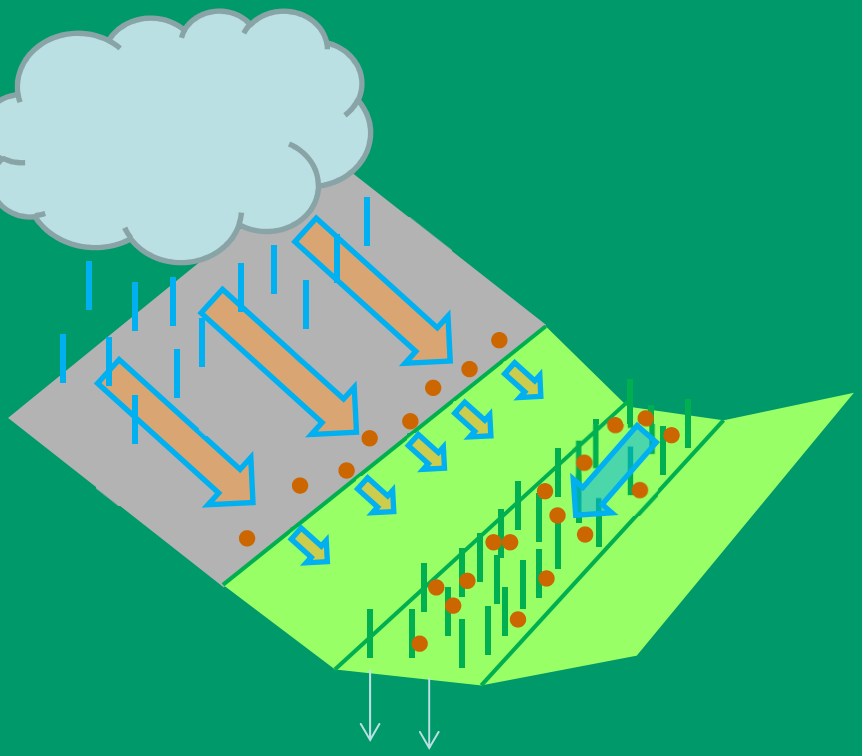
Vegetated Biofilter Design

Vegetated Biofilter

- L&D Vol. 2 Section 1117.2.2
- Provides quality treatment only

Vegetated Biofilter Treatment Processes



Design Process

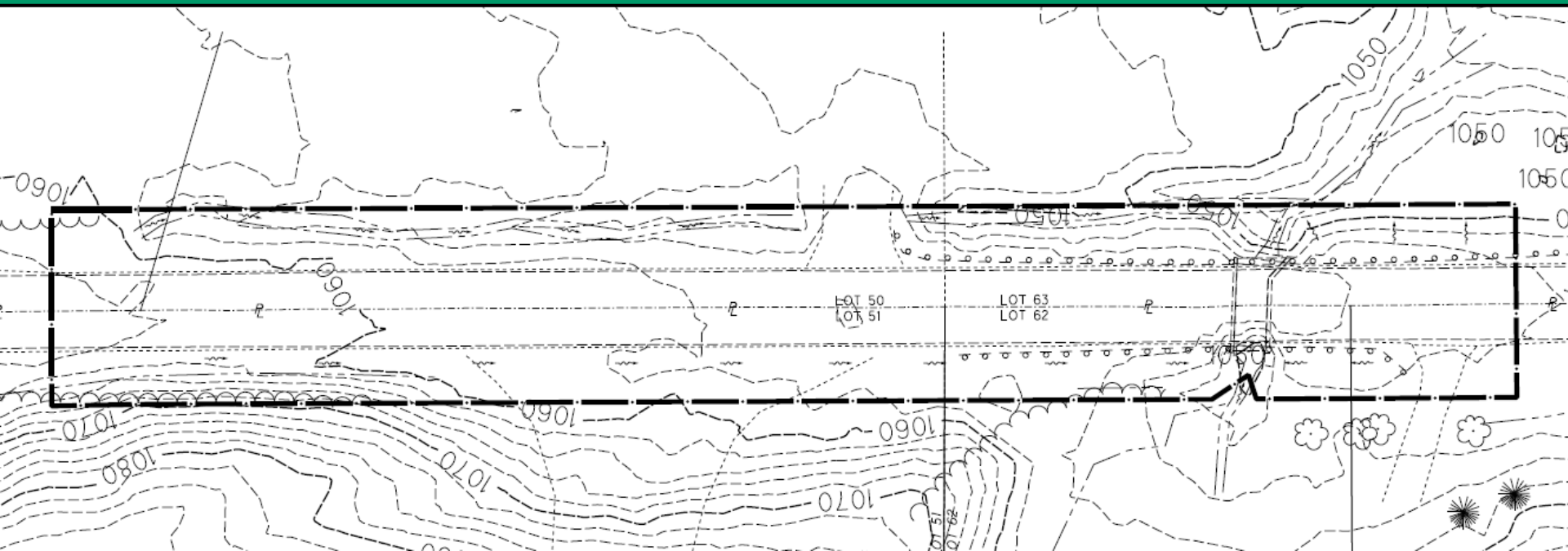
- Treatment Goals
- Siting Analysis
- Veg. Biofilter Sizing
- Other Considerations

Design Process

- Treatment Goals
- Siting Analysis
- Veg. Biofilter Sizing
- Other Considerations

Project Example

- Rural highway redevelopment
- Improve shoulders
- All within existing right-of-way



Project Example – Treatment Goals

- Project EDA = 3.0 ac
- All within existing right-of-way
- A_{ix} = 3.0 ac; A_{in} = 0.0 ac
- T% = [(A_{ix} x 20)+(A_{in} x 100)] / (A_{ix} + A_{in})
- T% = [(3.0 x 20)+(0.0 x 100)] / (3.0 + 0)
- T% = 20%
- 20% x 3.0 ac = <u>0.6 ac</u>

Project Example – Treatment Goals

- **Project EDA = 3.0 ac >= 1 ac**
  - Need a post-construction BMP
- **All redevelopment**
  - Need to treat 0.6 ac (20%)
- **All in existing right-of-way**
  - All existing right-of-way considered impervious
  - Therefore no “new impervious area in new permanent right-of-way”
  - Water quality treatment only required

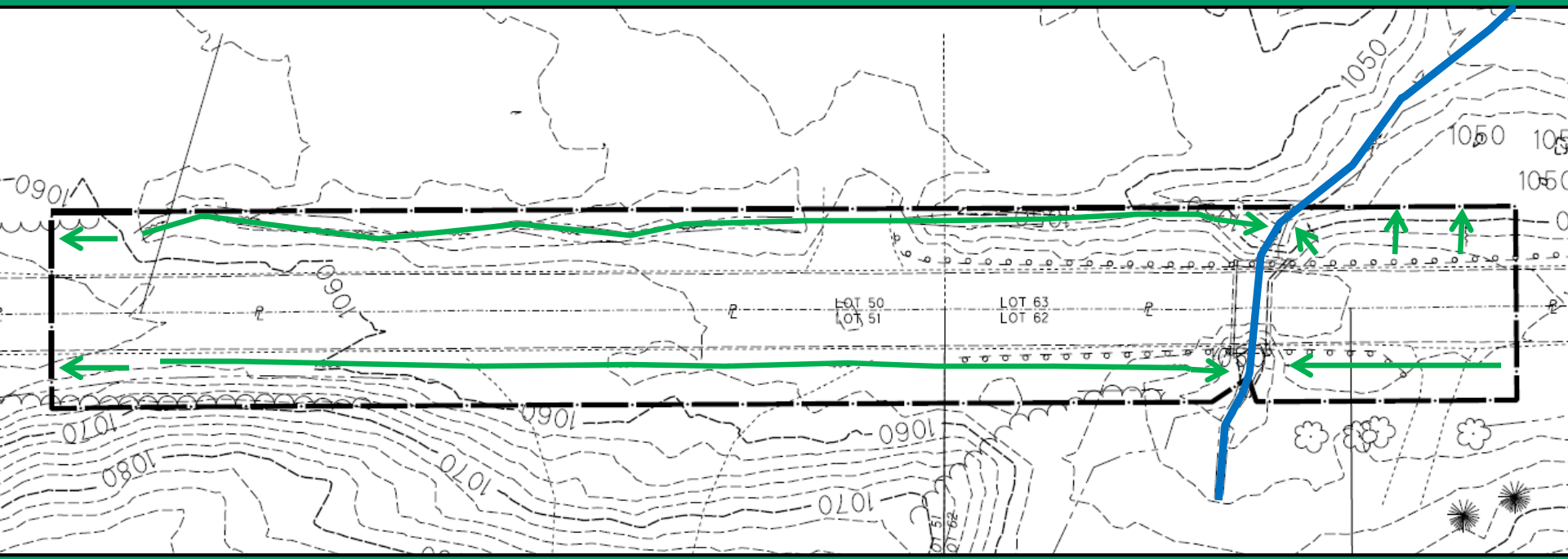
Design Process

- Treatment Goals
- Siting Analysis
- Veg. Biofilter Sizing
- Other Considerations

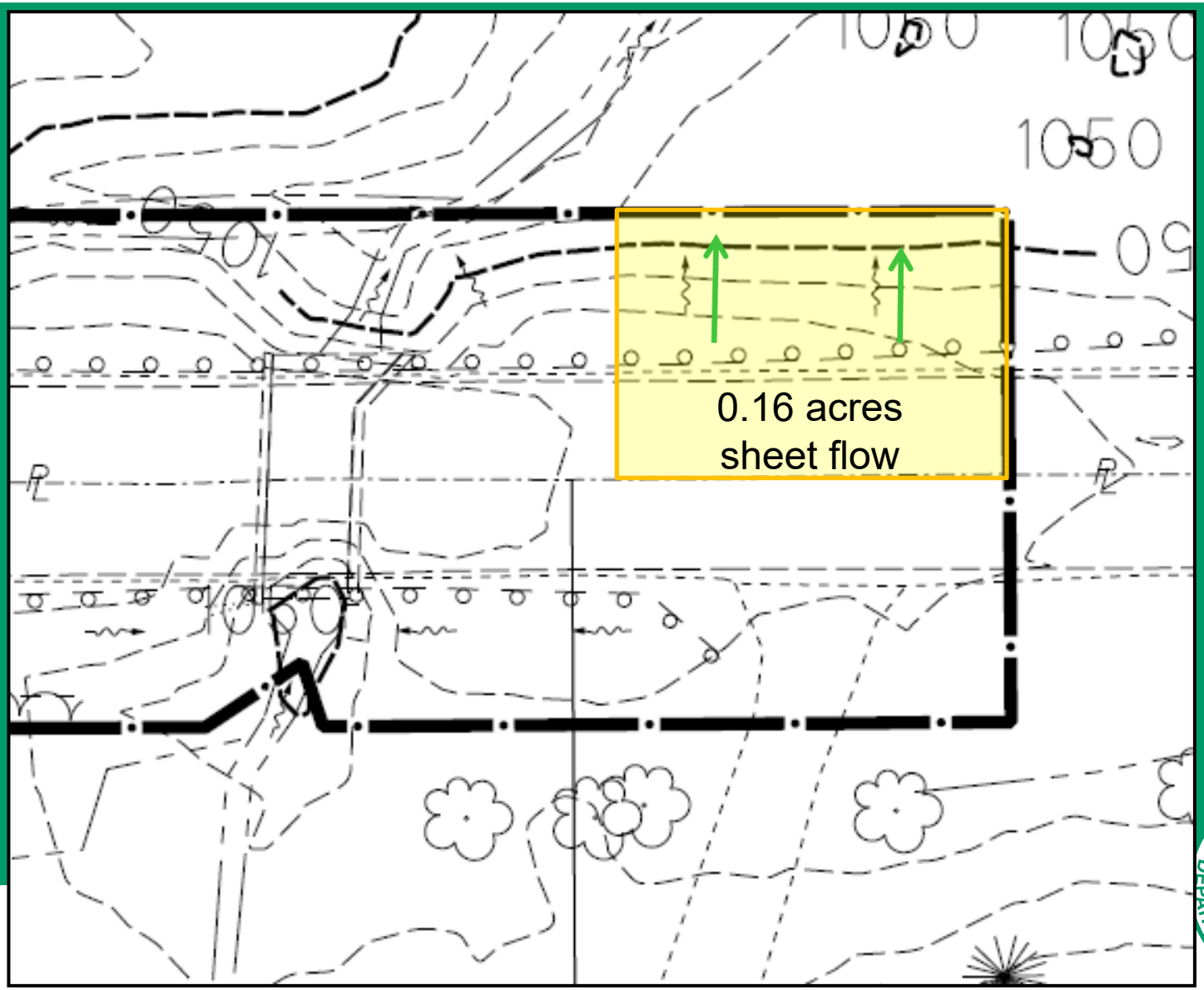
Siting Analysis

- Vegetated biofilters are at least 4 ft wide
- Veg. biofilters should receive unconcentrated flow along fore slope
- Look for existing grass ditches to make a little wider
- Use only if vegetated filter strip does not fit

Siting Analysis



Sheet Flow



Sheet Flow

- **L&D 1116.1**
  - "For projects where the drainage sheet flows off the roadway and continues outside existing or proposed right-of-way, do not channelize flow for the sole purpose of providing a post-construction BMP. Treatment is not required for areas where sheet flow off the roadway continues to sheet flow outside ODOT right-of-way. Areas where this occurs should be documented in the post-construction BMP calculations and identified on the Project Site Plan."

