APPENDIX C

HYDRAULIC CALCULATIONS

Urban Drainage Constructed Wetlands Channel 1
Bioswale Hydraulic Worksheets 6

10.0 CONSTRUCTED WETLANDS CHANNEL (CWC)—SEDIMENTATION FACILITY

10.1 Description

Constructed wetland-bottomed channels takes advantage of dense natural vegetation (rushes, willows, cattails, and reeds) to slow down runoff and allow time for settling out sediment and biological uptake. It is another form of a sedimentation facility and a treatment plant.

Constructed wetlands differ from "natural" wetlands as they are artificial and are built to enhance stormwater quality. Sometimes small wetlands that exist along ephemeral drainageways on Colorado's high plains may be enlarged and incorporated into the constructed wetland system. Such action, however, requires the approval of federal and state regulators.

Regulations intended to protect natural wetlands recognize a separate classification of wetlands constructed for a water quality treatment. Such wetlands generally are not allowed to be used to mitigate the loss of natural wetlands but are allowed to be disturbed by maintenance activities. Therefore, the legal and regulatory status of maintaining a wetland constructed for the primary purpose of water quality enhancement is separate from the disturbance of a natural wetland. Nevertheless, any activity that disturbs a constructed wetland should be first cleared through the U.S. Army Corps of Engineers to ensure it is covered by some form of an individual, general, or nationwide 404 permit.

10.2 General Application

Wetland bottom channels can be used in the following two ways:

- A wetland can be established in a totally man-made channel and can act as a conveyance system and water quality enhancement facility. This design can be used along wide and gently sloping channels.
- A wetland bottom channel can be located downstream of a stormwater detention facility (water quality and/or flood control) where a large portion of the sediment load can be removed. The

wetland channel then receives stormwater and base flows as they drain from the detention facility, provides water quality enhancement, and at the same time conveys it downstream. This application of a wetland channel is recommended upstream of receiving waters and within lesser (i.e., ephemeral) receiving waters, thereby delivering better quality water to the more significant receiving water system.

A CWC requires a net influx of water to maintain their vegetation and microorganisms. A complete water budget analysis is necessary to ensure the adequacy of the base flow.

10.3 Advantages/Disadvantages

10.3.1 General

Constructed wetlands offer several potential advantages, such as natural aesthetic qualities, wildlife habitat, erosion control, and pollutant removal. Constructed wetlands provide an effective follow-up treatment to onsite and source control BMPs that rely upon settling of larger sediment particles. In other words, they offer yet another effective BMP for larger tributary basins.

The primary drawback to wetlands is the need for a continuous base flow to ensure their presence. In addition, salts and scum can accumulate and unless properly designed and built, can be flushed out during larger storms.

Other disadvantages include the need for regular maintenance to provide nutrient removal. Regular harvesting and removal of aquatic plants, cattails, and willows is required if the removal of nutrients in significant amounts has to be assured. Even with that, recent data puts into question the net effectiveness of wetlands in removing nitrogen compounds and some form of phosphates. Periodic sediment removal is also necessary to maintain the proper distribution of growth zones and of water movement within the wetland.

10.3.2 Physical Site Suitability

A perennial base flow is needed to sustain a wetland, and should be determined using a water budget analysis. Loamy soils are needed in wetland bottom to permit plants to take root. Infiltration through a wetland bottom cannot be relied upon because the bottom is either covered by soils of low permeability or because the groundwater is higher than the wetland's bottom. Wetland bottom channels also require a near-zero longitudinal slope; drop structures are used to create and maintain a flat grade.

10.3.3 Pollutant Removal

Removal efficiencies of constructed wetlands vary significantly. Primary variables influencing removal efficiencies include design, influent concentrations, hydrology, soils, climate, and maintenance. With periodic sediment removal and plant harvesting, expected removal efficiencies for sediments, organic matter, and metals can be moderate to high; for phosphorous, low to moderate; and for nitrogen, zero to

low. Pollutants are removed primarily through sedimentation and entrapment, with some of the removal occurring through biological uptake by vegetation and microorganisms. Without a continuous dry-weather base flow, salts and algae can concentrate in the water column and can be released into the receiving water in higher levels at the beginning of a storm event as they are washed out.

Harvesting aquatic plants and periodic removal of sediment also removes nutrients and pollutants associated with the sediment. Researchers still do not agree that routine aquatic plant harvesting affects pollutant removals. Until research documents these effects, periodic harvesting for the general upkeep of wetland, and not routine harvesting of aquatic plants, is recommended.

10.4 Design Considerations

Wetlands can be set into a drainageway to form a wetland bottom channel (see Figure CWC-1). The criteria for a wetland bottom channel presented in the following section differs somewhat from the criteria presented in Volume 1 of the *Manual* under the MAJOR DRAINAGE chapter. This is because of the water quality focus of this BMP. An analysis of the water budget is needed so that the inflow of water throughout the year is sufficient to meet all the projected losses (such as evaporation, evapotranspiration, and seepage). An insufficient base flow could cause the wetland bottom channel to dry out and die.

10.5 Design Procedure and Criteria

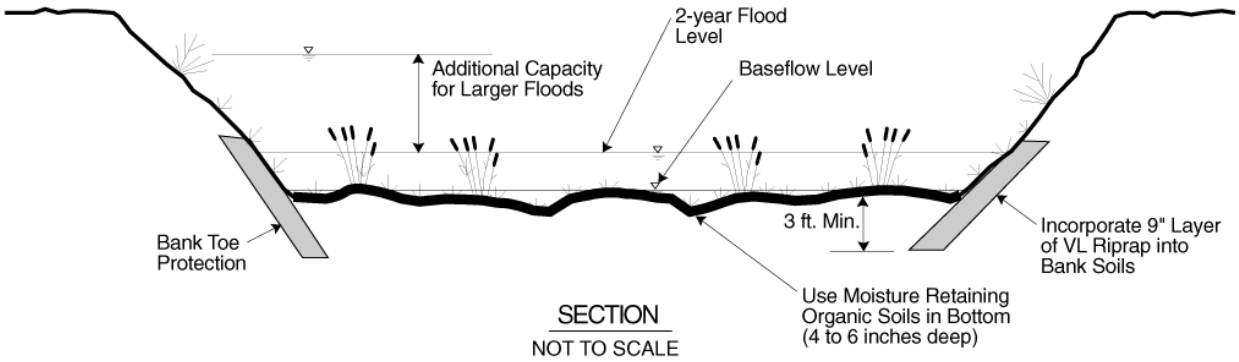
The following steps outline the Constructed Wetlands Channel design procedure. Refer to Figure CWC-1 for its design components.

1. Design Discharge	Determine the 2-year peak flow rate in the wetland channel *without* reducing it for any upstream ponding or flood routing effects.
2. Channel Geometry	Define the newly-built channel's geometry to pass the design 2-year flow rate at 2.0 feet per second with a channel depth between 2.0 to 4.0 feet. The channel cross-section should be trapezoidal with side slopes of 4:1 (Horizontal/Vertical) or flatter. Bottom width shall be no less than 8.0 feet.
3. Longitudinal Slope	Set the longitudinal slope using Manning's equation and a Manning's roughness coefficient of n=0.035, for the 2-year flow rate but no flatter that 0.001 ft/ft. If the desired longitudinal slope can not be satisfied with existing terrain, grade control checks or small drop structures must be incorporated to provide desired slope.
4. Final Channel Capacity	Calculate the final (or mature) channel capacity during a 2-year flood using a Manning's roughness coefficient of n=0.08 and the same geometry and slope used when initially designing the channel with n=0.03. The channel shall also provide enough capacity to contain the flow during a 100-year flood while maintaining one foot of free-board. Adjustment of the channel capacity may be done by increasing the bottom width of the channel. Minimum bottom width shall be 8 feet.
5. Drop Structures	Drop structures should be designed to satisfy the drop structure criteria of the MAJOR DRAINAGE chapter in Volume 1 of the *Manual.*

6. Vegetation	Vegetate the channel bottom and side slopes to provide solid entrapment and biological nutrient uptake. Cover the channel bottom with loamy soils upon which cattails, sedges, and reeds should be established. Side slopes should be planted with native or irrigated turf grasses.
7. Maintenance Access	Provide access for maintenance along the channel length. Maximum grades for maintenance vehicles should be 10 percent and provide a solid driving surface.

