3		45	1.2	1.7	3.1		79	0.1	0.2	0.3
12	4.6	16.2	47.3		46	1.1	1.6	2.8		80	0.1	0.2	0.3
13	5.3	18.4	52.3		47	1.0	1.5	2.6		81	0.1	0.1	0.2
14	6.1	20.3	55.0		48	0.9	1.4	2.4		82	0.1	0.1	0.2
15	6.8	22.0	50.7		49	0.8	1.3	2.2		83	0.1	0.1	0.2
16	7.4	20.9	47.3		50	0.8	1.2	2.0		84	0.1	0.1	0.2
17	7.9	19.7	43.9		51	0.7	1.1	1.8		85	0.1	0.1	0.2
18	8.2	18.5	40.6		52	0.7	1.0	1.6		86	0.1	0.1	0.2
19	7.7	17.2	37.4		53	0.6	0.9	1.5		87	0.1	0.1	0.1
20	7.3	16.1	34.4		54	0.6	0.9	1.4		88	0.1	0.1	0.1
21	6.9	14.9	31.8		55	0.6	0.8	1.3		89	0.1	0.1	0.1
22	6.5	13.8	29.4		56	0.5	0.7	1.2		90	0.1	0.1	0.1
23	6.1	12.9	26.8		57	0.5	0.7	1.1		91	0.1	0.1	0.1
24	5.7	12.0	24.5		58	0.5	0.6	1.0		92	0.1	0.1	0.1
25	5.4	11.1	22.2		59	0.4	0.6	1.0		93	0.1	0.1	0.0
26	5.0	10.2	20.1		60	0.4	0.6	0.9		94	0.1	0.1	0.0
27	4.8	9.3	18.2		61	0.4	0.5	0.8		95	0.1	0.1	0.0
28	4.5	8.6	16.4		62	0.4	0.5	0.8		96	0.1	0.1	0.0
29	4.2	7.8	14.8		63	0.3	0.4	0.7		97	0.1	0.1	0.0
30	3.9	7.1	13.5		64	0.3	0.4	0.6		98	0.1	0.0	0.0
31	3.6	6.6	11.9		65	0.3	0.4	0.6		99	0.0	0.0	0.0
32	3.4	5.9	10.7		66	0.3	0.4	0.5		100	0.0	0.0	0.0
33	3.1	5.3	9.5		67	0.2	0.3	0.5		101	0.0	0.0	0.0

The proposed geometry of the facility produced the following stage- volume characteristics:

STAGE – STORAGE CHARACTERISTICS FOR THE STORMWATER FACILITY

Stage H, ft	Incr. volume ΔV, af	stage H, ft	Incr. volume ΔV, af
0.00	0	1.30	0.041
0.10	0.021	1.40	0.043
0.20	0.023	1.50	0.044
0.30	0.025	1.60	0.045
0.40	0.026	1.70	0.047
0.50	0.029	1.80	0.048
0.60	0.031	1.90	0.050
0.70	0.032	2.00	0.052
0.80	0.035	2.10	0.053
0.90	0.036	2.20	0.056
1.00	0.038	2.30	0.058
1.10	0.039	2.40	0.060
1.20	0.040	2.80	0.261

In order to route the 2-, 10-, and 100-year inflow hydrographs through the facility with the specified stage- storage characteristics and the described outlet structure, the above information was entered into the appropriate worksheets of the PC-Route spreadsheet. The time increment, target discharges and inflow hydrographs were entered on the **Inflow HG** tab; the stage – storage characteristics were entered on the **Stage Vol** tab; and the V-notch weir characteristics were entered on the **Vol Outflow** tab. The crest of the outflow V-notch weir was set at 6-inches above the bottom of the facility in order to harvest the first 6-inches of stormwater storage for irrigation use on the project. The result of this routing effort are presented in the **Summary** tab and are reprinted here:

RESULTS:	max inflow		max outflow		target discharge		total inflow volume				max stage (H) *			
100-Year	55.0	cfs	10.4	cfs	25.5	cfs	57150	ft^3	1.312	af	2.40	ft at	32	min
10-Year	22.0	cfs	2.0	cfs	10.2	cfs	25190	ft^3	0.578	af	1.48	ft at	44	min
2-Year	8.2	cfs	0.2	cfs	3.8	cfs	10958	ft^3	0.252	af	0.85	ft at	75	min

PC-Route shows the peak 100-year outflow occurred at a stage of 2.4 feet, which is below the maximum stage of 2.8 feet and which puts a maximum head of 1.9 feet on the 2-foot high outflow structure (V-notch weir). PC-Route also shows that the 2-, 10-, and 100-year outflow hydrographs from the facility have peak discharges that are reduced a minimum of 10% from the respective pre-project peaks. For illustration, the individual worksheets from the PC-Route spreadsheet, containing the above input information, are included in Appendix A.

Appendix A

PIMA COUNTY REGIONAL FLOOD CONTROL DISTRICT

ROUTING OF A FLOOD HYDROGRAPH THROUGH A STORMWATER DETENTION / RETENTION FACILITY

INTRODUCTION: Please read and understand the following important application notes:

- This spreadsheet simulates passage of three storm hydrographs through a stormwater detention / retention facility. Input consists of: 1) project identification information; 2) the inflow hydrograph and associated constant time increment; 3) facility geometry; 4) configuration of the outlet works; and 5) a target discharge for each hydrograph. Output includes: 1) inflow volume; 2) outflow hydrograph; 3) peak outflow discharge; 4) time of peak outflow discharge; and 5) maximum stage in the facility. Facility geometry and outlet configuration are referenced to stage, which is measured vertically above the bottom of the facility.

- Project identification consisting of the project address and the name of the investigator are entered at the top of the worksheet tabbed: "**Inflow HG**". Date of run and spreadsheet version are automatically provided. All four pieces of information are automatically copied to all other worksheets which might be printed as documentation.

- Inflow hydrographs describing the time variation of the storm flows entering the facility are entered on the worksheet tabbed: "I**nflow HG**". Each hydrograph may contain up to 200 discharge points. Hydrographs with more than 200 points may be accomodated by adding rows to the worksheet. To add rows, insert them to the center of the range, and unhide all hidded columns in order to copy all equations into the new rows. Hydrograph may have multiple peaks and dry periods.

- All inflow hydrographs must use a constant time interval (Δt). This restriction is due to the Modified Puls computational method used by the spreadsheet. Δt is entered on worksheet tabbed: "I**nflow HG**". Inflow volume under each hydrograph is calculated from inflow hydrograph & Δt using Trapezoidal Rule, & is reported in the worksheets tabbed: "**Inflow HG**" & "**Summary**". Target discharges for each inflow hydrograph are also entered on the "**Inflow HG**" worksheet. These target discharges are copied to "**Vol Outflow**" and "**Summary**" worksheets. The target discharges do not enter the calculations and are recorded to facilate the design process.

- As of Rev. 04/17, the inflow hydrographs may be imported directly from PC-Hydro. Within PC-Hydro, once all hydrologic data is input and discharges are successfully calculated, the output button on the title bar is selected. Then select Generate Hydrograph to open the Generate Hydrograph dialog box. Select Output Format: XLXS (Excel/PC-ROUTE) and also select an appropriate Hydrograph Increment (min). Finally, hit the Generate Hydrograph button at the bottom of the dialog box. The hydrograph output will be saved in an Excel spreadsheet. You can now open this spreadsheet, navigate to the **"PC-ROUTE_LID Export"** tab, copy A1..C203, and paste it into cell A1 of the **"PC_Hydro Info"** tab of PC-ROUTE_05. The hydrographs will then automatically appear in the **"Inflow HG"** tab.

- Stage - volume data is entered on the worksheet tabbed: "**Stage Vol**", and may contain up to 26 data pairs. Data pairs may be either stage (ft)-area (ac) or stage (ft)-Δ volume (af). Larger data sets may be accomodated by adding rows to the worksheet. Add rows by inserting them into the center of the range, & unhide all hidden columns to copy all equations into the new rows. If stage-area data is provided, volume is automatically calculated by conic projection (Ref. "**Conic Proj**" tab). For rectangular or circular facilities, the stage - volume characteristics may be developed within the worksheet tabbed: "**Facility Geometry**", & then copied and pasted (paste special - values) into the worksheet tabbed: "**Stage Vol**". Stage - volume data must be entered in ascending order, otherwise spreadsheet produces eratic results. The first data pair must represent zero stage and volume. Zeros may not be added at the end of the stage - volume data; excess data must be cleared by highlighting the unwanted data, right-clicking, and selecting "clear contents".

- Retention volume may be incorporated into the facility by placing the crest or invert of all outflow elements a certain distance above the bottom of the facility. Retention volume is then (nominally) this depth multiplied by the bottom area of the facility, and the retention volume would exit the facility by a combination of infiltration and evaporation, or by withdrawal for irrigation under a water harvesting plan. Removal of retention volume is not sumulated by this spreadsheet.

- Volume - outflow data is entered on the worksheet tabbed: "**Vol Outflow**", and consists of selecting individual outflow elements to be incorporated into the outlet works for the facility. Available individual elements include three rectangular weirs, a triangular weir, an orifice plate (may be multiple), a box culvert (RCBC) & a circular culvert (RCP). Required input characteristics for the outflow elements are weir crest length, weir crest stage above bottom of the facility, weir crest side slope (triangular weir), orifice diameter & stage of orifice center above the facility bottom, culvert diameter, box span & rise, and invert of box or circular culvert above faciltiy bottom & all associated discharge coefficients. These characteristics are illustrated in the worksheet tabbed: "**Out Elements**". The "**Vol Outflow**" worksheet automatically divides the maximum facility depth from the **"Stage Vol"** tab into 100 equal increments & calculates total outflow at each stage increment. Alternatively, you may provide outflow data for each stage increment directly to the worksheet for up to 7 outflow elements. Note that outflow calculations for the orifice account for weir flow conditions through the orifice until the orifice is submerged; it then acts as an orifice.

- **N<u>otes:</u>** 1. Accounting for "piggy-back" events is left up to the user, and may be simulated with the appropriate inflow hydrograph and/or by accounting for less storage within the facility upon arrival of the inflow hydrograph. 2. Although not included as an optional outflow element, a facility should incorporate an emergency spillway to insure safe operation under failure of the outlet works, or under a storm larger than the design storm. 3. Equations behind the purple shaded cells may be recovered by copying the equations stored in a cell in the same column below the bottom of each table. These equations do not show up because the cell is assigned a white text color.

• SPREADSHEET IS FOR DEVELOPMENT WITHIN PIMA COUNTY, ARIZONA WHICH IS PRESENTED TO THE PIMA COUNTY REGIONAL FLOOD CONTROL DISTRICT (DISTRICT) FOR REVIEW. USER MUST APPLY ENGINEERING JUDGEMENT TO DETERMINE ACCURACY OF RESULTS.

Calc Notes:	• blue shaded cells are for input data.
	• purple shaded cells are for optional input data.
	• brown shaded cells are autopopulated from other worksheets.
	• green shaded cells are intermediate calculation work areas.
	• yellow shaded cells are for final calculated output.

