HOWARD STEIN HUDSON
Engineers + Planners

SUPPLEMENTAL DATA REPORT

Sheldon West

1139 West Street and
20 Hancock Street

Wrentham, Massachusetts

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Existing Conditions

The subject site for the Sheldon West Development exists as the western portion of property located at 1139 West Street and 20 Hancock Street, Wrentham, MA. The subject site is considered a single lot in common ownership, however for the purposes of the Sheldon West Development, this report will focus on a new 20-acre lot that will be created from a portion of 1139 West Street and a portion of 20 Hancock Street. This new lot will utilize frontage from West Street.

The property is located in the R-87 Agricultural and Residential Zoning District. The parcel remains undeveloped as an open field with a large wetland system to the rear, as well as a perennial stream to the east.

The parcel contains a mixture of open grassed field, woodlands, and wetland. Throughout the field portion of the site, the topography is fairly flat, generally sloping from north to south. Where the site maintains frontage along West Street, the site climbs approximately 10' in elevation to the road from the field. The open grassed field represents approximately 7.5 acres of upland.

The existing parcel entirely drains to a single analysis point, the wetland system surrounding the south, east, and west sides of the property.

Soil conditions on site are being characterized as A soils. Soil testing and hydrogeological testing has been performed and has confirmed this soil type and an infiltration rate of 8.27 in/hr. Please see Appendix H for the Hydrogeologist memo regarding the onsite testing and results.

While the site has no active utility connections, electric and water connections are available via the West Street Right of Way.

Proposed Conditions

The Sheldon West Development proposes to construct 9 single family homes within a Senior Living Community. An exterior walking loop is being provided to add to the existing wooded trails that navigate through the wooded, natural areas.

The homes within the community have been designed as a cluster around a common open space, with the road looping around the exterior of the cluster. This allows the creation of an interior common open space including a walkway which interconnects each unit, as well as open green space available for recreation use. A shared, covered pavilion structure is proposed in the open space to be used as a passive and active gathering area for the residents. Both clusters feature entrances on the courtyard side of the units which enter the interconnected walkways. This allows direct connections from each unit to the communal spaces in the center of the development.

The roadway has been designed at 22' wide, per the SLC design standards, and totals approximately 1,366 LF in length. The exterior of the road is proposed to be curbed, while the interior of the road is proposed as a 10' pervious parking shoulder. This will reduce the amount of runoff while also providing additional residential and guest parking for the community.

Electric, cable, and communications service as well as water service will be provided through the available connections within West Street. Sewer will be serviced through an on-site community septic system. The septic system is proposed to be located beneath the centralized green space within the loop.

The proposed stormwater management utilizes treatment best management practices (BMP's), street sweeping, proprietary inlet structures, grassed swales, as well as an infiltration basin on the east side of the entry drive. The main entry drive is proposed to be superelevated towards the east, where the stormwater will enter a curb cut, be pre-treated, and flow to the infiltration basin. The loop will be superelevated towards the outside of the road, enter one of two grassed swales series through several curb cuts. Each curb cut contains a proprietary treatment BMP prior to entering the swale. The swales will carry the stormwater to where they will exit the swales and enter the infiltration basin. As part of the pretreatment the roads will also be swept twice a year, in the spring and fall.

Using these series of treatment BMP's, street sweeping, swales, and the infiltration basin, the stormwater management system is designed to capture, treat, and infiltrate stormwater as required by the Massachusetts Stormwater Standards, as well as the local Wrentham Board of Health Stormwater Regulations. The proposed road is superelevated to direct stormwater to the exterior of the road where it enters grassed swales through treatment BMPs. The swales move the stormwater to the infiltration basin in the north east of the site. See the hydrology section of this report for further detail and information.

Zoning

The proposed parcel will remain within the R-87 Agricultural and Residential Zoning District. Within this district, a Senior Living Community (SLC) is approvable via a Site Plan and Special Permit Application to the Planning Board. This section with demonstrate compliance with appropriate dimensional requirements and special permit criteria as it relates to Section 13.5 (Senior Living Community) of the Wrentham Zoning Bylaws.

Dimensional Requirements

While the parcel exists within the R-87 Agricultural and Residential Zoning District, the SLC Special Permit allows adjusted dimensional requirements from the R-87 Agricultural and Residential Zoning District.

1139 West Street, Wrentham, MA
R-87 Agricultural and Residential
Proposed Use: Senior Living Community

Dimensional Requirements (R-87 Agricultural and Residential) (SLC)	Required	Proposed
Lot Area (SLC)	871,200 SF (20 AC)	888,602 SF (20.4 AC)
Developable Site Area	-	243,855 sf
Continuous Lot Frontage (SLC)	100' min.	253'±
Minimum Front Yard (SLC)	30' min.	308'±
Minimum Side Yard (SLC)	30' min.	68'±
Minimum Rear Yard (SLC)	30' min.	1,486'±
Maximum Building Coverage (SLC)	35% max.	2.2%
Minimum Open Space (SLC)	30% min.	36%
Impervious Area (On-Site)	-	77,929 sf
Impervious/Total Area (On-site)	-	0.076
Maximum Stories (SLC)	2 max.	2
Maximum Building Height (SLC)	28' max.	23'-8"
Maximum Density (SLC)	4 Units/AC	0.45 Units/AC
Minimum Distance Between (SLC)	15'	15'

Parking Requirements	Required	Proposed
Number of Parking Spaces	23 Spaces	18 Garage Spaces + 11 Exterior 24 Shared/Guest Spaces 53 Total Spaces

OPEN SPACE CALCULATION

Total Site Area = 888,602 SF

Total Wetland Area = 524,432 SF

Total Non-Usable Space = 80,533 SF

Required Open Space = (0.30) * 888,602 SF = 266,581 SF*

**Per the requirements of the SLC, not more than 25% of the required common open space may be wetland.'*

Allowable Wetland Area = (0.25) * 266,581 SF = 66,646 SF

Upland Open Space = 888,602 SF – (524,432 SF + 80,533 SF) = 283,637 SF

Total Open Space = 266,581 + 66,646 = 321,968 SF

Open Space % = 321,968 SF / 888,602 SF = 36%

Senior Living Community – Special Permit Criteria

Per Wrentham Bylaws Section 13.5.4 – Basic Requirements

A. A Senior Living Community Shall Comply with the following density regulations: 4 Units/Acre.

As shown within the Zoning Table, the Sheldon West project has an overall density of 0.45 Units/Acre.

B. Maximum building coverage shall not exceed thirty-five percent (35%) of the lot area for new construction or expansion of existing structures.

The proposed building coverage on site totals 2.6%.

C. For single family, cottage dwellings, duplexes or triplex style dwellings, the minimum setback shall be thirty feet (30') from all property lines in the Residential Districts, unless the Planning Board determines that a reduced setback is necessary to achieve the purposes of this section and will not have a detrimental impact on the neighborhood.

All units on site are proposed as single family. All proposed buildings remain at least thirty feet from all property lines. The closest unit is 68' from a property line, more than double the requirement.

D. No dwelling unit in a SLC shall have more than two bedrooms.

No dwelling unit is proposed to have more than two (2) bedrooms, see architectural plans containing within the submittal for floor plans.

E. The minimum distance between buildings in any SLC shall be fifteen feet (15').

The minimum distance between buildings proposed on site is more than 15', the lowest being 15.5'. Many of the buildings maintain approximately 20' or more of separation.

F. The minimum common open space in the development shall be thirty percent (30%) of the lot area and not more than twenty-five percent (25%) of the required minimum common open space shall consist of wetlands (as defined in MGL c.131, s40). The upland open space shall be contiguous and usable by residents of the development. A permanent Conversation Restriction running to or enforceable by the Town shall be recorded for the common open space area and shall include restrictions that the land be retained in perpetuity for conservation or passive recreation.

The total open space is 36%, which is greater than the 30% requirement. For the breakdown of this calculation please see Dimensional Requirements section of this report or on the cover sheet of the Plan set.

G. All SLC dwelling units shall be subject to an age restriction described in a deed, deed rider, restrictive covenant, or other document approved by the Planning Board that shall be recorded at the Registry of Deeds and/or Land Court. The age restriction shall limit occupancy of dwelling units to at least one individual age fifty-five (55) or over ad their spouse/partner and may provide for time-limited guest visitation rights of not more than one (1) month per year. The restriction, if the Planning Board so approved and specifies in the special permit, may authorize special exceptions that allow persons of all ages to live in a dwelling unit together with a senior resident for purposes such as care of a senior in ill health or enabling seniors to fulfill legal responsibilities of guardianship or custody. The special permit including age restriction shall run with the land in perpetuity and shall be enforceable by the Town and/or any owner(s) of the SLC dwelling units. In the event of the death of a qualifying owner or occupant(s) of a dwelling unit, or foreclosure or other involuntary transfer of a unit within the SLC, a one-year exemption to the restriction shall be allowed for the transfer of the unit to another eligible occupant.

This requirement is understood and agreeable to the applicant.

H. Minimum off-street parking requirements shall comply with Article 6.4, except as modified by the following standards:

   a. Single Family or Cottage style dwellings: two (2) spaces per unit

   b. Guest parking: one (1) space per two (2) units or three (3) beds, as applicable.

Per these requirements, the project is subject to the requirement of 23 parking spaces. The project proposes a total of 18 garage spaces, 11 exterior unit spaces (driveways and parking pads) and 24 surface spaces for a total of 53 proposed parking spaces on site, more than double the required parking per the SLC.

I. All streets within a SLC shall be private, and all sewerage, drainage facilities and utilities shall be designed and constructed in compliance with the Town of Wrentham Subdivision Rules and Regulations, except as modified by the following standards:

a. The minimum width of paved roadways shall be twenty-two feet (22').

b. There shall be a five-foot (5') sidewalk installed along one side of the roadway.

The roadway within the proposed SLC is shown at 22' wide, with an additional 10' wide pervious paver shoulder and a 6' sidewalk along the exterior loop of the roadway with direct connection to the intersection of West Street.

J. A SLC may have one (1) free standing sign at each principal access to the development from a public way, indicating the name and/or street address of the SLC. Such sign shall not exceed twelve (12) square feet in area per side or four (4') feet in height. The provisions of Article 18 shall also apply to signage within the SLC.

Signage has not been proposed at this time. Proposed signage will be designed and addressed at a later date further along in the permitting process and will meet the requirements of the SLC.

K. A SLC shall have an amenity structure designed to allow for a variety of passive and active recreational activities that support the residents of the SLC. Such uses that may be considered are community program spaces, fitness/therapeutic space, educational, recreational and accessory space; areas for neighborhood meetings and event space; and any other amenities and opportunities that are intended to create and promote an integrated neighborhood type environment.

A community shared pavilion structure has been provided within the common green area on the interior of the proposed units. The shared pavilion will be a three-season roofed, open-air structure with a level floor surface, and can be enclosed with winterized curtains and heated in the winter if it is the interest of the residents. This amenity structure can be used for passive and active recreational activities that support the resident of the SLC. This space can be used for community program space, fitness spaces, educational, recreational, neighborhood meetings, and events. The common green area can also be utilized for a number of different activities and includes an interconnected walking loop to each unit, as well an open green space to be utilized as desired by the residents. The project is also serviced by a 6' wide meandering sidewalk with benches placed intermittently at the outside of the project allowing a longer, uninterrupted loop at the edge of the wetland and forested areas for the use of the residents.

Per Wrentham Bylaws Section 13.5.8 – Development Standards

As part of the Planning Board's special permit review process, the Board shall evaluate the proposed Senior Living Community (SLC) for conformance to the following minimum design standards.

A. Architectural planning and design shall incorporate energy efficient design techniques, such as natural heating and cooling systems, use of sun and wind energy generation systems, and so forth.

   The architectural design of the single-family homes of the development will incorporate solar panel ready roof design for future installation of solar panels by unit owners. Also, all habitable rooms will have operable double hung window to take advantage of natural cooling/ventilation at the unit owners' discretion. The building envelope will be high efficiency so that mechanical system design loads can be reduced and be more energy efficient. The mechanical heating and cooling systems will be high efficiency electric heat pump split systems in conjunction with electric high efficiency water heaters.

   Also, exterior bollard style pedestrian lighting for the interior green space is a solar charged light fixture.

B. Structures located near the project property lines shall be designed and located in a manner that reflects consistency and compatibility with neighboring areas, and shall include appropriate use of building density, heights, and design to minimize intrusion on neighbors.

   Though the structures are not near the property lines due to the nature of the development, the new homes being constructed could possibly be seen by adjacent abutting properties, so attention has been given to the design of the new homes. All the new homes are over 50' from adjacent property lines. The new homes being built are consistent with the existing neighborhood in building footprint as well as in building height. The design of the roof lines is consistent with the surrounding neighborhood incorporating a main gable roof, gable and shed dormers, asphalt shingle roofs, horizontal lap and shake siding and double hung windows. Options are provided to allow for diversity within the development and provide visual interest. Providing (3) garage door styles and (3) exterior siding color options also provide further design diversity within the development. Most importantly, the development is treating the new homes as having (2) front elevations – one front elevation facing the ring road and the adjacent abutters as well as one front elevation facing inward to the "village green". The architectural design will not detract from the current feel of the surrounding neighborhood as this development enhances, reflects and is consistent with the surrounding existing neighborhood.

C. Outdoor recreation or gathering areas, particularly those that may generate significant noise and/or light and glare, shall be located to minimize intrusion on neighboring properties.

The outdoor gathering area is located away from all property lines within the center of all the units, proposed as a "village green". All noise, light, or glare generated from this area will be shielded by the proposed structures. There is also a meandering perimeter sidewalk along the exterior of the road of the development that allows for pedestrian walking without having to cross individual home driveways making for an uninterrupted walk with benches placed intermittently along the path. This increases the safety of pedestrians walking in and around the development. Lighting is provided along the road that are full cut off light fixtures so that there will not be any light spillage or glare onto adjacent abutting properties. These measures minimize any intrusion on neighboring properties.

D. Structures shall be clustered to reduce site disturbance and protect open spaces, natural and environmentally sensitive areas.

The proposed new homes are clustered around an internal "village green" common area to minimize site disturbance and protect open spaces on the site. The site plan and building placement respects natural land features and environmentally sensitive areas of the site. The closest building to the river, wetland, and vernal pool is 298', 135' and 150' respectively. The project is fully outside the 100' vernal pool offset and fully outside the 200' riparian area. Only small portions of the site are being disturbed within the 100' wetland buffer. The project is being proposed within the existing open field to minimize tree clearing.

E. Site design shall limit large grass areas and provide adequate access to shared amenities.

The site has been designed utilizing interior sidewalks within the formal greenspace and an exterior walking loop to interconnect and create universal accessibility to all areas on site. Large grass areas are avoided, and the natural environment is celebrated by clustering the project and limiting the land disturbance to allow for existing natural areas to be preserved by this development.

F. Building design shall avoid use of long unbroken facades, and shall include use of balconies, offset wall, trellises and other design elements to provide visual interest.

The structures have been designed with several gable options to break up facades on both the exterior facing and interior faces of the structure. The building dimensions are consistent with small New England style single family homes. Patios and porches have also been incorporated into the design to provide visual interest to the exterior of the building.

G. Building design, colors and materials shall generally correspond to the natural setting of the project site and promote the appearance of the Town's New England character.

The buildings have been designed with the New England aesthetic in mind utilizing colors such as brown, blue, and gray with vinyl shake siding, and vinyl lap siding. The visual design also promotes the New England aesthetic by incorporating gables to the structure.

H. Walking trails shall be accessible to all abilities and installed throughout the project.

An exterior walking loop has been proposed to meander around the exterior of the site. This walking loop, as well as the interior sidewalks interconnecting the units, has been proposed to be paved and adhere to all current ADA requirements.

I. The development shall be served by public water.

This development will be served by public water, accessed from the West Street Right of Way.

Hydrology

Standard 1. No New Untreated Discharges

The Massachusetts Stormwater Handbook requires that the project demonstrates that no new stormwater conveyances (e.g. outfalls) discharge untreated stormwater directly to or cause erosion in wetlands or waters of the Commonwealth.

The proposed project will not discharge stormwater directly to, or cause erosion in, wetlands or water of the Commonwealth and will treat stormwater prior to discharge or infiltration.

The infiltration basin is adjacent to a wetland and has been proposed with an outlet weir to allow treated discharge to flow from the pond to the wetland. All outlets have been designed to incorporate rip rap to minimize or eliminate erosion to wetlands.

Storm Event	2-inch	2-year	10-year	50-year	100-year
P1 Peak Discharge (fps)	0.00	0.00	0.00	0.00	0.00

Standard 2. Post-development Peak Discharge Rates Not to Exceed Pre-development Peak Discharge Rates

Post-development peak discharge rates do not exceed the pre-development peak discharge rates and total runoff volumes for all storm events. The proposed condition reduces rates by collecting and controlling the stormwater runoff within the stormwater management system.

Storm Event	2-inch	2-year	10-year	50-year	100-year
Pre-development rates (cfs) AP1 *to Wetland System*	0.0	0.0	0.1	1.5	3.4
Volume (cf)	0	29	3,182	15,188	25,005
Post-development rates (cfs) AP1 *to Wetland System*	0.0	0.0	0.1	1.0	2.0
Volume (cf)	0	109	2,171	8,777	13,965
Rate reductions (cfs)	**-0.0**	**-0.0**	**-0.0**	**-0.5**	**-1.4**
Volume Reductions (cf)	**-0**	**+80[1]**	**-1,027**	**-6,411**	**-11,040**

[1]The small increase in volume is due to the modified flow path for the runoff from the existing fire station located on West St, that currently flows onto the subject property.

Standard 3. Minimize or Eliminate Loss of Annual Recharge to Groundwater

Groundwater recharge will be accomplished using a shallow infiltration basin. As shown in the table summary for Standard 2, the project decreases the total volume and runoff for all storm events. All storms have a significant decrease over the existing condition for both volume and rate of runoff. This reduction in volume is generated by collecting and infiltrating all the impervious surfaces created on site.

RECHARGE VOLUME REQUIREMENT

- Rv = F x impervious area
- Rv = Required Recharge Volume, expressed in Ft3, cubic yards, or acre-feet
- F= Target Depth Factor associated with each Hydrologic Soil Group
- Impervious Area = pavement and rooftop area on site

RECHARGE VOLUME FOR THE ENTIRE SITE

Hydrologic Group Volume to Recharge (x Total New Impervious Area)	
A: 0.60 inches of runoff	77,929 SF x (0.60 x 1/12) = 3,896 CF
B: 0.35 inches of runoff	No B soils were found on site
C: 0.25 inches of runoff	No C soils were found on site
D: 0.10 inches of runoff	No D soils were found on site

TOTAL SITE RECHARGE PROVIDED = 28,409 CF RECHARGE VOLUME > 3,896 CF REQUIRED

10-YEAR DRAWDOWN WITHIN 24 HOURS

- Pond P1: 3,815 cf / [(8.27 in/hr)*(1 ft/12 in)*(5,553 sf)] = 1.0 hours < 24 hours, OK

100-YEAR DRAWDOWN WITHIN 72 HOURS

- Pond P1: 13,919 cf / [(8.27 in/hr)*(1 ft/12 in)*(5,553 sf)] = 3.6 hours < 72 hours, OK

Volumes and surface area for ponds acquired from HydroCAD stage storage tables. These tables are attached as an appendix at the end of the HydroCAD analysis.

Standard 4. Stormwater Management System to Remove 80% of the Average Annual Load of Total Suspended Solids (TSS)

The stormwater management system is designed to remove > 80% annual total suspended solids (TSS) from the proposed roadway, driveways, and sidewalks.

TSS REMOVAL CALCULATION

TREATMENT TRAIN #1 – RG1, RG2, RG3 TO INFILTRATION BASIN P1

Area of Impervious = 25,738 SF

BMP	TSS Removal Rate	Starting TSS Load	Amount Removed	Remaining Load
Street Sweeping – 3%	0.03	1.00	0.03	0.97
Rain Guardian Turret	0.79	0.97	0.77	0.20
Infiltration Basin	0.80	0.20	0.16	0.04
		Total TSS Removal	**96.0%**	

TREATMENT TRAIN #2 – RG4, RG5, RG6 RG7, TO INFILTRATION BASIN P1

Area of Impervious = 29,692 SF

BMP	TSS Removal Rate	Starting TSS Load	Amount Removed	Remaining Load
Street Sweeping – 3%	0.03	1.00	0.03	0.97
Rain Guardian Turret	0.79	0.97	0.77	0.20
Infiltration Basin	0.80	0.20	0.16	0.04
		Total TSS Removal	**96.0%**	

TREATMENT TRAIN #3 – FH1 & FH2 TO INFILTRATION BASIN P1

Area of Impervious = 14,007 SF

BMP	TSS Removal Rate	Starting TSS Load	Amount Removed	Remaining Load
Street Sweeping – 3%	0.03	1.00	0.03	0.97
Rain Guardian Foxhole	0.79	0.97	0.77	0.20
Infiltration Basin	0.80	0.20	0.16	0.04
		Total TSS Removal	**96.0%**	

TREATMENT TRAIN #4 – UNTREATED SIDEWALKS

Area of Impervious = 8,492 SF

- No Treatment – 0%

WEIGHTED TSS REMOVAL CALCULATION

Analyzed Impervious Area – 88,689 SF
(Total analyzed impervious [88,689 SF] – off-site impervious [10,760 SF])
On-site Impervious area – 77,929 SF

- Treatment Train # 1 – 25,738 SF
  Percentage of Site Impervious = 25,738 SF / 77,929 SF = 33.0%

Weighted TSS Removal = 96% x 33.0% = 31.7%

- Treatment Train # 2 – 29,692 SF
  Percentage of Site Impervious = 29,692 SF / 77,929 SF = 38.1%

Weighted TSS Removal = 96% x 38.1% = 36.6%

- Treatment Train # 3 – 14,007 SF
  Percentage of Site Impervious = 14,007 SF / 77,929 SF = 18.0%

Weighted TSS Removal = 96% x 18.0% = 17.3%

- Treatment Train # 4 – 8,492 SF
  Percentage of Site Impervious = 8,492 SF / 77,929 SF = 10.9%

Weighted TSS Removal = 0% x 10.9% = 0%

Total Sitewide TSS removal = 31.7% + 36.6%+ 17.3% = 85.6% > 80% OK

WATER QUALITY VOLUME

For new development, stormwater management systems must be designed to remove 80% of the average annual load (post-development conditions) of Total Suspended Solids (TSS). It is presumed that this standard is met when:

a) Suitable nonstructural practices for source control and pollution prevention are implemented.
b) Stormwater management best management practices (BMPs) are sized to capture the prescribed runoff volume; and
c) Stormwater management BMPs are maintained as designed.

In order to achieve the rated TSS Removal Rates, each BMP must be sized adequately. This development proposes to use ACF Rain Guardian Turrets, ACF Rain Guardian Foxholes, as well as an infiltration basin. The ACF Rain Guardian Turrets and ACF Rain Guardian Foxholes are flow based devices, and the flow calculations can be found below.

Flow rate associated with ACF Turrets and Foxholes:

Q = (qu)*(A)*(WQV), where:

Q = Peak flow rate associated with first 2-inch of runoff

qu = the unit peak discharge, in csm/in

A = impervious surface drainage area (in square miles)

WQV = water quality volume in watershed inches

ACF Rain Guardian Turret 1 (RG1):

ACF Rain Guardian Turret rated for 79% removal up to 0.50 cfs

qu= 717 csm/in (9 minute Tc)

Q = (717 csm/in)*(0.00032 square miles)*(2 inch)

Q = 0.46 CFS

Required Capacity = 0.46 CFS

ACF Turret 79% Removal Capacity = 0.50 CFS (See Appendix D for calculation)

0.50CFS > 0.46 CFS, **OK 79% Removal**

ACF Rain Guardian Turret 2 (RG2):

ACF Rain Guardian Turret rated for 79% removal up to 0.50 cfs

qu= 736 csm/in (8 minute Tc)

Q = (736 csm/in)*(0.00032 square miles)*(2 inch)

Q = 0.47 CFS

Required Capacity = 0.47 CFS

ACF Turret 79% Removal Capacity = 0.50 CFS (See Appendix D for calculation)

0.50 CFS > 0.47 CFS, **OK 79% Removal**

ACF Rain Guardian Turret 3 (RG3):

ACF Rain Guardian Turret rated for 79% removal up to 0.50 cfs

qu= 700 csm/in (10 minute Tc)

Q = (700 csm/in)*(0.00027 square miles)*(2 inch)

Q = 0.38 CFS

Required Capacity = 0.38 CFS

ACF Turret 79% Removal Capacity = 0.50 CFS (See Appendix D for calculation)

0.50 CFS > 0.38 CFS, **OK 79% Removal**

ACF Rain Guardian Turret 4 (RG4):

ACF Rain Guardian Turret rated for 79% removal up to 0.50 cfs

qu= 700 csm/in (10 minute Tc)

Q = (700 csm/in)*(0.00021 square miles)*(2 inch)

Q = 0.29 CFS

Required Capacity = 0.29 CFS

ACF Turret 79% Removal Capacity = 0.50 CFS (See Appendix D for calculation)

0.50 CFS > 0.29 CFS, **OK 79% Removal**

ACF Rain Guardian Turret 5 (RG5):

ACF Rain Guardian Turret rated for 79% removal up to 0.50 cfs

qu= 736 csm/in (8 minute Tc)

Q = (736 csm/in)*(0.00028 square miles)*(2 inch)

Q = 0.41 CFS

Required Capacity = 0.41 CFS

ACF Turret 79% Removal Capacity = 0.50 CFS (See Appendix D for calculation)

0.50 CFS > 0.41 CFS, **OK 79% Removal**

ACF Rain Guardian Turret 6 (RG6):

ACF Rain Guardian Turret rated for 79% removal up to 0.50 cfs

qu= 669 csm/in (12 minute Tc)

Q = (669 csm/in)*(0.00027 square miles)*(2 inch)

Q = 0.36 CFS

Required Capacity = 0.36 CFS

ACF Turret 79% Removal Capacity = 0.50 CFS (See Appendix D for calculation)

0.50 CFS > 0.36 CFS, **OK 79% Removal**

ACF Rain Guardian Turret 7 (RG6):

ACF Rain Guardian Turret rated for 79% removal up to 0.50 cfs

qu= 736 csm/in (8 minute Tc)

Q = (736 csm/in)*(0.00030 square miles)*(2 inch)

Q = 0.44 CFS

Required Capacity = 0.44 CFS

ACF Turret 79% Removal Capacity = 0.50 CFS (See Appendix D for calculation)

0.50 CFS > 0.44 CFS, **OK 79% Removal**

ACF Rain Guardian Foxhole 1 (FH1):

ACF Rain Guardian Foxhole rated for 79% removal up to 0.50 cfs

Q = (774 csm/in)*(0.00023 square miles)*(2 inch)

Q = 0.35 CFS

Required Capacity = 0.35 CFS

ACF Turret 79% Removal Capacity = 0.50 CFS (See Appendix D for calculation)

0.50 CFS > 0.35 CFS, **OK 79% Removal**

ACF Rain Guardian Foxhole 2 (FH2):

ACF Rain Guardian Foxhole rated for 79% removal up to 0.50 cfs

Q = (774 csm/in)*(0.00027 square miles)*(2 inch)

Q = 0.42 CFS

Required Capacity = 0.42 CFS

ACF Turret 79% Removal Capacity = 0.50 CFS (See Appendix D for calculation)

0.50 CFS > 0.42 CFS, **OK 79% Removal**

Standard 5. Land Uses with Higher Potential Pollutant Loads

The development is not considered a land use that generally produces higher potential pollutant loads.