10.6 Design Example

Design forms that provide a means of documenting the design procedure are included in the DESIGN FORMS chapter. A completed form follows as a design example.



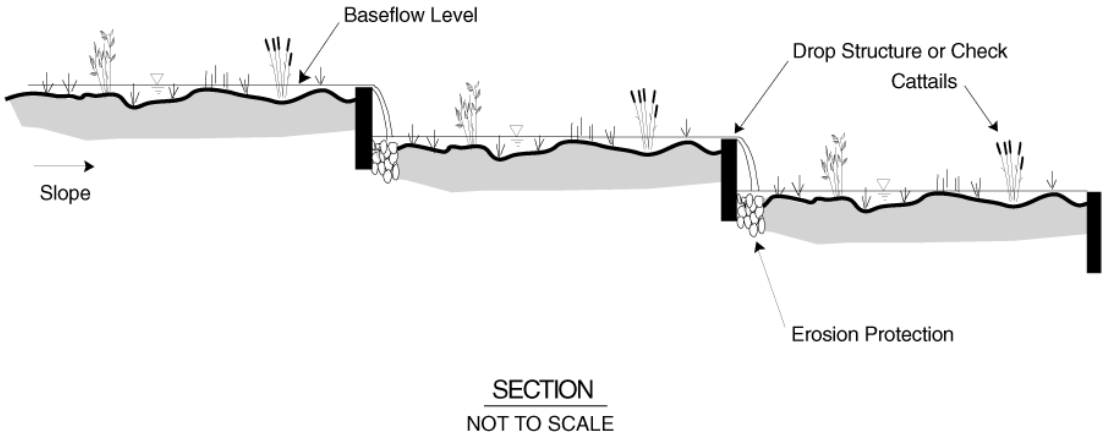


Figure CWC-1—Plan and Section of a Constructed Wetland Channel

Bioswale (Section 1) - 10YR
Worksheet for Irregular Channel

Project Description	
Worksheet	Bioswale (Section 1) - 10YR
Flow Element	Irregular Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Slope	0.001500	ft/ft
Discharge	0.00	cfs

Options	
Current Roughness Method	Improved Lotter's Method
Open Channel Weighting Method	Improved Lotter's Method
Closed Channel Weighting Metho	Horton's Method

Results		
Mannings Coefficient	0.035	
Water Surface Elevation	0.00	ft
Elevation Range	0.00 to 4.32	
Flow Area	0.0	ft²
Wetted Perimeter	0.00	ft
Top Width	0.00	ft
Actual Depth	0.00	ft
Critical Elevation	0.00	ft
Critical Slope	0.000000	ft/ft
Velocity	0.00	ft/s
Velocity Head	0.00	ft
Specific Energy	0.00	ft
Froude Number	0.00	
Flow Type	Subcritical	

Roughness Segments

Start Station	End Station	Mannings Coefficient
0+00	0+22	0.035
0+22	0+46	0.080
0+46	0+52	0.035

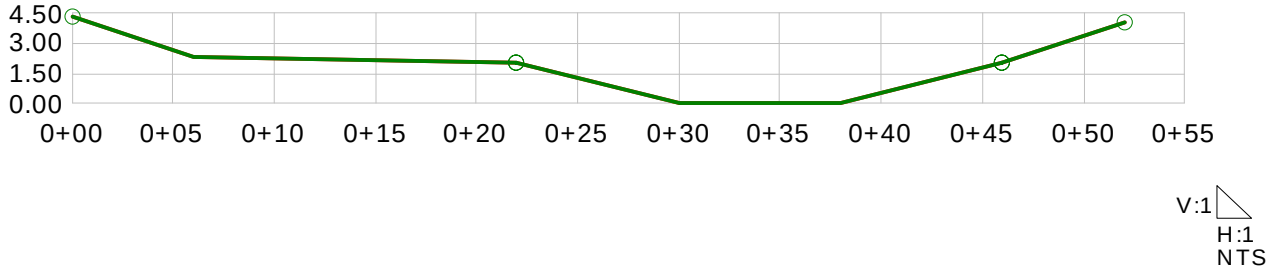
Natural Channel Points

Station (ft)	Elevation (ft)
0+00	4.32
0+06	2.32
0+22	2.00
0+30	0.00
0+38	0.00
0+46	2.00
0+52	4.00

Bioswale (Section 1) - 10YR Cross Section
Cross Section for Irregular Channel

Project Description	
Worksheet	Bioswale (Section 1) - 10YR
Flow Element	Irregular Channel
Method	Manning's Formula
Solve For	Channel Depth

Section Data		
Mannings Coefficient	0.035	
Slope	0.001500	ft/ft
Water Surface Elevation	0.00	ft
Elevation Range	0.00 to 4.32	
Discharge	0.00	cfs



Bioswale (Section 1) - 100YR
Worksheet for Irregular Channel

Project Description	
Worksheet	Bioswale (Section 1) - 100YR
Flow Element	Irregular Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Slope	0.001500	ft/ft
Discharge	7.93	cfs

Options	
Current Roughness Method	Improved Lotter's Method
Open Channel Weighting Method	Improved Lotter's Method
Closed Channel Weighting Metho	Horton's Method

Results		
Mannings Coefficient	0.080	
Water Surface Elevation	1.06	ft
Elevation Range	0.00 to 4.32	
Flow Area	13.0	ft²
Wetted Perimeter	16.77	ft
Top Width	16.51	ft
Actual Depth	1.06	ft
Critical Elevation	0.30	ft
Critical Slope	0.146961	ft/ft
Velocity	0.61	ft/s
Velocity Head	0.01	ft
Specific Energy	1.07	ft
Froude Number	0.12	
Flow Type	Subcritical	

Roughness Segments

Start Station	End Station	Mannings Coefficient
0+00	0+22	0.035
0+22	0+46	0.080
0+46	0+52	0.035

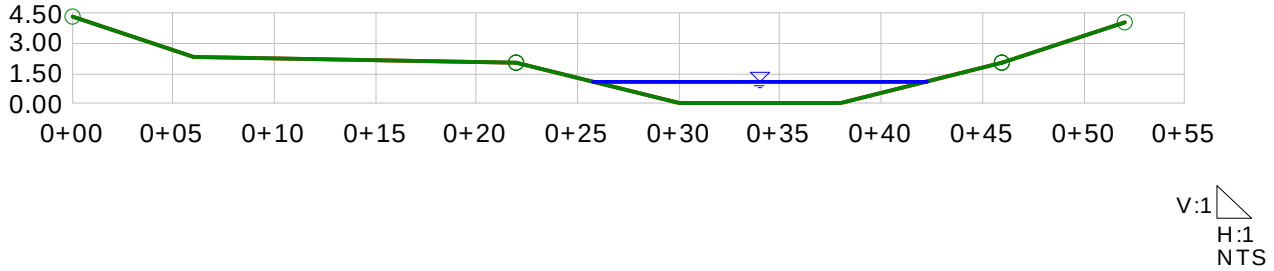
Natural Channel Points

Station (ft)	Elevation (ft)
0+00	4.32
0+06	2.32
0+22	2.00
0+30	0.00
0+38	0.00
0+46	2.00
0+52	4.00

Bioswale (Section 1) - 100YR Cross Section
Cross Section for Irregular Channel

Project Description	
Worksheet	Bioswale (Section 1) - 100YR
Flow Element	Irregular Channel
Method	Manning's Formula
Solve For	Channel Depth

Section Data		
Mannings Coefficient	0.080	
Slope	0.001500	ft/ft
Water Surface Elevation	1.06	ft
Elevation Range	0.00 to 4.32	
Discharge	7.93	cfs



Bioswale (Section 1) - 100YR (DCD Normal Operation)
Worksheet for Irregular Channel

Project Description	
Worksheet	Bioswale (Section 1) - 100YR (DCD=25cfs))
Flow Element	Irregular Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Slope	0.001500	ft/ft
Discharge	32.93	cfs

Options	
Current Roughness Method	Improved Lotter's Method
Open Channel Weighting Method	Improved Lotter's Method
Closed Channel Weighting Metho	Horton's Method

Results		
Mannings Coefficient	0.068	
Water Surface Elevation	2.15	ft
Elevation Range	0.00 to 4.32	
Flow Area	36.1	ft²
Wetted Perimeter	32.33	ft
Top Width	31.81	ft
Actual Depth	2.15	ft
Critical Elevation	0.71	ft
Critical Slope	0.082802	ft/ft
Velocity	0.91	ft/s
Velocity Head	0.01	ft
Specific Energy	2.16	ft
Froude Number	0.15	
Flow Type	Subcritical	