Excel Notes:	• screen resolution of 1152 x 864 w/o scroll bars will display worksheet on one screen.
	• to avoid "DIVIDE BY ZERO" ERROR, erase data using: RT CLK, CLEAR CONTENTS.
	• hidden rows and columns are red when displayed
	• spredsheet was developed in Excel 2003, and contains no macros
	Rev. 10/20

PIMA COUNTY
FLOOD CONTROL
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1	CP1	4.2
9	18.6	35.1
0.00	0.00	0.00
0.12	0.37	1.01
0.28	1.00	2.98
0.57	1.91	5.61
0.88	2.98	8.56
1.23	4.13	11.89
1.60	5.35	15.70
1.99	6.86	19.88
2.48	8.38	24.13
2.96	9.92	29.05
3.45	11.76	34.82
3.99	13.86	41.31
4.58	16.24	47.34
5.29	18.42	52.26
6.05	20.34	55.00
6.75	22.00	50.68
7.41	20.89	47.25
7.94	19.70	43.86
8.20	18.46	40.57
7.67	17.24	37.42
7.28	16.06	34.42
6.88	14.92	31.79
6.49	13.83	29.36
6.11	12.86	26.82
5.74	11.99	24.45
5.39	11.07	22.23
5.04	10.18	20.14
4.75	9.33	18.16
4.47	8.57	16.44
4.17	7.82	14.78
3.88	7.11	13.51
3.61	6.60	11.90
3.35	5.90	10.65
3.11	5.30	9.53
2.88	4.85	8.66
2.65	4.39	7.79
2.46	3.94	7.04
2.26	3.62	6.35
2.07	3.31	5.67
1.90	2.99	5.16
1.76	2.74	4.68
1.61	2.49	4.23
1.47	2.24	3.94
1.37	2.07	3.64
1.27	1.89	3.35
1.17	1.72	3.06
1.08	1.61	2.77
1.00	1.50	2.55
0.92	1.40	2.36
0.84	1.29	2.16
0.78	1.18	1.97
0.72	1.08	1.78
0.67	1.01	1.62
0.62	0.94	1.52
0.59	0.87	1.42
0.55	0.80	1.31
0.52	0.73	1.21
0.49	0.66	1.11
0.45	0.62	1.04
0.42	0.59	0.97
0.39	0.55	0.90
0.37	0.51	0.83
0.35	0.48	0.75
0.32	0.44	0.69
0.30	0.41	0.64
0.28	0.39	0.59
0.26	0.36	0.54
0.24	0.34	0.49
0.23	0.31	0.44
0.22	0.29	0.42
0.21	0.27	0.41
0.19	0.25	0.39
0.18	0.23	0.38
0.17	0.21	0.36
0.16	0.19	0.34
0.15	0.18	0.33
0.14	0.17	0.31
0.14	0.16	0.29
0.13	0.16	0.28
0.12	0.15	0.26
0.11	0.15	0.25
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0.08	0.12	0.17
0.07	0.11	0.15
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0.05	0.06	0.02
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PIMA COUNTY REGIONAL FLOOD CONTROL DISTRICT

ROUTING OF A FLOOD HYDROGRAPH THROUGH A STORMWATER DETENTION / RETENTION FACILITY

Worksheet to Input the Inflow Hydrograph, & Automatically Perform the Routing Calculations using the Stage-Volume data, Volume-Outflow data, & SO Working Curve

PIMA COUNTY FLOOD CONTROL

Example for PC-Route Manual	Project Address
RFCD	Designer
Friday, October 23, 2020	Run Date
PC-ROUTE_07_Example.xls	Program File Name

Rev. 10/20

GOVERNING EQUATION: *Ref: Applied Hydrology (Ven Te Chow, Editor 1964)*

Mass Conservation: $0.5 * (I_1 + I_2) * Dt - 0.5 * (O_1 + O_2) * Dt = S_2 - S_1$

Isolate, divide by Dt: $0.5 * (I_1 + I_2) + S_1 / Dt - 0.5 * O_1 = S_2 / Dt + 0.5 * O_2$

VARIABLES:

- Dt: time interval between hydrograph discharges.
- I_1, I_2: inflow rate into facility at start and end of time interval from inflow hydrograph
- O_1, O_2: facility outflow rate at start & end of time interval
- S_1, S_2: stormwater in storage in the facility at start and end of time interval

Note: Input Dt, target discharges & inflow hydrographs for 3 storm frequencies into blue cells. Outflow hydrographs (yellow) are calculated from specified outlet configuration (**vol-outflow** tab) and facility geometry (**Stage-Vol** tab). To add rows to this worksheet, add them in roughly the center of the range, then unhide all columns and copy hidden equations into the new rows. Zero discharge within and beyond the end of the hydrograph will not affect the routing. **All blue cells in this spreadsheet must either be blank (highlight, right-click, Clear Contents) or must contain a number. In addition, the Stage - Volume data must be entered in numerically ascending order. This spreadsheet does not have a "clear" button to clear all input data in one action; to accomplish this, restart Excel using a blank copy of the spreadsheet.**

RESULTS:

	max inflow		max outflow		total inflow volume				max stage (H) *				target ** discharge	
100-Year	55.0	cfs	10.4	cfs	57150	ft^3	1.312	af	2.40	ft	32	min	27.0	cfs
10-Year	22.0	cfs	2.0	cfs	25190	ft^3	0.578	af	1.48	ft	44	min	10.8	csf
2-Year	8.2	cfs	0.2	cfs	10958	ft^3	0.252	af	0.85	ft	75	min	4.1	cfs

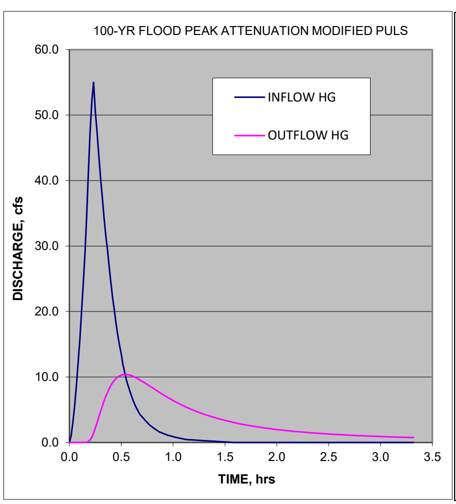
* Max Design Stage = 2.80 ft

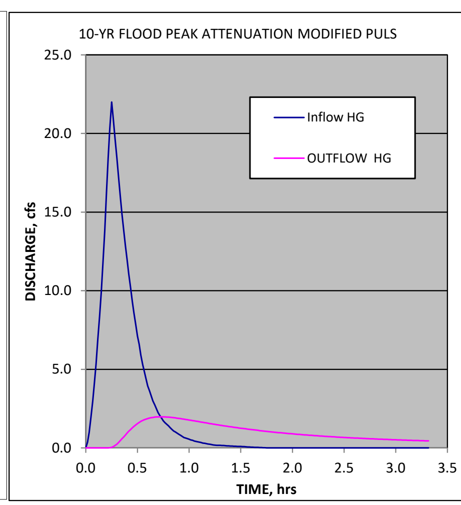
NOTE: IF H > MAX DESIGN STAGE, EXTEND STAGE-VOL DATA TO A HIGHER STAGE

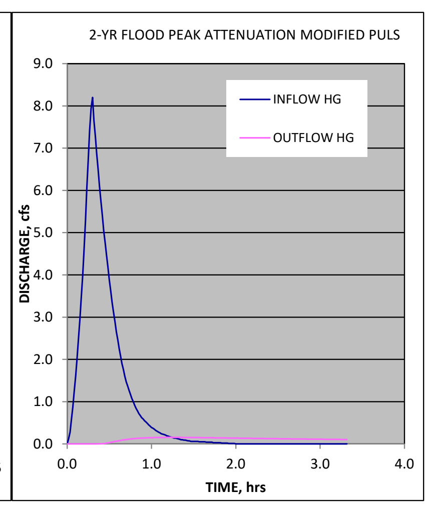
** target discharges not used in calculations; for informational use only

Dt = 1.00 min 0.0167 hr inflow hydrograph time interval

index count	100-Year Inflow I, cfs	100-Year time t, hr	100-Year S/Δt+O/2 cfs	10-Year Inflow I, cfs	10-Year S/Δt+O/2 cfs	2-Year Inflow I, cfs	2-Year S/Δt+O/2 cfs	100-Year outflow O, cfs	100-Year Stage H, ft	10-Year outflow O, cfs	10-Year Stage H, ft	2-Year outflow O, cfs	2-Year Stage H, ft
0	0.00	0.0000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	1.01	0.0167	0.51	0.37	0.19	0.12	0.06	0.00	0.00	0.00	0.00	0.00	0.00
2	2.98	0.0333	2.50	1.00	0.87	0.28	0.26	0.00	0.02	0.00	0.01	0.00	0.00
3	5.61	0.0500	6.80	1.91	2.33	0.57	0.69	0.00	0.04	0.00	0.02	0.00	0.00
4	8.56	0.0667	13.88	2.98	4.77	0.88	1.41	0.00	0.09	0.00	0.03	0.00	0.01
5	11.89	0.0833	24.11	4.13	8.33	1.23	2.47	0.00	0.15	0.00	0.05	0.00	0.02
6	15.70	0.1000	37.90	5.35	13.07	1.60	3.88	0.00	0.23	0.00	0.09	0.00	0.03
7	19.88	0.1167	55.69	6.86	19.17	1.99	5.68	0.00	0.33	0.00	0.12	0.00	0.04
8	24.13	0.1333	77.70	8.38	26.79	2.48	7.91	0.00	0.44	0.00	0.17	0.00	0.05
9	29.05	0.1500	104.29	9.92	35.94	2.96	10.63	0.00	0.56	0.00	0.22	0.00	0.07
10	34.82	0.1667	136.22	11.76	46.78	3.45	13.84	0.04	0.70	0.00	0.28	0.00	0.09
11	41.31	0.1833	174.24	13.86	59.59	3.99	17.56	0.15	0.85	0.00	0.35	0.00	0.11
12	47.34	0.2000	218.42	16.24	74.64	4.58	21.84	0.40	1.01	0.00	0.43	0.00	0.14
13	52.26	0.2167	267.82	18.42	91.97	5.29	26.78	0.81	1.18	0.00	0.51	0.00	0.17
14	55.00	0.2333	320.64	20.34	111.35	6.05	32.45	1.43	1.36	0.01	0.60	0.00	0.20
15	50.68	0.2500	372.05	22.00	132.51	6.75	38.85	2.19	1.52	0.03	0.69	0.00	0.24
16	47.25	0.2667	418.82	20.89	153.93	7.41	45.93	3.02	1.66	0.08	0.77	0.00	0.28
17	43.86	0.2833	461.36	19.70	174.14	7.94	53.60	3.88	1.78	0.15	0.85	0.00	0.32
18	40.57	0.3000	499.70	18.46	193.07	8.20	61.67	4.73	1.88	0.24	0.92	0.00	0.36
19	37.42	0.3167	533.96	17.24	210.68	7.67	69.61	5.54	1.98	0.34	0.98	0.00	0.40
20	34.42	0.3333	564.34	16.06	226.99	7.28	77.08	6.30	2.05	0.46	1.04	0.00	0.44
21	31.79	0.3500	591.14	14.92	242.02	6.88	84.16	7.01	2.12	0.58	1.10	0.00	0.47
22	29.36	0.3667	614.71	13.83	255.82	6.49	90.85	7.64	2.18	0.70	1.14	0.00	0.50
23	26.82	0.3833	635.16	12.86	268.47	6.11	97.15	8.21	2.23	0.82	1.19	0.00	0.53
24	24.45	0.4000	652.58	11.99	280.07	5.74	103.07	8.70	2.27	0.94	1.23	0.00	0.56
25	22.23	0.4167	667.22	11.07	290.66	5.39	108.64	9.13	2.30	1.06	1.26	0.00	0.58
26	20.14	0.4333	679.27	10.18	300.23	5.04	113.85	9.48	2.33	1.17	1.29	0.01	0.61
27	18.16	0.4500	688.94	9.33	308.81	4.75	118.73	9.77	2.35	1.28	1.32	0.01	0.63
28	16.44	0.4667	696.48	8.57	316.49	4.47	123.33	9.99	2.37	1.37	1.34	0.02	0.65
29	14.78	0.4833	702.09	7.82	323.31	4.17	127.63	10.16	2.38	1.46	1.37	0.02	0.66
30	13.51	0.5000	706.07	7.11	329.31	3.88	131.64	10.28	2.39	1.55	1.39	0.03	0.68
31	11.90	0.5167	708.49	6.60	334.62	3.61	135.35	10.36	2.39	1.62	1.40	0.04	0.70
32	10.65	0.5333	709.41	5.90	339.24	3.35	138.80	10.39	2.40	1.69	1.42	0.04	0.71
33	9.53	0.5500	709.11	5.30	343.16	3.11	141.98	10.38	2.40	1.74	1.43	0.05	0.72
34	8.66	0.5667	707.83	4.85	346.49	2.88	144.93	10.34	2.39	1.79	1.44	0.06	0.74
35	7.79	0.5833	705.72	4.39	349.32	2.65	147.64	10.27	2.39	1.83	1.45	0.06	0.75
36	7.04	0.6000	702.86	3.94	351.65	2.46	150.13	10.19	2.38	1.87	1.45	0.07	0.76
37	6.35	0.6167	699.37	3.62	353.56	2.26	152.42	10.08	2.37	1.90	1.46	0.08	0.77
38	5.67	0.6333	695.30	3.31	355.12	2.07	154.51	9.96	2.36	1.92	1.47	0.08	0.77
39	5.16	0.6500	690.75	2.99	356.35	1.90	156.41	9.82	2.35	1.94	1.47	0.09	0.78
40	4.68	0.6667	685.85	2.74	357.27	1.76	158.15	9.68	2.34	1.96	1.47	0.09	0.79