Standard 6. Stormwater Discharges to Critical Areas

The proposed stormwater system does not discharge to a critical area.

Standard 7. Redevelopment Projects

The project is not considered a redevelopment project.

Standard 8. Control Construction-related Impacts

The project will install erosion and sediment controls prior to any earthwork activity. Erosion control barriers will be placed down slope from the proposed construction to prevent erosion and sedimentation into the surrounding areas. The barriers will be maintained and inspected periodically during construction; sediment buildup will be removed, and any damaged barrier will be replaced as needed.

Standard 9. Long-Term Operation and Maintenance Plan

See **Appendix A** for the operation and maintenance requirements of the stormwater management system.

Standard 10. No Illicit Discharges

An illicit discharge compliance statement will be provided by the property owner under separate cover.

Appendix A – Long Term Pollution Prevention Plan

This Long-Term Pollution Prevention Plan (LTPPP) describes the approach for pollution prevention and related maintenance activities for Sheldon West in Wrentham, MA**.** In general, long-term pollution prevention and related maintenance activities will be conducted consistent with:

- The National Pollutant Discharge Elimination System (NPDES) General Permit for Stormwater Discharges from Small Municipal Separate Storm Sewer System (MS4),
- MassDEP Stormwater Handbook
- Town of Wrentham Stormwater Management Plan for MS4 Permit Compliance
- Order of Conditions issued by the Wrentham Conservation Commission, Wrentham Planning Board, and Wrentham Board of Health

This LTPPP satisfies the requirements related to pollution prevention under Massachusetts Stormwater Standards 4, 5, 6, and 10.

Practices for Long-Term Pollution Prevention

For the facilities covered, long-term pollution prevention includes the following measures.

- *Good housekeeping;*
- *Storing materials and waste products inside or under cover;*
- *Vehicle washing;*
- *Routine inspections and maintenance of SCMs;*
- *Spill prevention and response;*
- *Maintenance of lawns, gardens, and other landscaped areas;*
- *Storage and use of fertilizers, herbicides, and pesticides;*
- *Pet waste management;*
- *Operation and management of septic systems; and*
- *Proper management of deicing chemicals and snow.*

Litter Pick-up

Sheldon West, LLC, or whomever is contracted, both during and after construction, will conduct litter pick-up from the stormwater management facilities in conjunction with routine road maintenance activities.

Inspection and Maintenance of Stormwater Assets

Sheldon West, LLC, or whomever is contracted, both during and after construction, will conduct inspection and maintenance of drainage infrastructure and the stormwater control measures (SCMs) in accordance with the O&M Plan, as described herein.

Maintenance of Landscaped Areas

Routine mowing will be conducted. Embankments designed to impound water should be mowed as required to prevent establishment of woody vegetation. Mowing and landscape maintenance are not to take place past limit of work on plans.

Except in rare circumstances, do not use fertilizers, herbicides, and pesticides for the maintenance of facilities. Exceptions include using fertilizer to ensure the survival of new plantings and herbicides to control invasive plants. Use of fertilizers and herbicides may be reviewed and approved by the Wrentham Conservation Commission and Wrentham Board of Health prior to application.

Snow and Ice Management

Snow and Ice Management will be conducted consistent with the practices outlined in Part III, Article IV of the Wrentham Zoning Regulations. Snow and ice shall be stored within locations specified on the plan, and excess shall be hauled off site. Snow storage is prohibited from swale areas and other area onsite indicated by signage.

Street Sweeping

Routine street sweeping, with a brush-type street sweeper, will be conducted in accordance with standard Wrentham practices. Sweeping will occur bi-annually in the spring and fall.

Prohibition of Illicit Discharges

The MassDEP Stormwater Management Standard 10 prohibits illicit discharges to the stormwater management system. Illicit discharges are discharges that do not consist entirely of stormwater, except for certain specified non-stormwater discharges.

In accordance with the existing MS4 permit and anticipated TS4 permit requirements, examples of discharges from the following sources are not considered illicit discharges:

- Firefighting activities*
- Foundation drains
- Water line flushing
- Footing drains
- Landscape irrigation
- Individual residential car washing
- Uncontaminated groundwater
- Rising groundwater
- Diverted stream flows
- Flows from riparian habitats/wetlands
- Potable water sources
- Dechlorinated swimming pool water
- Street wash waters
- Wash water from residential buildings (no detergents)
- Condensation from air conditioning units
- Run-on from private driveways caused by precipitation
- Lawn watering
- Water from crawl space pumps

*Water from firefighting activities is allowed and need only be addressed where they are identified as significant sources of pollutants to waters of the United States.

Based on plan review and confirmation in the field, there are no known or proposed illicit connections associated with Sheldon West**.** Please see Sheldon West Illicit Discharge Statement for more information.

Spill Prevention and Response

Response procedures will be implemented at the infiltration basin for any significant release of hazardous materials such as fuels, oils, or chemical materials to any stormwater inlet or the infiltration basin onsite.

Reportable quantities will immediately be reported to the applicable Federal, State, and local agencies as required by law. Reportable quantities of chemical, fuels, or oils are established under the Clean Water Act and enforced through MassDEP. The MassDEP Emergency Response Program shall be immediately notified in accordance with required procedures for the report of a release (telephone (888) 304-1133).

In the case of a spill, applicable containment and clean-up procedures will be performed immediately. These procedures are implemented in accordance with the Unified Response Manual at the local level by first responders, which includes the Wrentham local public safety departments (e.g., fire, police, public works, board of health). Spill material collected during the response will be promptly removed and disposed of in accordance with Federal, State, and local requirements. If necessary, a licensed emergency response contractor will assist in cleanup of releases depending on the amount of the release and the ability of the responsible party to perform the required response.

Infiltration Basin and Berm

System Owner: Sheldon West, LLC, or future owner.
Estimated Annual Maintenance: $2,400
(Per DEP Stormwater Structural BMP's Vol 2)

In many cases, a landscaping contractor working elsewhere on the site can complete maintenance tasks. Inspect the basin and outlet structure to ensure no structural damage has occurred and that they are functioning properly and up to design standards.

Inspection and preventive maintenance are required at least twice per year, and after each major storm event. Note how long water remains standing in the basin after a storm. If water remains standing after 48 to 72 hours after a storm, the infiltration basin may be clogged.

At least twice per year, mow the berm/buffer area, side slopes, and basin bottom. Remove grass clippings, accumulated organic matter, trash and debris at this time.

Remove sediment from the basin as necessary when the basin is dry. Use light equipment when removing the top layer, as to not compact the underlying soil. Use deep tilling to break and remove any clogged surfaces and revegetate immediately.

The berm around the basin should be checked for erosion and settling and repaired if necessary. The berm shall be clear of debris and foliage and be able to be accessed by maintenance vehicles.

Important items to check during inspections include:

- Signs of differential settlement
- Cracking
- Erosion
- Leakage in the embankments
- Tree growth on the embankments
- Condition of rip rap
- Sediment accumulation
- Health of vegetation, turf

**** Paying careful attention to pretreatment, and operation and maintenance can extend the life of the soil media***

Date	Inspector	Condition	Maintenance Performed*

**Evidence of maintenance (i.e. receipts) must be provided.*

Street Sweeping

System Owner: Sheldon West, LLC, or future owner.

Estimated Annual Maintenance: $250-$500

(Per DEP Stormwater Structural BMP's Vol 2)

Street sweeping should be conducted at minimum twice a year, during fall and spring. Mechanical sweepers may be used, however vacuum and regenerative air sweepers are preferred to pick up fine-grained articles. Street sweeping shall be done in the paved surface as well as the pervious paver area.

Date	Inspector	Condition	Maintenance Performed*

**Evidence of maintenance (i.e. receipts) must be provided.*

Rip Rap Aprons and Swale Areas

System Owner: Sheldon West, LLC, or future owner.
Estimated Annual Maintenance: $600
(Per DEP Stormwater Structural BMP's Vol 2)

Inspect semi-annually the first year, and at least once a year thereafter. For swales inspect the grass for growth and the side slopes for signs of erosion and formation of rills and gullies. Plant an alternative grass species if the original grass cover is not successfully established. If grass growth is impaired by winter road salt or other deicer use, re-establish the grass in the spring. For rip-rap and swale areas: *Trash/Debris Removal:* Remove accumulated trash and debris. *Sediment removal:* Check on a yearly basis and clean as needed. Use hand methods (i.e., a person with a shovel) when cleaning to minimize disturbance to vegetation and or rip rap and underlying soils. Mow on an as-needed basis during the growing season so that the grass height does not exceed 6 inches.

Date	Inspector	Condition	Maintenance Performed*

**Evidence of maintenance (i.e. receipts) must be provided.*

ACF Rain Guardian

System Owner: Sheldon West, LLC, or future owner.
Estimated Annual Maintenance: $250-$500
(Per Manufacturer)

Depending on the characteristics of the contributing watershed and seasonal variation, common maintenance needs include periodic removal of accumulated leaves (and other organic debris) and garbage from the top grate and sediment and fine debris from the concrete dry filter box. Contributing watersheds with high sediment concentrations may require inspections monthly and clean them out at least four times a year. More frequent visits will be needed during the fall season and after storms with high winds to account for increased accumulation of leaves and other debris.

If sediment accumulates beyond an acceptable level in the system, it will be necessary to remove. This can be done by manual removal with a shovel or mechanical device. The filter screen can be cleaned manually through brushing or with pressurized water.

Date	Inspector	Condition	Maintenance Performed*

**Evidence of maintenance (i.e. receipts) must be provided.*

Infiltration Basin Weir

System Owner: Sheldon West, LLC, or future owner.
Estimated Annual Maintenance: $250-$500
(Per DEP Stormwater Structural BMP's Vol 2)

Infiltration Basin weir areas (rip rap) should be inspected annually and after major storms to check for displaced stones, slumping, and erosions at edges, especially downstream or downslope. If these areas have been damaged, they should be repaired immediately before any further damage can take place. Accumulated vegetation, mainly weeds, should also be removed from inflow and outflow areas.

If the amount of stones decreases in overflow/outflow areas, additional rip rap shall be purchased to replenish the stones to the original amount.

Date	Inspector	Condition	Maintenance Performed*

**Evidence of maintenance (i.e. receipts) must be provided.*

Pervious Pavers

System Owner: Sheldon West, LLC, or future owner.
Estimated Annual Maintenance: $500-$750
(Per Manufacturer)

Routine maintenance should include visual inspection of the pervious pavers to ensure that it is clean of debris and sediments, and that it will dewater between storms. Routine maintenance cleaning procedures include blowing (with leaf blower), truck sweeping and/or dry vacuuming.

It is good practice to perform periodic maintenance just before winter to ensure that the pervious paver voids are clean and free of non-compressible materials that may inhibit draining and, therefore, could contribute to freeze-thaw damage. Additionally, periodic maintenance may be required following winter to remove any anti-skid materials that may have been used. Proper cleaning procedures include pressure washing and/or vacuuming the area with either a dray vacuum or a regenerative vacuum sweeper.

Over time, deep cleaning/unclogging may become necessary, particularly if routine and periodic maintenance is not performed. Deep cleaning/unclogging is best accomplished by simultaneous pressure washing and vacuuming. Additionally, anti-icing pre-treatments and deicers containing magnesium chloride, calcium magnesium acetate or potassium acetate should never be used on pervious pavers in the wintertime.

Date	Inspector	Condition	Maintenance Performed*

**Evidence of maintenance (i.e. receipts) must be provided.*

Tech Spec Guide

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Your requested ICPI Tech Spec 23 follows this page.

Design and Installation Professionals frequently turn to interlocking concrete pavements and permeable interlocking concrete pavements because they offer lower initial and life cycle costs and provide environmentally sustainable solutions.

ICPI provides resources for ICP and PICP design, construction, and maintenance. These include: Tech Specs, Guide Specs, Detail Drawings, Construction Tolerance Guides, Fact Sheets, Design Manuals and design software. ICPI also offers several relevant continuing education courses at icpi.org and aecdaily.com

Find the right guide for your location.

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ICPI Tech Spec Library

- **Tech Spec 1**: Glossary of Terms for Segmental Concrete Pavement
- **Tech Spec 2**: Construction of Interlocking Concrete Pavements
- **Tech Spec 3**: Edge Restraints for Interlocking Concrete Pavements
- **Tech Spec 4**: Structural Design of Interlocking Concrete Pavement for Roads and Parking Lots
- **Tech Spec 5**: Cleaning, Sealing and Joint Sand Stabilization of Interlocking Concrete Pavement
- **Tech Spec 6**: Reinstatement of Interlocking Concrete Pavements
- **Tech Spec 7**: Repair of Utility Cuts Using Interlocking Concrete Pavements
- **Tech Spec 8**: Concrete Grid Pavements
- **Tech Spec 9**: Guide Specification for the Construction of Interlocking Concrete Pavement
- **Tech Spec 10**: Application Guide for Interlocking Concrete Pavements
- **Tech Spec 11**: Mechanical Installation of Interlocking Concrete Pavements
- **Tech Spec 12**: Snow Melting Systems for Interlocking Concrete Pavements
- **Tech Spec 13**: Slip and Skid Resistance of Interlocking Concrete Pavements
- **Tech Spec 14**: Concrete Paving Units
- **Tech Spec 15**: A Guide for the Construction of Mechanically Installed Interlocking Concrete Pavements
- **Tech Spec 16**: Achieving LEED Credits with Segmental Concrete Pavement
- **Tech Spec 17**: Bedding Sand Selection for Interlocking Concrete Pavements in Vehicular Applications
- **Tech Spec 18**: Construction of Permeable Interlocking Concrete Pavement Systems
- **Tech Spec 19**: Design, Construction and Maintenance of Interlocking Concrete Pavement Crosswalks
- **Tech Spec 20**: Construction of Bituminous- Sand Set Interlocking Concrete Pavement
- **Tech Spec 21**: Capping and Compression Strength Testing Procedures for Concrete Pavers
- **Tech Spec 22**: Geosynthetics for Segmental Concrete Pavements
- **Tech Spec 23**: Maintenance Guide for Permeable Interlocking Concrete Pavements
- **Tech Spec 25**: Construction Guidelines for Segmental Concrete Paving Slabs and Planks in Non-Vehicular Residential Applications

Tech Spec 23

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Maintenance Guide for Permeable Interlocking Concrete Pavements

Introduction

Permeable interlocking concrete pavements (PICP) are a proven method for reducing stormwater runoff and pollutants while supporting pedestrian and vehicular traffic. Many laboratory and in-situ research projects over the past two decades by universities, government stormwater agencies, and industry have demonstrated significant runoff and pollutant reductions with cost-saving benefits. The U.S. Federal Highway Administration **www.fhwa.dot.gov/pavement/concrete/pubs/hif19021.pdf** has published information supporting PICP use in walkways, plazas, driveways, parking lots, alleys and streets.

Like all stormwater control measures, PICP requires maintenance as it traps sediment on its surface not unlike an air conditioning filter. Larger particles are initially trapped while allowing water to pass. Some enter the jointing stone and are trapped there. The jointing stone with larger particles eventually captures smaller particles and this decreases the infiltration rate over time. While still infiltrating water, many smaller particles are trapped within the surface and interior joints. Smaller particles are trapped and eventually decrease infiltration which results in surface ponding.

Every PICP site varies in sediment deposition onto its surface, particle size distribution, and the resulting cleaning frequency. For example, beach sand (a coarse particle size distribution) on the surface will not clog as quickly and require less effort removing than fine clay sediment. Besides the particle size distribution, the rate of surface infiltration decline also depends on the traffic, size, and slope of a contributing impervious area, adjacent vegetation and eroding soil, paver joint widths and jointing stone sizes. ICPI offers a PICP site selection

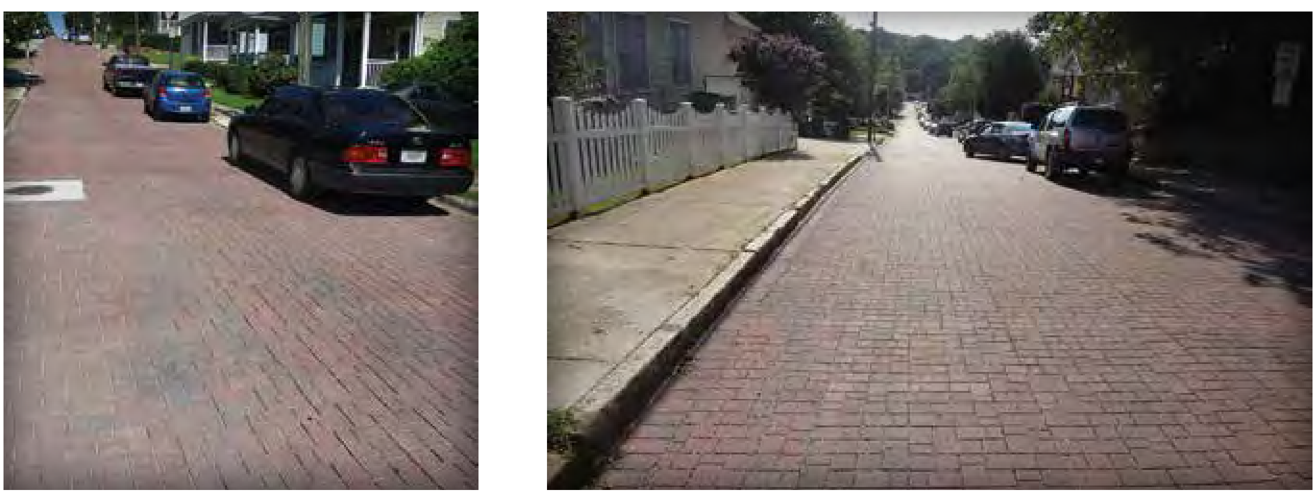

Figure 1. PICP is seeing increased use in municipal streets to reduce stormwater runoff, local flooding, storm pipe upsizing, and combined sewer overflows. These streets are in Atlanta, GA.

Figure 2. Sand-filled joints and bedding common to interlocking concrete pavement **are not used** *in PICP.*

tool on **www.icpi.org/software** to help identify favorable sites and avoid one that may incur additional maintenance.

While routine maintenance assures long-term infiltration, surface infiltration can be restored from neglected maintenance. A significant advantage of PICP is its ability to remove settled or wheel-packed sediment in the joints. This Tech Spec provides guidance on routine and restorative maintenance practices that support surface infiltration. This bulletin also provides guidance on maintaining the surface as an acceptable pedestrian and vehicular surface.

Practices Supporting Surface Infiltration

PICP design and construction that complies with ICPI guidelines are fundamental to long-term surface infiltration. Guidelines are found in ASCE 68-18 standard on PICP, the ICPI manual, *Permeable Interlocking Concrete Pavements* and in *ICPI Tech Spec 18–Construction of Permeable Interlocking Concrete Pavements* available on **www.icpi.org**. Some essential characteristics described below support continued infiltration.

PICP doesn't use sand. Unlike interlocking concrete pavements, sand jointing or bedding materials to support paving units and dense-graded aggregate bases are not used in PICP. Sand joints and bedding allow very little water to enter and often eventually clog for traffic borne detritus and sediment.

Construction E & S control is essential. Erosion and sediment control during construction is covered in the previously mentioned documents, and is customized to each project via the Stormwater Pollution Prevention Plan or SWPPP. An inspection checklist is provided at the end of this bulletin that includes sediment control. If the PICP is built first and construction traffic must use it, then it will very likely require vacuum cleaning upon construction completion. The ideal situation is PICP constructed late in the project such that it will not receive much construction traffic and sediment. This may require using temporary construction roads.

If PICP receives run-on from upslope pervious or impervious areas, inspect these areas for erosion and sediment, yard waste, materials storage, etc. Sweep or vacuum the contributing drainage area clean and free of any dirt, leaves and mulch as they are a major source of PICP clogging. Lawn and planting beds should be sloped away from PICP areas.

Maintain filled joints with stones. The jointing stones capture sediment at the surface so it can easily be removed. If sediment is allowed to settle and consolidate, then cleaning becomes more difficult since the sediment is inside the joint rather than on the surface. Settlement of jointing stones in the first few months is normal to PICP as open-graded aggregates for jointing and bedding choke into the larger base aggregates beneath and stabilize. This settlement often requires the joints to be refilled with aggregates three to six months after their initial installation. If possible, this should be included in the initial construction contract specifications. Aggregate-filled joints facilitate sediment removal at the surface and provide interlock for pavement structural stability.

Keeping the joints filled during the PICP service life is essential to trapping sediment and facilitating its removal at the surface and ensuring long term performance. Permeable segmental paving systems that do not use jointing aggregates may incur higher maintenance time and costs to extract accumulated sediment from deep within the joints and bedding, or eventually move through the base/subbase aggregates onto the subgrade and reduce its infiltration.

Filled paver joints means filled to the bottom of the paver chamfers with jointing stone. If the pavers have very

Figure 3. Whether eroded onto or dumped on PICP, erosion and sediment control are essential during construction.

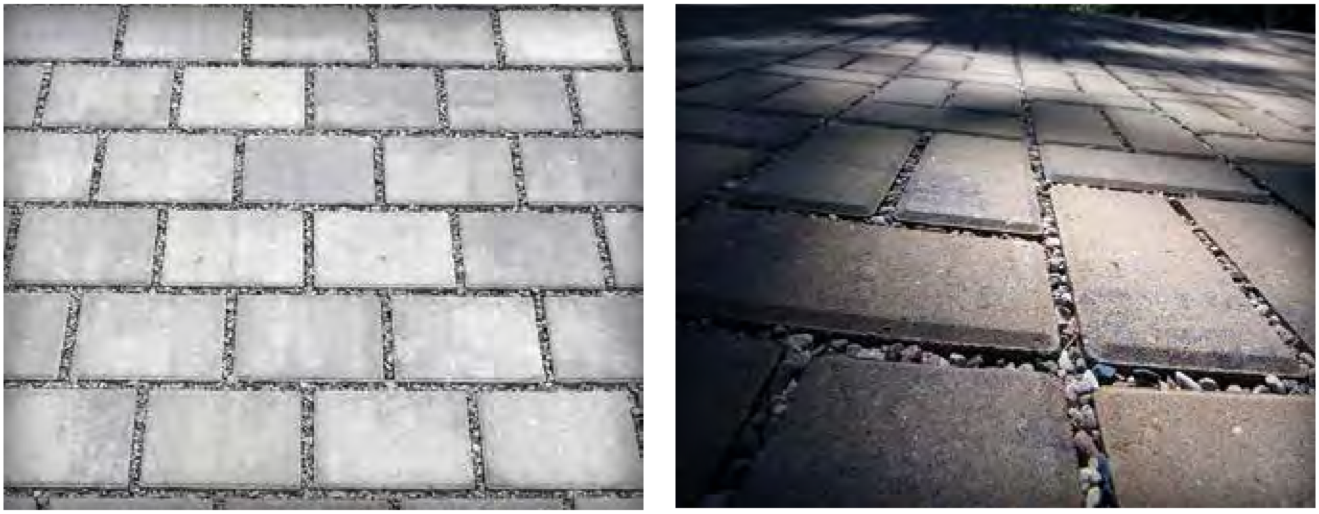

Figure 4. Keeping PICP joints filled with permeable aggregate facilitates removal of accumulated sediment.

small or no chamfers, then they should be filled within ¼ in. (6 mm) of the paver surface. Should the top of jointing stone settle below ¼ in. (6 mm), vacuum equipment can be less effective in removing sediment and cleaning becomes potentially more expensive.

Manage mulch, topsoil and winter sand. Finally, stockpiling mulch or topsoil on tarps or on other surfaces during site maintenance activities rather than directly on the PICP surface helps maintain infiltration. Figure 5 illustrates an example of correct management of landscaping material on PICP, as well as the need to exposed soil slopes.

Sand used in the winter for traction is not recommended. Figure 6 illustrates the consequence to PICP joints when subjected to winter sand for traction. If used, sand should be removed with vacuuming in the spring to prevent a substantial decrease in surface infiltration. Using jointing aggregate is recommended as a better alternative to using sand for winter traction. In addition, the aggregate can provide some refilling of the joints.

Surface Infiltration Inspection & Testing

Visual Inspection—Effective ways to assess PICP surface infiltration is by conducting visual inspections or tests on the surface before, during and immediately after rainfall.

Inspect Before a Rainfall—Sediment crusted in the joints when dry is the most opportune time to remove it. During dry periods, the sediment layer in each joint can sometimes dry out and curl upward. This layer can be easily loosened by vacuum equipment.

Additionally, deciduous leaves and pine needles eventually get crushed by traffic, degrade, and work their way into the joints, thereby reducing infiltration. See Figures 7 and 8. The site should be inspected for sediments from adjacent eroding areas and those areas stabilized immediately.

