Waterway Design for Flat Waterways with Out-of-Bank Flow

For waterways with slopes of less than 1 percent, out-of-bank flow will be permitted if the flow will not cause erosion. The minimum capacity of the vegetated portion of the waterway shall be the expected runoff from a 2-year - 24-hour storm. The velocity of the flow outside of the vegetated waterway, based on the runoff expected from a 10-year - 24-hour storm, will not exceed 1.5 fps for easily eroded and erodible soils or 2.0 fps for erosion resistant and very erosion resistant soils, as defined on pages IA7 - 10(1-7). Following are the minimum steps which must be documented in the design for these waterways:

1. The waterway design grade must be less than 1 percent.
2. Document the soil type and determine its soil erodibility category.
3. Determine the allowable out-of-bank flow depth from Table 1 on page IA7-20(15).

4 A. For Trapezoidal Waterways

a. Design the waterway for the Q_2 storm using the Waterway Design Tool (WDT).
b. Determine the dimensions for a Q_{10} waterway. In the WDT, set the minimum bottom width to the design bottom width for the Q_2 waterway. (step a.)
c. Add D_2 (depth of the Q_2 waterway) to the $d_{allowable}$ from Table 1. (step 3.)
d. If the value obtained in step c. is equal to or greater than D_{10}, then the design is ok.
e. If D_{10} is greater than the value from step c., then the design is not adequate. Go back to step a. and increase the flow for the "Q_2" design. Then go through steps a. through d. again. Repeat the process until the condition in step d. is met.

4 B. For Parabolic Waterways

a. Design the waterway for the Q_2 storm using the WDT. Record the top width, depth, and parabolic channel coefficient.
b. Determine the dimensions for a Q_{10} waterway using the WDT. Record the top width, depth, and parabolic channel coefficient.
c. Using the WDT, do a trial and error process to determine the dimensions of a waterway to carry the Q_{10} which has the same parabolic channel coefficient as the Q_2 waterway. To do this, keep the inputs the same as step b. Then go to the channel properties screen and input a flow width that is less than the Q_{10} waterway width. For a first guess, try a width that is 10 ft less than the Q_{10} width. Do a simulation. Compare the parabolic channel coefficient to the Q_2 coefficient from step a. If the numbers are not the same, change the top width and do another simulation. When the coefficients are approximately the same, record the "revised" Q_{10} waterway dimensions.
d. Add D_2 from step a. and $d_{allowable}$ from step 3.

e. Compare this value to D_{10}. If the value obtained in step d. is greater than or equal to $D_{10,}$ the design is ok.

f. If D_{10} is greater than the value from step d., then the design is not adequate. Go back to step a. and increase the flow for the "Q_2" design. Then go through steps a. through e. again. Repeat the process until the condition in step e. is met.

For example designs see pages IA7-20(16-25).

Sometimes it is difficult to design waterways with reasonable dimensions that also meet the requirements of the standard. In those cases it is acceptable to design waterways based on a capacity which is equal to or larger than Q_2 but less than Q_{10}. The following table gives the maximum depth for out of bank flow that results in non-erosive velocities.

TABLE 1. Maximum depths in feet for non-erosive flows ($d_{allowable}$).

Rows parallel to waterway (n = 0.035)		
S	V_{max} = 1.5 fps*	V_{max} = 2.0 fps**
0.1 %	1.18	1.82
0.2 %	0.70	1.08
0.3 %	0.52	0.80
0.4 %	0.42	0.64
0.5 %	0.35	0.54
0.6 %	0.31	0.47
0.7 %	0.27	0.42
0.8 %	0.25	0.38
0.9 %	0.23	0.35
1.0 %	0.21	0.32

Rows perpendicular to waterway (n = 0.040)		
S	V_{max} = 1.5 fps*	V_{max} = 2.0 fps**
0.1 %	1.44	2.22
0.2 %	0.86	1.32
0.3 %	0.63	0.97
0.4 %	0.51	0.79
0.5 %	0.43	0.66
0.6 %	0.38	0.58
0.7 %	0.34	0.52
0.8 %	0.30	0.47
0.9 %	0.28	0.43
1.0 %	0.26	0.40

***** For soils with an erosion category of “easily eroded” or “erodible”

****** For soils with an erosion category of “erosion resistant” or “very erosion resistant”

EXAMPLE 1.