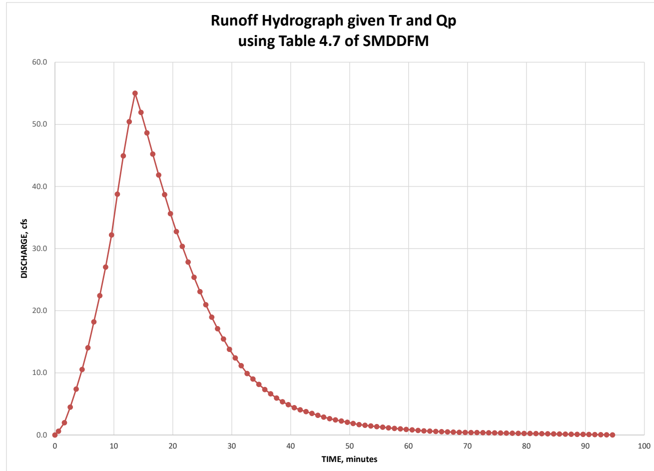




Dt =	1	min
T_r =	13.6	min
Q_p =	55	cfs

time	time	t/T_r	Q
min	hr	dim	cfs
0.0	0.000	0.000	0.00
0.6	0.010	0.044	0.61
1.6	0.027	0.118	1.98
2.6	0.043	0.191	4.48
3.6	0.060	0.265	7.38
4.6	0.077	0.338	10.55
5.6	0.093	0.412	14.03
6.6	0.110	0.485	18.20
7.6	0.127	0.559	22.43
8.6	0.143	0.632	27.03
9.6	0.160	0.706	32.20
10.6	0.177	0.779	38.76
11.6	0.193	0.853	44.93
12.6	0.210	0.926	50.43
13.6	0.227	1.000	55.00
14.6	0.243	1.074	51.93
15.6	0.260	1.147	48.62
16.6	0.277	1.221	45.21
17.6	0.293	1.294	41.85
18.6	0.310	1.368	38.68
19.6	0.327	1.441	35.61
20.6	0.343	1.515	32.74
21.6	0.360	1.588	30.36
22.6	0.377	1.662	27.83
23.6	0.393	1.735	25.38
24.6	0.410	1.809	23.07
25.6	0.427	1.882	20.96
26.6	0.443	1.956	18.95
27.6	0.460	2.029	17.10
28.6	0.477	2.103	15.44
29.6	0.493	2.176	13.79
30.6	0.510	2.250	12.40
31.6	0.527	2.324	11.15
32.6	0.543	2.397	9.90
33.6	0.560	2.471	9.01
34.6	0.577	2.544	8.14
35.6	0.593	2.618	7.32
36.6	0.610	2.691	6.63
37.6	0.627	2.765	5.94
38.6	0.643	2.838	5.36
39.6	0.660	2.912	4.87
40.6	0.677	2.985	4.39
41.6	0.693	3.059	4.06
42.6	0.710	3.132	3.76
43.6	0.727	3.206	3.47
44.6	0.743	3.279	3.18
45.6	0.760	3.353	2.88
46.6	0.777	3.426	2.63
47.6	0.793	3.500	2.43
48.6	0.810	3.574	2.24
49.6	0.827	3.647	2.05
50.6	0.843	3.721	1.86
51.6	0.860	3.794	1.67
52.6	0.877	3.868	1.56
53.6	0.893	3.941	1.46
54.6	0.910	4.015	1.35
55.6	0.927	4.088	1.25
56.6	0.943	4.162	1.15
57.6	0.960	4.235	1.06
58.6	0.977	4.309	0.98
59.6	0.993	4.382	0.90
60.6	1.010	4.456	0.82
61.6	1.027	4.529	0.74
62.6	1.043	4.603	0.66
63.6	1.060	4.676	0.62
64.6	1.077	4.750	0.58
65.6	1.093	4.824	0.54
66.6	1.110	4.897	0.50
67.6	1.127	4.971	0.46
68.6	1.143	5.044	0.43
69.6	1.160	5.118	0.41
70.6	1.177	5.191	0.40
71.6	1.193	5.265	0.38
72.6	1.210	5.338	0.37
73.6	1.227	5.412	0.35
74.6	1.243	5.485	0.33
75.6	1.260	5.559	0.32
76.6	1.277	5.632	0.30
77.6	1.293	5.706	0.29
78.6	1.310	5.779	0.27
79.6	1.327	5.853	0.25
80.6	1.343	5.926	0.24
81.6	1.360	6.000	0.22
82.6	1.377	6.074	0.21
83.6	1.393	6.147	0.19
84.6	1.410	6.221	0.17
85.6	1.427	6.294	0.16
86.6	1.443	6.368	0.14
87.6	1.460	6.441	0.13
88.6	1.477	6.515	0.11
89.6	1.493	6.588	0.09
90.6	1.510	6.662	0.08
91.6	1.527	6.735	0.06
92.6	1.543	6.809	0.05
93.6	1.560	6.882	0.03
94.6	1.577	6.956	0.02
95.6	1.593	7.029	0.01

curvilinear, dimensionless flood hydrograph	
t/T_r	Q/Q_p
dim	dim
0.0	0.000
0.1	0.025
0.2	0.087
0.3	0.160
0.4	0.243
0.5	0.346
0.6	0.451
0.7	0.576
0.8	0.738
0.9	0.887
1.0	1.000
1.1	0.924
1.2	0.839
1.3	0.756
1.4	0.678
1.5	0.604
1.6	0.545
1.7	0.482
1.8	0.424
1.9	0.372
2.0	0.323
2.2	0.241
2.4	0.179
2.6	0.136
2.8	0.102
3.0	0.078
3.4	0.049
3.8	0.030
4.2	0.020
4.6	0.012
5.0	0.008
7.0	0.000
8.0	0.000



PIMA COUNTY REGIONAL FLOOD CONTROL DISTRICT

ROUTING OF A FLOOD HYDROGRAPH THROUGH A STORMWATER DETENTION / RETENTION FACILITY

Worksheet to Input the Stage - Volume Relationship for the Facility

PIMA COUNTY FLOOD CONTROL

Rev.4/17

Example for PC-Route Manual	**Project Address**
RFCD	**Designer**
Friday, October 23, 2020	**Run Date**
PC-ROUTE_07_Example.xls	**Program File Name**

GOVERNING EQUATIONS: ***Ref: HEC-1 Flood Hydrograph Package User's Manual (USACOE September 1990)***

Conic method for reservoir volume: $\Delta V_{1\text{-}2} = 0.33 * h * (A_1 + A_2 + (A_1 * A_2)^{0.5})$ (see "**Conic Proj**" tab)

VARIABLES:

$\Delta V_{1\text{-}2}$ incremental facility storage volume between stages H_1 and H_2

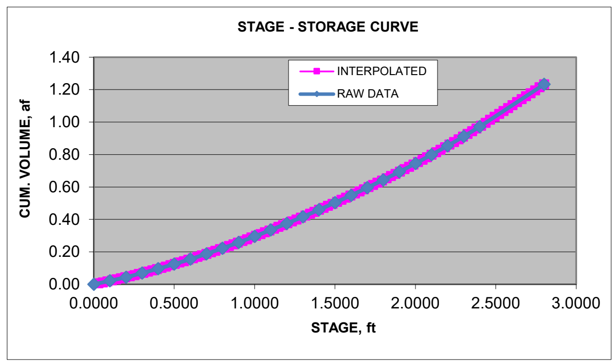
h elevation difference between A_1 and A_2

A1, A2 facility surface area at stages H_1 and H_2

2.80 = max design stage (ft)

stage H, ft	area A, ac	volume ΔV, af	for information only: area A, ft²	for information only: volume ΔV, ft³	for information only: ΣΔV S, ft³	ΣΔV S, af	index for interpolation
0.00	0.19931	0	8682	0	0	0	1
0.10	0.21885	0.021	9533	910	910	0.02090	2
0.20	0.23836	0.023	10383	996	1906	0.04375	3
0.30	0.25790	0.025	11234	1081	2986	0.06856	4
0.40	0.27741	0.027	12084	1166	4152	0.09532	5
0.50	0.29695	0.029	12935	1251	5403	0.12403	6
0.60	0.31648	0.031	13786	1336	6739	0.15470	7
0.70	0.33600	0.033	14636	1421	8160	0.18732	8
0.80	0.35553	0.035	15487	1506	9666	0.22189	9
0.90	0.36866	0.036	16059	1577	11243	0.25810	10
1.00	0.38180	0.038	16631	1634	12877	0.29562	11
1.10	0.39493	0.039	17203	1692	14569	0.33445	12
1.20	0.40806	0.040	17775	1749	16318	0.37460	13
1.30	0.42119	0.041	18347	1806	18124	0.41606	14
1.40	0.43434	0.043	18920	1863	19987	0.45884	15
1.50	0.44747	0.044	19492	1921	21907	0.50293	16
1.60	0.46061	0.045	20064	1978	23885	0.54833	17
1.70	0.47374	0.047	20636	2035	25920	0.59504	18
1.80	0.48687	0.048	21208	2092	28012	0.64307	19
1.90	0.50737	0.050	22101	2165	30178	0.69278	20
2.00	0.52787	0.052	22994	2255	32432	0.74454	21
2.10	0.54837	0.054	23887	2344	34776	0.79835	22
2.20	0.56887	0.056	24780	2433	37209	0.85421	23
2.30	0.58937	0.058	25673	2523	39732	0.91212	24
2.40	0.60989	0.060	26567	2612	42344	0.97208	25
2.80	0.69190	0.260	30139	11334	53677	1.23226	26

Note: Develop stage-storage curve on this worksheet by either entering in the blue shaded column the planimetered basin areas (in acres) at various stages or by entering facility stages and corresponding incremental volumes (acre-feet, purple shaded column). Graph of the stage-storage curve shown to verify proper interpolation (purple points) of facility volume by **Vol Outflow** tab. **You may insert rows into the middle of this table** to accomodate the size of your data set; empty rows below the extent of your data will not cause a problem. **Stage - Volume data must begin at stage = 0 ft with a volume of 0 af. Stage - Volume data must be entered in ascending order. Blue cells below the entered data must remain empty (highlight, right-click, clear contents). All blue cells must eigther be blank or must contain a number.**



PIMA COUNTY REGIONAL FLOOD CONTROL DISTRICT

ROUTING OF A FLOOD HYDROGRAPH THROUGH A STORMWATER DETENTION / RETENTION FACILITY

Worksheet to Develop the Stage - Discharge Characteristics of the Outlet Works for the Facility

PIMA COUNTY FLOOD CONTROL

Rev. 3/18

Example for PC-Route Manual	**Project Address**
RFCD	**Designer**
Friday, October 23, 2020	**Run Date**
PC-ROUTE_07_Example.xls	**Program File Name**

Note: Populate characteristics of selected outflow elements corresponding to facility outlet configuration (blue cells), or overwrite purple cells with outflows calculated outside this worksheet, as a function of the given facility stages. Storage (last column) at each stage is interpolated from stage-volume relationship (see "**Stage Vol**" tab). **Do not add rows** to this worksheet; it automatically divides maximum facility design stage into 100 increments to develop the volume-outflow curve.