Weeds growing from within joints indicate accumulated sediment in the joints and neglected maintenance. See Figure 9. Weeds will not germinate unless there is accu-

Figure 5. Mulch placed on tarps prevents more expensive cleaning of PICP.

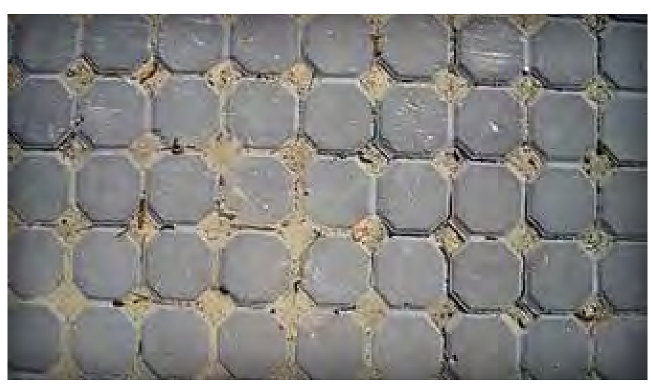

Figure 6. Sand from winter maintenance must be removed the following spring.

 

Figures 7 and 8. Pine needles and leaves eventually will degrade and get compacted into the joints from traffic. They should be removed by sweeping or vacuuming before that happens.

mulated sediment. Weeds should be removed by hand. Herbicide may kill weeds, but dead vegetation and roots will remain. They typically reduce infiltration and should eventually be removed.

Inspect During and Just After a Rainstorm— The extent of puddles and bird baths observed during and especially after rainstorm indicate a need for surface cleaning.

Table 1. ASTM C1781 test results: relationship between time required to infiltrate and calculated surface infiltration rate

Time to infiltrate water		Approximate surface infiltration rate inches/hr (mm/hr)	
Minutes	**Seconds**	**8 lbs. (3.6 kg) water**	**40 lbs. (18 kg) water**
0.5	30	235 (5,913)	1,175 (29,564)
1	60	117 (2,956)	587 (14,782)
2	120	59 (1,478)	294 (7,391)
4	240	29 (739)	147 (3,696)
6	360	20 (493)	98 (2,464)
8	480	15 (370)	73 (1,848)
15	900	8 (197)	39 (985)
30	1800	4 (99)	20 (493)
60	3600	2 (49)	10 (246)

Note: $I = (K \bullet M)/(D^2 \bullet t)$, where
I = Surface infiltration rate, in./hr (mm/hr)
K = 126,870 for US customary units (4,583,666,000 for metric)
M = water mass, lbs (kg)
D = ring diameter (12 in. or 305 mm)
t = time for water to infiltrate in seconds

- Acceptable performance > 100 in./hr (2,500 mm/h)
- Plan to clean soon
- Clean immediately < 20 in./hr (500 mm/hr)

A minor amount of ponding is likely to occur particularly at transitions from impervious pavement surfaces to PICP. This often occurs first as sediment is transported by runoff and vehicles. See Figures 10 and 11. Should ponding areas occupy more than 20% of the entire PICP surface, then surface cleaning should be conducted. While a rainstorm's exact conclusion is difficult to predict, standing water on PICP for more than 15 minutes during or after a rainstorm likely indicates a location approaching clogging.

Test Surface Infiltration—A quick and subjective test for the amount of surface infiltration is pouring water on PICP. If the water spreads rather than infiltrates, the extent of spreading suggests an area that may be clogging. Should more than approximately 20% of the surface area see ponding during or immediately after a rainstorm, a more objective measure of surface infiltration of these areas can be accomplished using ASTM C1781 *Standard Test Method for Surface Infiltration Rate of Permeable Unit Pavement Systems.* Figure 12 illustrates the test set up using a 12 in. (300 mm) diameter ring set on plumber's putty. (The ring can be metal or plastic.) Figure 13 illustrates the test apparatus in

Figure 9. Weeds indicate sediment accumulation and lack of surface cleaning to remove it.

Figure 10. Erosion of adjacent asphalt and sediment deposition on PICP.

Figure 11. Ponding on PICP typically first occurs at the junction with impermeable pavement.

Figure 12. Steps in setting up test equipment for measuring surface infiltration using ASTM C1781.

place with water poured into it.

ASTM C1781 test method begins with "pre-wetting" an area inside the ring to ensure the surface and materials beneath are wet. This is done by slowing pouring 8 lbs (3.6 kg) of water while not allowing the head of water on the paver surface to exceed 3/8 in. (10 mm) depth. If the time to infiltrate 8 lbs of water is less than 30 seconds (using a stopwatch typically on a cell phone), the subsequent test is done using 40 lbs (18 kg) of water. If more than 30 seconds, then 8 lbs of water is used in the subsequent tests. Again, a 3/8 in. (10 mm) head is maintained during the pour while being timed with a stopwatch. The surface infiltration rate is calculated using formulas in the test method.

If infiltration measurements on ponded areas consistently result in rates below 20 in./hour (508 mm/hr), they require immediate surface cleaning. PICP surfaces sloped over 2% with less than 40 in./hr infiltrate rate require immediate surface cleaning. An infiltration rate of 20 in./hr equates to 30 minutes' infiltration time and 40 in./hr results in 15 minutes. Table 1 further illustrates the relationship between time

Figure 13. ASTM C1781: pouring the wanter into a 12 in. (300 mm) inside diameter ring set on plumber's putty.

for 40 lbs (18 kg) of water to infiltrate and the calculated infiltration rate. ICPI offers a downloadable calculator for converting time of infiltration to infiltration rates when using C1781. See **www.icpi.org/software.**

Surface Infiltration Maintenance Types

Routine and Restorative Maintenance—There are two approaches or service types for maintaining PICP surface infiltration: routine and restorative. Routine maintenance is done regularly to maintain infiltration. It removes most loose sediment and debris from the surface before being trapped and stuck in the jointing aggregates thereby causing clogging. Routine maintenance may require reinstatement of a small amount of jointing stones or none at all.

Routine Maintenance Equipment Options for Maintaining Various Sized PICP Applications

Cleaning Small Pedestrian Areas and Driveways

Theas are typically under 2,000 sf or 200 m^2 and include patios, plazas, sidewalks, and driveways. Equipment options follow:

Hand-held Bristle Broom— Sweep as needed to clear the surface clear of loose debris. See Figure 14.

Leaf Blower (electric or gas powered)—A minimum air speed of 120 mph (190 kph) is recommended. Jointing aggregates remain in place while removing loose debris such as leaves from the surface. See Figure 15.

Rotary Brush with Plastic Bristles—These are often used to spread jointing stone during construction. Same equipment can be used to clean surface to top of joints. Bristles can flip debris out of joints (depends on bristle reach into the joints). A small amount of aggregate may need to be replaced in the joints after using. See Figure 16.

Wet/Dry Shop Vacuum or Walk-behind Vacuum—Use equipment with a minimum 4 (peak) HP motor with minimum 130 cubic feet (3.7 m^3) per minute suction. These machines can remove some jointing aggregates so they may require replenishment. See Figures 17 and 18.

Power Washer—This equipment should be capable of 1,400 to 1,800 psi (9.6 to 12.4 MPa) pressure. Apply the spray at a 30° angle approximately 18 to 24 in. (45 to 60 cm) from the surface and adjust as needed. This equipment will evacuate jointing aggregate and replenishment will be required. Power washing alone generally is not an optimal cleaning approach because there is almost no opportunity on most sites to remove the water-suspended sediment before the water is absorbed back into the pavement. See Figure 19.

Cleaning Large PICP Areas

These are typically over 2,000 sf or 200 m^2 such as large plazas, long sidewalks and driveways, parking lots, alleys and streets. Equipment options follow:

Street Sweepers—These typically have rotating plastic bristle brushes positioned near the curb side and center pickup into a hopper at the rear. Do not use water as it slows removal of loose dirt into the machine. This machine does provide a small vacuum force to manage dust, but the cleaning action is provided by the mechanical sweeping, so it is moderately effective among large machines for removing sediment in the joints. Bristles from the the main broom can reach into joints parallel to the direction of the broom rotation, but have little effect on the joints not aligned with the broom rotation. See Figure 20.

Regenerative Air Sweepers—Includes a box positioned under the truck and on the pavement through which air is blown and recirculated (hence the term regenerative air). The pavement must have no convex (or reverse) crown in order to create an adequate seal for suction in the box. Air pressure flowing through it picks up loose debris and sediment. Rotating brushes can be used to direct dirt and debris toward the box. See Figure 21.

Figure 14. Bristle broom for removing loose debris

Figure 15. Blowing debris to curbs or gutters for removal and disposal.

Figure 16. Rotary brushes increase cleaning efficiencies.

Restorative Infiltration Maintenance for Large Clogged Surfaces

Restorative maintenance is conducted when sediment has lodged in the jointing stones from traffic and weather. The condition indicates that the PICP surfaces have not been regularly cleaned. Restorative maintenance requires some or complete removal of the jointing aggregates to increase infiltration. The depth of jointing stone removed depends on the penetration depth of the sediment into the joints. This can be determined on a sample of a few clogged joints (typically where ponding occurred) by prying out stones and sediment with a flat head screwdriver until little or no accumulated sediment appears.

True Vacuum Sweepers—These can withdraw jointing material and even the concrete pavers. Therefore, the vacuum engine revolutions must be adjusted by the machine operator during a few test runs to find the setting that withdraws the needed depth of sediment and jointing aggregate. After withdrawal, jointing aggregates will require replenishment. The suction orifice is typically about a yard (meter) wide and positioned on the curb side of the truck. Extremely clogged surfaces will require two or more passes. Figure 22 shows this machine. It is often used by municipalities to clean out storm drain catch basins and may require a separate vacuum attachment to clean pavements.

High-power Washing and Vacuum Equipment—Figure 23 shows the equipment for restorative cleaning where water is applied to help loosen sediment and stones in the joints. Figure 23 shows a vacuum that withdraws sediment and stones immediately after applying water. The water and debris are drawn into a vac truck.

Figure 17. Wet/dry shop vacuum cleans loose sediment from a PICP residential driveway

Figure 18. Walk-behind vacuum cleans a small parking area.

Figure 19. Power washing requires a little practice to minimize jointing stone removal.

High Pressure Air/Vacuum—High pressure air is blasted into the joints and has been shown to be very effective at dislodging sediment and debris. A second step is then required to vacuum up the debris that is dislodged. In Figure 24, the machine in the foreground blows debris completely out of the joints and the second machine takes up the debris into a vac truck similar to that used to clean catch basins. See Figure 24. As with all restorative cleaning methods, clean jointing stone is spread and the empty joints are filled. After removing excess stones from the surface, the pavers with filled joints are compacted with a minimum 5,000 lbf (22 kN) vibratory plate compactor operating at 75-90 Hz. See Figure 25. This helps settle the stones into the joints. Any joints were stones have settled should be filled with more stones within a 1/4 inch (5 mm) of the paver surfaces.

Maintenance Equipment Performance

In 2020, the University of Toronto completed a two year research project, Maintenance Equipment Testing on Accelerated Clogged Permeable Interlocking Concrete Pavements. This study evaluated maintenance equipment for restoration of infiltration rates of PICP systems when joints become severely clogged. The research was conducted at the Toronto & Region Conservation Authority's Kortright Centre in Vaughn, Ontario. The research scope of work included the construction of seven 10 ft. by 10 ft. PICP partial infiltration test pads. The cells were carefully clogged to a surface infiltration rate of ≤ 10 in/hr. The sediment infill used to clog the system was regional street cleaning sediments with a known particle size distribution. Five different technologies were investigated: full vacuum sweeper, regenerative air sweeper, dry mechanical sweeper, water pressure washing, and a hybrid high pressure air/vac system specifically designed for permeable pavement. The objective of the study was to evaluate the effectiveness of each method at restoring surface infiltration rates. The impact of cohesive soil sediment was also evaluated as part of the study. All cleaning technologies significantly improve surface infiltration rates. However, the high pressure air-vac hybrid had the best and least variable results, and was the only technique able to fully restore surface infiltration rates. Joint penetration depth was generally a good indicator of restoration effectiveness, except if sediment gradation varies. A complete copy of the report can be found at **https://tinyurl.com/y67zhydz**.

Figure 20. This type of mechanical sweeper removes sediment from joints parallel to the direction of the broom rotation.

Also in 2020 the United States Geological Survey Madison, WI office published results of a four year investigation on cleaning PICP, Assessment of Restorative Maintenance Practices on the Infiltration Capacity of Permeable Pavement Assessment of Restorative Maintenance Practices on the Infiltration Capacity of Permeable Pavement. Since 2014, this research site has collected water quality, temperature, infiltration rates, and surface flow data with three types of permeable pavement sections (pervious asphalt, porous

Figure 21. A regenerative air machine does routine cleaning in a PICP parking lot.

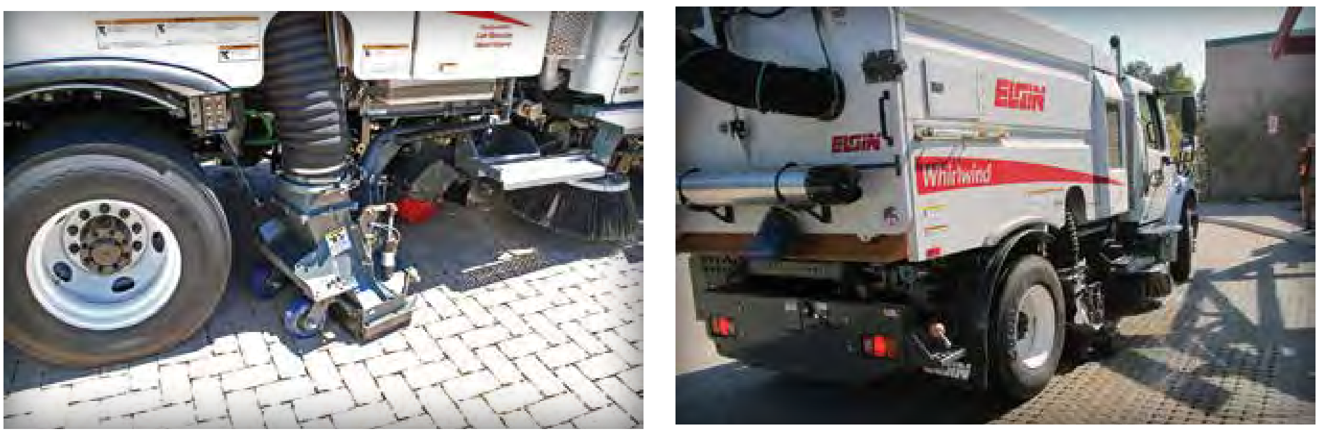

Figure 22. A true vacuum machine cleaning neglected PICP.

concrete, and permeable interlocking concrete pavement). Contributory drainage from an adjacent parking lot provided an opportunity for accelerate clogging and collect data for 9:1 and 5:1 drainage ratios. The following six pavement cleaning methods were evaluated over a 4-year period: manual cleaning with a masonry trowel; Leaf blower and broom; true vacuum; water-enhanced vacuum; high pressure air system; and pressure washer with soil vacuum. An evaluation of the efficiency of each method was based on comparing surface infiltration rates, pre and post cleaning. Surface variability was high due to surface flow patterns across the permeable surfaces. All cleaning methods improved surface infiltration rates. PICP showed the greatest recovery compared to pervious concrete or pervious asphalt. These systems were more difficult to maintain due to sedimentation penetrating into the solid matrix related to the twisting of interconnected pores created during placement. Different cleaning methods produce different results however, in all instances, when the same method was applied, PICP showed the greatest recovery in infiltration capacity. At this particular site the majority of clogging occurred within the top 1 inch. A complete copy of the report can be found at **https://tinyurl.com/yy9nhou8**.

Inspection Intervals and Procedures for Maintaining Surface Infiltration

Routine maintenance provides the best infiltration performance by implementing the following procedures:

1. **Weekly—**Prevent contamination from routine landscape maintenance such as grass clippings from mowing, hedge trimming, mulching plant beds, etc. by:
   - Broom sweep debris from the paver surface, or
   - Blow debris from the paver surface with a powered leaf blower onto other surfaces that will not retransmit it to the PICP surface.
   - Mechanically sweep paver surface.
   - Remove loose debris, leaves, needles, sediment, topsoil, mulch, etc. after severe rain storms using the above procedures.
   - Collect and dispose of debris.
2. **Semi-annually—**Remove loose surface debris from the pavers and jointing stones (1) when trees have defoliated in the fall and (2) at the end of winter snowfall.
   - Use a wet/dry vacuum for small areas and a regenerative air machine for larger areas.

Figure 23. This equipment provides combined washing and vacuum of unmaintained PICP.

Figure 24. This equipment blows sediment and soiled aggregate from the joints and uses vacuum equipment to remove them.

Figure 25. No matter the equipment used, after removing sediment soiled aggregate, clean aggregate is placed in the joints, the surfaced cleaned and compacted.

- Replenish jointing stone as needed to the bottom of the paver chamfers.
- Check any observation wells and outlet pipes from underdrains to confirm drain down and water outflows.

3. **As needed—**Based on observation and during rainstorms and subsequent surface infiltration tests, remove and replenish the jointing stones and sediment using restorative cleaning equipment and procedures.

Note: *Various factors will affect each project's routine maintenance schedule and each must be reviewed individually.*

Winter Maintenance

Snow Removal—Unlike other permeable pavement surfaces, PICP demonstrates durability in the winter. PICP can be plowed with steel or hard rubber blades. Steel blades typically scratch all pavement surfaces. When using commercial snow removal companies, confirm in writing they provide protective edges on the snowplow equipment to avoid scratching the surface. Most pavers have chamfers on their surface edges which can help protect the edges from chipping by snow plows. For smaller areas, use a plastic snow shovel and fit snow blowers with plastic on the scoops and on the gliders. When possible deposit plowed snow onto grassy areas and not on the PICP when the plowed snow is dirty. Such dirt will remain and likely help clog the PICP surface after the snow melts.

Deicers—When used sparingly, deicers should not damage PICP surfaces as the brine typically forms on the surface to lower the freezing temperature of water and eventually moves into the joints with melting ice or snow. Some deicers will accelerate surface wear on some styles of pavers with blasted or hammered surfaces.

A 2020 University of Toronto study on pavement deicing operations quantified some significant winter safety benefits when using PICP. Besides confirming that the use of permeable pavers can eliminate the occurrence of snow melt refreezing and forming black ice, snow and ice can also melt and dry quicker when deicers are used on PICP. More importantly, the research confirmed that a much lower deicing salt application rate is required on PICP compared to impervious asphalt, while still maintaining a high level

Figure 26. This is an example of snow that should have been deposited on a grassy area. If such areas are not available, then vacuum clean the PICP in the early spring.

Table 2. Maintenance guidelines for all PICP distresses

Distress	Activity	Frequency
Clogging	Schedule appropriate routine cleaning method based on site conditions. Utilize restoration cleaning methods as needed when surface infiltration rates decrease below project threshold. Hot spot cleaning may be appropriate.	1 to 2 times annually; adjust frequency based on sediment loading
Clogged/Damaged Secondary Features	Clean out or repair secondary drainage features.	Annually, after major rain event
Depressions	Repair all paver surface depressions, exceeding 0.5 in. (13 mm)	Annually, repair as needed
Rutting	Repair all paver surface rutting, exceeding 0.6 in. (15 mm)	Annually, repair as needed
Faulting	Repair all paver surface faulting, exceeding 0.25 in. (6 mm)	Annually, repair as needed
Damage Paver Units	Replace medium to high severity cracked, spalled or chipped paver units.	Annually, repair as needed
Edge Restraint Damage	Repair pavers offset by more than 0.25 in. (6 mm) from adjacent units or curbs, inlets, etc.	Annually, repair as needed
Excessive Joint Width	Repair pavers exhibiting joint widths exceeding 0.5 in. (13 mm)	Annually, repair as needed
Joint Filler Loss	Replenish aggregate in joints.	As needed
Horizontal Creep	Repair areas exhibiting horizontal creep exceeding 0.4 in. (10 mm)	Annually, repair as needed
Excessive Settlement	For settlements greater than 1 in. consult a pavement engineer versed in OGA design and construction to determine cause and correction.	As needed.
Additional Distresses	Missing pavers shall be replaced. A geotechnical investigation is recommended for pavement heaves.	Annually, repair as needed

of slip and skid resistance. The study also demonstrated that PICP systems can attenuate and buffer the release of salt back into the environment, an important finding since there is concern about snowmelt and stormwater runoff environmentally damaging lakes and rivers.

Deicer types acceptable for use in on PICP surfaces include sodium chloride, calcium chloride and potassium chloride. Do not use magnesium chloride as it will eventually destroy all concrete materials. Anti-icing agents that contain ammonium nitrate and ammonium sulfate should not be used since they can also erode concrete. Always read and follow the manufacturer's recommendations for use and heed all warnings and cautions.

Maintenance for Other Distresses

Over time and traffic, PICP can exhibit other distresses besides surface ponding from clogged joints. These are outlined in Table 2 and remedies are provided.

Utility Restoration Guidelines

1. Remove and store pavers for reuse. Secure undisturbed pavers in opening with wood or metal frame.
2. Remove and dispose of all jointing and bedding aggregate as they typically cannot be re-used.
3. Remove the aggregate base and subbase material. Incidental mixing of base and subbase aggregates is acceptable, but make every effort to separate them. Store in on impermeable pavement or a geotextile to prevent contamination. Do not reuse contaminated aggregate.
4. Re-compact subgrade material as required for stability during utility repairs.
5. Repair or install utility as required.
6. If below the bottom of the subbase, place and compact dense-graded road base in lifts not exceeding 6 in. (150 mm) and compact to 100 percent of standard Proctor maximum dry density. The top of the dense-graded aggregate should be at the same elevation as the bottom of the open-graded subbase aggregate. Alternately flowable fill could be used to reestablish the subgrade surface.
7. Reinstate and compact the subbase aggregate in minimum 6 in. (150 mm) lifts. Use a minimum 13,500 (65 kN) plate compactor with a compaction indicator. Add new subbase aggregate if needed.
8. Reinstate and compact the base aggregate as one 4 in. (100 mm) lift. Use a minimum 13,500 lbf (65 kN) plate compactor with a compaction indicator. A lightweight deflectomer (LWD) can be used to ensure that deflections of the compacted base aggregate are below an average of 0.5 mm (assuming a minimum 12 in. (300 mm)) compacted aggregate subbase. An LWD should be used according to ASTM E2835.
9. Place and screed new bedding aggregate in a consistent thickness layer between 1.5 and 2 in. (38 and 50 mm).
10. Reinstate pavers with at surface at least 1 in. (25 mm) higher than the final elevation. Compact the pavers in two perpendicular directions with a minimum 5,000 lbf (22 kN) plate compactor. Fill joints with aggregate, sweep away excess, and compact the pavers in two perpendicular directions again. Compact pavers so they are level with surrounding pavers.
11. Sweep surface clean and remove any excess aggregate and debris.

Other recommendations include keeping all removed materials clean and free of sediment and debris. Minimize excess debris from construction activities and equipment entering the permeable surface. Store all materials away from the permeable surface, otherwise separate materials from the permeable surface with geotextile. Pavement cuts located parallel and close to the wheel path should be extended to include the wheel path. Cuts located within 3 ft (1 m) of a curb or construction joint should include the removal of the adjacent base and subbase to the edge of the curb or construction joint.

References

Drake, et al. (2020), "De-icing Operations for Permeable Interlocking Concrete Pavements", University of Toronto, Dept. of Civil and Mineral Engineering

Danz, et al. (2020), "Assessment of Restorative Maintenance Practices on the Infiltration Capacity of Permeable Pavement", U.S. Geological Survey, Middleton, WI

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BOD Approved: August 2020

Appendix B – Draft Stormwater Pollution Prevention Plan (SWPPP)

SECTION 1: CONTACT INFORMATION/RESPONSIBLE PARTIES

To be completed prior to construction

SECTION 2: SITE EVALUATION, ASSESSMENT, AND PLANNING

2.1 Project/Site Information

Project Name and Address

Project/Site Name: Sheldon West
Street/Location: 1139 West St
City: Wrentham
State: Massachusetts
ZIP Code: 02093

Project Latitude/Longitude

Latitude: 42.03º N
(decimal degrees)

Longitude: - 71.39 º W
(decimal degrees)

Latitude/longitude data source: ☒ Map ☐ GPS ☐ Other (please specify):

Horizontal Reference Datum: ☐ NAD 27 ☒ NAD 83 ☐ WGS 84

Additional Site Information

Is your site located on Indian country lands, or on a property of religious or cultural significance to an Indian Tribe? ☐ Yes ☒ No

If yes, provide the name of the Indian Tribe associated with the area of Indian country (including the name of Indian reservation if applicable), or if not in Indian country, provide the name of the Indian Tribe associated with the property:

2.2 Discharge Information

Does your project/site discharge stormwater into a Municipal Separate Storm Sewer System (MS4)?

Are there any waters of the U.S. within 50 feet of your project's earth disturbances?

☐ Yes ☒ No

☐ Yes ☒ No

2.3 Nature of the Construction Activities

General Description of Project

Construction will include development of an undeveloped site consisting of mostly open grassed areas. Trees and shrubbery will be removed within the limit of work. Nine single family (senior living community) units will be constructed, along with the paving of a looping road for access. An on-site septic system will be constructed to service these 9 units. Earthwork will need to be done across the whole site in order to meet the required finished grades, with the need for a small retaining wall on the west side of the project. The drainage system being installed will include the construction of a grassed swale, setback from the looping road, leading to an infiltration basin on the east side of the property. The stormwater runoff on site will be deposited into the swale by means of ACF Rain Guardian Turrets and ACF Rain Guardian Foxholes. Water, electric, cable and telephone will be serviced from existing utilities within West Street.