Treatment Goals - Updated

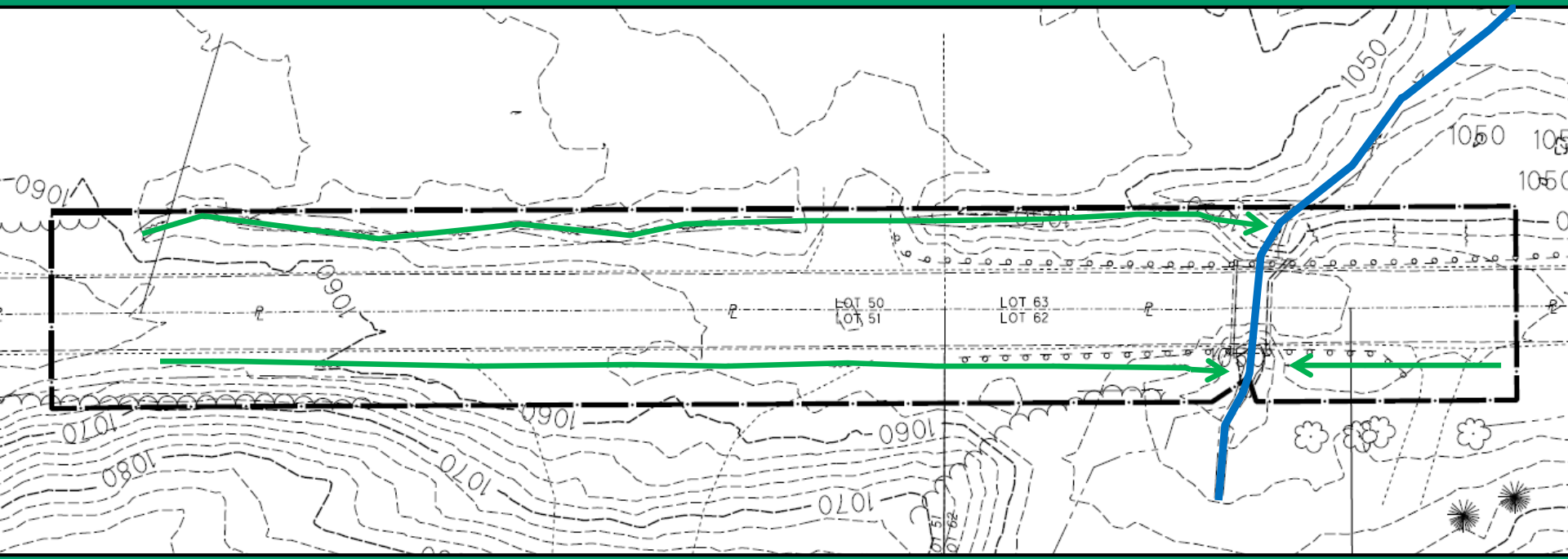
- Treatment not required for 0.16 ac sheet flow
- (Project EDA – sheet flow) * T%
- (3.0 ac – 0.16ac) * 20% = 0.57 ac

- WARNING! Not This Way
- (3.0 ac * 20%) – 0.16 ac = 0.44 ac

Design Process

- Treatment Goals
- Siting Analysis
- Veg. Biofilter Sizing
- Other Considerations

Siting Analysis

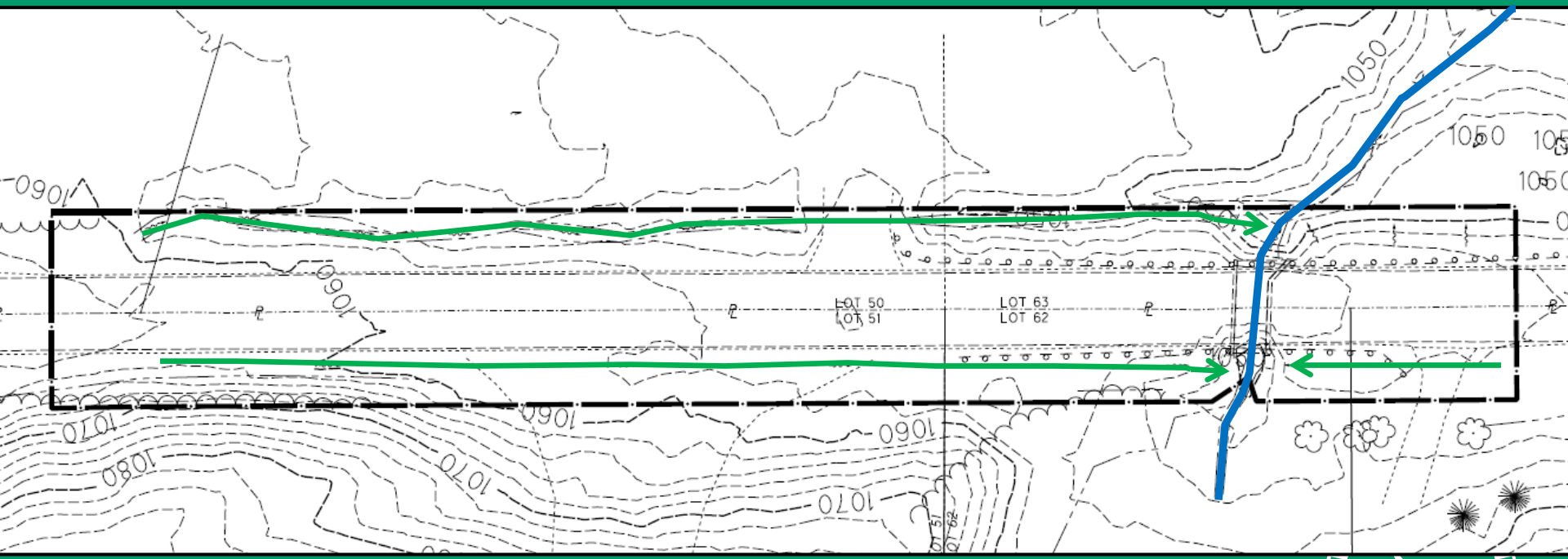


Design Process

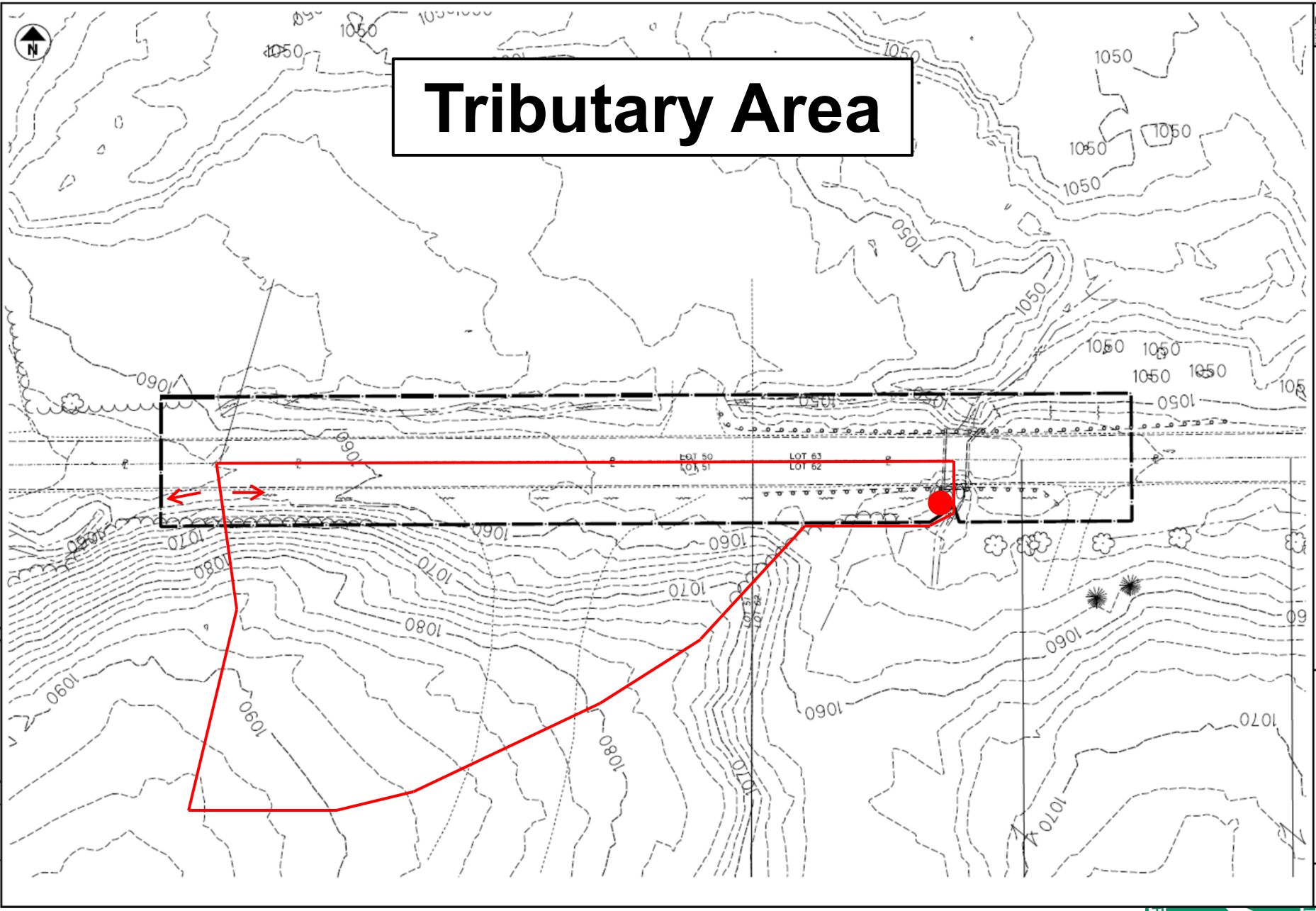
- Treatment Goals
- Siting Analysis
- Veg. Biofilter Sizing
- Other Considerations

Veg. Biofilter Sizing

- Size a vegetated biofilter for each ditch and pick the best one for the project.