GOVERNING EQUATIONS:

Orifice equation: $Q_0 = C * A * (2 * g * H)^{0.5}$ and see weir flow equation on "**Orifice**" tab

Rectangular Weir Equation: $Q_w = C * L * H^{1.5}$

Triangular Weir Equation: $Q_w = C_1 * Tan(\Theta/2) * H^{2.5}$

Box Culvert Equation: See Box Culvert equations for Inlet Control on **"RCBC"** tab

ORIFICE PLATE OUTFLOW ELEMENT

d_o (in) =		diameter	area (ft^2) =	0.000
C =		disch coefficient		
E_o (ft) =		stage @ orifice center	inv (in) =	0.00
N =		nbr identical openings	inv (ft) =	0.000

TRIANGULAR WEIR OUTFLOW ELEMENT

Z =	0.839	side slope
E_w (ft) =	0.50	stage at crest
C_1 =	2.50	disch coefficient
Θ (deg) =	80.0	notch angle

RECTANGULAR WEIR OUTFLOW ELEMENT(S)

	rect 1	rect 2	rect 3	
L (ft) =				crest length
C =				disch coefficient
E_w (ft) =				stage at crest

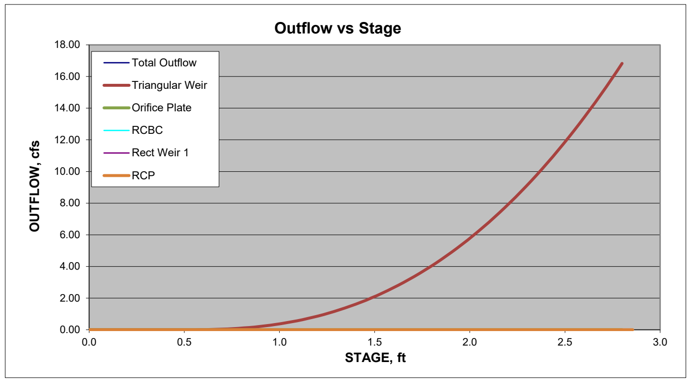
BOX or ROUND CULVERT OUTFLOW ELEMENT

	circ pipe	RCBC	
D (ft) =			barrel rise, dia
B (ft) =			barrel span
E_b (ft) =			barrel invert
n (dim) =			Manning's coef
S (ft/ft) =			barrel slope
L (ft) =			barrel length
K_e (dim)=			ent loss coef
TW (ft) =			tailwater depth

ROUTING RESULTS FOR DESIGN OF OUTLET WORKS

Max Design Stage = 2.80 ft

	Max Inflow		Max Outflow		Max Stage					target discharges	
100-Yr	55.0	cfs	10.4	cfs	2.40	ft	@	32	min	27.0	cfs
10-Yr	22.0	cfs	2.0	cfs	1.48	ft	@	44	min	10.8	cfs
2 -yr	8.2	cfs	0.2	cfs	0.85	ft	@	75	min	4.1	cfs



Stage	Orifice Plate	Weir Element(s)				RCP	RCBC	Outflow	S vol
		Triang 1	Rect 1	Rect 2	Rect 3				
H, ft	Q, cfs	Q, cfs	Q, cfs	Q, cfs	Q, cfs	Q, cfs	Q, cfs	O, cfs	S, af
0.0000								0.00	0.00000
0.0280								0.00	0.00585
0.0560								0.00	0.01170
0.0840								0.00	0.01756
0.1120								0.00	0.02364
0.1400								0.00	0.03004
0.1680								0.00	0.03644
0.1960								0.00	0.04284
0.2240								0.00	0.04971
0.2520								0.00	0.05665
0.2800								0.00	0.06360
0.3080								0.00	0.07070
0.3360								0.00	0.07819
0.3640								0.00	0.08569
0.3920								0.00	0.09318
0.4200								0.00	0.10106
0.4480								0.00	0.10910
0.4760								0.00	0.11714
0.5040		0.00						0.00	0.12526
0.5320		0.00						0.00	0.13385
0.5600		0.00						0.00	0.14243
0.5880		0.00						0.00	0.15102
0.6160		0.01						0.01	0.15992
0.6440		0.02						0.02	0.16905
0.6720		0.03						0.03	0.17818
0.7000		0.04						0.04	0.18732
0.7280		0.05						0.05	0.19700
0.7560		0.07						0.07	0.20668
0.7840		0.09						0.09	0.21636
0.8120		0.11						0.11	0.22623
0.8400		0.14						0.14	0.23637
0.8680		0.17						0.17	0.24651
0.8960		0.21						0.21	0.25665
0.9240		0.25						0.25	0.26710
0.9520		0.29						0.29	0.27761
0.9800		0.33						0.33	0.28811
1.0080		0.39						0.39	0.29873
1.0360		0.44						0.44	0.30960
1.0640		0.50						0.50	0.32047
1.0920		0.57						0.57	0.33135
1.1200		0.63						0.63	0.34248
1.1480		0.71						0.71	0.35372
1.1760		0.79						0.79	0.36497
1.2040		0.87						0.87	0.37626
1.2320		0.96						0.96	0.38787
1.2600		1.06						1.06	0.39948
1.2880		1.16						1.16	0.41109
1.3160		1.26						1.26	0.42291
1.3440		1.37						1.37	0.43488
1.3720		1.49						1.49	0.44686

PIMA COUNTY REGIONAL FLOOD CONTROL DISTRICT

ROUTING OF A FLOOD HYDROGRAPH THROUGH A STORMWATER DETENTION / RETENTION FACILITY

THIS TAB CONTAINS NO INPUT DATA

Worksheet to Develop the Storage - Outflow Working Curve to be Used in the Modified Puls Method

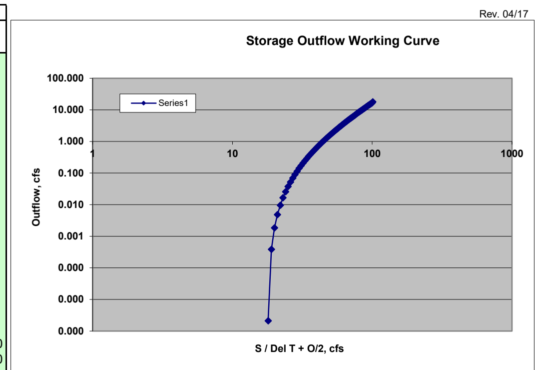
PIMA COUNTY FLOOD CONTROL

Example for PC-Route Manual	Project Address
RFCD	Designer
Friday, October 23, 2020	Run Date
PC-ROUTE_07_Example.xls	Program File Name

GOVERNING EQUATION:

Storage - Outflow Working Curve: Function = S/Δt + O/2

Rev. 04/17



Stage ft	Outflow Q, cfs	S vol S, af	S vol S, cfs-hr	S/Dt cfs	O/2 cfs	Function cfs	Outflow O, cfs	index for interpolation	Fcn cfs (for plotting)	Outflow O, cfs (for plotting)
RESULTS FROM VOLUME-OUTFLOW TAB										
0.00	0.0	0.0000	0.00	0.0	0.0	0.000	0.0	1		
0.03	0.0	0.0059	0.07	4.2	0.0	4.249	0.0	2		
0.06	0.0	0.0117	0.14	8.5	0.0	8.497	0.0	3		
0.08	0.0	0.0176	0.21	12.7	0.0	12.746	0.0	4		
0.11	0.0	0.0236	0.29	17.2	0.0	17.165	0.0	5		
0.14	0.0	0.0300	0.36	21.8	0.0	21.810	0.0	6		
0.17	0.0	0.0364	0.44	26.5	0.0	26.456	0.0	7		
0.20	0.0	0.0428	0.52	31.1	0.0	31.102	0.0	8		
0.22	0.0	0.0497	0.60	36.1	0.0	36.088	0.0	9		
0.25	0.0	0.0567	0.69	41.1	0.0	41.130	0.0	10		
0.28	0.0	0.0636	0.77	46.2	0.0	46.173	0.0	11		
0.31	0.0	0.0707	0.86	51.3	0.0	51.329	0.0	12		
0.34	0.0	0.0782	0.95	56.8	0.0	56.769	0.0	13		
0.36	0.0	0.0857	1.04	62.2	0.0	62.209	0.0	14		
0.39	0.0	0.0932	1.13	67.6	0.0	67.648	0.0	15		
0.42	0.0	0.1011	1.22	73.4	0.0	73.371	0.0	16		
0.45	0.0	0.1091	1.32	79.2	0.0	79.208	0.0	17		
0.48	0.0	0.1171	1.42	85.0	0.0	85.045	0.0	18		
0.50	0.0	0.1253	1.52	90.9	0.0	90.938	0.0	19	90.94	0.00
0.53	0.0	0.1338	1.62	97.2	0.0	97.172	0.0	20	97.17	0.00
0.56	0.0	0.1424	1.72	103.4	0.0	103.407	0.0	21	103.41	0.00
0.59	0.0	0.1510	1.83	109.6	0.0	109.642	0.0	22	109.64	0.00
0.62	0.0	0.1599	1.94	116.1	0.0	116.105	0.0	23	116.11	0.01
0.64	0.0	0.1691	2.05	122.7	0.0	122.739	0.0	24	122.74	0.02
0.67	0.0	0.1782	2.16	129.4	0.0	129.375	0.0	25	129.37	0.03
0.70	0.0	0.1873	2.27	136.0	0.0	136.012	0.0	26	136.01	0.04
0.73	0.1	0.1970	2.38	143.0	0.0	143.047	0.1	27	143.05	0.05
0.76	0.1	0.2067	2.50	150.0	0.0	150.083	0.1	28	150.08	0.07
0.78	0.1	0.2164	2.62	157.1	0.0	157.121	0.1	29	157.12	0.09
0.81	0.1	0.2262	2.74	164.2	0.1	164.304	0.1	30	164.30	0.11
0.84	0.1	0.2364	2.86	171.6	0.1	171.677	0.1	31	171.68	0.14
0.87	0.2	0.2465	2.98	179.0	0.1	179.053	0.2	32	179.05	0.17
0.90	0.2	0.2566	3.11	186.3	0.1	186.431	0.2	33	186.43	0.21
0.92	0.2	0.2671	3.23	193.9	0.1	194.039	0.2	34	194.04	0.25
0.95	0.3	0.2776	3.36	201.5	0.1	201.688	0.3	35	201.69	0.29
0.98	0.3	0.2881	3.49	209.2	0.2	209.338	0.3	36	209.34	0.33
1.01	0.4	0.2987	3.61	216.9	0.2	217.067	0.4	37	217.07	0.39
1.04	0.4	0.3096	3.75	224.8	0.2	224.989	0.4	38	224.99	0.44
1.06	0.5	0.3205	3.88	232.7	0.3	232.914	0.5	39	232.91	0.50
1.09	0.6	0.3313	4.01	240.6	0.3	240.840	0.6	40	240.84	0.57
1.12	0.6	0.3425	4.14	248.6	0.3	248.960	0.6	41	248.96	0.63
1.15	0.7	0.3537	4.28	256.8	0.4	257.158	0.7	42	257.16	0.71
1.18	0.8	0.3650	4.42	265.0	0.4	265.359	0.8	43	265.36	0.79
1.20	0.9	0.3763	4.55	273.2	0.4	273.600	0.9	44	273.60	0.87
1.23	1.0	0.3879	4.69	281.6	0.5	282.073	1.0	45	282.07	0.96
1.26	1.1	0.3995	4.83	290.0	0.5	290.549	1.1	46	290.55	1.06
1.29	1.2	0.4111	4.97	298.4	0.6	299.027	1.2	47	299.03	1.16
1.32	1.3	0.4229	5.12	307.0	0.6	307.660	1.3	48	307.66	1.26
1.34	1.4	0.4349	5.26	315.7	0.7	316.411	1.4	49	316.41	1.37
1.37	1.5	0.4469	5.41	324.4	0.7	325.165	1.5	50	325.16	1.49
1.40	1.6	0.4588	5.55	333.1	0.8	333.921	1.6	51	333.92	1.61
1.43	1.7	0.4712	5.70	342.1	0.9	342.948	1.7	52	342.95	1.74
1.46	1.9	0.4835	5.85	351.0	0.9	351.977	1.9	53	351.98	1.87
1.48	2.0	0.4959	6.00	360.0	1.0	361.010	2.0	54	361.01	2.01
1.51	2.2	0.5084	6.15	369.1	1.1	370.160	2.2	55	370.16	2.16
1.54	2.3	0.5211	6.31	378.3	1.2	379.466	2.3	56	379.47	2.31
1.57	2.5	0.5338	6.46	387.5	1.2	388.775	2.5	57	388.77	2.47
1.60	2.6	0.5465	6.61	396.8	1.3	398.087	2.6	58	398.09	2.64
1.62	2.8	0.5595	6.77	406.2	1.4	407.631	2.8	59	407.63	2.81
1.65	3.0	0.5726	6.93	415.7	1.5	417.216	3.0	60	417.22	2.99
1.68	3.2	0.5857	7.09	425.2	1.6	426.805	3.2	61	426.81	3.17
1.71	3.4	0.5989	7.25	434.8	1.7	436.474	3.4	62	436.47	3.36
1.74	3.6	0.6123	7.41	444.6	1.8	446.336	3.6	63	446.34	3.56
1.76	3.8	0.6258	7.57	454.3	1.9	456.202	3.8	64	456.20	3.77
1.79	4.0	0.6392	7.73	464.1	2.0	466.071	4.0	65	466.07	3.98
1.82	4.2	0.6530	7.90	474.1	2.1	476.188	4.2	66	476.19	4.20
1.85	4.4	0.6669	8.07	484.2	2.2	486.406	4.4	67	486.41	4.43
1.88	4.7	0.6809	8.24	494.3	2.3	496.627	4.7	68	496.63	4.66
1.90	4.9	0.6949	8.41	504.5	2.4	506.912	4.9	69	506.91	4.90
1.93	5.1	0.7093	8.58	515.0	2.6	517.557	5.1	70	517.56	5.15
1.96	5.4	0.7238	8.76	525.5	2.7	528.207	5.4	71	528.21	5.40
1.99	5.7	0.7383	8.93	536.0	2.8	538.859	5.7	72	538.86	5.67
2.02	5.9	0.7531	9.11	546.8	3.0	549.754	5.9	73	549.75	5.94
2.04	6.2	0.7682	9.30	557.7	3.1	560.831	6.2	74	560.83	6.21
2.07	6.5	0.7833	9.48	568.7	3.2	571.912	6.5	75	571.91	6.50
2.10	6.8	0.7983	9.66	579.6	3.4	582.997	6.8	76	583.00	6.79
2.13	7.1	0.8140	9.85	591.0	3.5	594.503	7.1	77	594.50	7.09
2.16	7.4	0.8296	10.04	602.3	3.7	606.012	7.4	78	606.01	7.40
2.18	7.7	0.8453	10.23	613.7	3.9	617.526	7.7	79	617.53	7.72
2.21	8.0	0.8612	10.42	625.2	4.0	629.222	8.0	80	629.22	8.04
2.24	8.4	0.8774	10.62	637.0	4.2	641.160	8.4	81	641.16	8.38
2.27	8.7	0.8936	10.81	648.7	4.4	653.102	8.7	82	653.10	8.72
2.30	9.1	0.9098	11.01	660.5	4.5	665.049	9.1	83	665.05	9.07
2.32	9.4	0.9265	11.21	672.6	4.7	677.356	9.4	84	677.36	9.42
2.35	9.8	0.9433	11.41	684.8	4.9	689.728	9.8	85	689.73	9.79
2.38	10.2	0.9601	11.62	697.0	5.1	702.104	10.2	86	702.10	10.16
2.41	10.5	0.9773	11.83	709.5	5.3	714.779	10.5	87	714.78	10.55
2.44	10.9	0.9955	12.05	722.7	5.5	728.198	10.9	88	728.20	10.94
2.46	11.3	1.0137	12.27	736.0	5.7	741.620	11.3	89	741.62	11.34
2.49	11.7	1.0319	12.49	749.2	5.9	755.047	11.7	90	755.05	11.75
2.52	12.2	1.0501	12.71	762.4	6.1	768.478	12.2	91	768.48	12.16
2.55	12.6	1.0683	12.93	775.6	6.3	781.914	12.6	92	781.91	12.59
2.58	13.0	1.0866	13.15	788.8	6.5	795.354	13.0	93	795.35	13.02
2.60	13.5	1.1048	13.37	802.1	6.7	808.798	13.5	94	808.80	13.47
2.63	13.9	1.1230	13.59	815.3	7.0	822.247	13.9	95	822.25	13.92
2.66	14.4	1.1412	13.81	828.5	7.2	835.701	14.4	96	835.70	14.38
2.69	14.9	1.1594	14.03	841.7	7.4	849.159	14.9	97	849.16	14.85
2.72	15.3	1.1776	14.25	855.0	7.7	862.621	15.3	98	862.62	15.33
2.74	15.8	1.1958	14.47	868.2	7.9	876.088	15.8	99	876.09	15.82
2.77	16.3	1.2140	14.69	881.4	8.2	889.560	16.3	100	889.56	16.32
2.80	16.8	1.2323	14.91	894.6	8.4	903.036	16.8	101	903.04	16.83
Intermediate Calculations:									930.00	17.87

PIMA COUNTY REGIONAL FLOOD CONTROL DISTRICT

ROUTING OF A FLOOD HYDROGRAPH THROUGH A STORMWATER DETENTION / RETENTION FACILITY

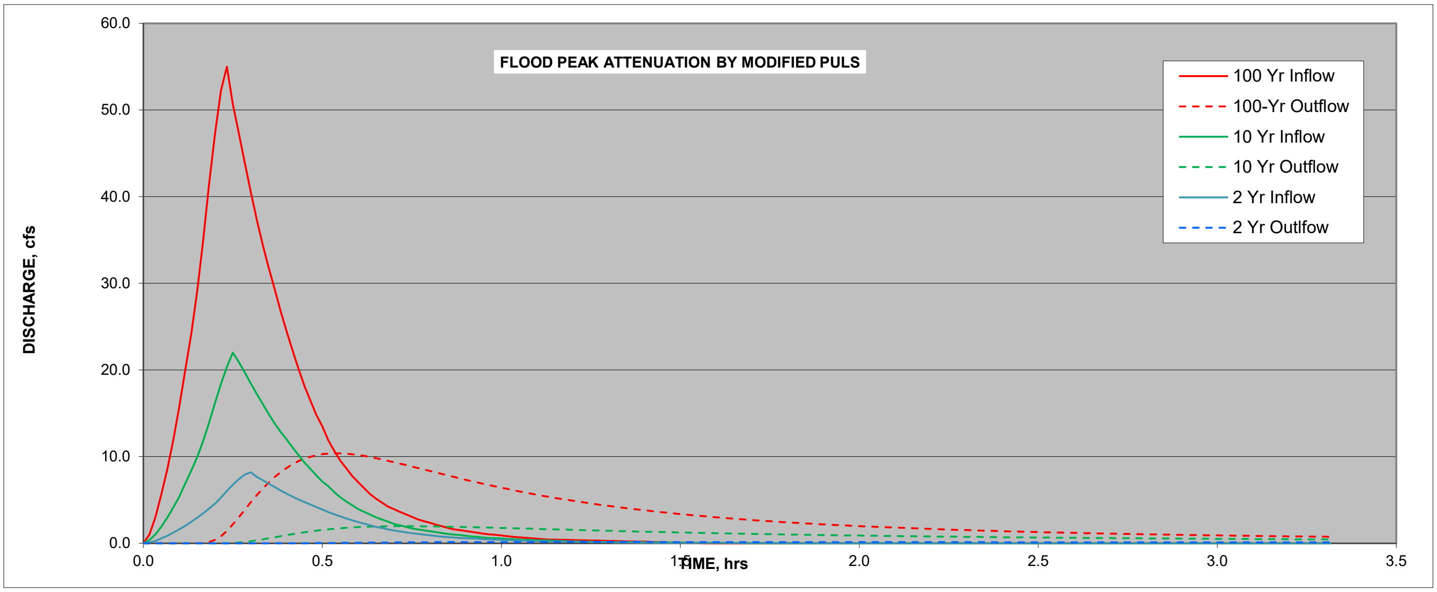
THIS TAB CONTAINS NO INPUT DATA

Summary of Reservoir Routing of the Inflow Hydrograph using the Specified Detention Facility and Outlet Works