Roughness Segments

Start Station	End Station	Mannings Coefficient
0+00	0+22	0.035
0+22	0+46	0.080
0+46	0+52	0.035

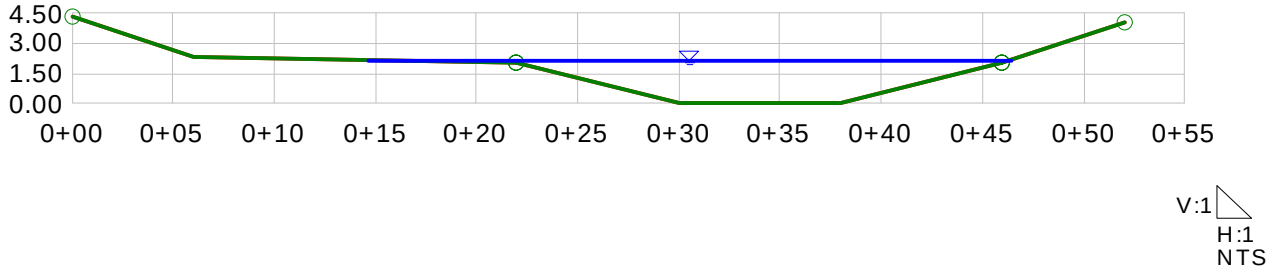
Natural Channel Points

Station (ft)	Elevation (ft)
0+00	4.32
0+06	2.32
0+22	2.00
0+30	0.00
0+38	0.00
0+46	2.00
0+52	4.00

Bioswale (Section 1) - 100YR (DCD Normal Operation) Cross Section
Cross Section for Irregular Channel

Project Description	
Worksheet	Bioswale (Section 1) - 100YR (DCD=25cfs))
Flow Element	Irregular Channel
Method	Manning's Formula
Solve For	Channel Depth

Section Data		
Mannings Coefficient	0.068	
Slope	0.001500	ft/ft
Water Surface Elevation	2.15	ft
Elevation Range	0.00 to 4.32	
Discharge	32.93	cfs



Bioswale (Section 1) - 100YR (DCD Normal Operation+Flood)
Worksheet for Irregular Channel

Project Description	
Worksheet	Bioswale (Section 1) - 100YR (DCD=25cfs+Flood
Flow Element	Irregular Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Slope	0.001500	ft/ft
Discharge	57.93	cfs

Options	
Current Roughness Method	Improved Lotter's Method
Open Channel Weighting Method	Improved Lotter's Method
Closed Channel Weighting Metho	Horton's Method

Results		
Mannings Coefficient	0.062	
Water Surface Elevation	2.60	ft
Elevation Range	0.00 to 4.32	
Flow Area	54.0	ft²
Wetted Perimeter	43.26	ft
Top Width	42.62	ft
Actual Depth	2.60	ft
Critical Elevation	0.99	ft
Critical Slope	0.063391	ft/ft
Velocity	1.07	ft/s
Velocity Head	0.02	ft
Specific Energy	2.62	ft
Froude Number	0.17	
Flow Type	Subcritical	

Roughness Segments

Start Station	End Station	Mannings Coefficient
0+00	0+22	0.035
0+22	0+46	0.080
0+46	0+52	0.035

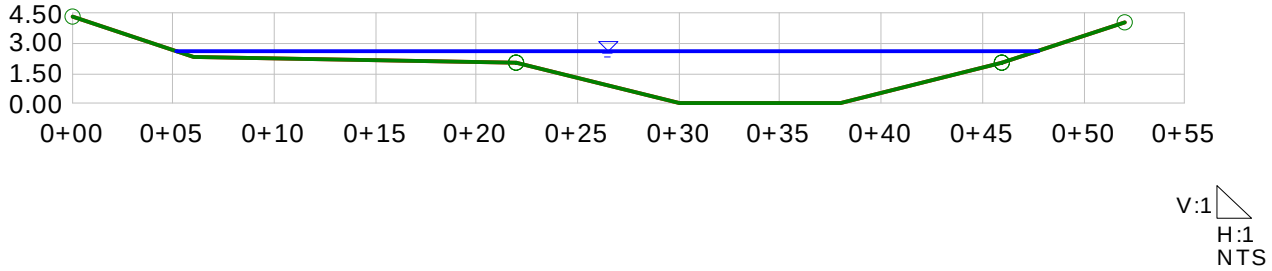
Natural Channel Points

Station (ft)	Elevation (ft)
0+00	4.32
0+06	2.32
0+22	2.00
0+30	0.00
0+38	0.00
0+46	2.00
0+52	4.00

Bioswale (Section 1) - 100YR (DCD Normal Operation+Flood) Cross Section
Cross Section for Irregular Channel

Project Description	
Worksheet	Bioswale (Section 1) - 100YR (DCD=25cfs+Flood
Flow Element	Irregular Channel
Method	Manning's Formula
Solve For	Channel Depth

Section Data		
Mannings Coefficient	0.062	
Slope	0.001500	ft/ft
Water Surface Elevation	2.60	ft
Elevation Range	0.00 to 4.32	
Discharge	57.93	cfs



Bioswale (Section 1) - 100YR (DCD Full Decreed Flow)
Worksheet for Irregular Channel

Project Description	
Worksheet	Bioswale (Section 1) - 100YR (DCD=71cfs))
Flow Element	Irregular Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Slope	0.001500	ft/ft
Discharge	78.93	cfs

Options	
Current Roughness Method	Improved Lotter's Method
Open Channel Weighting Method	Improved Lotter's Method
Closed Channel Weighting Metho	Horton's Method

Results		
Mannings Coefficient	0.062	
Water Surface Elevation	2.86	ft
Elevation Range	0.00 to 4.32	
Flow Area	65.6	ft²
Wetted Perimeter	44.95	ft
Top Width	44.23	ft
Actual Depth	2.86	ft
Critical Elevation	1.18	ft
Critical Slope	0.059286	ft/ft
Velocity	1.20	ft/s
Velocity Head	0.02	ft
Specific Energy	2.89	ft
Froude Number	0.17	
Flow Type	Subcritical	

Roughness Segments

Start Station	End Station	Mannings Coefficient
0+00	0+22	0.035
0+22	0+46	0.080
0+46	0+52	0.035

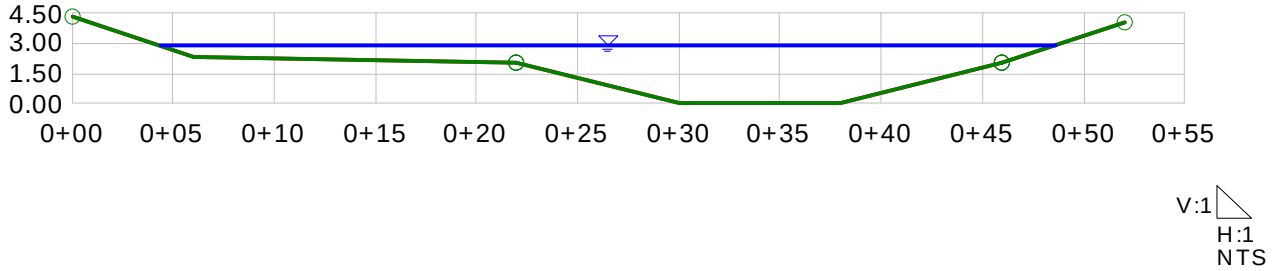
Natural Channel Points

Station (ft)	Elevation (ft)
0+00	4.32
0+06	2.32
0+22	2.00
0+30	0.00
0+38	0.00
0+46	2.00
0+52	4.00

Bioswale (Section 1) - 100YR (DCD Full Decreed Flow) Cross Section
Cross Section for Irregular Channel

Project Description	
Worksheet	Bioswale (Section 1) - 100YR (DCD=71cfs))
Flow Element	Irregular Channel
Method	Manning's Formula
Solve For	Channel Depth

Section Data		
Mannings Coefficient	0.062	
Slope	0.001500	ft/ft
Water Surface Elevation	2.86	ft
Elevation Range	0.00 to 4.32	
Discharge	78.93	cfs



Bioswale (Section 1) - 100YR (DCD Full Decreed Flow+Flood)
Worksheet for Irregular Channel

