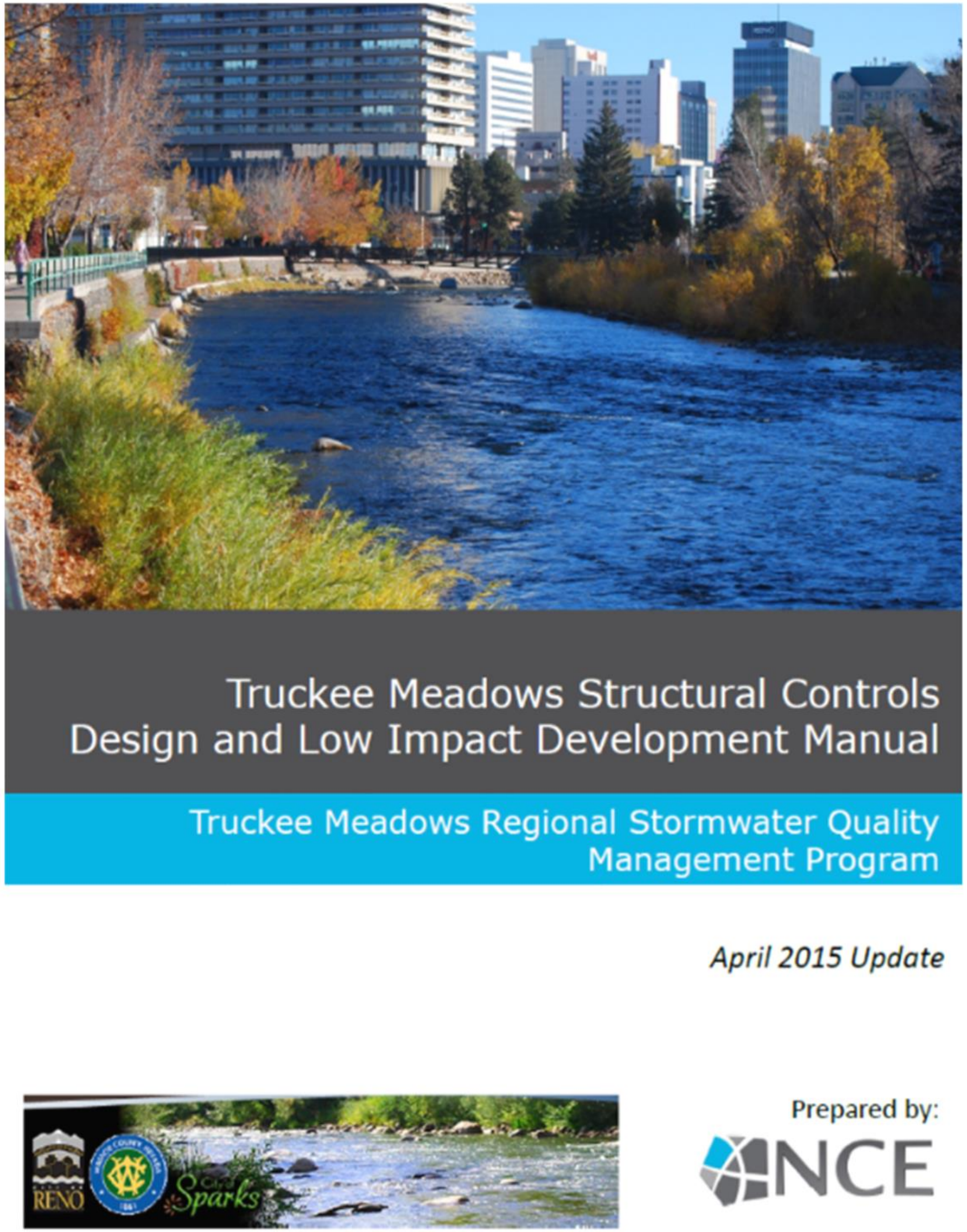
Theresa Jones Introduction



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Truckee Meadows Structural Controls Design and Low Impact Development Manual

Virtual Technical Training

Design Guidance Worksheets Module

Spring 2021

Using the Design Guidance Worksheets

- Truckee Meadows Standard Design Guidance Worksheets
  - Developed as part of the toolkit to assist designers incorporating LID into projects
  - Sufficient engineering analysis must show that the proposed stormwater quality measures are capable of capturing runoff and potential pollutants from the site in compliance with the appropriate jurisdictions Structural Controls Ordinance

  - Worksheet is accessible via Truckee Meadows Stormwater website (tmstormwater.com)
    - http://tmstormwater.com/construction/
    - https://www.reno.gov/home/showdocument?id=55429
      - An excel spreadsheet will download

Truckee Meadows Storm Water Quality Management Program
Design Guidance Worksheet: Sedimentation Basin TC-40

* Fill out worksheet from top to bottom

Designer:

Company:

Date:

Project:

Location:

Key: User Input | Calculated Result | *Italicized Font Indicates Value is Outside Re*

1. Water Quality Volume (WQ_V) - Sedimentation Basin Storage

a) Percent of Watershed Impervious Area = I

b) Drainage Area = A (acres) (43,560 ft^2 = 1 acre)
- minimum drainage area of 5 acres

c) Watershed Runoff Coefficient = R_V (unitless)

d) 90th Percentile Precipitation Depth = P (inches)

e) Water Quality Volume = WQ_V (ft^3)

a)

b) A=

c) R_v =

e) WQ_V =

WQ_V = ft^3

Designer to select value for Water Quality Volume for actual design

2. Outlet Structure

Truckee Meadows Design Guidance Worksheets

These worksheets have been developed for the Cities of Reno and Sparks and Washoe County, NV.
They are to be used with the Truckee Meadows Structural Controls Design Manual to assist with
the design and review of stormwater treatment controls. By clicking OK below, the user
acknowledges they have read and agreed to the Disclaimer.

The intent is for the user to complete the Project Summary and Pass-Fail Checklist Worksheet identifying each drainage sub-area within the project and the corresponding treatment control (TC) referenced in the Truckee Meadows Structrual Controls Design Manual (e.g. TC-10 is a vegetated swale). Hardcopies of the completed worksheets are to provide supporting documentation of the project
to the jurisdiction reviewing the plans.

OK

INTRO | SUMMARY | PassFail | TC-STA | TC-10 | TC-11 | TC-20 | TC-21 | TC-30 | TC-40 | TC-41 | TC-50 | TC-51 | TC-60 | TC-61(a) | TC-61(b) | TC-62(a) | TC

Water Quality Design Criteria

- To adequately treat runoff and enhance water quality, design criteria are required for both flow and volume-based structural treatment controls
- Flows in excess of water quality flow or volume must be diverted around or through structural treatment controls to prevent scour or re-suspension of collected sediments
- Manual describes the development of regional sizing criteria for flow and volume-based treatment controls and diversion structures in the Truckee Meadows

Truckee Meadows Storm Water Quality Management Program
Design Guidance Worksheet: Sedimentation Basin TC-40

* Fill out worksheet from top to bottom — Truckee Meadows Version 2.0 Released 2015

page 1 of 2

Designer: ______
Company: ______
Date: ______
Project: ______
Location: ______

Subbasin #

Key: User Input | Calculated Result | *Italicized Font Indicates Value is Outside Recommended Range*

1. Water Quality Volume (WQ_V) - Sedimentation Basin Storage	a)	Sub-basin area ____ ft^2
		Sub-basin impervious area ____ ft^2
a) Percent of Watershed Impervious Area = I		% Imperviousness ____
b) Drainage Area = A (acres) (43,560 ft^2 = 1 acre) - minimum drainage area of 5 acres	b)	A= ____ ac
	c)	R_v = ____
c) Watershed Runoff Coefficient = R_V (unitless)		
d) 90th Percentile Precipitation Depth = P (inches)	e)	WQ_V = ____ ft^3
		WQ_V = ____ ft^3
e) Water Quality Volume = WQ_V (ft^3)		Designer to select value for Water Quality Volume for actual design
2. Outlet Structure		
a) Depth of water above the centerline of the bottom row of perforations, H (8' max.)	a)	H = ____ feet
b) Number of perforations per column, n_{perf}	b)	n_{perf} = ____
c) Target drain time, t. (48 hour min., 168 hour max.)	c)	t= ____ hours
d) Detention basin bottom slope, S	d)	S= ____ ft/ft
e) Required Maximum Outlet Area per Column = A_o	e)	A_o = ____ in^2
f) Number of Columns, n_c	f)	n_c = ____
g) Area of Each Perforation = A_{perf}	g)	A_{perf} = ____ in^2

Flow-Based Structural Treatment Controls

Vegetated Swales (TC-10)

> **Description**

- Shallow earthen open channels covered with dense vegetative growth (commonly grasses) along the bottom and side slopes
- Stormwater runoff is conveyed along the length of low slope channel
- Vegetation traps sediments, decreases velocity of overland flows and reduces erosion
- Recommend at least 100 feet in length since pollutant removal and treatment efficiency improves as contact time and infiltration increases

> **Applications and Advantages**

- Typically located in parks, parkways, or private landscaped areas (rights of way)
- Can be designed as natural drainage features with temporary irrigation

Vegetated swales along sidewalk.
Source: Structural Controls and LID Manual (2015).

Vegetated Swales (TC-10)

> **Performance Data**

- Range reflects differences in design, variable influent concentration levels and flow rates, permeability of underlying soils

Pollutant	Percent Removal Efficiency
Total Suspended Solids	60 – 95%
Total Phosphorus	5 – 45%
Total Nitrogen	15 – 65%
Nitrate	25 – 65%
Metals	20 – 90%

Sources: UDFCD, 1999; CASQA, 2003

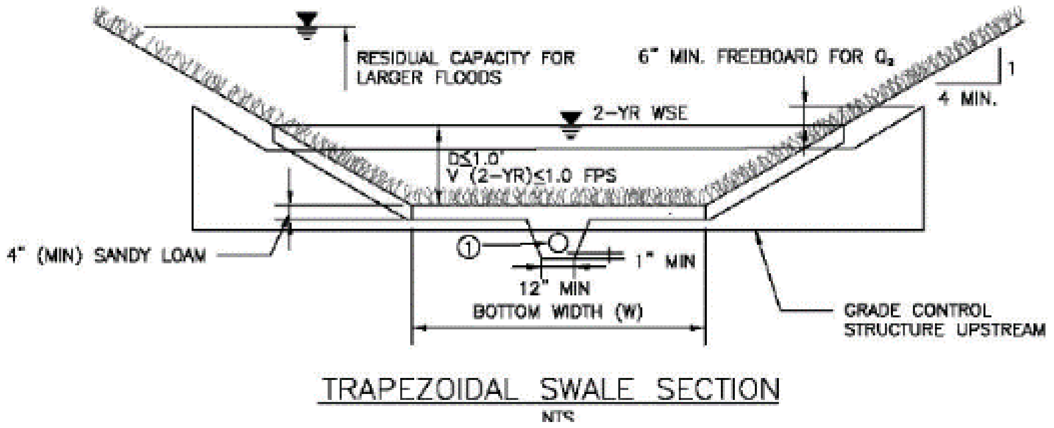
Vegetated Swales (TC-10)

- **Limitations**
  - Supplemental irrigation may be required in arid climates (like the Truckee Meadows)
  - Infiltration rates of local soils can be limiting unless underdrains are installed
  - Possible formation of mosquito breeding habitat if water does not drain or infiltrate
- **Siting Criteria**
  - Max. swale drainage area = 10 Ac
  - Not to be applied in areas with adjacent slopes of ≥ 5% or in areas with highly erodible soils
    - NRCS created an outline covering the procedure for making highly erodible land determination: https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_031522.pdf
  - Seasonally high groundwater table should be a minimum of 3 feet below swale
  - Minimum length of swale = 100 feet
  - Minimum and maximum longitudinal slope of 0.5% and 2.5%, respectively

Vegetated Swales (TC-10)

> **Design and Construction Criteria**

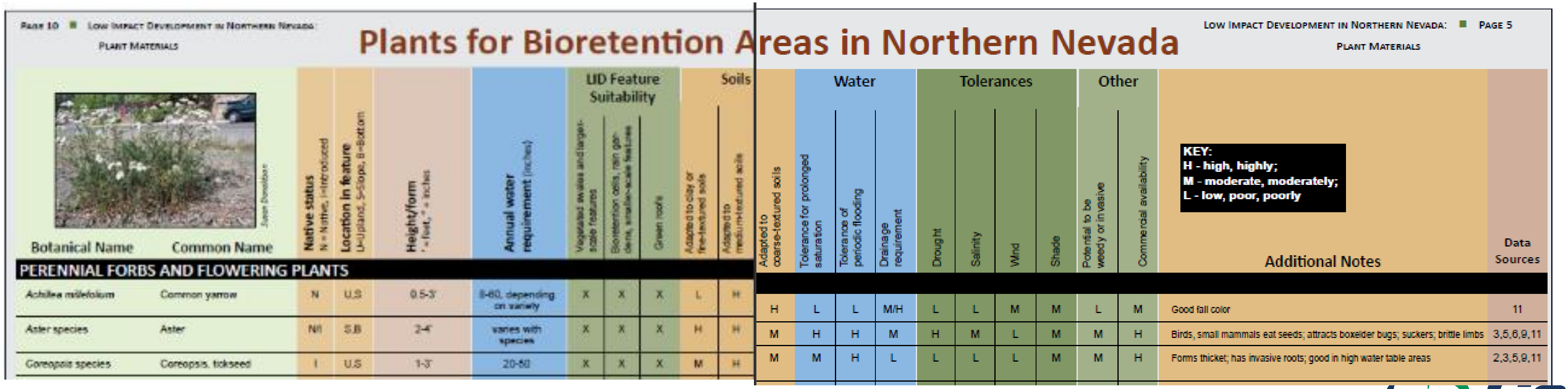
- Registered PE and landscape architect should work together to assess site and develop designs
- At locations where concentrated flows will enter the swale, install energy dissipation apron and flow spreader to prevent erosion and promote sheet flow
- Install a rock apron if trash and debris may enter the swale
- Swale must not hold standing water for more than 7 days during May through October
- Utilize the Design Guidance Worksheet
- See Manual for additional design criteria



Source: Structural Controls and LID Manual (2015).

Vegetated Swales (TC-10)

- **Vegetation Criteria**
  - Diverse selection of low growing plants that thrive under site specific soils and specified proposed watering conditions Vegetation height – 4 to 6 inches for turf grasses
  - Drought tolerant vegetation, use fertilizer and water sparingly
  - See Appendix B for vegetation recommendations
- **Inspection and Maintenance Requirements**
  - Mowing weeds, watering during the dry season and reseeding of non-vegetated areas
  - Inspection swales at least twice annually, and after large storm events to ensure no standing water



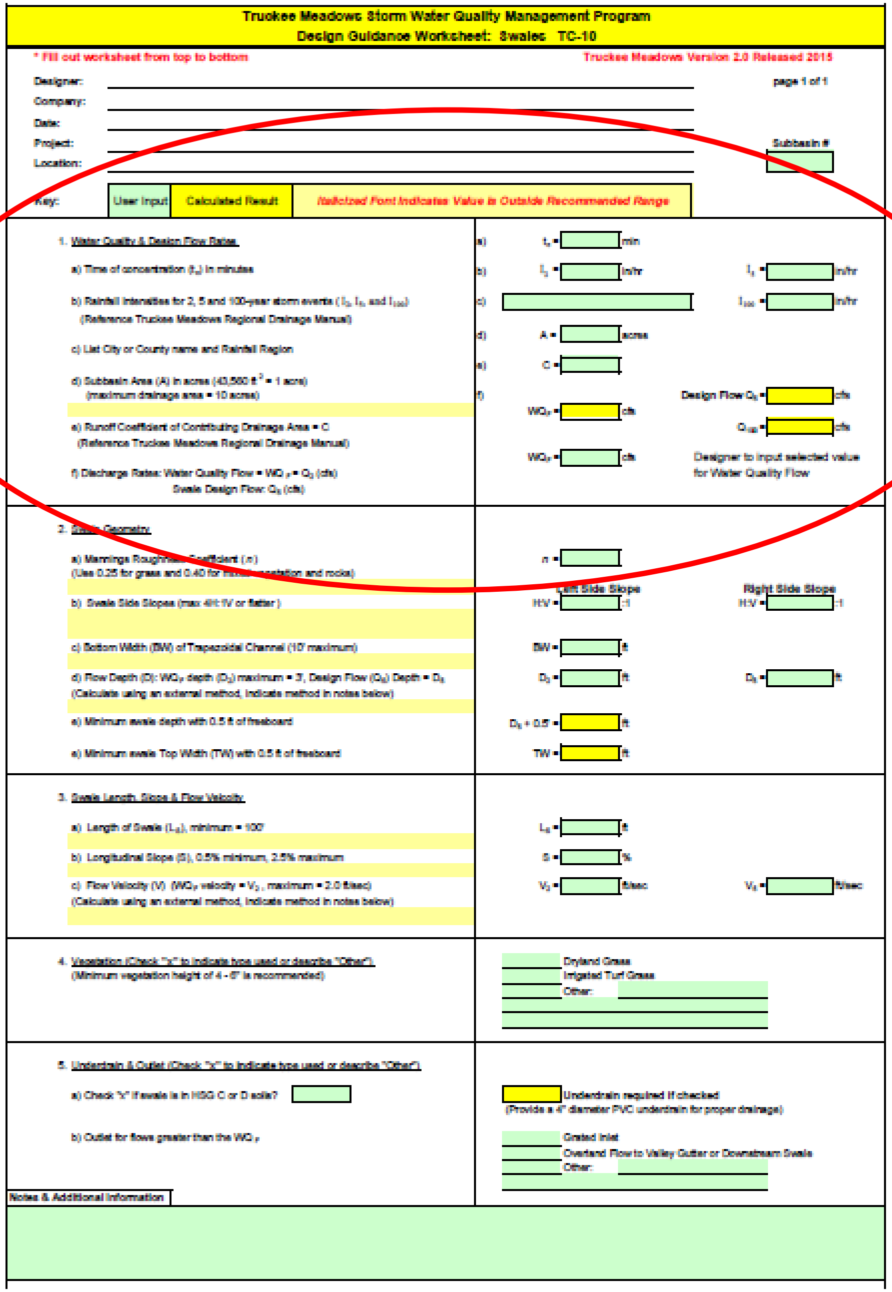
Plants for Bioretention Areas in Northern Nevada

KEY:
H - high, highly;
M - moderate, moderately;
L - low, poor, poorly

Botanical Name	Common Name	Native status (N = Native, I=Introduced)	Location in feature (U=Upland, S=Slope, B=Bottom)	Height/form (' = feet, " = inches)	Annual water requirement (inches)	LID Feature Suitability: Vegetated swales and larger-scale features	LID Feature Suitability: Bioretention cells, rain gardens, smaller-scale features	LID Feature Suitability: Green roofs	Soils: Adapted to clay or fine-textured soils	Soils: Adapted to medium-textured soils	Soils: Adapted to coarse-textured soils	Water: Tolerance for prolonged saturation	Water: Tolerance of periodic flooding	Water: Drainage requirement	Tolerances: Drought	Tolerances: Salinity	Tolerances: Wind	Tolerances: Shade	Other: Potential to be weedy or invasive	Other: Commercial availability	Additional Notes	Data Sources
PERENNIAL FORBS AND FLOWERING PLANTS																						
Achillea millefolium	Common yarrow	N	U,S	0.5-3'	8-60, depending on variety	X	X	X	L	H	H	L	L	M/H	L	L	M	M	L	M	Good fall color	11
Aster species	Aster	N/I	S,B	2-4'	varies with species	X	X	X	H	H	M	H	H	M	H	M	L	M	M	H	Birds, small mammals eat seeds; attracts boxelder bugs; suckers; brittle limbs	3,5,6,9,11
Coreopsis species	Coreopsis, tickseed	I	U,S	1-3'	20-60	X	X	X	M	H	M	M	H	L	L	L	L	M	M	H	Forms thicket; has invasive roots; good in high water table areas	2,3,5,9,11

TC-10: Local Example

- Water quality and design flow rates steps applicable for many structures
- 2 basic methods - Rational Formula vs the SCS Unit Hydrograph
- Walk through a local example using Rational Formula Method



Truckee Meadows Storm Water Quality Management Program
Design Guidance Worksheet: Swales TC-10

* Fill out worksheet from top to bottom — Truckee Meadows Version 2.0 Released 2015

page 1 of 1

Designer:
Company:
Date:
Project:
Location:
Subbasin #

Key: User Input | Calculated Result | *Italicized Font Indicates Value is Outside Recommended Range*

1. Water Quality & Design Flow Rates
   - a) Time of concentration (t_c) in minutes — t_c = ___ min
   - b) Rainfall intensities for 2, 5 and 100-year storm events (I_2, I_5, and I_{100}) (Reference Truckee Meadows Regional Drainage Manual) — I_2 = ___ in/hr; I_5 = ___ in/hr; I_{100} = ___ in/hr
   - c) List City or County name and Rainfall Region
   - d) Subbasin Area (A) in acres (43,560 ft^2 = 1 acre) (maximum drainage area = 10 acres) — A = ___ acres
   - e) Runoff Coefficient of Contributing Drainage Area = C (Reference Truckee Meadows Regional Drainage Manual) — C = ___
   - f) Discharge Rates: Water Quality Flow = WQ_F = Q_2 (cfs); Swale Design Flow: Q_5 (cfs) — WQ_F = ___ cfs; Design Flow Q_5 = ___ cfs; Q_{100} = ___ cfs; WQ_F = ___ cfs; Designer to input selected value for Water Quality Flow

2. Swale Geometry
   - a) Mannings Roughness Coefficient (n) (Use 0.25 for grass and 0.40 for mixed vegetation and rocks) — n = ___
   - b) Swale Side Slopes (max 4H:1V or flatter) — Left Side Slope H:V = ___ :1; Right Side Slope H:V = ___ :1
   - c) Bottom Width (BW) of Trapezoidal Channel (10' maximum) — BW = ___ ft
   - d) Flow Depth (D): WQ_F depth (D_2) maximum = 3', Design Flow (Q_5) Depth = D_5 (Calculate using an external method, indicate method in notes below) — D_2 = ___ ft; D_5 = ___ ft
   - e) Minimum swale depth with 0.5 ft of freeboard — D_5 + 0.5' = ___ ft
   - e) Minimum swale Top Width (TW) with 0.5 ft of freeboard — TW = ___ ft

3. Swale Length, Slope & Flow Velocity
   - a) Length of Swale (L_S), minimum = 100' — L_S = ___ ft
   - b) Longitudinal Slope (S), 0.5% minimum, 2.5% maximum — S = ___ %
   - c) Flow Velocity (V) (WQ_F velocity = V_2, maximum = 2.0 ft/sec) (Calculate using an external method, indicate method in notes below) — V_2 = ___ ft/sec; V_5 = ___ ft/sec

4. Vegetation (Check "x" to indicate type used or describe "Other") (Minimum vegetation height of 4 - 6" is recommended) — Dryland Grass; Irrigated Turf Grass; Other:

5. Underdrain & Outlet (Check "x" to indicate type used or describe "Other")
   - a) Check "x" if swale is in HSG C or D soils? — Underdrain required if checked (Provide a 4" diameter PVC underdrain for proper drainage)
   - b) Outlet for flows greater than the WQ_F — Grated Inlet; Overland Flow to Valley Gutter or Downstream Swale; Other:

Notes & Additional Information

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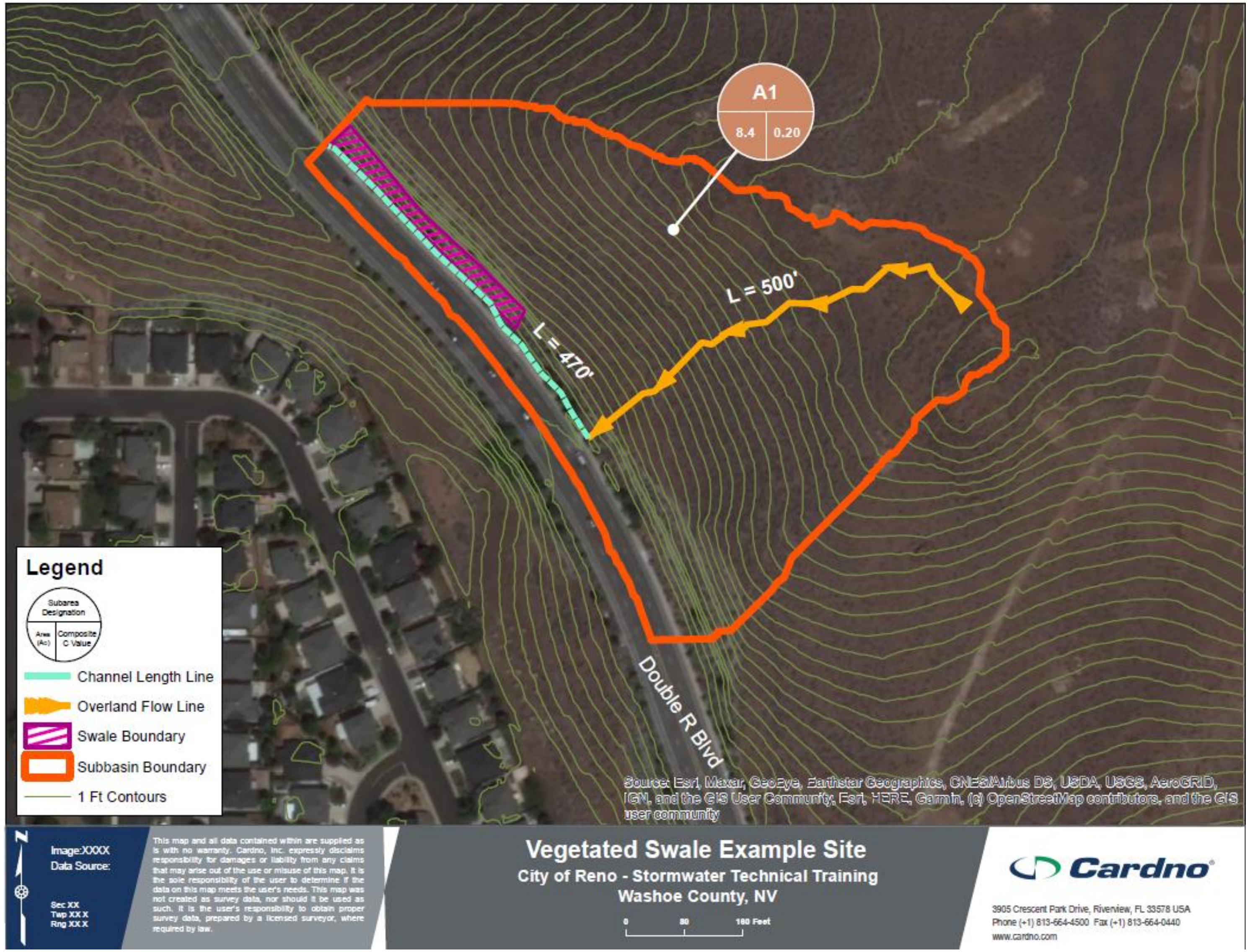
TC-10: Vegetated Swale Local Example

- Site location: Double R Blvd and Amston Rd
- Design a vegetated swale by:
  - Using the Rational Formula to compute Water Quality (WQf) and Swale Design Flow
  - Using the WQf to determine swale geometry



TC-10: 1. a)

1. Water Quality & Design Flow Rates

a) Time of concentration (t_c) in minutes

b) Rainfall Intensities for 2, 5 and 100-year storm events (I_2, I_5, and I_{100})
(Reference Truckee Meadows Regional Drainage Manual)

c) List City or County name and Rainfall Region

d) Subbasin Area (A) in acres (43,560 ft^2 = 1 acre)
(maximum drainage area = 10 acres)

e) Runoff Coefficient of Contributing Drainage Area = C
(Reference Truckee Meadows Regional Drainage Manual)

f) Discharge Rates: Water Quality Flow = $WQ_F = Q_2$ (cfs)
Swale Design Flow: Q_5 (cfs)

a) t_c = ____ min

b) I_2 = ____ in/hr I_5 = ____ in/hr

c) ____ I_{100} = ____ in/hr

d) A = ____ acres

e) C = ____

f) **Design Flow** Q_5 = ____ cfs
WQ_F = ____ cfs
Q_{100} = ____ cfs
WQ_F = ____ cfs   Designer to input selected value for Water Quality Flow

> **Truckee Meadows Regional Drainage Manual (TMRDM)**

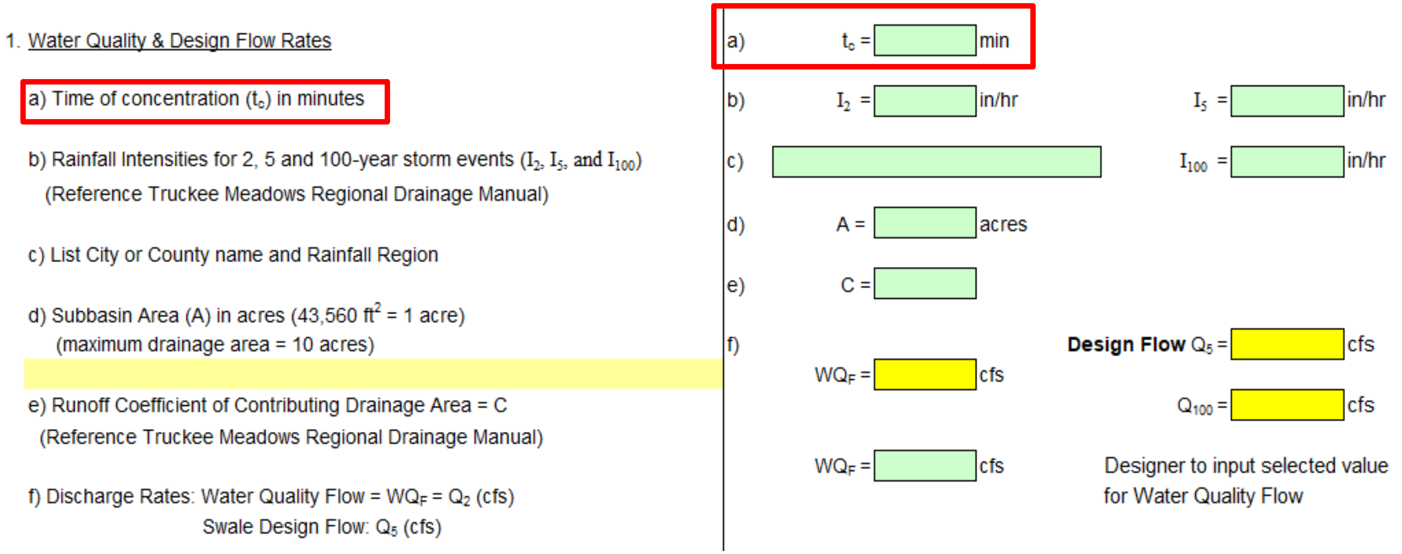
– $t_c = t_i + t_t$ *(Eq. 1)*

- t_c = time of concentration (mins), t_i = initial, inlet, or overland flow time (mins), t_t = travel time in ditch, channel, gutter, sewer, etc. (mins)
- ***The minimum t_c in Washoe County for non-urban watersheds = 10 mins, urban watersheds = 5 mins***
- Use of Standard Form 2

TC-10: 1. a)

> Computing initial and overland flow time, t_i

- $t_i = \frac{1.8(1.1-R)L_o^{1/2}}{S^{1/3}}$ (Eq. 2)
  - **t_i =** initial, inlet, or overland flow time (mins), **R =** flow runoff coefficient, **L_o =** length of overland flow (ft, 500 ft max.), **S =** average overland basin slope (%)
- $t_t = \frac{L}{60 \times v}$ (Eq. 3)
  - **t_t =** travel time; **L =** gutter/channel flow length in subbasin X, **v =** runoff velocity
- $t_c = \frac{L}{180+10}$ (Eq. 4)
  - Note Urban Area top-end "bracket" not to exceed tc



1. Water Quality & Design Flow Rates

a) Time of concentration (t_c) in minutes

b) Rainfall Intensities for 2, 5 and 100-year storm events (I_2, I_5, and I_{100})
(Reference Truckee Meadows Regional Drainage Manual)

c) List City or County name and Rainfall Region

d) Subbasin Area (A) in acres (43,560 ft^2 = 1 acre)
(maximum drainage area = 10 acres)

e) Runoff Coefficient of Contributing Drainage Area = C
(Reference Truckee Meadows Regional Drainage Manual)

f) Discharge Rates: Water Quality Flow = WQ_F = Q_2 (cfs)
Swale Design Flow: Q_5 (cfs)

a) t_c = min

b) I_2 = in/hr I_5 = in/hr

c) I_{100} = in/hr

d) A = acres

e) C =

f) **Design Flow** Q_5 = cfs

WQ_F = cfs

Q_{100} = cfs

WQ_F = cfs

Designer to input selected value for Water Quality Flow

TC-10: 1. e)

1. Water Quality & Design Flow Rates

a) Time of concentration (t_c) in minutes

b) Rainfall Intensities for 2, 5 and 100-year storm events (I_2, I_5, and I_{100})
(Reference Truckee Meadows Regional Drainage Manual)

c) List City or County name and Rainfall Region

d) Subbasin Area (A) in acres (43,560 ft^2 = 1 acre)
(maximum drainage area = 10 acres)

e) Runoff Coefficient of Contributing Drainage Area = C
(Reference Truckee Meadows Regional Drainage Manual)

f) Discharge Rates: Water Quality Flow = $WQ_F = Q_2$ (cfs)
Swale Design Flow: Q_5 (cfs)

a) t_c = min

b) I_2 = in/hr I_5 = in/hr

c) I_{100} = in/hr

d) A = acres

e) C =

f) **Design Flow** Q_5 = cfs

WQ_F = cfs

Q_{100} = cfs

WQ_F = cfs

Designer to input selected value for Water Quality Flow

> **TMRDM – Runoff Coefficients**

- Identify land use: Undeveloped – Range
- Rational Method
- $R = C_5 \equiv$ 5-yr runoff coefficient (Table 701 in TMRDM)
- $C_5 = 0.20$; $C_{100} = 0.50$
- $R = C_5 = 0.20$
  - If multiple subbasins, runoff coefficients $R_A = R_B = R_C = C_5$

RATIONAL FORMULA METHOD
RUNOFF COEFFICIENTS

Land Use or Surface Characteristics	Aver. % Impervious Area	Runoff Coefficients 5-Year (C_5)	100-Year (C_{100})
Business/Commercial:			
Downtown Areas	85	.82	.85
Neighborhood Areas	70	.65	.80
Residential:			
(Average Lot Size)			
⅛ Acre or Less (Multi-Unit)	65	.60	.78
¼ Acre	38	.50	.65
⅓ Acre	30	.45	.60
½ Acre	25	.40	.55
1 Acre	20	.35	.50
Industrial:	72	.68	.82
Open Space:			
(Lawns, Parks, Golf Courses)	5	.05	.30
Undeveloped Areas:			
Range	0	.20	.50
Forest	0	.05	.30
Streets/Roads:			
Paved	100	.88	.93
Gravel	20	.25	.50
Drives/Walks:	95	.87	.90
Roof:	90	.85	.87

Notes:

1. Composite runoff coefficients shown for Residential, Industrial, and Business/Commercial Areas assume irrigated grass landscaping for all pervious areas. For development with landscaping other than irrigated grass, the designer must develop project specific composite runoff coefficients from the surface characteristics presented in this table.