Design a waterway for a field in Story County, Iowa. The drainage area of the waterway is measured to be 88 acres and the runoff curve number is calculated to be 78. The survey shows that the waterway slope is 0.9 percent. The hydraulic length of the watershed is 2,450 feet and the average watershed slope is 2.6 percent. The producer has indicated that the rows will run perpendicular to the waterway and that he will not normally mow the waterway. Use a trapezoidal waterway with 8:1 side slopes.

Step 1. The waterway is 0.9 percent. It is allowable to use this procedure.

Step 2. The peak discharges from EFH 2 are: (See page IA7-20(17))

Q_2 = 67 cfs

Q_{10} = 145 cfs

Step 3. The soil type is a Webster. The erosion category is "very erosion resistant."

(See page IA7-10(7))

Step 4. The allowable flow depth for out-of bank flow is 0.43 feet ($d_{allowable}$).

(See Table 1)

Step 5. Dimensions for a Q_2 waterway. (See page IA7-20(18))

b_2 = 10 ft D_2 = 1.82 ft

Step 6. Dimensions for a Q_{10} waterway. (See page IA7-20(19))

b_{10} = 10 ft D_{10} = 2.21 ft

Step 7. Add $d_{allowable}$ from Table 1 to D_2

0.43 + 1.82 = 2.25 ft

Step 8. Compare this to D_{10}:

2.25 ft > 2.21 ft   The design is ok.

Construct a trapezoidal waterway with a 10 foot bottom width, 8:1 side slopes, and 1.8 feet deep.

Client: Example 1
County: STORY State: IA
Practice: Grassed Waterway
Calculated By: MJJ Date: 4/13/2011
Checked By: __________ Date: ____________

Drainage Area:	88	Acres	(user entered value)
Curve Number:	78		(user entered value)
Watershed Length:	2450	Feet	
Watershed Slope:	2.6	Percent	
Time of Concentration:	0.72	Hours	(calculated value)
Rainfall Type:	II		

Storm Number	1	2	3	4	5	6	7
Frequency (yrs)	2	5	10	25	50	100	
24-Hr rainfall (in)	3.10	4.00	4.70	5.40	6.00	6.60	
Ia/P Ratio	0.18	0.14	0.12	0.10	0.09	0.09	0.00
Used	0.18	0.14	0.12	0.10	0.10	0.10	0.00
Runoff (in)	1.20	1.89	2.46	3.05	3.58	4.11	
(ac-ft)	8.80	13.86	18.04	22.37	26.25	30.14	0.00
Unit Peak Discharge (cfs/acre/in)	0.631	0.656	0.669	0.678	0.681	0.681	0.000
Peak Discharge (cfs)	67	109	145	182	214	247	

Story County Example 1: Starting Station 0+00, Ending Station 16+50.0

Input

Channel Data

Bank Slopes, z1,z2: 8.0, 8.0 **Bed Slope:** 0.903% **Freeboard:** NA **Min Bed Width:** 10.00 ft

Flow Depth: NA **Flow Width:** NA **Discharge:** 67.0 cfs

Soil Data

Grain Roughness: 0.0156

Allowable Stress: Very Erosion Resistant - 0.070 lb/sq.ft

Vegetal Data

	Stem Length	Density	Ret Curve Index	Vegetal Cover Factor
Stability			4.44 (D)	Turf grasses (Buffalo grass, 0.87)
Capacity			7.64 (B)	

Outputs

Bed Width determined by specified minimum value for Stability Conditions (Stress not the limiting factor)