Project Description	
Worksheet	Bioswale (Section 1) - 100YR (DCD=71cfs+Flood
Flow Element	Irregular Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Slope	0.001500	ft/ft
Discharge	101.93	cfs

Options	
Current Roughness Method	Improved Lotter's Method
Open Channel Weighting Method	Improved Lotter's Method
Closed Channel Weighting Metho	Horton's Method

Results		
Mannings Coefficient	0.060	
Water Surface Elevation	3.11	ft
Elevation Range	0.00 to 4.32	
Flow Area	76.7	ft²
Wetted Perimeter	46.52	ft
Top Width	45.71	ft
Actual Depth	3.11	ft
Critical Elevation	1.36	ft
Critical Slope	0.055164	ft/ft
Velocity	1.33	ft/s
Velocity Head	0.03	ft
Specific Energy	3.14	ft
Froude Number	0.18	
Flow Type	Subcritical	

Roughness Segments

Start Station	End Station	Mannings Coefficient
0+00	0+22	0.035
0+22	0+46	0.080
0+46	0+52	0.035

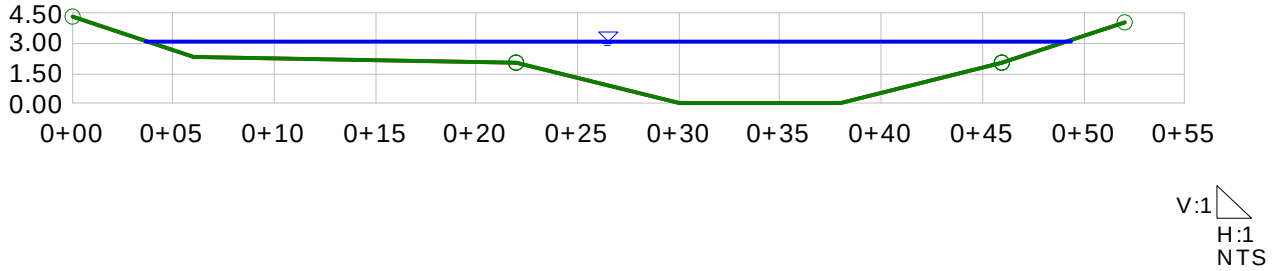
Natural Channel Points

Station (ft)	Elevation (ft)
0+00	4.32
0+06	2.32
0+22	2.00
0+30	0.00
0+38	0.00
0+46	2.00
0+52	4.00

Bioswale (Section 1) - 100YR (DCD Full Decreed Flow+Flood) Cross Section
Cross Section for Irregular Channel

Project Description	
Worksheet	Bioswale (Section 1) - 100YR (DCD=71cfs+Flood
Flow Element	Irregular Channel
Method	Manning's Formula
Solve For	Channel Depth

Section Data		
Mannings Coefficient	0.060	
Slope	0.001500	ft/ft
Water Surface Elevation	3.11	ft
Elevation Range	0.00 to 4.32	
Discharge	101.93	cfs



Bioswale (Section 2) - 10YR
Worksheet for Irregular Channel

Project Description	
Worksheet	Bioswale (Section 2) - 10YR
Flow Element	Irregular Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Slope	0.001500	ft/ft
Discharge	26.43	cfs

Options	
Current Roughness Method	Improved Lotter's Method
Open Channel Weighting Method	Improved Lotter's Method
Closed Channel Weighting Metho	Horton's Method

Results		
Mannings Coefficient	0.080	
Water Surface Elevation	1.96	ft
Elevation Range	0.00 to 4.32	
Flow Area	31.1	ft²
Wetted Perimeter	24.17	ft
Top Width	23.69	ft
Actual Depth	1.96	ft
Critical Elevation	0.62	ft
Critical Slope	0.118990	ft/ft
Velocity	0.85	ft/s
Velocity Head	0.01	ft
Specific Energy	1.97	ft
Froude Number	0.13	
Flow Type	Subcritical	

Roughness Segments

Start Station	End Station	Mannings Coefficient
0+00	0+22	0.035
0+22	0+46	0.080
0+46	0+52	0.035

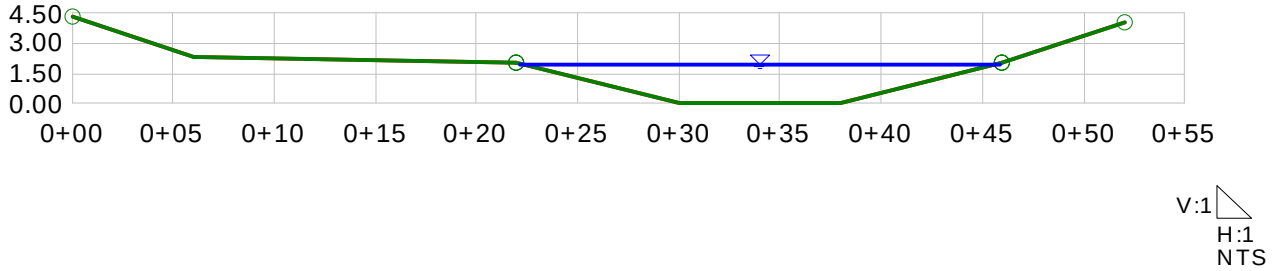
Natural Channel Points

Station (ft)	Elevation (ft)
0+00	4.32
0+06	2.32
0+22	2.00
0+30	0.00
0+38	0.00
0+46	2.00
0+52	4.00

Bioswale (Section 2) - 10YR Cross Section
Cross Section for Irregular Channel

Project Description	
Worksheet	Bioswale (Section 2) - 10YR
Flow Element	Irregular Channel
Method	Manning's Formula
Solve For	Channel Depth

Section Data		
Mannings Coefficient	0.080	
Slope	0.001500	ft/ft
Water Surface Elevation	1.96	ft
Elevation Range	0.00 to 4.32	
Discharge	26.43	cfs



Bioswale (Section 2) - 100YR
Worksheet for Irregular Channel

Project Description	
Worksheet	Bioswale (Section 2) - 100YR
Flow Element	Irregular Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Slope	0.001500	ft/ft
Discharge	39.32	cfs

Options	
Current Roughness Method	Improved Lotter's Method
Open Channel Weighting Method	Improved Lotter's Method
Closed Channel Weighting Metho	Horton's Method

Results		
Mannings Coefficient	0.062	
Water Surface Elevation	2.29	ft
Elevation Range	0.00 to 4.32	
Flow Area	41.3	ft²
Wetted Perimeter	40.04	ft
Top Width	39.50	ft
Actual Depth	2.29	ft
Critical Elevation	0.79	ft
Critical Slope	0.066306	ft/ft
Velocity	0.95	ft/s
Velocity Head	0.01	ft
Specific Energy	2.31	ft
Froude Number	0.16	
Flow Type	Subcritical	

Roughness Segments

Start Station	End Station	Mannings Coefficient
0+00	0+22	0.035
0+22	0+46	0.080
0+46	0+52	0.035

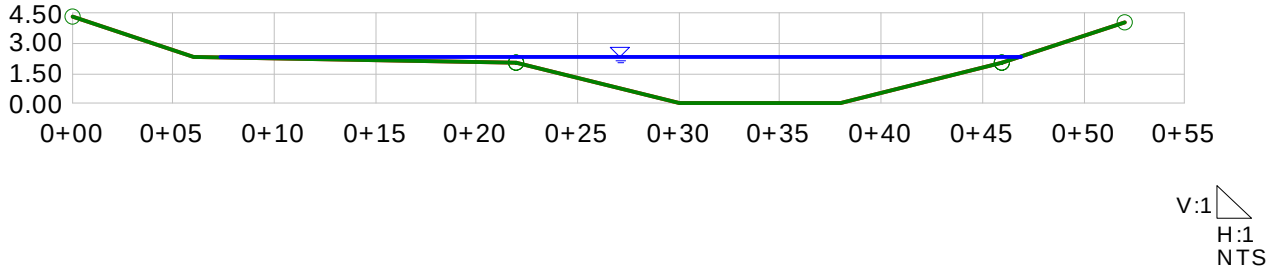
Natural Channel Points

Station (ft)	Elevation (ft)
0+00	4.32
0+06	2.32
0+22	2.00
0+30	0.00
0+38	0.00
0+46	2.00
0+52	4.00