Business days and hours for the project: Allowed construction hours per the Town of Wrentham

Size of Construction Site

Size of Property	Approximately 20 ½ acres
Total Area Expected to be Disturbed by Construction Activities	Approximately 4 ½ acres
Maximum Area Expected to be Disturbed at Any One Time, Including On-site and Off-site Construction Support Areas	TBD

Type of Construction Site *(check all that apply):*

☒ Single-Family Residential ☐ Multi-Family Residential ☐ Commercial ☐ Industrial

☐ Institutional ☐ Highway or Road ☐ Utility ☒ Other: Senior Living Community

Will you be discharging dewatering water from your site?	☐ Yes	☒ No
If yes, will you be discharging dewatering water from a current or former Federal or State remediation site?	☐ Yes	☒ No

Pollutant-Generating Activities

General Description of Project

Pollutant-Generating Activity (e.g., paving operations; concrete, paint, and stucco washout and waste disposal; solid waste storage and disposal; and dewatering operations)	**Pollutants or Pollutant Constituents** (e.g., sediment, fertilizers, pesticides, paints, caulks, sealants, fluorescent light ballasts, contaminated substrates, solvents, fuels)
Tree/shrub Removal	Sediment
Paving Operations	Sediment, Harmful Chemicals/Materials
Cut/Fill Earthwork	Sediment, Possible Erosion

Construction Support Activities *(only provide if applicable)*

For a project of this size, there will need to be a vehicle and equipment storage area, along with a material storage area. To fulfill the earthwork necessary, there will also have to be a borrow area. These areas have been estimated and shown on the Erosion Control Plans.

2.4 Sequence and Estimated Dates of Construction Activities

Phase I

Site Clearing, Setup Stormwater Management System and Construction Entrance	
Estimated Start Date of Construction Activities for this Phase	TBD
Estimated End Date of Construction Activities for this Phase	TBD
Estimated Date(s) of Application of Stabilization Measures for Areas of the Site Required to be Stabilized	TBD *[Add additional dates as necessary]*
Estimated Date(s) when Stormwater Controls will be Removed	TBD *[Add additional dates as necessary]*

Phase II

Install Site Furnishings, Pavement, Curbs, and Landscaping	
Estimated Start Date of Construction Activities for this Phase	TBD
Estimated End Date of Construction Activities for this Phase	TBD
Estimated Date(s) of Application of Stabilization Measures for Areas of the Site Required to be Stabilized	TBD *[Add additional dates as necessary]*
Estimated Date(s) when Stormwater Controls will be Removed	TBD *[Add additional dates as necessary]*

2.5 Authorized Non-Stormwater Discharges

List of Authorized Non-Stormwater Discharges Present at the Site

Authorized Non-Stormwater Discharge	Will or May Occur at Your Site?
Discharges from emergency fire-fighting activities	☒ Yes ☐ No
Fire hydrant flushing	☒ Yes ☐ No
Landscape irrigation	☒ Yes ☐ No
Water used to wash vehicles and equipment	☒ Yes ☐ No
Water used to control dust	☒ Yes ☐ No
Potable water including uncontaminated water line flushing	☒ Yes ☐ No
External building washdown (soaps/solvents are not used and external surfaces do not contain hazardous substances)	☒ Yes ☐ No
Pavement wash waters	☒ Yes ☐ No
Uncontaminated air conditioning or compressor condensate	☒ Yes ☐ No

Authorized Non-Stormwater Discharge	**Will or May Occur at Your Site?**
Uncontaminated, non-turbid discharges of ground water or spring water	☒ Yes ☐ No
Foundation or footing drains	☒ Yes ☐ No
Uncontaminated construction dewatering water	☒ Yes ☐ No

(Note: You are required to identify the likely locations of these authorized non-stormwater discharges on your site map. See Section 2.6, below, of this SWPPP Template.)

2.6 Site Maps

See Sheldon West Site Plan and Appendixes located in the Supplemental Data Report

SECTION 3: DOCUMENTATION OF COMPLIANCE WITH OTHER FEDERAL REQUIREMENTS

3.1 Endangered Species Protection

Eligibility Criterion

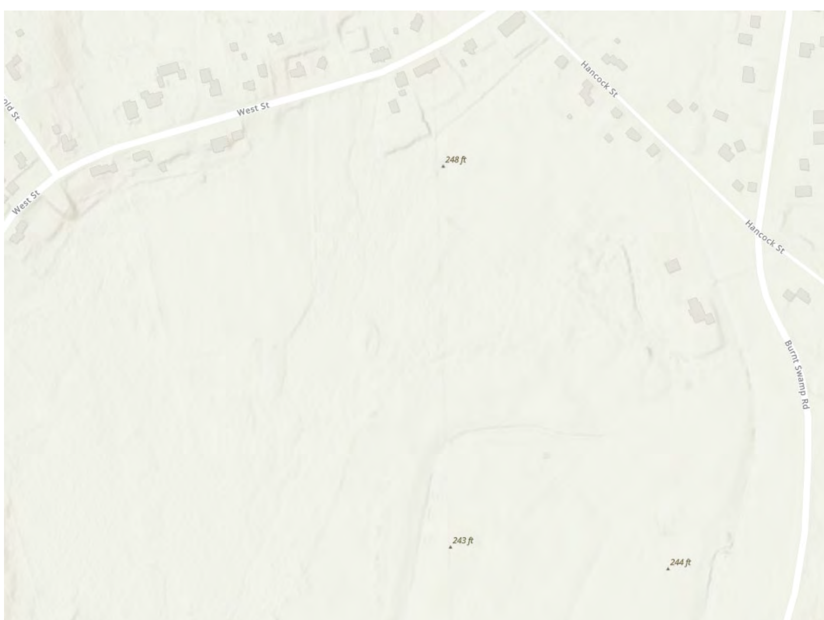
Following the process outlined in Appendix D, under which criterion are you eligible for coverage under this permit?

☒ **Criterion A**: No ESA-listed species and/or designated critical habitat present in action area. Using the process outlined in Appendix D of the CGP, you certify that ESA-listed species and designated critical habitat(s) under the jurisdiction of the USFWS or NMFS are not likely to occur in your site's "action area" as defined in Appendix A of the CGP. *Please Note: NMFS' jurisdiction includes ESA-listed marine and estuarine species that spawn in inland rivers.*

☐ Check to confirm you have provided documentation in your SWPPP as required by CGP Appendix D (Note: reliance on State resources is not acceptable; see CGP Appendix D).

Documentation: Using the USFWS and NMFS GIS service, it was determined that there were no designated critical habitats located in the vicinity of the proposed area of work.

Figure: USFWS GIS Map of Site



3.2 Historic Property Screening Process

Appendix E, Step 1

Do you plan on installing any stormwater controls that require subsurface earth disturbance, including, but not limited to, any of the following stormwater controls at your site? Check all that apply below, and proceed to Appendix E, Step 2.

☐ Dike

☐ Berm

☐ Catch Basin

☒ Pond

☒ Constructed Site Drainage Feature (e.g., ditch, trench, perimeter drain, swale, etc.)

☐ Culvert

☒ Channel

☒ Other type of ground-disturbing stormwater control: Drainage Discharge Pipes

(Note: If you will not be installing any subsurface earth-disturbing stormwater controls, no further documentation is required for Section 3.2 of the Template.)

Appendix E, Step 2

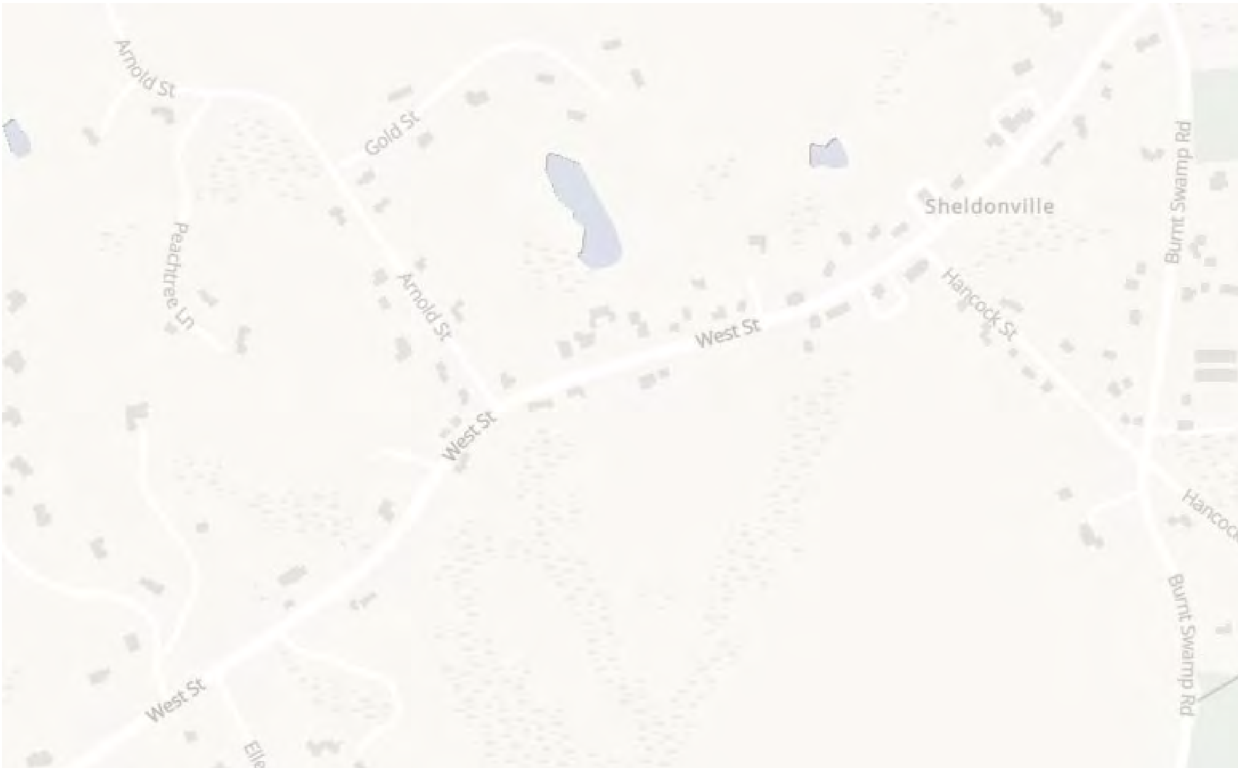
If you answered yes in Step 1, have prior professional cultural resource surveys or other evaluations determined that historic properties do not exist, or have prior disturbances at the site have precluded the existence of historic properties? ☐ YES ☒ NO

- If yes, no further documentation is required for Section 3.2 of the Template and you may provide the prior documentation in your SWPPP.
- If no, proceed to Appendix E, Step 3.

Appendix E, Step 3

If you answered no in Step 2, have you determined that your installation of subsurface earth-disturbing stormwater controls will have no effect on historic properties? ☒ YES ☐ NO

- If yes, provide documentation of the basis for your determination.
  GIS for National Register of Historic Places from US National Parks Service



- If no, proceed to Appendix E, Step 4.

Appendix E, Steps 4 and 5

If you answered no in Step 3, did the State Historic Preservation Officer (SHPO), Tribal Historic Preservation Office (THPO), or other Tribal representative (whichever applies) respond to you within 15 calendar days to indicate their views as to the likelihood that historic properties are potentially present on your site and may be impacted by the installation of stormwater controls that require subsurface earth disturbance? ☐ YES ☐ NO

- If yes, describe the nature of their response:
  - ☐ Written indication that no historic properties will be affected by the installation of stormwater controls.
  - ☐ Written indication that adverse effects to historic properties from the installation of stormwater controls can be mitigated by agreed upon actions.
  - ☐ No agreement has been reached regarding measures to mitigate effects to historic properties from the installation of stormwater controls.
  - ☐ Other:

- If no, no further documentation is required for Section 3.2 of the Template.

3.3 Safe Drinking Water Act Underground Injection Control Requirements

Do you plan to install any of the following controls? Check all that apply below.

- ☐ Infiltration trenches (if stormwater is directed to any bored, drilled, driven shaft or dug hole that is deeper than its widest surface dimension, or has a subsurface fluid distribution system)
- ☐ Commercially manufactured pre-cast or pre-built proprietary subsurface detention vaults, chambers, or other devices designed to capture and infiltrate stormwater flow
- ☐ Drywells, seepage pits, or improved sinkholes (if stormwater is directed to any bored, drilled, driven shaft or dug hole that is deeper than its widest surface dimension, or has a subsurface fluid distribution system)

SECTION 4: EROSION AND SEDIMENT CONTROLS AND DEWATERING PRACTICES

All work will stay outside of the 50' foot wetland buffer. The general erosion and sediment controls that will be used during construction include a straw wattle with silt fence backing around the perimeter of the area of work. Additionally, a construction entrance for trucks will be installed to minimize sediment track-out. All stockpiles and storage areas will be located outside of wetland no disturb buffers and will have sediment fences around them on the downslope side. No accumulated sediment will be hosed down or swept into any stormwater control devices, which will have inlet protection added from time of installation until construction has concluded.

4.1 Natural Buffers or Equivalent Sediment Controls

Buffer Compliance Alternatives

Are there any receiving waters within 50 feet of your project's earth disturbances? ☐ YES ☒ NO

(Note: If no, no further documentation is required for Section 4.1 in the SWPPP Template. Continue to Section 4.2.)

4.2 Perimeter Controls

General

- Compost Sock with Silt Fence backing will be installed around the perimeter of the limit of work for the construction project. Additionally, these same sediment control measures will be installed around the perimeter of sediment stockpiles on the downslope side.

Specific Perimeter Controls

Compost Sock with Silt Fence Backing	
Description: A fence consisting of filter fabric and wooden posts will be installed with compost sock backing to prevent siltation of areas downslope from the proposed work.	
Installation	Insert approximate date of installation
Maintenance Requirements	Remove sediment before it has accumulated to one-half of the above-ground height of any perimeter control. After a storm event, if there is evidence of stormwater circumventing or undercutting the perimeter control, extend controls and/or repair undercut areas to fix the problem.
Design Specification	See Site Plan Detail Sheet 10.1 and 10.2

4.3 Sediment Track-Out

General

- A stabilized construction entrance and exit will be installed in order to minimize sediment track-out, with vehicle washing station.

Specific Track-Out Controls

Stabilized Construction Entrance/Exit	
Description: Gravel/stone area that trucks must use before accessing public roads	
Installation	TBD
Maintenance Requirements	Where sediment has been tracked-out from the site onto paved roads, sidewalks, or other paved areas outside of your site, remove the deposited sediment by the end of the same business day in which the track-out occurs or by the end of the next business day if track-out occurs on a non-business day. Remove the track-out by sweeping, shoveling, or vacuuming these surfaces, or by using other similarly effective means of sediment removal. Hosing or sweeping tracked-out sediment into any constructed or natural site drainage feature, storm drain inlet, or receiving water is prohibited.
Design Specifications	See Site Plan Detail sheet 10.1

4.4 Stockpiles or Land Clearing Debris Piles Comprised of Sediment or Soil

General

- Compost Sock with silt fence backing will be installed around the downslope portion of stockpile areas. For piles that are unused for more than 14 days, appropriate cover will be applied.

Specific Stockpile Controls

Compost sock with Silt Fence Backing	
Description: Same as Perimeter Control	
Installation	TBD
Maintenance Requirements	Same as Perimeter Control

Compost sock with Silt Fence Backing	
Design Specifications	Same as Perimeter Control

4.5 Minimize Dust

General

- In areas of exposed soil, the appropriate application of water or other dust suppression techniques will be used to control the generation of pollutants that could be discharged in stormwater from the site.

Specific Dust Controls

Misting Water Spray	
Description: Periodic water misting spray from truck that will reduce airborne dust from demolition work and earthwork.	
Installation	Periodic Application to ground within limit of work
Maintenance Requirements	TBD
Design Specifications	TBD

[Repeat as needed for individual dust controls.]

4.6 Minimize Steep Slope Disturbances

General

- Insert general description of how you will comply with CGP Part 2.2.7

Specific Steep Slope Controls

TBD	
Description: TBD	
Installation	TBD
Maintenance Requirements	TBD
Design Specifications	TBD

[Repeat as needed for individual steep slope controls.]

4.7 Topsoil

General

- Cut topsoil will be screened and stored onsite in designated areas for later use. Only the topsoil that needs to be cut/filled will be disturbed, the rest can remain undisturbed.

Specific Topsoil Controls

TBD	
Description: TBD	
Installation	TBD
Maintenance Requirements	TBD
Design Specifications	TBD

4.8 Soil Compaction

General

- Excessive vehicle and equipment use will be prohibited in the proposed infiltration basin area and field area associated with the septic system so as to not affect the designed infiltration rate of the soil. Before seeding this same area, rehabilitative techniques will be used on the soil to support vegetative growth.

Specific Soil Compaction Controls

TBD	
Description: TBD	
Procedure	TBD
Maintenance Requirements	N/A
Design Specifications	TBD

4.9 Storm Drain Inlets

General

- There are no pre-existing stormwater BMPs on the construction site, temporary inlet protection will be placed into the new inlets after they are installed in the construction process. Any downstream catch basins in West Street will be installed with temporary inlet protection.

Specific Storm Drain Inlet Controls

Silt Sack	
Description: Silt sack that is placed within inlet to catch excess sediment.	
Installation	TBD
Maintenance Requirements	Clean, or remove and replace, the inlet protection measures as sediment accumulates, the filter becomes clogged, and/or performance is compromised. Where there is evidence of sediment accumulation adjacent to the inlet protection measure, remove the deposited sediment by the end of the same business day in which it is found or by the end of the following business day if removal by the same business day is not feasible.
Design Specifications	See detail sheet C10.1

Compost Sock Barrier	
Description: Compost Sock Barrier for pervious pavers and curb inlets	
Installation	TBD
Maintenance Requirements	Clean, or remove and replace, the inlet protection measures as sediment accumulates, the filter becomes clogged, and/or performance is compromised. Where there is evidence of sediment accumulation adjacent to the inlet protection measure, remove the deposited sediment by the end of the same business day in which it is found or by the end of the following business day if removal by the same business day is not feasible.
Design Specifications	TBD

4.10 Constructed Site Drainage Feature

General

- Temporary Sediment basins will be installed around the site to collect sediment runoff during construction.

Specific Constructed Site Drainage Features

Temporary Sediment Basins	
Description: TBD	
Installation	TBD
Maintenance Requirements	TBD
Design Specifications	TBD

4.11 Sediment Basins or Similar Impoundments

General

- N/A

Specific Sediment Basin Controls

Insert name of sediment basin control to be installed	
Description: Insert description of sediment basin control to be installed	
Installation	Insert approximate date of installation
Maintenance Requirements	Insert maintenance requirements for the sediment basin control. (Note: At a minimum, you must comply with following requirement in CGP Part 2.2.12.f: "Remove accumulated sediment to maintain at least one-half of the design capacity and conduct all other appropriate maintenance to ensure the basin or impoundment remains in effective operating condition.")
Design Specifications	Include copies of design specifications here

4.12 Chemical Treatment

Soil Types

List all the soil types including soil types expected to be exposed during construction in areas of the project that will drain to chemical treatment systems and those expected to be found in fill material: N/A

Treatment Chemicals

List all treatment chemicals that will be used at the site and explain why these chemicals are suited to the soil characteristics: N/A

Describe the dosage of all treatment chemicals you will use at the site or the methodology you will use to determine dosage: N/A

Provide information from any applicable Safety Data Sheets (SDS): N/A

Describe how each of the chemicals will be stored consistent with CGP Part 2.2.13c: N/A

Include references to applicable State or local requirements affecting the use of treatment chemicals, and copies of applicable manufacturer's specifications regarding the use of your specific treatment chemicals and/or chemical treatment systems: N/A

Special Controls for Cationic Treatment Chemicals (if applicable)

If the applicable EPA Regional Office authorized you to use cationic treatment chemicals, include the official EPA authorization letter or other communication, and identify the specific controls and implementation procedures designed to ensure that your use of cationic treatment chemicals will not lead to a discharge that does not meet water quality standards: N/A

Schematic Drawings of Stormwater Controls/Chemical Treatment Systems

Provide schematic drawings of any chemically enhanced stormwater controls or chemical treatment systems to be used for application of treatment chemicals: N/A

Training

Describe the training that personnel who handle and apply chemicals have received prior to permit coverage, or will receive prior to the use of treatment chemicals: N/A

4.13 Dewatering Practices

General

- N/A

Specific Dewatering Practices

N/A	
Description: N/A	
Installation	N/A
Maintenance Requirements	N/A
Design Specifications	N/A

[Repeat as needed for individual dewatering practices.]

4.14 Other Stormwater Controls

General

- N/A

Specific Stormwater Control Practices

N/A	
Description: N/A	
Installation	N/A
Maintenance Requirements	N/A
Design Specifications	N/A

4.15 Site Stabilization

Total Amount of Land Disturbance Occurring at Any One Time

☒ *Five Acres or less*
☐ *More than Five Acres*

Use this template box if you are <u>not</u> located in an arid, semi-arid, or drought-stricken area and are not discharging to a sediment- or nutrient-impaired water or Tier 2, Tier 2.5, or Tier 3 water.

Insert name of site stabilization practice	
☒ *Vegetative* ☐ *Non-Vegetative* ☐ *Temporary* ☒ *Permanent*	
Description: ▪ Slopes to be loamed and seeded ▪ Will be completed as soon as construction activities have permanently ceased.	
Installation	Insert approximate date of installation

Insert name of site stabilization practice	
Completion	Insert approximate completion date
Maintenance Requirements	Insert maintenance requirements for the stabilization practice
Design Specifications	Include copies of design specifications here

[Repeat as needed for additional stabilization practices.]

Use this template box if you are located in an arid, semi-arid, or drought-stricken area.

Insert name of site stabilization practice	
☐ *Vegetative* ☐ *Non-Vegetative* ☐ *Temporary* ☐ *Permanent*	
Description: ▪ Insert description of stabilization practice to be installed ▪ Note how design will meet requirements of Part 2.2.14.b	
Dry Period	▪ Beginning month of seasonally dry period: Insert approximate date ▪ Ending month of seasonally dry period: Insert approximate date ▪ Site conditions during this period: Describe your site conditions during this period
Installation and completion schedule	Describe the schedule you will follow for initiating and completing vegetative stabilization ▪ Approximate installation date: Insert approximate date ▪ Approximate completion date: Insert approximate date
Maintenance Requirements	Insert maintenance requirements for the stabilization practice
Design Specifications	Include copies of design specifications here

[Repeat as needed for additional stabilization practices.]

Use this template box if you are discharging to a sediment- or nutrient-impaired water or to a water that is identified by your State, Tribe, or EPA as Tier 2, Tier 2.5, or Tier 3 for antidegradation purposes.

Insert name of site stabilization practice	
☐ *Vegetative* ☐ *Non-Vegetative* ☐ *Temporary* ☐ *Permanent*	
Description: ▪ Insert description of stabilization practice to be installed ▪ Note how design will meet requirements of Part 2.2.14.b.iii	
Installation	Insert approximate date of installation
Completion	*(Must be completed as soon as practicable, but no later than seven calendar days after stabilization has been initiated)* Insert approximate completion date
Maintenance Requirements	Insert maintenance requirements for the stabilization practice
Design Specifications	Include copies of design specifications here

[Repeat as needed for additional stabilization practices.]

Use this template box if unforeseen circumstances have delayed the initiation and/or completion of vegetative stabilization. Note: You will not be able to include this information in your initial SWPPP. If you are affected by circumstances such as those described in CGP Part 2.2.14.b.ii, you will need to modify your SWPPP to include this information.

<table>
<tr><th colspan="2">TBD</th></tr>
<tr><td colspan="2">☐ Vegetative ☐ Non-Vegetative
☐ Temporary ☐ Permanent</td></tr>
<tr><td colspan="2">Description:

▪ Insert description of stabilization practice to be installed
▪ Note how design will meet requirements of Part 2.2.14.b.ii</td></tr>
<tr><td>Justification</td><td>Insert description of circumstances that prevent you from meeting the deadlines required in CGP CGP Parts 2.2.14.a</td></tr>
<tr><td rowspan="2">Installation and completion schedule</td><td>Vegetative Measures:
Describe the schedule you will follow for initiating and completing vegetative stabilization
▪ Approximate installation date: Insert approximate date
▪ Approximate completion date: Insert the approximate date</td></tr>
<tr><td>Non-Vegetative Measures:
(Must be completed within 14 days of the cessation of construction if disturbing 5 acres or less; within 7 days if disturbing more than 5 acres)
▪ Approximate installation date: Insert the approximate date
▪ Approximate completion date: Insert the approximate date</td></tr>
<tr><td>Maintenance Requirements</td><td>Insert maintenance requirements for the stabilization practice</td></tr>
<tr><td>Design Specifications</td><td>Include copies of design specifications here</td></tr>
</table>

SECTION 5: POLLUTION PREVENTION CONTROLS

5.1 Potential Sources of Pollution

Construction Site Pollutants

Pollutant-Generating Activity	**Pollutants or Pollutant Constituents** (That could be discharged if exposed to stormwater)	**Location on Site** (Or reference SWPPP site map where this is shown)
Paving Operations	Sediment, asphalt	Looping Road
Concrete Placement		
Road Striping		
Waste disposal		
Vehicle Emissions		
General Construction work		

[Include additional rows as necessary.]

5.2 Spill Prevention and Response

Insert spill prevention and response procedures here

5.3 Fueling and Maintenance of Equipment or Vehicles

General

- Have spill kits readily available at all times

Specific Pollution Prevention Practices

Insert name of pollution prevention practice	
Description: Insert description of practice to be implemented	
Implementation	Insert approximate date of implementation
Maintenance Requirements	Insert maintenance requirements for the pollution prevention practice
Design Specifications	If applicable include copies of design specifications here

5.4 Washing of Equipment and Vehicles

General

- TBD

Specific Pollution Prevention Practices

TBD	
Description: TBD	
Implementation	TBD
Maintenance Requirements	TBD

TBD	
Design Specifications	TBD

5.5 Storage, Handling, and Disposal of Building Products, Materials, and Wastes

5.5.1 Building Materials and Building Products

(Note: Examples include asphalt sealants, copper flashing, roofing materials, adhesives, concrete admixtures, and gravel and mulch stockpiles.)