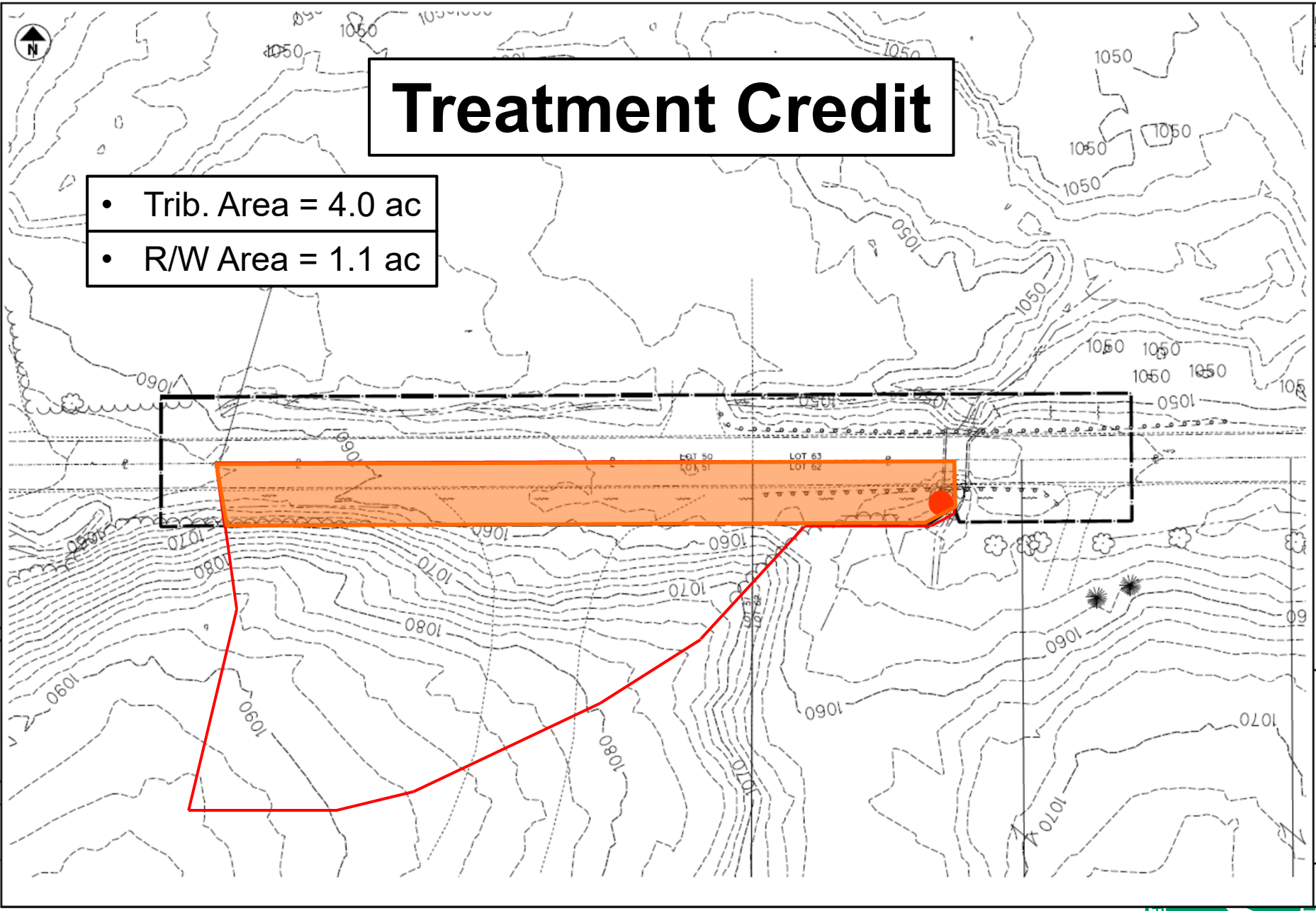


Tributary Area



Treatment Credit

- Trib. Area = 4.0 ac
- R/W Area = 1.1 ac



Coefficient of Runoff – WQ_F BMP

- Right-of-Way = 1.1 ac; C = 0.9
- Woods = 2.9 ac; C = 0.3
- Weighted C = [(1.1*0.9)+(2.9*0.3)] / (1.1+2.9) = 0.465

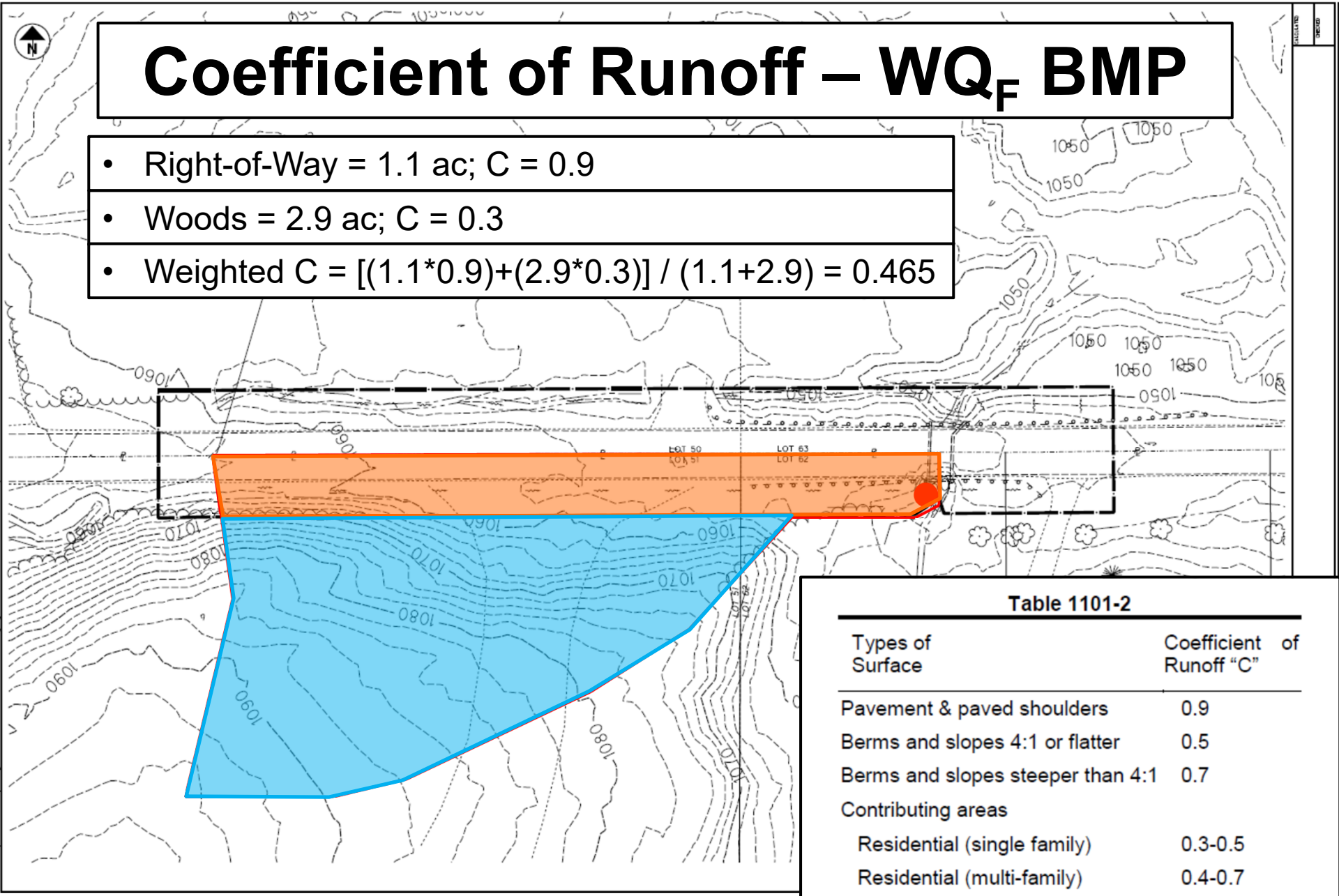
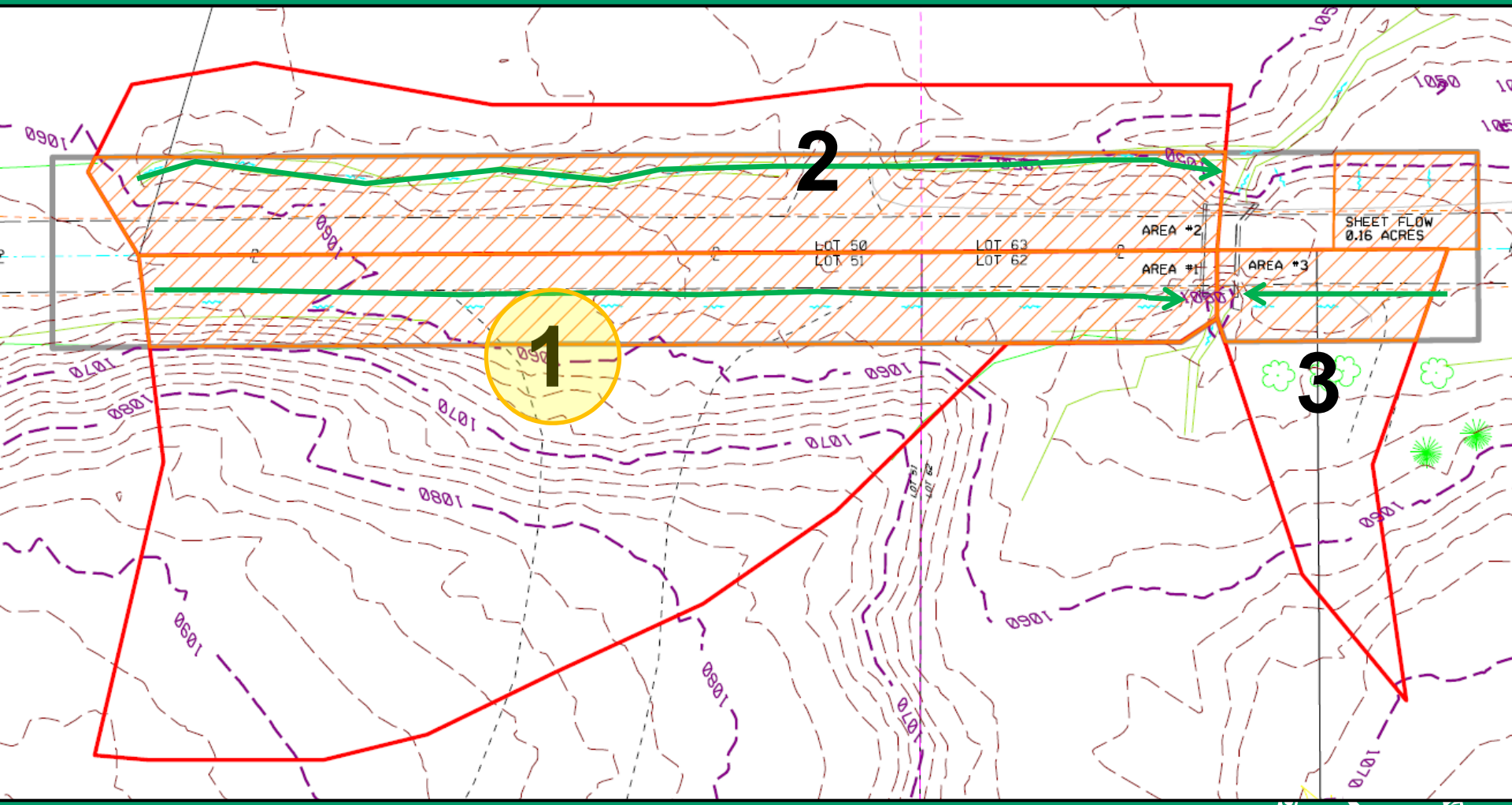