Bioswale (Section 2) - 100YR Cross Section
Cross Section for Irregular Channel

Project Description	
Worksheet	Bioswale (Section 2) - 100YR
Flow Element	Irregular Channel
Method	Manning's Formula
Solve For	Channel Depth

Section Data		
Mannings Coefficient	0.062	
Slope	0.001500	ft/ft
Water Surface Elevation	2.29	ft
Elevation Range	0.00 to 4.32	
Discharge	39.32	cfs



Bioswale (Section 2) - 100YR (DCD Normal Operation)
Worksheet for Irregular Channel

Project Description	
Worksheet	Bioswale (Section 2) - 100YR (DCD=25cfs)
Flow Element	Irregular Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Slope	0.001500	ft/ft
Discharge	47.01	cfs

Options	
Current Roughness Method	Improved Lotter's Method
Open Channel Weighting Method	Improved Lotter's Method
Closed Channel Weighting Metho	Horton's Method

Results		
Mannings Coefficient	0.062	
Water Surface Elevation	2.43	ft
Elevation Range	0.00 to 4.32	
Flow Area	47.0	ft²
Wetted Perimeter	42.21	ft
Top Width	41.63	ft
Actual Depth	2.43	ft
Critical Elevation	0.88	ft
Critical Slope	0.064687	ft/ft
Velocity	1.00	ft/s
Velocity Head	0.02	ft
Specific Energy	2.45	ft
Froude Number	0.17	
Flow Type	Subcritical	

Roughness Segments

Start Station	End Station	Mannings Coefficient
0+00	0+22	0.035
0+22	0+46	0.080
0+46	0+52	0.035

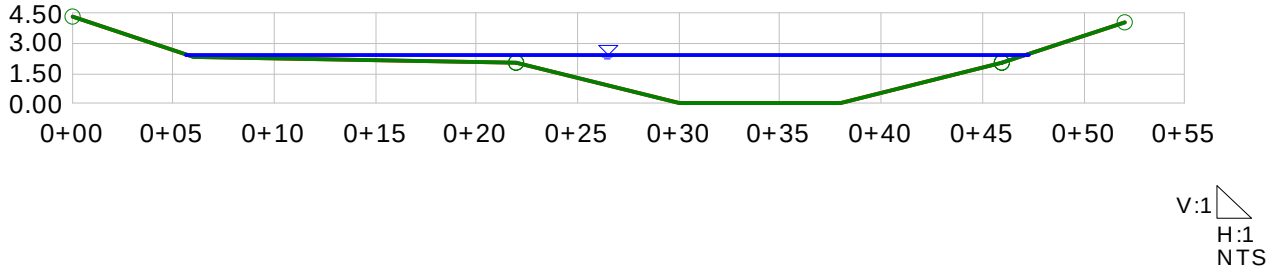
Natural Channel Points

Station (ft)	Elevation (ft)
0+00	4.32
0+06	2.32
0+22	2.00
0+30	0.00
0+38	0.00
0+46	2.00
0+52	4.00

Bioswale (Section 2) - 100YR (DCD Normal Operation) Cross Section
Cross Section for Irregular Channel

Project Description	
Worksheet	Bioswale (Section 2) - 100YR (DCD=25cfs)
Flow Element	Irregular Channel
Method	Manning's Formula
Solve For	Channel Depth

Section Data		
Mannings Coefficient	0.062	
Slope	0.001500	ft/ft
Water Surface Elevation	2.43	ft
Elevation Range	0.00 to 4.32	
Discharge	47.01	cfs



Bioswale (Section 2) - 100YR (DCD Normal Operation+Flood)
Worksheet for Irregular Channel

Project Description	
Worksheet	Bioswale (Section 2) - 100YR (DCD=25cfs+Flood
Flow Element	Irregular Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Slope	0.001500	ft/ft
Discharge	70.01	cfs

Options	
Current Roughness Method	Improved Lotter's Method
Open Channel Weighting Method	Improved Lotter's Method
Closed Channel Weighting Metho	Horton's Method

Results		
Mannings Coefficient	0.062	
Water Surface Elevation	2.76	ft
Elevation Range	0.00 to 4.32	
Flow Area	60.9	ft²
Wetted Perimeter	44.27	ft
Top Width	43.58	ft
Actual Depth	2.76	ft
Critical Elevation	1.10	ft
Critical Slope	0.061061	ft/ft
Velocity	1.15	ft/s
Velocity Head	0.02	ft
Specific Energy	2.78	ft
Froude Number	0.17	
Flow Type	Subcritical	

Roughness Segments

Start Station	End Station	Mannings Coefficient
0+00	0+22	0.035
0+22	0+46	0.080
0+46	0+52	0.035

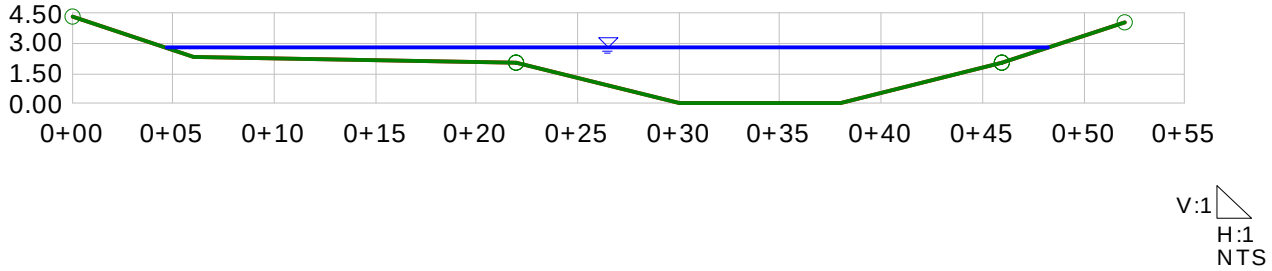
Natural Channel Points

Station (ft)	Elevation (ft)
0+00	4.32
0+06	2.32
0+22	2.00
0+30	0.00
0+38	0.00
0+46	2.00
0+52	4.00

Bioswale (Section 2) - 100YR (DCD Normal Operation+Flood) Cross Section
Cross Section for Irregular Channel

Project Description	
Worksheet	Bioswale (Section 2) - 100YR (DCD=25cfs+Flood
Flow Element	Irregular Channel
Method	Manning's Formula
Solve For	Channel Depth

Section Data		
Mannings Coefficient	0.062	
Slope	0.001500	ft/ft
Water Surface Elevation	2.76	ft
Elevation Range	0.00 to 4.32	
Discharge	70.01	cfs



Bioswale (Section 2) - 100YR (DCD Full Decreed Flow)
Worksheet for Irregular Channel

Project Description	
Worksheet	Bioswale (Section 2) - 100YR (DCD=71cfs)
Flow Element	Irregular Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Slope	0.001500	ft/ft
Discharge	87.88	cfs

Options	
Current Roughness Method	Improved Lotter's Method
Open Channel Weighting Method	Improved Lotter's Method
Closed Channel Weighting Metho	Horton's Method

Results		
Mannings Coefficient	0.061	
Water Surface Elevation	2.97	ft
Elevation Range	0.00 to 4.32	
Flow Area	70.1	ft²
Wetted Perimeter	45.59	ft
Top Width	44.83	ft
Actual Depth	2.97	ft
Critical Elevation	1.25	ft
Critical Slope	0.057589	ft/ft
Velocity	1.25	ft/s
Velocity Head	0.02	ft
Specific Energy	2.99	ft
Froude Number	0.18	
Flow Type	Subcritical	

Roughness Segments

Start Station	End Station	Mannings Coefficient
0+00	0+22	0.035
0+22	0+46	0.080
0+46	0+52	0.035

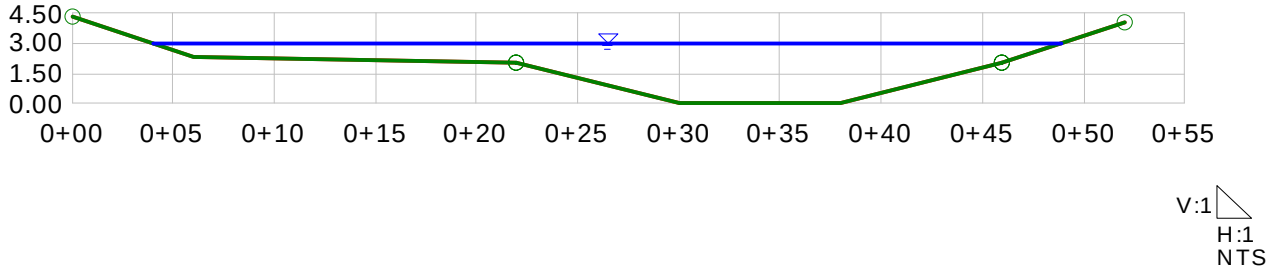
Natural Channel Points

Station (ft)	Elevation (ft)
0+00	4.32
0+06	2.32
0+22	2.00
0+30	0.00
0+38	0.00
0+46	2.00
0+52	4.00