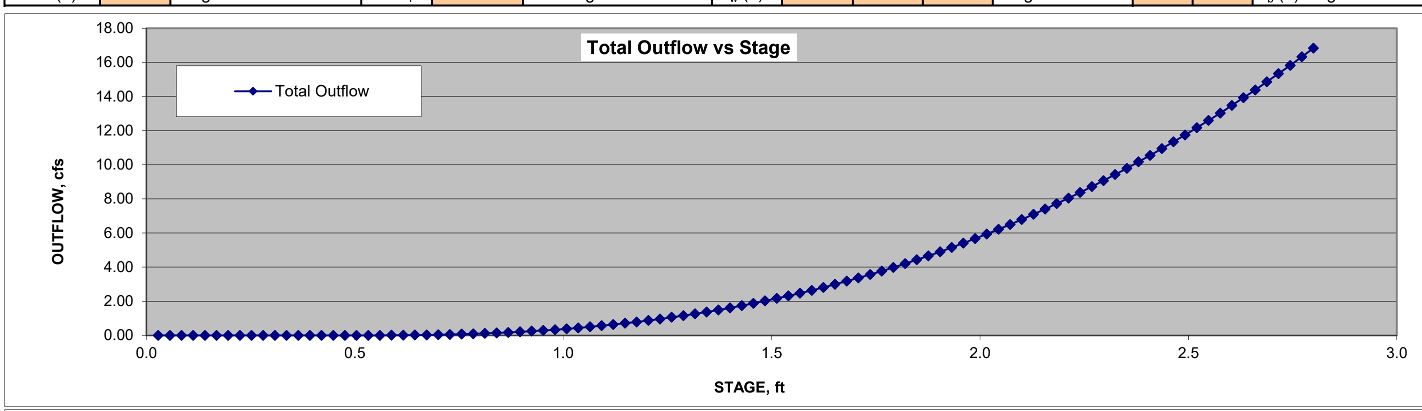
PIMA COUNTY FLOOD CONTROL

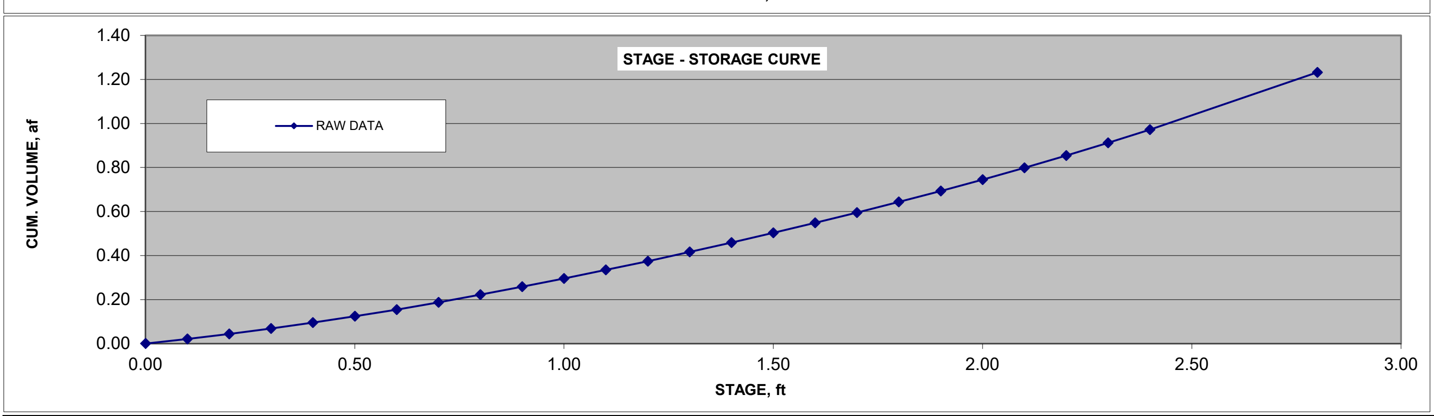
Example for PC-Route Manual	**Project Address**
RFCD	**Designer**
Friday, October 23, 2020	**Run Date**
PC-ROUTE_07_Example.xls	**Program File Name**

Rev.04/17



ORIFICE PLATE			TRIANGULAR WEIR			RECTANGULAR WEIR(S)					RCP / RCBC		
							rect 1	rect 2	rect 3		RCP	RCBC	
d_o (in) =	0.0	diameter	Z =	0.8	side slope	L (ft) =	0.0	0.0	0.0	crest length	0.0	0.0	D (ft) rise / diameter
C (dim) =	0.0	discharge coefficient	E_w (ft) =	0.50	stage at weir crest	C =	0.0	0.0	0.0	discharge coef		0.0	B (ft) span
N =	0.0	nbr identical openings	Θ =	80.0	8 notch angle	E_w (ft) =	0.00	0.00	0.00	stage at crest	0.00	0.00	E_b (ft) stage at invert
inv (ft) =	0.00	stage at invert	C_1 =	2.5	discharge coefficient								





RESULTS:

	max inflow		max outflow		target discharge		total inflow volume				max stage (H) *			
100-Year	55.0	cfs	10.4	cfs	27	cfs	57150	ft^3	1.312	af	2.40	ft at	32	min
10-Year	22.0	cfs	2.0	cfs	10.8	cfs	25190	ft^3	0.578	af	1.48	ft at	44	min
2-Year	8.2	cfs	0.2	cfs	4.1	cfs	10958	ft^3	0.252	af	0.85	ft at	75	min

* Max Design Stage (ft) = 2.80

NOTE: IF H > MAX DESIGN STAGE, EXTEND STAGE-VOL DATA TO A HIGHER STAGE

Worksheet to Illustrate the Various Characteristics of the Available Outflow Elements

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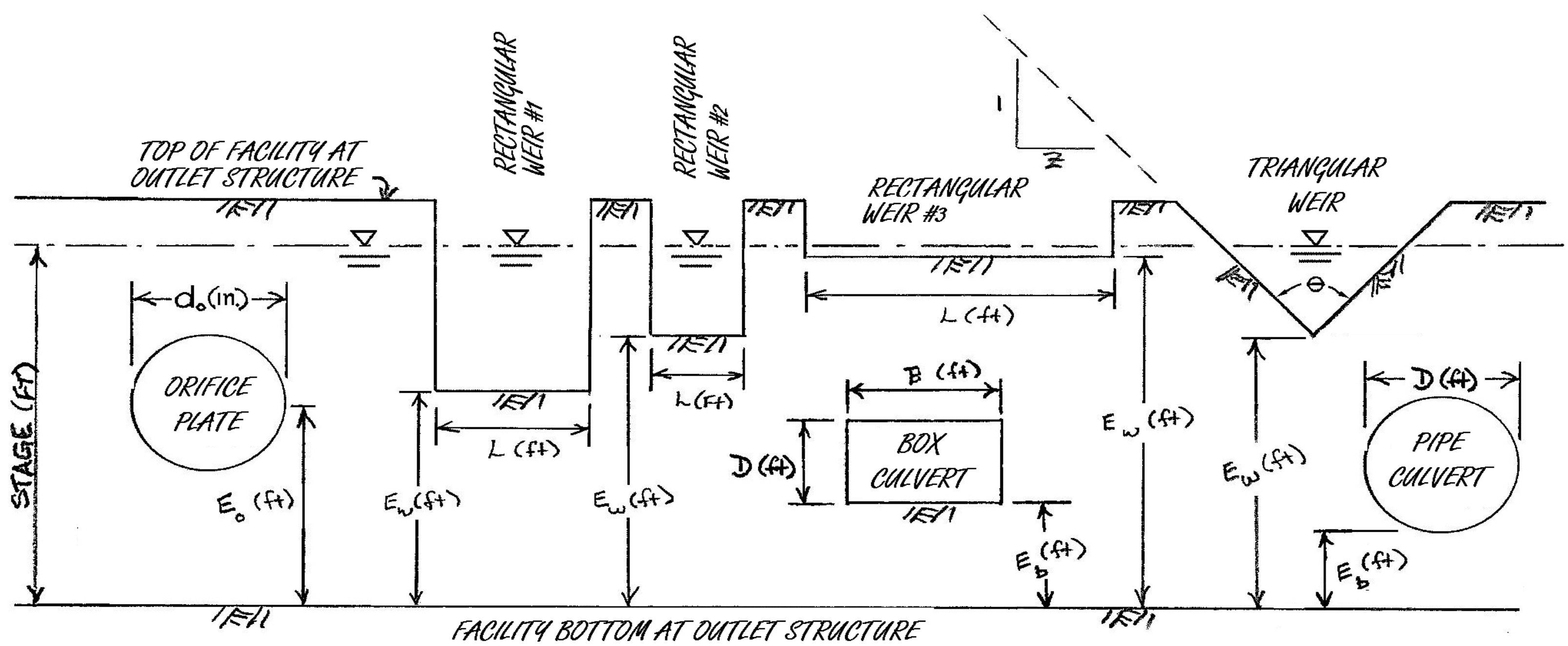

Worksheet to Illustrate the Conic Method of Calculating Detention Facility Volume from Stage - Area Data

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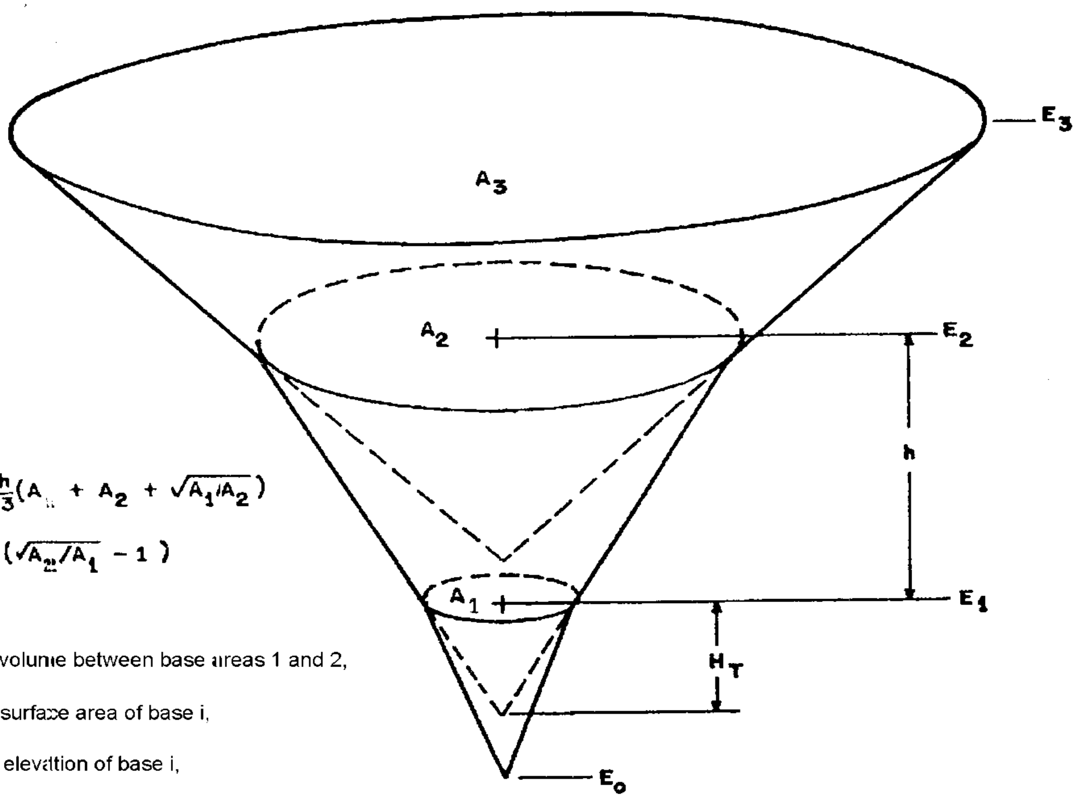


$$\Delta V_{12} = \frac{h}{3}\left(A_1 + A_2 + \sqrt{A_1 A_2}\right)$$

$$H_T = h / \left(\sqrt{A_2 / A_1} - 1\right)$$

Where

ΔV_{12} = volume between base areas 1 and 2,

A_i = surface area of base i,

E_i = elevation of base i,

h = vertical distance (E_2 - E_1) between bases A_1 and A_2, and

H_T = height of truncated part of cone.