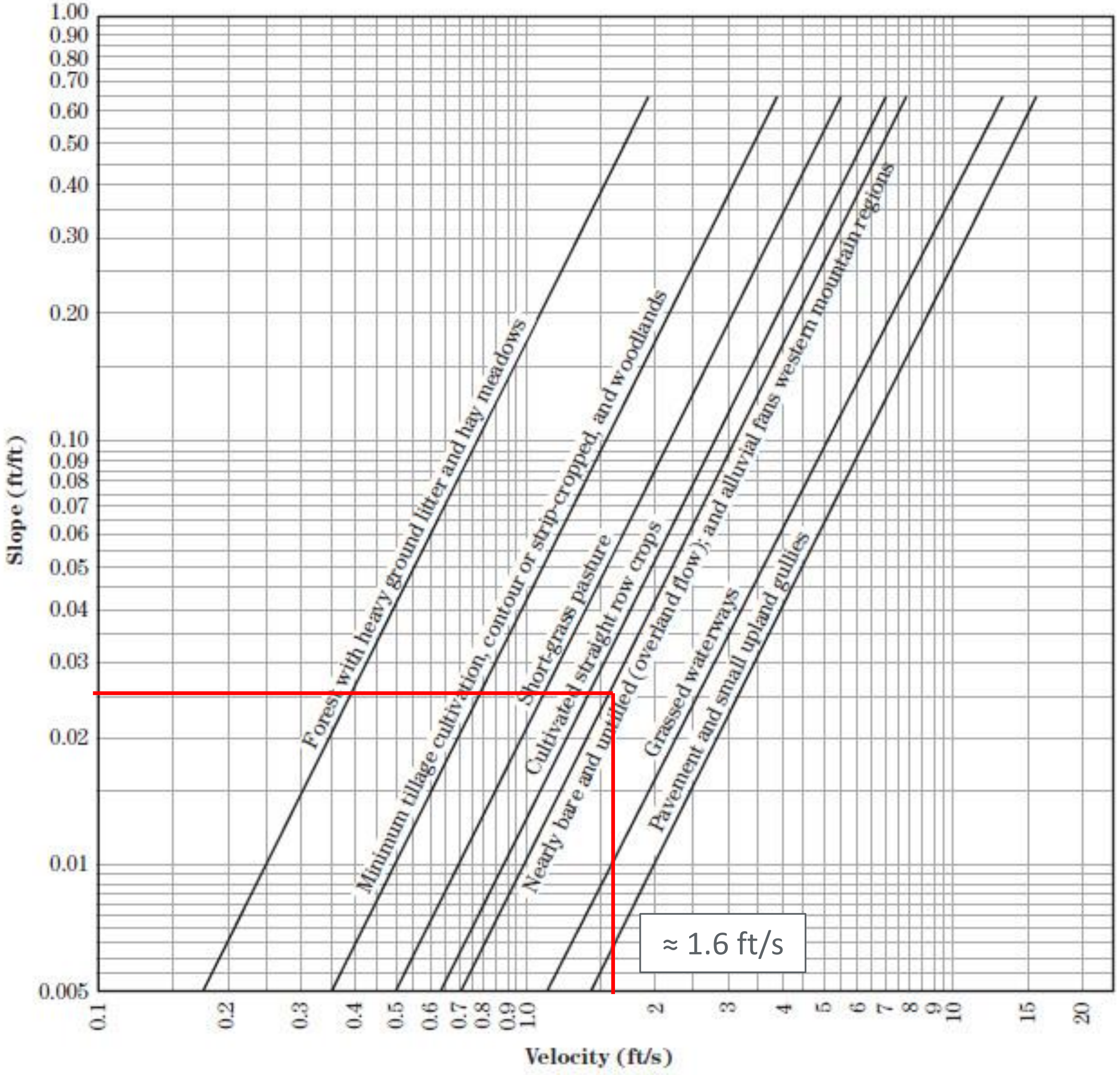
VERSION: April 30, 2009	REFERENCE: USDCM, DROCOG, 1969 (with modifications)	TABLE 701
WRC ENGINEERING, INC		

TC-10: 1. a)

- Computing initial and overland flow time, t_i
  - $t_i = \frac{1.8(1.1-R){L_o}^{1/2}}{S^{1/3}}$ *(Eq. 2)*
  - **t_i =** initial, inlet, or overland flow time (mins), **R =** flow runoff coefficient, **L_o =** length of overland flow (ft, 500 ft max.), **S =** average overland basin slope (%)
  - R = 0.20
  - L_o = 500 ft
  - S = 4.8%
  - **t_i = 21.5 mins**

TC-10: 1. a) Standard Form 2

- Travel time velocity (Fig. 701 in TMRDM)
- Travel time of the runoff from the drainage basin to the swale
- Choose pavement
- Assume runoff combines and flows down street at 2.5% grade
- v = 1.6 ft/s
- Drainage basin flow length to swale = 470 ft
- $t_t = \frac{L}{60 \times v} =$ **4.9 mins**



TC-10: 1. a)

> Computing time of concentration, t_c

- $t_c = t_i + t_t$ *(Eq. 1)*
- t_i = 21.5 mins
- t_t = 4.9 mins
- **t_c = 26.4 mins**
  - **Greater than 10 min, therefore fine to perform computation**
  - **For small areas, acceptable to conservatively default to minimums of:**
    - **10 minutes (Rural Areas)**
    - **5 minutes (non-Rural Areas)**

TC-10: 1. a) Standard Form 2

VERSION: April 30, 2009

WASHOE COUNTY
HYDROLOGIC CRITERIA AND DRAINAGE DESIGN MANUAL

TIME OF CONCENTRATION

DEVELOPMENT ____________

CALCULATED BY ____________ DATE ____________

SUB-BASIN DATA			INITIAL/OVERLAND TIME (t_i)			TRAVEL TIME (t_t)				t_c ($t_i + t_t$)	t_c URBANIZED BASINS CHECK		FINAL t_c	REMARKS
DESIG: (1)	R (2)	AREA Ac (3)	LENGTH Ft (4)	SLOPE % (5)	t_i Min (6)	LENGTH Ft (7)	SLOPE % (8)	VEL FPS (9)	t_t Min (10)	t_c Min (11)	TOTAL LENGTH FT (12)	$t_c = (L/180) + 10$ Min (13)	Min (14)	

$$t_i = 1.8 \, (1.1 - R) \, L^{1/2} / S^{1/3}$$

STANDARD FORM 2

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TC-10: 1. b)

1. Water Quality & Design Flow Rates

a) Time of concentration (t_c) in minutes

b) Rainfall Intensities for 2, 5 and 100-year storm events (I_2, I_5, and I_{100})
(Reference Truckee Meadows Regional Drainage Manual)

c) List City or County name and Rainfall Region

d) Subbasin Area (A) in acres (43,560 ft^2 = 1 acre)
(maximum drainage area = 10 acres)

e) Runoff Coefficient of Contributing Drainage Area = C
(Reference Truckee Meadows Regional Drainage Manual)

f) Discharge Rates: Water Quality Flow = $WQ_F = Q_2$ (cfs)
Swale Design Flow: Q_5 (cfs)

a) t_c = min

b) I_2 = in/hr I_5 = in/hr

c) I_{100} = in/hr

d) A = acres

e) C =

f) **Design Flow** Q_5 = cfs

WQ_F = cfs

Q_{100} = cfs

WQ_F = cfs

Designer to input selected value for Water Quality Flow

- **Rainfall Intensity**
  - 2 sources depending on site location
    - TMRDM (City of Sparks)
    - NOAA (City of Reno/unincorporated areas of Washoe County)
  - *24-hour storm duration is standard design storm duration for hydrologic methods other than Rational Method

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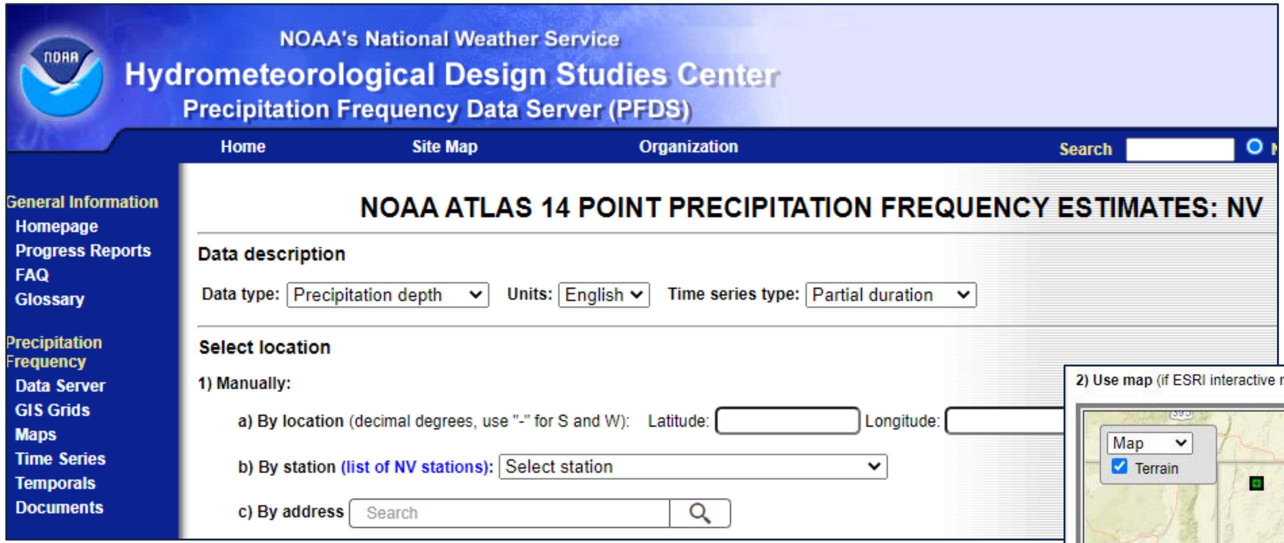
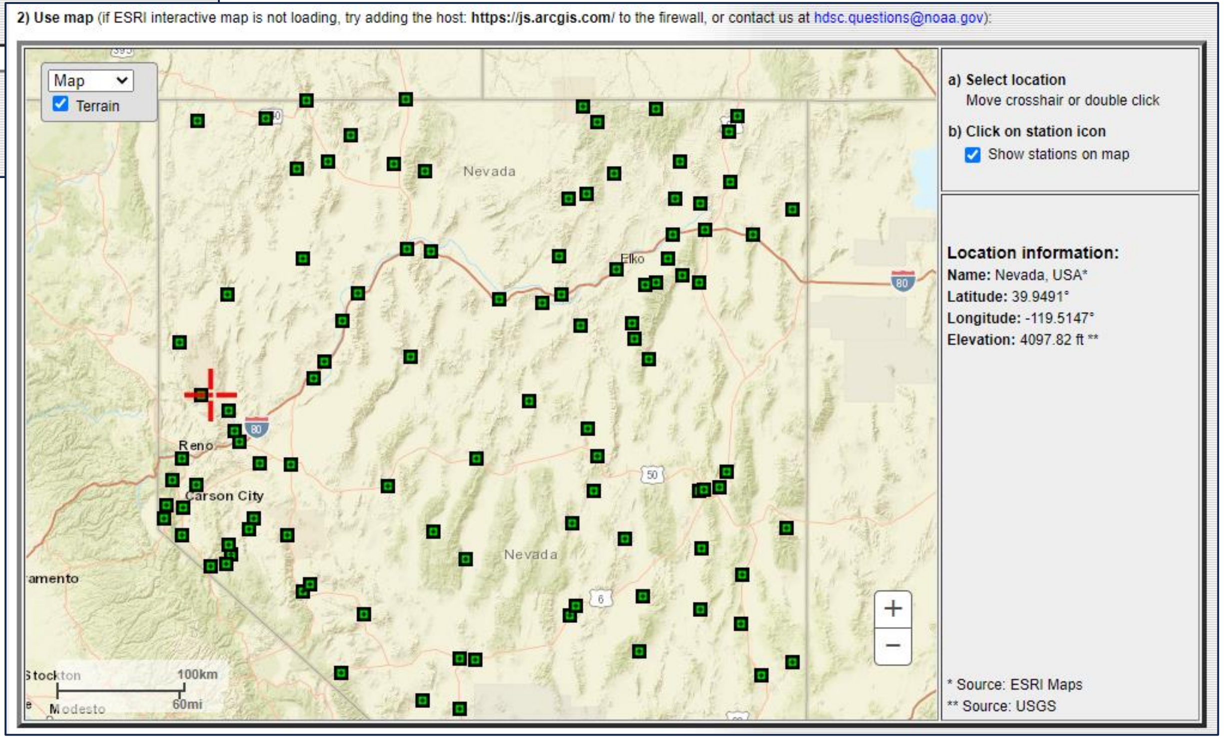
TC-10: 1. b)





- **National Oceanic and Atmospheric Administration (NOAA)**
  - More precise results for site area compared to TMRDM
  - Search by location, station, or specific address through entry or ESRI map
  - Input coordinates from Google Earth (39.462663, -119.727983)

TC-10: 1. b)

> **NOAA Precipitation Table**

- Computed time of concentration, tc = 26.4 mins
- Total rainfall, P (in)
- P_2 interpolation:
  - $0.218 + \left[\frac{26.4-15}{30-15} \times (0.294 - 0.218)\right] = 0.276$
- P_5 interpolation:
  - $0.293 + \left[\frac{26.4-15}{30-15} \times (0.395 - 0.293)\right] = 0.371$
- P_{100} interpolation:
  - $0.716 + \left[\frac{26.4-15}{30-15} \times (0.964 - 0.716)\right] = 0.904$
- 5-yr recurrence frequency
- Rainfall intensity, ***i_2* = 0.63 in/hr, *i_5* = 0.84 in/hr, *i_{100}* = 2.05 in/hr**

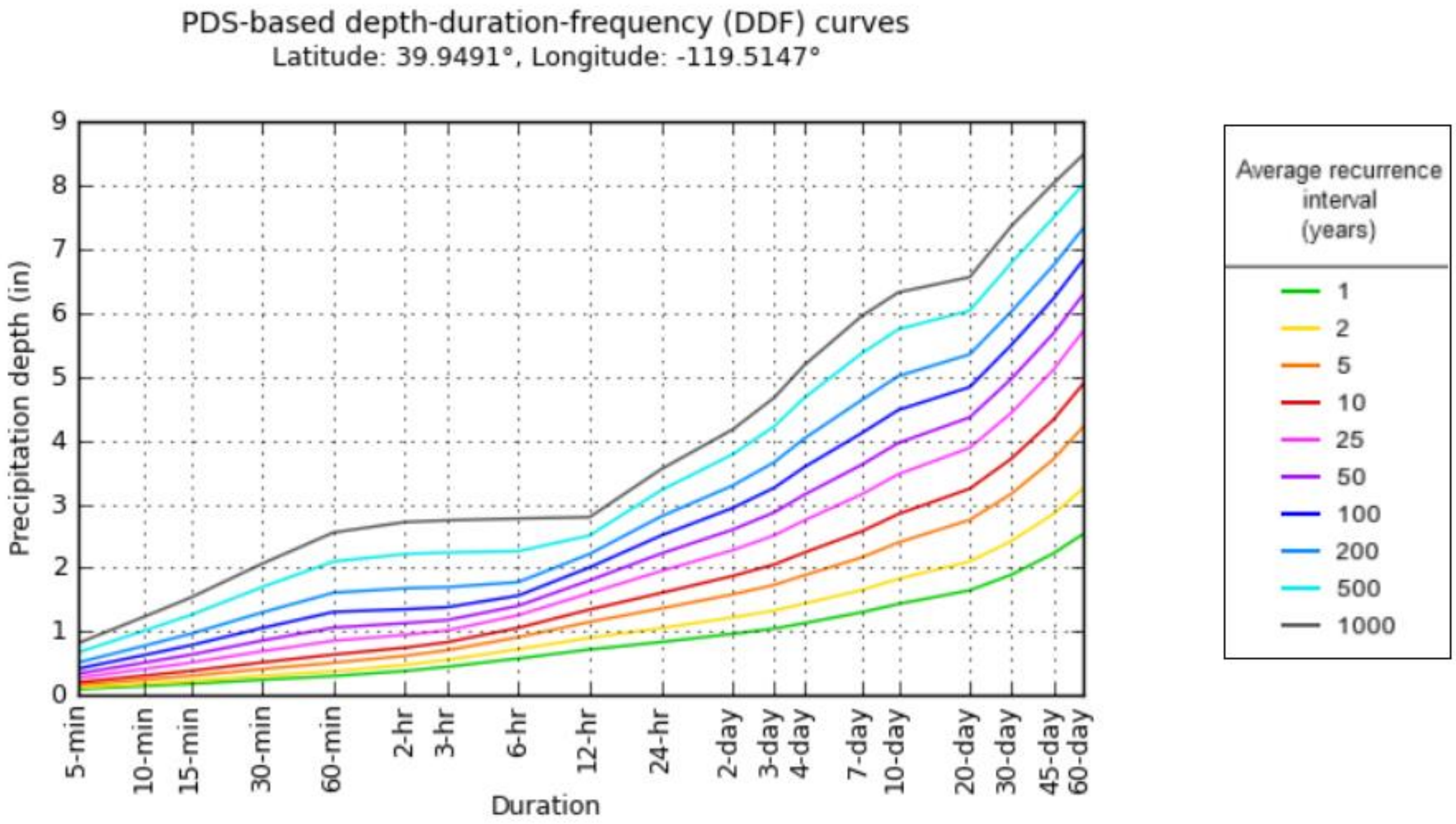
PF tabular | PF graphical | Supplementary information | Print page

PDS-based precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	**0.093** (0.080-0.108)	**0.116** (0.099-0.137)	**0.155** (0.132-0.185)	**0.193** (0.163-0.229)	**0.255** (0.209-0.306)	**0.312** (0.247-0.379)	**0.380** (0.291-0.467)	**0.461** (0.339-0.580)	**0.594** (0.409-0.772)	**0.715** (0.469-0.950)
10-min	**0.142** (0.121-0.165)	**0.177** (0.150-0.208)	**0.237** (0.201-0.281)	**0.293** (0.248-0.349)	**0.388** (0.319-0.465)	**0.475** (0.376-0.576)	**0.578** (0.443-0.711)	**0.702** (0.516-0.883)	**0.904** (0.623-1.18)	**1.09** (0.715-1.45)
15-min	**0.176** (0.150-0.205)	**0.218** (0.186-0.258)	**0.293** (0.250-0.348)	**0.363** (0.307-0.433)	**0.481** (0.395-0.577)	**0.589** (0.467-0.715)	**0.716** (0.549-0.881)	**0.870** (0.640-1.10)	**1.12** (0.772-1.46)	**1.35** (0.886-1.79)
30-min	**0.237** (0.202-0.275)	**0.294** (0.250-0.347)	**0.395** (0.336-0.469)	**0.489** (0.413-0.583)	**0.647** (0.532-0.777)	**0.793** (0.628-0.962)	**0.964** (0.739-1.19)	**1.17** (0.862-1.47)	**1.51** (1.04-1.96)	**1.82** (1.19-2.41)
60-min	**0.293** (0.250-0.341)	[illegible]	[illegible]	**0.605** (0.512-0.721)	**0.801** (0.658-0.962)	**0.981** (0.777-1.19)	[illegible]	**1.45** (1.07-1.82)	**1.87** (1.29-2.43)	**2.25** (1.48-2.99)
2-hr	**0.387** (0.340-0.447)	[illegible]	[illegible]	**0.738** (0.634-0.854)	**0.919** (0.765-1.07)	**1.08** (0.876-1.28)	[illegible]	**1.49** (1.14-1.84)	**1.90** (1.39-2.45)	**2.29** (1.61-3.02)
3-hr	**0.460** (0.410-0.523)	[illegible] (0.516-0.657)	[illegible] (0.643-0.825)	**0.842** (0.739-0.963)	**1.01** (0.870-1.16)	**1.15** (0.974-1.34)	[illegible] (1.10-1.57)	**1.55** (1.25-1.86)	**1.95** (1.53-2.48)	**2.32** (1.77-3.05)
6-hr	**0.642** (0.574-0.723)	**0.807** (0.720-0.912)	**1.00** (0.893-1.13)	**1.15** (1.02-1.31)	**1.35** (1.18-1.54)	**1.50** (1.29-1.72)	**1.65** (1.40-1.92)	**1.83** (1.52-2.16)	**2.12** (1.71-2.54)	**2.44** (1.93-3.08)
12-hr	**0.841** (0.752-0.942)	**1.06** (0.945-1.19)	**1.34** (1.19-1.51)	**1.56** (1.38-1.75)	**1.84** (1.60-2.10)	**2.06** (1.77-2.36)	**2.29** (1.93-2.66)	**2.51** (2.08-2.96)	**2.81** (2.26-3.38)	**3.05** (2.40-3.74)
24-hr	**1.04** (0.943-1.17)	**1.31** (1.19-1.46)	**1.66** (1.50-1.84)	**1.94** (1.75-2.16)	**2.33** (2.08-2.59)	**2.64** (2.34-2.94)	**2.96** (2.61-3.33)	**3.30** (2.87-3.73)	**3.76** (3.22-4.30)	**4.13** (3.48-4.76)
2-day	**1.23** (1.10-1.38)	**1.55** (1.39-1.74)	**1.97** (1.76-2.21)	**2.31** (2.06-2.59)	**2.78** (2.46-3.13)	**3.16** (2.77-3.57)	**3.56** (3.09-4.05)	**3.97** (3.41-4.56)	**4.55** (3.82-5.29)	**5.00** (4.13-5.91)
3-day	**1.34** (1.20-1.50)	**1.69** (1.52-1.89)	**2.16** (1.94-2.43)	**2.55** (2.28-2.86)	**3.10** (2.74-3.49)	**3.54** (3.11-3.99)	**4.01** (3.48-4.55)	**4.50** (3.86-5.15)	**5.19** (4.36-6.03)	**5.75** (4.74-6.76)
4-day	**1.45** (1.30-1.63)	**1.83** (1.65-2.05)	**2.36** (2.12-2.65)	**2.79** (2.50-3.14)	**3.41** (3.03-3.84)	**3.92** (3.44-4.42)	**4.46** (3.87-5.05)	**5.03** (4.31-5.74)	**5.84** (4.89-6.76)	**6.50** (5.36-7.61)
7-day	**1.70** (1.52-1.93)	**2.16** (1.92-2.45)	**2.81** (2.49-3.18)	**3.33** (2.95-3.78)	**4.07** (3.57-4.63)	**4.66** (4.06-5.32)	**5.29** (4.56-6.07)	**5.95** (5.07-6.87)	**6.87** (5.75-8.05)	**7.62** (6.28-9.02)
10-day	**1.90** (1.68-2.15)	**2.42** (2.15-2.74)	**3.16** (2.80-3.58)	**3.75** (3.31-4.25)	**4.56** (3.99-5.18)	**5.19** (4.52-5.92)	**5.86** (5.06-6.71)	**6.56** (5.59-7.56)	**7.51** (6.29-8.76)	**8.26** (6.84-9.73)

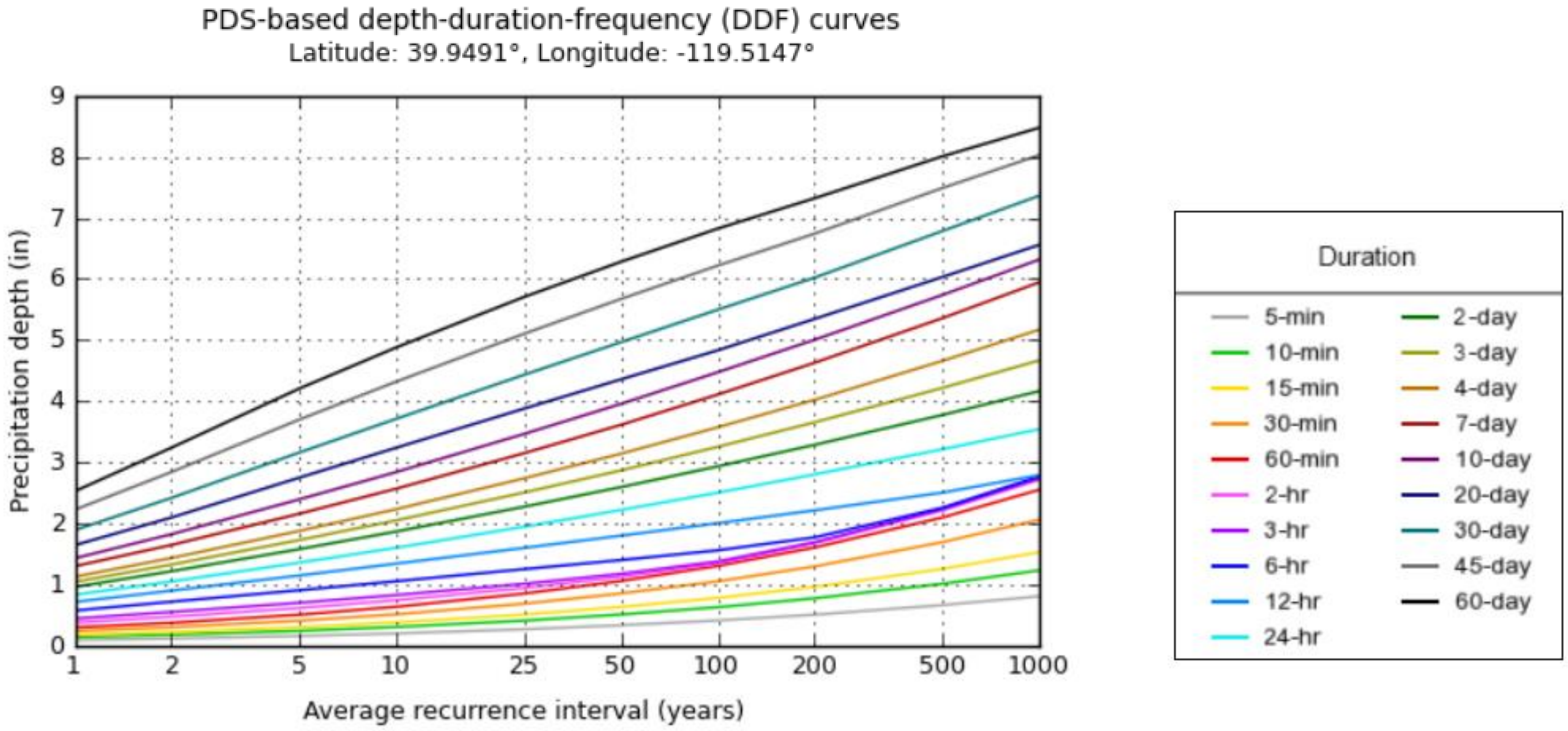
TC-10: 1. b)

> **NOAA DDF Curves**



TC-10: 1. b)

> **NOAA DDF Curves**



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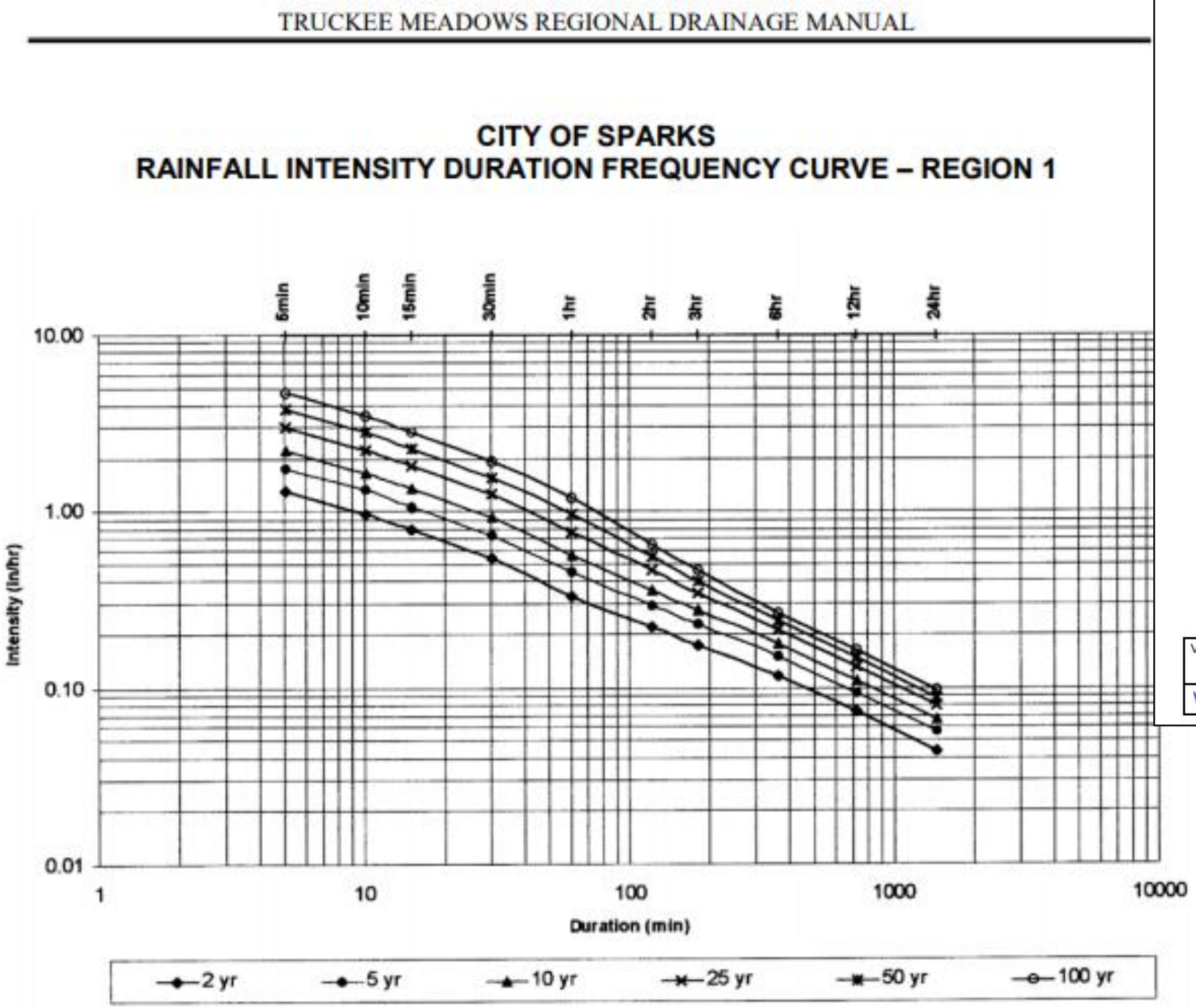
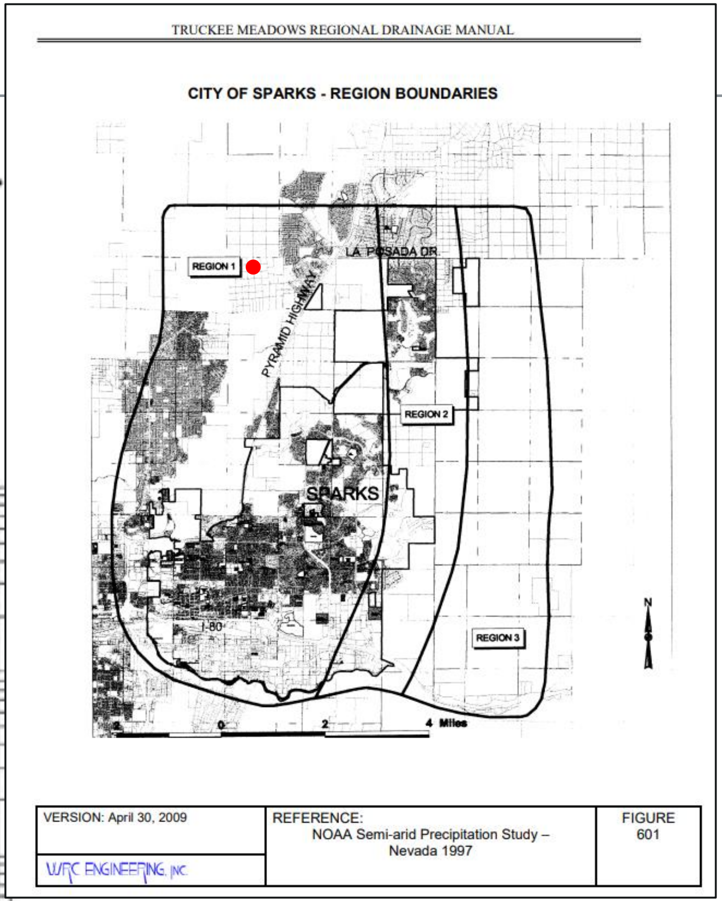
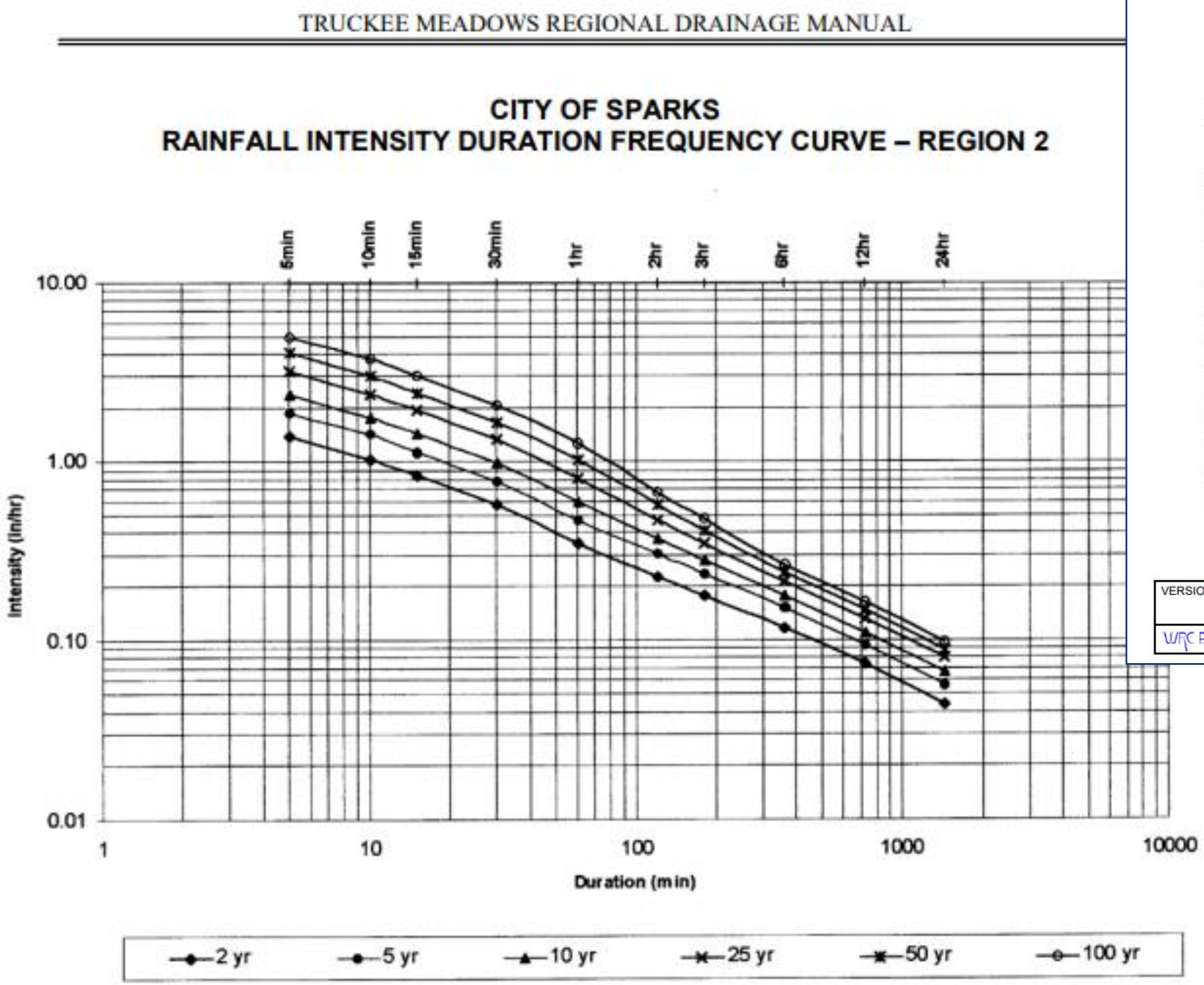
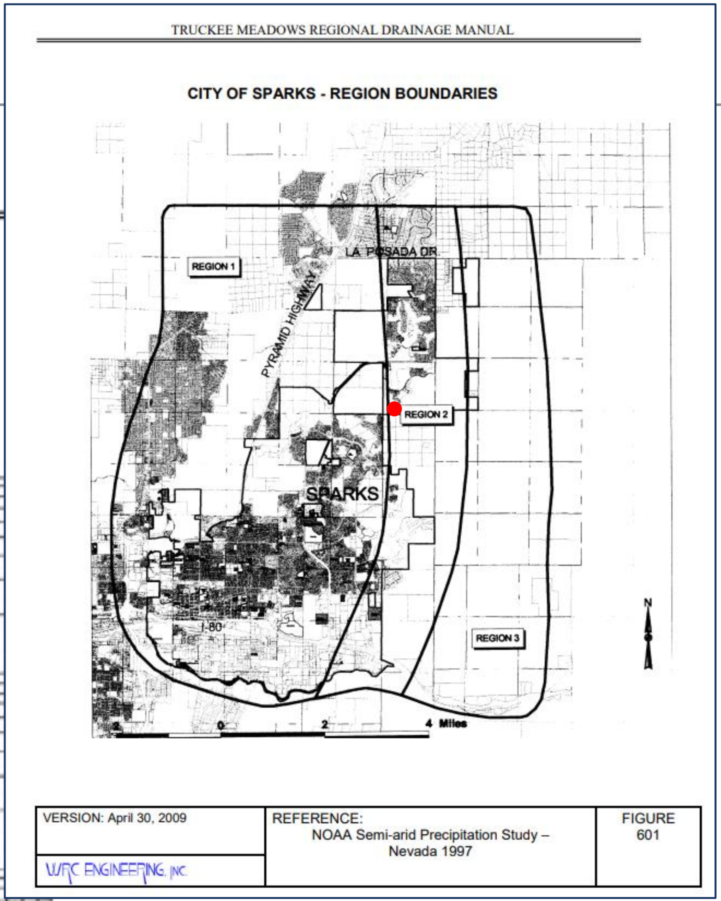
TC-10: 1. b)


TRUCKEE MEADOWS REGIONAL DRAINAGE MANUAL
CITY OF SPARKS
RAINFALL INTENSITY DURATION FREQUENCY CURVE – REGION 1
5min
10min
15min
30min
1hr
2hr
3hr
6hr
12hr
24hr
10.00
1.00
0.10
0.01
Intensity (in/hr)
1
10
100
1000
10000
Duration (min)
2 yr
5 yr
10 yr
25 yr
50 yr
100 yr


TRUCKEE MEADOWS REGIONAL DRAINAGE MANUAL
CITY OF SPARKS - REGION BOUNDARIES
REGION 1
LA POSADA DR
PYRAMID HIGHWAY
REGION 2
SPARKS
I-80
REGION 3
N
0
2
4 Miles
VERSION: April 30, 2009
WRC ENGINEERING, INC
REFERENCE:
NOAA Semi-arid Precipitation Study – Nevada 1997
FIGURE
601

TC-10: 1. b)





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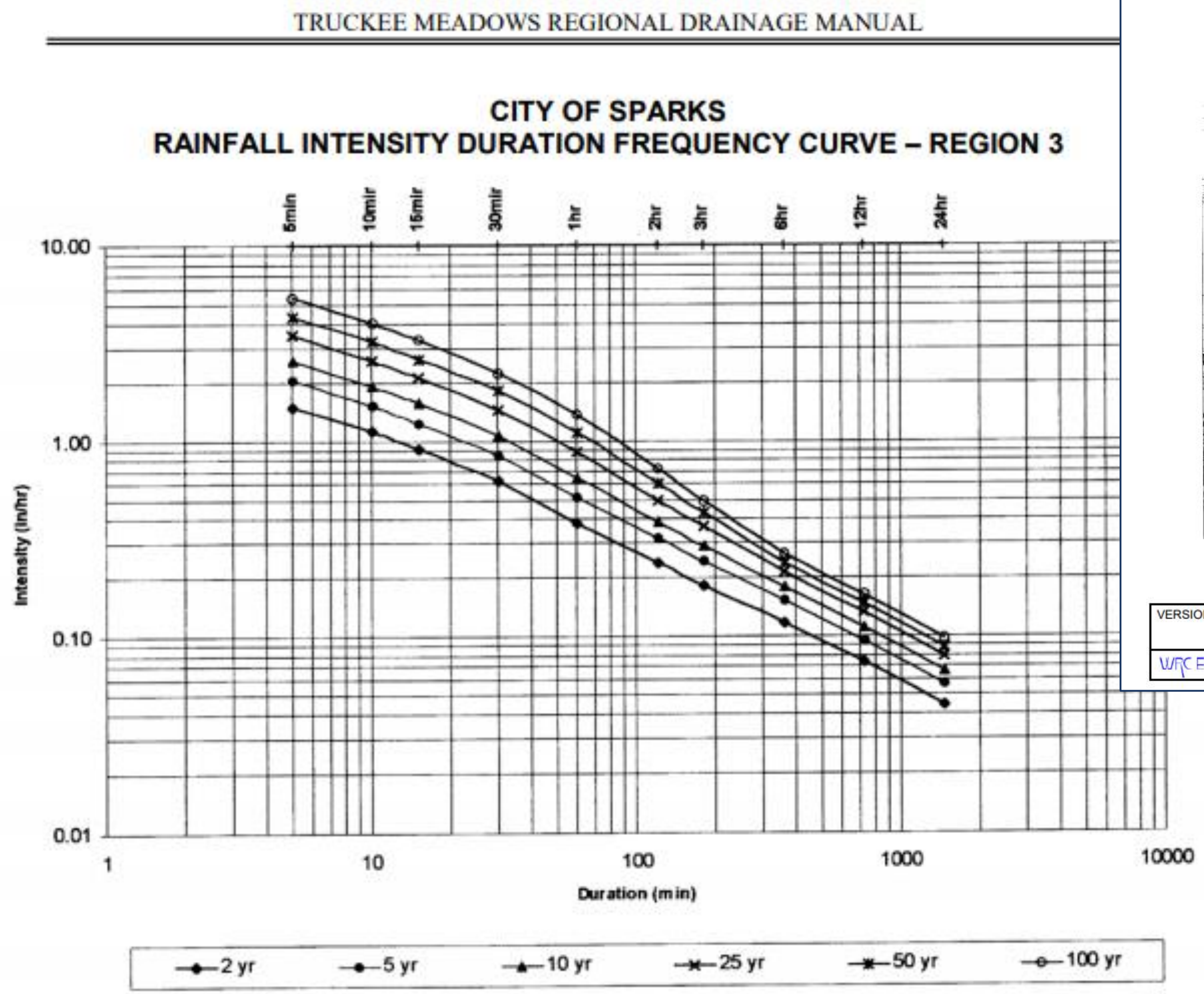
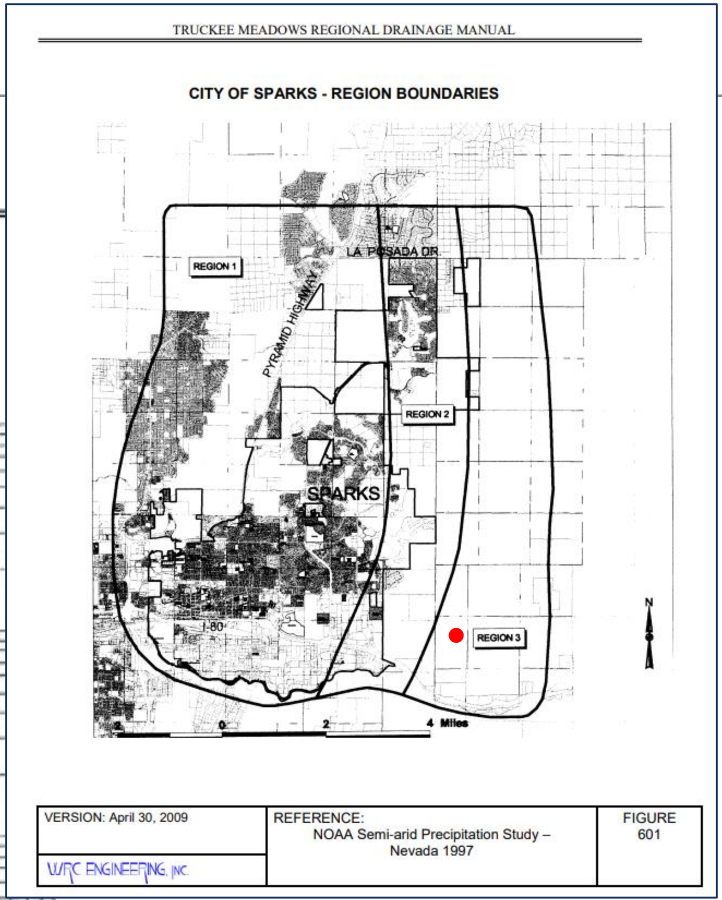
TC-10: 1. b)



TRUCKEE MEADOWS REGIONAL DRAINAGE MANUAL
CITY OF SPARKS
RAINFALL INTENSITY DURATION FREQUENCY CURVE – REGION 3
5min
10min
15min
30min
1hr
2hr
3hr
6hr
12hr
24hr
10.00
1.00
0.10
0.01
Intensity (in/hr)
1
10
100
1000
10000
Duration (min)
2 yr
5 yr
10 yr
25 yr
50 yr
100 yr

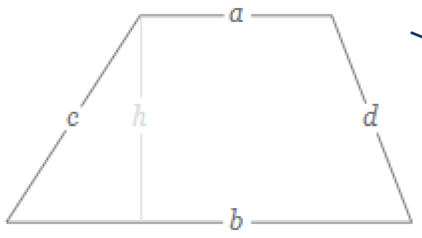


TRUCKEE MEADOWS REGIONAL DRAINAGE MANUAL
CITY OF SPARKS - REGION BOUNDARIES
REGION 1
LA POSADA DR.
PYRAMID HIGHWAY
REGION 2
SPARKS
I-80
REGION 3
N
0
2
4 Miles
VERSION: April 30, 2009
REFERENCE:
NOAA Semi-arid Precipitation Study – Nevada 1997
FIGURE 601
WRC ENGINEERING, INC.