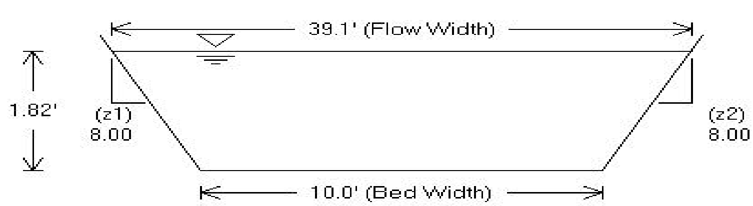
Flow Conditions with Minimum cover (Stability)

Manning's n	Average Velocity	Flow Depth	Effect. Soil Stress	Flow Width
0.0408	2.95 ft/sec	1.17 ft	0.013 lb/sq.ft	28.7 ft
X-sect. Area	**Hydraulic Radius**		**Bed Width**	**Flow Width w/Fb**
22.7 sq.ft	0.79 ft		10.0 ft	NA

Capacity Flow Conditions

Manning's n	Average Velocity	Flow Depth		Flow Width
0.1026	1.50 ft/sec	1.82 ft		39.1 ft
X-sect. Area	**Hydraulic Radius**		**Bed Width**	**Flow Width w/Fb**
44.6 sq.ft	1.13 ft		10.0 ft	NA

Trapezoidal Channel



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Story County Example 1 - Q10: Starting Station 0+00, Ending Station 16+50.0

Input

Channel Data

Bank Slopes, z1,z2: 8.0, 8.0 **Bed Slope:** 0.903% **Freeboard:** NA **Min Bed Width:** 10.00 ft

Flow Depth: NA **Flow Width:** NA **Discharge:** 145.0 cfs

Soil Data

Grain Roughness: 0.0156

Allowable Stress: Very Erosion Resistant - 0.070 lb/sq.ft

Vegetal Data

	Stem Length	Density	Ret Curve Index	Vegetal Cover Factor
Stability			4.44 (D)	Turf grasses (Buffalo grass, 0.87)
Capacity			7.64 (B)	

Outputs

Bed Width determined by specified minimum value for Stability Conditions (Stress not the limiting factor)

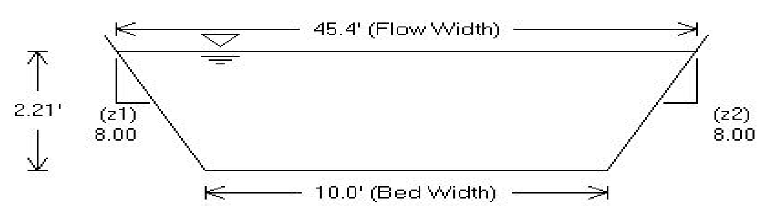
Flow Conditions with Minimum cover (Stability)

Manning's n	Average Velocity	Flow Depth	Effect. Soil Stress	Flow Width
0.0351	4.06 ft/sec	1.58 ft	0.023 lb/sq.ft	35.3 ft
X-sect. Area	**Hydraulic Radius**		**Bed Width**	**Flow Width w/Fb**
35.7 sq.ft	1.01 ft		10.0 ft	NA

Capacity Flow Conditions

Manning's n	Average Velocity	Flow Depth		Flow Width
0.0727	2.37 ft/sec	2.21 ft		45.4 ft
X-sect. Area	**Hydraulic Radius**		**Bed Width**	**Flow Width w/Fb**
61.2 sq.ft	1.34 ft		10.0 ft	NA

Trapezoidal Channel



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EXAMPLE 2.

Design a reach of a parabolic waterway for a field in Grundy County, Iowa. The drainage area of the waterway is measured to be 477 acres and the runoff curve number is calculated to be 78. The survey indicates that the waterway slope is 0.3 percent. The hydraulic length of the watershed is 8,800 feet and the average watershed slope is 2.4 percent. The producer has indicated that the rows will run parallel to the waterway and that he will normally mow the waterway.

Step 1. The waterway is 0.3 percent, which is less than 1 percent; therefore, it is allowable to use this procedure.