Bioswale (Section 2) - 100YR (DCD Full Decreed Flow) Cross Section
Cross Section for Irregular Channel

Project Description	
Worksheet	Bioswale (Section 2) - 100YR (DCD=71cfs)
Flow Element	Irregular Channel
Method	Manning's Formula
Solve For	Channel Depth

Section Data		
Mannings Coefficient	0.061	
Slope	0.001500	ft/ft
Water Surface Elevation	2.97	ft
Elevation Range	0.00 to 4.32	
Discharge	87.88	cfs



Bioswale (Section 2) - 100YR (DCD Full Decreed Flow+Flood)
Worksheet for Irregular Channel

Project Description	
Worksheet	Bioswale (Section 2) - 100YR (DCD=71cfs+Flood
Flow Element	Irregular Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Slope	0.001500	ft/ft
Discharge	110.88	cfs

Options	
Current Roughness Method	Improved Lotter's Method
Open Channel Weighting Method	Improved Lotter's Method
Closed Channel Weighting Metho	Horton's Method

Results		
Mannings Coefficient	0.060	
Water Surface Elevation	3.20	ft
Elevation Range	0.00 to 4.32	
Flow Area	80.8	ft²
Wetted Perimeter	47.07	ft
Top Width	46.24	ft
Actual Depth	3.20	ft
Critical Elevation	1.42	ft
Critical Slope	0.053773	ft/ft
Velocity	1.37	ft/s
Velocity Head	0.03	ft
Specific Energy	3.23	ft
Froude Number	0.18	
Flow Type	Subcritical	

Roughness Segments

Start Station	End Station	Mannings Coefficient
0+00	0+22	0.035
0+22	0+46	0.080
0+46	0+52	0.035

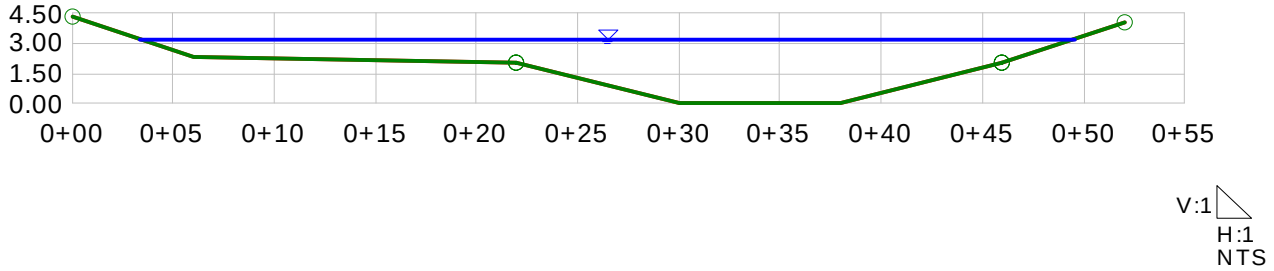
Natural Channel Points

Station (ft)	Elevation (ft)
0+00	4.32
0+06	2.32
0+22	2.00
0+30	0.00
0+38	0.00
0+46	2.00
0+52	4.00

Bioswale (Section 2) - 100YR (DCD Full Decreed Flow+Flood) Cross Section
Cross Section for Irregular Channel

Project Description	
Worksheet	Bioswale (Section 2) - 100YR (DCD=71cfs+Flood
Flow Element	Irregular Channel
Method	Manning's Formula
Solve For	Channel Depth

Section Data		
Mannings Coefficient	0.060	
Slope	0.001500	ft/ft
Water Surface Elevation	3.20	ft
Elevation Range	0.00 to 4.32	
Discharge	110.88	cfs



Bioswale (Section 3) - 10YR
Worksheet for Irregular Channel

Project Description	
Worksheet	Bioswale (Section 3) - 10YR
Flow Element	Irregular Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Slope	0.001500	ft/ft
Discharge	26.43	cfs

Options	
Current Roughness Method	Improved Lotter's Method
Open Channel Weighting Method	Improved Lotter's Method
Closed Channel Weighting Metho	Horton's Method

Results		
Mannings Coefficient	0.080	
Water Surface Elevation	1.82	ft
Elevation Range	0.00 to 4.00	
Flow Area	31.5	ft²
Wetted Perimeter	25.03	ft
Top Width	24.58	ft
Actual Depth	1.82	ft
Critical Elevation	0.56	ft
Critical Slope	0.121440	ft/ft
Velocity	0.84	ft/s
Velocity Head	0.01	ft
Specific Energy	1.83	ft
Froude Number	0.13	
Flow Type	Subcritical	

Roughness Segments

Start Station	End Station	Mannings Coefficient
0+00	0+07	0.035
0+07	0+35	0.080
0+35	0+42	0.035

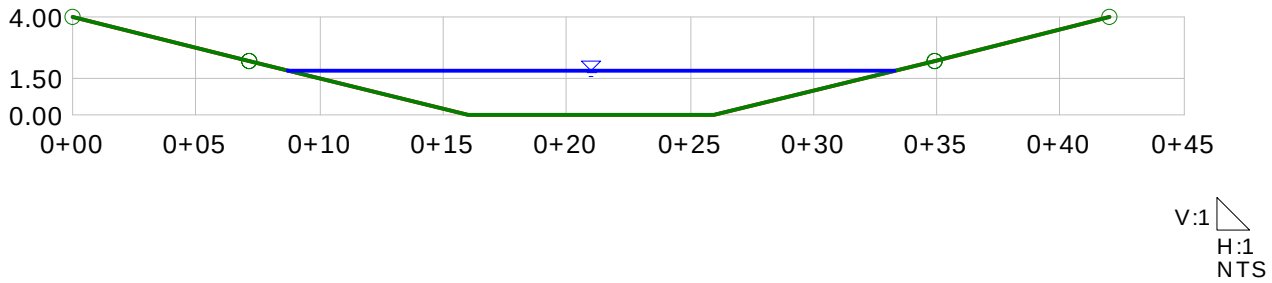
Natural Channel Points

Station (ft)	Elevation (ft)
0+00	4.00
0+07	2.22
0+16	0.00
0+26	0.00
0+35	2.22
0+42	4.00

Bioswale (Section 3) - 10YR Cross Section
Cross Section for Irregular Channel

Project Description	
Worksheet	Bioswale (Section 3) - 10YR
Flow Element	Irregular Channel
Method	Manning's Formula
Solve For	Channel Depth

Section Data		
Mannings Coefficient	0.080	
Slope	0.001500	ft/ft
Water Surface Elevation	1.82	ft
Elevation Range	0.00 to 4.00	
Discharge	26.43	cfs



Bioswale (Section 3) - 100YR
Worksheet for Irregular Channel

Project Description	
Worksheet	Bioswale (Section 3) - 100YR
Flow Element	Irregular Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Slope	0.001500	ft/ft
Discharge	39.32	cfs

Options	
Current Roughness Method	Improved Lotter's Method
Open Channel Weighting Method	Improved Lotter's Method
Closed Channel Weighting Metho	Horton's Method

Results		
Mannings Coefficient	0.080	
Water Surface Elevation	2.22	ft
Elevation Range	0.00 to 4.00	
Flow Area	42.0	ft²
Wetted Perimeter	28.34	ft
Top Width	27.79	ft
Actual Depth	2.22	ft
Critical Elevation	0.71	ft
Critical Slope	0.113302	ft/ft
Velocity	0.94	ft/s
Velocity Head	0.01	ft
Specific Energy	2.24	ft
Froude Number	0.13	
Flow Type	Subcritical	

Roughness Segments

Start Station	End Station	Mannings Coefficient
0+00	0+07	0.035
0+07	0+35	0.080
0+35	0+42	0.035