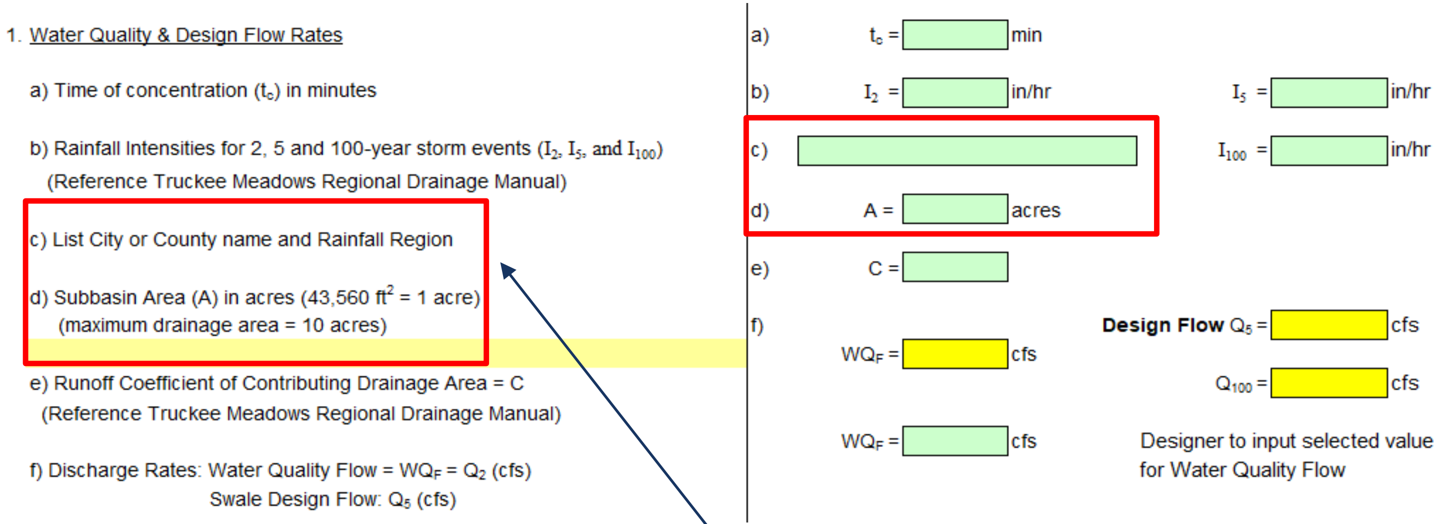
TC-10: 1. c-d)

d) Subbasin Area:

- Example is a trapezoidal channel
  - $A = \frac{a+b}{2} h$



- Usually measured using mapping or survey info (LiDAR, DEM, etc)



1. Water Quality & Design Flow Rates

a) Time of concentration (t_c) in minutes

b) Rainfall Intensities for 2, 5 and 100-year storm events (I_2, I_5, and I_{100})
(Reference Truckee Meadows Regional Drainage Manual)

c) List City or County name and Rainfall Region

d) Subbasin Area (A) in acres (43,560 ft^2 = 1 acre)
(maximum drainage area = 10 acres)

e) Runoff Coefficient of Contributing Drainage Area = C
(Reference Truckee Meadows Regional Drainage Manual)

f) Discharge Rates: Water Quality Flow = WQ_F = Q_2 (cfs)
Swale Design Flow: Q_5 (cfs)

a) t_c = min

b) I_2 = in/hr I_5 = in/hr

c) I_{100} = in/hr

d) A = acres

e) C =

f) Design Flow Q_5 = cfs

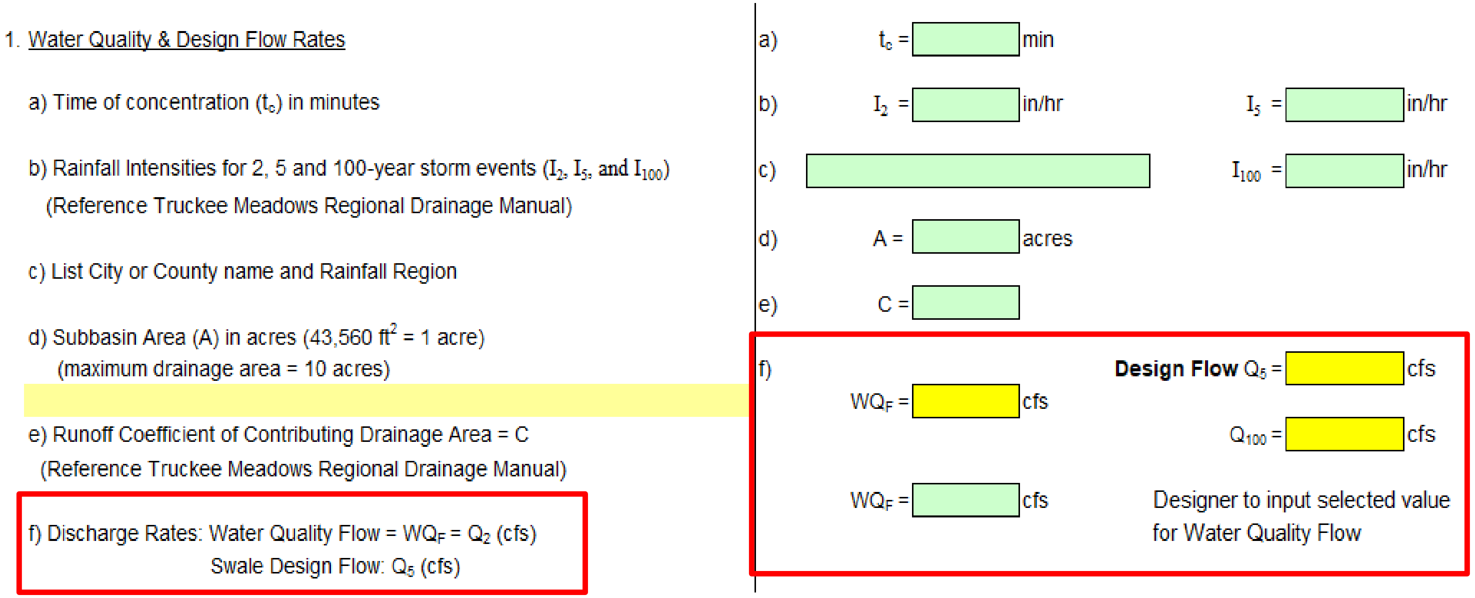
WQ_F = cfs

Q_{100} = cfs

WQ_F = cfs Designer to input selected value for Water Quality Flow

c) Reno, NV or Washoe county

TC-10: 1. e)



1. Water Quality & Design Flow Rates

a) Time of concentration (t_c) in minutes

b) Rainfall Intensities for 2, 5 and 100-year storm events (I_2, I_5, and I_{100})
(Reference Truckee Meadows Regional Drainage Manual)

c) List City or County name and Rainfall Region

d) Subbasin Area (A) in acres (43,560 ft^2 = 1 acre)
(maximum drainage area = 10 acres)

e) Runoff Coefficient of Contributing Drainage Area = C
(Reference Truckee Meadows Regional Drainage Manual)

f) Discharge Rates: Water Quality Flow = WQ_F = Q_2 (cfs)
Swale Design Flow: Q_5 (cfs)

a) t_c = min

b) I_2 = in/hr I_5 = in/hr

c) I_{100} = in/hr

d) A = acres

e) C =

f) **Design Flow** Q_5 = cfs
WQ_F = cfs
Q_{100} = cfs
WQ_F = cfs
Designer to input selected value for Water Quality Flow

> **Computing Water Quality Flow**

– Use design storm with duration equal to watershed's time of concentration

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TC-10: 1. f)

> **Computing Water Quality Design Flow (WQF)**

– Rational Method (cont'd)

- $Q = CiA$ [cfs]
- **Q =** maximum rate of runoff; **C =** runoff coefficient [dimensionless], ***i*** **=** average intensity of rainfall [in/hr], **A =** contributing basin area [Ac]
- $C_2 = C_5 = 0.2$
- $i_2 = 0.63$ in/hr
- A = 8.36 Ac
- **$Q_2 \equiv$ WQf = 1.1 cfs**
- $i_5 = 0.84$ in/hr
- **Q_5 = 1.4 cfs**

TC-10: Overview

> **Rational Formula Method Overview**

- Step 1: Obtained runoff coefficients (R) from Table 701 for contributing subbasin; based on R = C_5
- Step 2: Calculated initial overland flow time, t_i; we used L_0 = 500 ft; slope = 4.8%
- Step 3: Calculated travel time (t_t) using Figure 701 (TMDRM) to obtain velocity
- Step 4: Calculated time of concentration (t_c) by summing t_i and t_t
- Step 5: Determined rainfall intensity using data from NOAA site, using 2, 5, and 10-yr reoccurrence intervals and computed t_c as our parameters
- Step 6: Calculated WQf (Q_2)and Swale Design Flow (Q_5) using Q = C*i*A

TC-10: 2. a-e)

2. Swale Geometry

a) Mannings Roughness Coefficient (*n*) (Use 0.25 for grass and 0.40 for mixed vegetation and rocks)	*n* =	
	Left Side Slope	**Right Side Slope**
b) Swale Side Slopes (max 4H:1V or flatter)	H:V = :1	H:V = :1
c) Bottom Width (BW) of Trapezoidal Channel (10' maximum)	BW = ft	
d) Flow Depth (D): WQ_F depth (D_2) maximum = 3', Design Flow (Q_5) Depth = D_5 (Calculate using an external method, indicate method in notes below)	D_2 = ft	D_5 = ft
e) Minimum swale depth with 0.5 ft of freeboard	D_5 + 0.5' = ft	
e) Minimum swale Top Width (TW) with 0.5 ft of freeboard	TW = ft	

3. Swale Length, Slope & Flow Velcoity

a) Length of Swale (L_S), minimum = 100'	L_S = ft	
b) Longitudinal Slope (S), 0.5% minimum, 2.5% maximum	S = %	
c) Flow Velocity (V) (WQ_F velocity = V_2 , maximum = 2.0 ft/sec) (Calculate using an external method, indicate method in notes below)	V_2 = ft/sec	V_5 = ft/sec

> **Truckee Meadows Regional Drainage Manual**

– Manning's n for Channels (Chow, 1959) for additional site uses

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TC-10: 2. a-e)

Module TC-10 *Swale Geometry*			
Manning's Roughness Coefficient, n			**Criteria**
n	0.4	Manual input	
Left Swale Side Slopes			
H:V=X:1 (Left)	2	Manual input	Max 4H:1V or flatter
H:V=X:1 (Right)	2		
Bottom Width, BW (ft)			
BW	10		10' max
Flow Depths, D (ft)			
D_2 (Q_2/WQf)	0.65	Calc'd using What-if Goal Seek	Max = 3'
D_5 (Q_5)	0.77		
Swale Dimensions			
Min. Swale Depth + 0.5 ft FB	1.15		
Min. Swale Top Width + 0.5 ft FB	40	Manual input	
Length of Swale, Ls (ft)	400	Manual input	Min = 100'
Longitudinal Slope, S (%)	0.5	Manual input	Range: 0.5-2.5%
v_2 (ft/s)	0.40	Calc'd using What-if Goal Seek	
v_5 (ft/s)	0.45		

2. Swale Geometry

a) Mannings Roughness Coefficient (*n*)
(Use 0.25 for grass and 0.40 for mixed vegetation and rocks)

b) Swale Side Slopes (max 4H:1V or flatter)

c) Bottom Width (BW) of Trapezoidal Channel (10' maximum)

d) Flow Depth (D): WQ_F depth (D_2) maximum = 3', Design Flow (Q_5) Depth = D_5
(Calculate using an external method, indicate method in notes below)

e) Minimum swale depth with 0.5 ft of freeboard

e) Minimum swale Top Width (TW) with 0.5 ft of freeboard

3. Swale Length, Slope & Flow Velcoity

a) Length of Swale (L_S), minimum = 100'

b) Longitudinal Slope (S), 0.5% minimum, 2.5% maximum

c) Flow Velocity (V) (WQ_F velocity = V_2 , maximum = 2.0 ft/sec)
(Calculate using an external method, indicate method in notes below)

TC-10: 4-5.

4. Vegetation (Check **"x"** to indicate type used or describe "Other")
(Minimum vegetation height of 4 - 6" is recommended)

X	Dryland Grass
	Irrigated Turf Grass
	Other:

5. Underdrain & Outlet (Check **"x" to indicate** type used or describe "Other")

a) Check "x" if swale is in HSG C or D soils?

Underdrain required if checked
(Provide a 4" diameter PVC underdrain for proper drainage)

b) Outlet for flows greater than the WQ_F

	Grated Inlet
	Overland Flow to Valley Gutter or Downstream Swale
	Other:

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Vegetated Buffer Strips (TC-11)

> **Description**

– Vegetated surfaces that can be interspersed with shrubs and trees

– Gently sloping and uniformly graded to provide treatment in relatively small drainage areas

– Slow the velocity of runoff waters to promote infiltration and the filtration of sediments and pollutants

> **Applications and Advantages**

– Used as pretreatment devices for other treatment controls or combined with riparian zones for treating sheet flows and stabilizing channel banks adjacent to drainage ways

– Appropriate along the edge of developments where irrigated landscaping is planned

– Supplemental irrigation may also be required

Vegetated buffer.
Source: Structural Controls and LID Manual (2015).

Vegetated Buffer Strips (TC-11)

> **Performance Data**

– Pollutant removal depends on factors such as soil permeability, land uses and slopes of adjacent drainage area, runoff volumes and velocities, the flow across the buffer strip and the type and density of vegetation used

Pollutant	Percent Removal Efficiency
Total Suspended Solids	10 - 74
Total Phosphorus	0 - 10
Total Nitrogen	0 - 15
Total Recoverable Zinc	0 - 10

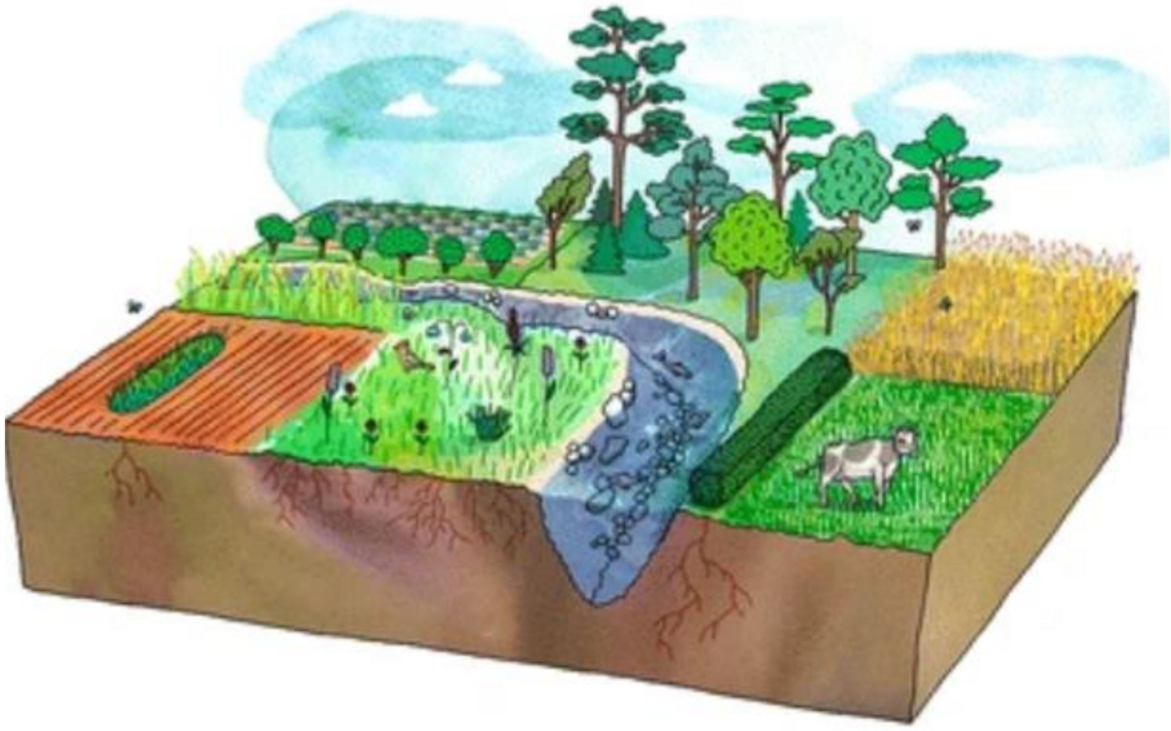
Sources: UDFCD, 1999; CASQA, 2003.

Source: Structural Controls and LID Manual (2015).

Vegetated Buffer Strips (TC-11)

> **Limitations**
  - Uniformly graded thick vegetative cover is required
  - Impractical in urban areas with little pervious ground
  - Not capable of treating SW from large drainage areas
  - May not be applicable adjacent to industrial sites where spills may occur

> **Siting Criteria**
  - Best suited for treating runoff from roads, roofs, small parking lots, and pervious surfaces
  - Avoid highly trafficked areas
  - Seasonally high groundwater table should be minimum 3 feet below buffer strip



Vegetated strips.
Source: Springer Nature.

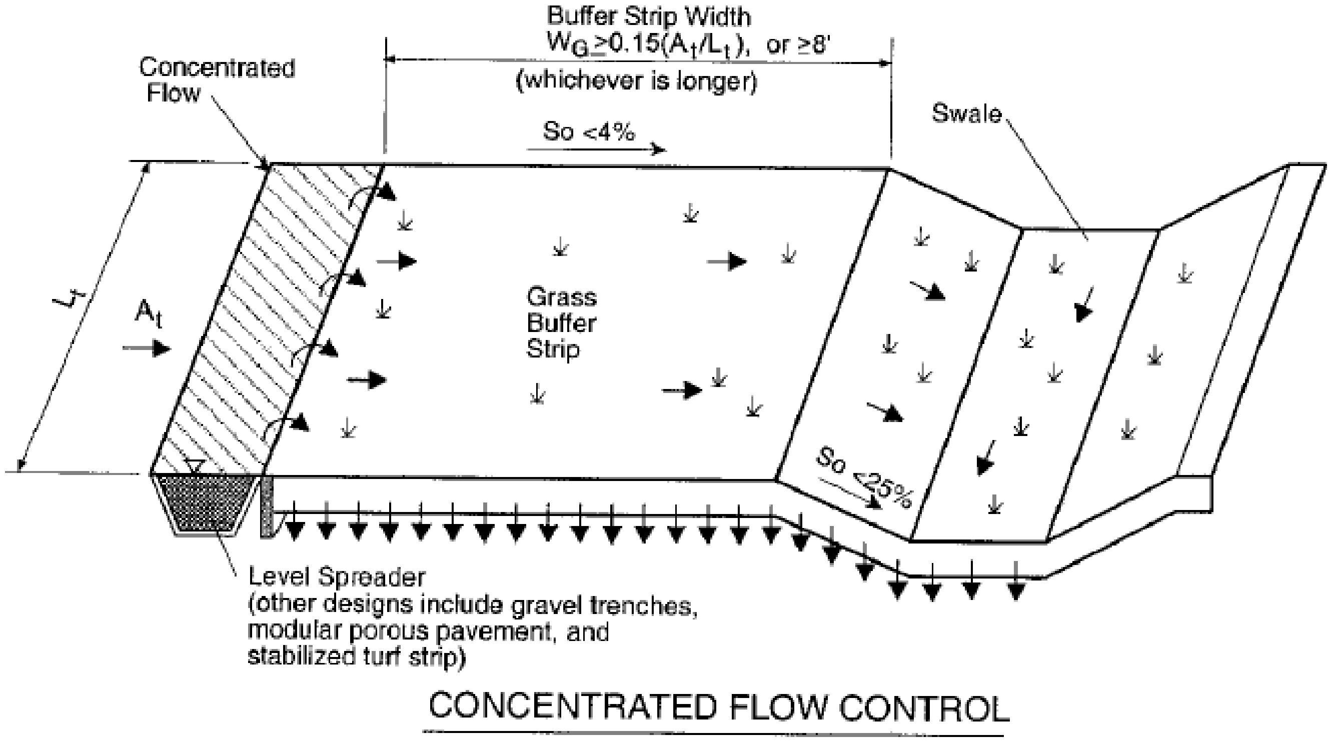
Vegetated Buffer Strips (TC-11)

> **Design and Construction Criteria**

- Registered PE and landscape architect should work together to assess site and develop designs
- Design Guidance Worksheet
- See Manual for specific design values

> **Inspection and Maintenance Requirements Criteria**

- Maintenance (weed removal, mowing and irrigation of grasses)
- Grasses or turf should be maintained at height of 2-6 inches
- See Manual for more additional requirements

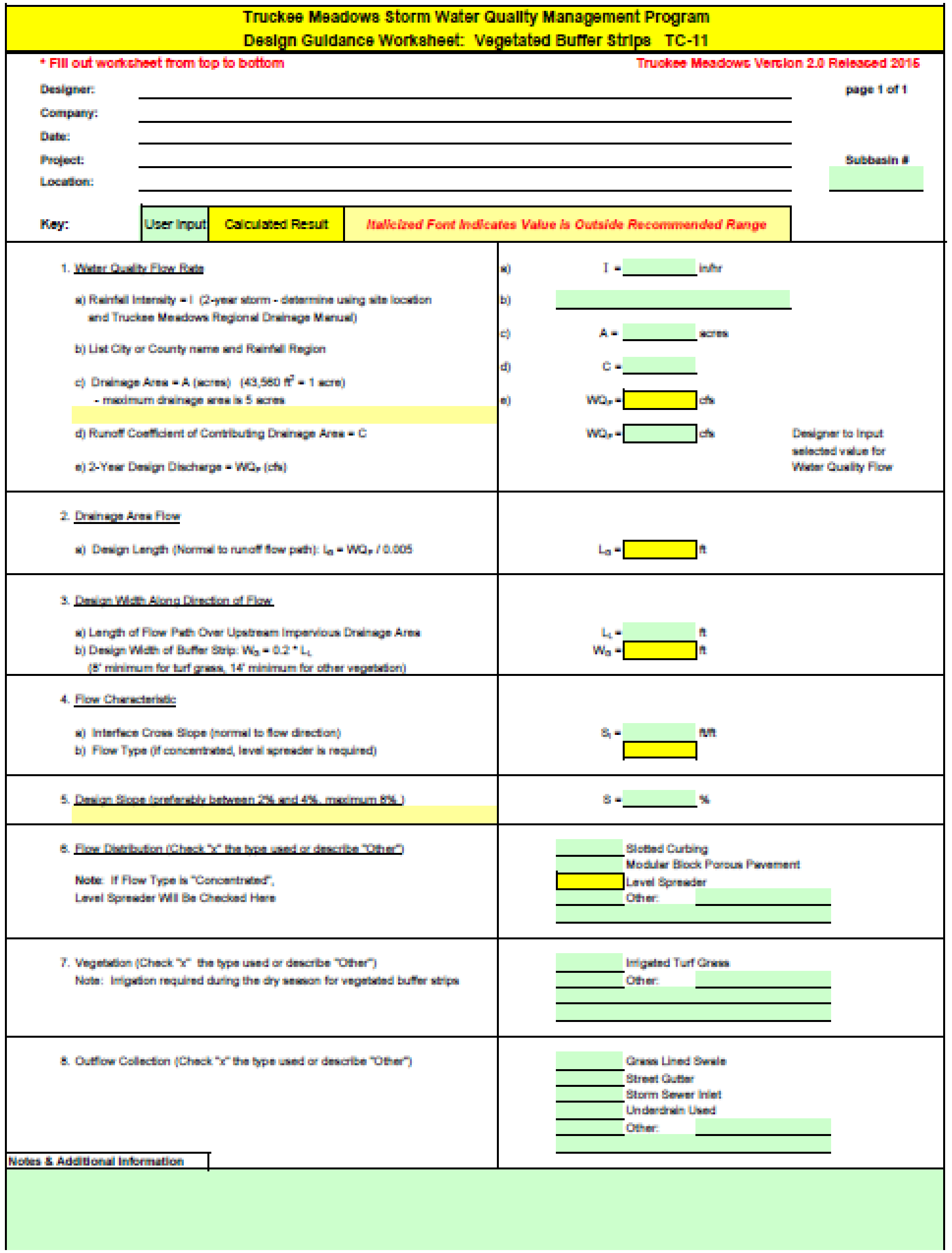


Source: Structural Controls and LID Manual (2015).

TC-11

> Method for calculating Water Quality Flow Rate explained for TC-10

1. Using Rainfall Intensity and Runoff Coefficient values from TC-10 example to calculate Water Quality Flow Rate
2. Drainage Area Flow
3. Design Width Along Direction of Flow
4. Flow Characteristic
5. Design Slope
6. Flow Distribution
7. Vegetation
8. Outflow Collection



Truckee Meadows Storm Water Quality Management Program
Design Guidance Worksheet: Vegetated Buffer Strips TC-11

* Fill out worksheet from top to bottom

Truckee Meadows Version 2.0 Released 2015

page 1 of 1

Designer: ______
Company: ______
Date: ______
Project: ______
Location: ______

Subbasin # ______

Key: User Input | Calculated Result | *Italicized Font Indicates Value is Outside Recommended Range*

1. Water Quality Flow Rate
   - a) Rainfall Intensity = I (2-year storm - determine using site location and Truckee Meadows Regional Drainage Manual) — a) I = ______ in/hr
   - b) List City or County name and Rainfall Region — b) ______
   - c) Drainage Area = A (acres) ($43{,}560\ ft^2 = 1$ acre) - maximum drainage area is 5 acres — c) A = ______ acres
   - d) Runoff Coefficient of Contributing Drainage Area = C — d) C = ______
   - e) 2-Year Design Discharge = WQ_F (cfs) — e) WQ_F = ______ cfs; WQ_F = ______ cfs — Designer to Input selected value for Water Quality Flow

2. Drainage Area Flow
   - a) Design Length (Normal to runoff flow path): $L_G = WQ_F / 0.005$ — L_G = ______ ft

3. Design Width Along Direction of Flow
   - a) Length of Flow Path Over Upstream Impervious Drainage Area — L_L = ______ ft
   - b) Design Width of Buffer Strip: $W_G = 0.2 * L_L$ (8' minimum for turf grass, 14' minimum for other vegetation) — W_G = ______ ft

4. Flow Characteristic
   - a) Interface Cross Slope (normal to flow direction) — S_I = ______ ft/ft
   - b) Flow Type (if concentrated, level spreader is required) — ______

5. Design Slope (preferably between 2% and 4%, maximum 6%) — S = ______ %

6. Flow Distribution (Check "x" the type used or describe "Other")

   Note: If Flow Type is "Concentrated", Level Spreader Will Be Checked Here

   ______ Slotted Curbing
   ______ Modular Block Porous Pavement
   ______ Level Spreader
   ______ Other: ______

7. Vegetation (Check "x" the type used or describe "Other")

   Note: Irrigation required during the dry season for vegetated buffer strips

   ______ Irrigated Turf Grass
   ______ Other: ______

8. Outflow Collection (Check "x" the type used or describe "Other")

   ______ Grass Lined Swale
   ______ Street Gutter
   ______ Storm Sewer Inlet
   ______ Underdrain Used
   ______ Other: ______

Notes & Additional Information

TC-11: 1. e)

1. Water Quality Flow Rate	a)	I =	0.63	in/hr
a) Rainfall Intensity = I (2-year storm - determine using site location and Truckee Meadows Regional Drainage Manual)	b)			
b) List City or County name and Rainfall Region	c)	A =	5.0	acres
c) Drainage Area = A (acres) (43,560 ft^2 = 1 acre) - maximum drainage area is 5 acres	d)	C =	0.2	
d) Runoff Coefficient of Contributing Drainage Area = C	e)	WQ_F =		cfs
e) 2-Year Design Discharge = WQ_F (cfs)		WQ_F =		cfs — Designer to Input selected value for Water Quality Flow

1. Using Rainfall Intensity and Runoff Coefficient values from TC-10 example to calculate Water Quality Flow Rate
   - From TC-10 example: i_2 = 0.63 in/hr, C_2 = 0.2
   - Section 6.8.1 states "maximum contributing drainage area is 5 acres"

$$WQ_f(\text{cfs}) = C_2 i_2 A = 0.2 \times 0.63\ \frac{\text{in}}{\text{hr}} \times 5\ \text{acres} = 0.63\ \text{cfs}$$

TC-11: 2-3.

2. Drainage Area Flow a) Design Length (Normal to runoff flow path): $L_G = WQ_F / 0.005$	$L_G =$ ft
3. Design Width Along Direction of Flow a) Length of Flow Path Over Upstream Impervious Drainage Area b) Design Width of Buffer Strip: $W_G = 0.2 * L_L$ (8' minimum for turf grass, 14' minimum for other vegetation)	$L_L =$ 60 ft $W_G =$ ft

2. Drainage Area Flow
   a) Design Length (L_G):

$$L_G = \frac{WQ_F}{0.005} = \frac{0.63\ \text{cfs}}{0.005} = 126\ \text{ft}$$

3. Design Width Along Direction of Flow
   a) Length of Flow Path Over Upstream Impervious Drainage Area (L_L):
      - Use maximum length of 60 feet (CASQA)

   b) Design Width of Buffer Strip:
      $W_G = 0.2 \times L_L = 0.2 \times 60\ \text{ft} = 12\ \text{ft}$

TC-11: 4-5.

4. Flow Characteristic a) Interface Cross Slope (normal to flow direction) b) Flow Type (if concentrated, level spreader is required)	S_I = 0.15 ft/ft
5. Design Slope (preferably between 2% and 4%, maximum 8%)	S = 3 %

4. Flow Characteristic
   a) Interface Cross Slope:
      - Use maximum slope of 15% (CASQA)
   b) Flow Type:
      Sheet flow: $L_L \times S_I \leq 1$ or Concentrated flow: $L_L \times S_I > 1$
      $L_L \times S_I = 60\text{ ft} \times 0.15 = 9 \rightarrow$ Concentrated flow, level spreader required

5. Design Slope: Input site slope, note constraints

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TC-11: 6.

6. Flow Distribution (Check "x" the type used or describe "Other")

Note: If Flow Type is "Concentrated", Level Spreader Will Be Checked Here

	Slotted Curbing
	Modular Block Porous Pavement
X	Level Spreader
	Other:

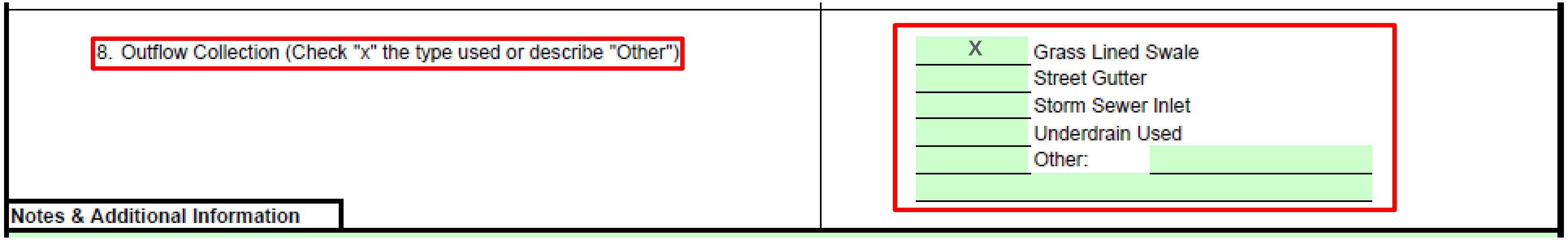
6. Flow Distribution
   - Level spreader was checked because it is required for the concentrated flow resulting from this example
   - If the flow isn't concentrated and another type is used, check that box instead

TC-11: 7.

7. Vegetation (Check "x" the type used or describe "Other") Note: Irrigation required during the dry season for vegetated buffer strips	X Irrigated Turf Grass Other:

7. Vegetation
   - Irrigated Turf Grass was checked for this example
   - If a different type is used, check other and describe

TC-11: 8.



8. Outflow Collection (Check "x" the type used or describe "Other")

X Grass Lined Swale
Street Gutter
Storm Sewer Inlet
Underdrain Used
Other:

Notes & Additional Information

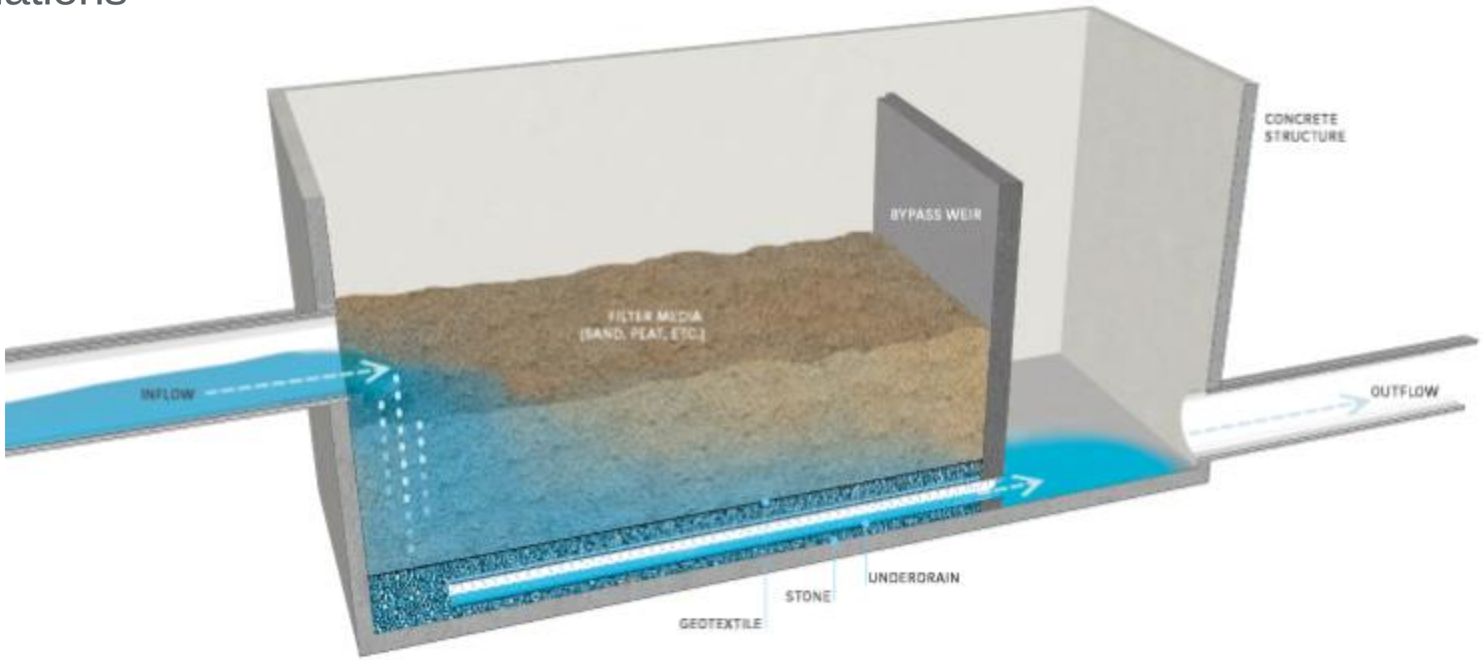
8. Vegetation
   - Grass Lined Swale was checked in this example as it can provide additional treatment
   - If a different collection type is used check that instead
   - If the type used is not listed, check other and describe

Volume-Based Structural Treatment Controls

Media Filtration Systems

> Typically consist of two chambers, a pretreatment settling basin and a filter bed filled with sand or some other absorptive filtering media
  – Large particles transported in stormwater runoff settle in the pretreatment basin while finer particles and associated pollutants are removed by filtering through media in the second chamber

> Numerous design variations

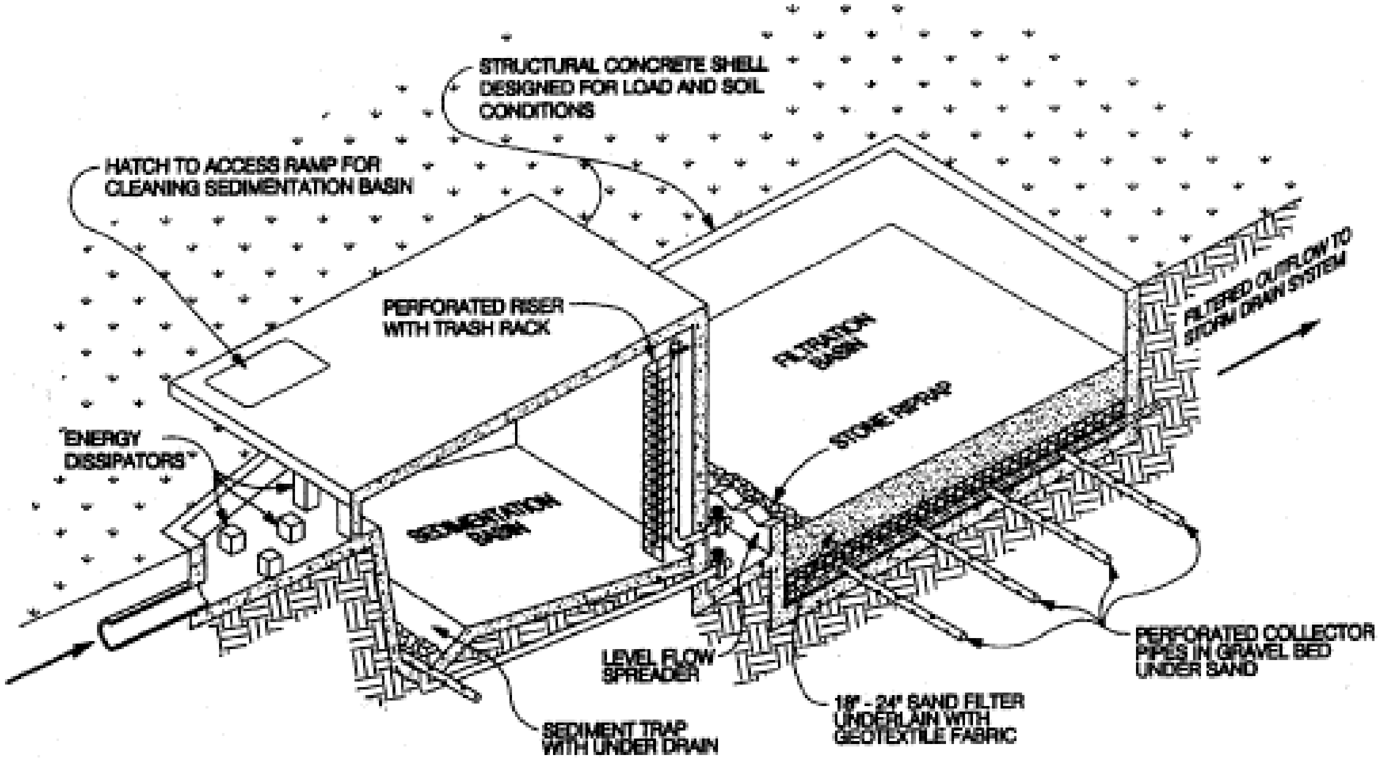


Media filter with typical features
Source: Philadelphia Water Department

Surface Sand Filter (TC-60)

> **Description**

- Applies a combination of sedimentation, filtration and adsorption to remove sediment and associated pollutants
- Comprises an upstream bypass structure (weir), a sedimentation chamber, a flow distribution cell, and a sand filter bed
- Sedimentation basin removes floatables and heavier suspended sediments
- Sand filter removes lighter suspended sediments and additional contaminants



Source: Structural Controls and LID Manual (2015).