General

Specific Pollution Prevention Practices

TBD	
Description: TBD	
Implementation	TBD
Maintenance Requirements	TBD
Design Specifications	TBD

[Repeat as needed.]

5.5.2 Pesticides, Herbicides, Insecticides, Fertilizers, and Landscape Materials

General

- N/A

Specific Pollution Prevention Practices

TBD	
Description: N/A	
Implementation	TBD
Maintenance Requirements	N/A
Design Specifications	N/A

[Repeat as needed.]

5.5.3 Diesel Fuel, Oil, Hydraulic Fluids, Other Petroleum Products, and Other Chemicals

General

- Diesel fuel stored on site will be stored in water-tight containers and will be covered to minimize exposure to precipitation and stormwater. Spill kits will be available at all times on site to handle potential fuel spills. If there are any spills, dry cleanup methods will be used when possible. Fuels and potentially hazardous fluids will always be stored at least 50 feet from all wetlands and bodies of water.
- Note: The requirements in CGP Part 2.3.3.c differ based on whether you chemical containers on your site are less than 55 gallons, or 55 gallons or more. See CGP Parts 2.3.3.c.i and ii.

Specific Pollution Prevention Practices

Fuel Spill Kits	
Description: Provides methods to mitigate contamination from fuel spills	
Implementation	TBD
Maintenance Requirements	N/A

Fuel Spill Kits	
Design Specifications	TBD

[Repeat as needed.]

5.5.4 Hazardous or Toxic Waste

(Note: Examples include paints, caulks, sealants, fluorescent light ballasts, solvents, petroleum-based products, wood preservatives, additives, curing compounds, and acids.)

General

Insert general description of how you wil comply with CGP Part 2.3.3.d

Specific Pollution Prevention Practices

TBD	
Description: TBD	
Implementation	TBD
Maintenance Requirements	TBD
Design Specifications	TBD

[Repeat as needed.]

5.5.5 Construction and Domestic Waste

(Note: Examples include packaging materials, scrap construction materials, masonry products, timber, pipe and electrical cuttings, plastics, styrofoam, concrete, demolition debris, and other trash or discarded materials.)

General

- Dumpsters of sufficient size and number will be provided to contain construction wastes.
- If there are wastes that are subject to the exception in Part 2.3.3.e.ii, describe the specific wastes that will be stored on your site. N/A

Specific Pollution Prevention Practices

Construction Waste Dumpsters	
Description: Containers to hold waste from Construction Process	
Implementation	TBD
Maintenance Requirements	If dumpsters overflow, empty immediately
Design Specifications	Covered dumpsters are preferred in order to mitigate potential exposure to precipitation

[Repeat as needed.]

5.5.6 Sanitary Waste

General

- Portable toilets will be positioned so that they are secure and will not be tipped or knocked over. They will be located as far as possible from bodies of water and wetlands.

Specific Pollution Prevention Practices

TBD	
Description: TBD	
Implementation	TBD
Maintenance Requirements	TBD
Design Specifications	TBD

[Repeat as needed.]

5.6 Washing of Applicators and Containers used for Stucco, Paint, Concrete, Form Release Oils, Cutting Compounds, or Other Materials

General

- When washing applicators and containers, wash water will be directed a leak proof container or leak proof pit so that no overflows can occur. Concrete waste should be removed similarly to how other construction waste is removed.

Specific Pollution Prevention Practices

TBD	
Description: TBD	
Implementation	TBD
Maintenance Requirements	TBD
Design Specifications	TBD

5.7 Application of Fertilizers

General

- TBD

Specific Pollution Prevention Practices

TBD	
Description: TBD	
Implementation	TBD
Maintenance Requirements	TBD
Design Specifications	TBD

[Repeat as needed for individual fertilizer practices.]

SECTION 6: INSPECTION, MAINTENANCE, AND CORRECTIVE ACTION

6.1 Inspection Personnel and Procedures

Site Inspection Schedule

Select the inspection frequency(ies) that applies, based on CGP Parts 4.2, 4.3, or 4.4

(Note: you may be subject to different inspection frequencies in different areas of the site. Check all that apply and indicate which portion(s) of the site it applies to.)

Standard Frequency:
☐ Every 7 calendar days ☒ Every 14 calendar days and within 24 hours of either: ▪ A storm event that produces 0.25 inches or more of rain within a 24-hour period (including when there are multiple, smaller storms that alone produce less than 0.25 inches but together produce 0.25 inches or more in 24 hours), or ▪ A storm event that produces 0.25 inches or more of rain within a 24-hour period on the first day of a storm and continues to produce 0.25 inches or more of rain on subsequent days (you conduct an inspection within 24 hours of the first day of the storm and within 24 hours after the last day of the storm that produces 0.25 inches or more of rain (i.e., only two inspections would be required for such a storm event)), or ▪ A discharge caused by snowmelt from a storm event that produces 3.25 inches or more of snow within a 24-hour period.
Increased Frequency (if applicable):
For areas of sites discharging to sediment or nutrient-impaired waters or to waters designated as Tier 2, Tier 2.5, or Tier 3 ☐ Every 7 days and within 24 hours of either: ▪ A storm event that produces 0.25 inches or more of rain within a 24-hour period, or ▪ A discharge caused by snowmelt from a storm event that produces 3.25 inches or more of snow within a 24-hour period.
Reduced Frequency (if applicable)

For stabilized areas

☒ Twice during first month, no more than 14 calendar days apart; then once per month after first month until permit coverage is terminated consistent with Part 9 in any area of your site where the stabilization steps in 2.2.14.a have been completed.

- Specify locations where stabilization steps have been completed
- Insert date that they were completed
  (Note: It is likely that you will not be able to include this in your initial SWPPP. If you qualify for this reduction (see CGP Part 4.4.1), you will need to modify your SWPPP to include this information. If construction activity resumes in this portion of the site at a later date, the inspection frequency immediately increases to that required in Parts 4.2 and 4.3, as applicable.)

For stabilized areas on "linear construction sites" (as defined in Appendix A)

☒ Twice during first month, no more than 14 calendar days apart; then once more within 24 hours of a storm event that produces 0.25 inches or more of rain within a 24-hour period, or within 24 hours of a snowmelt discharge from a storm event that produces 3.25 inches or more of snow within a 24-hour period

- Specify locations where stabilization steps have been completed
- Insert date that they were completed
  (Note: It is likely that you will not be able to include this in your initial SWPPP. If you qualify for this reduction (see CGP Part 4.4.1), you will need to modify your SWPPP to include this information.)

For arid, semi-arid, or drought-stricken areas during seasonally dry periods or during drought

☐ Once per month and within 24 hours of either:

- A storm event that produces 0.25 inches or more of rain within a 24-hour period, or
- A snowmelt discharge from a storm event that produces 3.25 inches or more of snow within a 24-hour period.

Insert beginning and ending month identified as the seasonally dry period for your area or the valid period of drought:

- Beginning month of the seasonally dry period: Insert approximate date
- Ending month of the seasonally dry period: Insert approximate date

For frozen conditions where construction activities are being conducted
☐ Once per month Insert beginning and ending dates of frozen conditions on your site: ▪ Beginning date of frozen conditions: Insert approximate date ▪ Ending date of frozen conditions: Insert approximate date
For frozen conditions where construction activities are suspended
☒ Inspections are temporarily suspended Insert beginning and ending dates of frozen conditions on your site: ▪ Beginning date of frozen conditions: Insert approximate date ▪ Ending date of frozen conditions: Insert approximate date

Dewatering Inspection Schedule

Select the inspection frequency that applies based on CGP Part 4.3.2

Dewatering Inspection
☐ Once per day on which the discharge of dewatering water occurs.

Rain Gauge Location (if applicable)

TBD

Inspection Report Forms

Inspection Report

Project Name: Sheldon West, Wrentham MA

SWPPP Contact:

Inspections shall be conducted at least once every fourteen (14) days and within 24 hours of the end of a storm event of one-half inch (0.5”) or greater.

Inspection Type: ❑ Routine (14 calendar days) ❑ Pre-Storm

❑ During Storm ❑ Post-Storm

Name of Inspector: ____________________________ Date of Inspection: ______________________

Weather / Storm Event Information: ____

Storm Start Time: _____________________ Storm Duration: _____________________________

Time Elapsed Since Last Storm: _____________ Approx. Amount of Rainfall: ________________

Start date of major grading activities: ____

Date when construction activities temporarily cease on portions of the site: ___________________

Date when construction activities permanently cease on portions of the site: ___________________

Date when stabilization measures are initiated: ____

____

Identify those portions of the site which are stabilized: ______________________________________

____

Location(s) of discharges of sediment or other pollutants from site: ______________________________

____

Location(s) of BMPs that need to be maintained: ____

____

Location(s) of BMPs that failed to operate as designed or proved inadequate for a particular location:

____

____

Location(s) where additional BMPs are needed: ______________________________

____

Corrective action required, including any changes to the SWPPP and/or implementation dates: _____

____

6.2 Corrective Action

Personnel Responsible for Corrective Actions
TBD

(Note: EPA has developed a sample corrective action log that CGP operators can use. The form is available at https://www.epa.gov/npdes/stormwater-discharges-construction-activities#resources)

6.3 Delegation of Authority

Duly Authorized Representative(s) or Position(s):
TO BE DETERMINED AT A LATER DATE

Delegation of Authority

I, ________________________ (name), hereby designate the person or specifically described position below to be a duly authorized representative for the purpose of overseeing compliance with environmental requirements, including the Construction General Permit, at the ______________________________________ construction site. The designee is authorized to sign any reports, stormwater pollution prevention plans and all other documents required by the permit.

____ (name of person or position)

____ (company)

____ (address)

____ (city, state, zip)

____ (phone)

By signing this authorization, I confirm that I meet the requirements to make such a designation as set forth in Appendix I of EPA's Construction General Permit (CGP), and that the designee above meets the definition of a "duly authorized representative" as set forth in Appendix I.

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gathered and evaluated the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Name: ____

Company: ____

Title: ____

Signature: ____

Date: ____

SECTION 7: TURBIDITY BENCHMARK MONITORING FOR DEWATERING DISCHARGES

Procedures:

Collecting and evaluating samples	**TBD**
Reporting results and keeping monitoring information records	**TBD**
Taking corrective action when necessary	**TBD**

Turbidity Meter:

Type of turbidity meter	**TBD**

Turbidity meter manuals and manufacturer instructions

Coordinating Arrangements for Turbidity Monitoring (if applicable):

Permitted operator name	TBD
Permitted operator NPDES ID	TBD
Coordinating Arrangement	TBD

[Repeat as necessary.]

Alternate turbidity benchmark (if applicable):

Alternate turbidity benchmark (NTU)	TBD
Data and documentation used to request the alternate benchmark	TBD

SECTION 8: CERTIFICATION AND NOTIFICATION

To be completed at a later date

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gathered and evaluated the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I have no personal knowledge that the information submitted is other than true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

Name: ______________________________ Title: ______________________________

Signature: ______________________________________ Date: __________________

SWPPP APPENDICES

Attach the following documentation to the SWPPP:

Appendices to be completed at a later date.

Appendix C – Proprietary BMP Information

ACF Rain Guardian Turret/Bunker/Foxhole

UNIVERSITY OF MINNESOTA

ST. ANTHONY FALLS LABORATORY
Engineering, Environmental and Geophysical Fluid Dynamics

Project Report No. 586

Capture of Gross Solids and Sediment by Pretreatment Practices for Bioretention

Final Report for the Project:
Field performance assessment of sediment and gross solids removal from surface inlet pretreatment practices for bioretention

by

Andrew J. Erickson and Matt A. Hernick

St. Anthony Falls Laboratory, University of Minnesota,
2 Third Avenue SE Minneapolis, MN 55455

Prepared for
University of Minnesota Water Resources Center,
Minnesota Stormwater Research Council
and
Anoka Conservation District

January 2019
Minneapolis, Minnesota

This project was supported by the University of Minnesota Water Resources Center and by the Minnesota Stormwater Research Council with financial contributions from

- Capitol Region Watershed District
- Mississippi Watershed Management Organization
- Ramsey-Washington Metro Watershed District
- South Washington Watershed District
- Valley Branch Watershed District, and
- City of Edina

For more information about the Center and the Council, visit https://www.wrc.umn.edu/projects/storm-waste-water

Water Resources Center

UNIVERSITY OF MINNESOTA
Driven to Discover℠

EXECUTIVE SUMMARY

The purpose of this project was to measure the performance of several pretreatment practices for bioretention, both proprietary and non-proprietary, commonly used in Minnesota using field-based performance testing. Five pretreatment practices for bioretention were assessed for capturing sediment and gross solids with field testing.

Most bioretention practices in Minnesota are designed to store the volume of runoff from a 1-inch rainfall event. Design volume tests involved measuring performance at the design storage volume (full storage volume before bypass) of the bioretention practice and were completed for four pretreatment practices. For this testing, the full design storage volume was added from a fire hydrant to the pretreatment and bioretention within 40 minutes (low intensity) or within 20 minutes (high intensity). The pretreatment and bioretention practices were not allowed to overflow or bypass during the design volume tests. Four pretreatment practices were tested, including:

- grass lined inlet (i.e., grassed buffer strip),
- Rain Guardian Bunker proprietary device,
- Rain Guardian Turret proprietary device,
- rock lined inlet (i.e., riprap).

A fifth pretreatment practice, an in-line shallow sump grit chamber, was tested for performance when the design storage volume was added in 30 minutes (low intensity) and 15 minutes (high intensity). The shallow sump grit chamber was also with bypass conditions, which involved adding approximately two and a half times the design volume to the pretreatment and bioretention practice, causing the system to overflow and bypass some water and solids to the downstream conveyance system. The goal of this testing was to determine the performance of an in-line shallow sump grit chamber under bypass conditions.

Prior to testing each pretreatment practice was thoroughly cleaned. Three sediment sizes including a coarse sediment (D_{50} = 1.17mm), a medium sediment (D_{50} = 0.41mm), and a fine sediment (D_{50} = 0.12mm) and three types of gross solids (plastic forks, synthetic leaves, and wood dowels) were added to water from a fire hydrant throughout the duration of each test. After testing was complete, sediment and gross solids were collected and then analyzed at St. Anthony Falls Laboratory to determine capture performance.

Summary of Results

All five pretreatment practices captured greater than 88% of the total sediment and greater than 65% of the fine sediment fraction (D_{50} = 0.12mm) in the low intensity tests, from an initially clean condition. During the high intensity tests, all practices captured greater than 70% of the total sediment mass and greater than 30% of the fine sediment fraction, similarly from an initially clean condition. Four of the five pretreatment practices captured 75% of the gross solids during low intensity tests and more than 55% of the gross solids during high intensity tests. The grass lined inlet captured the least gross solids; 20% during low intensity and 30% during high intensity. The performance for several sequential tests and maintenance needed for long-term operation of these pretreatment practices was not measured in this project.

Bypass tests were conducted to determine the performance of an in-line shallow sump grit chamber under bypass conditions. During these tests, overall sediment captured decreased from 95% during low intensity design volume tests down to 80% capture during high intensity bypass tests. Gross solids capture decreased from greater than 80% to below 40%. Thus, bypass at these flow rates had minimal effect on the sediment, but measurable effect on the gross solids performance.

Though at least four of the five pretreatment practices performed similarly in terms of sediment and gross solids capture, only three out of the five appear to be simple to inspect and maintain. When maintenance is required, the grass lined inlet and rock lined inlet likely require the same amount of effort and cost to maintain them as would be needed to install them. In addition, the grass lined inlet and rock lined inlet would likely become filled with sediment within a few storm events. Of the pretreatment practices tested in this study, the grass lined inlet and rock lined inlet are among the most difficult and costly to maintain.

To maintain the Rain Guardian Bunker, Rain Guardian Turret, and shallow sump, one would need to remove the top grate and either shovel or hydro-vac the collected sediment and gross solids from within the collection chamber. The Bunker and Turret are both easily visible from the street so visual inspections of accumulated sediment depth are simple. The shallow sump is hidden underground, which makes assessing sediment accumulation depth more challenging. The Bunker, Turret, and shallow sump appear to have ample storage volume for collection and retaining sediment and gross solids. Of the pretreatment practices tested in this study, the Bunker and Turret are among the easiest to maintain, and the shallow sump is moderately easy to maintain.

Partnerships

This project was funded by the Minnesota Stormwater Research Council with additional funding and in-kind support provided by Anoka Conservation District. St. Anthony Falls Laboratory conducted the field testing and laboratory analysis; Anoka Conservation District provided staff and materials to install pretreatment practices to be consistent with industry standards.

ACKNOWLEDGEMENTS

This project was supported by the University of Minnesota Water Resources Center and by the Minnesota Stormwater Research Council with financial contributions from:

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For more information about the Center and the Council, visit https://www.wrc.umn.edu/projects/storm-waste-water

In addition, this project was supported by the Anoka Conservation District (ACD). The authors wish the thank the Water Resources Center and the Minnesota Stormwater Research Council and affiliated entities for provided funding to support this project. In addition, the authors wish to thank the ACD for provided funding and in-kind match (labor and materials) for this project.

Support and assistance from several organizations and individuals are listed below and is greatly appreciated. Support and assistance for the contracting process was provided by Jeff Peterson, John Bilotta, Ann Lewandowski, Cheryel Konate, Jenni Larson, Chris Lord, and Jared Wagner. In addition, Chris Lord, Jared Wagner, Mitch Haustein, and Jackson Miller (MN Conservation Corps Apprentice) provided in-kind support via labor and materials throughout testing conducted in Anoka. Support provided by St. Anthony Falls Laboratory (SAFL) staff and students include Rob Gabrielson, Peter Olson, Ben Erickson, Jim Tucker, Rikita Patel, Camila Merino-Franco, and Parker Brown.

The Cities of Anoka and Bloomington, MN provided staff, access to fire hydrants, and supplied water meters and hose for use in field testing. The authors wish to thank Marcus Mihelich from the City of Anoka, and Steve Gurney, Pat Conrad, and Ben Whitcomb from the City of Bloomington for their assistance. The City of Anoka donated 12,939 cubic feet of water and the City of Bloomington donated 1,560 cubic feet of water for field testing. In addition, owners of the property on which the rain gardens were located cooperated with field testing and supplied garden hose and donated water for field testing.

TABLE OF CONTENTS

FIGURES

TABLES

ACRONYMS AND ABBREVIATIONS

ACD = Anoka Conservation District

BBP = Bloomington Bypass (Shallow sump grit chamber, nonproprietary, City of Bloomington design)

BDV = Bloomington Design Volume (Shallow sump grit chamber, nonproprietary, City of Bloomington design)

BP = Bypass

cfs = cubic feet per second

GLI = Grass Lined Inlet

MSRC = Minnesota Stormwater Research Council

RGB = Rain Guardian Bunker

RGT = Rain Guardian Turret

RLI = Rock Lined Inlet

RPD = Relative Percent Difference

SAFL = St. Anthony Falls Laboratory

TD = Total Duration

UMN = University of Minnesota

CHAPTER 1: INTRODUCTION

Bioretention practices, often called rain gardens, have become an increasingly common stormwater treatment option in Minnesota. Beyond stormwater treatment, bioretention areas have aesthetic and other benefits and may be designed in a variety of ways to fit the characteristics of a given site. A primary purpose for these practices, however, is to capture sediment from stormwater while it infiltrates into the bioretention media. This sediment can accumulate over time and eventually clog a bioretention cell. Thus, pretreatment of incoming stormwater is an integral part of the treatment process and is required for bioretention by the Minnesota Stormwater Manual, as described in "Design Criteria for Bioretention:"

> *"Warning: To prevent clogging of the infiltration or filtration system with trash, gross solids, and particulate matter, use of a pretreatment device such as a vegetated filter strip, vegetated swale, small sedimentation basin (forebay), or water quality inlet (e.g., grit chamber) to settle particulates before the stormwater discharges into the infiltration or filtration system is REQUIRED." (MPCA 2017a)*

The Minnesota Stormwater Manual also describes criteria for pretreatment (settling devices, screens, and vegetative filter strips), and provides performance recommendations:

> *"It is recommended that pretreatment practices be designed for easy maintenance and capture a minimum of 25 percent of the sediment from runoff. Pretreatment practices capture solids that are quickly settled or screened, including gross solids and most sand particles (roughly 100 microns (µm) and larger), although some pretreatment practices also capture floatables. In many watersheds, this material accounts for a large portion of the total pollutant load." (MPCA 2017b)*

Actual data on the effectiveness of pretreatment practices, whether from field studies or laboratory or field testing, is limited or varies widely in method and results. This is of limited value to designers tasked with striking the right balance of effectiveness, initial construction costs, and long-term maintenance costs for the pretreatment and treatment practice system. The performance effectiveness of small and simple above-ground pretreatment practices for bioretention is a significant knowledge gap for industry professionals.

This project encompassed field-based performance testing of several pretreatment practices, both proprietary and non-proprietary, commonly used in Minnesota. The goal of the project is to gather performance data that will assist project designers, local government maintenance forces, and others by:

- Providing a quantitative measurement of effectiveness of several pretreatment practices;
- Offering a common point of comparison for different practices, by using the same test method;
- Informing assumptions about maintenance frequency of the pretreatment practice, and the bioretention practice;
- Improving understanding of how these practices function;
- Prompting innovations or design improvements based on measured data;
- Demonstrating a test method that can be applied in other locations and to other pretreatment practices.

This final report is organized into several chapters that describe the site locations (Chapter 2), the pretreatment practices (Chapter 3), the field methods (Chapter 4), the results and discussion (Chapter 5), the conclusions (Chapter 6) and lessons learned from this project as well as suggestions for future research (Chapter 7) that would continue data collection started with this project.

CHAPTER 2: SITE LOCATIONS

Site selection is critical to the success of field testing and monitoring. For this project, criteria used for site selection included safe roadway access, a nearby water source (fire hydrant), low traffic on nearby streets, adequate retention volume for longer tests, and a nearby storm sewer. Anoka Conservation District (ACD) suggested a site in the City of Anoka for testing of the Rain Guardian Bunker. The site characteristics also allowed for testing of a grass lined inlet, Rain Guardian Turret, and rock lined inlet with modification of the pretreatment entrance, thus allowing comparison of performance within the same bioretention practice and under the same test conditions for four practices. An additional non-proprietary in-line shallow sump grit chamber that has been designed and constructed in several locations within the City of Bloomington was also recommended for testing by industry professionals. The site in Anoka could not be modified to accommodate this practice, so another site in the City of Bloomington was selected for testing this practice. The sites used for testing as part of this project are described in detail within this chapter.

2.1 ANOKA SITE

ACD identified a newly-constructed bioretention facility in the city of Anoka, Minnesota at the northeast corner of 38th Lane N and 8th Lane (Figure 1 and Figure 2) which met the desired site characteristics described above. In addition, this site was constructed in 2017 and little of the planned vegetation was installed prior to testing, allowing testing to occur without interference from or interfering with the vegetation.

Figure 1. Photo of the Anoka site in May 2018, prior to testing. Gutter flow along 38th Lane is from right to left in the photo, encountering the basin inlet before the large catch basin nearest the fire hydrant.

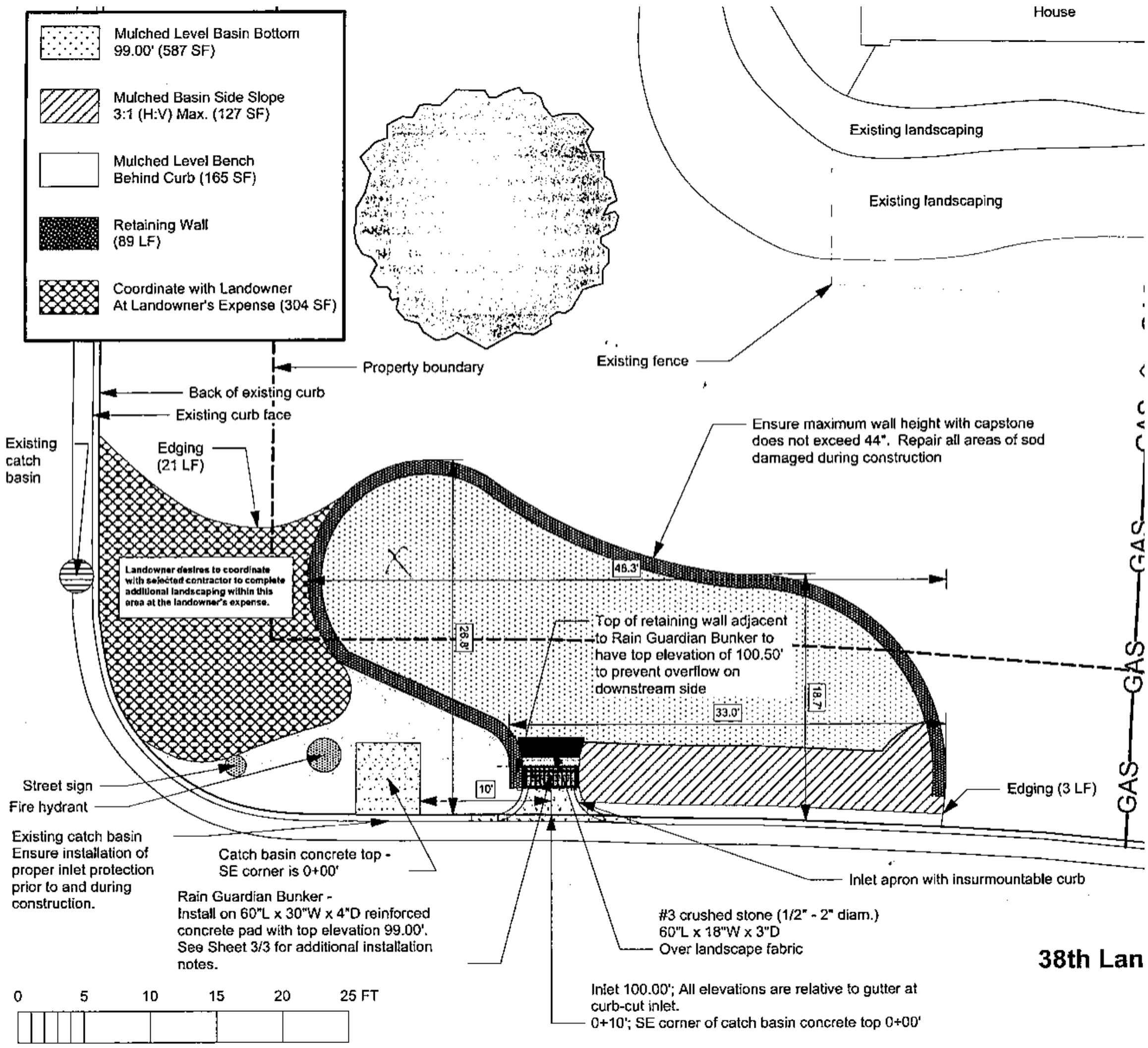


Figure 2. Site plan of the Anoka field site. (courtesy of Anoka Conservation District)

The design volume for the bioretention was 600 cubic feet (600 square feet x 1 ft deep). The watershed that drains to the bioretention is approximately 10.5 acres of low-density residential with little topographic elevation change, a portion of which is shown in Figure 3. Hydrologic modeling by ACD revealed that a 0.11-inch rainfall event on the contributing area would produce 600 cubic feet of runoff to the bioretention, which corresponds to the design volume of the bioretention. As is often the case, this bioretention was a "garden of opportunity" in which ACD was able to partner with the homeowner to build a bioretention on the property but was limited by the space available. It is the intention that more bioretention practices will be installed within the watershed to reduce the burden on this specific bioretention and increase the overall effectiveness of all bioretention practices. During testing, it was evident that infiltration was rapid (~25 inches/hr) at this basin. The bioretention is newly constructed and the subsoil at the site and in most of Anoka is sandy, which explains the rapid infiltration rate.