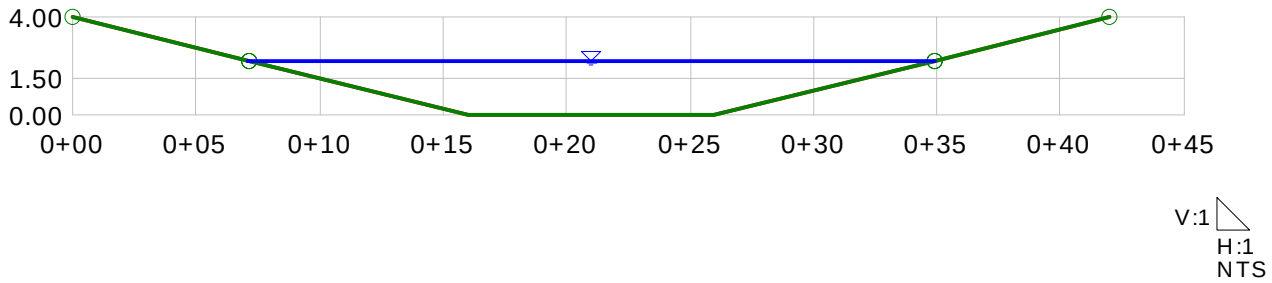
Natural Channel Points

Station (ft)	Elevation (ft)
0+00	4.00
0+07	2.22
0+16	0.00
0+26	0.00
0+35	2.22
0+42	4.00

Bioswale (Section 3) - 100YR Cross Section
Cross Section for Irregular Channel

Project Description	
Worksheet	Bioswale (Section 3) - 100YR
Flow Element	Irregular Channel
Method	Manning's Formula
Solve For	Channel Depth

Section Data		
Mannings Coefficient	0.080	
Slope	0.001500	ft/ft
Water Surface Elevation	2.22	ft
Elevation Range	0.00 to 4.00	
Discharge	39.32	cfs



Bioswale (Section 3) - 100YR (DCD Normal Operation)
Worksheet for Irregular Channel

Project Description	
Worksheet	Bioswale (Section 3) - 100YR (DCD=25cfs)
Flow Element	Irregular Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Slope	0.001500	ft/ft
Discharge	47.01	cfs

Options	
Current Roughness Method	Improved Lotter's Method
Open Channel Weighting Method	Improved Lotter's Method
Closed Channel Weighting Metho	Horton's Method

Results		
Mannings Coefficient	0.078	
Water Surface Elevation	2.39	ft
Elevation Range	0.00 to 4.00	
Flow Area	46.9	ft²
Wetted Perimeter	29.74	ft
Top Width	29.15	ft
Actual Depth	2.39	ft
Critical Elevation	0.79	ft
Critical Slope	0.103836	ft/ft
Velocity	1.00	ft/s
Velocity Head	0.02	ft
Specific Energy	2.41	ft
Froude Number	0.14	
Flow Type	Subcritical	

Roughness Segments

Start Station	End Station	Mannings Coefficient
0+00	0+07	0.035
0+07	0+35	0.080
0+35	0+42	0.035

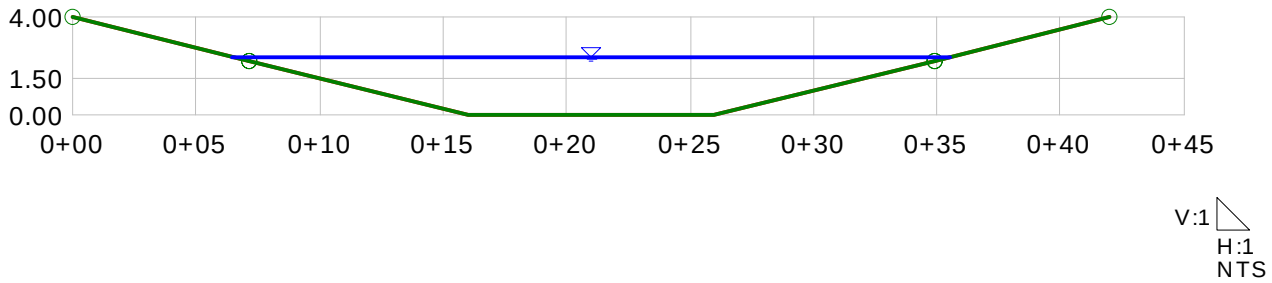
Natural Channel Points

Station (ft)	Elevation (ft)
0+00	4.00
0+07	2.22
0+16	0.00
0+26	0.00
0+35	2.22
0+42	4.00

Bioswale (Section 3) - 100YR (DCD Normal Operation) Cross Section
Cross Section for Irregular Channel

Project Description	
Worksheet	Bioswale (Section 3) - 100YR (DCD=25cfs)
Flow Element	Irregular Channel
Method	Manning's Formula
Solve For	Channel Depth

Section Data		
Mannings Coefficient	0.078	
Slope	0.001500	ft/ft
Water Surface Elevation	2.39	ft
Elevation Range	0.00 to 4.00	
Discharge	47.01	cfs



Bioswale (Section 3) - 100YR (DCD Normal Operation+Flood)
Worksheet for Irregular Channel

Project Description	
Worksheet	Bioswale (Section 3) - 100YR (DCD=25cfs+Flood
Flow Element	Irregular Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Slope	0.001500	ft/ft
Discharge	70.01	cfs

Options	
Current Roughness Method	Improved Lotter's Method
Open Channel Weighting Method	Improved Lotter's Method
Closed Channel Weighting Metho	Horton's Method

Results		
Mannings Coefficient	0.074	
Water Surface Elevation	2.83	ft
Elevation Range	0.00 to 4.00	
Flow Area	60.3	ft²
Wetted Perimeter	33.33	ft
Top Width	32.64	ft
Actual Depth	2.83	ft
Critical Elevation	1.00	ft
Critical Slope	0.087474	ft/ft
Velocity	1.16	ft/s
Velocity Head	0.02	ft
Specific Energy	2.85	ft
Froude Number	0.15	
Flow Type	Subcritical	

Roughness Segments

Start Station	End Station	Mannings Coefficient
0+00	0+07	0.035
0+07	0+35	0.080
0+35	0+42	0.035

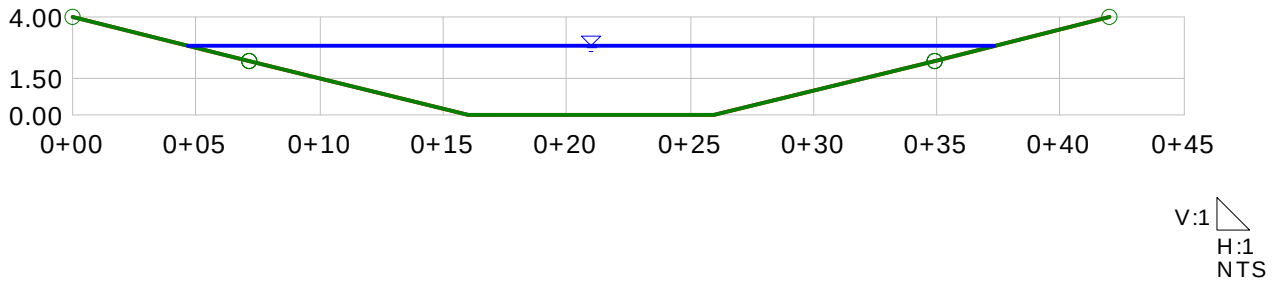
Natural Channel Points

Station (ft)	Elevation (ft)
0+00	4.00
0+07	2.22
0+16	0.00
0+26	0.00
0+35	2.22
0+42	4.00

Bioswale (Section 3) - 100YR (DCD Normal Operation+Flood) Cross Section
Cross Section for Irregular Channel

Project Description	
Worksheet	Bioswale (Section 3) - 100YR (DCD=25cfs+Flood
Flow Element	Irregular Channel
Method	Manning's Formula
Solve For	Channel Depth

Section Data		
Mannings Coefficient	0.074	
Slope	0.001500	ft/ft
Water Surface Elevation	2.83	ft
Elevation Range	0.00 to 4.00	
Discharge	70.01	cfs



Bioswale (Section 3) - 100YR (DCD Full Decreed Flow)
Worksheet for Irregular Channel

Project Description	
Worksheet	Bioswale (Section 3) - 100YR (DCD=71cfs)
Flow Element	Irregular Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Slope	0.001500	ft/ft
Discharge	87.88	cfs

Options	
Current Roughness Method	Improved Lotter's Method
Open Channel Weighting Method	Improved Lotter's Method
Closed Channel Weighting Metho	Horton's Method