Surface Sand Filter (TC-60)

> **Applications and Advantages**

- Drainage areas ranging from .5 to 50 acres and containing pervious and impervious surfaces
- Commonly applied to transportation facilities, large parking areas, and around commercial developments
- In areas with high sediment loads, use sand filters in conjunction with pretreatment

> **Limitations**

- Clogging can be an issue in area with highly erodible or unstable soils

> **Siting Criteria**

- Areas need to have sufficient vertical relief in land topography to allow the system to drain by gravity
- Maintain distance between the high seasonal water table and bottom of the filter bed

Surface Sand Filter (TC-60)

> **Design and Construction Criteria**
  - Registered PE should design surface sand filters and utilize Design Guidance Worksheet
  - Consider pre-treatment BMP upstream in areas with large sediment loads
  - A liner may be recommended in areas of shallow groundwater to prevent contamination
  - Refer to Manual for more design details

> **Inspection and Maintenance Requirements**
  - Inspections at least 3 times per year, once at the beginning of the rainy season and after any major storm events
  - Rake the sand to ensure drainage rates are maintained
  - Sand and gravel filter media may need to be replaced every 3 to 5 years

TC-60

1. Water Quality Volume
2. Sedimentation Basin Design
3. Sand Filter Basin Design

Truckee Meadows Storm Water Quality Management Program
Design Guidance Worksheet: Surface Sand Filter TC-60

* Fill out worksheet from top to bottom — Truckee Meadows Version 2.0 Released 2015

page 1 of 1

Designer: ____
Company: ____
Date: ____
Project: ____ Subbasin # ____
Location: ____

Key: User Input | Calculated Result | *Italicized Font Indicates Value is Outside Recommended Range*

1. Water Quality Volume (WQ_V)	a) Sub-basin area ___ ft^2; Sub-basin impervious area ___ ft^2; % imperviousness ___
a) Percent of Watershed Impervious Area = I	
b) Drainage Area = A (acres) (43,560 ft^2 = 1 acre) - drainage areas between 0.5 and 50 acres	b) A= ___ ac
c) Watershed Runoff Coefficient = R_V (unitless)	c) R_v = ___
d) 90th Percentile Precipitation Depth = 0.6(inches)	
e) Water Quality Volume = WQ_V (ft^3)	e) WQ_V = ___ ft^3; WQ_V = ___ ft^3; Designer to select value for Water Quality Volume for actual design
2. Sedimentation Basin Design	
a) Depth of Sand Filter = d_f (ft) (minimum depth of 3 ft)	d_f = ___ ft
b) Surface Area of the Sedimentation Basin = A_S (ft^2); minimum WQv/10	A_S = ___ ft^2
c) Basin Length	L = ___ ft
d) Basin Width	W = ___ ft
e) Basin length to width ratio (L:W, min. 2:1)	L:W = ___ :1
3. Sand Filter Basin Design	
a) Sand bed depth = d_f (minimum depth 1.5 feet)	d_f = ___ ft
b) Coef of permeability for sand filter = k ft/hr (typically 1.18 ft/hr for clean, well-graded sand and gravel)	k = ___ ft/hr
c) One half the maximum allowable water depth (2h) over filter bed = h	h = ___ ft
d) Time required for the WQ_V to pass through the filter = t_f	t_f = ___ hrs
e) Surface area of the filter basin = A_f (ft^2)	A_f = ___ ft^2

Notes & Additional Information:

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TC-60: Local Example

- Site location: Spaghetti Bowl Xpress (focus on Basin 3-01)
- Design a Surface Sand Filter by
  - Using Equation 6-2 from Section 6.3.2 of TMSCDLIDM to compute Water Quality Volume (WQv)
  - Using the WQv to determine surface area of the filter basin (Af)

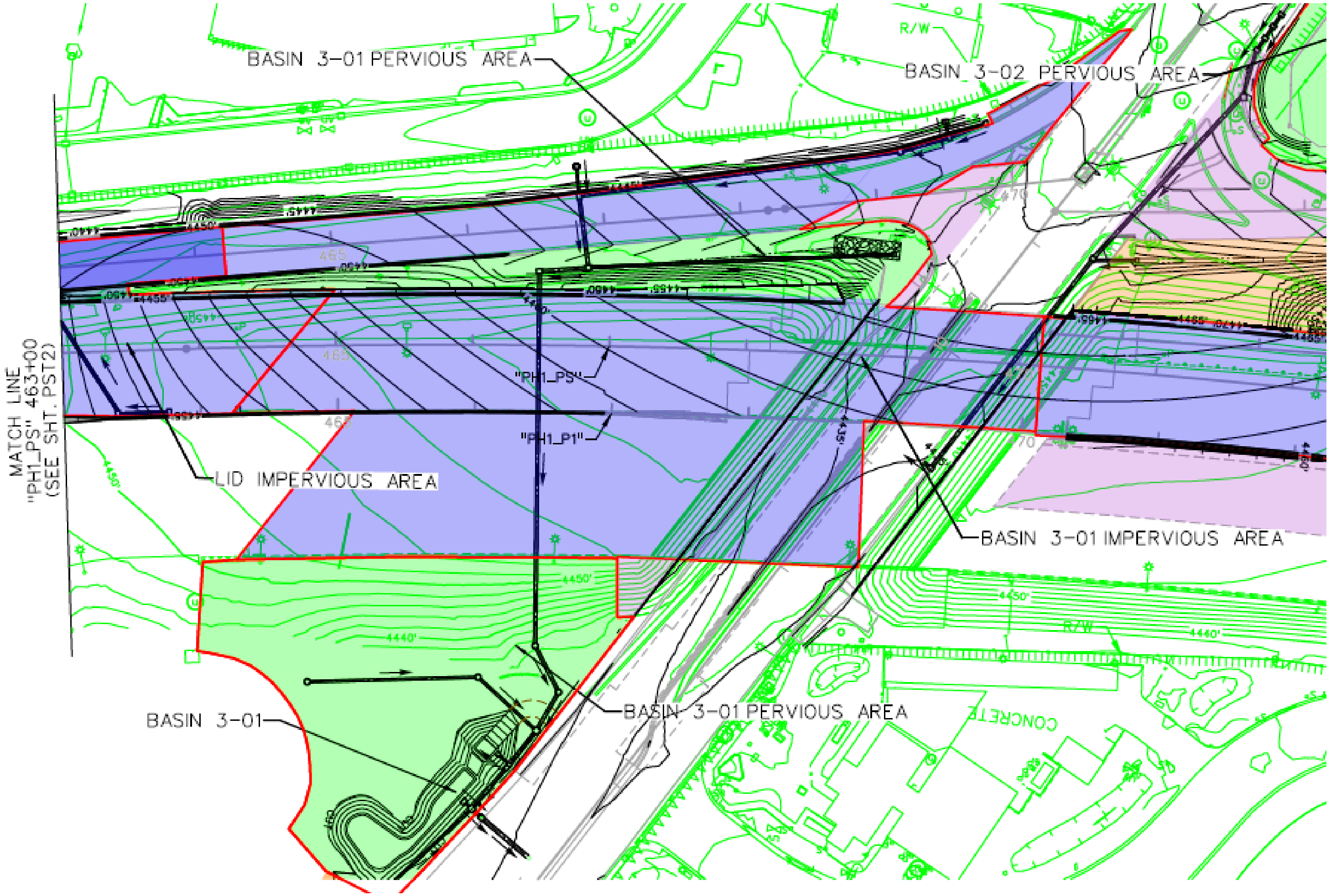

Image from Horrocks Engineers' Drainage Design Report (October 2020)

TC-60: Local Example 1. a)

1. Water Quality Volume (WQ_V)	a) Sub-basin area 182,404 ft^2; Sub-basin impervious area 117,439 ft^2; **% Imperviousness 64.38**
a) Percent of Watershed Impervious Area = I	
b) Drainage Area = A (acres) (43,560 ft^2 = 1 acre) - drainage areas between 0.5 and 50 acres	b) A= 4.19 ac
c) Watershed Runoff Coefficient = R_V (unitless)	c) R_V = 0.63
d) 90th Percentile Precipitation Depth = 0.6(inches)	e) WQ_V = 5,741 ft^3
e) Water Quality Volume = WQ_V (ft^3)	WQ_V = 5,741 ft^3 **Designer to select value for Water Quality Volume for actual design**

a) Percent of Watershed Impervious Area (I)

$$\%\ \text{Imperviousness} = \frac{\text{Subbasin impervious area}}{\text{Subbasin area}} = \frac{117{,}439\ \text{ft}^2}{182{,}404\ \text{ft}^2} = 64.38\%$$

TC-60: Local Example 1. b)

1. Water Quality Volume (WQ_V)	a)	Sub-basin area	182,404 ft^2
		Sub-basin impervious area	117,439 ft^2
a) Percent of Watershed Impervious Area = I		**% Imperviousness**	**64.38**
b) Drainage Area = A (acres) (43,560 ft^2 = 1 acre) - drainage areas between 0.5 and 50 acres	b)	A=	**4.19** ac
c) Watershed Runoff Coefficient = R_V (unitless)	c)	R_V =	0.63
d) 90th Percentile Precipitation Depth = 0.6(inches)			
e) Water Quality Volume = WQ_V (ft^3)	e)	WQ_V =	5,741 ft^3
		WQ_V =	5,741 ft^3
	Designer to select value for Water Quality Volume for actual design		

Subbasin #	Basin 3-01	Subbasin Area (sq.ft.):	182,404
T_c (min.):	9	Subbasin Area (acres):	4.19
		2-yr Rainfall intensity from IDF curve	1.04
		Pre-Development Impervious area (sq ft):	0
		Post-Development Impervious area (sq ft):	117,439
		Pre-Development Runoff Coefficient:	0.00
		Post-Development Runoff Coefficient:	0.64
		Pre-Development Percent Impervious:	0
		Post-Development Percent Impervious:	64
		Pre-dev. Subbasin WQ_f (ft^3/sec)	0.00
		Pre-dev. Subbasin WQ_v (ft^3)	0
		Post-dev. Subbasin WQ_f (ft^3/sec)	2.77
		Post-dev. Subbasin WQ_v (ft^3)	5,741
		Post - Pre WQ_f (ft^3/sec) Min. Requiring treatment	2.77
		Post - Pre WQ_v (ft^3) Min. Requiring Treatment	5,741
		Enter Treatment Control or indicate if "self treating"	TC-60
		Actual WQ_f (ft^3/sec), if 'self treating' enter min WQf	2.77
		Actual Subbasin WQ_v (ft^3)	6159
		Sub-basin %WQf	100.00
		Sub-basin %WQv	107.29
		Sub-basin	**Pass**

b) Drainage Area (A)

$$A(\text{acres}) = 182{,}404\ \text{ft}^2 \times \frac{1\ \text{acre}}{43{,}560\ \text{ft}^2} = 4.19\ \text{acres}$$

TC-60: Local Example 1. c)

1. Water Quality Volume (WQ_V)	a)	Sub-basin area: 182,404 ft^2
		Sub-basin impervious area: 117,439 ft^2
a) Percent of Watershed Impervious Area = I		**% Imperviousness: 64.38**
b) Drainage Area = A (acres) (43,560 ft^2 = 1 acre) - drainage areas between 0.5 and 50 acres	b)	A= 4.19 ac
c) Watershed Runoff Coefficient = R_V (unitless)	c)	R_v = 0.63
d) 90th Percentile Precipitation Depth = 0.6(inches)	e)	WQ_V = 5,741 ft^3
e) Water Quality Volume = WQ_V (ft^3)		WQ_V = 5,741 ft^3
		Designer to select value for Water Quality Volume for actual design

c) Watershed Runoff Coefficient (Rv)

$$R_v = 0.05 + (0.009 \times I) = 0.05 + (0.009 \times 64.38) = 0.63$$

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TC-60: Local Example 1. e)

1. Water Quality Volume (WQ_V)	a) Sub-basin area 182,404 ft^2
	Sub-basin impervious area 117,439 ft^2
a) Percent of Watershed Impervious Area = I	**% Imperviousness** 64.38
b) Drainage Area = A (acres) (43,560 ft^2 = 1 acre)	b) A= 4.19 ac
- drainage areas between 0.5 and 50 acres	
c) Watershed Runoff Coefficient = R_V (unitless)	c) R_V = 0.63
d) 90th Percentile Precipitation Depth = 0.6(inches)	e) WQ_V = 5,741 ft^3
	WQ_V = 5,741 ft^3
e) Water Quality Volume = WQ_V (ft^3)	**Designer to select value for Water Quality Volume for actual design**

e) Water Quality Volume (WQv)

$$WQ_v(ft^3) = \frac{P^* \times R_v \times A}{12} = \frac{0.6\ in \times 0.63 \times 182{,}404\ ft^2}{12} = 5{,}741\ ft^3$$

TC-60: Local Example 2. b)

2. Sedimentation Basin Design

a) Depth of Sand Filter = d_f (ft) (minimum depth of 3 ft)	d_f = 3.0 ft
b) Surface Area of the Sedimentation Basin = A_s (ft^2); minimum WQv/10	A_s = ft^2
c) Basin Length	L = ft
d) Basin Width	W = ft
e) Basin length to width ratio (L:W, min. 2:1)	L:W = :1

a) Assume minimum depth of 3 ft for df

b) Surface Area of the Sedimentation Basin (As):

$$A_s(\mathrm{ft}^2) = \frac{WQ_v}{d_f} = \frac{5{,}741\ \mathrm{ft}^3}{3\ ft} = 1{,}913.7\ \mathrm{ft}^2$$

TC-60: Local Example 2. c-e)

2. Sedimentation Basin Design

a) Depth of Sand Filter = d_f (ft) (minimum depth of 3 ft)	d_f =	3.0 ft
b) Surface Area of the Sedimentation Basin = A_s (ft^2); minimum WQv/10	A_s =	1,913.7 ft^2
c) Basin Length	L =	ft
d) Basin Width	W =	ft
e) Basin length to width ratio (L:W, min. 2:1)	L:W =	2 :1

Solving for basin length and width assuming the min length to width ratio of 2:1

$$A_s = L \times W \qquad W = \frac{L}{2} \qquad A_s = \frac{L^2}{2}$$

c) Basin Length: $L = \sqrt{2 \times A_s} = \sqrt{2 \times 1{,}913.7\ ft^2} = 61.87ft$

d) Basin Width: $W = \frac{L}{2} = \frac{61.87\ ft}{2} = 30.94\ ft$

TC-60: Local Example 3. e)

3. Sand Filter Basin Design

a) Sand bed depth = d_f	d_f =	1.5	ft
b) Coef of permeability for sand filter = k ft/hr (typically 1.18 ft/hr for clean, well graded sand and gravel)	k =	1.18	ft/hr
c) One half the maximum allowable water depth (2h) over filter bed = h	h =	1.0	ft
d) Time required for the WQ_V to pass through the filter = t_f	t_f =	24.0	hrs
e) Surface area of the filter basin = A_f (ft^2)	A_f =	121.6	ft^2

Notes & Additional Information:

e) Surface Area of the Filter Basin (Af)

$$A_f(ft^2) = \frac{WQ_v \times d_f}{k \times (h + d_f) \times t_f} = \frac{5{,}741\ ft^3 \times 1.5\ ft}{1.18\ \frac{ft}{hr} \times (1.0\ ft + 1.5\ ft) \times 24.0\ hrs} = 121.6\ ft^2$$

Infiltration Systems

- Allow stormwater to slowly enter ground and migrate downward through unsaturated zone
- Sediments and pollutants are retained in near surface soils
- Infiltration process also provides additional treatment effectiveness for many structural treatment controls
- Natural soils utilize natural processes such as physical filtering, ion exchange, adsorption, biological procession, conversion, and uptake to remove pollutants
- Site assessments incorporate groundwater recharge feasibility, hydraulic conductivity tests
  - Suitable recharge conditions are favourable
  - Hydraulic conductivity of 0.5 inches per hour minimum
- Should not be implemented where there is high potential for spills that may directly infiltrate

Infiltration Trenches (TC-20)

> **Description**

- Lined with filter fabric and filled with rock matrix
- Allow for water retention such that partial or total infiltration of SW runoff into underlying soil
- Efficiency depends types and concentration of pollutants in SW influent, porosity of rock matrix, infiltration capacity of underlying soils

> **Applications and Advantages**

- Typically drain areas less than 5 Acres
- Allows for application along unused sections of developed sites
- Good for retrofitting

> **Performance Criteria**

- Can be improved by adding organics and loam to the subsoil

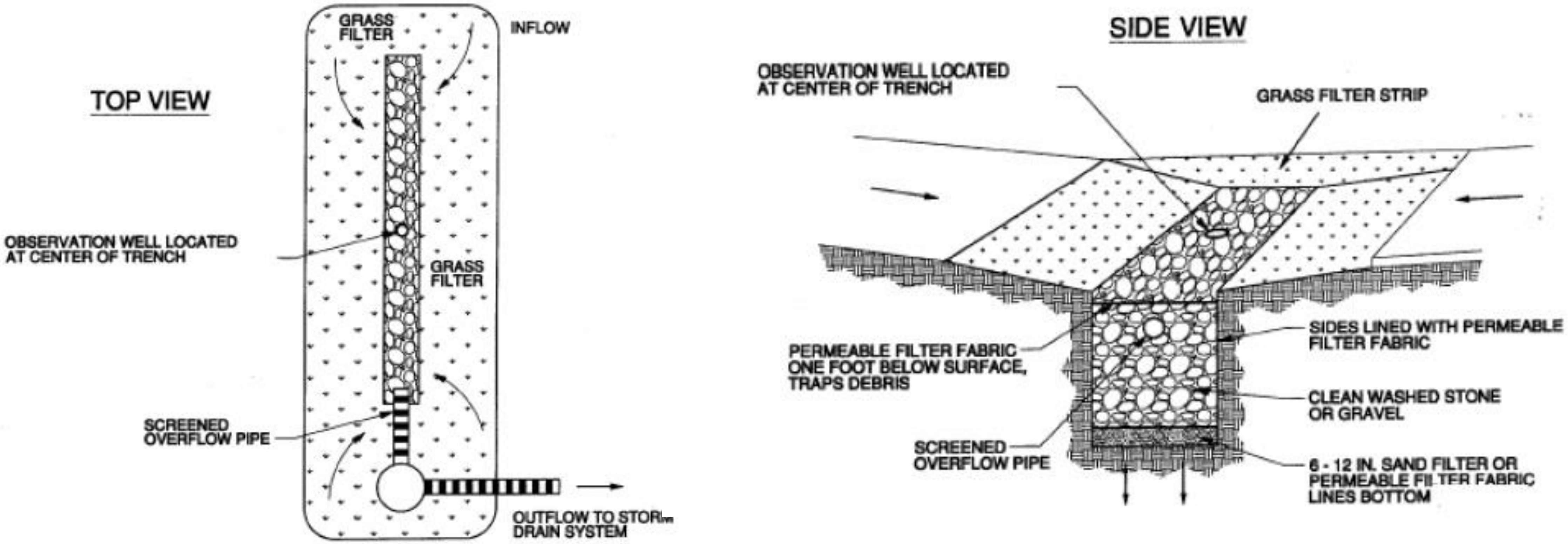
Pollutant	Percent Removal Efficiency
Total Suspended Solids	75 - 90
Total Phosphorus	50 - 70
Total Nitrogen	45 - 60
Metals	75 - 90
BOD	70 - 80
Bacteria	75 - 90

Source: Schueler, 1987

Source: Structural Controls and LID Manual (2015).

Infiltration Trench (TC-20)

> Example of a median strip Infiltration Trench with a grass buffer strip

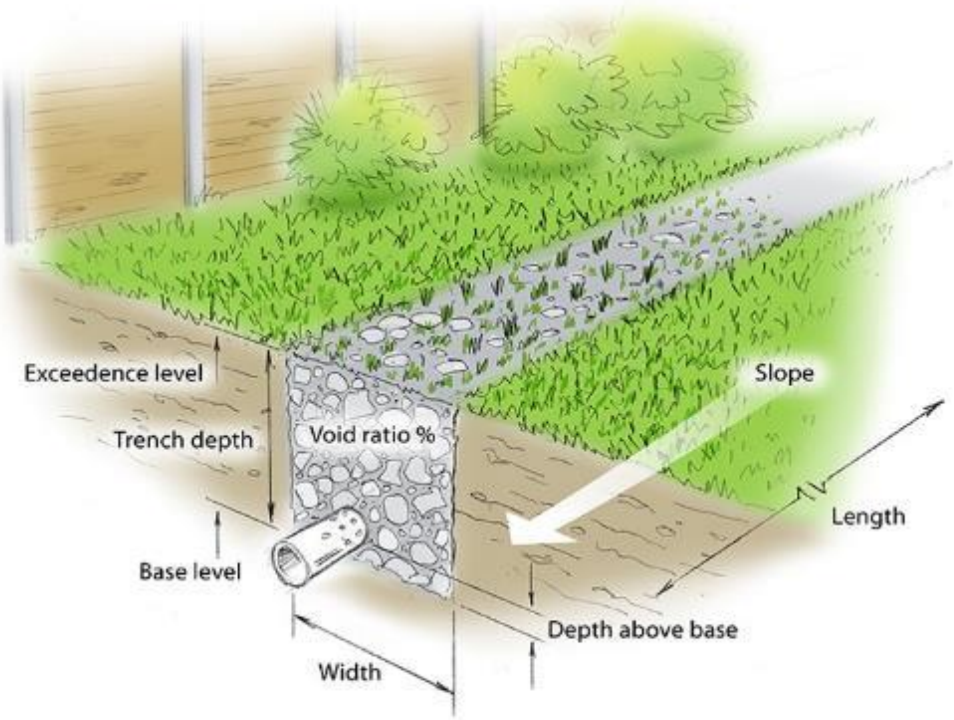


Source: Structural Controls and LID Manual (2015).

Infiltration Trenches (TC-20)

> **Limitations**
  – Avoid in areas with highly erodible, clary or silty soils and slopes greater than 20%
  – Infiltration rates of existing site soils > 0.5 in/hr; > 2.4 in/hr, consider groundwater contaminations
  – Frozen soil conditions can severely affect pollutant removal efficiency
  – Contributing drainage area should not be larger than 5 acres

> Siting Criteria
  – Seasonally high groundwater should not be within 3 feet of the bottom of the infiltration trench
  – Should not be installed in areas of high-risk land use such as gas stations or heavy industrial sites
  – See Manual for specific siting values



Infiltration Trench.
Source: Innovyze
https://help.innovyze.com/display/XDH2016v1/Infiltration+Trench

Infiltration Trenches (TC-20)

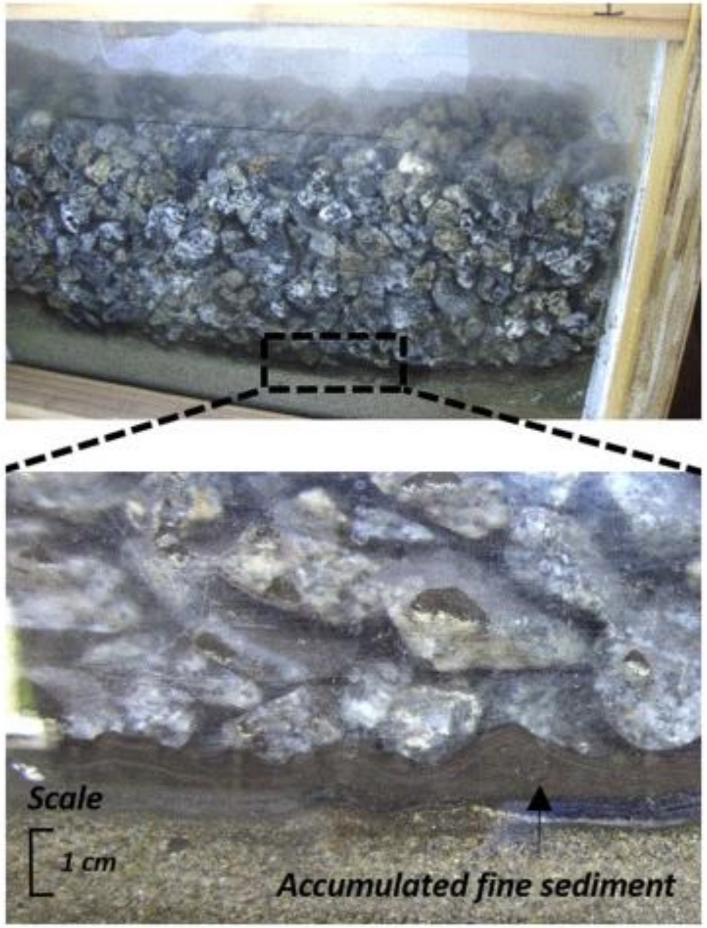
> Design and Construction Criteria
  - Designed by a PE using the Design Guidance Worksheets
  - Size the infiltration trench to capture and treat the WQv and flows in excess should be diverted
  - Provide pretreatment such as grassed swales or vegetated filter strips to reduce sediment loads
  - Consider groundwater conditions and whether trench is considered an “injection well”
  - Do not allow water to pond for more than 7 days from May through October
  - An observation well should be installed in the infiltration trench to monitor drainage and rates of sediment accumulation
  - See Manual for specific design values

> Infiltration Media Criteria
  - Defines the type of media that should be used, the spacing, hydraulic conductivity ratings
  - See Manual for specific criteria

Infiltration Trenches (TC-20)

> **Inspection and Maintenance Requirements**

- Life span of infiltration trenches ranges from 5 – 15 years, depending on maintenance
- Inspect following major storm events during first year after installation
- Clogging is likely to occur in top surface of the trench, between filter fabric and top gravel layer
- If a spill occurs and hazardous materials contaminate the sands or gravels, remove and replace soils as soon as possible



Accumulation of sediment.
Source: Water Research, https://www.sciencedirect.com/science/article/pii/S2589914720300098#fig2

TC-20

1. Method for calculating Water Quality Volume explained for TC-60
2. Infiltration Trench Dimensions
3. Infiltration Trench Floor Slope

Truckee Meadows Storm Water Quality Management Program
Design Guidance Worksheet: Infiltration Trenches TC-20

* Fill out worksheet from top to bottom

Truckee Meadows Version 2.0 Released 2015

page 1 of 1

Designer:
Company:
Date:
Project:
Location:

Subbasin #

Key: User Input | Calculated Result | *Italicized Font Indicates Value is Outside Recommended Range*

1. Water Quality Volume (WQ_v) - Infiltration Trench Storage

a) Percent of Watershed Impervious Area = I

b) Drainage Area = A (acres) (43,560 ft^2 = 1 acre)
- maximum drainage area 5 acres

c) Watershed Runoff Coefficient = R_v (unitless)

d) 90th Percentile Precipitation Depth = 0.6 inches

e) Water Quality Volume = WQ_v (ft^3)

a) Sub-basin area ft^2
Sub-basin impervious area ft^2
% Imperviousness

b) A= ac

c) R_v =

e) WQ_v = ft^3

WQ_v = ft^3

Designer to select value for Water Quality Volume for actual design

2. Infiltration Trench Dimensions

a) Surface Area (SA) of Trench — SA = ft^2

b) Porosity (void space of rock matrix) (unitless)

c) Total Trench Voume = V_T — V_T = ft^3

d) Depth of Trench = D (recommended min 3 feet, max 6 feet) — D = ft

3. Infiltration Trench Floor Slope
not to exceed 1% — %

Notes & Additional Information

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TC-20: 2. a-c)

2. Infiltration Trench Dimensions	
a) Surface Area (SA) of Trench	SA = 3,000 ft^2
b) Porosity (void space of rock matrix) (unitless)	0.35
c) Total Trench Voume = V_T	V_T = ft^3
d) Depth of Trench = D (recommended min 3 feet, max 6 feet)	D = ft

a) Surface Area (SA): Used 3,000 ft^2 for this example

b) Porosity: TMSCDLIDM states it should be between 0.3 and 0.4, used 0.35 for example

c) Total Trench Volume (V_T):

- Use WQ_V from TC-60 since drainage area is less than 5 acres

$$V_T = \frac{WQ_V}{\text{porosity}} = \frac{5{,}741\ \text{ft}^3}{0.35} = 16{,}402.9\ \text{ft}^3$$

TC-20: 2. d)

2. Infiltration Trench Dimensions	
a) Surface Area (SA) of Trench	SA = 3,000 ft^2
b) Porosity (void space of rock matrix) (unitless)	0.35
c) Total Trench Voume = V_T	V_T = 16,402.9 ft^3
d) Depth of Trench = D (recommended min 3 feet, max 6 feet)	D = ft

d) Depth of Trench (D):

$$D = \frac{V_T}{SA} = \frac{16{,}402.9\ ft^3}{3{,}000\ ft^2} = 5.5\ ft$$

TC-20: 3.

3. Infiltration Trench Floor Slope
not to exceed 1%

%

Notes & Additional Information

3. Infiltration Trench Floor Slope: Use max of 1% for example

Infiltration Basins (TC-21)

Description

> Lined with filter fabric and filled with rock matrix

> Allow for water retention such that partial or total infiltration of stormwater runoff into underlying soil

> Efficiency depends on the types and concentration of pollutants in stormwater influent, porosity of rock matrix, infiltration capacity of underlying soils

> **Applications and Advantages**

– Typically drainage areas are less than 5 acres

– Allows for application along unused sections of developed sites

– Good for retrofitting

> **Performance Data**

– Can provide 100% reduction in pollutant loading to surface waters

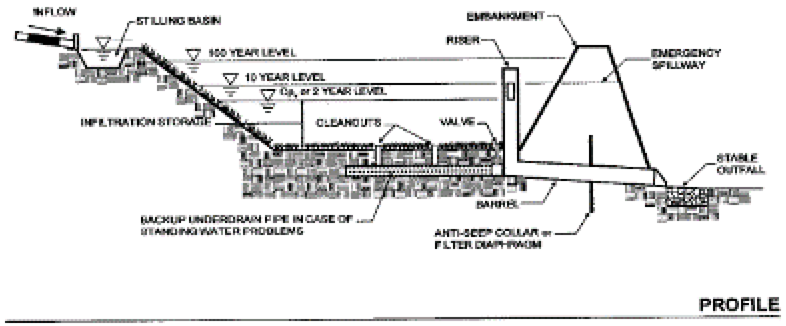
– Moderate efficiency for soluble pollutants

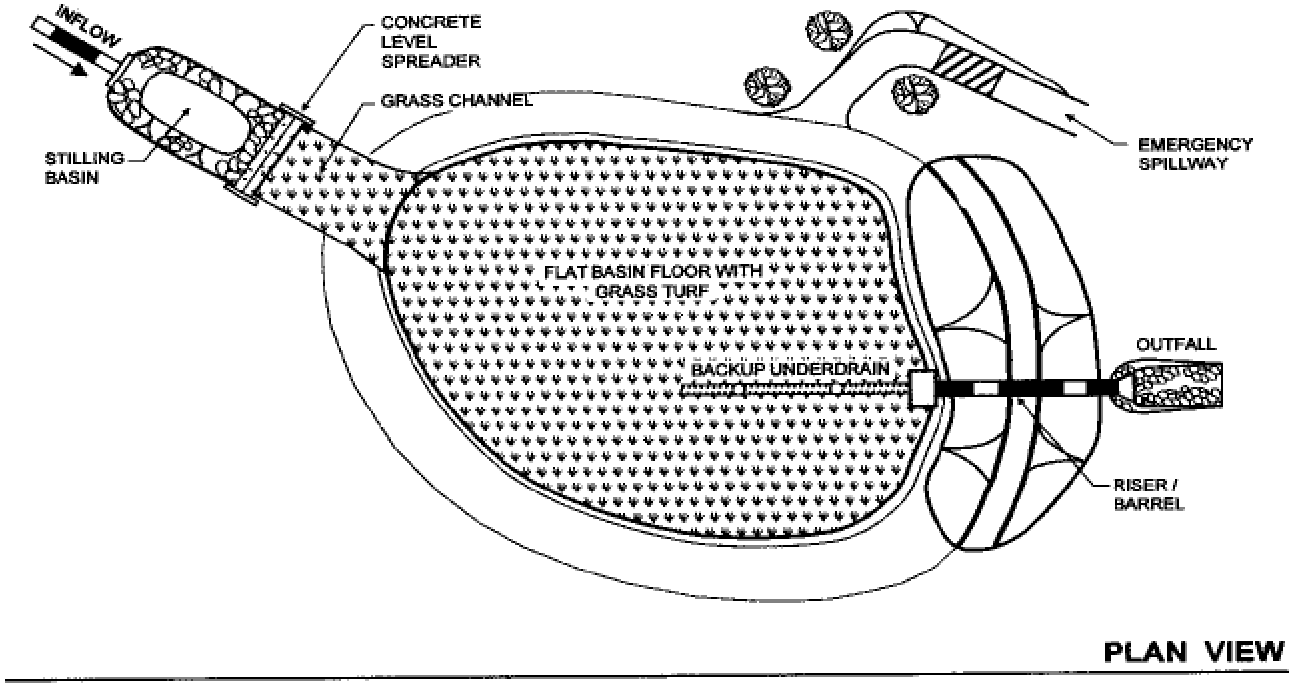
Pollutant	Percent Removal Efficiency
Total Suspended Solids	55 – 75
Total Phosphorus	45 – 55
Total Nitrogen	10 – 20
Total Recoverable Zinc	30 – 60
Total Recoverable Lead	55 – 80

Source: UDFCD, 1999.

Infiltration Basins (TC-21)

> Example of a typical infiltration basin design





Source: Structural Controls and LID Manual (2015).

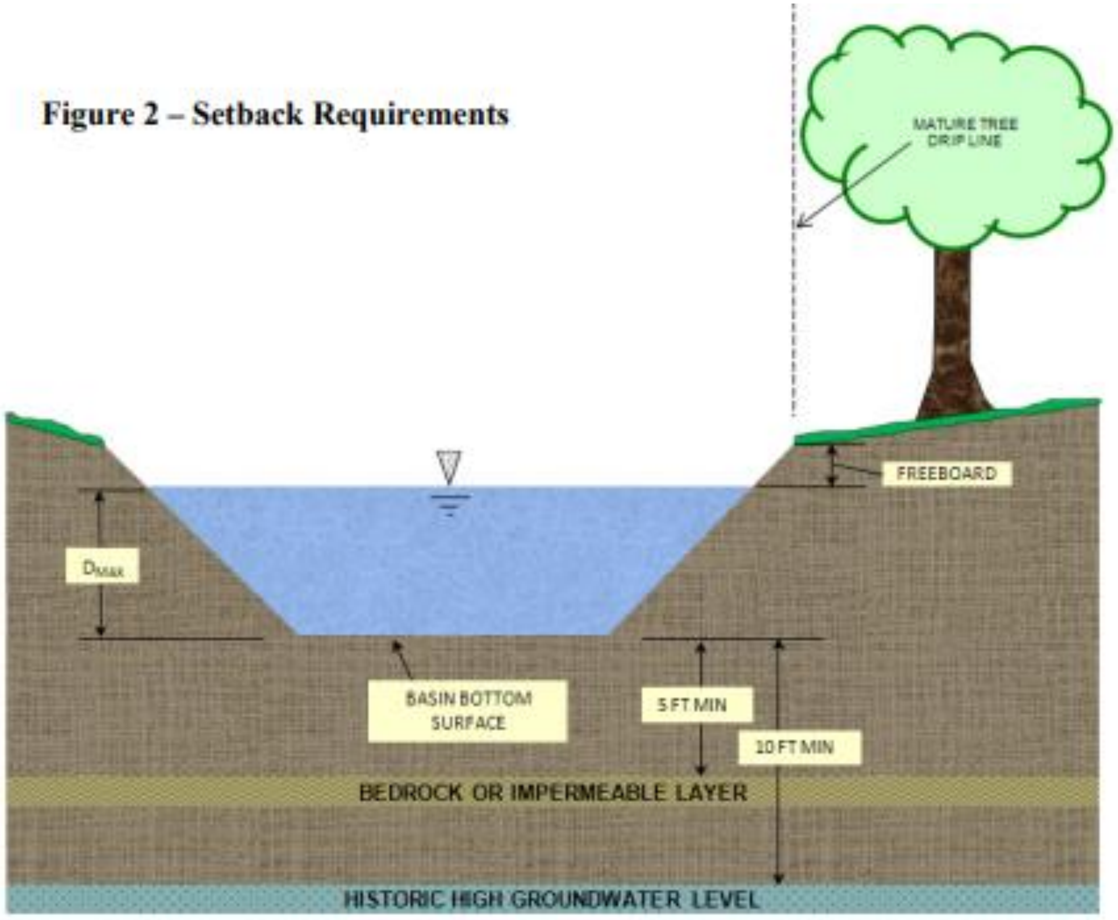
Infiltration Basins (TC-21)

> **Limitations**

- May be significant concerns regarding the potential to degrade groundwater
- Do not apply on slopes greater than 20%
- Infiltration rates of existing site soils > 0.5 in/hr
- Frozen soil conditions can severely affect pollutant removal efficiency

> **Siting Criteria**

- Should not be installed in areas of high-risk land use such as gas stations or heavy industrial sites
- See Manual for specific siting values



Setback requirements for infiltration basins
Source: Riverside County Flood Control and Water Conservation District

Infiltration Basins (TC-21)

> **Design and Construction Criteria**
  - Designed by a PE using the Design Guidance Worksheets
  - Size the infiltration trench to capture and treat the WQv and flows in excess should be diverted
  - Consider groundwater conditions and whether trench is considered an “injection well”
  - Infiltration basins can be joined with detention basins to improve water quality
  - Drain the entire WQv within a maximum of 7 days
  - See Manual for specific design values

> **Inspection and Maintenance Requirements**
  - Inspect following major storm events during first year after installation
  - Clogging is likely to occur in top surface of the trench, between filter fabric and top gravel layer
  - Be prepared to remove and replace contaminated soils as soon as possible

TC-21

1. Use Water Quality Volume from TC-60 since drainage area was less than 5 acres
2. Infiltration Basin Data
3. Basin Side Slopes
4. Basin Floor Slope

Truckee Meadows Storm Water Quality Management Program
Design Guidance Worksheet: Infiltration Basin TC-21

* Fill out worksheet from top to bottom — Truckee Meadows Version 2.0 Released 2015

Designer: ______ page 1 of 1
Company: ______
Date: ______
Project: ______ Subbasin #
Location: ______

Key: User Input | Calculated Result | *Italicized Font Indicates Value is Outside Recommended Range*

1. Water Quality Volume (WQ_V) - Landscape Detention Basin Storage	a) Sub-basin area ___ ft^2; Sub-basin impervious area ___ ft^2; **% Imperviousness** ___
a) Percent of Watershed Impervious Area = I	
b) Drainage Area = A (acres) (43,560 ft^2 = 1 acre) - maximum drainage area 5 acres	b) A= ___ ac
c) Watershed Runoff Coefficient = R_v (unitless)	c) R_v = ___
d) 90th Percentile Precipitation Depth = P (inches)	
e) Water Quality Volume = WQ_V (ft^3)	e) WQ_V = ___ ft^3; WQ_V = ___ ft^3; Designer to select value for Water Quality Volume for actual design
2. Infiltration Basin Data	
a) Native Soil Infiltration Rate = K_h (in/hr)	K_h = ___ in/hr
b) Basin Invert Area = A	A= ___ ft^2
c) Maximum Drain Time = t (168 hours or 7 days) $t = WQ_V/(0.5(K_h/12) \times A)$	t= ___ hrs
3. Basin Side Slopes (H:V = 3:1 or flatter)	H:V= ___ :1
4. Basin floor slope not to exceed 5%	___ %

Notes & Additional Information

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TC-21: 2. a-c)

2. Infiltration Basin Data	
a) Native Soil Infiltration Rate = K_h (in/hr)	K_h = 0.5 in/hr
b) Basin Invert Area = A	A= 2,000 ft^2
c) Maximum Drain Time = t (168 hours or 7 days) t = WQ_V/(0.5(K_h /12) x A)	t= hrs

2. Infiltration Basin Data
   a) Native Soil Infiltration Rate (K_h): use minimum of 0.5 $\frac{\text{in}}{\text{hr}}$ stated in TMSCDLIDM
   b) Basin Invert Area (A): using 2,000 ft^2 for this example
   c) Maximum Drain Time (t):

$$t = \frac{WQ_v}{0.5 \times \frac{K_h}{12} \times A} = \frac{5{,}741\ \text{ft}^3}{0.5 \times \frac{0.5\ \frac{\text{in}}{\text{hr}}}{12} \times 2{,}000\ \text{ft}^2} = 137.8\ \text{hrs}$$

TC-21: 3-4.