Step 2. The peak discharges from EFH 2 are: (See page IA7-20(21))
Q_2 = 182 cfs
Q_{10} = 382 cfs

Step 3. The soil type is a Clyde silty clay loam. The erosion category for a Clyde soil is "erosion resistant." (See page IA7-10(2))

Step 4. The allowable flow depth ($d_{allowable}$) for out-of bank flow is 0.80 ft. (See Table 1)

Step 5. Dimensions for a Q_2 waterway from the WDT. (See page IA7-20(22))
Top width = 66.6 ft D_2 = 2.09 ft   Parabolic Channel Coefficient = 0.00189

Step 6. Dimensions of a Q_{10} waterway from the WDT. (See page IA7-20(23))
Top width = 85.6 ft D_{10} = 2.53 ft   Parabolic Channel Coefficient = 0.00138

Step 7. Use a trial and error procedure with the waterway design tool to find the dimensions of a Q_{10} waterway with the same Parabolic Channel Coefficient as the Q_2 waterway.

Q_{10}		T	D	P Channel Coeff	See Page
382		85.6	2.53	0.00138 < 0.00189	
	Try	80	2.61	0.00163 < 0.00189	IA7-20(24)
	Try	75	2.68	0.00191 $\simeq$ 0.00189	IA7-20(25)

0.00191 $\simeq$ 0.00189   Therefore, the D_{10} depth is 2.68 ft.

Step 8. $D_2 + d_{allowable}$ = 2.09 + 0.80 = 2.89 ft
2.89 ft > D_{10} = 2.68 ft   Therefore, the design is good.

Construct a parabolic waterway with T = 68 ft and depth = 2.1 ft.

Client: Example 2
County: GRUNDY State: IA
Practice: Grassed Waterway
Calculated By: MJJ Date: 4/13/2011
Checked By: __________ Date: ____________

Drainage Area:	477	Acres	(user entered value)
Curve Number:	78		(user entered value)
Watershed Length:	8800	Feet	
Watershed Slope:	2.4	Percent	
Time of Concentration:	2.07	Hours	(calculated value)
Rainfall Type:	II		

Storm Number	1	2	3	4	5	6	7
Frequency (yrs)	2	5	10	25	50	100	
24-Hr rainfall (in)	3.10	4.00	4.60	5.30	5.80	6.50	
Ia/P Ratio	0.18	0.14	0.12	0.11	0.10	0.09	0.00
Used	0.18	0.14	0.12	0.11	0.10	0.10	0.00
Runoff (in)	1.20	1.89	2.38	2.97	3.40	4.02	
(ac-ft)	47.70	75.13	94.61	118.06	135.15	159.80	0.00
Unit Peak Discharge (cfs/acre/in)	0.319	0.331	0.337	0.342	0.344	0.344	0.000
Peak Discharge (cfs)	182	298	382	484	558	660	

Grundy Q2: Starting Station 6+00, Ending Station 15+00

Input

Channel Data

Limiting BS, z:1: 8.0 **Bed Slope:** 0.300% **Freeboard:** NA **:**

Flow Depth: NA **Flow Width:** NA **Discharge:** 182.0 cfs

Offsets 1,2,3: 0.00, 0.00, 0.00

Soil Data

Grain Roughness: 0.0156

Allowable Stress: Erosion Resistant - 0.050 lb/sq.ft

Vegetal Data

	Stem Length	Density	Ret Curve Index	Vegetal Cover Factor
Stability			4.44 (D)	Turf grasses (Buffalo grass, 0.87)
Capacity			5.60 (C)	

Outputs

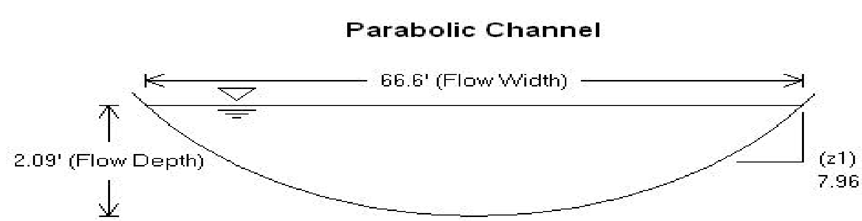
Parabolic Channel Coefficient determined by specified bank slope limit for Capacity Conditions (Stress not the limiting factor)