Table 1101-2

Types of Surface	Coefficient of Runoff "C"
Pavement & paved shoulders	0.9
Berms and slopes 4:1 or flatter	0.5
Berms and slopes steeper than 4:1	0.7
Contributing areas	
Residential (single family)	0.3-0.5
Residential (multi-family)	0.4-0.7
Woods	0.3
Cultivated	0.3-0.6

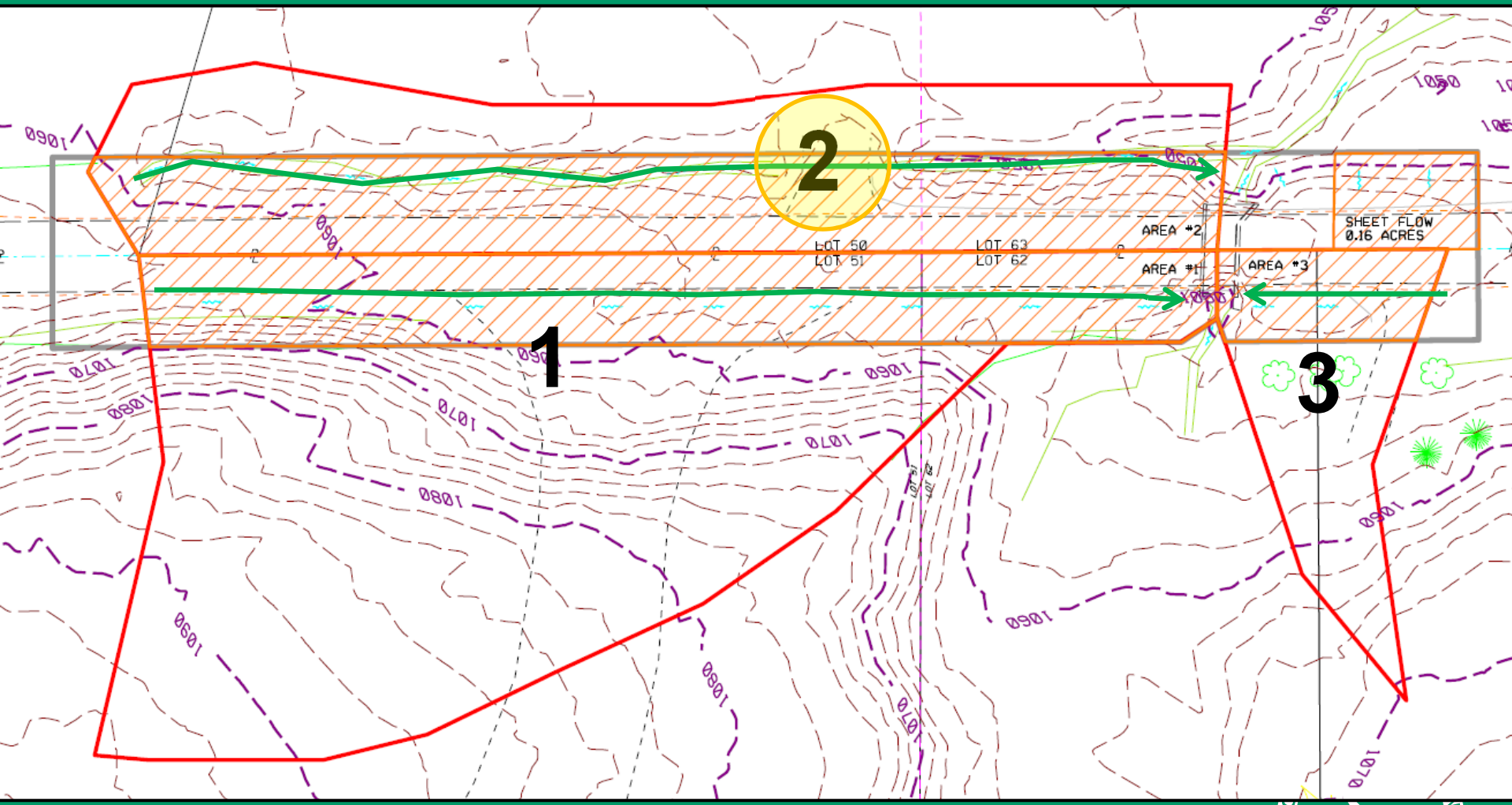
Veg. Biofilter Sizing



Veg. Biofilter Sizing

- **Area 1 (4.0 ac):**
  - 1.1 ac within R/W; C=0.9
  - 2.9 ac woods; C=0.3
  - (1.1ac * 0.9 + 2.9ac * 0.3) / 4.0 ac
  - Weighted C = 0.465
  - WQ_F = 0.465 * 0.65in/hr * 4.0ac = 1.209 cfs
  - Treatment credit = 1.1 ac
  - 1.1 ac > 0.57 ac

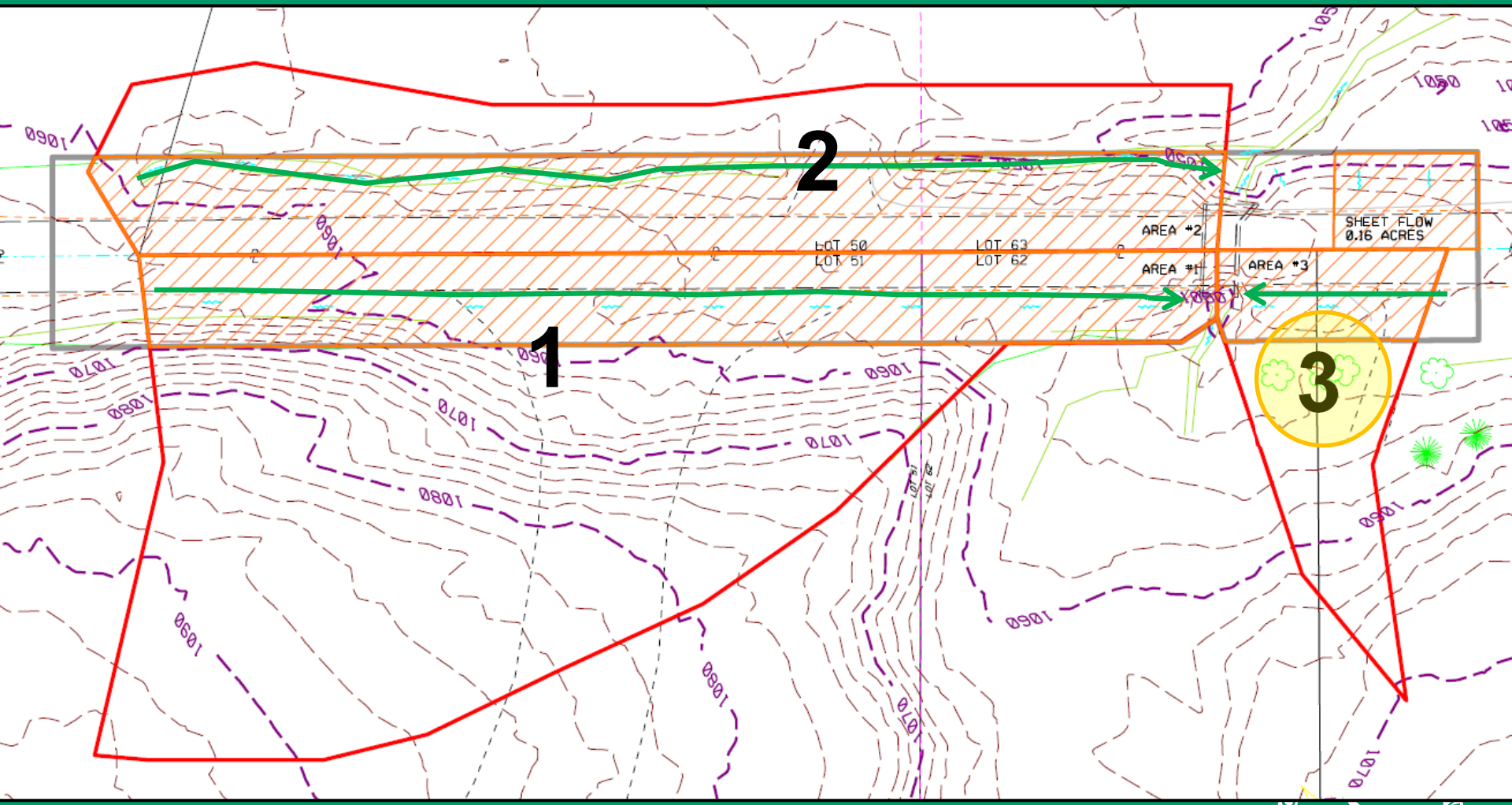
Veg. Biofilter Sizing



Veg. Biofilter Sizing

- **Area 2 (2.1 ac):**
  - 1.3 ac within R/W; C=0.9
  - 0.8 ac woods; C=0.3
  - (1.3ac * 0.9 + 0.8ac * 0.3) / 2.1 ac
  - Weighted C = 0.67
  - WQF = 0.67 * 0.65in/hr * 2.1ac = 0.915 cfs
  - Treatment credit = 1.3 ac
  - 1.3 ac > 0.57 ac

Veg. Biofilter Sizing



Veg. Biofilter Sizing

- **Area 3 (0.6 ac):**
  - 0.2 ac within R/W
  - Since 0.2 ac < 0.57 ac treatment requirement, don't go any further

Veg. Biofilter Sizing

- **Determine vegetated biofilter bottom width for Area 1 and Area 2: Manning's Equation:**

Manning's Equation:

$$Q = \frac{1.49}{n} * AR^{2/3} * S^{1/2}$$

Where:

Q = flow rate (cfs)

n = Manning's Roughness Coefficient (0.15 for Vegetated Biofilter)

A = Cross section area of flow (ft^2)

R = Hydraulic Radius (ft) (Area / Wetted Perimeter)

S = Longitudinal Slope of ditch (ft/ft)

Veg. Biofilter Sizing

$$Q = \frac{1.49}{n} * AR^{2/3} * S^{1/2}$$

- Q = WQ_F calculated using Rational Method **Project Specific**

- n = 0.15 (for flow within height of grass)
- Depth <= 4 inches
- Velocity <= 1 fps