3. Basin Side Slopes (H:V = 3:1 or flatter)	H:V= 3 :1
4. Basin floor slope not to exceed 5%	5 %
Notes & Additional Information	

3. Basin Side Slopes: using max ratio for example
4. Basin Floor Slope: using max slope for example

Bioretention Systems

> Biofiltration systems, rain gardens or landscape detention systems

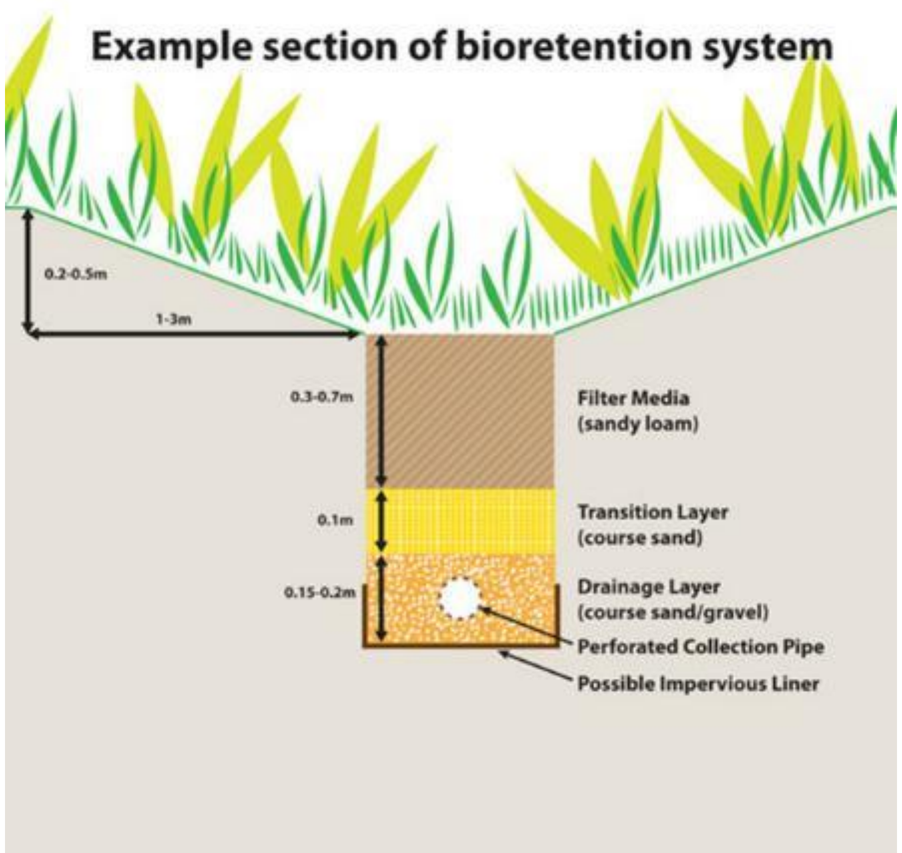
> Can be paired with infiltration for additional treatment effectiveness

> Use soil and plant-based filtration to remove pollutants through a variety of physical, biological and chemical treatment processes

> Runoff can enter the system directly off an impervious surface via a curb cut or pipe

> Plant species should be:

- Native or easily naturalized
- Low water, fertilizer and maintenance requirements
- Attractive in all seasons
- Able to withstand periodic flooding and prolonged periods of inundation

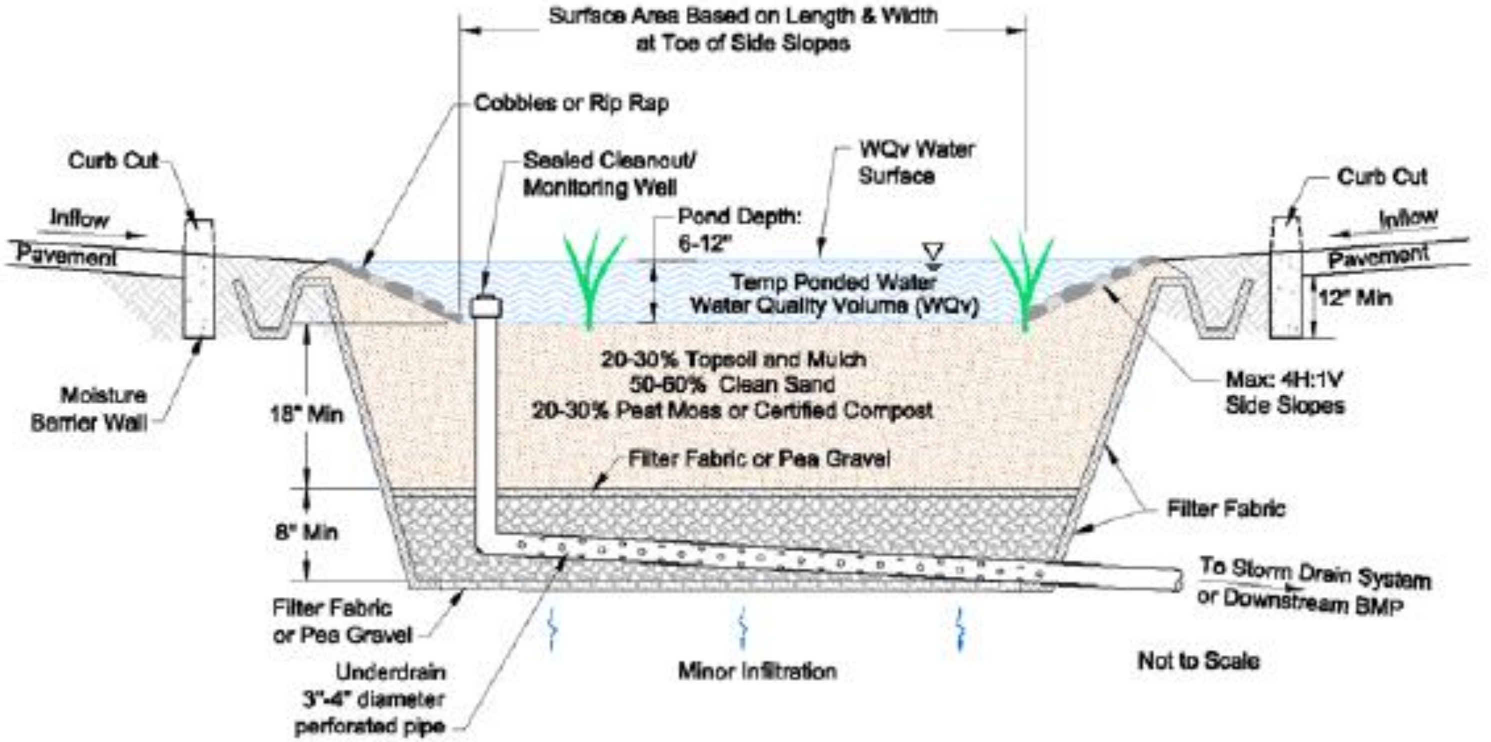


Source: Riversands, https://www.riversands.com.au/bioretention-system.php

Landscape Detention (TC-30)

> **Description**

- Vegetated basins underlaid by a layer of permeable growing media, a drain rock layer and an underdrain system
- Uses soils and plants to remove pollutants from stormwater runoff through physical and biological processes
- Schematic illustrates a cross-section of this BMP



Source: Structural Controls and LID Manual (2015).

Landscape Detention (TC-30)

> **Applications and Advantages**
  - Can be implemented in commercial, residential and industrial areas
  - Well suited for street median strips, parking lot islands and roadside swales
  - Designers can utilize natural surface depressions and swales on the site

> **Limitations**
  - Not suitable for locations with seasonally high groundwater
  - Clogging may be an issue with high sediment loads in the runoff
  - Freezing may prevent infiltration of the runoff

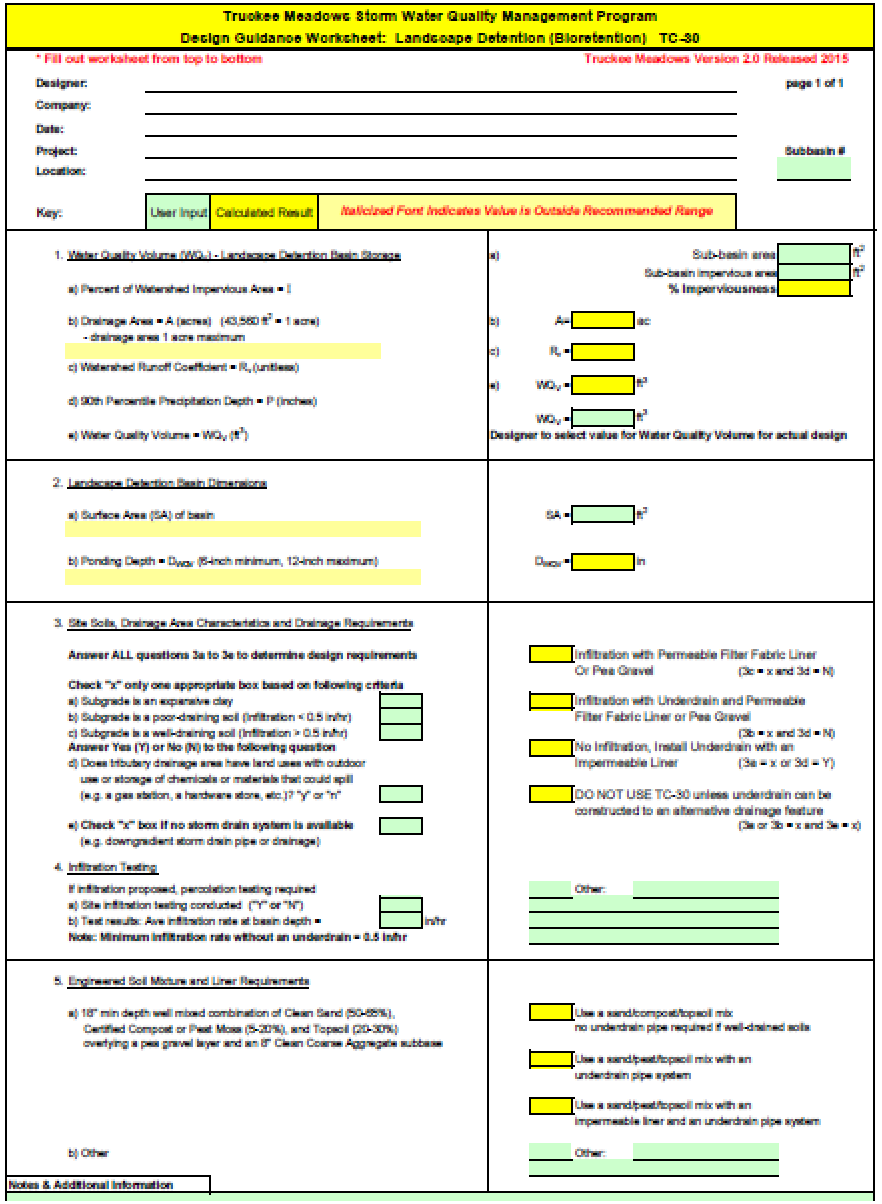
> **Siting Criteria**
  - Drainage area less than one acre
  - Can be on-line or off-line to the primary drainage system
  - Layout will ultimately be determined by the site's constraints (utilities, soils, existing vegetation, drainage patterns)

Landscape Detention (TC-30)

- **Design and Construction Criteria**
  - Designed by a PE using the Design Guidance Worksheets
  - Appropriate plant species can stabilize banks and increase infiltration capacity
  - Flows in excess of the WQv should be diverted to conventional storm drain system
  - Refer to the Manual for additional criteria related to:
    - Planting Soils and Drain Rock Layer
    - Infiltration and Underdrain
    - Vegetation and Planting
- **Inspection and Maintenance Requirements**
  - Regular landscaping maintenance (weeding, pruning, replace mulch)
  - Inspect monthly and after large storm events
  - Biannual health inspection of trees and shrubs
  - If spill occurs, remove and replace affected soils and materials immediately

TC-30

1. Water Quality Volume
2. Landscape Detention Basin Dimensions
3. Site Soils, Drainage Area Characteristics and Drainage Requirements
4. Infiltration Testing
5. Engineered Soil Mixture and Liner Requirements



Truckee Meadows Storm Water Quality Management Program
Design Guidance Worksheet: Landscape Detention (Bioretention) TC-30

* Fill out worksheet from top to bottom — Truckee Meadows Version 2.0 Released 2015

Designer: — page 1 of 1
Company:
Date:
Project: — Subbasin #
Location:

Key: User Input | Calculated Result | *Italicized Font Indicates Value is Outside Recommended Range*

1. Water Quality Volume (WQV) - Landscape Detention Basin Storage
a) Percent of Watershed Impervious Area = I — a) Sub-basin area ft²; Sub-basin impervious area ft²; % Imperviousness
b) Drainage Area = A (acres) (43,560 ft² = 1 acre) - drainage area 1 acre maximum — b) A= ac
c) Watershed Runoff Coefficient = R_v (unitless) — c) R_v =
d) 90th Percentile Precipitation Depth = P (inches)
e) Water Quality Volume = WQ_V (ft³) — e) WQ_V = ft³; WQ_V = ft³
Designer to select value for Water Quality Volume for actual design

2. Landscape Detention Basin Dimensions
a) Surface Area (SA) of basin — SA = ft²
b) Ponding Depth = D_{WQV} (6-inch minimum, 12-inch maximum) — D_{WQV} = in

3. Site Soils, Drainage Area Characteristics and Drainage Requirements
Answer ALL questions 3a to 3e to determine design requirements
Check "x" only one appropriate box based on following criteria
a) Subgrade is an expansive clay
b) Subgrade is a poor-draining soil (infiltration < 0.5 in/hr)
c) Subgrade is a well-draining soil (infiltration > 0.5 in/hr)
Answer Yes (Y) or No (N) to the following question
d) Does tributary drainage area have land uses with outdoor use or storage of chemicals or materials that could spill (e.g. a gas station, a hardware store, etc.)? "y" or "n"
e) Check "x" box if no storm drain system is available (e.g. downgradient storm drain pipe or drainage)

Infiltration with Permeable Filter Fabric Liner Or Pea Gravel (3c = x and 3d = N)
Infiltration with Underdrain and Permeable Filter Fabric Liner or Pea Gravel (3b = x and 3d = N)
No Infiltration, Install Underdrain with an Impermeable Liner (3a = x or 3d = Y)
DO NOT USE TC-30 unless underdrain can be constructed to an alternative drainage feature (3a or 3b = x and 3e = x)

4. Infiltration Testing
If infiltration proposed, percolation testing required
a) Site infiltration testing conducted ("Y" or "N")
b) Test results: Ave infiltration rate at basin depth = in/hr
Note: Minimum infiltration rate without an underdrain = 0.5 in/hr
Other:

5. Engineered Soil Mixture and Liner Requirements
a) 18" min depth well mixed combination of Clean Sand (50-65%), Certified Compost or Peat Moss (5-20%), and Topsoil (20-30%) overlying a pea gravel layer and an 8" Clean Coarse Aggregate subbase
Use a sand/compost/topsoil mix no underdrain pipe required if well-drained soils
Use a sand/peat/topsoil mix with an underdrain pipe system
Use a sand/peat/topsoil mix with an impermeable liner and an underdrain pipe system
b) Other — Other:

Notes & Additional Information

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TC-30: 1. e)

1. Water Quality Volume (WQ_V) - Landscape Detention Basin Storage	a)	Sub-basin area [ ] ft^2
		Sub-basin impervious area [ ] ft^2
a) Percent of Watershed Impervious Area = I		% Imperviousness [ ]
b) Drainage Area = A (acres) (43,560 ft^2 = 1 acre) - drainage area 1 acre maximum	b)	A= 1 ac
c) Watershed Runoff Coefficient = R_v (unitless)	c)	R_v = 0.63
d) 90th Percentile Precipitation Depth = P (inches)		
e) Water Quality Volume = WQ_V (ft^3)	e)	WQ_V = [ ] ft^3
		WQ_V = [ ] ft^3
		Designer to select value for Water Quality Volume for actual design

b) Drainage Area (A): use max of 1 acre

c) Watershed Runoff Coefficient (R_v): use value from TC-60 (0.63)

e) Water Quality Volume (WQ_v)

$$WQ_v(ft^3) = \frac{P^* \times R_v \times A}{12} = \frac{0.6\text{ in} \times 0.63 \times 43{,}560\text{ ft}^2}{12} = 1{,}372\text{ ft}^3$$

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TC-30: 2. b)

2. Landscape Detention Basin Dimensions	
a) Surface Area (SA) of basin	SA = 2,000 ft^2
b) Ponding Depth = D_{WQV} (6-inch minimum, 12-inch maximum)	D_{WQV} = ___ in

a) Surface Area (SA): use 2,000 ft^2 for example

b) Ponding Depth (D_{WQV}):

$$\text{D}_{\text{WQV}} = \frac{\text{WQ}_\text{v}}{\text{SA}} \times 12 = \frac{1{,}372\ \text{ft}^3}{2{,}000\ \text{ft}^2} \times 12 = 8.2\ \text{in}$$

TC-30: 3. a-e)

3. Site Soils, Drainage Area Characteristics and Drainage Requirements

Answer ALL questions 3a to 3e to determine design requirements

Check "x" only one appropriate box based on following criteria

a) Subgrade is an expansive clay	
b) Subgrade is a poor-draining soil (Infiltration < 0.5 in/hr)	
c) Subgrade is a well-draining soil (Infiltration > 0.5 in/hr)	X
Answer Yes (Y) or No (N) to the following question	
d) Does tributary drainage area have land uses with outdoor use or storage of chemicals or materials that could spill (e.g. a gas station, a hardware store, etc.)? "y" or "n"	N
e) Check "x" box if no storm drain system is available (e.g. downgradient storm drain pipe or drainage)	

X	Infiltration with Permeable Filter Fabric Liner Or Pea Gravel (3c = x and 3d = N)
	Infiltration with Underdrain and Permeable Filter Fabric Liner or Pea Gravel (3b = x and 3d = N)
	No Infiltration, Install Underdrain with an Impermeable Liner (3a = x or 3d = Y)
	DO NOT USE TC-30 unless underdrain can be constructed to an alternative drainage feature (3a or 3b = x and 3e = x)

a-c) Check the box that describes the subgrade (c was checked for this example)

d) If there is danger of chemical/material spills mark “Y”, if not mark “N” (N was used for this example)

e) Mark the box if there is no storm drain system available (not marked for this example)

Then mark the appropriate yellow box on the right that is associated with your answers from a-e

TC-30: 4. a-b)

4. Infiltration Testing

If infiltration proposed, percolation testing required			Other:
a) Site infiltration testing conducted ("Y" or "N")	Y		
b) Test results: Ave infiltration rate at basin depth =	0.5	in/hr	

Note: Minimum infiltration rate without an underdrain = 0.5 in/hr

a) If infiltration is proposed in the result from section 3 the testing is required (mark “Y”), if not (mark “N”)

b) Test results: using minimum of 0.5 for this example

TC-30: 5. a-b)

5. Engineered Soil Mixture and Liner Requirements	
a) 18" min depth well mixed combination of Clean Sand (50-65%), Certified Compost or Peat Moss (5-20%), and Topsoil (20-30%) overlying a pea gravel layer and an 8" Clean Coarse Aggregate subbase	X Use a sand/compost/topsoil mix no underdrain pipe required if well-drained soils
	Use a sand/peat/topsoil mix with an underdrain pipe system
	Use a sand/peat/topsoil mix with an impermeable liner and an underdrain pipe system
b) Other	Other:

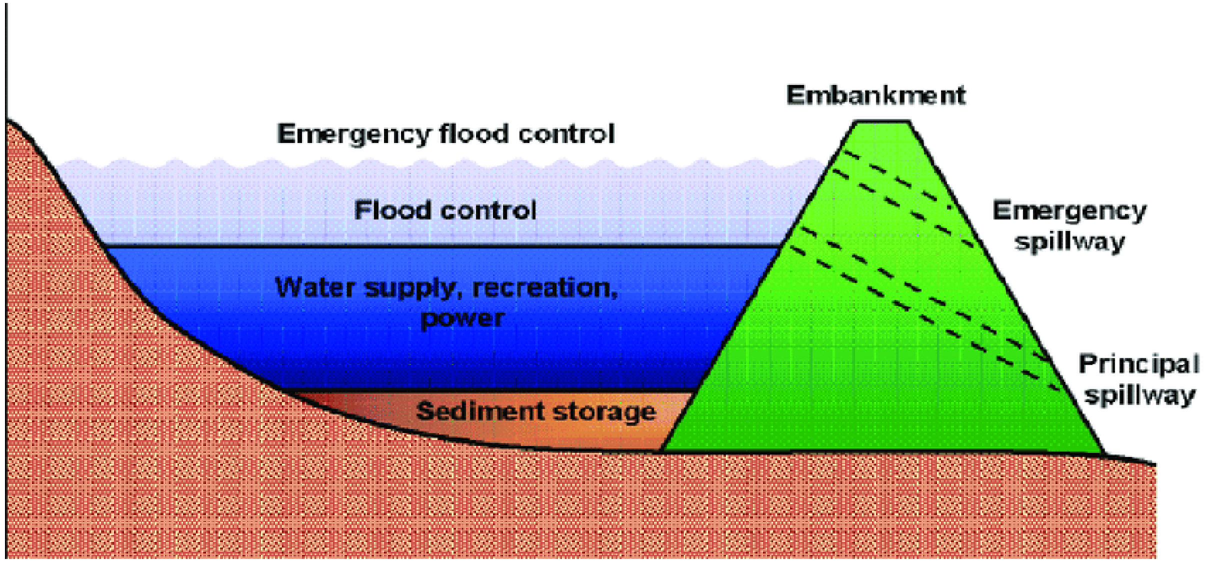
Notes & Additional Information

a) Mark the combination of soil mixture and underdrain that will be used for the design

b) Other: state the soil and drainage being used if it is not one of the options provided

Extended Detention Basins

- Designed to detain the WQv produced by frequently occurring storm events
- Stormwater is slowly released by outlet structure and pollutants are removed through settling and biochemical processes
- Do not have permanent pool and water is not retained during storm events
- Used for flood control by including additional flood detention storage and outlet structures



Components of reservoir with flood water detention
Source: Neitsch et al., 2011, https://www.researchgate.net/figure/Components-of-a-reservoir-with-flood-water-detention-Neitsch-et-al-2011_fig4_283418112

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Sedimentation Basins (TC-40)

> **Description**
  - Allows fine-grained sediments and associated pollutants to settle
  - Unlined and can have potential infiltration
  - Existing flood control structures can be converted to sedimentation basins by modifying existing outlet structure
  - Requires minimal amount of hydraulic head; few siting constraints

> **Applications and Advantages**
  - Residential, commercial, and industrial areas

> **Limitations**
  - Discharges from sedimentation basins can increase water temperatures downstream
  - May not be effective at settling very find sediment particles
  - Cannot be placed on steep slopes

Sedimentation Basins (TC-40)

> **Siting Criteria**

- Not recommended to be place adjacent to sensitive wetlands or perennial streams
- Existing flood control detention basins can be retrofitted with sedimentation basin outlet structures
- Appropriate for sites with drainage area greater than 5 Ac

> **Design and Construction Criteria**

- Registered PE and landscape architect should work together on design
- Impermeable liner may be necessary to prevent infiltration and groundwater contamination
- Stabilize basin sidewalls with riprap and vegetation
- See Manual for additional design guidelines

Sedimentation Basin.
Source: RCD Monterey,
https://www.rcdmonterey.org/water-sedimentation-basins

Sedimentation Basins (TC-40)

- **Hydraulic Design Criteria**
  - See Design Guidance Worksheet and Manual for specific design criteria
- **Inspection and Maintenance Requirements Criteria**
  - Inspect after first large storm event to ensure basin is draining
  - Inspect before and after rainy season for standing water, animal burrows, slope stability
  - Install a staff gage to indicate depth of accumulated sediment – should not exceed 10% of basin volume

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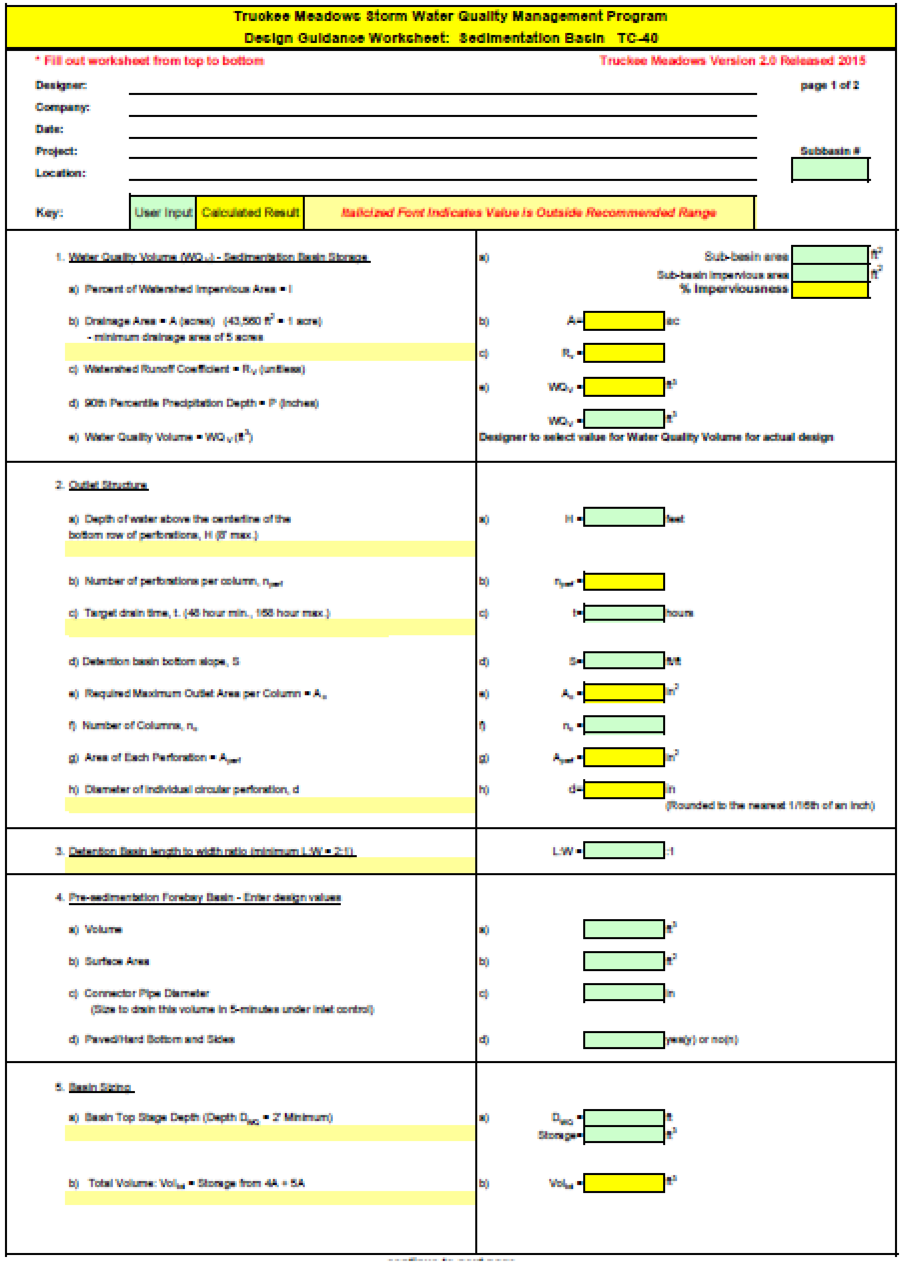
TC-40

1. Water Quality Volume
2. Outlet Structure
3. Detention Basin Length to Width Ratio
4. Pre-sedimentation Forebay Basin
5. Basin Sizing
6. Basin Side Slopes
7. Dam Embankment Side Slopes
8. Vegetation



Truckee Meadows Storm Water Quality Management Program
Design Guidance Worksheet: Sedimentation Basin TC-40

* Fill out worksheet from top to bottom — Truckee Meadows Version 2.0 Released 2015

Designer: — page 1 of 2
Company:
Date:
Project: — Subbasin #
Location:

Key: User Input | Calculated Result | *Italicized Font Indicates Value is Outside Recommended Range*

1. Water Quality Volume (WQ_V) - Sedimentation Basin Storage	a) Sub-basin area ft²; Sub-basin impervious area ft²; % Imperviousness
a) Percent of Watershed Impervious Area = I	
b) Drainage Area = A (acres) (43,560 ft² = 1 acre) - minimum drainage area of 5 acres	b) A= ac
c) Watershed Runoff Coefficient = R_V (unitless)	c) R_v =
d) 90th Percentile Precipitation Depth = P (inches)	e) WQ_V = ft³
e) Water Quality Volume = WQ_V (ft³)	WQ_V = ft³ Designer to select value for Water Quality Volume for actual design
2. Outlet Structure	
a) Depth of water above the centerline of the bottom row of perforations, H (8' max.)	a) H = feet
b) Number of perforations per column, n_{perf}	b) n_{perf} =
c) Target drain time, t. (48 hour min., 168 hour max.)	c) t= hours
d) Detention basin bottom slope, S	d) S= ft/ft
e) Required Maximum Outlet Area per Column = A_o	e) A_o = in²
f) Number of Columns, n_c	f) n_c =
g) Area of Each Perforation = A_{perf}	g) A_{perf} = in²
h) Diameter of individual circular perforation, d	h) d= in (Rounded to the nearest 1/16th of an inch)
3. Detention Basin length to width ratio (minimum L:W = 2:1)	L:W = :1
4. Pre-sedimentation Forebay Basin - Enter design values	
a) Volume	a) ft³
b) Surface Area	b) ft²
c) Connector Pipe Diameter (Size to drain this volume in 5-minutes under inlet control)	c) in
d) Paved/Hard Bottom and Sides	d) yes(y) or no(n)
5. Basin Sizing	
a) Basin Top Stage Depth (Depth D_{WQ} = 2' Minimum)	a) D_{WQ} = ft; Storage= ft³
b) Total Volume: Vol_{tot} = Storage from 4A + 5A	b) Vol_{tot} = ft³

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TC-40: 1. e)

1. Water Quality Volume (WQ_V) - Sedimentation Basin Storage	a) Sub-basin area [ ] ft^2 Sub-basin impervious area [ ] ft^2 **% Imperviousness** [ ]
a) Percent of Watershed Impervious Area = I	
b) Drainage Area = A (acres) (43,560 ft^2 = 1 acre) - minimum drainage area of 5 acres	b) A= [ ] ac
c) Watershed Runoff Coefficient = R_V (unitless)	c) R_v = [ ]
d) 90th Percentile Precipitation Depth = P (inches)	
e) Water Quality Volume = WQ_V (ft^3)	e) WQ_v = [ ] ft^3 WQ_v = [ ] ft^3 **Designer to select value for Water Quality Volume for actual design**

b) Drainage Area (A): use min of 5 acres (217,800 ft^2)

c) Watershed Runoff Coefficient (R_v): use value from TC-60 (0.63)

e) Water Quality Volume (WQ_v)

$$WQ_v(\text{ft}^3) = \frac{P^* \times R_v \times A}{12} = \frac{0.6\text{ in} \times 0.63 \times 217{,}800\text{ ft}^2}{12} = 6{,}861\text{ ft}^3$$

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TC-40: 2. a-d)

2. Outlet Structure

a) Depth of water above the centerline of the bottom row of perforations, H (8' max.)	a)	H = 3	feet
b) Number of perforations per column, n_{perf}	b)	n_{perf} = 9	
c) Target drain time, t. (48 hour min., 168 hour max.)	c)	t= 72	hours
d) Detention basin bottom slope, S	d)	S= 0.01	ft/ft
e) Required Maximum Outlet Area per Column = A_o	e)	A_o =	in^2
f) Number of Columns, n_c	f)	n_c =	
g) Area of Each Perforation = A_{perf}	g)	A_{perf} =	in^2
h) Diameter of individual circular perforation, d	h)	d=	in (Rounded to the nearest 1/16th of an inch)

a) Depth of Water Above the Centerline of the Bottom Row of Perforations: use 3' for example

b) Number of Perforations per Column (n_{perf}): 9

- Orifices are spaced on 4" centers: with 8 feet depth orifices will be at 0, 4, 8, 12, 16, 20, 24, 28, and 32 inches from bottom

c) Target Drain Time (t): TMSCDLIDM states the recommended detention time is 72 hrs

d) Detention Basin Bottom Slope (S): 1% used for example

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TC-40: 2. e)

2. Outlet Structure

a) Depth of water above the centerline of the bottom row of perforations, H (8' max.)	a)	H =	3	feet
b) Number of perforations per column, n_{perf}	b)	n_{perf} =	9	
c) Target drain time, t. (48 hour min., 168 hour max.)	c)	t=	72	hours
d) Detention basin bottom slope, S	d)	S=	0.01	ft/ft
e) Required Maximum Outlet Area per Column = A_o	e)	A_o =		in^2
f) Number of Columns, n_c	f)	n_c =		
g) Area of Each Perforation = A_{perf}	g)	A_{perf} =		in^2
h) Diameter of individual circular perforation, d	h)	d=		in (Rounded to the nearest 1/16th of an inch)

e) Required Maximum Outlet Area per Column (A_0):

$$a = 1.22(S^{-0.09}) = 1.85$$

$$b = 2.6(S^{0.3}) = 0.65$$

$$c = 0.95$$

$$d = 0.085$$

$$A_0 = \frac{72a\left[Vol^{(0.95/H^{0.085})}\right]}{t\,(H^b)}$$

$$Vol(acre-ft) = 6{,}861\ ft^3\left(\frac{1\ acre{-}ft}{43559.9\ ft^3}\right) = 0.16\ acre-ft$$

$$A_0 = \frac{72(1.85)\left[0.16^{(0.95/3^{0.085})}\right]}{72\,(3^{0.65})} = 0.19\ in^2$$

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TC-40: 2. f-h)

2. Outlet Structure

a) Depth of water above the centerline of the bottom row of perforations, H (8' max.)	a)	H =	3	feet
b) Number of perforations per column, n_{perf}	b)	n_{perf} =	9	
c) Target drain time, t. (48 hour min., 168 hour max.)	c)	t=	72	hours
d) Detention basin bottom slope, S	d)	S=	0.01	ft/ft
e) Required Maximum Outlet Area per Column = A_o	e)	A_o =	0.19	in^2
f) Number of Columns, n_c	f)	n_c =	16	
g) Area of Each Perforation = A_{perf}	g)	A_{perf} =	0.11	in^2
h) Diameter of individual circular perforation, d	h)	d=	3/8	in (Rounded to the nearest 1/16th of an inch)

f) Number of Columns (n_c):16

g) Area of Each Perforation (A_{perf}):

$$A = \pi r^2 = \pi \times (0.1875 \text{ in})^2 = 0.11 \text{ in}^2$$

f) Diameter of individual circular perforation (d): 3/8 inch

TC-40: 3-4.

3. Detention Basin length to width ratio (minimum L:W = 2:1)		L:W = 2 :1
4. Pre-sedimentation Forebay Basin - Enter design values		
a) Volume	a)	686.1 ft^3
b) Surface Area	b)	343 ft^2
c) Connector Pipe Diameter (Size to drain this volume in 5-minutes under inlet control)	c)	24 in
d) Paved/Hard Bottom and Sides	d)	Y yes(y) or no(n)

3. Detention Basin Length to Width Ratio: used min of 2:1
4. Pre-Sedimentation Forebay Basin:
   a) Volume: 5-10% of WQ_v (City and County of Sacramento, 2007)

      $\text{Volume} = .1 \times 6{,}861\ \text{ft}^3 = 686.1\ \text{ft}^3$
   a) Surface Area: assume 2 foot depth, 343 ft^3 surface area
   b) Connector Pipe Diameter: 24 in.
   c) Paved/Hard Bottom and Sides: said yes because it makes any necessary maintenance easier

TC-40: 5. a-b)

5. Basin Sizing

a) Basin Top Stage Depth (Depth D_{WQ} = 2' Minimum)	a)	D_{WQ} =	2	ft
		Storage=	7,547.1	ft^3
b) Total Volume: Vol_{tot} = Storage from 4A + 5A	b)	Vol_{tot} =	8,233.2	ft^3

a) Basin Top Stage Depth (D_{WQ}): used 2 ft minimum

- Storage: TMSCDLIDM states the basin should be designed to detain a volume equal to 120% of WQ_v

$$8{,}233.2\ \text{ft}^3 - 686.1\ \text{ft}^3 = 7{,}547.1\ \text{ft}^3$$

b) Total Volume (Vol_{tot}):

$$Vol_{tot} = 1.2 \times 6{,}861\ \text{ft}^3 = 8{,}233.2\ \text{ft}^3$$

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TC-40: 6-8.

6. Basin Side Slopes (side-slopes within sedimentation basin) H:V = horizontal distance per unit vertical (minimum 4:1, flatter preferred)	H:V = 4 :1
7. Dam Embankment Side Slopes (exterior side slopes) H:V = horizontal distance per unit vertical, (minimum 3:1, flatter preferred)	H:V = 3 :1
8. Vegetation (Check "x" the method or describe "Other")	X Native Grass Irrigated Turf Grass Other:

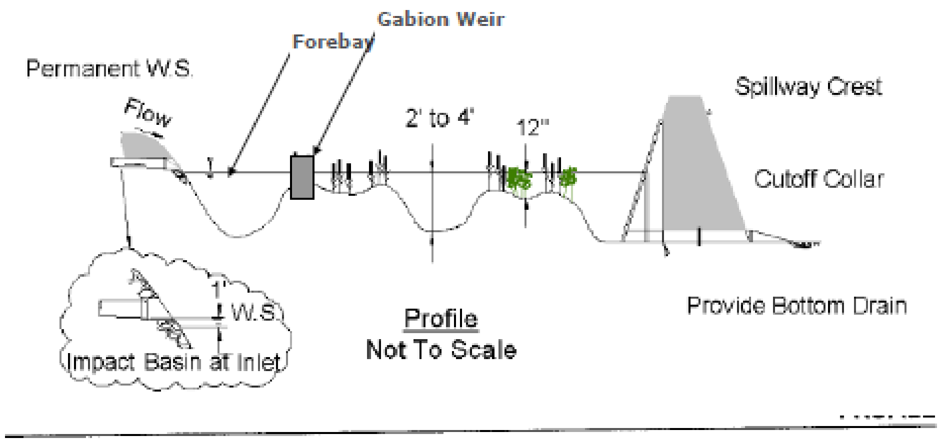
Notes & Additional Information

6. Basin Side Slopes: used min 4:1
7. Dam Embankment Side Slopes: used min 3:1
8. Vegetation: checked native grass, if turf or other is used check and describe

Stormwater Wetlands (TC-51)

> **Description**

- Shallow ponds with a perennial baseflow that supports the growth of rushes, willows, cattails, reeds and other wetland vegetation
- Purpose is to slow the flow of water and allow sediments to settle out of suspension as well as the biological uptake of nutrients by vegetation
- Artificial structures but can incorporate sections of “natural” wetlands following state and federal regulations
- Differ from stormwater ponds by having relatively large shallow areas with complex micro-topography that supports a greater and larger variety of wetland vegetation



Source: Structural Controls and LID Manual (2015).