Flow Conditions with Minimum cover (Stability)

Manning's n	Average Velocity	Flow Depth	Effect. Soil Stress	Flow Width
0.0397	2.36 ft/sec	1.85 ft	0.007 lb/sq.ft	62.6 ft
X-sect. Area	**Hydraulic Radius**	**Bank Slope, z:1**	**P-Channel Coeff**	**Flow Width w/Fb**
77.2 sq.ft	1.23 ft	8.45	0.00189	NA

Capacity Flow Conditions

Manning's n	Average Velocity	Flow Depth		Flow Width
0.0519	1.96 ft/sec	2.09 ft		66.6 ft
X-sect. Area	**Hydraulic Radius**	**Bank Slope, z:1**	**P-Channel Coeff**	**Flow Width w/Fb**
92.9 sq.ft	1.39 ft	7.96	0.00189	NA



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Grundy Q10: Starting Station 6+00, Ending Station 15+00

Input

Channel Data

Limiting BS, z:1: 8.0 | **Bed Slope:** 0.300% | **Freeboard:** NA | **:**

Flow Depth: NA | **Flow Width:** NA | **Discharge:** 382.0 cfs

Offsets 1,2,3: 0.00, 0.00, 0.00

Soil Data

Grain Roughness: 0.0156

Allowable Stress: Erosion Resistant - 0.050 lb/sq.ft

Vegetal Data

	Stem Length	Density	Ret Curve Index	Vegetal Cover Factor
Stability			4.44 (D)	Turf grasses (Buffalo grass, 0.87)
Capacity			5.60 (C)	

Outputs

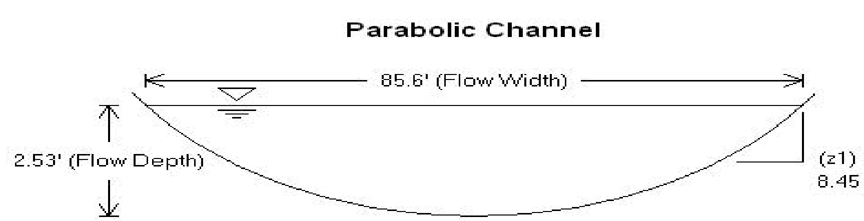
Parabolic Channel Coefficient determined by specified bank slope limit for Capacity Conditions (Stress not the limiting factor)

Flow Conditions with Minimum cover (Stability)

Manning's n	Average Velocity	Flow Depth	Effect. Soil Stress	Flow Width
0.0349	3.09 ft/sec	2.28 ft	0.011 lb/sq.ft	81.3 ft
X-sect. Area	**Hydraulic Radius**	**Bank Slope, z:1**	**P-Channel Coeff**	**Flow Width w/Fb**
123.6 sq.ft	1.52 ft	8.88	0.00138	NA

Capacity Flow Conditions

Manning's n	Average Velocity	Flow Depth		Flow Width
0.0438	2.64 ft/sec	2.53 ft		85.6 ft
X-sect. Area	**Hydraulic Radius**	**Bank Slope, z:1**	**P-Channel Coeff**	**Flow Width w/Fb**
144.7 sq.ft	1.69 ft	8.45	0.00138	NA



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Grundy Q10 80: Starting Station 6+00, Ending Station 15+00

Input

Channel Data

Limiting BS, z:1: 8.0 **Bed Slope:** 0.300% **Freeboard:** NA **:**

Flow Depth: NA **Flow Width:** 80.0 **Discharge:** 382.0 cfs

Offsets 1,2,3: 0.00, 0.00, 0.00

Soil Data

Grain Roughness: 0.0156

Allowable Stress: Erosion Resistant - 0.050 lb/sq.ft

Vegetal Data

	Stem Length	Density	Ret Curve Index	Vegetal Cover Factor
Stability			4.44 (D)	Turf grasses (Buffalo grass, 0.87)
Capacity			5.60 (C)	