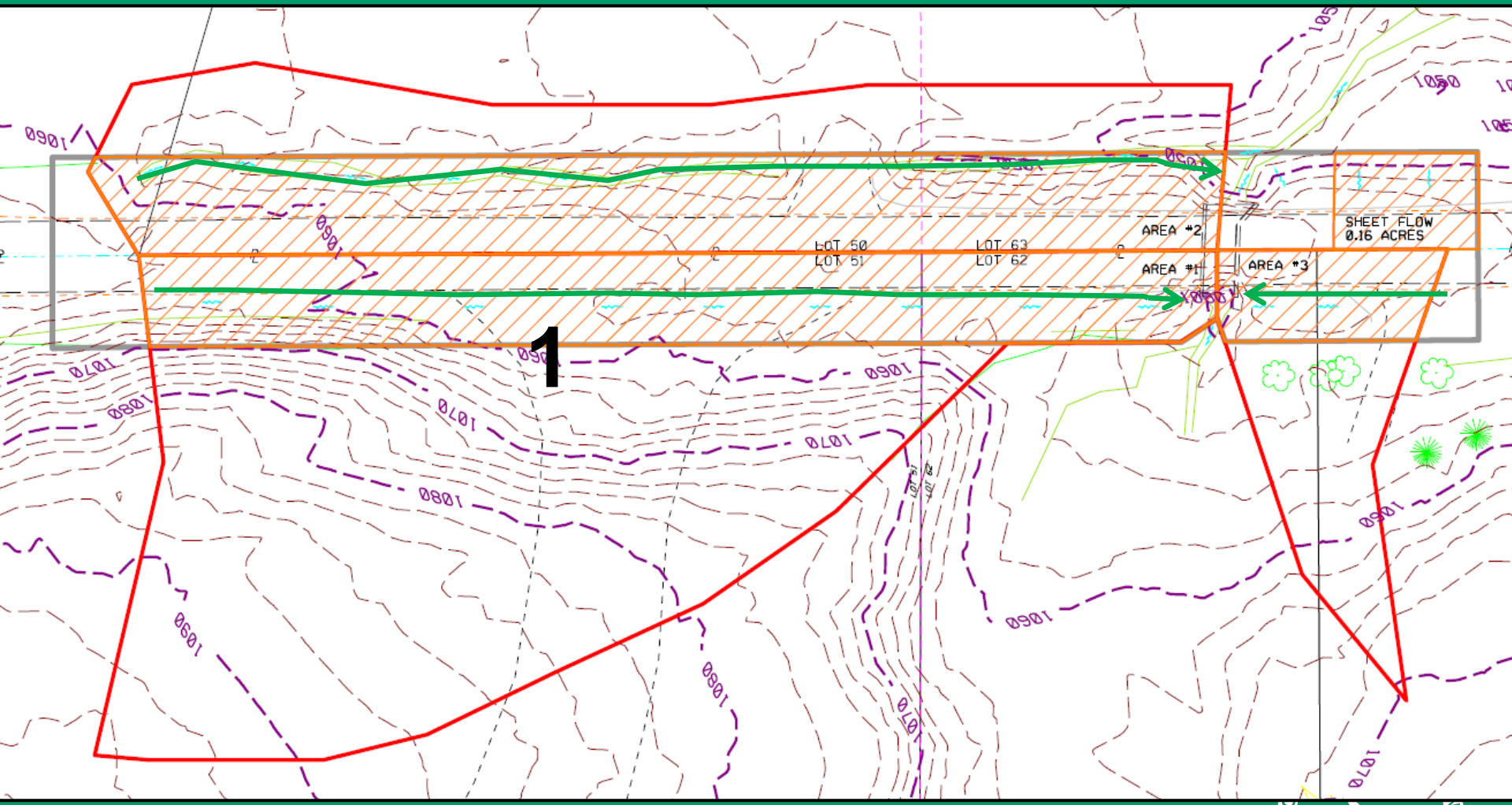
  Specified in L&D

Veg. Biofilter Sizing

- **Use a program or spreadsheet, given:**
  - Q
  - n
  - Channel geometry
  - Longitudinal slope
- **Calculate**
  - Normal depth
  - Average velocity

$$Q = \frac{1.49}{n} * AR^{2/3} * S^{1/2}$$

Veg. Biofilter Sizing



Veg. Biofilter Sizing – Area 1

- Longitudinal slope = 0.01 ft/ft
- Assume fore slope = 2:1
- Assume back slope = 2:1
- Manning's n = 0.15
- Q = 1.209 cfs
- Use trial and error until you find a bottom with that gives a velocity <= 1 fps and a depth <= 4 in

Veg. Biofilter Sizing – Area 1

- See FHWA Hydraulic Toolbox 4.20
- See Excel spreadsheet

ODOT Design Resources

- BMP_Calcs_(Updated Jan 2019).xls

ODOT Design Resources

Ohio Department of Transportation - Office of Hydraulic Engineering

Post-Construction BMP Calculation Spreadsheet

Vegetated Biofilter

Location Information					Hydrology			Channel Characteristics					Analysis Results			
VBF	Route	Begin Station	End Station	Side	Total Tributary Area (acres)	Tributary Area in ODOT R/W (acres)[1]	WQ_F (cfs)	VBF Bottom Width (ft)[note2]	VBF Fore Slope (z:1)	VBF Back Slope (z:1)	VBF Longitudinal Slope (ft/ft)	Manning's Roughness Coefficient[3]	Depth of Runoff at WQ_F (inches)[4]	Velocity of Runoff at WQ_F (ft/sec)[4]	Standard Ditch Width (feet)[5]	Required Ditch Width (feet)
VBF#1	SR XX	01+00	09+00	RT	4.00	1.10	1.209	8	2	2	0.010	0.15	3.83	0.44	2	8
VBF#2												0.15				
VBF#3												0.15				
VBF#4												0.15				
VBF#5												0.15				
VBF#6												0.15				
VBF#7												0.15				
VBF#8												0.15				
VBF#9												0.15				
VBF#10												0.15				

Total Treatment Credit from VBFs (within R/W): 1.10 acres

(Treatment is for quality only, not quantity)

ODOT Design Resources

Ohio Department of Transpor
Post-Construction

Calculating Normal Depth in a Trapezoidal Channel (Knowing Flow Rate)
Bisection Method

Manning's Equation
Q=(1.49/N)*A*R^(2/3)*(So)^(1/2)

Q cfs	1.209	flow rate
So ft/ft	0.010	slope
N	0.15	Manning's Roughness
B ft	8	Bottom Width
Z1	2	Fore Slope (Z:1)
Z2	2	Back Slope (Z:1)

(The Solution is at the Bottom-Right)

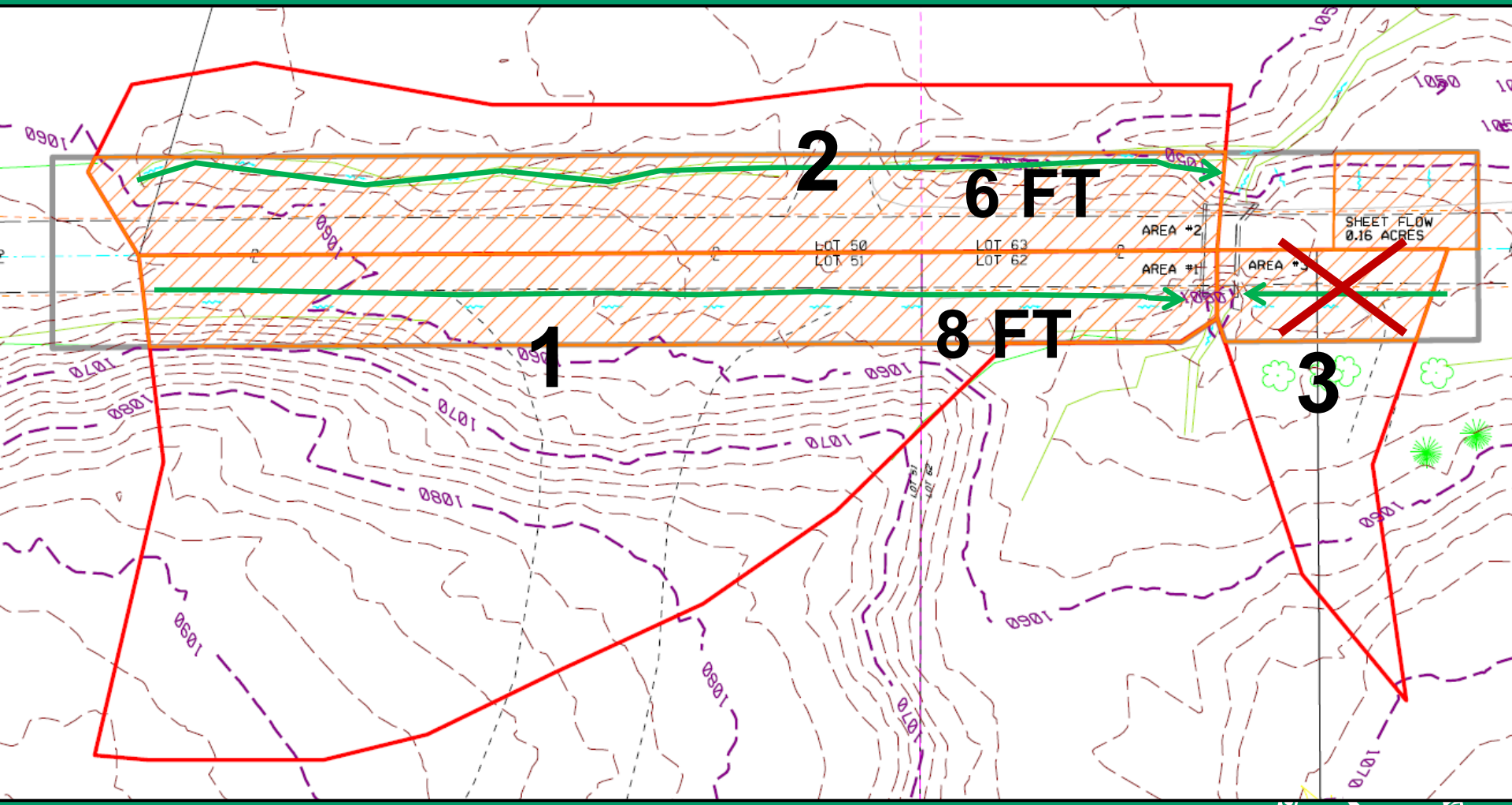
Rearrange Manning's Equation. When the equation equals zero,
(Q*N)/(1.49*So^(1/2)) - A*R^(2/3) = 0

	Q	So	N	B	Z1	Z2	Choose the next depth based on the bisection result. Low Guess: Depth ft (XI)	Function ft (FXI)	Area SF	Wet. Perin ft	HydRad ft	Choose the next depth based on the b High Guess: Depth ft (Xu)	Function ft (FXu)	Are SF
1	1.209	0.01	0.15	8	2	2	0.0001	1.2171	0.0008	8.0004	0.0001	10.0000	-851.1087	280.0
2	1.209	0.01	0.15	8	2	2	0.0001	1.2171	0.0008	8.0004	0.0001	5.0001	-184.5087	90.00
3	1.209	0.01	0.15	8	2	2	0.0001	1.2171	0.0008	8.0004	0.0001	2.5001	-44.9777	32.50
4	1.209	0.01	0.15	8	2	2	0.0001	1.2171	0.0008	8.0004	0.0001	1.2501	-11.6083	13.12
5	1.209	0.01	0.15	8	2	2	0.0001	1.2171	0.0008	8.0004	0.0001	0.6251	-2.5964	5.78
6	1.209	0.01	0.15	8	2	2	0.3126	0.0443	2.6962	9.3980	0.2869	0.6251	-2.5964	5.78

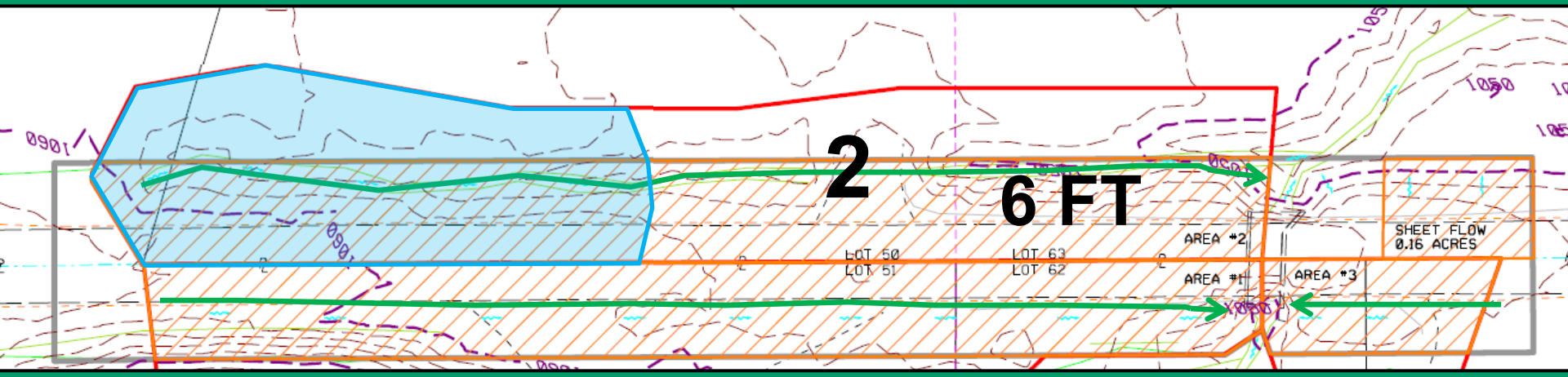
Veg. Biofilter Sizing

Area	Q	s	FS	BS	n	B	Vel.	Depth
	cfs	ft/ft	H:V	H:V		ft	fps	in
1	1.209	0.01	2:1	2:1	0.15	8	0.44	3.83
2	0.915	0.01	2:1	2:1	0.15	6	0.43	3.84