Stormwater Wetlands (TC-51)

> **Applications and Advantages**

– Applied to treat stormwater runoff from large tributary catchment areas

> **Limitations**

– Require a perennial baseflow to sustain wetland vegetation

> **Performance Data**

– No data on metals, but effective at reducing TSS

Pollutant	Influent	Effluent
Total Suspended Solids (mg/l)	82.1 (65.7-103)	19.7 (16.6-23.4)
Total Copper (ug/l)	n/a	n/a
Dissolved Copper (ug/l)	n/a	n/a
Total Lead (ug/l)	12.6 (3.8-42)	3.25 (1.9-5.6)
Dissolved Lead (ug/l)	n/a	n/a
Total Zinc (ug/l)	164 (54.6-494)	1119 (32.8-429)
Dissolved Zinc (ug/l)	n/a	n/a
Total Phosphorus (mg/l)	2.91 (1.9-4.6)	0.15 (0.07-0.33)
Total Nitrogen (mg/l)	2.56 (1.6-4)	2.42 (1.46-4.0)
TKN (mg/l)	1.23 (1-1.6)	1.33 (0.84-2.11)

Source: UDFCD, 2005.

Source: Structural Controls and LID Manual (2015).

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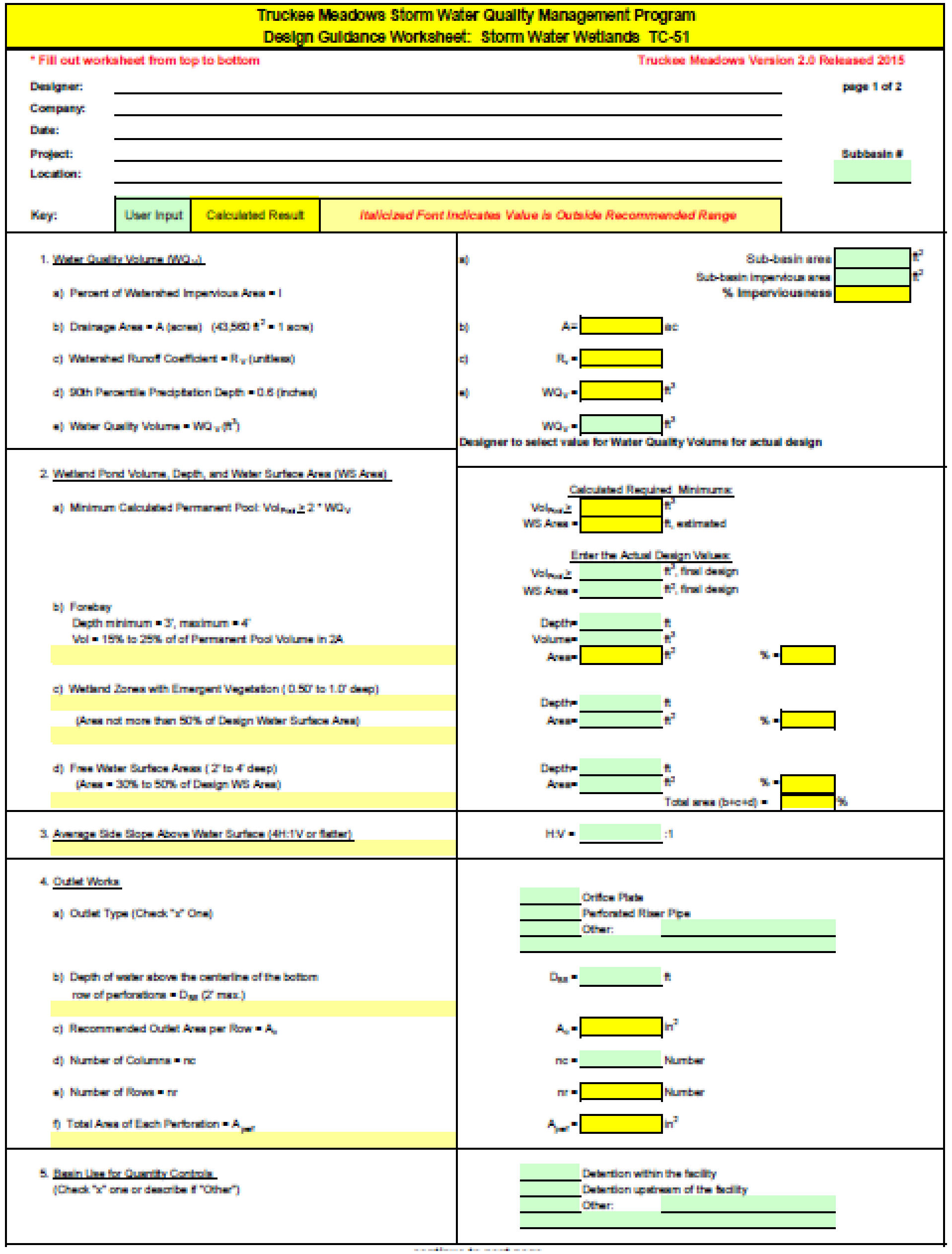
Stormwater Wetlands (TC-51)

- **Siting Criteria**
  - Areas with high volumes of suspended sediments and dissolved contaminants
  - Site the wetland and design for inflow offline from other high flow or flood flow conveyance
- **Design and Construction Criteria**
  - Registered PE and landscape architect should work together and utilize Design Guidance Worksheet to design stormwater ponds
  - Should be sized to contain the permanent pool plus the WQv
  - Impermeable liner may be needed if the pond is located in an area with porous soils
  - Refer to Manual for more design details
- **Inspection and Maintenance Requirements**
  - Inspect semi-annually for structural integrity, sediment accumulation and burrows
  - Cut and remove wetland plants annually to remove nutrients; remove sediments
  - Stock pond with mosquito fish

TC-51

1. Water Quality Volume
2. Wetland Pond Volume, Depth, and Water Surface Area
3. Average Side Slope Above Water Surface
4. Outlet Works
5. Basin Use for Quantity Controls
6. Basin Length to Width Ratio
7. Basin Side Slopes
8. Annual/Seasonal Water Balance
9. Vegetation



Truckee Meadows Storm Water Quality Management Program
Design Guidance Worksheet: Storm Water Wetlands TC-51

* Fill out worksheet from top to bottom — Truckee Meadows Version 2.0 Released 2015

Designer: — page 1 of 2
Company:
Date:
Project: — Subbasin #
Location:

Key: User Input | Calculated Result | *Italicized Font Indicates Value is Outside Recommended Range*

1. Water Quality Volume (WQ_V)
   a) Percent of Watershed Impervious Area = I — a) Sub-basin area ___ ft^2; Sub-basin impervious area ___ ft^2; % Imperviousness ___
   b) Drainage Area = A (acres) (43,560 ft^2 = 1 acre) — b) A= ___ ac
   c) Watershed Runoff Coefficient = R_V (unitless) — c) R_v = ___
   d) 90th Percentile Precipitation Depth = 0.6 (inches) — e) WQ_V = ___ ft^3
   e) Water Quality Volume = WQ_V (ft^3) — WQ_V = ___ ft^3

   Designer to select value for Water Quality Volume for actual design

2. Wetland Pond Volume, Depth, and Water Surface Area (WS Area)
   a) Minimum Calculated Permanent Pool: $Vol_{Pool} \geq 2 * WQ_V$
      Calculated Required Minimums: $Vol_{Pool} \geq$ ___ ft^3; WS Area = ___ ft, estimated
      Enter the Actual Design Values: $Vol_{Pool} \geq$ ___ ft^3, final design; WS Area = ___ ft^2, final design
   b) Forebay
      Depth minimum = 3', maximum = 4'
      Vol = 15% to 25% of of Permanent Pool Volume in 2A
      Depth= ___ ft; Volume= ___ ft^3; Area= ___ ft^2; % = ___
   c) Wetland Zones with Emergent Vegetation (0.50' to 1.0' deep)
      (Area not more than 50% of Design Water Surface Area)
      Depth= ___ ft; Area= ___ ft^2; % = ___
   d) Free Water Surface Areas (2' to 4' deep)
      (Area = 30% to 50% of Design WS Area)
      Depth= ___ ft; Area= ___ ft^2; % = ___
      Total area (b+c+d) = ___ %

3. Average Side Slope Above Water Surface (4H:1V or flatter) — H:V = ___ :1

4. Outlet Works
   a) Outlet Type (Check "x" One) — Orifice Plate; Perforated Riser Pipe; Other:
   b) Depth of water above the centerline of the bottom row of perforations = D_{SS} (2' max.) — D_{SS} = ___ ft
   c) Recommended Outlet Area per Row = A_o — A_o = ___ in^2
   d) Number of Columns = nc — nc = ___ Number
   e) Number of Rows = nr — nr = ___ Number
   f) Total Area of Each Perforation = A_{perf} — A_{perf} = ___ in^2

5. Basin Use for Quantity Controls
   (Check "x" one or describe if "Other")
   Detention within the facility; Detention upstream of the facility; Other:

TC-51: 1. e)

1. Water Quality Volume (WQ_V)	a) Sub-basin area [ ] ft^2 Sub-basin impervious area [ ] ft^2 **% Imperviousness** [ ]
a) Percent of Watershed Impervious Area = I	
b) Drainage Area = A (acres) (43,560 ft^2 = 1 acre)	b) A= [ ] ac
c) Watershed Runoff Coefficient = R_V (unitless)	c) R_v = [ ]
d) 90th Percentile Precipitation Depth = 0.6 (inches)	e) WQ_V = [ ] ft^3
e) Water Quality Volume = WQ_V (ft^3)	WQ_V = [ ] ft^3 Designer to select value for Water Quality Volume for actual design

e) Water Quality Volume:

- No statement in TMSCDLIDM about min or max drainage area
- Will use TC-60 value of $5{,}741\ \mathrm{ft}^3$ in this example

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TC-51: 2. a)

2. Wetland Pond Volume, Depth, and Water Surface Area (WS Area)

a) Minimum Calculated Permanent Pool: $Vol_{Pool} \geq 2 * WQ_V$

Calculated Required Minimums:

$Vol_{Pool} \geq$ ____ ft^3

WS Area = ____ ft, estimated

Enter the Actual Design Values:

$Vol_{Pool} \geq$ ____ ft^3, final design

WS Area = ____ ft^2, final design

b) Forebay
Depth minimum = 3', maximum = 4'
Vol = 15% to 25% of of Permanent Pool Volume in 2A

Depth= ____ ft
Volume= ____ ft^3
Area= ____ ft^2 % = ____

c) Wetland Zones with Emergent Vegetation (0.50' to 1.0' deep)
(Area not more than 50% of Design Water Surface Area)

Depth= ____ ft
Area= ____ ft^2 % = ____

d) Free Water Surface Areas (2' to 4' deep)
(Area = 30% to 50% of Design WS Area)

Depth= ____ ft
Area= ____ ft^2 % = ____

Total area (b+c+d) = ____ %

a) Minimum Calculated Permanent Pool:

$$2 \times WQ_v = 2 \times 5{,}741\ ft^3 = 11{,}482\ ft^3$$

- Use max depth of 4 ft

$$WS\ Area = \frac{Vol_{pool}}{Depth} = \frac{11{,}482\ ft^3}{4\ ft} = 2{,}870.5\ ft^2$$

TC-51: 2. b)

2. Wetland Pond Volume, Depth, and Water Surface Area (WS Area)

a) Minimum Calculated Permanent Pool: $Vol_{Pool} \geq 2 * WQ_V$

Calculated Required Minimums:

$Vol_{Pool} \geq$ [ ] ft^3

WS Area = [ ] ft, estimated

Enter the Actual Design Values:

$Vol_{Pool} \geq$ 11,482 ft^3, final design

WS Area = 2,870.5 ft^2, final design

b) Forebay
Depth minimum = 3', maximum = 4'
Vol = 15% to 25% of of Permanent Pool Volume in 2A

Depth= 4 ft

Volume= 2,296.4 ft^3

Area= [ ] ft^2 % = [ ]

c) Wetland Zones with Emergent Vegetation (0.50' to 1.0' deep)
(Area not more than 50% of Design Water Surface Area)

Depth= [ ] ft

Area= [ ] ft^2 % = [ ]

d) Free Water Surface Areas (2' to 4' deep)
(Area = 30% to 50% of Design WS Area)

Depth= [ ] ft

Area= [ ] ft^2 % = [ ]

Total area (b+c+d) = [ ] %

b) Forebay: use max depth of 4 ft

$$\text{Vol} = 0.20 \times \text{Vol}_{\text{pool}} = 0.20 \times 11{,}482 \text{ ft}^3 = 2{,}296.4 \text{ ft}^3$$

$$\text{Area} = \frac{\text{Vol}}{\text{Depth}} = \frac{2{,}296.4 \text{ ft}^3}{4 \text{ ft}} = 574.1 \text{ ft}^2 \qquad \% = \frac{574.1 \text{ ft}^2}{2{,}870.5 \text{ ft}^2} = 20\%$$

TC-51: 2. c)

2. Wetland Pond Volume, Depth, and Water Surface Area (WS Area)

a) Minimum Calculated Permanent Pool: $Vol_{Pool} \geq 2 * WQ_V$

Calculated Required Minimums:

$Vol_{Pool} \geq$		ft^3
WS Area =		ft, estimated

Enter the Actual Design Values:

$Vol_{Pool} \geq$	11,482	ft^3, final design
WS Area =	2,870.5	ft^2, final design

b) Forebay
Depth minimum = 3', maximum = 4'
Vol = 15% to 25% of of Permanent Pool Volume in 2A

Depth=	4	ft		
Volume=	2,296.4	ft^3		
Area=	574.1	ft^2	% =	20

c) Wetland Zones with Emergent Vegetation (0.50' to 1.0' deep)
(Area not more than 50% of Design Water Surface Area)

Depth=		ft		
Area=		ft^2	% =	

d) Free Water Surface Areas (2' to 4' deep)
(Area = 30% to 50% of Design WS Area)

Depth=		ft		
Area=		ft^2	% =	
		Total area (b+c+d) =		%

c) Wetland Zones with Emergent Vegetation: use max depth of 1 ft

$$\text{Area} = WS\ Area \times 0.40 = 2{,}870.5\ \text{ft}^2 \times 0.40 = 1{,}148.2\ \text{ft}^2$$

$$\% = 40\%$$

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TC-51: 2. d)

2. Wetland Pond Volume, Depth, and Water Surface Area (WS Area)

a) Minimum Calculated Permanent Pool: $Vol_{Pool} \geq 2 * WQ_V$

Calculated Required Minimums:

$Vol_{Pool} \geq$ ___ ft^3

WS Area = ___ ft, estimated

Enter the Actual Design Values:

$Vol_{Pool} \geq$ 11,482 ft^3, final design

WS Area = 2,870.5 ft^2, final design

b) Forebay
Depth minimum = 3', maximum = 4'
Vol = 15% to 25% of of Permanent Pool Volume in 2A

Depth=	4	ft	
Volume=	2,296.4	ft^3	
Area=	574.1	ft^2	% = 20

c) Wetland Zones with Emergent Vegetation (0.50' to 1.0' deep)
(Area not more than 50% of Design Water Surface Area)

Depth=	1	ft	
Area=	1,148.2	ft^2	% = 40

d) Free Water Surface Areas (2' to 4' deep)
(Area = 30% to 50% of Design WS Area)

Depth=	4	ft	
Area=	1,148.2	ft^2	% = 40
Total area (b+c+d) =			100 %

d) Free Water Surface Areas: use max depth of 4 ft

$$\text{Area} = WS\ Area \times 0.40 = 2{,}870.5\ \text{ft}^2 \times 0.40 = 1{,}148.2\ \text{ft}^2$$

$$\% = 40\%$$

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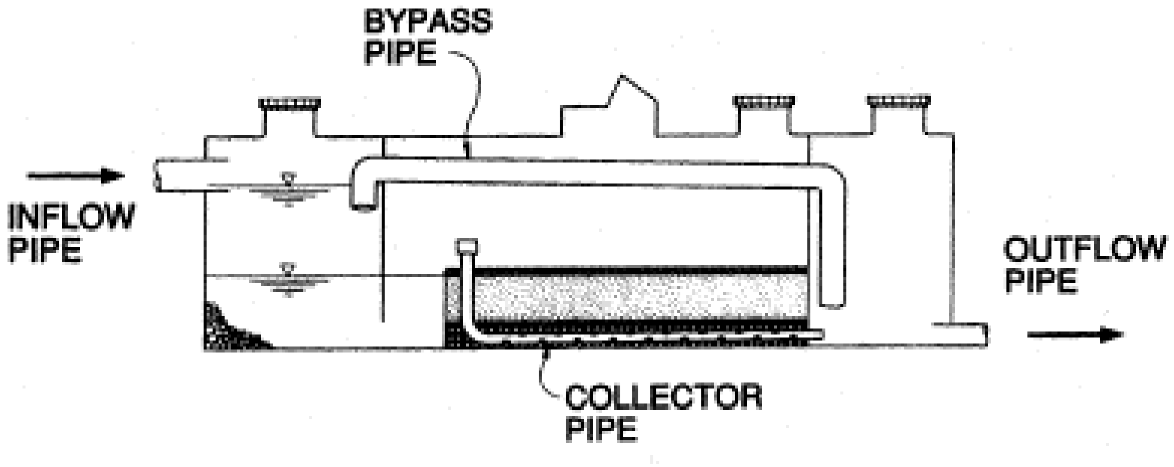
Underground Sand Filter (TC-61)

> **Description**

- Composed of three main chambers and is isolated underground
- Known as D.C. or Delaware sand filter
- Comprised of a bypass chamber, a sedimentation chamber, a flow distribution cell and a sand filter bed
- Sedimentation chamber removes floatables and heavy sediments
- Sand filter bed removes suspended sediments and associated pollutants such as:
  - fecal coliform bacteria, trace metals, and oil and grease from the runoff



D.C. UNDERGROUND SAND FILTER HOODED BYPASS ILLUSTRATION

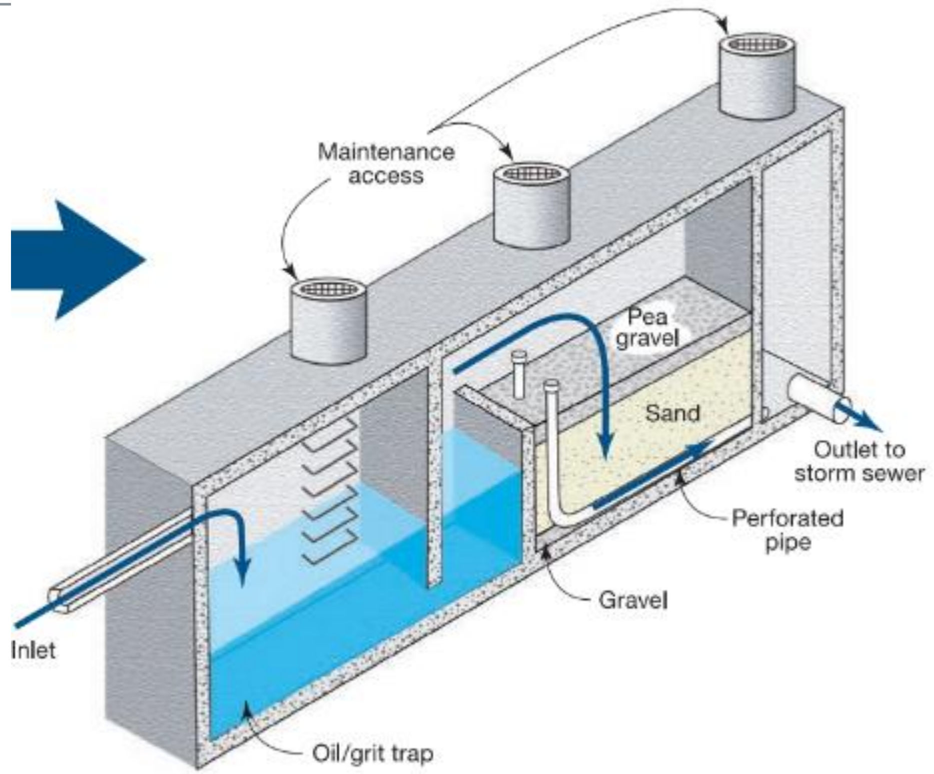
Source: Structural Controls and LID Manual (2015).

Underground Sand Filter (TC-61)

> **Applications and Advantages**
  – Treating runoff from drainage areas containing a significant percentage of impervious area such as roadways, parking lots, commercial and industrial areas
  – Well adapted for locations with limited land area
  – Climate does not have a large impact on the effectiveness because they are underground

> **Limitations**
  – Standing water may provide mosquito habitat if access through manhole or other points of entry is available

> **Siting Criteria**
  – Under roadways, parking lots, sidewalks or landscaped areas
  – Also along the perimeter of parking lots



Underground sand filter.

Source: Montgomery County, Maryland, Department of Environmental Protection.

Underground Sand Filter (TC-61)

> **Design and Construction Criteria**
  - Registered PE should design surface sand filters and utilize Design Guidance Worksheet
  - Flows in excess of the WQv should be diverted around the underground sand filter
  - Refer to Manual for more design details

> **Inspection and Maintenance Requirements**
  - Life of a well-maintained underground sand filter is between 5 and 20 years
  - Water levels should be monitored every 3 months and after each big storm for the first year
  - Monitor 3 times per year, and keep records of your observations
  - Consider what access will look like (ladders with manhole)
  - Filter media may need to be replaced every 3 to 5 years

TC-61(a)

1. Water Quality Volume
2. Sand Filter Basin Design
3. Filter Dimensions
4. System Storage Volume
5. Permanent Pool

Truckee Meadows Storm Water Quality Management Program
Design Guidance Worksheet: Underground Sand Filter - D.C. Type TC-61(a)

* Fill out worksheet from top to bottom — Truckee Meadows Version 2.0 Released 2015

Designer: ______ page 1 of 1
Company: ______
Date: ______
Project: ______ Subbasin #
Location: ______

Key: User Input | Calculated Result | *Italicized Font Indicates Value is Outside Recommended Range*

1. Water Quality Volume (WQ_V)
   a) Percent of Watershed Impervious Area = I — a) Sub-basin area ____ ft^2; Sub-basin impervious area ____ ft^2; % Imperviousness ____
   b) Drainage Area = A (acres) (43,560 ft^2 = 1 acre); max 1.5 acres — b) A= ____ ac
   c) Watershed Runoff Coefficient = R_V (unitless) — c) R_v = ____
   d) 90th Percentile Precipitation Depth = P (inches) — e) WQ_V = ____ ft^3
   e) Water Quality Volume = WQ_V (ft^3) — WQ_V = ____ ft^3
   Designer to select value for Water Quality Volume for actual design

2. Sand Filter Basin Design
   a) Filter depth: $d_f = d_g + d_s$
   d_g = gravel bed, minimum 16-inches thick — d_g = ____ in ____ ft
   d_s = sand filter layer, minimum 18-inches thick — d_s = ____ in ____ ft; d_f = ____ ft
   b) Coefficient of permeability for sand filter = k (Use k = 1.18 ft/hr for clean, well-graded sand and gravel) — k = ____ ft/hr
   c) Maximum allowable water depth in sand filter = h_{max}; h_{max} = inlet elevation - outlet elevation — h_{max} = ____ ft
   d) One half the maximum allowable water depth (2h) over filter bed = h (2h = h_{max} - d_f) — h = ____ ft
   e) Time required for the WQ_V to pass through the filter = t_f (max time = 48 hrs) — t_f = ____ hrs
   f) Surface area of the filter basin = A_f (ft^2) — A_f = ____ ft^2

3. Filter Dimensions
   a) Filter width = W_f — W_f = ____ ft
   b) Length: Lf = Af/Wf — L_f = ____ ft

4. System Storage Volume
   a) Available Storage Above Filter Bed: $V_f = A_f \times 2h$ — V_f = ____ ft^3
   b) Storage in Filter Voids: $V_v = 0.4 \times A_f \times d_f$ — V_v = ____ ft^3
   c) Flow Through the Filter During Filling $V_q = kA_f(d_f + h)t_f/d_f$, assume t_f = 1 hr and k per 2.b above — V_q = ____ ft^3

5. Permanent Pool
   a) Required net storage Vst = WQv - Vf - Vv - Vq — V_{st} = ____ ft^3
   b) Minimum Length: $L_{pm} = V_{st}/(2h)(W_f)$ — L_{pm} = ____ ft

Notes & Additional Information:

TC-61(a): 1. e)

1. Water Quality Volume (WQ_V)	
a) Percent of Watershed Impervious Area = I	a) Sub-basin area ___ ft^2 Sub-basin impervious area ___ ft^2 % Imperviousness ___
b) Drainage Area = A (acres) (43,560 ft^2 = 1 acre); max 1.5 acres	b) A= ___ ac
c) Watershed Runoff Coefficient = R_V (unitless)	c) R_v = ___
d) 90th Percentile Precipitation Depth = P (inches)	
e) Water Quality Volume = WQ_V (ft^3)	e) WQ_V = ___ ft^3 WQ_V = ___ ft^3 Designer to select value for Water Quality Volume for actual design

b) Drainage Area (A): use max of 1.5 acres (65,340 ft^2)

c) Watershed Runoff Coefficient (R_v): use value from TC-60 (0.63)

e) Water Quality Volume (WQ_v)

$$WQ_v(ft^3) = \frac{P^* \times R_v \times A}{12} = \frac{0.6\ in \times 0.63 \times 65{,}340\ ft^2}{12} = 2{,}058\ ft^3$$

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TC-61(a): 2. a)

2. Sand Filter Basin Design

a) Filter depth: $d_f = d_g + d_s$ d_g = gravel bed, minimum 16-inches thick d_s = sand filter layer, minimum 18-inches thick	d_g = 16 in d_s = 18 in	d_f = ft
b) Coefficient of permeability for sand filter = k (Use k = 1.18 ft/hr for clean, well-graded sand and gravel)	k = ft/hr	
c) Maximum allowable water depth in sand filter = h_{max} h_{max} = inlet elevation - outlet elevation	h_{max} = ft	
d) One half the maximum allowable water depth (2h) over filter bed = h (2h = $h_{max} - d_f$)	h = ft	
e) Time required for the WQ_V to pass through the filter = t_f (max time = 48 hrs)	t_f = hrs	
f) Surface area of the filter basin = A_f (ft^2)	A_f = ft^2	

a) Filter Depth: Use minimums for d_g and d_s

$$d_g = 16 \text{ in} \times \frac{1 \text{ ft}}{12 \text{ in}} = 1.33 \text{ ft}$$

$$d_s = 18 \text{ in} \times \frac{1 \text{ ft}}{12 \text{ in}} = 1.5 \text{ ft}$$

$$d_f = d_g + d_s = 1.33 \text{ ft} + 1.5 \text{ ft} = 2.83 \text{ ft}$$

TC-61(a): 2. b-d)

2. Sand Filter Basin Design

a) Filter depth: $d_f = d_g + d_s$
d_g = gravel bed, minimum 16-inches thick
d_s = sand filter layer, minimum 18-inches thick

b) Coefficient of permeability for sand filter = k
(Use k = 1.18 ft/hr for clean, well-graded sand and gravel)

c) Maximum allowable water depth in sand filter = h_{max}
h_{max} = inlet elevation - outlet elevation

d) One half the maximum allowable water depth (2h) over filter bed = h (2h = $h_{max} - d_f$)

e) Time required for the WQ_V to pass through the filter = t_f
(max time = 48 hrs)

f) Surface area of the filter basin = A_f (ft^2)

d_g =	16	in	1.33	ft
d_s =	18	in	1.5	ft
		d_f =	2.83	ft
k =	1.18	ft/hr		
h_{max} =	4	ft		
h =		ft		
t_f =		hrs		
A_f =		ft^2		

b) Coefficient of Permeability for Sand Filter (k): use 1.18 $\frac{\text{ft}}{\text{hr}}$

c) Maximum Allowable Water Depth (h_{max}): use 4 ft for example

d) One Half the Maximum Allowable Water Depth Over Filter Bed (h):

$$h(\text{ft}) = \frac{h_{max} - d_f}{2} = \frac{4\text{ ft} - 2.83\text{ ft}}{2} = 0.585\text{ ft}$$

TC-61(a): 2. e-f)

2. Sand Filter Basin Design	
a) Filter depth: $d_f = d_g + d_s$	$d_g =$ 16 in — 1.33 ft
d_g = gravel bed, minimum 16-inches thick	$d_s =$ 18 in — 1.5 ft
d_s = sand filter layer, minimum 18-inches thick	$d_f =$ 2.83 ft
b) Coefficient of permeability for sand filter = k (Use k = 1.18 ft/hr for clean, well-graded sand and gravel)	k = 1.18 ft/hr
c) Maximum allowable water depth in sand filter = h_{max} h_{max} = inlet elevation - outlet elevation	$h_{max} =$ 4 ft
d) One half the maximum allowable water depth (2h) over filter bed = h (2h = $h_{max} - d_f$)	h = 0.585 ft
e) Time required for the WQ_v to pass through the filter = t_f (max time = 48 hrs)	$t_f =$ 48 hrs
f) Surface area of the filter basin = A_f (ft^2)	$A_f =$ ft^2

e) Time Required for WQ_v to Pass Through the Filter (t_f): use max of 48 hrs

f) Surface Area of the Filter Basin (A_f):

$$A_f(\text{ft}^2) = \frac{WQ_v \times d_f}{k \times (h + d_f) \times t_f} = \frac{2{,}058\ \text{ft}^3 \times 2.83\ ft}{1.18\frac{ft}{hr} \times (0.585\ ft + 2.83\ ft) \times 48\ hrs} = 30.1\ \text{ft}^2$$

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TC-61(a): 3. a-b)

3. Filter Dimensions	
a) Filter width = W_f	W_f = 4 ft
b) Length: Lf = Af/Wf	L_f = ft

a) Filter Width (W_f):

- assume width of 4 ft for example
- consider site constraints for actual design

b) Length (L_f):

$$L_f = \frac{A_f}{W_f} = \frac{30.1\ \text{ft}^2}{4\ \text{ft}} = 7.5\ \text{ft}$$

TC-61(a): 4. a-c)

4. System Storage Volume	
a) Available Storage Above Filter Bed: $V_{tf} = A_f \times 2h$	V_{tf} = ____ ft^3
b) Storage in Filter Voids: $V_v = 0.4 \times A_f \times d_f$	V_v = ____ ft^3
c) Flow Through the Filter During Filling $V_q = kA_f(d_f + h)t_f/d_f$, assume t_f = 1 hr and k per 2.b above	V_q = ____ ft^3

a) Available Storage Above Filter Bed (V_f):

$$V_f = A_f \times 2h = 30.1\ ft^2 \times (4\ ft - 2.83\ ft) = 35.2\ ft^3$$

b) Storage in Filter Voids (V_v):

$$V_v = 0.4 \times A_f \times d_f = 0.4 \times 30.1\ ft^2 \times 2.83\ ft = 34.1\ ft^3$$

c) Flow Through the Filter During Filling (V_q):

- TMSCDLIDM: assume $k = 0.0833\ \frac{ft}{hr}$, $t_f = 1\ hr$

$$V_q = \frac{k \times A_f \times (d_f + h) \times t_f}{d_f} = \frac{0.0833\ \frac{ft}{hr} \times 30.1\ ft^2 \times (2.83\ ft + 0.585\ ft) \times 1\ hr}{2.83\ ft} = 3.0\ ft^3$$

TC-61(a): 5. a-b)

5. Permanent Pool

a) Required net storage
Vst = WQv - Vtf - Vv - Vq

b) Minimum Length: $L_{pm} = V_{st} / (2h)(W_f)$

V_{st} = ____ ft^3

L_{pm} = ____ ft

Notes & Additional Information:

a) Required Net Storage (V_{st}):

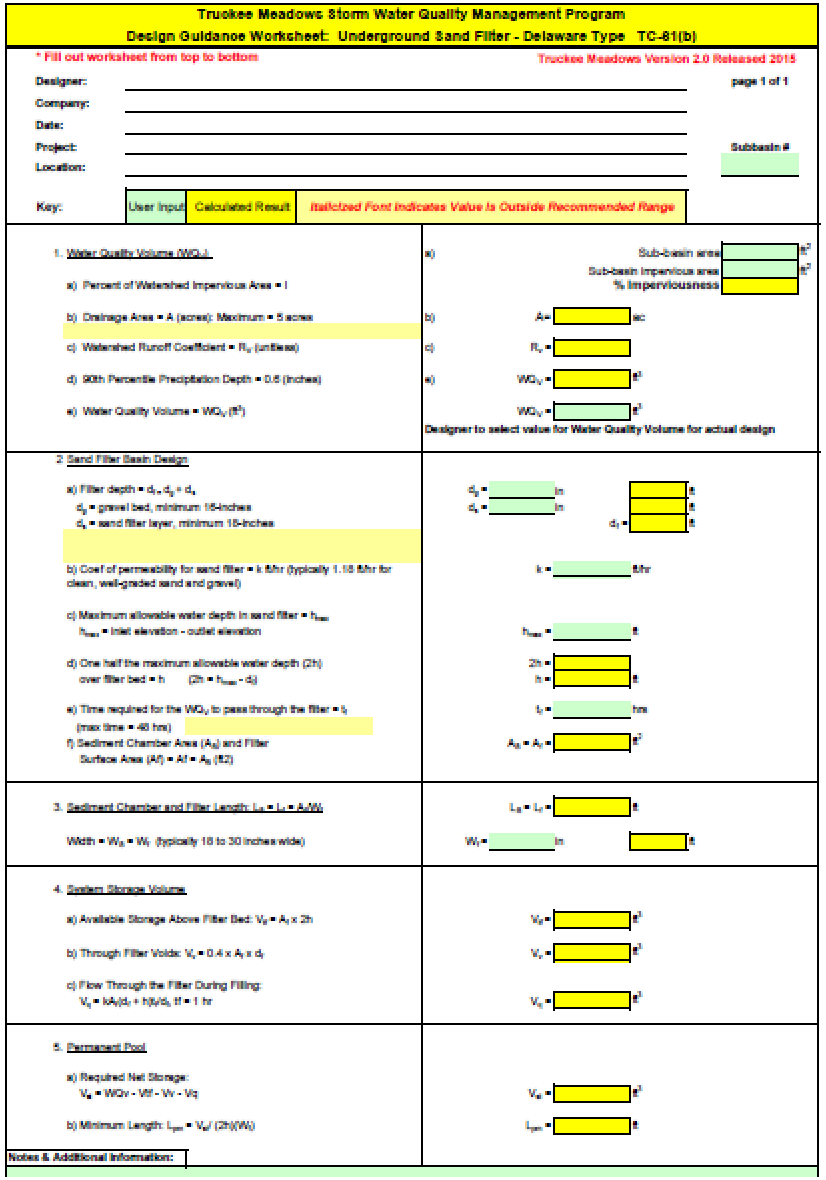
$$V_{st} = WQ_v - V_{tf} - V_v - V_q = 2{,}058\ ft^3 - 35.2\ ft^3 - 34.1\ ft^3 - 3.0\ ft^3$$
$$= 1{,}985.7\ ft^3$$

b) Minimum Length (L_{pm}):

$$L_{pm}\ (ft) = \frac{V_{st}}{2h \times W_f} = \frac{1{,}985.7\ ft^3}{(4\ ft - 2.83\ ft) \times 4\ ft} = 424.3\ ft$$

TC-61(b)

1. Water Quality Volume
2. Sand Filter Basin Design
3. Sediment Chamber and Filter Length
4. System Storage Volume
5. Permanent Pool



Truckee Meadows Storm Water Quality Management Program

Design Guidance Worksheet: Underground Sand Filter - Delaware Type TC-61(b)

* Fill out worksheet from top to bottom

Truckee Meadows Version 2.0 Released 2015

Designer: ______ page 1 of 1

Company: ______

Date: ______

Project: ______ Subbasin #

Location: ______

Key: User Input | Calculated Result | *Italicized Font Indicates Value is Outside Recommended Range*

1. Water Quality Volume (WQ_v)	
a) Percent of Watershed Impervious Area = I	a) Sub-basin area ___ ft^2; Sub-basin Impervious area ___ ft^2; % Imperviousness ___
b) Drainage Area = A (acres): Maximum = 5 acres	b) A= ___ ac
c) Watershed Runoff Coefficient = R_v (unitless)	c) R_v = ___
d) 90th Percentile Precipitation Depth = 0.6 (inches)	e) WQ_V = ___ ft^3
e) Water Quality Volume = WQ_V (ft^3)	WQ_V = ___ ft^3; Designer to select value for Water Quality Volume for actual design
2. Sand Filter Basin Design	
a) Filter depth = d_f, $d_f = d_s$; d_g = gravel bed, minimum 16-inches; d_s = sand filter layer, minimum 18-inches	d_g = ___ in; d_s = ___ in; ___ ft; ___ ft; d_f = ___ ft
b) Coef of permeability for sand filter = k ft/hr (typically 1.18 ft/hr for clean, well-graded sand and gravel)	k = ___ ft/hr
c) Maximum allowable water depth in sand filter = h_{max}; h_{max} = inlet elevation - outlet elevation	h_{max} = ___ ft
d) One half the maximum allowable water depth (2h) over filter bed = h (2h = h_{max} - d_f)	2h = ___; h = ___ ft
e) Time required for the WQ_V to pass through the filter = t_f (max time = 48 hrs)	t_f = ___ hrs
f) Sediment Chamber Area (A_S) and Filter Surface Area (Af) = Af = A_S (ft2)	A_S = A_f = ___ ft^2
3. Sediment Chamber and Filter Length: $L_S = L_f = A_f/W_f$	$L_S = L_f$ = ___ ft
Width = W_S = W_f (typically 18 to 30 inches wide)	W_f = ___ in ___ ft
4. System Storage Volume	
a) Available Storage Above Filter Bed: $V_f = A_f \times 2h$	V_f = ___ ft^3
b) Through Filter Voids: $V_v = 0.4 \times A_f \times d_f$	V_v = ___ ft^3
c) Flow Through the Filter During Filling: $V_q = kA_f(d_f + h)t_f/d_f$, tf = 1 hr	V_q = ___ ft^3
5. Permanent Pool	
a) Required Net Storage: V_s = WQv - Vf - Vv - Vq	V_s = ___ ft^3
b) Minimum Length: $L_{pp} = V_s/(2h)(W_f)$	L_{pp} = ___ ft

Notes & Additional Information:

TC-61(b): 1. e)

1. Water Quality Volume (WQ_V)	
a) Percent of Watershed Impervious Area = I	a) Sub-basin area [ ] ft^2 Sub-basin impervious area [ ] ft^2 **% Imperviousness** [ ]
b) Drainage Area = A (acres): Maximum = 5 acres	b) A= [ ] ac
c) Watershed Runoff Coefficient = R_V (unitless)	c) R_v = [ ]
d) 90th Percentile Precipitation Depth = 0.6 (inches)	e) WQ_V = **5,741** ft^3
e) Water Quality Volume = WQ_V (ft^3)	WQ_V = [ ] ft^3 **Designer to select value for Water Quality Volume for actual design**

e) Water Quality Volume:

- Max drainage area 5 acres
- Will use TC-60 value of 5,741 ft^3 in this example

TC-61(b): 2. a-d)

2 Sand Filter Basin Design

a) Filter depth = $d_f = d_g + d_s$ d_g = gravel bed, minimum 16-inches d_s = sand filter layer, minimum 18-inches	d_g = 16 in d_s = 18 in	ft ft d_f = 2.83 ft
b) Coef of permeability for sand filter = k ft/hr (typically 1.18 ft/hr for clean, well-graded sand and gravel)	k = 1.18 ft/hr	
c) Maximum allowable water depth in sand filter = h_{max} h_{max} = inlet elevation - outlet elevation	h_{max} = 4 ft	
d) One half the maximum allowable water depth (2h) over filter bed = h (2h = h_{max} - d_f)	2h = 1.17 h = 0.585 ft	
e) Time required for the WQ_v to pass through the filter = t_f (max time = 48 hrs)	t_f = hrs	
f) Sediment Chamber Area (A_S) and Filter Surface Area (Af) = Af = A_S (ft2)	$A_S = A_f$ = ft^2	

a) Filter Depth (d_f): use 2.83 ft from TC-61(a)

b) Coef of Permeability for Sand Filter (k): use 1.18 $\frac{ft}{hr}$

c) Maximum Allowable Water Depth in sand filter ($h_{\max}$): use 4 ft like TC-61(a)

d) One Half the Maximum Allowable Water Depth Over Filter Bed: use 2h and h values from TC-61(a)

TC-61(b): 2. e-f)

2 Sand Filter Basin Design

a) Filter depth = $d_f = d_g + d_s$ d_g = gravel bed, minimum 16-inches d_s = sand filter layer, minimum 18-inches	d_g = 16 in d_s = 18 in ft ft d_f = 2.83 ft
b) Coef of permeability for sand filter = k ft/hr (typically 1.18 ft/hr for clean, well-graded sand and gravel)	k = 1.18 ft/hr
c) Maximum allowable water depth in sand filter = h_{max} h_{max} = inlet elevation - outlet elevation	h_{max} = 4 ft
d) One half the maximum allowable water depth (2h) over filter bed = h (2h = h_{max} - d_f)	2h = 1.17 h = 0.585 ft
e) Time required for the WQ_v to pass through the filter = t_f (max time = 48 hrs)	t_f = 48 hrs
f) Sediment Chamber Area (A_S) and Filter Surface Area (Af) = Af = A_S (ft2)	$A_S = A_f$ = ft²

e) Time Required for the WQ_v to Pass Through the Filter (t_f): use max 48 hrs

f) Sediment Chamber Area (A_s) and Filter Surface Area (A_f):

$$A_f(\text{ft}^2) = \frac{WQ_v \times d_f}{k \times (h + d_f) \times t_f} = \frac{5{,}741\ \text{ft}^3 \times 2.83\ ft}{1.18\frac{ft}{hr} \times (0.585\ ft + 2.83\ ft) \times 48\ hrs} = 84\ \text{ft}^2$$

TC-61(b): 3.