Figure 3. Aerial photo and topography in the vicinity of the Anoka field site, which is identified with a star. Image and contours from MnTOPO (https://www.dnr.state.mn.us/maps/mntopo/index.html)

This bioretention basin was designed to use a Rain Guardian Bunker pretreatment device, which included a concrete pad as the bottom of the structure. The Rain Guardian could be removed, leaving a combination of concrete and composite frame (Figure 4). With modification, a Rain Guardian Turret could be installed in this same location. With construction of a sloped surface, a rock lined inlet and grass lined inlet could also be installed in this location. Thus, the curb inlet and bioretention basin features remained the same for all testing conducted at the Anoka site.

Figure 4. At the Anoka site, the outer frame and concrete pad of the Rain Guardian Bunker device was left in place and adapted for all tests.

2.2 BLOOMINGTON SITE

The site in Anoka could not be modified to accommodate a shallow in-line sump grit chamber that was recommended for testing by industry professionals and used at several sites in the City of Bloomington, Minnesota. The City has installed numerous rain gardens and has developed several different pretreatment designs. One of the most recent designs was selected for testing because the site met the site selection criteria described above and because the design is different from the four pretreatment practices tested at the Anoka site.

A rain garden site located on Queen Avenue between 86th and 88th Street was chosen for field testing, as shown in Figure 5, featuring Bloomington's "new" pretreatment design. The rain garden, pretreatment, and street improvements were constructed in 2016 and the rain garden was reconstructed in 2017 due to lack of infiltration. The residential watershed area draining to the rain garden is estimated to be approximately 2.3 acres, which is visible but not outlined in Figure 6.

Figure 5. Queen Avenue rain garden in Bloomington, looking north. The inlet to the pretreatment device is through the furthest curb grate. The gutter low point is between the middle and bottom catch basins.

The typical bioretention design specified a storage volume of 150 cubic feet, though the actual volume of this bioretention basin including the pretreatment device sump was found to be ~119 cubic feet, assuming no infiltration. Using a similar hydrologic estimation process as was used on the Anoka site, it is estimated that a 0.1-inch rainfall event on the contributing area will produce 119 cubic feet of runoff for the site in Bloomington, which corresponds to the design volume of the bioretention. Similar to the Anoka site, this bioretention was a “garden of opportunity” in which the City was able to partner with the homeowner to build a bioretention on the property but was limited by the space available. It is the intention that more bioretention practices will be installed within the watershed to reduce the burden on this specific bioretention and increase the overall effectiveness of all bioretention practices.

Figure 6. Aerial photo and topography in the vicinity of the Bloomington field site, which is identified with a star. Image and contours from MnTOPO (https://www.dnr.state.mn.us/maps/mntopo/index.html)

It is important to note that white-colored turbidity may be visible in photos of water from the Bloomington tests (BDV, BBP, shallow sump grit chamber). This turbidity was visible during testing and was explained by City staff as lime residue from water treatment in the distribution pipes. The City of Bloomington does not flush their hydrants or water supply lines, so this residue can build up and become visible during “high flow” events such as our use during testing. This residue is very fine grain and was not visible in samples collected from Bloomington compared to samples collected from Anoka. It is not expected that this residue had any effect on the testing results.

CHAPTER 3: PRETREATMENT PRACTICES

Pretreatment practices are intended to reduce maintenance and prolong the lifespan of structural stormwater BMPs by removing trash, debris, organic materials, coarse sediments, and associated pollutants prior to entering structural stormwater BMPs (MPCA 2017b). The performance goal set forth by the MPCA is capture of gross solids and 25% of sediment greater than 100μm. In addition, proper pretreatment practices can provide a stable inlet into a bioretention practice that prevents erosion and minimizes disturbance of ground cover (e.g., mulch) within the bioretention.

Five pretreatment practices were tested as part of this study: grass lined inlet, Rain Guardian Bunker, Rain Guardian Turret, rock lined inlet, and in-line shallow sump grit chamber. The primary treatment mechanisms for stormwater pretreatment are screening, settling, and filtration and are described for each of the five practices tested in this project in Table 1.

Table 1. Pretreatment practices, brief description, and treatment mechanisms

Practice	Description	Treatment mechanisms
Grass Lined Inlet	Non-proprietary, grassed conveyance, sloped between curb cut and bottom of bioretention.	• settling among vegetation, • vegetative filtration
Rain Guardian Bunker	Proprietary rectangular chamber with top grate, concrete bottom, screened exit wall, and skimming debris wall.	• screening on top grate, • settling within the chamber, • screening by the screen wall • skimming of floatables by debris wall
Rain Guardian Turret	Proprietary cylindrical chamber with top grate, concrete bottom, screened exit wall, and skimming debris wall.	• screening on top grate, • settling within the chamber, • screening by the screen wall • skimming of floatables by debris wall
Rock Lined Inlet	Non-proprietary, rock-covered conveyance, sloped between curb cut and bottom of bioretention.	• settling among rocks
Shallow Sump Grit Chamber	Non-proprietary, shallow sump below gutter and connected to bioretention by three sub-surface PVC pipes.	• screening on top grate, • settling in shallow sump

Each practice was assigned a unique identifier for labeling samples as shown in Table 2. The Bloomington shallow sump grit chamber was tested in two different ways, first to the rain garden design volume (BDV), and then with a larger water volume, inducing bypass (BBP). To differentiate between tests and clarify labeling, a unique identifier combining the practice (3 letter identifier), flow rate (3 number fraction of one cfs), and replicate (sequential letter) was utilized. For example, the first replicate of the grass lined inlet at 0.5cfs would be labeled GLI-050-A, and the second replicate of the Rain Guardian Turret at 0.25cfs would be labeled RGT-025-B.

Table 2. Pretreatment practice, Unique identifier, storage and flow rate capacity, test flow rates and durations, and number of replicates. cfs = cubic feet per second.

Pretreatment Practice	**ID**	**Flow rate and Storage Capacity**	**Test flow rate and duration (replicates)**
Grass Lined Inlet	GLI	Storage capacity = minimal (depth of grass). Flow rate capacity = unknown.	0.25cfs for 40 minutes (2), 0.5cfs for 20 minutes (2)
Rain Guardian Bunker	RGB	Storage capacity = 2.85ft^3. Flow rate capacity = 6.11cfs.	0.25cfs for 40 minutes (2), 0.5cfs for 20 minutes (2)
Rain Guardian Turret	RGT	Storage capacity = 4.02ft^3. Flowr ate capacity = 3.45cfs.	0.25cfs for 40 minutes (2), 0.5cfs for 20 minutes (2)
Rock Lined Inlet	RLI	Storage capacity = minimal (pore space between rock). Flow rate capacity = unknown.	0.25cfs for 40 minutes (2), 0.5cfs for 20 minutes (2)
Shallow sump grit chamber (bypass)	BBP	Storage capacity = ~6ft^3. Flow rate capacity = unknown.	0.12cfs for 40 minutes (1), 0.25cfs for 20 minutes (1)
Shallow sump grit chamber (design volume)	BDV	Storage capacity = ~6ft^3. Flow rate capacity = unknown.	0.06cfs for 30 minutes (2), 0.12cfs for 15 minutes (2)

3.1 GRASS LINED INLET

A grass lined inlet (GLI) in a non-proprietary grassed conveyance that is sloped between the curb cut and the bottom of bioretention, as shown in Figure 7. It is also sometimes called a filter strip, buffer strip, or vegetative filter. GLIs capture sediment and gross solids by a combination of settling and vegetative filtration. As water, sediment and gross solids flow over the GLI, the vegetation both intercepts particles and gross solids (vegetative filtration) and reduces the flow velocity near the soil surface, which allows for settling of sediment. Sediment that settles on the soil within the vegetation is thus protected by the vegetation within a non-turbulent boundary layer.

Figure 7. Flow on grass lined inlet at 0.25 cfs (GLI-025-B). Curb cut entrance along bottom of the picture, exit into the bioretention practice at the top.

The width, length, and slope of the GLIs varies based on design parameters and site constraints. For this project, the dimensions of the GLI were approximately 48 inches wide, 52 inches long, and an elevation change of 10.5 inches which produced a slope of 5H : 1V, or 20%. This slope is greater than 8%, which is the maximum recommended by the Minnesota Stormwater Manual (MPCA 2017a). Extending the length to reduce the slope angle to 8% or less was considered, but experience and field observations of the authors and industry experts suggest ~20% slope is consistent with actual installations of GLIs.

3.2 RAIN GUARDIAN BUNKER

The Rain Guardian Bunker (RGB) is a proprietary, rectangular chamber with top grate, concrete bottom, screened exit wall, and skimmer beam, as shown in Figure 8. Water, sediment, and gross solids flow into the RGB from the curb inlet, first through the top grate which captures gross solids by screening. Water, sediment, and any uncaptured gross solids then fall into the rectangular chamber where sedimentation captures sediment and settleable gross solids. Water then exits the chamber through a screen exit wall, which screens additional sediment and gross solids. When the water level is near the top of the screen wall, a skimmer beam intercepts floatables. When the flow exceeds the capacity of the screen wall, water overtops the screen wall. A cross section of the RGB is shown in Figure 9. No modifications to the installation or design of the RGB were made for testing.

Figure 8. Overhead view of Rain Guardian Bunker (RGB) at 0.25 cfs during gross solids addition (RGB-025-B). Entrance from the curb cut comes into the RGB from the right of the picture; flow through the screen wall exiting the RGB in the center of the picture towards the left.

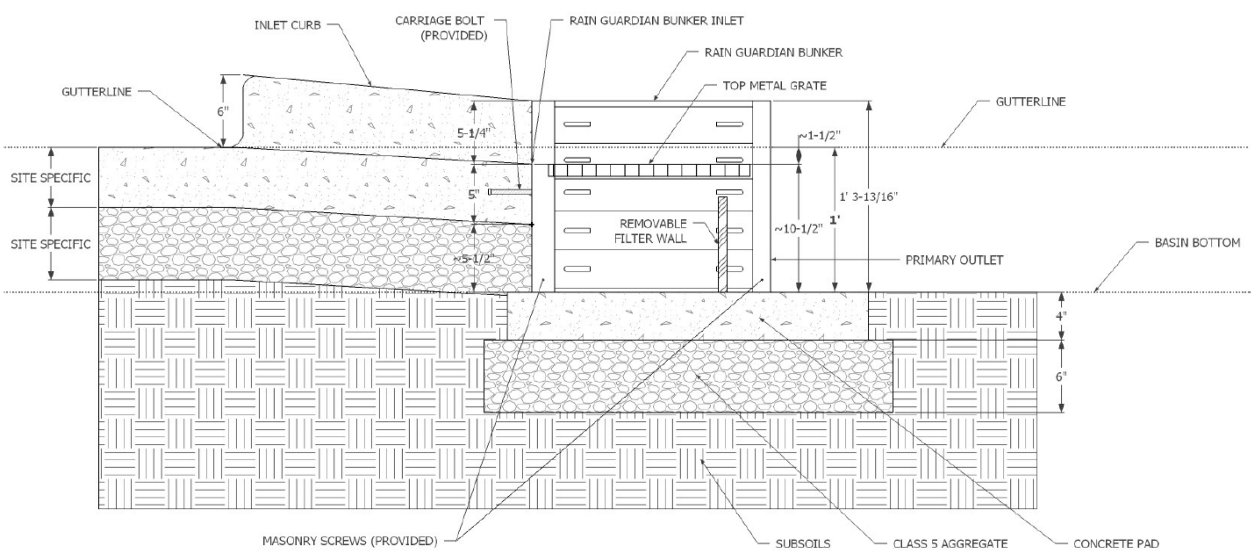


Figure 9. Cross section of Rain Guardian Bunker (flow from left to right) (http://www.rainguardian.biz/installation/downloads)

3.3 RAIN GUARDIAN TURRET

The Rain Guardian Turret (RGT) is a proprietary, cylindrical chamber with top grate, concrete bottom, screened exit wall, and skimmer beam as shown in Figure 10. Water, sediment, and gross solids flow into the RGT from the curb inlet, first through the top grate which captures gross solids by screening. Water, sediment, and any uncaptured gross solids then fall into the cylindrical chamber where sedimentation captures sediment and settleable gross solids. Water then exits the chamber through a screen exit wall, which screens additional sediment and gross solids. Compared to the Rain Guardian Bunker, the RGT has a larger grate area, larger settling chamber, and smaller screen wall area, with larger screen openings. When the water level is near the top of the screen wall, a skimmer beam intercepts floatables. When the flow exceeds the capacity of the screen wall, water overtops the screen wall. A cross section of the RGT is shown in Figure 11. To facilitate testing of the RGT, diversion plates were constructed from lightweight insulation panels (pink, shown in Figure 10) to divert flow into the opening of the RGT.

Figure 10. Rain Guardian Turret testing at 0.25 cfs (RGT-025-A). Entrance from the curb cut comes into the RGT from the right of the picture; flow through the screen wall exiting the RGT in the center of the picture towards the left.

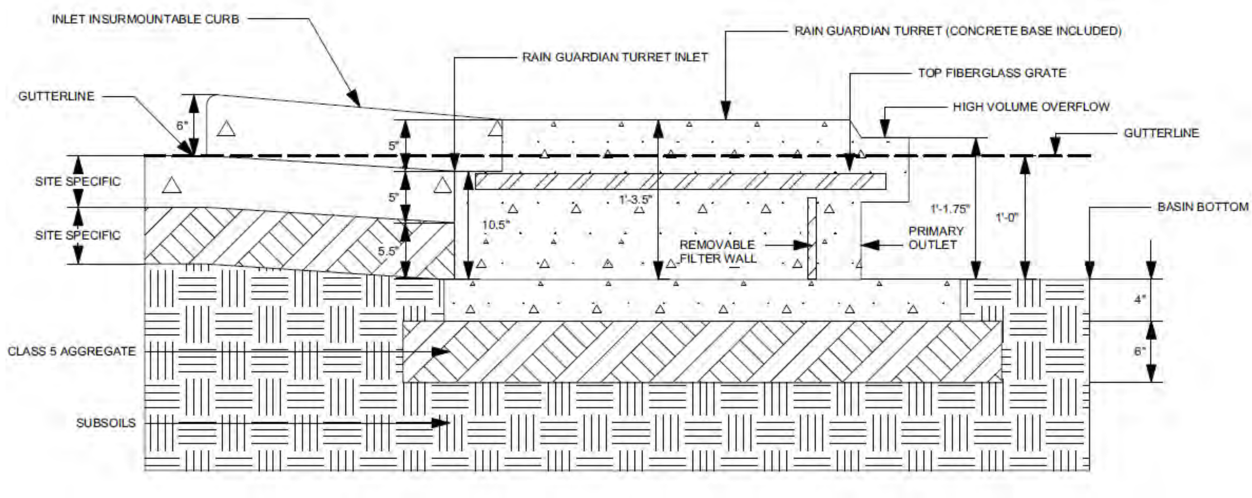


Figure 11. Rain Guardian Turret cross section (flow from left to right) (http://www.rainguardian.biz/installation/downloads)

3.4 ROCK LINED INLET

A rock lined inlet (RLI) in a non-proprietary rock-covered conveyance that is sloped between the curb cut and the bottom of bioretention, as shown in Figure 12. It is also sometimes called a riprap entrance, rock channel, or rock buffer strip. RLIs capture sediment and gross solids by settling among the rocks. As water, sediment and gross solids flow over the RLI, the rocks create roughness that intercepts sediment and gross solids and reduces the flow velocity near the rock surface, which allows for settling of sediment. Sediment that settles among the rock is thus protected by the non-turbulent boundary layer.

Figure 12. Rock lined inlet after testing at 0.50 cfs for 20 minutes. Entrance from the curb cut comes into the RLI from the right of the picture; exit into the bioretention practice at left.

The width, length, and slope of the RLIs varies based on design parameters and site constraints. For this project, the dimensions of the RLI were approximately 48 inches wide, 52.5 inches long, and an elevation change of 10.5 inches which produced a slope of 5H : 1V, or 20%. Experience and field observations of the authors and industry experts suggest ~20% slope is consistent with actual installations of RLIs.

3.5 SHALLOW SUMP GRIT CHAMBER

The in-line shallow sump grit chamber tested during this project comprises a rectangular catch basin, approximately 36 inches long by 24 inches wide with a 12-inch sump. There are five 4-inch holes in the bottom of the concrete chamber floor which allow for infiltration of water from the sump into the subsurface soils. The grit chamber is installed in-line with the gutter and has three 4-inch outlet pipes leading to the bioretention basin (Figure 13). Stormwater flows down the street gutter line and drops through the grate into the sump. When flow into the sump and through the outlet pipes is greater than the infiltration rate, the water will continue to rise in the sump and the bioretention basin simultaneously.

Figure 13. Shallow sump pretreatment with surface grate removed. This photo was taken upon arrival at the site, before cleaning the sump in preparation for testing.

When the water depth in the bioretention reaches 12 inches, the water level in the shallow sump is approximately at the elevation of the gutter (Figure 14). As the water level increases above this depth, water will begin to flow from the shallow sump grit chamber into the downstream gutter and on to the downstream conveyance. Water that flows out of the shallow sump grit chamber into the gutter is considered "bypass" because it bypasses treatment by the bioretention. During bypass conditions, water is treated by the shallow sump grit chamber and some water flows into the bioretention (assuming infiltration occurs), but sediment and gross solids may flow over the top of the grit chamber or be resuspended within the shallow sump grit chamber and allowed to flow out of the device and into the gutter. During larger rainfall and flow events, this could mobilize previously-captured sediment and release it from the shallow sump grit chamber.

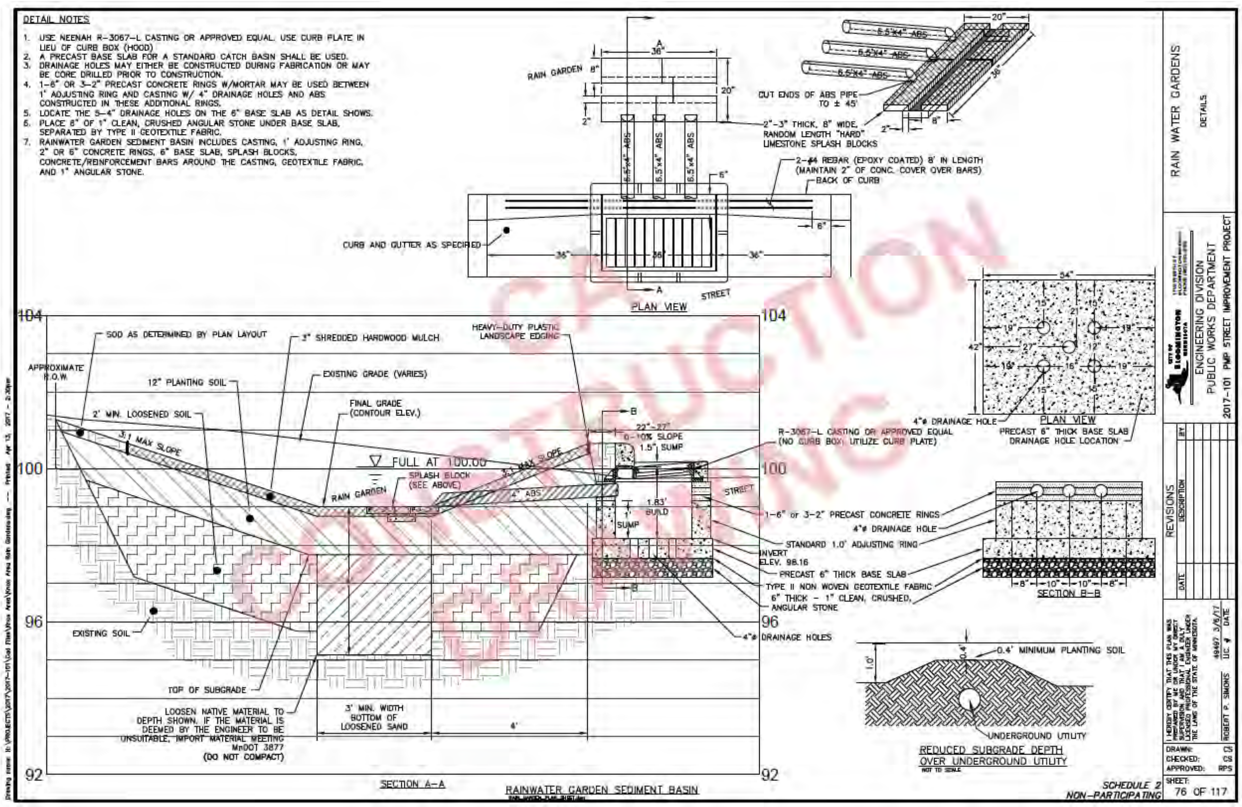


Figure 14. Shallow sump bioretention pretreatment practice design plan

CHAPTER 4: METHODS

4.1 FIELD-BASED TESTING

A field-based testing approach was used in this project because several of the available pretreatment practices are installed and easily accessible in the field. The relatively short duration of this project and the uncertainty associated with field monitoring prevented the use of long-term monitoring to measure performance. Thus, a field-testing methodology was adopted to produce repeatable results on five different pretreatment practices within a single summer season.

Field-testing allows for control of several variables associated with performance, including flow rate, volume, and duration; pollutant characteristics and amount; timing of testing during specific weather conditions; and the ability to repeat tests if results are inaccurate or errors appear. In addition, field-testing allowed for collection of all sediment captured by the pretreatment practices which were transported back to the analytical laboratory to be measured in whole. Long-term field monitoring produces sub-samples which have been shown to be inaccurate for sediment measurement (Gettel *et al.* 2011). Though field-testing was used in this study, laboratory testing can be more accurate, more cost-effective, and a better method for comparing multiple practices side-by-side under identical conditions. This is explained in more detail in Lessons Learned.

Another advantage of field testing compared to monitoring is that the testing approach is based on the design storage volume of the bioretention and is independent of the actual contributing area. As described above, both the Anoka and Bloomington sites become filled to design volume with runoff from a 0.1-inch rainfall event, which is considerably less than the recommended capture volume of a 1-inch event (MPCA 2017b). If performance was measured by monitoring, it would be evident that the bioretention (and pretreatment practices) were undersized and frequently filled beyond capacity. Field testing, however, can supply exactly the design volume in multiple replicates to measure the performance of the pretreatment practice for the volume and sediment mass for which it was designed. In general, the testing protocol was similar between both sites and all five different pretreatment practices, as follows:

1. Prepare gross solids and sediment to be used in field testing,
2. Prepare for test by gathering all field equipment and transporting it to the field site,
3. Deploy field testing equipment at the field site,
4. Prepare the site by installing the pretreatment practice to be tested,
5. Thoroughly clean the pretreatment practice prior to testing,
6. Saturate the soil of the bioretention practice prior to the first test of a testing day,
7. Conduct a test, as follows:
    a. Open gate valve at water meter to begin flow,
    b. Adjust flow until target rate is achieved,
    c. Start sediment feed and stopwatch (t = 0), and record water meter reading,
    d. Periodically feed gross solids one handful at a time,
    e. Check flow rate and make slight adjustments if necessary,
    f. Stir sediment in sediment feeder supply as needed,
    g. Periodically record water depth inside the corral area (to be defined later),
    h. Take photos and notes as needed,
    i. When test volume reaches design volume or test volume, stop sediment feed, close valve to stop water flow, and record the stop time (total duration).
8. Drain or pump out excess water from the basin,
9. Carefully collect, label, and store sediment and gross solids,

10. Set up for the next test, if applicable, until all tests for that day are complete,
11. Restore pretreatment practice to normal operating condition,
12. Collect all field equipment and transport equipment and samples back to SAFL,
13. Process collected sediment and gross solids,
14. Record and check results.

It is important to note that a clean water "rinse" was performed at the beginning of each testing day to ensure clean conditions and saturate the bioretention soils so that infiltration characteristics were similar for all tests. The testing process is described in further detail in the following sections.

4.2 SYNTHETIC STORMWATER

Field testing uses synthetic stormwater to control the rate, volume, duration, and pollutant characteristics throughout testing. For this project, the synthetic stormwater consisting of potable water from municipal fire hydrants and carefully chosen solids added to the water to achieve a solids concentration of 200mg/L. The volume, duration, and flow rate of synthetic stormwater were selected based on the size of the bioretention facility and the water supply limitations. The volume of water used for testing corresponded to the design storage volume of the bioretention practice (600 cubic feet for Anoka, 150 cubic feet for Bloomington). Two flow rates were selected based on the capacity of the fire hydrant and duration over which the flow rates could be achieved. A flow rate of 0.25 cubic feet per second (cfs) for 40 minutes and a flow rate of 0.5cfs for 20 minutes were selected for tests conducted at the Anoka site (GLI, RGB, RGT, RLI). Because the flow volume for these events are identical, they will be described as low intensity (0.25cfs for 40 minutes) and high intensity (0.5cfs for 20 minutes). Two replicates of all these tests were performed.