Veg. Biofilter Sizing

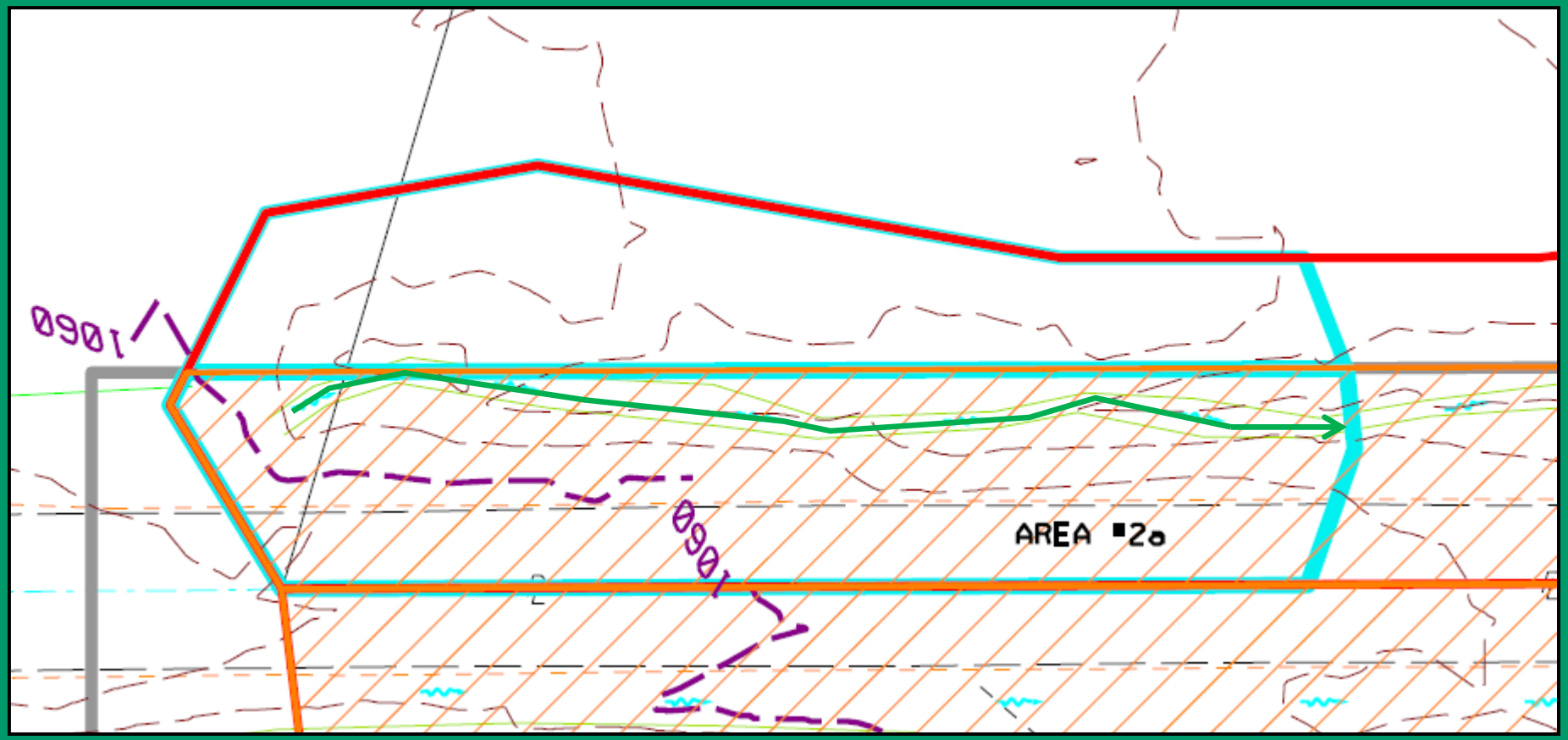


Veg. Biofilter Sizing



- Area 2 treatment credit = 1.3 ac
- Only need 0.57 ac
- Sub-delineate to reduce BMP size

Veg. Biofilter Sizing – Area 2



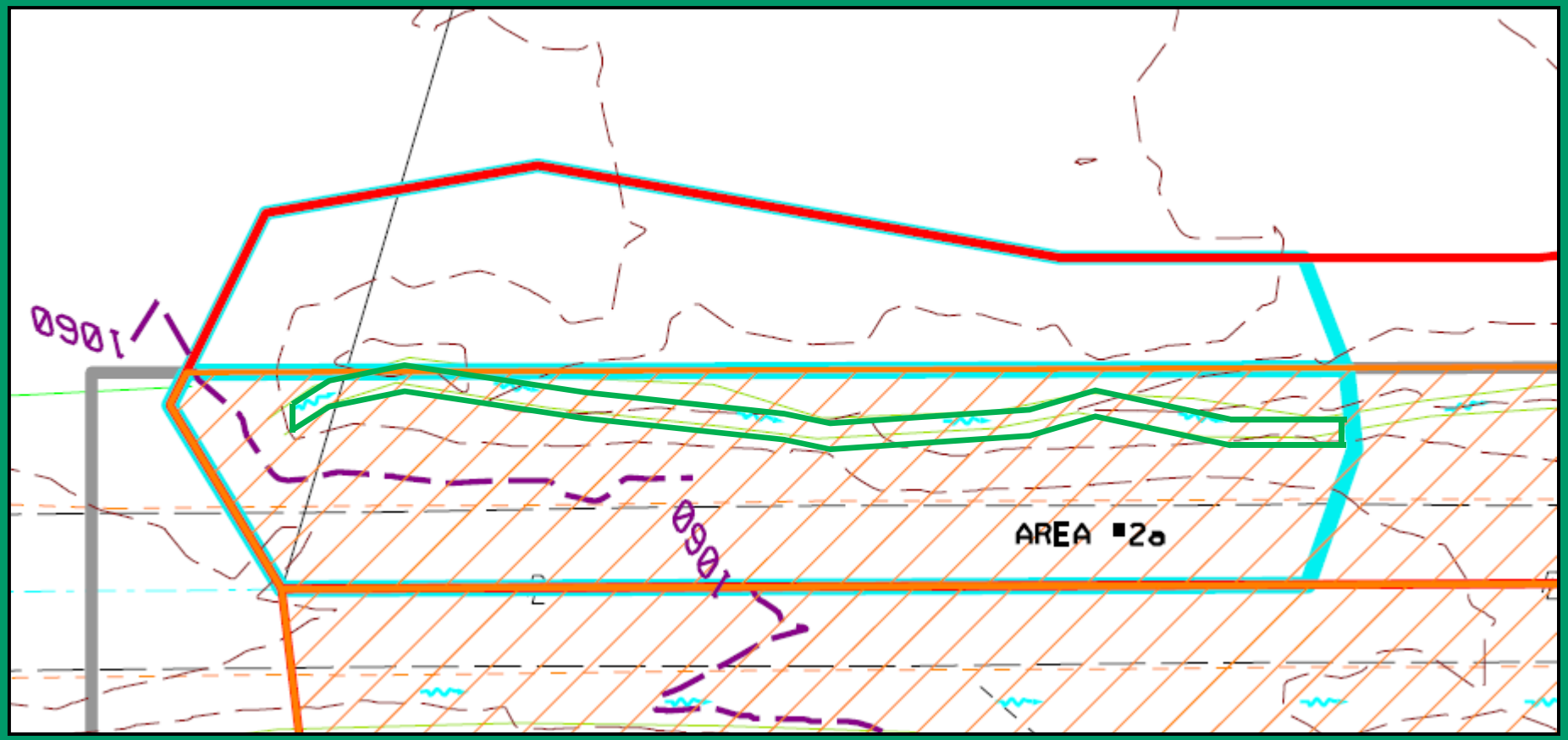
Veg. Biofilter Sizing – Area 2

- **New area = 0.97 ac**
  - 0.57 ac within R/W; C=0.9
  - 0.40 ac woods; C=0.3
  - (0.57 ac * 0.9 + 0.40 ac * 0.3) / 0.97 ac
  - Weighted C = 0.653
  - WQF = 0.653 * 0.65in/hr * 0.97ac = 0.412 cfs
  - Treatment credit = 0.57 ac
  - 0.57 ac = 0.57 ac

Veg. Biofilter Sizing

Area	Q	s	FS	BS	n	B	Vel.	Depth
	cfs	ft/ft	H:V	H:V		ft	fps	in
1	1.209	0.01	2:1	2:1	0.15	8	0.44	3.83
2	0.915	0.01	2:1	2:1	0.15	6	0.43	3.84
2a	0.412	0.01	2:1	2:1	0.15	3	0.39	3.54
2a	0.412	0.01	2:1	2:1	0.15	4	0.36	3.02

Veg. Biofilter Sizing – Area 2



Design Process

- Treatment Goals
- Siting Analysis
- Veg. Biofilter Sizing
- Other Considerations