Results		
Mannings Coefficient	0.072	
Water Surface Elevation	3.11	ft
Elevation Range	0.00 to 4.00	
Flow Area	69.8	ft²
Wetted Perimeter	35.66	ft
Top Width	34.89	ft
Actual Depth	3.11	ft
Critical Elevation	1.14	ft
Critical Slope	0.079830	ft/ft
Velocity	1.26	ft/s
Velocity Head	0.02	ft
Specific Energy	3.14	ft
Froude Number	0.16	
Flow Type	Subcritical	

Roughness Segments

Start Station	End Station	Mannings Coefficient
0+00	0+07	0.035
0+07	0+35	0.080
0+35	0+42	0.035

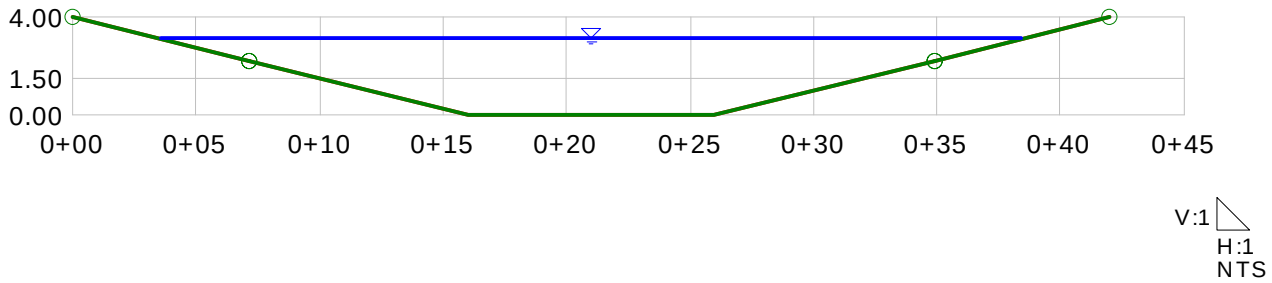
Natural Channel Points

Station (ft)	Elevation (ft)
0+00	4.00
0+07	2.22
0+16	0.00
0+26	0.00
0+35	2.22
0+42	4.00

Bioswale (Section 3) - 100YR (DCD Full Decreed Flow) Cross Section
Cross Section for Irregular Channel

Project Description	
Worksheet	Bioswale (Section 3) - 100YR (DCD=71cfs)
Flow Element	Irregular Channel
Method	Manning's Formula
Solve For	Channel Depth

Section Data		
Mannings Coefficient	0.072	
Slope	0.001500	ft/ft
Water Surface Elevation	3.11	ft
Elevation Range	0.00 to 4.00	
Discharge	87.88	cfs



Bioswale (Section 3) - 100YR (DCD Full Decreed Flow+Flood)
Worksheet for Irregular Channel

Project Description	
Worksheet	Bioswale (Section 3) - 100YR (DCD=71cfs+Flood
Flow Element	Irregular Channel
Method	Manning's Formula
Solve For	Channel Depth

Input Data		
Slope	0.001500	ft/ft
Discharge	110.88	cfs

Options	
Current Roughness Method	Improved Lotter's Method
Open Channel Weighting Method	Improved Lotter's Method
Closed Channel Weighting Metho	Horton's Method

Results		
Mannings Coefficient	0.070	
Water Surface Elevation	3.43	ft
Elevation Range	0.00 to 4.00	
Flow Area	81.2	ft²
Wetted Perimeter	38.25	ft
Top Width	37.41	ft
Actual Depth	3.43	ft
Critical Elevation	1.30	ft
Critical Slope	0.072814	ft/ft
Velocity	1.37	ft/s
Velocity Head	0.03	ft
Specific Energy	3.45	ft
Froude Number	0.16	
Flow Type	Subcritical	

Roughness Segments

Start Station	End Station	Mannings Coefficient
0+00	0+07	0.035
0+07	0+35	0.080
0+35	0+42	0.035

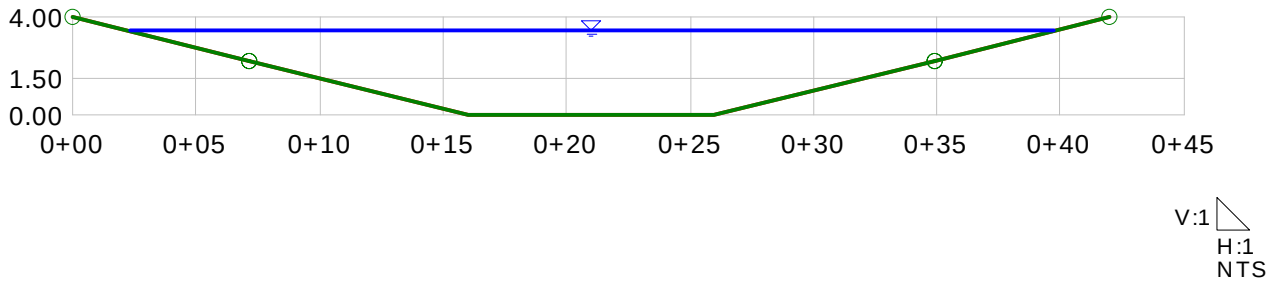
Natural Channel Points

Station (ft)	Elevation (ft)
0+00	4.00
0+07	2.22
0+16	0.00
0+26	0.00
0+35	2.22
0+42	4.00

Bioswale (Section 3) - 100YR (DCD Full Decreed Flow+Flood) Cross Section
Cross Section for Irregular Channel

Project Description	
Worksheet	Bioswale (Section 3) - 100YR (DCD=71cfs+Flood
Flow Element	Irregular Channel
Method	Manning's Formula
Solve For	Channel Depth

Section Data		
Mannings Coefficient	0.070	
Slope	0.001500	ft/ft
Water Surface Elevation	3.43	ft
Elevation Range	0.00 to 4.00	
Discharge	110.88	cfs



Design Procedure Form: Constructed Wetlands Channel (CWC) - Sedimentation Facility

Designer: Jim Brzostowicz
Company: Drexel, Barrell & Co
Date: April 26, 2010
Project: Hogan Pancost
Location: Boulder County

1. Design Discharge (total)	Q_2 = 26 cfs Q_{100} = 111 cfs
2. Channel Geometry (New Channel - No Wetland Veg. in Bottom)	
A) Channel Side Slopes (Z:1, i.e., H/V) (Z $\geq$ 2.5)	Z = 4.0 (horizontal/vertical)
B) 2-Year Design Flow Depth (D_2) Maximum D_2 = 4', Minimum D_2 = 2'	D_2 = 2.0 feet
C) Idealized Depth of the channel (D_{2i}) - 2-foot to 4-foot	D_{2i} = 2.0 feet
C) Idealized Bottom width of the channel (B_{2i}) - 8-foot minimum	B_{2i} = 8.0 feet
D) Idealized Top width of the 2-Year Design Water Surface (W_{2i})	W_{2i} = 24.0 feet
3. Longitudinal Slope (Based on a Manning's n = 0.035 for the idealized channel, velocity set to 2 fps, minimum slope = 0.001)	S = 0.0015 feet/feet
4. Final Channel Goemetry - Wetland Vegetation in Bottom) (Based on a Manning's n = 0.08)	
A) Calculated channel geometry required to maintain design discharge during a 2-year event with newly established and mature vegetation. Calculated resulting flow velocities. Max. mature velocities should be kept to 1 fps or less for the 2-year flow.	
B) Geometry and velocity to use for the 100-year discharge: Suggest the design for a 100-year capacity channel follow the guidance contained in the Major Drainage chapter of Volume 1 of the USDCM, or through the use of the UD-CHANNELS workbook.	
5. Number of grade control structures required	_____ number
6. Vegetation (Check the type or describe "Other")	_____ Native Grass _____ Irrigated Turf Grass _____ Wetland Species _____ Other: _____

	New 2-Yr. Channel		Mature 2-Yr. Channel	
D_2 =	2.0	feet	2.0	feet
B_2 =	8.0	feet	8.0	feet
W_2 =	24.1	feet	24.0	feet
Q_2 =	64	cfs	28	cfs
V_2 =	2.0	fps	0.9	fps

Notes: CONCEPT ONLY TO VERIFY OVERALL CHANNEL WIDTH…….NOT FOR FINAL DESIGN OR ANALYSIS