3. Sediment Chamber and Filter Length: $L_s = L_f = A_s/W_s$	$L_s = L_f =$ ft
Width $= W_s = W_f$ (typically 18 to 30 inches wide)	$W_f =$ 24 in ft

- Width (W_s , W_f): use 24 inches (2 feet) for example
- Sediment Chamber and Filter Length (L_s , L_f):

$$L_s = L_f = \frac{A_s}{W_s} = \frac{84\ \mathrm{ft}^2}{2\ ft} = 42\ ft$$

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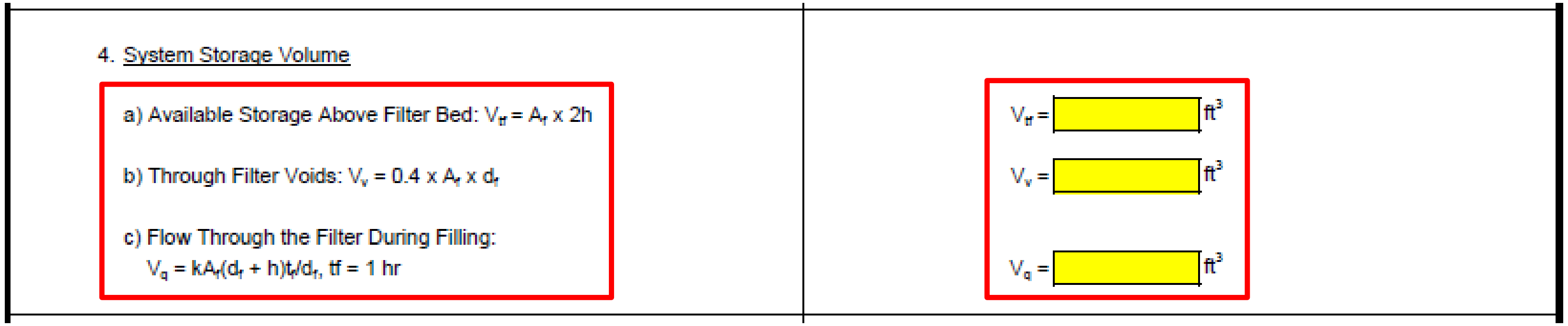
TC-61(b): 4. a-c)


4. System Storage Volume

a) Available Storage Above Filter Bed: $V_{tf} = A_f \times 2h$

b) Through Filter Voids: $V_v = 0.4 \times A_f \times d_f$

c) Flow Through the Filter During Filling: $V_q = kA_f(d_f + h)t_f/d_f$, tf = 1 hr

$V_{tf} =$ ____ ft^3

$V_v =$ ____ ft^3

$V_q =$ ____ ft^3

a) Available Storage Above Filter Bed (V_f):

$$V_f = A_f \times 2h = 84\ ft^2 \times 1.17\ ft = 98.28\ ft^3$$

b) Storage in Filter Voids (V_v):

$$V_v = 0.4 \times A_f \times d_f = 0.4 \times 84\ ft^2 \times 2.83\ ft = 95.1\ ft^3$$

c) Flow Through the Filter During Filling (V_q):

- TMSCDLIDM: assume $k = 0.0833\ \frac{ft}{hr}$, $t_f = 1\ hr$

$$V_q = \frac{k \times A_f \times (d_f + h) \times t_f}{d_f} = \frac{0.0833\ \frac{ft}{hr} \times 84\ ft^2 \times (2.83\ ft + 0.585\ ft) \times 1\ hr}{2.83\ ft} = 8.4\ ft^3$$

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TC-61(b): 5. a-b)

5. Permanent Pool

a) Required Net Storage:
V_{st} = WQv - Vtf - Vv - Vq

b) Minimum Length: $L_{pm} = V_{st}/(2h)(W_f)$

V_{st} = ____ ft^3

L_{pm} = ____ ft

Notes & Additional Information:

a) Required Net Storage (V_{st}):

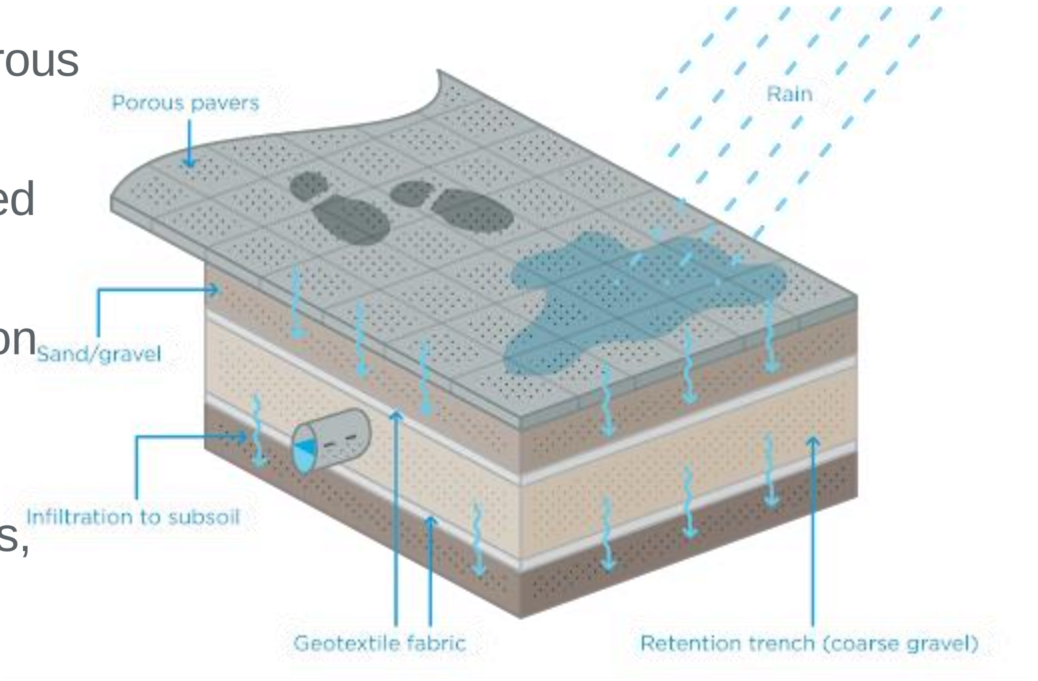
$$V_{st} = WQ_v - V_{tf} - V_v - V_q = 5{,}741\ ft^3 - 98.28\ ft^3 - 95.1\ ft^3 - 8.4\ ft^3 = 5{,}539.2\ ft^3$$

b) Minimum Length (L_{pm}):

$$L_{pm}\ (ft) = \frac{V_{st}}{2h \times W_f} = \frac{5{,}539.2\ ft^3}{1.17\ ft \times 2\ ft} = 2{,}367.2\ ft$$

Porous Pavements (TC-62)

- Porous paving systems allow infiltration of stormwater while providing a stable load-bearing surface for walking and driving
- Contain void spaces to provide infiltration of runoff into their porous materials and then into existing site soils
- Underlying materials consist of clean sands or gravels separated from existing site soils by synthetic filter fabric
- Underlying materials detain and filter pollutants prior to infiltration into underlying soils or discharge to a conventional storm drain system through an underdrain system
- Porous paving systems can preserve natural discharge patterns, enhance groundwater recharge and soil moisture, and help establish and maintain roadside vegetation
- Not ideal for heavily trafficked applications



Porous Pavements.

Source: http://urbanwater.melbourne.vic.gov.au/industry/treatment-types/what-is-porous-pavement/

Porous Pavement Types

- **Porous Pavement Detention (TC-62A)**
  - Installation of open-celled block pavers that is flat with a 2-inch deep surcharge zone to store temporarily the WQv
  - Best for parking areas and low traffic volume roadways where little to no truck traffic is anticipated
- **Open Celled Block Pavers (TC-62B) and Open Jointed Block Pavers (TC-62C)**
  - Blocks or slabs made of concrete or brick with open surface voids that penetrate their surface area
  - Solid block units made of concrete, clay or stone that form an interlocking, flexible pavement surface
  - Pavers reduce runoff from paved areas and the ponding that typically occurs in parking lots
  - Also best in parking areas and low traffic volume roadways

Porous Pavement Types

- **Porous Concrete and Asphalt (TC-62D)**
  - Constructed by binding open-graded aggregate and therefore contain void spaces that allow water to pass through a permeable subbase layer
  - Ideal for light to medium duty applications like residential access roads
  - Airport runways and highways as it creates a favorable driving surface in rainy weather
- **Porous Turf Pavement (TC-62E)**
  - Stabilized grass surface that can support intermittent pedestrian or vehicular traffic
  - Gives the appearance of "green space"

Driveable Grass.

Source: The Houzz, https://www.houzz.com/photos/drivable-grass%C2%AE-porous-grass-paving-contemporary-landscape-san-diego-phvw-vp~5111917

Porous Pavement Types

> **Porous Gravel Pavement (TC-62F)**

– Loose gravel-surface paving placed over a porous sub-base

– Reduces runoff from paved areas and the ponding that occurs during and after large storm events

– Can be used as a substitute for conventional pavement

> **Open Celled Plastic Grids (TC-62G)**

– Manufactured plastic lattices that can be filled with aggregate or topsoil and planted with turf

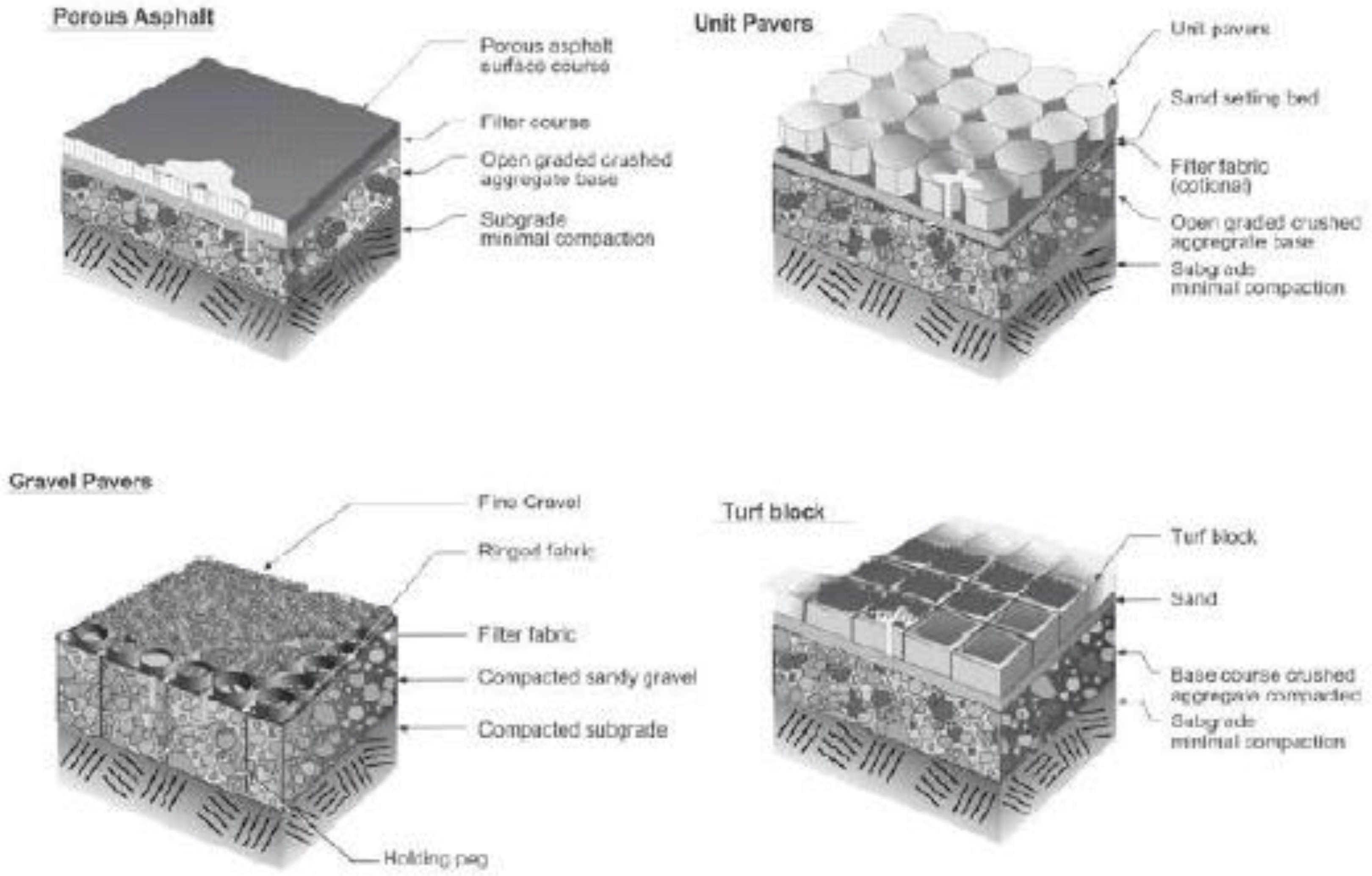
– Also referred to as geocells, and made with recycled plastics

– Limited to low intensity use and areas with low traffic speeds, such as driveways, residential street parking lanes or parking lots

Pavers.

Source: True Grid Paver, https://www.truegridpaver.com/complete-guide-permeable-paving-systems%EF%BB%BF/

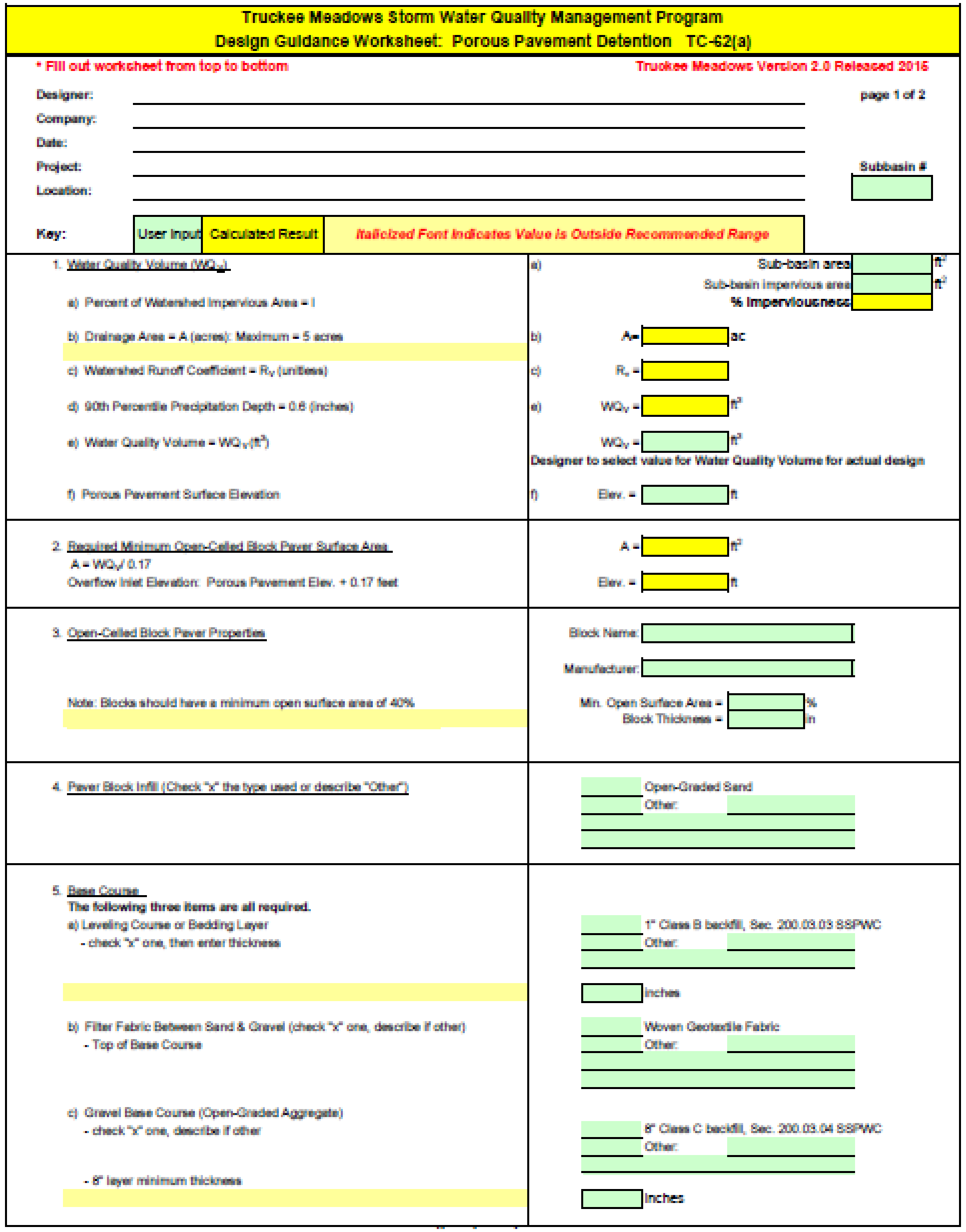
Porous Pavement Types



Source: Structural Controls and LID Manual (2015).

TC-62(a)

1. Water Quality Volume
2. Required Minimum Open-Celled Block Paver Surface Area
3. Open-Celled Block Paver Properties
4. Paver Block Infill
5. Base Course
6. Perimeter Wall
7. Draining of Porous Pavement



Truckee Meadows Storm Water Quality Management Program
Design Guidance Worksheet: Porous Pavement Detention TC-62(a)

* Fill out worksheet from top to bottom — Truckee Meadows Version 2.0 Released 2015

page 1 of 2

Designer: ______
Company: ______
Date: ______
Project: ______ Subbasin #
Location: ______

Key: User Input | Calculated Result | *Italicized Font Indicates Value is Outside Recommended Range*

1. Water Quality Volume (WQ_V)	a) Sub-basin area ___ ft²; Sub-basin impervious area ___ ft²; % Imperviousness ___
a) Percent of Watershed Impervious Area = I	
b) Drainage Area = A (acres): Maximum = 5 acres	b) A= ___ ac
c) Watershed Runoff Coefficient = R_V (unitless)	c) R_v = ___
d) 90th Percentile Precipitation Depth = 0.6 (inches)	e) WQ_V = ___ ft³
e) Water Quality Volume = WQ_V (ft³)	WQ_V = ___ ft³ Designer to select value for Water Quality Volume for actual design
f) Porous Pavement Surface Elevation	f) Elev. = ___ ft
2. Required Minimum Open-Celled Block Paver Surface Area A = WQ_V / 0.17 Overflow Inlet Elevation: Porous Pavement Elev. + 0.17 feet	A = ___ ft² Elev. = ___ ft
3. Open-Celled Block Paver Properties Note: Blocks should have a minimum open surface area of 40%	Block Name: ___ Manufacturer: ___ Min. Open Surface Area = ___ % Block Thickness = ___ in
4. Paver Block Infill (Check "x" the type used or describe "Other")	___ Open-Graded Sand ___ Other: ___
5. Base Course **The following three items are all required.** a) Leveling Course or Bedding Layer - check "x" one, then enter thickness	___ 1" Class B backfill, Sec. 200.03.03 SSPWC ___ Other: ___ ___ Inches
b) Filter Fabric Between Sand & Gravel (check "x" one, describe if other) - Top of Base Course	___ Woven Geotextile Fabric ___ Other: ___
c) Gravel Base Course (Open-Graded Aggregate) - check "x" one, describe if other - 8" layer minimum thickness	___ 8" Class C backfill, Sec. 200.03.04 SSPWC ___ Other: ___ ___ Inches

TC-62(a): 1. e-f)

1. Water Quality Volume (WQ_V)	a)	Sub-basin area [ ] ft^2
		Sub-basin impervious area [ ] ft^2
a) Percent of Watershed Impervious Area = I		**% Imperviousness** [ ]
b) Drainage Area = A (acres): Maximum = 5 acres	b)	A= [ ] ac
c) Watershed Runoff Coefficient = R_V (unitless)	c)	R_V = [ ]
d) 90th Percentile Precipitation Depth = 0.6 (inches)	e)	WQ_V = [ ] ft^3
e) Water Quality Volume = WQ_V (ft^3)		WQ_V = 5,741 ft^3
		Designer to select value for Water Quality Volume for actual design
f) Porous Pavement Surface Elevation	f)	Elev. = 100 ft

e) Water Quality Volume (WQ_v):

- Max drainage area 5 acres
- Will use TC-60 value of 5,741 ft^3 in this example

f) Porous Pavement Surface Elevation: use 100 ft for example

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TC-62(a): 2.

2. Required Minimum Open-Celled Block Paver Surface Area A = WQ_V/ 0.17 Overflow Inlet Elevation: Porous Pavement Elev. + 0.17 feet	A = ft^2 Elev. = ft

- Required Minimum Open-Celled Block Paver Surface Area (A):

$$A = \frac{WQ_v}{0.17} = \frac{5{,}741\ \text{ft}^3}{0.17} = 33{,}770.6\ \text{ft}^3$$

- Overflow Inlet Elevation:

$$\text{Porous Pavement Elev.} + 0.17\ \text{ft} = 100\ \text{ft} + 0.17\ \text{ft} = 100.17\ \text{ft}$$

TC-62(a): 3.

3. Open-Celled Block Paver Properties	Block Name:
	Manufacturer:
Note: Blocks should have a minimum open surface area of 40%	Min. Open Surface Area = 40 %
	Block Thickness = 2 in

- State block's name and manufacturer
- Min. Open Surface Area: use 40% for example
- Block thickness: use 2 in for example

TC-62(a): 4.

4. Paver Block Infill (Check "x" the type used or describe "Other")	X	Open-Graded Sand
		Other:

- Paver Block Infill:
  - Checked Open-Graded Sand for this example
  - If a different type is used check other and describe the infill

TC-62(a): 5. a-c)

5. Base Course **The following three items are all required.** a) Leveling Course or Bedding Layer - check "x" one, then enter thickness	X 1" Class B backfill, Sec. 200.03.03 SSPWC Other:
	1 inches
b) Filter Fabric Between Sand & Gravel (check "x" one, describe if other) - Top of Base Course	X Woven Geotextile Fabric Other:
c) Gravel Base Course (Open-Graded Aggregate) - check "x" one, describe if other	X 8" Class C backfill, Sec. 200.03.04 SSPWC Other:
- 8" layer minimum thickness	8 inches

a) Leveling Course: checked 1" Class B backfill, if something different is used check other and describe (enter thickness)

b) Filter Fabric: checked Woven Geotextile Fabric, if different fabric is used check other and describe

c) Gravel Base Course: checked 8" Class C backfill, if something different is used check other and describe (enter thickness)

TC-62(a): 6.

6. Perimeter Wall (check "x" type, describe if other) - recommended to be 6 inches thick in width - depth must extend 6 inches from the bottom of the base course	X Concrete Other width = in depth = in

- Concrete was checked for this example
- If something else is used check other and describe
- Specify the width and depth

TC-62(a): 7. a-d)

7. Draining of porous pavement

Answer questions 7a through 7d to determine design requirements

Check "x" only one appropriate box based on following criteria

a) Subgrade is a heavy or expansive clay	
b) Subgrade is a silty or clayey sand	
c) Subgrade is a well-draining soil	X
Answer Yes (Y) or No (N) to the following question	
d) Does tributary drainage area have land uses with outdoor use or storage of chemicals or materials that could spill (e.g. a gas station, a hardware store, etc.)? "Y" or "N"	N

X	Design: Infiltration to subgrade with Woven geotextile fabric liner 7c = x **and** 7d = N
	Design: Underdrain with 16-mil. Impermeable fabric 7a = x **or** 7d = Y
	Design: Underdrain with Woven geotextile fabric 7b = x **and** 7d = N
	Other:

a-c) Check the box that describes the subgrade (c was checked for this example)

d) If there is danger of chemical/material spills mark “Y”, if not mark “N” (N was used for this example)

- Then mark the appropriate yellow box on the right that is associated with your answers from a-d

TC-62(a): 8.

8. Overflow For Larger Storms	N	Yes / No (y or n)
Notes & Additional Information:		

- Specify if overflow will occur with larger storms (no used for this example)

TC-62(b)

1. Water Quality Volume
2. Open-Celled Block Pavers Properties
3. Block Paver Cells Fill Material
4. Base Course
5. Design Impervious Area to Porous Pavement Area Ratio
6. Perimeter Wall
7. Contained Cells
8. Draining of Modular Block Pavement

Truckee Meadows Storm Water Quality Management Program
Design Guidance Worksheet: Open-Celled Block Pavers TC-62(b)

* Fill out worksheet from top to bottom — Truckee Meadows Version 2.0 Released 2016

page 1 of 2

Designer: ______
Company: ______
Date: ______
Project: ______ Subbasin #
Location: ______

Key: User Input | Calculated Result | *Italicized Font Indicates Value Is Outside Recommended Range*

1. Water Quality Volume (WQ_V)	a) Sub-basin area ____ ft² ; Sub-basin impervious area ____ ft² ; % Imperviousness ____
a) Percent of Watershed Impervious Area = I	
b) Drainage Area = A (acres): Maximum = 5 acres	b) A= ____ ac
c) Watershed Runoff Coefficient = R_V (unitless)	c) R_v = ____
d) 90th Percentile Precipitation Depth = 0.6 (inches)	e) WQ_V = ____ ft³
e) Water Quality Volume = WQ_V (ft³)	WQ_V = ____ ft³ ; Designer to select value for Water Quality Volume for actual design
2. Open-Celled Block Pavers Properties	Block Name: ____ ; Manufacturer: ____
Note: Blocks should have a minimum open surface area void space of 20%	Min. Open Surface Area = ____ % ; Block Thickness = ____ in
3. Block Paver Cells Fill Material (Check the type or describe "Other")	____ Open-Graded Sand ; ____ Turf ; ____ Other: ____
4. Base Course — The following three items are all required. a) Leveling Course or Bedding Layer - Open-Graded Aggregate - check "x" one, describe if other	____ Class B backfill, Section 200.03.03 SSPWC ; ____ Other: ____
- recommended bedding layer thickness of 1 to 2 inches	____ inches
b) Filter Fabric Between Base Course & Bedding Layer -Top of Base Course (check "x" one, describe if other)	____ Woven Geotextile Fabric ; ____ Other: ____
c) Gravel Base Course (Open-Graded Aggregate)	____ 8" min. Class C backfill, Sec. 200.03.04 SSPWC ; ____ Other: ____
8" minimum thickness required	____ inches ____ ft
5. Design Impervious Area to Porous Pavement Area Ratio (Max. = 2):	Ratio = ____ (A_{imp} / A_{POROUS})
6. Perimeter Wall (check "x" type, describe if other) - recommended to be 6 inches thick in width - depth must extend 6 inches from the bottom of the base course	____ Concrete ; ____ Other: ____ ; width = ____ in ; depth = ____ in

continue to next page

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TC-62(b): 1. a-e)

1. Water Quality Volume (WQ_V)			
a) Percent of Watershed Impervious Area = I	a)	Sub-basin area	ft^2
		Sub-basin impervious area	ft^2
		% Imperviousness	
b) Drainage Area = A (acres): Maximum = 5 acres	b)	A=	ac
c) Watershed Runoff Coefficient = R_V (unitless)	c)	R_v =	
d) 90th Percentile Precipitation Depth = 0.6 (inches)	e)	WQ_V =	ft^3
e) Water Quality Volume = WQ_V (ft^3)		WQ_V = 5,741	ft^3
		Designer to select value for Water Quality Volume for actual design	

e) Water Quality Volume (WQ_v):

- Max drainage area 5 acres
- Will use TC-60 value of $5{,}741\ ft^3$ in this example

TC-62(b): 2.

2. Open-Celled Block Pavers Properties

Note: Blocks should have a minimum open surface area void space of 20%

Block Name:
Manufacturer:

Min. Open Surface Area = 20 %
Block Thickness = 2 in

- State block's name and manufacturer
- Min. Open Surface Area: use 20% for example
- Block thickness: use 2 in for example

TC-62(b): 3.

3. Block Paver Cells Fill Material (Check the type or describe "Other")	X Open-Graded Sand __ Turf __ Other: ______

- Block Paver Cells Fill Material:
  - Checked Open-Graded Sand for this example
  - If a different type is used check Turf or other and describe the material

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TC-62(b): 4. a-c)

4. <u>Base Course</u>	
The following three items are all required.	
a) Leveling Course or Bedding Layer - Open-Graded Aggregate	X Class B backfill, Section 200.03.03 SSPWC
- check "x" one, describe if other	Other:
- recommended bedding layer thickness of 1 to 2 inches	1.5 inches
b) Fitler Fabric Between Base Course & Bedding Layer	X Woven Geotextile Fabric
-Top of Base Course	Other:
(check "x" one, describe if other)	
c) Gravel Base Course (Open-Graded Aggregate)	X 8" min. Class C backfill, Sec. 200.03.04 SSPWC
	Other:
8" minimum thickness required	8 inches 0.67 ft

a) Leveling Course: checked Class B backfill, if something different is used check other and describe (enter thickness)

b) Filter Fabric: checked Woven Geotextile Fabric, if different fabric is used check other and describe

c) Gravel Base Course: checked 8” Class C backfill, if something different is used check other and describe (enter thickness)

TC-62(b): 5-6.

5. Design Impervious Area to Porous Pavement Area Ratio (Max. = 2):	Ratio = 2 (A_{Imp} / A_{POROUS})
6. Perimeter Wall (check "x" type, describe if other) - recommended to be 6 inches thick in width - depth must extend 6 inches from the bottom of the base course	X Concrete Other width = in depth = in

5. Design Impervious Area to Porous Pavement Area Ratio: used max of 2 for example
6. Perimeter Wall:
   - Checked concrete for example, if another material is used check other and describe
   - Specify the width and depth

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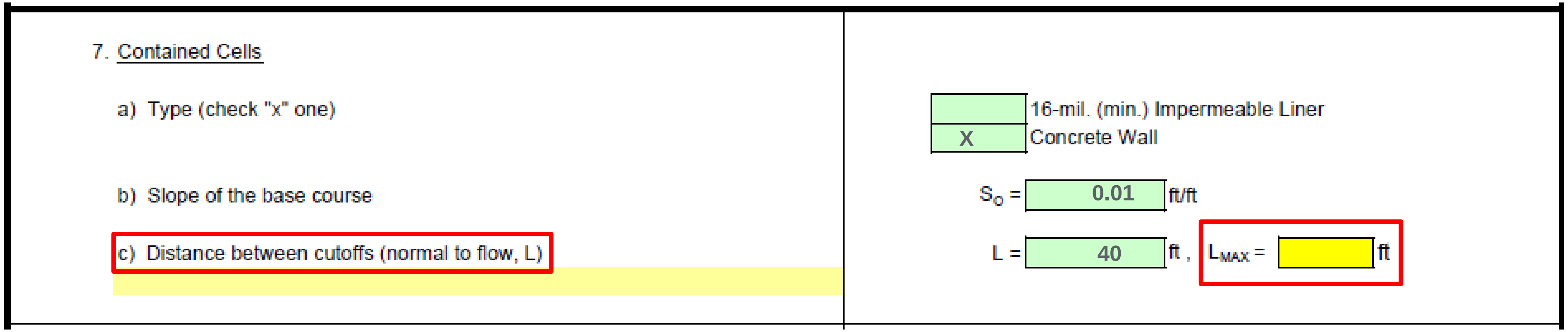
TC-62(b): 7. a-c)



7. Contained Cells

a) Type (check "x" one)

	16-mil. (min.) Impermeable Liner
X	Concrete Wall

b) Slope of the base course — S_O = 0.01 ft/ft

c) Distance between cutoffs (normal to flow, L) — L = 40 ft , L_{MAX} = ft

a) Type: checked Concrete Wall for example

b) Slope of Base Course: used 0.01 for example

- TMSCDLIDM states pervious pavement can be used on gentle slopes that do not exceed 5%

a) Distance Between Cutoffs

$$L_{max} = \frac{D}{1.5 \times S_0} = \frac{0.67\ \text{ft}}{1.5 \times 0.01} = 44.7\ \text{ft}$$

- L of 40 ft chosen with a L_{max} of 44.7 ft

TC-62(b): 8. a-d)

8. Draining of modular block pavement

Answer questions 8a to 8d to determine design requirements

Check "x" only one appropriate box based on following criteria

a) Subgrade is a heavy or expansive clay	
b) Subgrade is a silty or clayey sand	
c) Subgrade is a well-draining soil	X

Answer Yes (Y) or No (N) to the following question

d) Does tributary drainage area have land uses with outdoor use or storage of chemicals or materials that could spill (e.g. a gas station, a hardware store, etc.)? "Y" or "N"	N

X	Design: Infiltration to subgrade with Woven geotextile fabric liner 8c = x **and** 8d = N
	Design: Underdrain with 16-mil. Impermeable fabric 8a = x **or** 8d = Y
	Design: Underdrain with Woven geotextile fabric 8b = x **and** 8d = N
	Other:

Notes & Additional Information:

a-c) Check the box that describes the subgrade (c was checked for this example)

d) If there is danger of chemical/material spills mark “Y”, if not mark “N” (N was used for this example)

- Then mark the appropriate yellow box on the right that is associated with your answers from a-d

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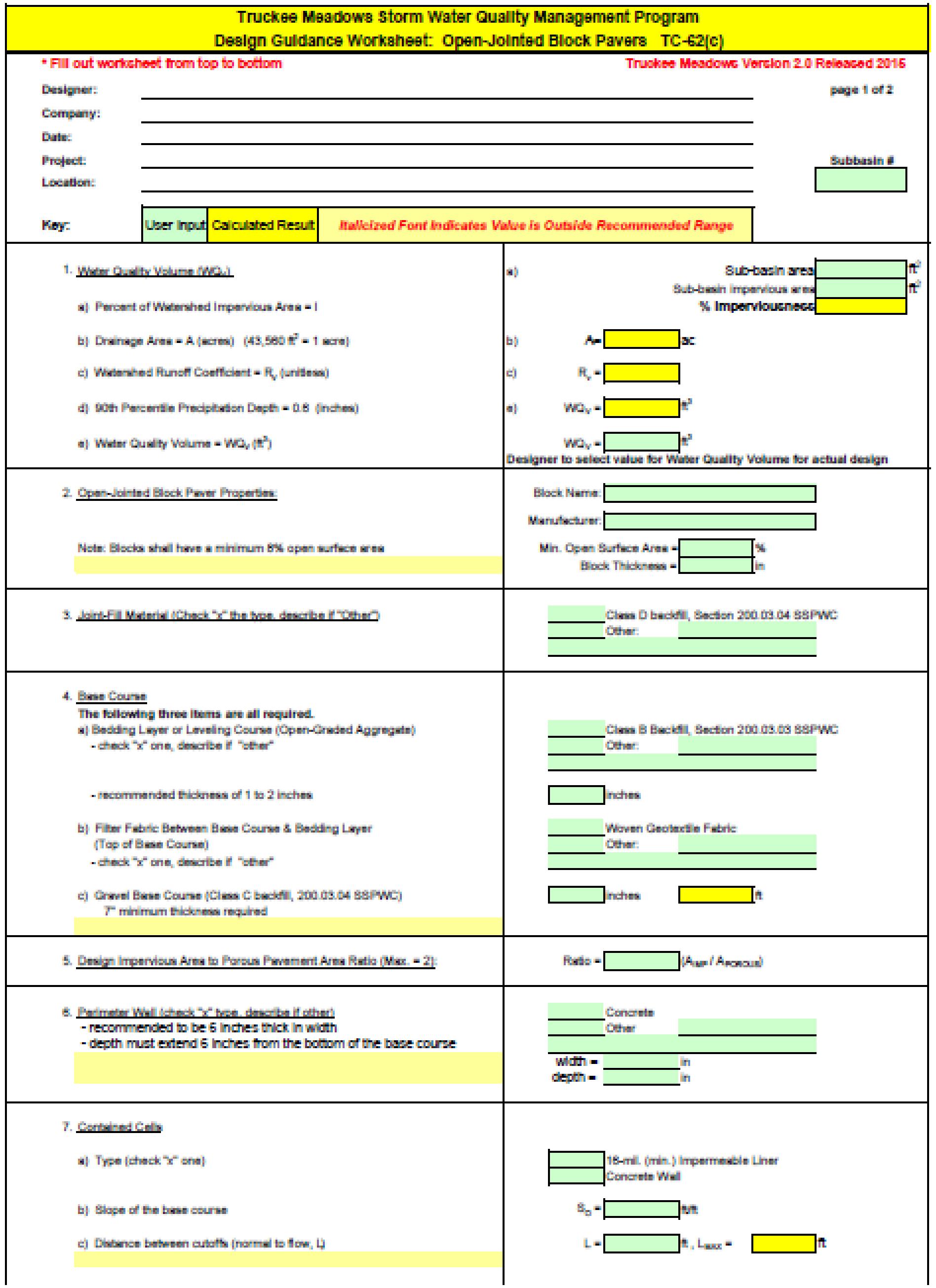
TC-62(c)

1. Water Quality Volume
2. Open-Jointed Block Paver Properties
3. Joint-Fill Material
4. Base Course
5. Design Impervious Area to Porous Pavement Area Ratio
6. Perimeter Wall
7. Contained Cells
8. Draining of Open-Jointed Block Pavers



Truckee Meadows Storm Water Quality Management Program
Design Guidance Worksheet: Open-Jointed Block Pavers TC-62(c)

* Fill out worksheet from top to bottom
Truckee Meadows Version 2.0 Released 2015
page 1 of 2

Designer:
Company:
Date:
Project:
Location:
Subbasin #

Key: User Input | Calculated Result | *Italicized Font Indicates Value is Outside Recommended Range*

1. Water Quality Volume (WQ_V)	a) Sub-basin area ft² / Sub-basin impervious area ft² / % Imperviousness
a) Percent of Watershed Impervious Area = I	
b) Drainage Area = A (acres) (43,560 ft² = 1 acre)	b) A= ac
c) Watershed Runoff Coefficient = R_v (unitless)	c) R_v =
d) 90th Percentile Precipitation Depth = 0.6 (inches)	e) WQ_V = ft³
e) Water Quality Volume = WQ_V (ft³)	WQ_V = ft³ Designer to select value for Water Quality Volume for actual design
2. Open-Jointed Block Paver Properties: Note: Blocks shall have a minimum 8% open surface area	Block Name: / Manufacturer: / Min. Open Surface Area = % / Block Thickness = in
3. Joint-Fill Material (Check "x" the type, describe if "Other")	Class D backfill, Section 200.03.04 SSPWC / Other:
4. Base Course The following three items are all required. a) Bedding Layer or Leveling Course (Open-Graded Aggregate) - check "x" one, describe if "other"	Class B Backfill, Section 200.03.03 SSPWC / Other:
- recommended thickness of 1 to 2 inches	inches
b) Filter Fabric Between Base Course & Bedding Layer (Top of Base Course) - check "x" one, describe if "other"	Woven Geotextile Fabric / Other:
c) Gravel Base Course (Class C backfill, 200.03.04 SSPWC) 7" minimum thickness required	inches ft
5. Design Impervious Area to Porous Pavement Area Ratio (Max. = 2):	Ratio = (A_{imp} / A_{porous})
6. Perimeter Wall (check "x" type, describe if other) - recommended to be 6 inches thick in width - depth must extend 6 inches from the bottom of the base course	Concrete / Other: / width = in / depth = in
7. Contained Cells	
a) Type (check "x" one)	18-mil. (min.) Impermeable Liner / Concrete Wall
b) Slope of the base course	S_O = ft/ft
c) Distance between cutoffs (normal to flow, L)	L = ft, L_{MAX} = ft

TC-62(c): 1. e)

1. Water Quality Volume (WQ_V)	a) Sub-basin area [ ] ft^2
	Sub-basin impervious area [ ] ft^2
a) Percent of Watershed Impervious Area = I	**% Imperviousness** [ ]
b) Drainage Area = A (acres) (43,560 ft^2 = 1 acre)	b) A= [ ] ac
c) Watershed Runoff Coefficient = R_V (unitless)	c) R_v = [ ]
d) 90th Percentile Precipitation Depth = 0.6 (inches)	e) WQ_V = [ ] ft^3
e) Water Quality Volume = WQ_V (ft^3)	WQ_V = **5,741** ft^3
	Designer to select value for Water Quality Volume for actual design

e) Water Quality Volume (WQ_v):

- No max or min drainage area specified
- Will use TC-60 value of $5{,}741\ ft^3$ in this example

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TC-62(c): 2.