For Bloomington, the tests of the shallow sump grit chamber at the design volume (BDV) proposed to use flow rates of 0.06cfs for 40 minutes (low intensity) and 0.12cfs for 20 minutes (high intensity), both of which correspond to a volume of 150 cubic feet. Actual test duration and flow volume were determined in the field based on actual storage volume within the bioretention. Two replicates for these tests were performed.

Additional tests for the shallow sump grit chamber were added to measure the performance when the storage volume within the in-line sump grit chamber and bioretention practice were exceeded (i.e., experienced bypass). For these bypass tests (BBP), flow rates of 0.12cfs for 40 minutes (low intensity) and 0.25cfs for 20 minutes (high intensity) were used. These tests correspond to a volume of 300 cubic feet, which is approximately 2.5 times the design volume of the bioretention. Only one replicate for each of these tests were performed, due to time constraints and weather. A summary of recorded volumes, flow rates, and test times is shown in Table 7 in the Appendix.

4.2.1 Solids composition

A study of stormwater runoff in the Twin Cities Metropolitan Area found that the average event mean total suspended solids (TSS) concentration was 184mg/L, based on 520 measurements (Brezonik and Stadelmann, 2002). While there is substantial variability in reported TSS concentrations, this value was used as a basis for choosing the total solids concentration of 200mg/L.

Typically, gross solids (GS) refer to solids larger than 4.75 mm, including vegetation and trash, while sediment refers to sediment less than 4.75 mm. For this project, a ratio of 80% sediment and 20% gross solids by mass was used to create the total solids at a concentration of 200 mg/L. From Kalinosky (2015), recovered solids from street sweeping were classified as fine solids (assumed to be principally sediment) or coarse organics (size > 2mm). Typical of many Minnesota watersheds, the proportion of coarse organics increased significantly in the autumn (September-November), while fine sediments peaked during early spring (February to April). The overall average proportion was approximately 80% fine solids and 20% coarse organics. Thus, a total solids concentration consisting of 80% sediment and 20% gross solids by mass was selected for testing in this project, as shown in Figure 15.

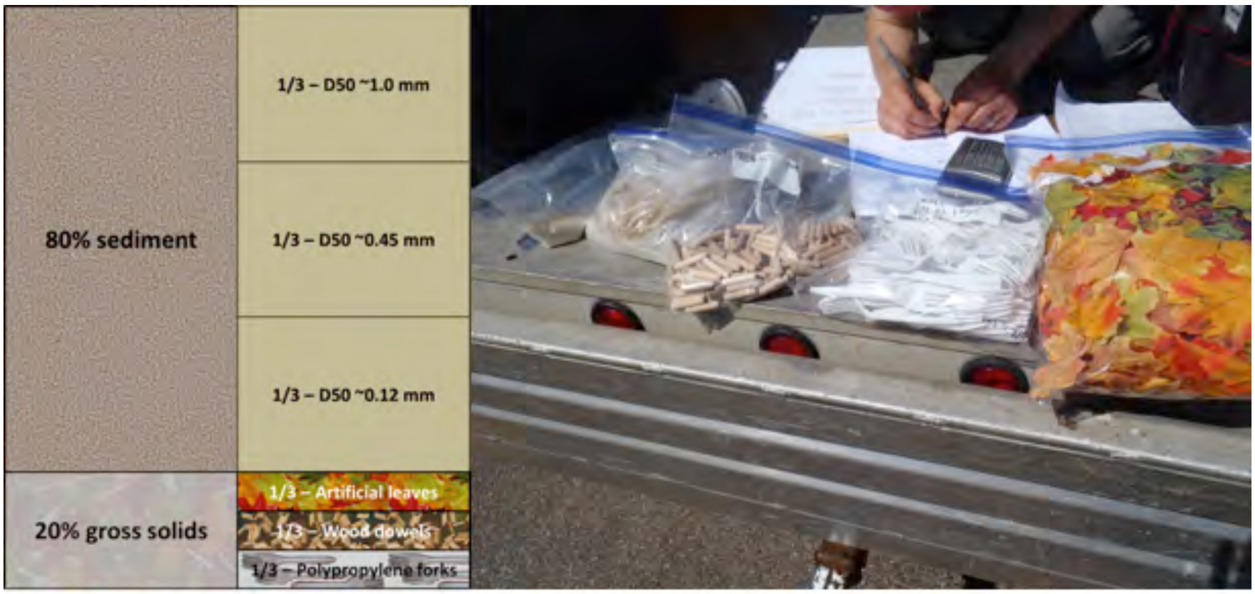


Figure 15. Synthetic stormwater solids composition. The height of each labeled box (left) is mass-proportional to the amount used in testing. The picture at right shows approximately the volume used of each component.

An adequate amount of sediment and gross solids had to be used in each test to ensure any error in the sample processing (collection, drying, weighing, etc.) would be minimal compared to the total mass measured. Given a total solids concentration of 200mg/L and a ratio of 80% sediment and 20% gross solids, the mass needed for each test was calculated based on the design volume for both the Anoka (600 cubic feet) and Bloomington field sites (150 cubic feet), as listed in Table 3.

Table 3. Target mass of sediment and gross solids for total solids loading of 200mg/L.

Solids type (% of Total)	Anoka (600 ft^3 design volume)		Bloomington (150 ft^3 design volume)	
	Mass (g)	Mass (lb)	Mass (g)	Mass (lb)
Sediment (80%)	2,718.4	5.99	679.6	1.50
Coarse Sand D_{50}=1.17 mm (26.7%)	226.5	0.50	56.6	0.12
Medium Sand D_{50}=0.41 mm (26.7%)	226.5	0.50	56.6	0.12
Fine Sand D_{50}=0.12 mm (26.7%)	226.5	0.50	56.6	0.12
Gross Solids (20%)	679.6	1.50	169.9	0.37
Forks (6.7%)	1,132.7	2.50	283.2	0.62
Leaves (6.7%)	1,132.7	2.50	283.2	0.62
Dowels (6.7%)	1,132.7	2.50	283.2	0.62
Total solids (100%)	3,398.0	7.49	849.5	1.87

4.2.2 Gross solids

Three types of gross solid (GS) material were chosen for testing: artificial leaves, wood dowels, and polypropylene forks. These items were chosen because they had properties similar to documented stormwater debris as summarized by McIntire *et al.* (2012), were cleanable and re-usable for multiple tests, non-degrading in water, stable during oven drying, amenable to handling, and readily available. Several other materials were evaluated and ultimately eliminated from use in testing because they did not meet the above criteria. Actual leaves and other organic materials (grass clippings, etc.), when used in testing, break apart into smaller particles and do not remain a consistent mass between wetting and drying cycles. Thus, the materials used in testing to represent gross solids and properties thereof are listed in Table 4.

Table 4. Properties of gross solids materials used in testing.

	Artificial Leaves	Dowels	Forks
Mass per piece	0.25 g	1.2 g	2.6 g
Dimensions	3.25" x 2.75"	5/16" dia x 1.5" length	5.75" length x 1" width
Material	polypropylene	hardwood	polypropylene
Name (source)	Gresorth (Amazon.com)	Fluted wood dowel pins (McMaster-Carr)	Medium weight forks (Litin's Party Value, Minneapolis)
Observed buoyancy	Initially float until saturated, then slowly sink except when suspended by air bubbles	Initially float, become neutrally buoyant or sink when fully waterlogged	Slowly sink except where suspended by air bubbles (rare)

Artificial leaves represent vegetation and are also similar in form to plastic or paper trash. The slight surface texture, jagged leaf-like edges, buoyancy, and flexibility mimic some properties of actual leaves. Wood dowels were chosen to represent cigarette butts, small organic debris (i.e., wood sticks), and floatables. Forks represent plastic debris, trash, or waterlogged (slightly sinking) sticks. Polystyrene utensils were tested but melted during drying and thus could not be used.

Polypropylene forks were found to be flexible and oven stable. Figure 16 shows a bag of synthetic gross solids next to actual gross solids recovered from the Bloomington field site during pre-cleaning.

Figure 16. A bag of synthetic gross solids used in testing (leaves, dowels, and forks) next to actual maple leaves and a cigarette butt recovered from the Bloomington site.

4.2.3 Sediment

Pretreatment for bioretention is primarily intended to capture particles greater than 100µm, as represented in Figure 17 (MPCA 2017b). To represent this range, the sediment portion of the synthetic stormwater solids consisted of a blend of one-third of each of three sizes of silica sand (Figure 18), each having a relatively narrow particle size distribution (Figure 19). Using a blend of three distinct sizes enabled sediment removal efficiency analysis for each size class as well as overall removal efficiency. The coarse sand (Agsco 12-20, D_{50} ~1170µm) and medium sand (Agsco 35-50, D_{50} ~410µm) were purchased in 50-lb bags from Agsco Corporation, Wheeling, IL (www.agsco.com). The fine sand (Agsco 120-200, D_{50} ~120µm) was a custom blend produced by Agsco.

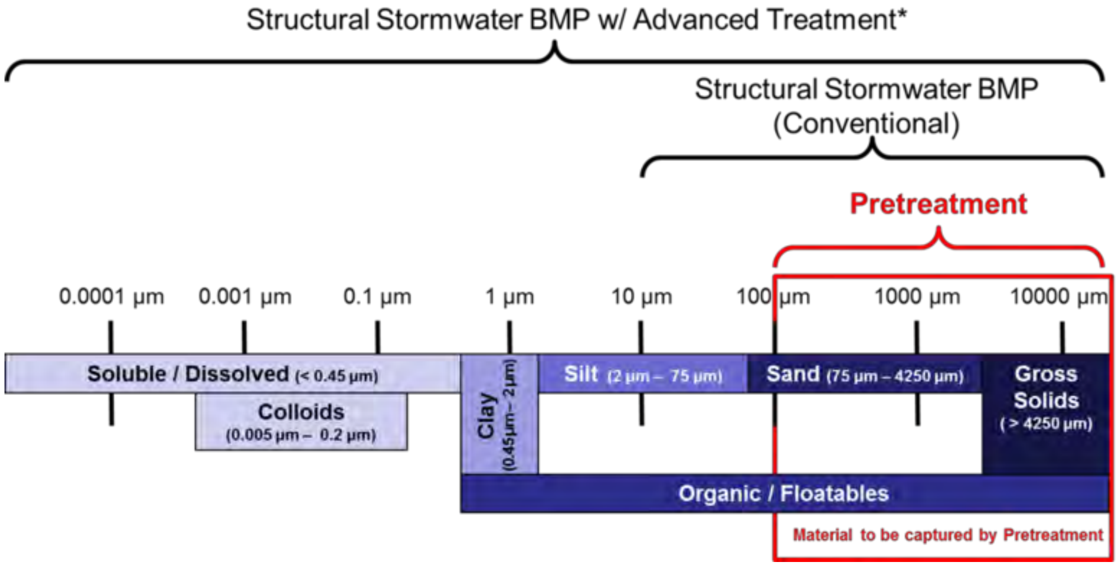


Figure 17. Pretreatment is intended to capture a portion of particles greater than 100µm (MPCA 2017b).

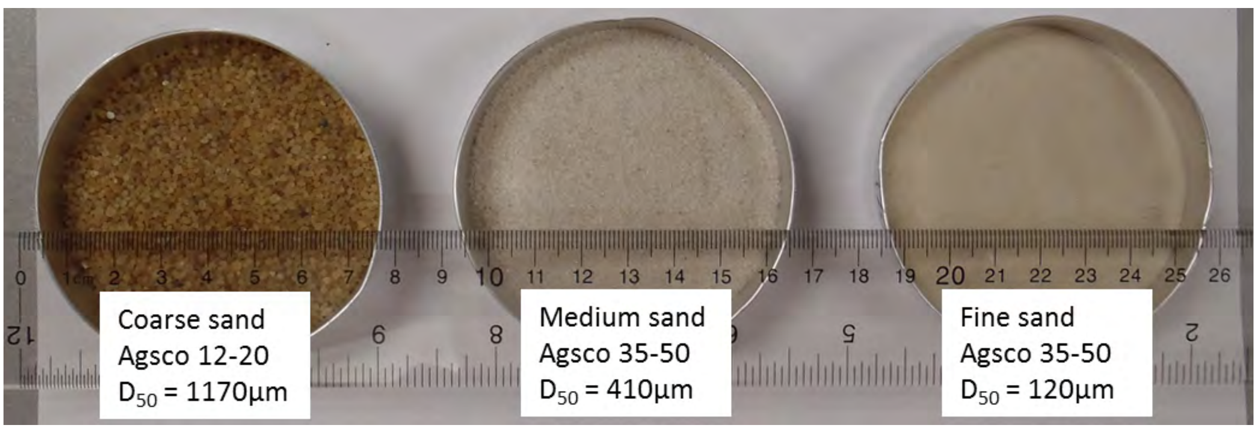


Figure 18. The three silica sands were blended in equal proportions by mass to create the sediment mix.

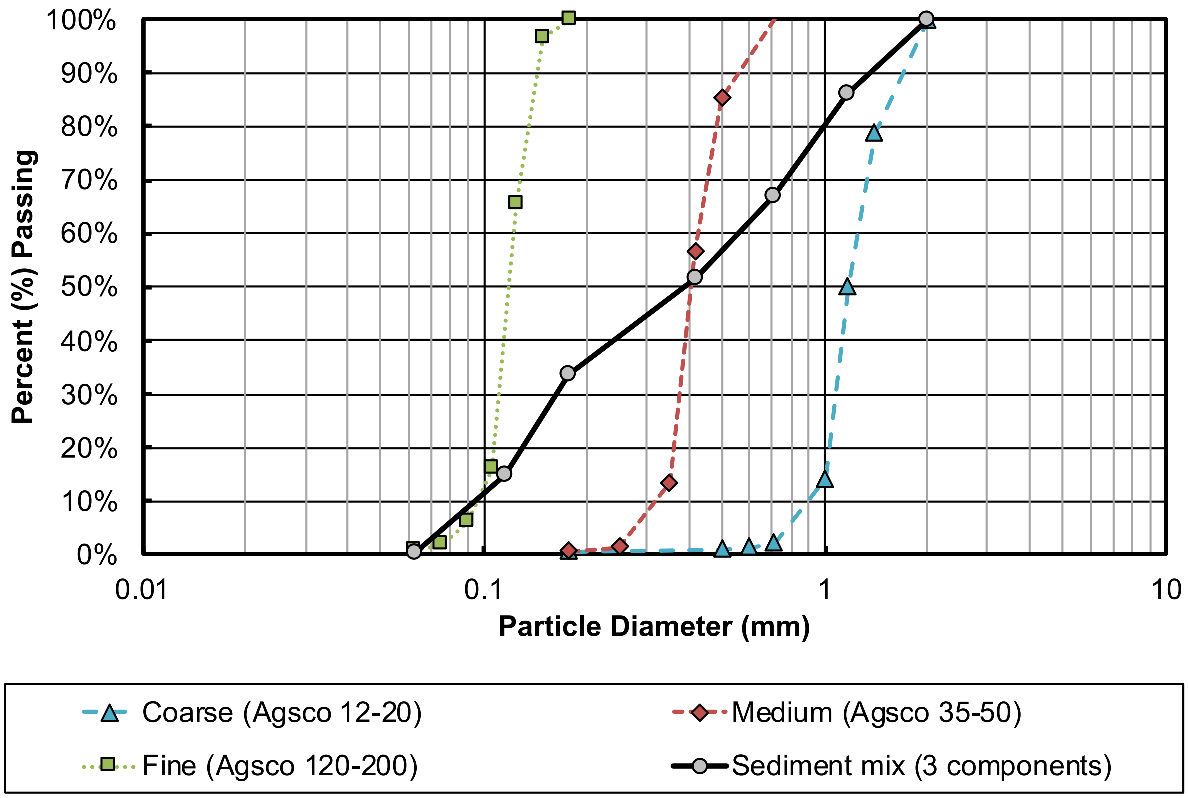


Figure 19. Particle size distribution chart of sand used in testing. Data from SAFL sieve testing.

Sieve analysis of the sediment was done at the SAFL sediment lab using standard 8-inch sieves. A Cole-Parmer Symmetry model S-PT 4202I balance with readability of 0.01g (10mg) was calibrated and used to measure mass of sediment, sieves, and gross solids. Comparison testing established there was no appreciable mass difference between oven-dry sediment and sediment taken from the supply bags, which were stored in the sediment lab. Therefore, masses for oven dry sediment taken from pretreatment devices were compared directly to initial masses taken from the stored sediment. Prior to each day of field testing, sediment was weighed and proportioned into labeled plastic zip top bags.

When sediment was collected from the pretreatment practices following testing, a sieve analysis was used to separate the coarse, medium, and fine sizes for comparison to the input values. After several trials, a set of 6 sieves was found to adequately characterize the sediment, with divisions between size classes shown in Table 5.

Table 5. Sieve analysis of whole sediment mix and division of sediment classes

US Std. Sieve #	Opening size (mm)	Percent passing	Sediment Retained
10	2.00	100.0%	Foreign material
16	1.17	86.2%	Coarse
25	0.71	67.1%	Coarse
40	0.42	51.5%	Medium
80	0.18	33.5%	Medium
(140 or 120)	0.12	14.9%	Fine
Pan	--	--	Fine

4.3 TEST EQUIPMENT

A substantial amount of equipment was needed to conduct field testing for this project, as shown in Figure 20. The equipment can be separated into several categories:

- Equipment was needed to control and deliver water to the pretreatment practice (hydrant, hose, and water meter supplied by the City of Anoka and City of Bloomington, respectively)
- Equipment to dissipate the energy from flow out of a fire hose and spread the flow evenly across the entire width of entrance into the pretreatment practice (barrel and flow spreader constructed by SAFL staff)
- Equipment to add sediment and gross solids at a constant rate throughout the duration of the tests (calibrated sediment feeder and SAFL staff adding gross solids by hand)
- Equipment to prevent sediment and gross solids from entering the bioretention practice (“corral” constructed of wire mesh and geotextile fabric, wire ties, stapler)
- Equipment to collect sediment and gross solids during grass lined inlet testing (new geotextile fabric large enough to fully capture any sediment and gross solids deposited in the corral)
- Equipment to draw water from within the bioretention cell after a test is complete (gas-powered pump, hose, intake screen, shovel and rake)
- Equipment to collect sediment and gross solids captured during tests (gas-powered generator, wet-dry vac equipped with custom-designed filter screen, garden hose and rinsing nozzles, clean buckets and tubs, custom-designed rinse rack for washing rock during rock lined inlet testing)
- Equipment to store and transport collected samples back to SAFL for analysis (clean buckets and zip top bags)
- Equipment to install and change pretreatment practice (wooden sloped frame, sod, rock, proprietary devices, battery-powered drills and screws, hammer, wrenches, stapler)
- Equipment to restore the site to operating condition (rake, shovel, hose and spray nozzle)

Figure 20. Field equipment used at Anoka field site.

4.3.1 Water supply and distribution

The City of Anoka Public Works water and sewer division supported the research by providing a hydrant flow meter, HPM model FHM03, with gate valve and a 2.5-inch hose for water supply. The City of Bloomington provided a 3-inch Sensus Omni H2/V2 water meter with gate valve and a long hose to reach from a nearby hydrant to the pretreatment practice. The hose end was secured to a hole near the top of a blue 55-gallon plastic barrel that dissipated turbulence from the high-pressure jet from the hose. At the bottom of the barrel, a 4-inch diameter pipe stub carried water to the flow distributor and level spreader. The flow distributor was constructed from wood and sheet metal to spread the incoming water to an even depth across 24 inches of width, to represent typical curb inlet flow. For tests conducted at the Anoka site, the edge of the flow distributor was located 18 inches upstream from the pretreatment practice lip and the distributor was centered in the curb inlet to the pretreatment practice. For tests conducted at the Bloomington site, the flow distributor was directed down the gutter line and into the grate (Figure 21). The flow distributor was modified to narrow the flow width to match the grate width.

Figure 21. Bloomington field site during pre-wetting flow. Flow enters the shallow sump through the curb grate and emerges into the fenced area of the rain garden through pipes, shown in a subsequent photo.

4.3.2 Sediment feeder and gross solids

A steady rate of sediment was supplied via an auger-type Accurate model 302 sediment feeder with a one-inch diameter nozzle and solid flight auger, which was powered by a small portable generator. The feed rate settings were calibrated at SAFL with the sediment mix on the basis of grams per minute. The feeder was mounted so that sediment fell in the center of the flow distributor and was carried downstream into the pretreatment practice by the flow (Figure 22). A metal plate was used in the first test to spread the falling sediment across the flow distributor, but moisture on the plate during testing begin to accumulate sediment by cohesion. Thus, the plate was rinsed and removed during the test to ensure all sediment discharged from the feeder was added to the distributor, and the pretreatment practice. The plate was not used in subsequent tests.

Figure 22. Sediment feeder and flow distributor.

Prior to each test, the sediment feeder was filled with the appropriate amount of pre-weighed and pre-mixed sediment blend. An additional 100g of sediment mix was added to the feeder to compensate for sediment remaining in the feeder and auger tube at the end of a given test. At the end of each test, sediment was carefully removed from the sediment feeder and auger tube by physically dumping it out from the top and sides of the feeder. This sediment was stored in a zip top bad and labeled "Not Fed" for analysis.

Prior to each test, the appropriate amount of pre-weighed gross solids was mixed into a bucket of clean water to allow the gross solids to become saturated and better represent gross solids that would be carried in stormwater to a pretreatment practice. Throughout the duration of each test, gross solids were carefully added by hand to the flow immediately downstream of the flow distributor.

During the field tests in Anoka, a clean geotextile fabric was placed on top of the concrete apron between the flow distributor and the pretreatment practice to ensure sediment or gross solids were not captured on the concrete apron prior to entering the pretreatment practice. The geotextile also prevented entrainment of any sediment, concrete, or gross solids that was on the apron, which would bias the results of the testing. This geotextile was observed throughout the duration of each test to ensure sediment and gross solids did not accumulate on its surface.

4.3.3 Downstream sediment and gross solids collection

To simplify cleanup and restoration, a "corral" was constructed to contain sediment and gross solids that flowed out of the pretreatment practice and into the bioretention. In addition, the corral was used to measure performance of the grass lined inlet, as described in section 4.5 below. The corral was constructed of hardware mesh with ½-inch square holes, attached to steel fence posts set into the ground. For testing in Anoka, the corral area was approximately 28 square feet, expanding from 48 inches wide at the bottom of the pretreatment practice to 67 inches wide, and was approximately 70 inches long. Geotextile fabric was clipped or clamped to the hardware mesh around the edges and weighted against floatation with clean stones at the bottom. The hardware mesh and geotextile were attached to the pretreatment practice frame so as to not allow flow through gaps.

The geotextile fabric would clog over time so that the water level inside the corral was higher than in the water level in the bioretention basin outside the corral. Thus, an overflow outlet was created in the fabric sides to prevent water from fully submerging the pretreatment practice and backing up into the curb inlet. Water levels were periodically measured inside the corral, referenced to the base slab (see Figure 4).

For the tests conducted in Bloomington, the corral was made of hardware mesh with ¼-inch openings and was approximately two feet wide and three feet long and did not include the geotextile fabric (Figure 23). This is because the bioretention was fully established with vegetation, and the corral could not be larger without impacting vegetation.

Figure 23. Gross solids containment area at Bloomington field site. Flow from the shallow sump box enters the bioretention basin through the three pipes at right.

4.3.4 Drain pump

To allow for as many tests as possible in each testing day, the water within the bioretention practice was removed using a three-inch gas-powered semi-trash pump. The pump intake was installed within a five-gallon plastic bucket that was placed in an excavated hole in the bottom of the bioretention at the Anoka site. In Bloomington, a smaller pump was used and placed directly on the bottom of the bioretention basin. Fencing was used to control the movement of floating wood mulch toward the pump, but raking was still required to redistribute the mulch after testing. A small electric submersible pump was also used during some tests to dewater the area immediately adjacent to the pretreatment practice.

4.3.5 Field collection of sediment and gross solids

Gross solids were collected by hand in all tests and transferred directly to a properly labeled storage containers. Hands were washed prior to gross solids collection, and hands and any other items contacting the gross solids and sediment were carefully rinsed after collection into the appropriate location so as not to misallocate mass.

A device was needed to collect sediment from within the pretreatment practices, but that would allow the collected sediment to be quickly and easily separated and stored for transport back to SAFL for analysis. A standard wet-dry vacuum could collect wet sediment, but fine sediment could become trapped within the filter cartridge or mesh filter screen within the vacuum. To overcome this limitation, a secondary filter bucket (Figure 24) was constructed to capture and contain collected sediment. A nozzle and green flexible hose were connected to an inlet pipe, which were attached with a gasket to the lid of a standard 5-gallon bucket. A fine screen (#270 mesh, 53μm) was wrapped around a mesh cylinder within the bucket, which also sealed to the 5-gallon bucket lid and connected to a standard 5-hp Shop-Vac wet-dry vacuum via a black outlet pipe. The lid was then attached to a clean 5-gallon bucket. When the wet-dry vacuum was running, suction would collect wet sediment through the nozzle and into the 5-gallon bucket, but the #270 mesh screen would prevent sediment from leaving the bucket or entering the wet-dry vacuum. Thus, sediment was collected within the 5-gallon bucket.

When wet sediment was difficult to collect within a pretreatment practice, a plastic squeeze bottle with clean water was used to mobilize sediment as the wet-dry vacuum collected it. In addition, this bucket-collection system was most efficient when using two pre-cleaned buckets. Once the first bucket was partially filled with a water/sediment mix, the lid with attached hoses was carefully switched to a second bucket to continue vacuuming. Meanwhile, water from the first bucket was poured through a #325 sieve (US Standard mesh, 44μm) to separate collected sediment from the water. Once all sediment water collected from the pretreatment practice, the nozzle, hose, filter, and second bucket were thoroughly rinsed into a single bucket and partly decanted through the sieve so that all sediment was captured in a single bucket. This bucket was then sealed, properly labeled, and transported back to SAFL for analysis.