Figure 3.11 Conic Method for Reservoir Volumes

U.S. Army Corps of Engineers, 1990, "HEC-1 Flood Hydrograph Package, User's Manual", The Hydrologic Engineering Center, Davis, California

PIMA COUNTY REGIONAL FLOOD CONTROL DISTRICT

ROUTING OF A FLOOD HYDROGRAPH THROUGH A STORMWATER DETENTION / RETENTION FACILITY

Worksheet to Develop Stage - Volume Data for Rectangular or Circular Detention Facility

PIMA COUNTY FLOOD CONTROL

Rev. 04/17

GOVERNING EQUATIONS:

Area of L x W rectangular detention facility with side slope Z at depth Y:	$(L * W) + (2 * Z * Y *(L + W)) + (4 * Z^2 * Y^2)$
Volume of L x W rectangular detention facility with side slope Z at depth Y:	$(L * W * Y) + (Z * (L + W) * Y^2) + 1.33 * Z^2 * Y^3$
Area of truncated cone detention facility with bottom dia D & side slope Z at depth Y:	$0.25 * p * (D + 2 * Z * Y)^2$
Volume of truncated cone detention facility with bottom dia D & side slope Z at depth Y:	$p * (0.25 * D^2 * Y + 0.5 * Z * D * Y^2 + 0.33 * Z^2 * Y^3)$

Note: This worksheet may be used to develop the stage - area - Δ volume curves for either a rectangular or circular detention facility. Enter the dimensions of the detention facility in the blue shaded areas, and adjust Δ Y to produce 25 lines of data. Then copy the yellow shaded data, and paste it in the blue shaded area of the **Stage Vol** tab using Paste Special - Values.

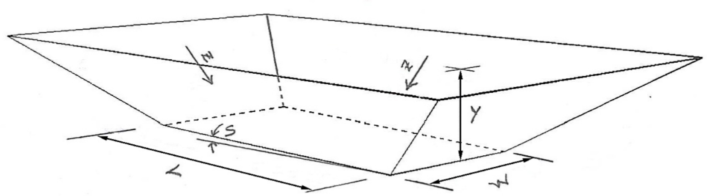
Rectangular Facility / Circular Facility

Rectangular				Circular		
			diameter of bottom of detention facility	D =	350.0	ft
L =	160.0	ft	length of bottom of detention facility			
W =	200.0	ft	width of bottom of detention facility			
Z =	1.0	ft/ft	side slope (H:V) of detention facility walls	Z =	4.0	ft/ft
Y =	3.0	ft	maximum depth of detention facility	Y =	6.0	ft
ΔY =	0.12	ft	depth increment for calculating area / volume characteristics	ΔY =	0.25	ft
S =	0.01	ft/ft	bottom slope along L for positive drainage			
	1.6	ft	rise in bottom due to bottom slope			
	25		number of lines of data in table		24	

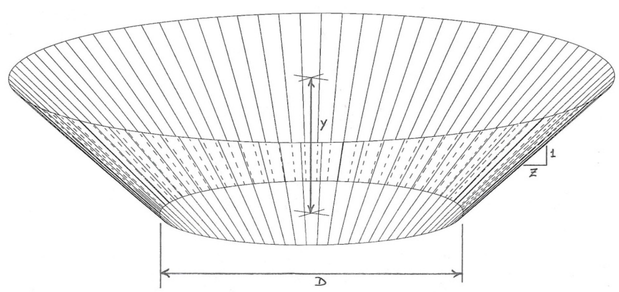
Rectangular Facility

stage H, ft	area A, ac	volume DV, af
0.00	0.00000	0.000000
0.12	0.05571	0.003343
0.24	0.11156	0.010037
0.36	0.16754	0.016746
0.48	0.22366	0.023472
0.60	0.27991	0.030214
0.72	0.33629	0.036972
0.84	0.39280	0.043746
0.96	0.44945	0.050535
1.08	0.50624	0.057341
1.20	0.56315	0.064163
1.32	0.62020	0.071001
1.44	0.67738	0.077855
1.56	0.73470	0.084725
1.68	0.76265	0.091396
1.80	0.76467	0.091639
1.92	0.76669	0.091882
2.04	0.76872	0.092125
2.16	0.77075	0.092368
2.28	0.77278	0.092612
2.40	0.77482	0.092856
2.52	0.77685	0.093100
2.64	0.77890	0.093345
2.76	0.78094	0.093590
2.88	0.78298	0.093835
3.00	0.78503	0.094081

Total Volume = 1.7 af



RECTANGULAR FACILITY



CIRCULAR FACILITY

Circular Facility

stage H, ft	area A, ac	volume DV, af
0.00	2.209	0.000
0.25	2.234	0.555
0.50	2.259	0.562
0.75	2.285	0.568
1.00	2.311	0.574
1.25	2.337	0.581
1.50	2.363	0.587
1.75	2.389	0.594
2.00	2.415	0.601
2.25	2.442	0.607
2.50	2.468	0.614
2.75	2.495	0.620
3.00	2.522	0.627
3.25	2.549	0.634
3.50	2.576	0.641
3.75	2.604	0.647
4.00	2.631	0.654
4.25	2.659	0.661
4.50	2.686	0.668
4.75	2.714	0.675
5.00	2.742	0.682
5.25	2.771	0.689
5.50	2.799	0.696
5.75	2.827	0.703
6.00	2.856	0.710

Total Volume = 15.2 af

PIMA COUNTY REGIONAL FLOOD CONTROL DISTRICT
ROUTING OF A FLOOD HYDROGRAPH THROUGH A STORMWATER DETENTION / RETENTION FACILITY

PIMA COUNTY FLOOD CONTROL

Worksheet to Develop the Outflow Characteristics of a RCB Culvert under Inlet Control

GOVERNING EQUATIONS:

Unsubmerged, form 1: $HW = H_c + D * K * (Q / (A * D^{0.5}))^M - 0.5 * D * S$

Submerged: $Q = A_o * D^{0.5} * ((HW / D - Y + 0.5 * S) / c)^{0.5}$

	K	M	c	Y	scale
308 to 758 wingwall flare:	0.026	1.00	0.0385	0.81	1
908 & 158 wingwall flare:	0.061	0.75	0.0400	0.80	2
08 wingwall flare:	0.061	0.75	0.0423	0.82	3

Note: This worksheet presents calculations necessary to rate flow through a reinforced concrete box culvert when it is flowing under inlet control. **This data is automatically provided to the "Vol Outflow" tab when a box culvert is selected as one of the outlfow elements**

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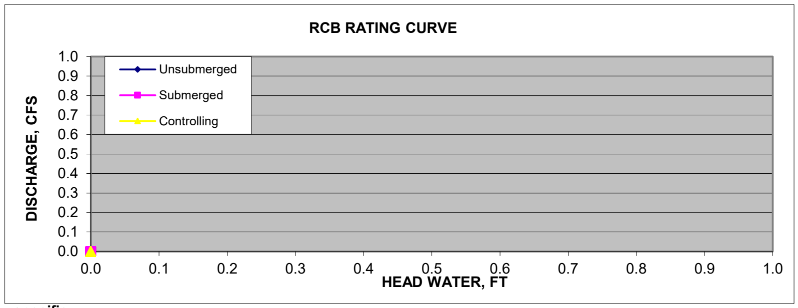
D =	0.0	ft	box rise (nom)
B =	0.0	ft	box span (nom)
K =	0.026	dim	inlet control coefs,
M =	1	dim	p. 147 HDS5 for
c =	0.0385	dim	RCBC chart 8
Y =	0.81	dim	(see table above)
S =	0.02	ft/ft	barrel slope
A_o =	0.00	ft²	barrel area



critical depth box culvert Y_c, ft	Flow Area ft²	critical discharge ft³/s	critical velocity ft/s	critical velocity head ft	specific head H_c, ft	$Q_c/(Ad_o^{0.5})$	$d_oK(Q_c/(Ad_o)^{0.5})^M$	HW ft	submerged Q, ft³/s	weir Q, ft³/s	combined Q, ft³/s	index for interpolation
0.000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	1
0.000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	2
0.000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	3
0.000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	4
0.000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	5
0.000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	6
0.000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	7
0.000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	8
0.000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	9
0.000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	10
0.000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	11
0.000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	12
0.000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	13
0.000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	14
0.000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	15
0.000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	16
0.000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	17
0.000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	18
0.000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	19
0.000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	20
0.000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	21
0.000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	22
0.000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	23
0.000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	24
0.000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	25
0.000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	26
0.000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	27
0.000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	28
0.000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	29
0.000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	30
0.000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	31
0.000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	32
0.000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	33
0.000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	34
0.000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	35
0.000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	36
0.000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	37
0.000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	38
0.000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	39
0.000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	40
0.000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	41
0.000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	42
0.000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	43
0.000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	44
0.000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	45
0.000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	46
0.000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	47
0.000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	48
0.000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	49
0.000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	50
0.000	0.0000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	51

PIMA COUNTY REGIONAL FLOOD CONTROL DISTRICT

ROUTING OF A FLOOD HYDROGRAPH THROUGH A STORMWATER DETENTION / RETENTION FACILITY

Worksheet to Develop the Outflow Characteristics of an Orifice Plate under both Submerged and Unsubmerged Conditions

PIMA COUNTY
FLOOD CONTROL

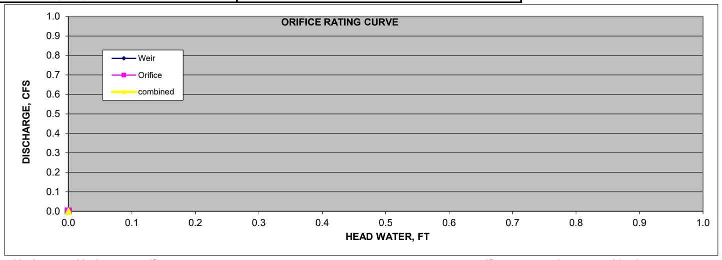
GOVERNING EQUATIONS:

Partial Full Circular Section Flow Area (Chow p. 21) :	$(\Theta - SIN\ \Theta) * d_o^2 / 8$ Θ is in radians
Partial Full Circular Section Wetted Perimeter (Chow p. 21) :	$0.5 * \Theta * d_0$
Partial Full Circular Section Top Width (Chow p. 21) :	$SIN(\Theta / 2) * d_o$
Critical Discharge for Circular Section (Chow Equ 4-21) :	$Q_c = 0.251 * (\Theta - \sin \Theta)^{1.5} * d_0^{2.5} / (\sin\ \Theta / 2)^{0.5}$
Inlet Control Equation, Unsubmerged (Form 1, Equ 26 FHWA HDS-5) :	$HW = H_c + K * d_o * ((Q/ (Ao * do^{0.5}))^M$
were :	$H_c = Y_c + V_c^2 / (2 * G)$, and $Q / A_o * d_o^{0.5} <= 3.5$

Note: This worksheet presents calculations necessary to rate flow through an orifice when there is a possibility of the orifice being unsubmerged for some of the discharge rating points. In other words, when the orifice is unsubmerged, the flow is determined as if the orifice was a circular weir. **This data is automatically provided to the "Vol Outflow" Tab when an Orifice Plate is selected as one of the outlfow elements.**

Rev. 04/17

d_o =	0.00	ft	orifice diameter
K =	0.0078	dim	inlet control coefficients,
M =	2	dim	unsubmerged from P 147, HDS 5
C =	0	dim	orifice discharge coefficient
E_o =	0	ft	orifice center height above facility bottom
Inv =	0.00	ft	invert height above facility bottom
A_o =	0.00	ft^2	orifice area
P_o =	0.0000	ft	orifice perimeter



critical depth circ sec Y_c, ft	Θ rad	Flow Area ft^2	wet perim ft	hydr rad ft	top wid ft	critical discharge ft^3/s	critical velocity ft/s	critical vel head ft	specific head H_c, ft	$Q_c/(A_od_o^{0.5})$	$d_oK(Q_c/(A_od_o)^{0.5})^M$	HW ft	stage (H) ft	orifice discharge ft^3/s	weir discharge ft^3/s	combined discharge ft^3/s	index for interpolation
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	1
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	2
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	3
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	4
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	5
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	6
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	7
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	8
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	9
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	10
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	11
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	12
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	13
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	14
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	15
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	16
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	17
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	18
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	19
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	20
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	21
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	22
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	23
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	24
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	25
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	26
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	27
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	28
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	29
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	30
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	31
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	32
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	33
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	34
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	35
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	36
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	37
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	38
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	39
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	40
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	41
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	42
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	43
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	44
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	45
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	46
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	47
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	48
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	49
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	50
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	51
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	52
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	53
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	54
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	55
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	56
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	57
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	58
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	59
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	60
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	61
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	62
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	63
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	64
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	65
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	66
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	67
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	68
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	69
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	70
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	71
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	72
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	73
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	74
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	75
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	76
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	77
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	78
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	79
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	80
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	81
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	82
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	83
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	84
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	85
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	86
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	87
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	88
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	89
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	90
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	91
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	92
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	93
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.00	0.0000	0.0000	0.0000	94