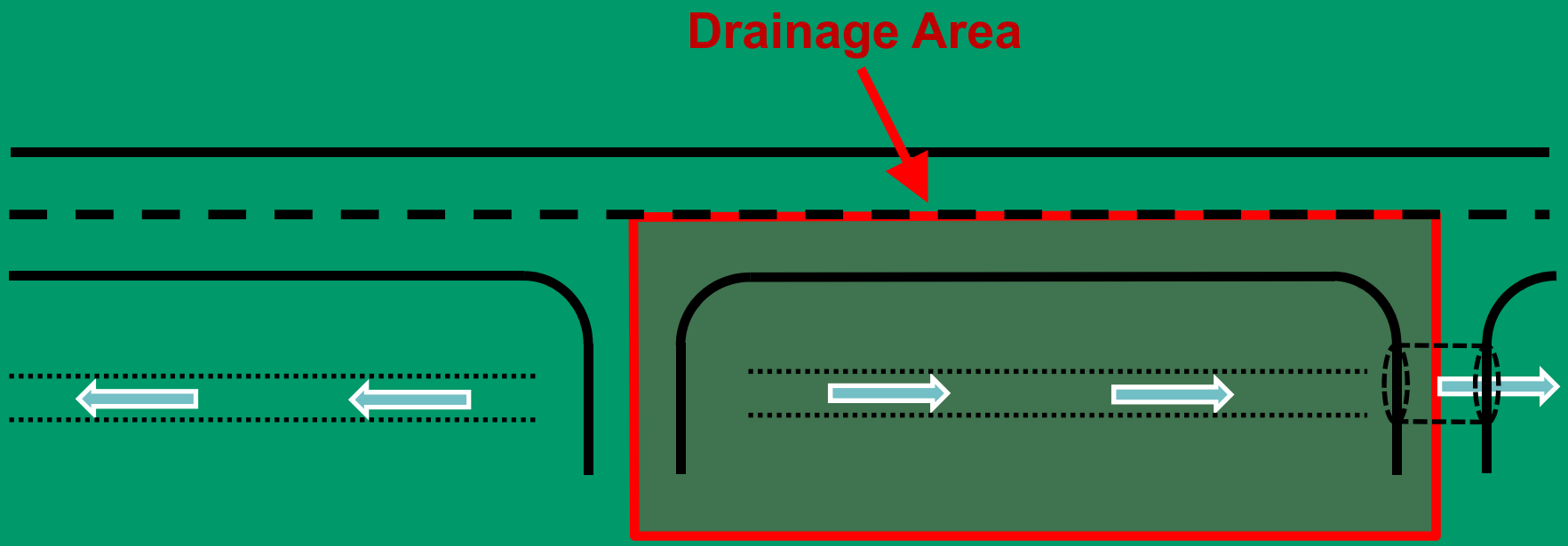
Vegetated Biofilter Treatment Credit

ODOT L&D Vol 2, Section 1117.2.2

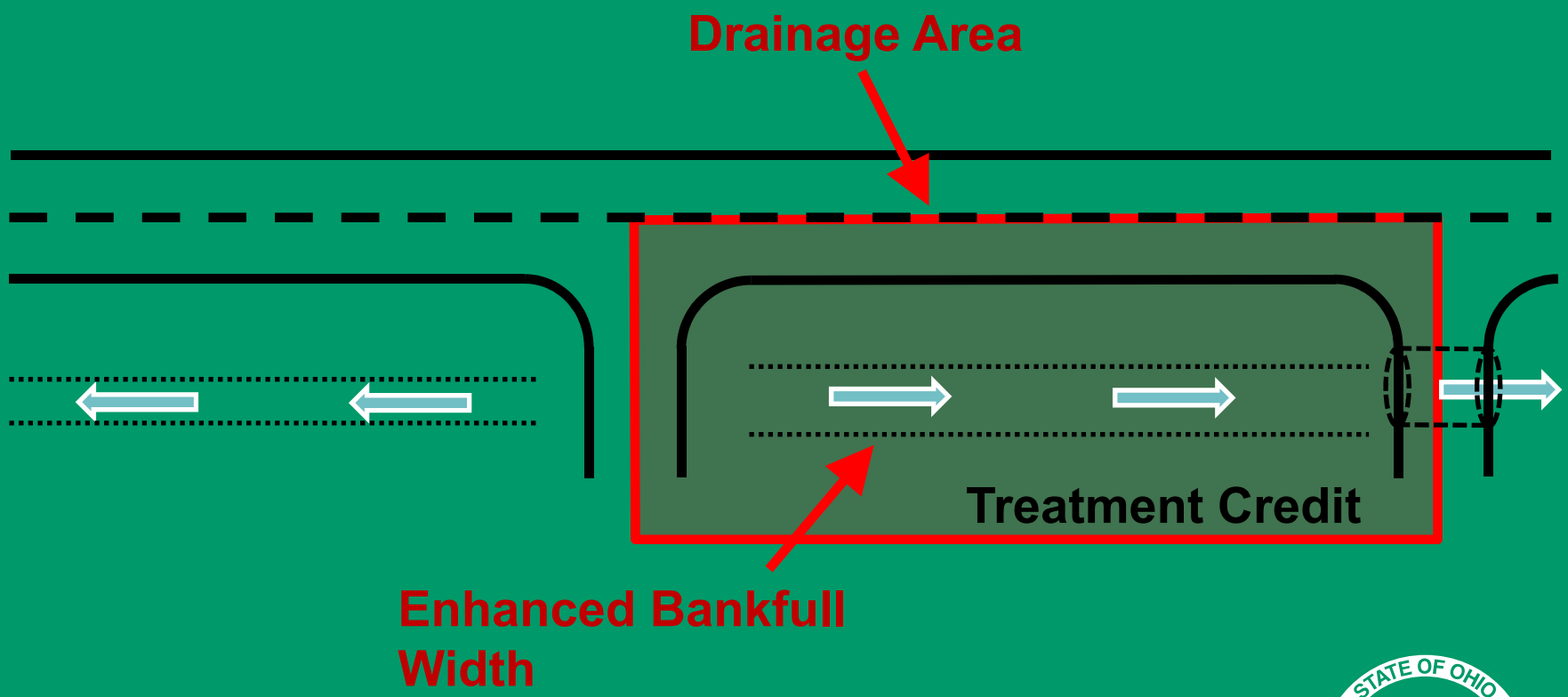
Treatment Credit for Vegetated Biofilter is given to:

1. **Areas within the project limits that sheet flow off of the roadway into a grassed shoulder, grassed foreslope, and then into a grassed trapezoidal ditch sized as described above. (Tributary areas to a Vegetated Biofilter that do not meet this criteria, i.e. drainage from concentrated flow or outside project limits, must be included in the determination of the EBW, but do not receive treatment credit.)**
2. **The area of the defined Vegetated Biofilter (the shoulder, foreslope, ditch bottom, and backslope) within the permanent right-of-way.**