Outputs

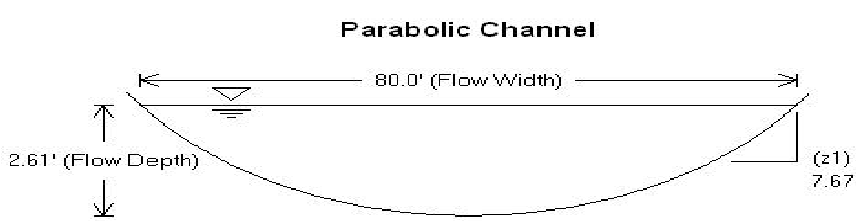
Parabolic Channel Coefficient determined by total stress on vegetal cover

Flow Conditions with Minimum cover (Stability)

Manning's n	Average Velocity	Flow Depth	Effect. Soil Stress	Flow Width
0.0344	3.20 ft/sec	2.35 ft	0.012 lb/sq.ft	76.0 ft
X-sect. Area	**Hydraulic Radius**	**Bank Slope, z:1**	**P-Channel Coeff**	**Flow Width w/Fb**
119.3 sq.ft	1.57 ft	8.07	0.00163	NA

Capacity Flow Conditions

Manning's n	Average Velocity	Flow Depth		Flow Width
0.0429	2.75 ft/sec	2.61 ft		80.0 ft
X-sect. Area	**Hydraulic Radius**	**Bank Slope, z:1**	**P-Channel Coeff**	**Flow Width w/Fb**
139.1 sq.ft	1.73 ft	7.67	0.00163	NA



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Grundy Q10 75: Starting Station 6+00, Ending Station 15+00

Input

Channel Data

Limiting BS, z:1: 8.0 **Bed Slope:** 0.300% **Freeboard:** NA :

Flow Depth: NA **Flow Width:** 75.0 **Discharge:** 382.0 cfs

Offsets 1,2,3: 0.00, 0.00, 0.00

Soil Data

Grain Roughness: 0.0156

Allowable Stress: Erosion Resistant - 0.050 lb/sq.ft

Vegetal Data

	Stem Length	Density	Ret Curve Index	Vegetal Cover Factor
Stability			4.44 (D)	Turf grasses (Buffalo grass, 0.87)
Capacity			5.60 (C)	

Outputs

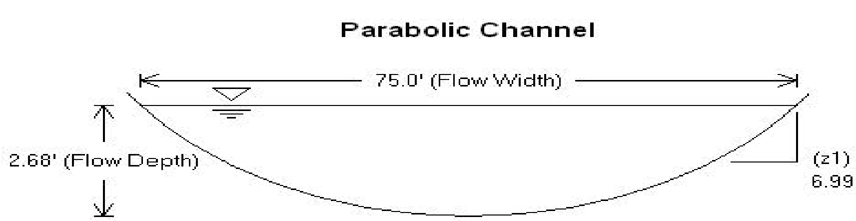
Parabolic Channel Coefficient determined by total stress on vegetal cover

Flow Conditions with Minimum cover (Stability)

Manning's n	Average Velocity	Flow Depth	Effect. Soil Stress	Flow Width
0.0339	3.31 ft/sec	2.43 ft	0.013 lb/sq.ft	71.3 ft
X-sect. Area	**Hydraulic Radius**	**Bank Slope, z:1**	**P-Channel Coeff**	**Flow Width w/Fb**
115.3 sq.ft	1.61 ft	7.35	0.00191	NA

Capacity Flow Conditions

Manning's n	Average Velocity	Flow Depth		Flow Width
0.0421	2.85 ft/sec	2.68 ft		75.0 ft
X-sect. Area	**Hydraulic Radius**	**Bank Slope, z:1**	**P-Channel Coeff**	**Flow Width w/Fb**
134.1 sq.ft	1.78 ft	6.99	0.00191	NA



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