PIMA COUNTY REGIONAL FLOOD CONTROL DISTRICT

ROUTING OF A FLOOD HYDROGRAPH THROUGH A STORMWATER DETENTION / RETENTION FACILITY

Worksheet to Develop the Outflow Characteristics of a circular pipe under Inlet and outlet Control

GOVERNING EQUATIONS:

Partial Full Circular Section Flow Area (Chow p. 21) :	$(\Theta - SIN\ \Theta) * d_o^2 / 8$ — Θ is in radians
Partial Full Circular Section Wetted Perimeter (Chow p. 21) :	$0.5 * \Theta * d_0$
Partial Full Circular Section Top Width (Chow p. 21) :	$SIN(\Theta / 2) * d_o$
Critical Discharge for Circular Section (Chow Equ 4-21) :	$Q_c = 0.251 * (\Theta - \sin\Theta)^{1.5} * d_0^{2.5} / (\sin\ \Theta / 2)^{0.5}$
Inlet Control, Unsubmerged (Form 1, Equ 26 FHWA HDS-5) :	$HW = H_c + K * d_o * ((Q/(A_o * d_o^{0.5}))^M - 0.5 * d_o * S$
Outlet Control, available head (Equ 3, USBPR HEC 5, 4/64):	$H = HW + L * S - h$, where $h = MAX(TW, (Y_c + d_o)/2)$
Discharge from available head (Manning's & Energy Balance):	$Q = \pi * d_o^2 / 4 * (2 * g * H / (1 + K_e + 29 * n^2 * L / (d_o/4)^{1.33})^{0.5}$

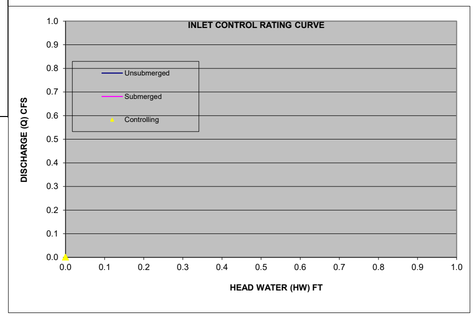
Submerged: $Q = A_o * d_o^{0.5} * ((HW / d_o - Y + 0.5 * S) / c)^{0.5}$

were : $H_c = Y_c + V_c^2 / (2 * G)$, and $Q / A_o * d_o^{0.5} <= 3.5$

Note: This worksheet presents calculations necessary to rate flow through a round pipe culvert under both inlet and outlet control. **This data is automatically provided to the "Vol Outflow" Tab when a round culvert is selected as one of the outlfow elements.**

RCP:	K	M	c	Y	scale
square edge w/headwall:	0.0098	2.0	0.0398	0.67	1
groove end w/headwall:	0.0078	2.0	0.0292	0.74	2
groove end projecting:	0.0045	2.0	0.0317	0.69	3
CMP:					
headwall:	0.0078	2.0	0.0379	0.69	1
mitered to slope:	0.021	1.3	0.0463	0.75	2
projecting:	0.034	1.5	0.0553	0.54	3

K_e =	0.20	dim	entrance loss coefficient (default 0.2)
L =	20.0	ft	barrel length (default 20)
n =	0.013	dim	Manning's roughness coefficient (default 0.013)
d_o =	0.00	ft	round pipe diameter
S =	0.000	ft/ft	pipe barrel slope (default 0.00)
A_o =	0.00	ft^2	pipe cross section flow area
P_o =	0.00	ft	pipe cross section perimeter
TW =	0.00	ft	tailwater depth above outlet invert
K =	0.0098	dim	inlet control coefs, p. 147 HDS5 for RCP or CMP (see table above)
M =	2	dim	
c =	0.0398	dim	
Y =	0.67	dim	



DEVELOP HW VS Q_{IC} CURVE FOR INLET CONTROL CONDITIONS

Start by guessing a critical flow depth within the culvert; 94 rows show these guesses between depths of 0.0 and just shy of the culvert diameter, in increments of 0.01 * Dia and 0.02 * Dia (ft). Then for each guess, evaluate critical discharge for flow in a circular conduit using Chow's equation. This gives the information necessary to evaluate inlet control HW for these discharges under unsubmerged conditions using Form (1) of the equations presented in HDS 5. Using this HW, then evaluate the inlet control equation for submerged conditions. Finally, compare the unsubmerged vs submerged discharges for each HW to determine the controling Inlet Control Discharge.

critical depth circ sec Y_c, ft	Θ rad	Flow Area ft^2	wet perim ft	hydr rad ft	top wid ft	critical discharge ft^3/s	critical velocity ft/s	critical vel head ft	specific head H_c, ft	$Q_c/(Ad_o^{0.5})$	$d_oK(Q_c/(Ad_o)^{0.5})^M$	HW ft	submerged discharge ft^3/s	unsub. discharge ft^3/s	controlling discharge Q_{IC}, ft^3/s	index for interpolation
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	1
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	2
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	3
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	4
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	5
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	6
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	7
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	8
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	9
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	10
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	11
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	12
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	13
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	14
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	15
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	16
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	17
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	18
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	19
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	20
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	21
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	22
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	23
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	24
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	25
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	26
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	27
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	28
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	29
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	30
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	31
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	32
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	33
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	34
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	35
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	36
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	37
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	38
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	39
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	40
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	41
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	42
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	43
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	44
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	45
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	46
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	47
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	48
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	49
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	50
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	51
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	52
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	53
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	54
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	55
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	56
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	57
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	58
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	59
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	60
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	61
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	62
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	63
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	64
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	65
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	66
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	67
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	68
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	69
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	70
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	71
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	72
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	73
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	74
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	75
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	76
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	77
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	78
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	79
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	80
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	81
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	82
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	83
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	84
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	85
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	86
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	87
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	88
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	89
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	90
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	91
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	92
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	93
0.000	0.0000	0.0000	0.0000	0.0000	0.000	0.0000	0.00	0.00	0.00	0.00	0.0000	0.00	0.0000	0.0000	0.0000	94

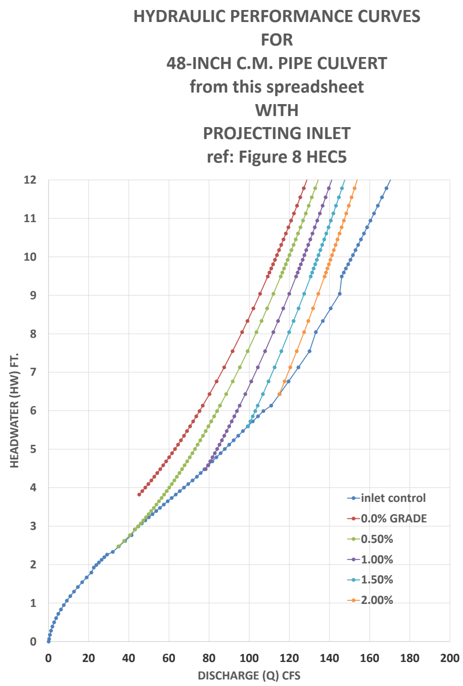
Table 1. - Entrance Loss Coefficients

Coefficient k_e to apply to velocity head $\frac{V^2}{2g}$ for determination of head loss at entrance to a structure, such as a culvert or conduit, operating full or partly full with control at the outlet.

$$\text{Entrance head loss } H_e = k_e \frac{V^2}{2g}$$

Type of Structure and Design of Entrance	Coefficient k_e
Pipe, Concrete	
Projecting from fill, socket end (groove-end)	0.2
Projecting from fill, sq. cut end	0.5
Headwall or headwall and wingwalls	
Socket end of pipe (groove-end)	0.2
Square-edge	0.5
Rounded (radius = 1/12D)	0.2
Mitered to conform to fill slope	0.7
*End-Section conforming to fill slope	0.5
Pipe, or Pipe-Arch, Corrugated Metal	
Projecting from fill (no headwall)	0.9
Headwall or headwall and wingwalls	
Square-edge	0.5
Mitered to conform to fill slope	0.7
*End-Section conforming to fill slope	0.5
Box, Reinforced Concrete	
Headwall parallel to embankment (no wingwalls)	
Square-edged on 3 edges	0.5
Rounded on 3 edges to radius of 1/12 barrel dimension	0.2
Wingwalls at 30° to 75° to barrel	
Square-edged at crown	0.4
Crown edge rounded to radius of 1/12 barrel dimension	0.2
Wingwalls at 10° to 25° to barrel	
Square-edged at crown	0.5
Wingwalls parallel (extension of sides)	
Square-edged at crown	0.7

*Note: "End Section conforming to fill slope", made of either metal or concrete, are the sections commonly available from manufacturers. From limited hydraulic tests they are equivalent in operation to a headwall in both inlet and outlet control. Some end sections, incorporating a closed taper in their design have a superior hydraulic performance. These latter sections can be designed using the information given for the bevelled inlet, p. 5-13.


HYDRAULIC PERFORMANCE CURVES
FOR
48-INCH C.M. PIPE CULVERT
from this spreadsheet
WITH
PROJECTING INLET
ref: Figure 8 HEC5
HEADWATER (HW) FT.
DISCHARGE (Q) CFS
inlet control
0.0% GRADE
0.50%
1.00%
1.50%
2.00%

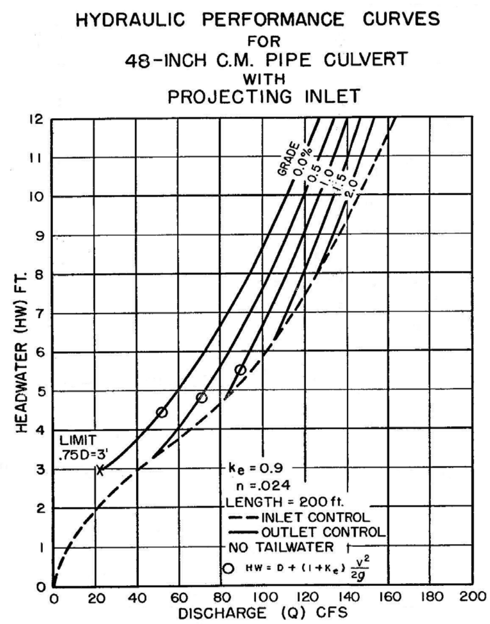

HYDRAULIC PERFORMANCE CURVES
FOR
48-INCH C.M. PIPE CULVERT
WITH
PROJECTING INLET
GRADE
0.0%
0.5
1.0
1.5
2.0
HEADWATER (HW) FT.
DISCHARGE (Q) CFS
LIMIT
.75D=3'
$k_e = 0.9$
n =.024
LENGTH = 200 ft.
INLET CONTROL
OUTLET CONTROL
NO TAILWATER
$HW = D + (1 + K_e)\frac{V^2}{2g}$

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Figure 8