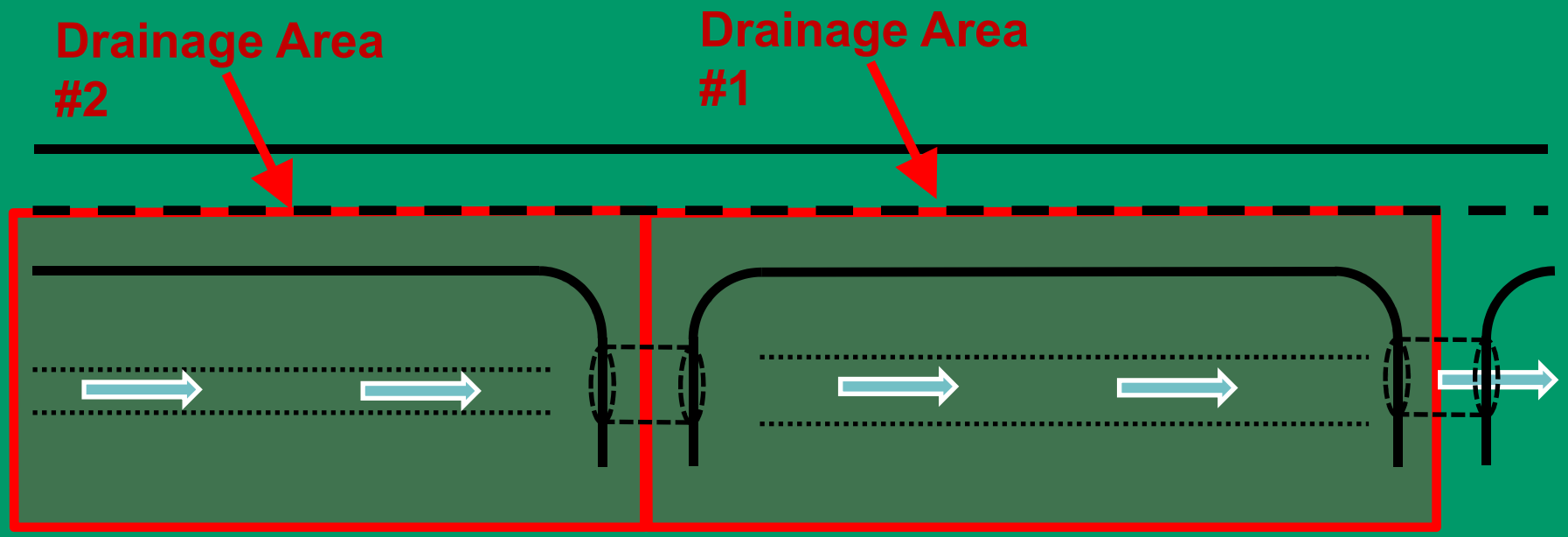
Vegetated Biofilter Credit Example



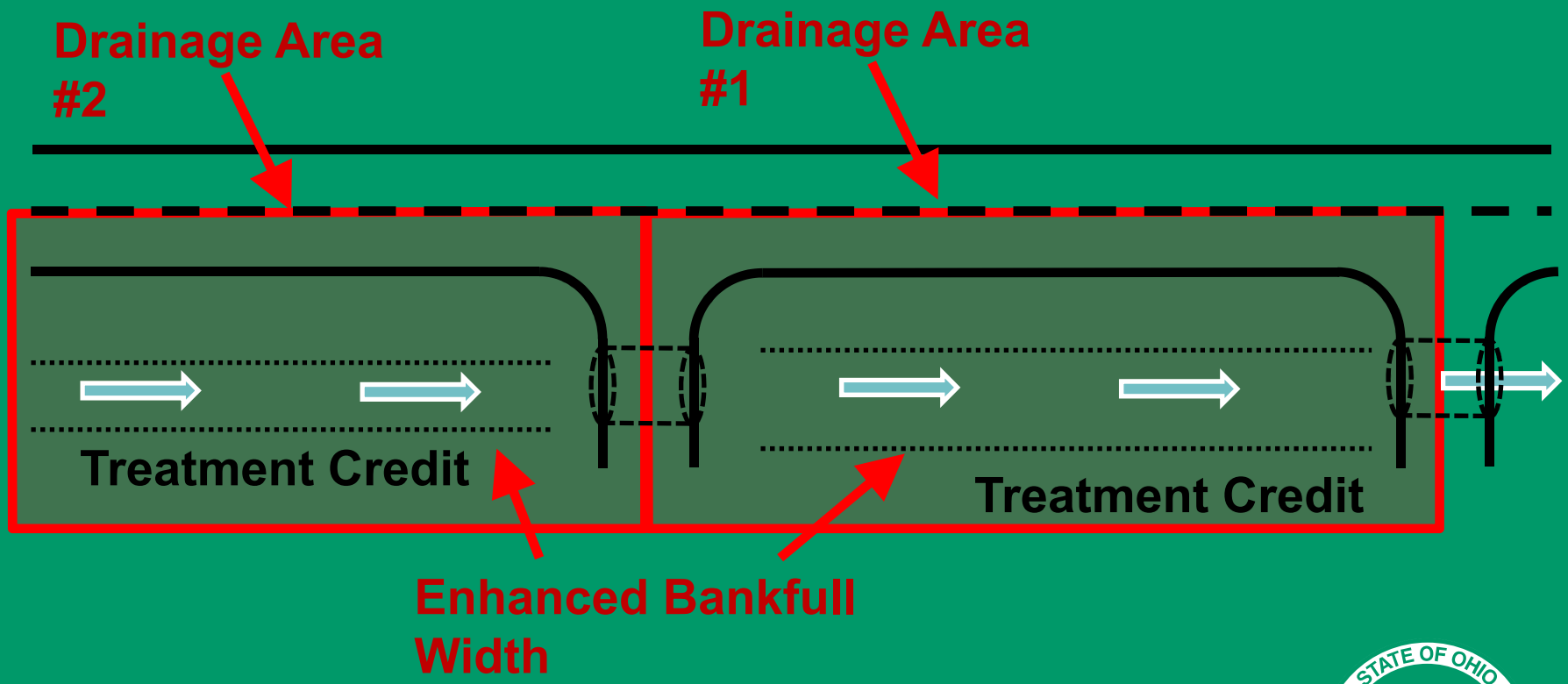
Vegetated Biofilter Credit Example



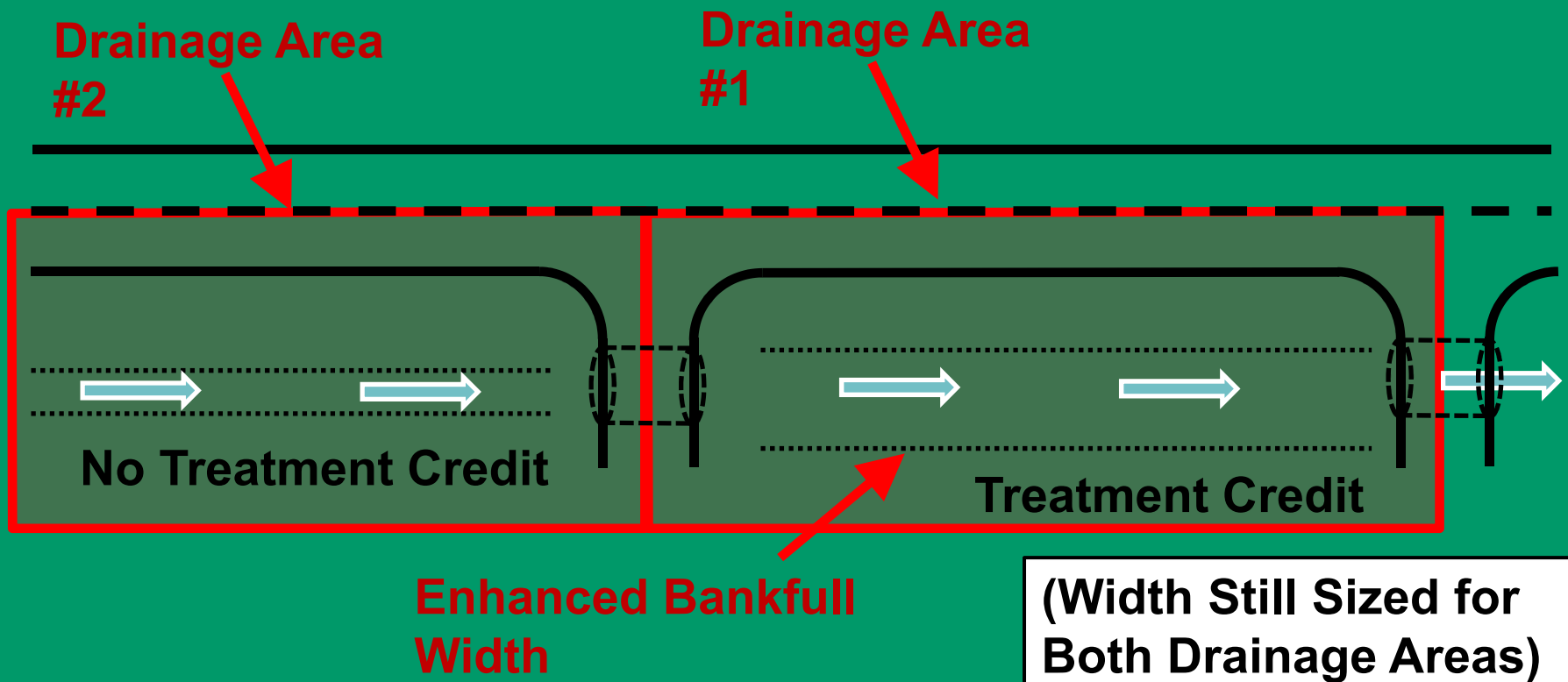
Vegetated Biofilter Credit Example



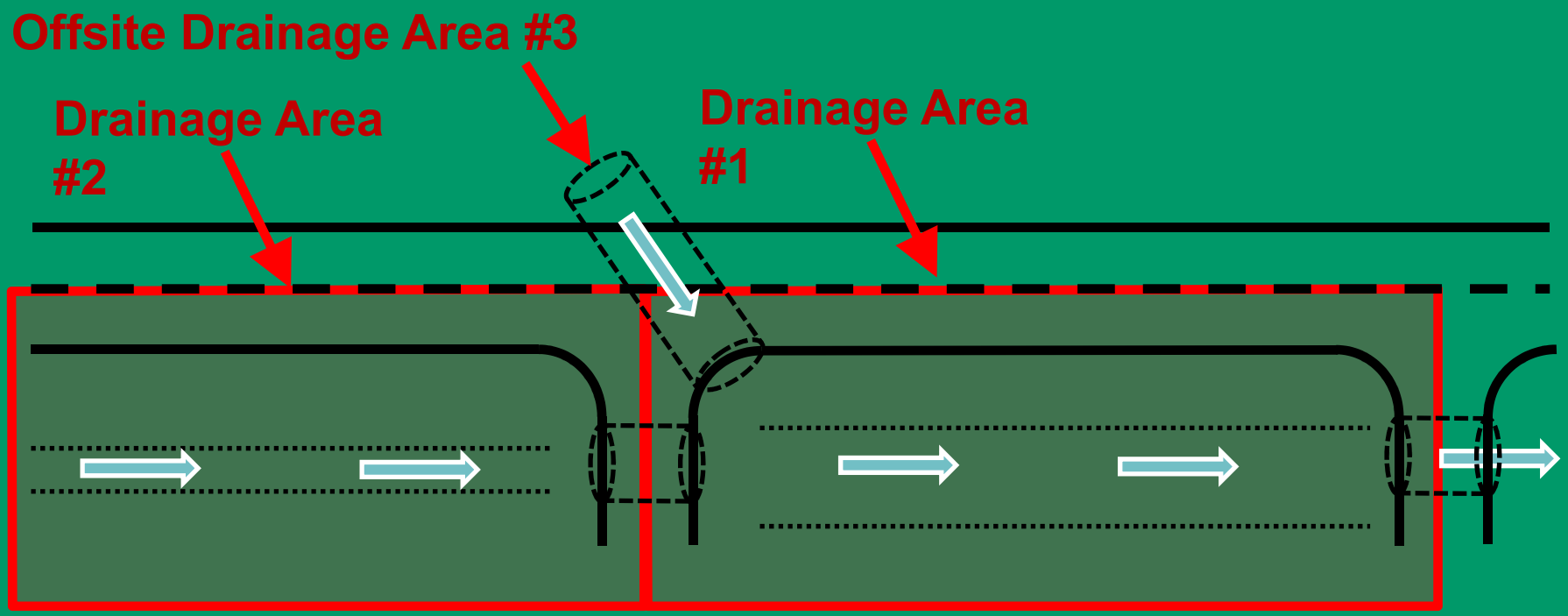
Vegetated Biofilter Credit Example



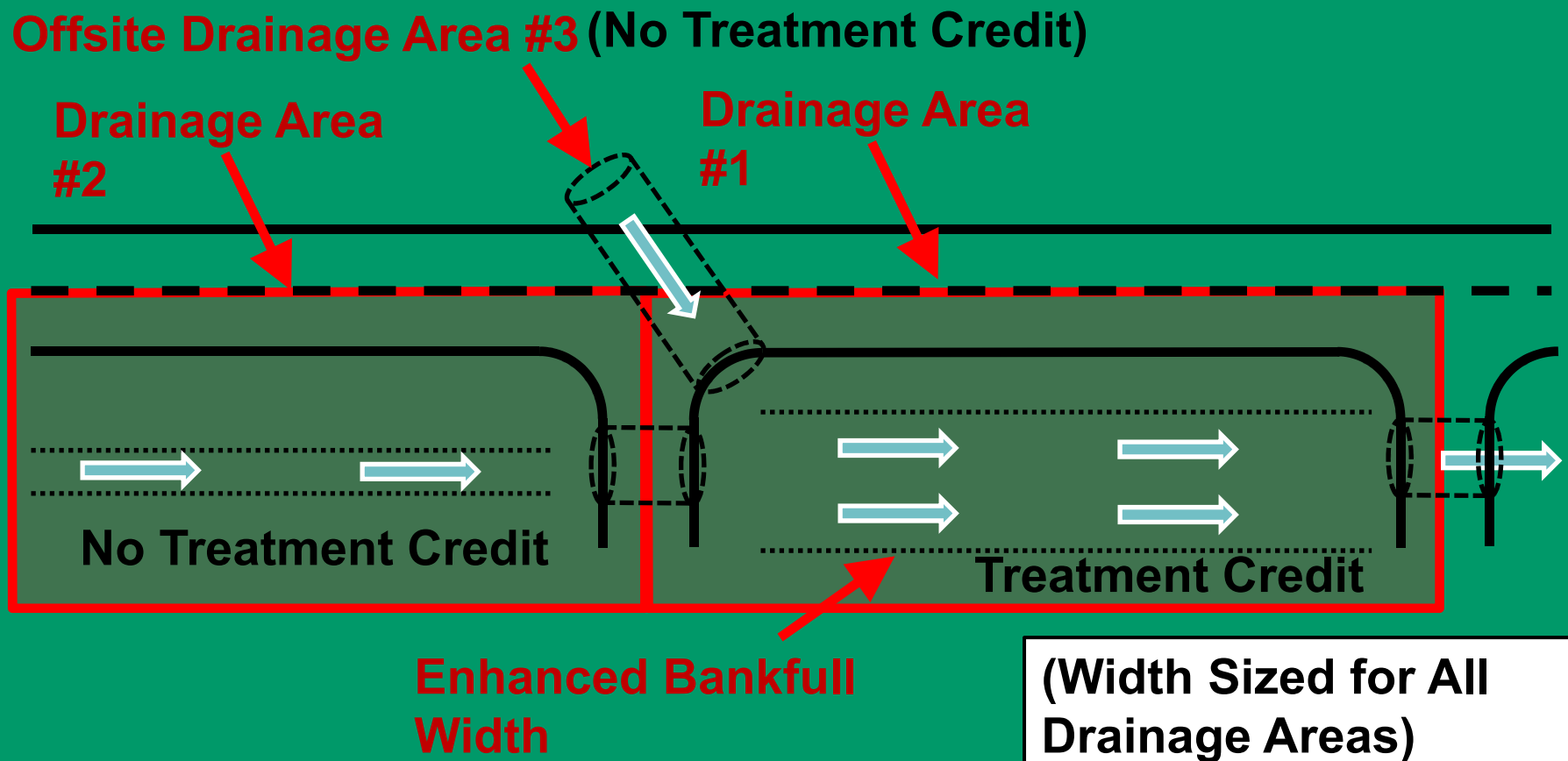
Vegetated Biofilter Credit Example



Vegetated Biofilter Credit Example



Vegetated Biofilter Credit Example



Vegetated Biofilter Plan Components

- Add 4” of Item 659 topsoil to the vegetated portion of the shoulder and foreslope
- Add Item 670, Ditch Erosion Protection
- Show vegetated biofilters on Project Site Plan
- Call out vegetated biofilters on plan / profile sheets
- Call out vegetated biofilters on cross sections

Sample Plan Note

W105 **VEGETATED BIOFILTER**

THIS PLAN UTILIZES VEGETATED BIOFILTER(S) FOR POST CONSTRUCTION STORM WATER TREATMENT. PLACE EITHER ITEM 660 SODDING OR ITEM 659 SEEDING AND MULCHING WITH A 4-INCH LIFT OF TOPSOIL AS SHOWN IN THE PLANS TO ANY DISTURBED AREA ON THE SHOULDER AND FORESLOPE DRAINING TO A VEGETATED BIOFILTER. THE DITCH FOR EACH VEGETATED BIOFILTER SHALL BE TRAPEZOIDAL, AS SHOWN IN THE PLAN CROSS SECTIONS. PROVIDE ITEM 670 AS SPECIFIED IN THE PLANS.

Designer Note: Use this plan note on all projects that have vegetated biofilters identified in the plan. Pay for grass planting and topsoil as Item 659 or Item 660 and include with quantities for the rest of the project. Pay for erosion control mat as Item 670, ditch erosion protection and include with quantities for the rest of the project.

Performance Metrics

- 70% Grass Coverage on Foreslope and Bottom
- No Ruts, Rills, Gullies, or Concentrated Flow
- Flat Ditch Bottom
- Remove Accumulated Trash and Sediment

Initial Grass Establishment
70% Grass Coverage

Initial Grass Establishment
Rills & 70% Grass Coverage

Don’t Mow When Wet
Ruts & 70% Grass

Erosion Protection and Catch Downcutting Early Gullies / Concentrated Flow

Maintain Positive Drainage
Don’t Design too Flat; Clear Downstream

Maintenance

- **Keep Grass Alive**
- **Mow at least Twice a Year**
- **Don’t Mow when Wet**
- **Catch Downcutting Early**
- **After Sediment does Accumulate, must Regrade and Re-establish Grass**
  - Grading Different than Normal Ditching to Get Flat Bottom

Questions ?

Jon Prier, P.E.
jonathan.prier@dot.ohio.gov
614-644-1876