2. Open-Jointed Block Paver Properties:	Block Name:		
	Manufacturer:		
Note: Blocks shall have a minimum 8% open surface area	Min. Open Surface Area =	8	%
	Block Thickness =	2	in

- State block’s name and manufacturer
- Min. Open Surface Area: use 8% for example
- Block thickness: use 2 in for example

TC-62(c): 3.

3. Joint-Fill Material (Check "x" the type, describe if "Other")	X Class D backfill, Section 200.03.04 SSPWC Other:

- Joint-Fill Material:
  - Checked Class D backfill for this example
  - If a different type is used check other and describe the material

TC-62(c): 4. a-c)

4. <u>Base Course</u> **The following three items are all required.** a) Bedding Layer or Leveling Course (Open-Graded Aggregate) - check "x" one, describe if "other"	X Class B Backfill, Section 200.03.03 SSPWC Other:
- recommended thickness of 1 to 2 inches	1.5 inches
b) Filter Fabric Between Base Course & Bedding Layer (Top of Base Course) - check "x" one, describe if "other"	X Woven Geotextile Fabric Other:
c) Gravel Base Course (Class C backfill, 200.03.04 SSPWC) 7" minimum thickness required	7 inches 0.58 ft

a) Leveling Course: checked Class B backfill, if something different is used check other and describe (enter thickness)

b) Filter Fabric: checked Woven Geotextile Fabric, if different fabric is used check other and describe

c) Gravel Base Course: specify thickness in inches and feet

TC-62(c): 5-6.

5. Design Impervious Area to Porous Pavement Area Ratio (Max. = 2):	Ratio = 2 (A_{IMP} / A_{POROUS})
6. Perimeter Wall (check "x" type, describe if other) - recommended to be 6 inches thick in width - depth must extend 6 inches from the bottom of the base course	X Concrete Other width = in depth = in

5. Design Impervious Area to Porous Pavement Area Ratio: used max of 2 for example
6. Perimeter Wall:
   - Checked concrete for example, if another material is used check other and describe
   - Specify the width and depth

TC-62(c): 7. a-c)

7. Contained Cells	
a) Type (check "x" one)	[ ] 16-mil. (min.) Impermeable Liner [x] Concrete Wall
b) Slope of the base course	S_O = 0.01 ft/ft
c) Distance between cutoffs (normal to flow, L)	L = 35 ft; L_{MAX} = ____ ft

a) Type: checked Concrete Wall for example

b) Slope of Base Course: used 0.01 for example

- TMSCDLIDM states not to install pavers on slopes greater than 15%

a) Distance Between Cutoffs

$$L_{max} = \frac{D}{1.5 \times S_0} = \frac{0.58 \text{ ft}}{1.5 \times 0.01} = 38.7 \text{ ft}$$

- L of 35 ft chosen with a L_{max} of 38.7 ft

TC-62(c): 8. a-d)

8. Draining of Open-Jointed Block Pavers

Answer questions 8a to 8d to determine design requirements

Check "x" only one appropriate box based on following criteria

a) Subgrade is a heavy or expansive clay	
b) Subgrade is a silty or clayey sand	
c) Subgrade is a well-draining soil	X
Answer Yes (Y) or No (N) to the following question	
d) Does tributary drainage area have land uses with outdoor use or storage of chemicals or materials that could spill (e.g. a gas station, a hardware store, etc.)? "Y" or "N"	N

X	Design: Infiltration to subgrade with Woven geotextile fabric liner 8c = x and 8d = N
	Design: Underdrain with 16-mil. Impermeable fabric 8a = x or 8d = Y
	Design: Underdrain with Woven geotextile fabric 8b = x and 8d = N
	Other:

Notes & Additional Information:

a-c) Check the box that describes the subgrade (c was checked for this example)

d) If there is danger of chemical/material spills mark “Y”, if not mark “N” (N was used for this example)

- Then mark the appropriate yellow box on the right that is associated with your answers from a-d

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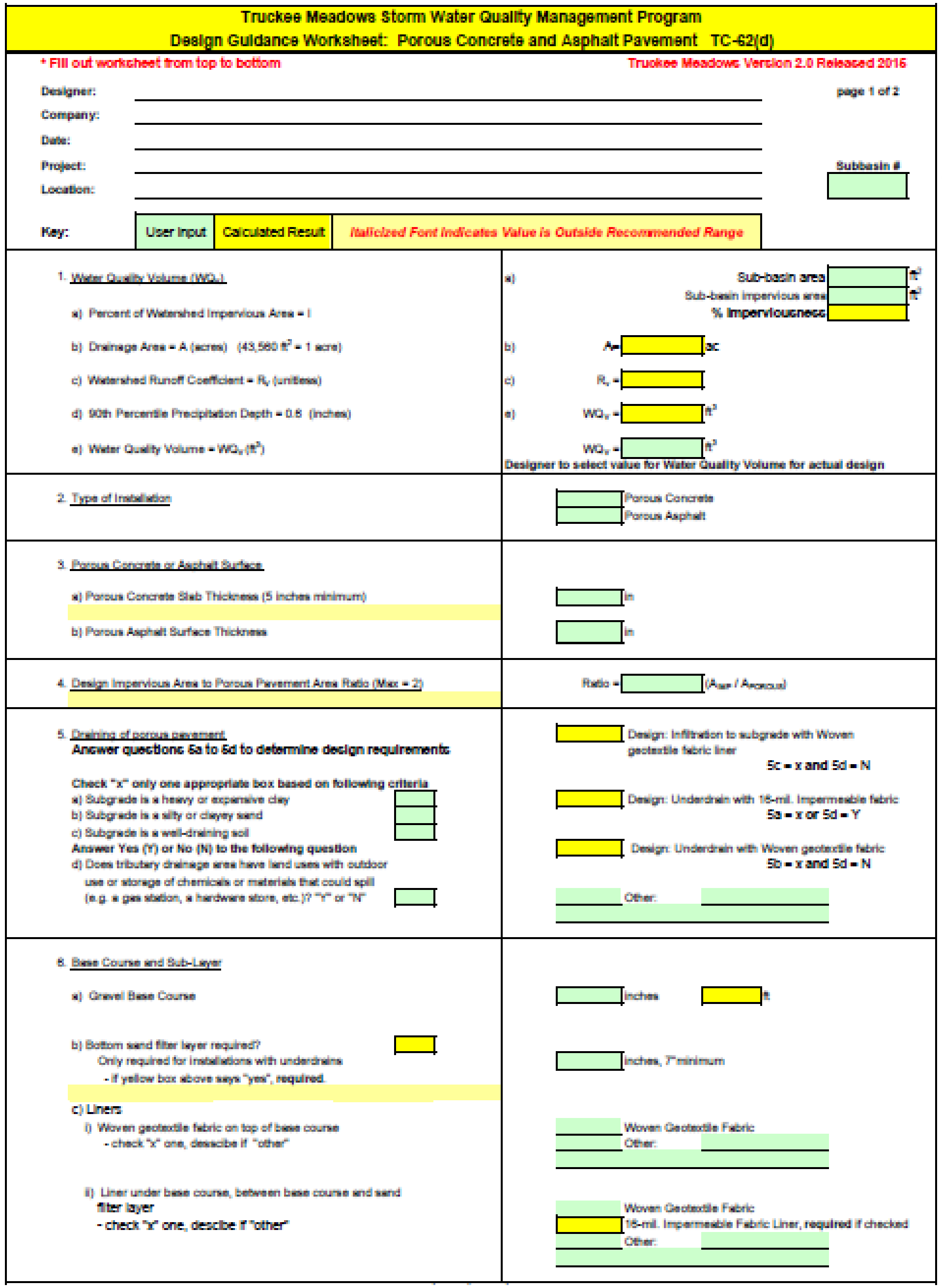
TC-62(d)

1. Water Quality Volume
2. Type of Installation
3. Porous Concrete or Asphalt Surface
4. Design Impervious Area to Porous Pavement Area Ratio
5. Draining of Porous Pavement
6. Base Course and Sub-Layer
7. Contained Cells



Truckee Meadows Storm Water Quality Management Program
Design Guidance Worksheet: Porous Concrete and Asphalt Pavement TC-62(d)

* Fill out worksheet from top to bottom — Truckee Meadows Version 2.0 Released 2016

page 1 of 2

Designer: ____
Company: ____
Date: ____
Project: ____
Location: ____
Subbasin #

Key: User Input | Calculated Result | *Italicized Font Indicates Value is Outside Recommended Range*

1. Water Quality Volume (WQ_v)
   a) Percent of Watershed Impervious Area = I — a) Sub-basin area ____ ft²; Sub-basin impervious area ____ ft²; % Imperviousness ____
   b) Drainage Area = A (acres) (43,560 ft² = 1 acre) — b) A= ____ ac
   c) Watershed Runoff Coefficient = R_v (unitless) — c) R_v = ____
   d) 90th Percentile Precipitation Depth = 0.6 (inches) — e) WQ_v = ____ ft³
   e) Water Quality Volume = WQ_v (ft³) — WQ_v = ____ ft³

   Designer to select value for Water Quality Volume for actual design

2. Type of Installation — ____ Porous Concrete; ____ Porous Asphalt

3. Porous Concrete or Asphalt Surface
   a) Porous Concrete Slab Thickness (5 inches minimum) — ____ in
   b) Porous Asphalt Surface Thickness — ____ in

4. Design Impervious Area to Porous Pavement Area Ratio (Max = 2) — Ratio = ____ (A_{IMP} / A_{POROUS})

5. Draining of porous pavement
   Answer questions 5a to 5d to determine design requirements

   Check "x" only one appropriate box based on following criteria
   a) Subgrade is a heavy or expansive clay
   b) Subgrade is a silty or clayey sand
   c) Subgrade is a well-draining soil
   Answer Yes (Y) or No (N) to the following question
   d) Does tributary drainage area have land uses with outdoor use or storage of chemicals or materials that could spill (e.g. a gas station, a hardware store, etc.)? "Y" or "N"

   ____ Design: Infiltration to subgrade with Woven geotextile fabric liner — 5c = x and 5d = N
   ____ Design: Underdrain with 16-mil. Impermeable fabric — 5a = x or 5d = Y
   ____ Design: Underdrain with Woven geotextile fabric — 5b = x and 5d = N
   ____ Other: ____

6. Base Course and Sub-Layer
   a) Gravel Base Course — ____ inches ____ ft
   b) Bottom sand filter layer required? ____
      Only required for installations with underdrains
      - if yellow box above says "yes", required. — ____ inches, 7" minimum
   c) Liners
      i) Woven geotextile fabric on top of base course
         - check "x" one, describe if "other" — ____ Woven Geotextile Fabric; ____ Other: ____
      ii) Liner under base course, between base course and sand filter layer
         - check "x" one, describe if "other" — ____ Woven Geotextile Fabric; ____ 16-mil. Impermeable Fabric Liner, required if checked; ____ Other: ____

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TC-62(d): 1. e)

1. Water Quality Volume (WQ_v)	a)	Sub-basin area		ft^2
		Sub-basin impervious area		ft^2
a) Percent of Watershed Impervious Area = I		**% Imperviousness**		
b) Drainage Area = A (acres) (43,560 ft^2 = 1 acre)	b)	A=		ac
c) Watershed Runoff Coefficient = R_v (unitless)	c)	R_v =		
d) 90th Percentile Precipitation Depth = 0.6 (inches)	e)	WQ_V =		ft^3
e) Water Quality Volume = WQ_v (ft^3)		WQ_V =	5,741	ft^3
	Designer to select value for Water Quality Volume for actual design			

e) Water Quality Volume (WQ_v):

- No max or min drainage area specified
- Will use TC-60 value of $5{,}741\ ft^3$ in this example

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TC-62(d): 2-4.

2. Type of Installation	[X] Porous Concrete [ ] Porous Asphalt
3. Porous Concrete or Asphalt Surface a) Porous Concrete Slab Thickness (5 inches minimum) b) Porous Asphalt Surface Thickness	 5 in in
4. Design Impervious Area to Porous Pavement Area Ratio (Max = 2)	Ratio = 2 (A_{IMP} / A_{POROUS})

2. Type of Installation: check porous concrete or porous asphalt
3. Porous Concrete or Asphalt Surface: specify thickness of surface chosen
   - Used minimum of 5 inches for concrete
4. Design Impervious Area to Porous Pavement Area Ratio: used max of 2 for example

TC-62(d): 5. a-d)

5. Draining of porous pavement
Answer questions 5a to 5d to determine design requirements

Check "x" only one appropriate box based on following criteria

a) Subgrade is a heavy or expansive clay	
b) Subgrade is a silty or clayey sand	X
c) Subgrade is a well-draining soil	
Answer Yes (Y) or No (N) to the following question	
d) Does tributary drainage area have land uses with outdoor use or storage of chemicals or materials that could spill (e.g. a gas station, a hardware store, etc.)? "Y" or "N"	N

	Design: Infiltration to subgrade with Woven geotextile fabric liner 5c = x and 5d = N
	Design: Underdrain with 16-mil. Impermeable fabric 5a = x or 5d = Y
X	Design: Underdrain with Woven geotextile fabric 5b = x and 5d = N
	Other:

a-c) Check the box that describes the subgrade (b was checked for this example)

d) If there is danger of chemical/material spills mark “Y”, if not mark “N” (N was used for this example)

- Then mark the appropriate yellow box on the right that is associated with your answers from a-d

TC-62(d): 6. a-c)

6. Base Course and Sub-Layer	
a) Gravel Base Course	8 inches 0.67 ft
b) Bottom sand filter layer required? X Only required for installations with underdrains - if yellow box above says "yes", **required**.	7 inches, 7"minimum
c) Liners i) Woven geotextile fabric on top of base course - check "x" one, desscibe if "other"	X Woven Geotextile Fabric Other:
ii) Liner under base course, between base course and sand filter layer - check "x" one, descibe if "other"	X Woven Geotextile Fabric 16-mil. Impermeable Fabric Liner, **required** if checked Other:

a) Gravel Base Course: no min specified so assumed 8 inches was appropriate

b) Bottom Sand Filter Layer Required: the design resulting from section 5 included an underdrain so it is required

c) Liners: Woven Geotextile Fabric was chosen based on the design resulting from section 5

TC-62(d): 7. a-c)

7. Contained Cells	
a) Type (check "x" one)	[ ] 16-mil. (min.) Impermeable Liner [X] Concrete Wall
b) Slope of the base course	S_O = 0.01 ft/ft
c) Distance between cutoffs (normal to flow, L)	L = 40 ft L_{MAX} = 44.7 ft
Notes & Additional Information:	

a) Type: checked Concrete Wall for example

b) Slope of Base Course: used 0.01 for example

- TMSCDLIDM states not to install pavers on slopes greater than 5%

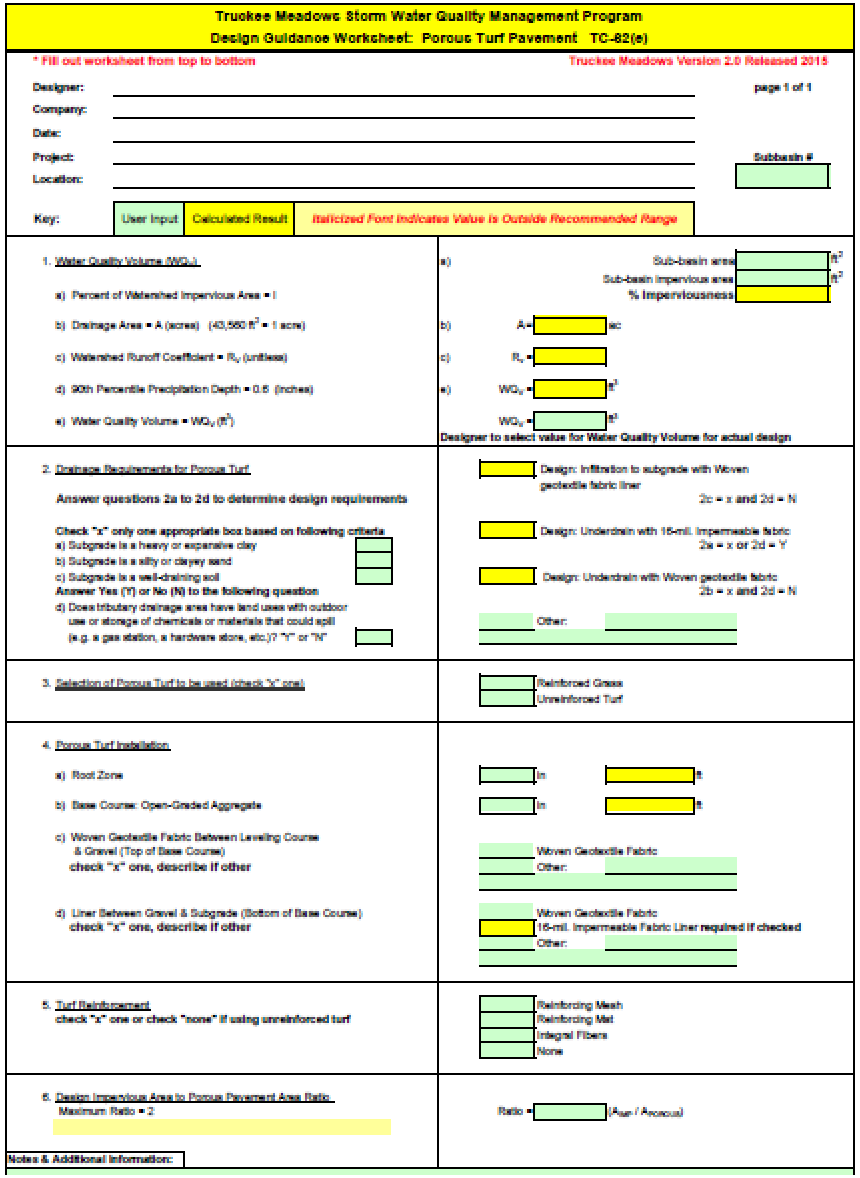
c) Distance Between Cutoffs

$$L_{max} = \frac{D}{1.5 \times S_0} = \frac{0.67\ \text{ft}}{1.5 \times 0.01} = 44.7\ \text{ft}$$

- L of 40 ft chosen with a L_{max} of 44.7 ft

TC-62(e)

1. Water Quality Volume
2. Drainage Requirements for Porous Turf
3. Section of Porous Turf to be Used
4. Porous Turf Installation
5. Turf Reinforcement
6. Design Impervious Area to Porous Pavement Area Ratio



Truckee Meadows Storm Water Quality Management Program
Design Guidance Worksheet: Porous Turf Pavement TC-62(e)

* Fill out worksheet from top to bottom — Truckee Meadows Version 2.0 Released 2015

Designer: ______ page 1 of 1
Company: ______
Date: ______
Project: ______ Subbasin #
Location: ______

Key: User Input | Calculated Result | *Italicized Font Indicates Value is Outside Recommended Range*

1. Water Quality Volume (WQ_V)
   a) Percent of Watershed Impervious Area = I — a) Sub-basin area ft²; Sub-basin impervious area ft²; % Imperviousness
   b) Drainage Area = A (acres) (43,560 ft² = 1 acre) — b) A= ac
   c) Watershed Runoff Coefficient = R_v (unitless) — c) R_v =
   d) 90th Percentile Precipitation Depth = 0.6 (inches) — e) WQ_v = ft³
   e) Water Quality Volume = WQ_v (ft³) — WQ_v = ft³
   Designer to select value for Water Quality Volume for actual design

2. Drainage Requirements for Porous Turf
   Answer questions 2a to 2d to determine design requirements
   Check "x" only one appropriate box based on following criteria
   a) Subgrade is a heavy or expansive clay
   b) Subgrade is a silty or clayey sand
   c) Subgrade is a well-draining soil
   Answer Yes (Y) or No (N) to the following question
   d) Does tributary drainage area have land uses with outdoor use or storage of chemicals or materials that could spill (e.g. a gas station, a hardware store, etc.)? "Y" or "N"
   - Design: Infiltration to subgrade with Woven geotextile fabric liner — 2c = x and 2d = N
   - Design: Underdrain with 16-mil. Impermeable fabric — 2a = x or 2d = Y
   - Design: Underdrain with Woven geotextile fabric — 2b = x and 2d = N
   - Other:

3. Selection of Porous Turf to be used (check "x" one)
   - Reinforced Grass
   - Unreinforced Turf

4. Porous Turf Installation
   a) Root Zone — in — ft
   b) Base Course: Open-Graded Aggregate — in — ft
   c) Woven Geotextile Fabric Between Leveling Course & Gravel (Top of Base Course) check "x" one, describe if other
   - Woven Geotextile Fabric
   - Other:
   d) Liner Between Gravel & Subgrade (Bottom of Base Course) check "x" one, describe if other
   - Woven Geotextile Fabric
   - 16-mil. Impermeable Fabric Liner required if checked
   - Other:

5. Turf Reinforcement
   check "x" one or check "none" if using unreinforced turf
   - Reinforcing Mesh
   - Reinforcing Mat
   - Integral Fibers
   - None

6. Design Impervious Area to Porous Pavement Area Ratio
   Maximum Ratio = 2
   Ratio = (A_{imp} / A_{porous})

Notes & Additional Information:

TC-62(e): 1. e)

1. Water Quality Volume (WQ_V)	a) Sub-basin area		ft^2
	Sub-basin impervious area		ft^2
a) Percent of Watershed Impervious Area = I	% Imperviousness		
b) Drainage Area = A (acres) (43,560 ft^2 = 1 acre)	b) A=		ac
c) Watershed Runoff Coefficient = R_V (unitless)	c) R_v =		
d) 90th Percentile Precipitation Depth = 0.6 (inches)	e) WQ_V =		ft^3
e) Water Quality Volume = WQ_V (ft^3)	WQ_V =	5,741	ft^3
	Designer to select value for Water Quality Volume for actual design		

e) Water Quality Volume (WQ_v):

- No max or min drainage area specified
- Will use TC-60 value of $5{,}741\ ft^3$ in this example

TC-62(e): 2. a-d)

2. Drainage Requirements for Porous Turf

Answer questions 2a to 2d to determine design requirements

Check "x" only one appropriate box based on following criteria

a) Subgrade is a heavy or expansive clay	X
b) Subgrade is a silty or clayey sand	
c) Subgrade is a well-draining soil	

Answer Yes (Y) or No (N) to the following question

d) Does tributary drainage area have land uses with outdoor use or storage of chemicals or materials that could spill (e.g. a gas station, a hardware store, etc.)? "Y" or "N"	N

	Design: Infiltration to subgrade with Woven geotextile fabric liner 2c = x and 2d = N
X	Design: Underdrain with 16-mil. Impermeable fabric 2a = x or 2d = Y
	Design: Underdrain with Woven geotextile fabric 2b = x and 2d = N
	Other:

a-c) Check the box that describes the subgrade (a was checked for this example)

d) If there is danger of chemical/material spills mark “Y”, if not mark “N” (N was used for this example)

- Then mark the appropriate yellow box on the right that is associated with your answers from a-d

TC-62(e): 3.

3. Selection of Porous Turf to be used (check "x" one)		Reinforced Grass
	X	Unreinforced Turf

- Check either reinforced grass or unreinforced turf
- Unreinforced turf checked in this example

TC-62(e): 4. a-d)

4. Porous Turf Installation				
a) Root Zone	12	in	1	ft
b) Base Course: Open-Graded Aggregate	8	in	0.67	ft
c) Woven Geotextile Fabric Between Leveling Course & Gravel (Top of Base Course) **check "x" one, describe if other**	X	Woven Geotextile Fabric		
		Other:		
d) Liner Between Gravel & Subgrade (Bottom of Base Course) **check "x" one, describe if other**		Woven Geotextile Fabric		
	X	16-mil. Impermeable Fabric Liner required if checked		
		Other:		

a) Root Zone: TMSCDLIDM states the sandy root zone should be 12 inches thick

b) Base Course: No minimum stated, assumed 8 inches was appropriate

c) Woven Geotextile Fabric Between Leveling Course & Gravel: Woven Geotextile Fabric was checked for this example, if something else is used check other and describe

d) Liner between Gravel & Subgrade: 16-mil. Impermeable Fabric Liner was chosen based on design results from section 2

TC-62(e): 5-6.

5. Turf Reinforcement check "x" one or check "none" if using unreinforced turf	[ ] Reinforcing Mesh [ ] Reinforcing Mat [ ] Integral Fibers [X] None
6. Design Impervious Area to Porous Pavement Area Ratio Maximum Ratio = 2	Ratio = 2 (A_{IMP} / A_{POROUS})
Notes & Additional Information:	

5. Turf Reinforcement: selected none because unreinforced turf was selected in section 3
6. Design Impervious Area to Porous Pavement Area Ratio: used max of 2 for this example

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TC-62(f)

1. Water Quality Volume
2. Porous Gravel Course
3. Draining of Porous Gravel Pavement
4. Base Course and Sub-Layer
5. Design Impervious Area to Porous Pavement Area Ratio
6. Contained Cells

Truckee Meadows Storm Water Quality Management Program
Design Guidance Worksheet: Porous Gravel Pavement TC-62(f)

* Fill out worksheet from top to bottom — Truckee Meadows Version 2.0 Released 2015

page 1 of 2

Designer:
Company:
Date:
Project:
Location:

Subbasin #

Key: User Input | Calculated Result | *Italicized Font Indicates Value is Outside Recommended Range*

1. Water Quality Volume (WQ_V)
   - a) Percent of Watershed Impervious Area = I — a) Sub-basin area (ft^2); Sub-basin impervious area (ft^2); % Imperviousness
   - b) Drainage Area = A (acres) (43,560 ft^2 = 1 acre) — b) A = ac
   - c) Watershed Runoff Coefficient = R_V (unitless) — c) R_V =
   - d) 90th Percentile Precipitation Depth = 0.6 (inches) — e) WQ_V = ft^3
   - e) Water Quality Volume = WQ_V (ft^3) — WQ_V = ft^3

   Designer to select value for Water Quality Volume for actual design

2. Porous Gravel Course
   Depth of gravel base course (D) — D = inches; ft

3. Draining of porous gravel pavement

   Answer questions 3a to 3d to determine design requirements
   Check "x" only one appropriate box based on following criteria
   - a) Subgrade is a heavy or expansive clay
   - b) Subgrade is a silty or clayey sand
   - c) Subgrade is a well-draining soil

   Answer Yes (Y) or No (N) to the following question
   - d) Does tributary drainage area have land uses with outdoor use or storage of chemicals or materials that could spill (e.g. a gas station, a hardware store, etc.)? "Y" or "N"

   Design: Infiltration to subgrade with Woven geotextile fabric liner — 3c = x and 3d = N
   Design: Underdrain with 16-mil. Impermeable fabric — 3a = x or 3d = Y
   Design: Underdrain with Woven geotextile fabric — 3b = x and 3d = N
   Other:

4. Base Course and Sub-Layer
   - a) Bottom sand filterlayer required? — in (4" minimum); Other:
     Only required for installations over expansive soils and with underdrains
   - b) Liners
     - i) With underdrain system:
       (check "x" one, describe if "other")
       - Liner to be installed on top of and below sand filter layer — Woven Geotextile Fabric; Other:
       - Liner to be installed under base course and below underdrain trench if checked "x" to prohibit infiltration — 16-mil. Impermeable Fabric Liner required under base course with underdrain system
     - ii) Without Underdrain System
       (check "x" one, describe if "other") — Woven Geotextile Fabric; Other:

5. Design Impervious Area to Porous Pavement Area Ratio (Max. = 2) — Ratio = (A_{IMP} / A_{POROUS})

TC-62(f): 1. e)

1. Water Quality Volume (WQ_V)	a) Sub-basin area [ ] ft^2; Sub-basin impervious area [ ] ft^2; **% Imperviousness** [ ]
a) Percent of Watershed Impervious Area = I	
b) Drainage Area = A (acres) (43,560 ft^2 = 1 acre)	b) A= [ ] ac
c) Watershed Runoff Coefficient = R_v (unitless)	c) R_v = [ ]
d) 90th Percentile Precipitation Depth = 0.6 (inches)	
e) Water Quality Volume = WQ_V (ft^3)	e) WQ_V = [ ] ft^3; WQ_V = 5,741 ft^3
	Designer to select value for Water Quality Volume for actual design

e) Water Quality Volume (WQ_v):

- No max or min drainage area specified
- Will use TC-60 value of $5{,}741\ ft^3$ in this example

Cardno®

TC-62(f): 2.

2. Porous Gravel Course Depth of gravel base course (D)	D = 8 inches 0.67 ft

2. Depth of Gravel Base Course (D):
   - No max or min depth specified
   - Assumed 8 inches was appropriate for this example

TC-62(f): 3. a-d)

3. Draining of porous gravel pavement

Answer questions 3a to 3d to determine design requirements

Check "x" only one appropriate box based on following criteria

a) Subgrade is a heavy or expansive clay	
b) Subgrade is a silty or clayey sand	
c) Subgrade is a well-draining soil	X

Answer Yes (Y) or No (N) to the following question

d) Does tributary drainage area have land uses with outdoor use or storage of chemicals or materials that could spill (e.g. a gas station, a hardware store, etc.)? "Y" or "N"	N

X	Design: Infiltration to subgrade with Woven geotextile fabric liner 3c = x **and** 3d = N
	Design: Underdrain with 16-mil. Impermeable fabric 3a = x **or** 3d = Y
	Design: Underdrain with Woven geotextile fabric 3b = x **and** 3d = N
	Other:

a-c) Check the box that describes the subgrade (c was checked for this example)

d) If there is danger of chemical/material spills mark “Y”, if not mark “N” (N was used for this example)

- Then mark the appropriate yellow box on the right that is associated with your answers from a-d

TC-62(f): 4. a-b)

4. Base Course and Sub-Layer	
a) Bottom sand filterlayer required? Only required for installations over expansive soils and with underdrains	in (4" minimum) Other:
b) Liners	
i) With underdrain system: (check "x" one, describe if "other") - Liner to be installed on top of and below sand filter layer	Woven Geotextile Fabric Other:
- Liner to be installed under base course and below underdrain trench if checked "x" to prohibit infiltration	16-mil. Impermeable Fabric Liner required under base course with underdrain system
ii) Without Underdrain System (check "x" one, describe if "other")	X Woven Geotextile Fabric Other:

a) Bottom Sand Filter Layer Required: not required because the design resulting from section 3 was not over expansive soils and doesn't require an underdrain

b) Liners:

i. With Underdrain System: No underdrain system so this section wasn't used

ii. Without Underdrain System: Woven Geotextile Fabric chosen to match the design resulting from section 3

TC-62(f): 5.

5. Design Impervious Area to Porous Pavement Area Ratio (Max. = 2)	Ratio = 2 (A_{IMP} / A_{POROUS})

5. Design Impervious Area to Porous Pavement Area Ratio: used max of 2 for this example

TC-62(f): 6. a-c)

6. Contained Cells

a) Type (check "x" one)

	16-mil. (min.) Impermeable Liner
X	Concrete Wall

b) Slope of the base course — S_O = 0.01 ft/ft

c) Distance between cutoffs (normal to flow, L) — L = 40 ft, L_{MAX} = 44.7 ft

Notes & Additional Information:

a) Type: checked Concrete Wall for example

b) Slope of Base Course: used 0.01 for example

- TMSCDLIDM states not to install pavers on slopes greater than 5%

c) Distance Between Cutoffs

$$L_{max} = \frac{D}{1.5 \times S_0} = \frac{0.67 \text{ ft}}{1.5 \times 0.01} = 44.7 \text{ ft}$$

- L of 40 ft chosen with a L_{max} of 44.7 ft

TC-62(g)

1. Water Quality Volume
2. Open-Celled Plastic Grid Properties
3. Fill Material
4. Reinforced Grass Pavement
5. Drainage Requirements for Open-Celled Plastic Grids

Truckee Meadows Storm Water Quality Management Program
Design Guidance Worksheet: Open-Celled Plastic Grids TC-62(g)

* Fill out worksheet from top to bottom — Truckee Meadows Version 2.0 Released 2015

Designer: — page 1 of 1
Company:
Date:
Project: — Subbasin #
Location:

Key: User Input | Calculated Result | *Italicized Font Indicates Value is Outside Recommended Range*

1. Water Quality Volume (WQ_V)	a) Sub-basin area ___ ft^2; Sub-basin impervious area ___ ft^2; % Imperviousness ___
a) Percent of Watershed Impervious Area = I	
b) Drainage Area = A (acres) (43,560 ft^2 = 1 acre)	b) A= ___ ac
c) Watershed Runoff Coefficient = R_V (unitless)	c) R_v = ___
d) 90th Percentile Precipitation Depth = 0.6 (inches)	e) WQ_V = ___ ft^3
e) Water Quality Volume = WQ_V (ft^3)	WQ_V = ___ ft^3 Designer to select value for Water Quality Volume for actual design
2. Open-Celled Plastic Grid Properties:	Model: ___ Manufacturer: ___ Min. Open Surface Area = ___ % Grid Thickness = ___ in
3. Fill Material (Check "x" the type or describe "Other")	___ Open-Graded Aggregate ___ Turf ___ Other: ___
4. Reinforced Grass Pavement	
a) Setting Layer for Open-Celled Plastic Grid	___ in ___ ft
b) Base Course	___ in ___ ft
c) Liner Between Base Course and Subgrade (Bottom of Base Course) - check "x" one, describe if "other"	___ Woven Geotextile Fabric ___ 16-mil. Impermeable Fabric Liner required (from #5) ___ Other: ___
5. Drainage Requirements for Open-Celled Plastic Grids	___ Design: Infiltration to subgrade with Woven geotextile fabric liner 5c = x and 5d = N
Answer questions 5a to 5d to determine design requirements **Check "x" only one appropriate box based on following criteria** a) Subgrade is a heavy or expansive clay ___ b) Subgrade is a silty or clayey sand x c) Subgrade is a well-draining soil ___	___ Design: Underdrain with 16-mil. Impermeable fabric 5a = x or 5d = Y
Answer Yes (Y) or No (N) to the following question d) Does tributary drainage area have land uses with outdoor use or storage of chemicals or materials that could spill (e.g. a gas station, a hardware store, etc.)? "Y" or "N" n	x Design: Underdrain with Woven geotextile fabric 5b = x and 5d = N ___ Other: ___
Notes & Additional Information:	

TC-62(g): 1. e)

1. Water Quality Volume (WQ_V)	a)	Sub-basin area		ft^2
		Sub-basin impervious area		ft^2
a) Percent of Watershed Impervious Area = I		**% Imperviousness**		
b) Drainage Area = A (acres) (43,560 ft^2 = 1 acre)	b)	A=		ac
c) Watershed Runoff Coefficient = R_V (unitless)	c)	R_v =		
d) 90th Percentile Precipitation Depth = 0.6 (inches)	e)	WQ_V =		ft^3
e) Water Quality Volume = WQ_V (ft^3)		WQ_V =	5,741	ft^3
	Designer to select value for Water Quality Volume for actual design			

e) Water Quality Volume (WQ_v):

- No max or min drainage area specified
- Will use TC-60 value of $5{,}741\ ft^3$ in this example

TC-62(g): 2-3.

2. Open-Celled Plastic Grid Properties:	Model: Manufacturer: Min. Open Surface Area = 40 % Grid Thickness = 2 in
3. Fill Material (Check "x" the type or describe "Other")	X Open-Graded Aggregate Turf Other:

2. Open-Celled Plastic Grid Properties:
   - State model and manufacturer
   - Min. Open Surface Area: use 40% for example
   - Block thickness: use 2 in for example
3. Fill Material: checked Open-Graded Aggregate for example, if something else is used check Turf or Other and describe

TC-62(g): 4.

4. Reinforced Grass Pavement

a) Setting Layer for Open-Celled Plastic Grid	2	in		ft
b) Base Course	8	in		ft
c) Liner Between Base Course and Subgrade (Bottom of Base Course) - check "x" one, describe if "other"	X	Woven Geotextile Fabric		
		16-mil. Impermeable Fabric Liner **required** (from #5)		
		Other:		

a) Setting Layer for Open-Celled Plastic Grid: no min or max stated, 2 inches was used for example

b) Base Course: no min or max stated, 8 inches was used for example

c) Liner Between Base Course and Subgrade: Woven Geotextile Fabric was checked to match the resulting design from section 5

TC-62(g): 5.

5. Drainage Requirements for Open-Celled Plastic Grids

Answer questions 5a to 5d to determine design requirements

Check "x" only one appropriate box based on following criteria

a) Subgrade is a heavy or expansive clay	
b) Subgrade is a silty or clayey sand	x
c) Subgrade is a well-draining soil	

Answer Yes (Y) or No (N) to the following question

d) Does tributary drainage area have land uses with outdoor use or storage of chemicals or materials that could spill (e.g. a gas station, a hardware store, etc.)? "Y" or "N"	n

	Design: Infiltration to subgrade with Woven geotextile fabric liner 5c = x **and** 5d = N
	Design: Underdrain with 16-mil. Impermeable fabric 5a = x **or** 5d = Y
x	**Design: Underdrain with Woven geotextile fabric** 5b = x **and** 5d = N
	Other:

Notes & Additional Information:

This section was already filled out in the TMSCDLIDM

a-c) Check the box that describes the subgrade (b was checked)

d) If there is danger of chemical/material spills mark "Y", if not mark "N" (N was used)

- Then mark the appropriate yellow box on the right that is associated with your answers from a-d

Treatment controls: Local Examples

Mt. Rose Highway, Proprietary StormFilter and Vortechnics

Source: Cardno (2020).

Treatment controls: Local Examples

> Placeholder to highlight additional local examples brought forward by the City or SWPCC

Questions?

CEUs / PDHs

> Placeholder

EXTRA SLIDES

Manufactured (Proprietary) Treatment Controls

- MTC are commercially available stormwater treatment devices that are designed and distributed by private companies
- Prefabricated and available in various sizes based on flow rate or volume to be treated
- **Note that these are often designed and sized based on pre-determined criteria that may differ from local municipalities**
  - Recall the importance of sizing based on the WQf or WQv
  - Determine whether these can replace the public domain treatment controls
- Useful in situations where space is limited, such as in urban settings, or retrofit developments

Manufactured (Proprietary) Treatment Controls

- **Hydrodynamic Separators (MTC-10)**
  - Round gravity separators designed to remove trash, debris and non-dissolved pollutants from urban runoff using energy from stormwater flow to operate centrifuge
- **Wet Vaults (MTC-20)**
  - Subterranean structures designed to dissipate the energy of stormater runoff with baffles and chambers and promote the settling of pollutants
- **Catch Basin Inserts (MTC-30)**
  - Filters placed in drop inlets to help remove sediment and debris from stormwater runoff

Manufactured (Proprietary) Treatment Controls

> **Modular Wetlands (MTC-40)**
  - Wetlands that provide water quality treatment through routing of subsurface flows of stormwater through gravel and wetland vegetation root systems

> **Media Filtration Systems (MTC-50)**
  - Subsurface BMPs with a settling basin to remove large particles and floatables, and a sand filter/absorptive filter basin to remove finer grained particles and other particulates

> **Landscape Filtration Systems (MTC-60)**
  - Subsurface structures that filter stormwater runoff and use that water to irrigate turf or landscaped vegetation, or store water for future use

Refer to Manual Section 6 for further details on these proprietary treatment controls