Figure 24. A filter bucket was designed to trap sediment in the 5-gallon bucket (right), with suction provided by a wet-dry vac (left).

4.3.6 Sample storage

Sediment collected during field testing was stored in clean 5-gallon plastic buckets with lids, sealed with duct tape, and labeled prior to transportation back to SAFL for analysis. Gross solids were collected by hand and stored in clean, clear, zip top bags, then sealed and labeled prior to transportation back to SAFL for analysis. For tests in which geotextile fabric was used to collect sediment and/or gross solids, the fabric was carefully folded to retain solids, stored inside a large zip top bag, labeled, and placed inside a clean 5-gallon bucket for transportation.

4.4 SAMPLE PROCESSING AND ANALYTICAL METHODS

Labeled containers of gross solids and sediment, sealed zip top plastic bags or sealed 5-gallon buckets, were transported to SAFL at the end of each testing day and stored until processing could be completed. For the first few runs, sediment and foreign material was rinsed from the gross solids under running water on coarse mesh over a watertight bin (Figure 25). All water from the bins was poured through coarse (US standard #10, 2mm opening) and then very fine (US standard #325, 44µm opening) sieves (Figure 26). The #10 was chosen because the openings are larger than any sediment that was used in field testing and thus anything captured on this sieve is foreign material that was not part of the testing. Material retained on the coarse sieve such as grass blades and seeds were gently rinsed to remove any sediment, then discarded. Sediment retained on the #325 sieve was rinsed into pans for oven drying and processing. Because the #325 sieve is finer than any sediment used in testing, any material passing this sieve was discarded.

Figure 25: Rinsing gross solids on a mesh box over a watertight bin. This method was later revised (see Figure 27).

Figure 26. The rinse bin was poured carefully through a #325 sieve to retain sediment particles.

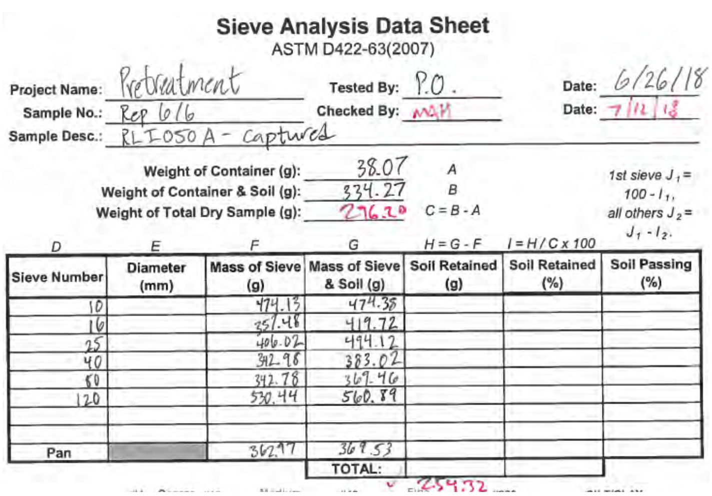
A more effective and efficient method was developed using two 5-gallon buckets (Figure 27). A bag of gross solids was emptied into a clean bucket then rinsed to remove any sediment clinging to the bag. The bucket with gross solids was filled about three-quarters full with clean water. A second clean bucket was also filled about three-quarters full with clean water. Small, loosely held handfuls of gross solids were gently swirled and shaken while underwater in the first bucket, then carefully removed and placed into the second bucket. Once all the gross solids were transferred to the second bucket, the water from the first bucket was poured through the #10 sieve to exclude foreign materials larger than 2mm and through a #325 sieve to retain test sediment. In addition, the bucket was rinsed, and rinse water was also passed through the sieves. Any sediment retained on the #325 sieve was added to a sediment drying tray and properly labeled.

Figure 27. Two bucket rinse method of cleaning sediment from gross solids. The grey mesh wastebasket (lower left) was used to dry gross solids in the oven.

Using the same submerged swirling process, gross solids were moved from the second bucket to a labeled drying bin (wire mesh wastebasket) for drying in a large sediment oven. The second bucket was then poured through the sieves, and the sediment was added to the collected sediment tray. There were typically only a few grains of sediment in the second bucket; if more was apparent, a third rinse cycle was added. After fully drying in the oven at 200°F for at least 24 hours, the gross solids were sorted and weighed by type (leaves, dowels, forks).

Captured sediment was transferred from buckets or bags to labeled metal pans for oven drying. Excess water was removed from the sediment using a #325 sieve (Figure 28). Sediment was dried in the oven at 200°F for at least 24 hours and then sieved to determine particle size distribution. When necessary, the dry captured sediment was split into several portions to be sieved sequentially. Weights were recorded on paper sheets (Figure 29), and then input into a spreadsheet for calculations of percent passing each sieve. All of the sequential portions were totaled. The pre-sieve total mass was compared to the sum of the sequential portions and samples were re-sieved if error was significant. The small amount of “not fed” sediment removed from the feeder was sieved and weighed in the same manner as the captured sediment. The average percent error for all sieved samples was 0.29% (n = 74).

Figure 28. Rinsing sediment from a sieve into a pan for oven drying.



Sieve Analysis Data Sheet
ASTM D422-63(2007)

Project Name: Pretreatment   Tested By: P.O.   Date: 6/26/18
Sample No.: Rep 6/6   Checked By: MAH   Date: 7/12/18
Sample Desc.: RLI050A - captured

Weight of Container (g): 38.07   A
Weight of Container & Soil (g): 334.27   B
Weight of Total Dry Sample (g): 296.20   C = B - A

1st sieve J_1 = 100 - I_1, all others J_2 = J_1 - I_2.

D	E	F	G	H = G - F	I = H / C x 100	
Sieve Number	Diameter (mm)	Mass of Sieve (g)	Mass of Sieve & Soil (g)	Soil Retained (g)	Soil Retained (%)	Soil Passing (%)
10		474.13	474.38			
16		357.48	419.72			
25		406.02	494.12			
40		342.98	383.02			
80		342.78	369.46			
120		530.44	560.89			
Pan		362.97	369.53			
			TOTAL:			

254.32

Figure 29. Sample sieve analysis data sheet.

4.5 GRASS LINED INLET

4.5.1 Testing setup and cleanup

To install a GLI within the bioretention site in Anoka, a wooden frame was constructed to support the GLI, simulate infiltration of water through the GLI, and capture of sediment and gross solids on the surface of the GLI. The wood frame was constructed by ACD as a sloped plywood surface that was attached to the outer frame of the original Rain Guardian Bunker at the Anoka site (Figure 30). Several small holes were drilled along horizontally-oriented shallow grooves in the plywood (T1-11 siding) to simulate infiltration into the subsoil. The frame was constructed so that the top of the sod was approximately level with the curb inlet edge at the entrance, and approximately level with the bioretention bottom elevation at the exit of the GLI.

Figure 30. Wood frame and slope used for rock- and grass-lined inlet testing.

Commercially grown bluegrass sod was purchased and installed on the day of testing (Figure 31). The sections of sod were rolled out perpendicular to the flow direction and seams were closed as tightly as possible to prevent water flow between sections and under the sod. In addition, the sod was attached to the wooden frame with standard wood screws through the root mat (approximately 1-inch thick). Fresh sod was used for each test. After the first test, sod was wrapped up the sides of the box to minimize turbulence and lifting of the edges of the sod.

Figure 31. Preparing the grass lined inlet with fresh sod.

As described previously, sediment and gross solids are captured on the surface of a GLI. When removing this sediment after a test, however, it is likely that grass and organic soil associated with the sod would also be collected. Separating test sediment from solids contributed by the sod would be challenging and time consuming. Thus, performance was measured by comparing the influent sediment to the amount of sediment that was NOT captured by the GLI, but rather was delivered to the bioretention. Also, because fresh sod was used for each test of the GLI, a clean water rinse of approximately 300 cubic feet was passed over the GLI to wash away any loose grass clippings or soil material prior to testing.

As previously described, a “corral” was constructed to capture gross solids and sediment that flowed out of the pretreatment practices during testing. For the GLI tests, a new, seamless piece of nonwoven geotextile (Propex Geotex 801) was added to the corral for each test run. Prior to field testing, this geotextile was tested in the laboratory to ensure it allowed water to pass through but retained the sediment used in field testing. Clean rocks were used to weigh the fabric to prevent floating (Figure 32).

Figure 32. Grass lined inlet with fabric lined corral, after rinsing, ready for a test.

Figure 33 is a photograph taken during the GLI-025-B (grass lined inlet, 0.25 cfs flow rate, replicate B) test run. At the end of each test, the water was drained from the bioretention as described above and any gross solids resting on or in the grass were collected, properly stored, and labeled "captured." In the corral area, sediment was rinsed off the weight stones onto the geotextile. Then, excess geotextile that was clearly not touched by sediment was cut off and the remaining sediment-laden geotextile was carefully folded to retain sediment and gross solids and stored for lab processing. After all samples were collected, the site was prepared for a subsequent test or restored to an operational condition.

Figure 33. Flow on grass lined inlet at 0.25 cfs (GLI-025-B).

4.5.2 Sample processing

At the laboratory, the geotextile containing the non-captured (passing) sediment and gross solids was spread out on a plastic sheet. Gross solids were removed by hand (Figure 34) and rinsed to remove and retain sediment as described above. The geotextile was cut with a heavy scissors into pieces approximately 4 ft by 6 ft for ease of handling. Then, each piece of fabric was thoroughly rinsed with clean water over a watertight bin (Figure 34). This process required one person to hold and manipulate the fabric and one person to spray sediment down the fabric into the bin. Beyond this, samples were processed as described above.

Figure 34. For the grass lined inlet, solids passing the pretreatment and landing in the geotextile were processed and weighed. Gross solids were removed from the geotextile at SAFL (left) and sediment was rinsed from the fabric (right).

4.6 RAIN GUARDIAN BUNKER

4.6.1 Testing setup and cleanup

Testing setup for the RGB required no additional setup because the site was originally designed and constructed with an RGB. Thus, the site simply needed to be cleaned prior to testing. Figure 35 is a photo taken during RGB testing. After a test was complete, gross solids were carefully removed from the top grate by hand and sediment was rinsed from the grate into a bin and decanted through a #325 sieve. The chamber area below the grate and upstream of the screen wall (sometimes noted as pre-screen) was cleared of gross solids by hand. Then sediment was removed from the chamber using the custom filter bucket described above. Gross solids were removed from the screen wall, which was then disassembled and rinsed in a bin (Figure 36) to remove sediment from the screen, backing, and aluminum rails. ACD provided a new screen wall assembly for each of the four tests to eliminate the possibility of cross-contamination and allow for quick re-assembly of the Bunker between tests. Sediment was also collected from the small area of slab just beyond the screen wall and counted as captured because this area is also part of the surface prescribed for maintenance by ACD. All of the capture locations were combined for reporting. After all samples were collected, the site was prepared for a subsequent test or restored to an operational condition.

Figure 35. Rain Guardian Bunker at 0.5cfs test flow (RGB-050-A)

Figure 36. Rinsing the partially disassembled Rain Guardian Bunker screen wall in a bin (foreground) and vacuuming captured sediment from the bunker (background).

4.6.2 Sample processing

Sediment and gross solids were collected separately from several “captured” locations (grate, chamber, screen wall, immediately downstream of screen wall), and separate processing was maintained for each of these locations. Gross solids recovered from the corral area were cleaned and dried as described but not weighed or quantified. Beyond this, samples were processed as described above.

4.7 RAIN GUARDIAN TURRET

4.7.1 Testing setup and cleanup

The RGT is made of concrete and weights slightly over 1,000 lbs, precluding easy installation and removal at the Anoka bioretention site. Instead, ACD supplied a dimensionally accurate lightweight replica of the Turret (Figure 37) which was used for testing in conjunction with normal grates and screen wall. To form the base, a short plywood box with a top elevation the same as the Bunker concrete base slab was overlain by a piece of geotextile fabric with a 1/8th inch sheet of clear polycarbonate plastic on top. Weatherstripping on the underside of the Turret model allowed a sediment-tight seal with the clear plastic sheet. The Turret was held in place by the weight of the top grates (~160 lb) and a ratchet strap to the Bunker frame. Waterproof tape was used to seal slight gaps at the curb inlet lip transition, which was overlain by a piece of geotextile fabric positioned under the flow distributor as described above.

Figure 37. A special lightweight replica of the Rain Guardian Turret was used in testing at the Anoka site.

The test procedure as described above was followed. Figure 38 and Figure 39 show the RGT during testing. After testing, the heavy grates required two people to lift off and suspend over a bin to rinse down any attached sediment. Figure 40 is an example of the cleanout process for the RGT. Similar to the RGB, sediment was collected from the area directly in downstream of the screen wall according to manufacturer’s maintenance guidance. After all samples were collected, the site was prepared for a subsequent test or restored to an operational condition.

Figure 38. Rain Guardian Turret testing at 0.25cfs (RGT-025-A).

Figure 39. Rain Guardian Turret testing at 0.50cfs at a high water level (RGT-050-B).

Figure 40. Cleanout gross solids and sediment from the Rain Guardian Turret.

4.7.2 Sample processing

Sediment and gross solids were collected separately from several "captured" locations (grate, chamber, screen wall, immediately downstream of screen wall), and separate processing was maintained for each of these locations. Beyond this, samples were processed as described above.

4.8 ROCK LINED INLET

4.8.1 Testing setup and cleanup

To install a RLI within the bioretention site in Anoka, a wooden frame was constructed to support the RLI, simulate infiltration of water through the RLI, and capture of sediment and gross solids within the RLI. This wood frame was identical to the wood frame constructed for the GLI and described in section 4.5.1 above, but installed slightly lower in elevation such that the top of the rock was approximately level with the curb inlet edge at the entrance, and approximately level with the bioretention bottom elevation at the exit of the RLI. The end of the slope extended several inches below the grade of the mulch layer on the basin floor and rocks were held in place by a short vertical piece of wire mesh with half inch openings. The frame was covered with geotextile fabric shingled horizontally at a seam and extending up the frame walls. The fabric also extended under the water distribution pan such that no sediment could escape from the system through small cracks or gaps.

Round, pre-washed cobbles 3 – 5 inches in diameter were then placed on the fabric and approximately leveled. Although an effort was made to remove unsound rocks before any testing, a number of rocks showed wear or chipped pieces in the first test. These rocks were removed from further testing and the pieces removed where possible in post-test processing. Figure 41 shows the

RLI with water beginning to flow, immediately prior to the start of sediment feed at t=0. Figure 42 illustrates the post-test condition for two tests.

Figure 41. Beginning of flow on RLI, just prior to the start of a test. Gross solids and sediment are ready to be fed.

Figure 42. Rock lined inlet after testing at 0.25 cfs for 40 minutes (left) and 0.50 cfs for 20 minutes (right).

Immediately following each test, water was drained down and gross solids were removed from the surface of the rocks and placed in a labeled container (Figure 43) for processing at the lab. Stones were then removed and thoroughly rinsed onsite (Figure 44) with a hose and sprayer over a watertight bin. The bin was periodically decanted through a #10 sieve (2mm openings) and a #325 sieve, as described above. Sediment from the sieve was then transferred to a labeled container for processing at the lab. After all rocks were rinsed, the bin was thoroughly rinsed with all rinse water passing through the sieves. After the rocks were removed, a considerable amount of sediment remained on the geotextile fabric below (Figure 45). The fabric was cut and carefully folded to contain sediment, then transferred to a labeled container for processing at the lab. After all samples were collected, the site was prepared for a subsequent test or restored to an operational condition.

Figure 43. Removal of gross solids from the rock lined inlet.

Figure 44. Rinsing rocks from the rock lined inlet.

Figure 45. Sediment remaining on geotextile when rocks were removed from RLI.

4.8.2 Sample processing

At the laboratory, the geotextile containing the captured sediment that was present under the rocks was rinsed into a water tight bin and processed as described above. Beyond this, samples were processed as described above.

4.9 SHALLOW SUMP GRIT CHAMBER (DV)

4.9.1 Testing setup and cleanup

Testing at the in-line shallow sump grit chamber in Bloomington was slightly different than testing at the sites in Anoka, as described above. In addition, some specific modifications to the practice or site were made to accommodate testing. The base slab of the shallow sump grit chamber has five (5), four-inch diameter holes designed for infiltration, which were plugged with red plumbing test plugs to limit the loss of test solids into the holes (Figure 46). During testing it was observed that water could seep into the chamber around some plugs and in the gap between the base slab and walls. It is unclear whether sediment or water were lost through these unsealed seams.

Figure 46. A wet-dry vac was used to remove sediment from the bottom of the Bloomington sump. The red plugs were inserted to seal infiltration holes in the slab to limit sediment loss.

After setting up the flow distributor along the curb line (Figure 21), the pretreatment practice and bioretention basin was flushed with water, and then pumped down. The grate was thoroughly rinsed. The connecting pipes were then sprayed out and the sump was hosed down and cleaned. For testing at this site, cleaning the sump after rinsing was necessary before every test.

For the first test at the design volume (BDV), water flow rate adjustment was done before beginning the sediment feed at t=0. However, due to the small basin volume, subsequent tests started sediment feed at t=0 as soon as water began to flow through the distributor. Flow rate was the adjusted in the first few minutes of the test. For the design volume tests (BDV), each test was run until just before overflow of water to the downstream gutter, when the water elevation was at the top of the grate. This occurred at staff gauge elevation of approximately 12 inches above the bottom of the bioretention basin. When this water elevation was reached, the sediment feeder was shut down, the water was turned off, and the stop time was recorded. Test duration was approximately 15 minutes for the 0.06 cfs flow rate and 30 minutes for the 0.12 flow rate, compared to the proposed test duration of 20 minutes and 40 minutes, respectively.

Collection of sediment and gross solids was similar to collection from the chambers of the RGB and RGT but was complicated by the presence of standing water in the sump. The first step after flow was shut off was to slowly pump the water out of the bioretention basin. The drain rate was slow enough that sediment and gross solids were not observed to move. After the water receded to the invert level of the pipes connecting the sump to the bioretention, the grate surface was gently rinsed into the sump, then raised in place and rinsed again to remove any sediment, then removed and placed out of the way. There was typically very little accumulation of gross solids and sediment on the grate. Gross solids were then removed by hand from the sump and placed in labeled containers for lab processing.

Clear water in the sump was pumped away with a suspended, small submersible pump to within about three inches of the sediment surface so as not to entrain sediment. The remaining water was vacuumed off using a wet-dry vacuum and filter bucket as described in Section 4.3.5 . This water was passed through the #325 sieve to retain any sediment. Vacuuming then continued to remove all the captured sediment (Figure 46) as described above. This was complicated by the gap between the bottom slab and wall; applying too much suction near the wall tended to draw in fine organic particles (Figure 47), which were excluded where possible. Captured sediment from the filter bucket was labeled and stored for lab processing. Any sediment in the connecting pipes was rinsed into the bioretention basin and was not counted as captured. The corral was cleaned of gross solids, which was bagged and taken to the lab for cleaning but was not counted or weighed. After all samples were collected, the site was prepared for a subsequent test or restored to an operational condition.

Figure 47. Fine organic material retained on sieve.

4.9.2 Sample processing

Samples were processed as described above.

4.10 SHALLOW SUMP GRIT CHAMBER (BYPASS)

4.10.1 Testing setup and cleanup

To measure the performance of the shallow sump grit chamber during bypass conditions, sediment and gross solids had to be collected in additional locations: in the gutter downstream of the sump and in a second downstream catch basin, which is connected to the city's storm sewer system. This was accomplished by fitting the downstream catch basin with a geotextile basket to capture solids (Figure 48), and thoroughly cleaning the 6 feet of gutter between the two catch basins by flushing and vacuuming before testing. The grate of the downstream catch basin was also thoroughly rinsed. The geotextile fabric was secured below the grate of the downstream catch basin and all gaps were sealed or covered with waterproof tape. The flow distributor was also sealed to the frame of the pretreatment practice inlet to prevent sediment or gross solids from backing up the curb line during elevated water due to bypass flows.

Figure 48. For the bypass tests of the Bloomington pretreatment practice, the downstream catchbasin was lined with a geotextile basket to capture sediment and gross solids bypassing and/or washing out of the pretreatment practice.

As previously described, the bypass tests used approximately twice the design volume to induce bypass of the pretreatment practice, as shown in Figure 49. At the highest flow rate (BBP-025), the test was stopped slightly early (test duration = 30 minutes) because the geotextile basket in the downstream catch basin was on the verge of bypassing.

At the conclusion of the test, water was shut off and the surcharged bioretention basin was allowed to drain down before being pumped out. Sediment and gross solids in the shallow sump grit chamber were collected as described above. Collection of sediment and gross solids that had bypassed the pretreatment consisted of thoroughly vacuuming the street gutter between the pretreatment inlet and the downstream catch basin and collecting the geotextile fabric basket from the downstream catch basin. The catch basin grate was rinsed down into the fabric with clean water, then the grate was raised and rinsed further before removal (Figure 50). Excess fabric was cut off and then the fabric with sediment and gross solids was carefully removed and placed in a labeled container for lab processing. After all samples were collected, the site was prepared for a subsequent test or restored to an operational condition.

Figure 49. Flow in the gutter during bypass (BBP-025-A).

Figure 50. Gross solids and slight amount of sediment captured on geotextile fabric in the downstream catch basin frame (BBP-012-A).

4.10.2 Sample processing

Samples were processed as described above.

4.11 CALCULATIONS

The calculation of solids removal is shown in the following mass balance equation and is the same for both sediment and gross solids. The captured dry mass is the material captured by the pretreatment practice that has been oven dried and weighed; and the net initial dry mass is the mass fed to the system minus any mass not fed.

$$Removal = (captured\ dry\ mass)/(net\ initial\ dry\ mass)$$

For the gross solids, the net initial dry mass was the pre-weighed amount prepared at the laboratory minus any gross solids not fed to the system. In all but one replicate, the complete amount of gross solids was fed during the tests. For the sediment, the net initial dry mass is the pre-weighed amount prepared at the laboratory minus the “not fed” amount recovered from the sediment feeder. This calculation was repeated for each sediment fraction and type of gross solid, and then combined for a grand total for each test run. The following is an example calculation for the smallest sediment size (D_{50}~120µm, designated as) for test RLI-050-A:

$$Removal\ of\ D_{50}120\mu m = \frac{captured\ dry\ mass}{net\ initial\ dry\ mass} = \frac{311.76g}{939.47g - 29.06g} = 0.342 \times 100\% = 34.2\%$$

A similar example calculation for artificial leaves, designated as part of the gross solids mix, also for test RLI-050-A:

$$Removal\ of\ leaves = \frac{captured\ dry\ mass}{net\ initial\ dry\ mass} = \frac{226.47g}{79.64g - 0g} = 0.351 \times 100\% = 35.1\%$$

An example calculation for the total of all sediment in RLI-050-A:

$$Removal\ of\ total\ sediment = \frac{2162.63g}{2818.34g - 46.56g} = 0.780 \times 100\% = 78.0\%$$

This same process is also used for the bypass tests (BBP) because the net initial dry mass and captured dry mass are measured directly. The additional mass collected as bypass is reported to illustrate the potential for resuspension.

For the GLI, the mass of solids retained within the GLI was not measured and thus the above calculation is not possible. For the GLI test data, a modified removal calculation was used:

$$Removal = \frac{net\ initial\ dry\ mass - untreated\ dry\ mass}{net\ initial\ dry\ mass}$$

The net initial dry mass is the same as above and is equal to the mass fed to the system minus any mass not fed. The untreated dry mass is the material that passed untreated through the pretreatment practice and was captured downstream in the corral and has been oven dried and weighed. An example calculation is below with data from test run GLI-050-A for the intermediate sediment, identified as D_{50}~410µm. A total of 939.47g of the intermediate sediment was placed in the feeder, 21.35g were collected from the feeder after the test as not fed, and 179.93g was collected in the corral (untreated):

$$Removal\ of\ \ D_{50}410\mu m\ = \frac{(939.47g - 21.35g) - 179.93g}{939.47g - 21.35g} = 0.804 \times 100\% = 80.4\%$$

It is important to note that the calculations for the RGB, RGT, RLI, BDV, and BBP all calculate performance efficiency directly from the mass captured within the pretreatment practice, whereas the calculation for the GLI is based on the difference between input and untreated mass. Thus, any error associated with the measurements are mathematically included in the performance of the GLI and omitted from the performance of the other pretreatment practices. In general, this would bias the performance of the GLI to be larger (i.e., better) than the actual performance by the amount of the error. The error is discussed in Section 5.3 Error and Uncertainty.

Calculations were repeated for each flow rate and replicate. Actual calculations were performed in a spreadsheet. Results are reported in CHAPTER 9: Appendix.

Precision was calculated using the Relative Percent Difference (RPD) to determine how much two or more data replicates are in agreement with each other. For this project, two replicates (A & B) were conducted for each pretreatment practice for each flow rate tested (except for the bypass tests). From this data, the Relative Percent Difference (RPD) was calculated as follows:

RPD = (A – B) ÷ ((A + B) / 2) x 100

where A is the larger of the two duplicate sample values and B is the smaller value.

CHAPTER 5: RESULTS AND DISCUSSION

5.1 ANOKA SITE: GRASS LINED INLET, RAIN GUARDIAN BUNKER, RAIN GUARDIAN TURRET, AND ROCK LINED INLET

5.1.1 Sediment Capture

5.1.1.1 Low intensity (Q = 0.25cfs for 40 minutes)

Sediment capture for the tests designed to simulate the design storage volume of the bioretention practice (600 cubic feet for Anoka) for the low intensity flow conditions is shown in Figure 51. In general, all pretreatment practices captured at least 95% of the coarse sediment fraction (D_{50} = 1.17mm) mass and the medium sediment fraction (D_{50} = 0.41mm) mass. The pretreatment practices also captured 65 – 80% of the fine sediment fraction (D_{50} = 0.12mm).

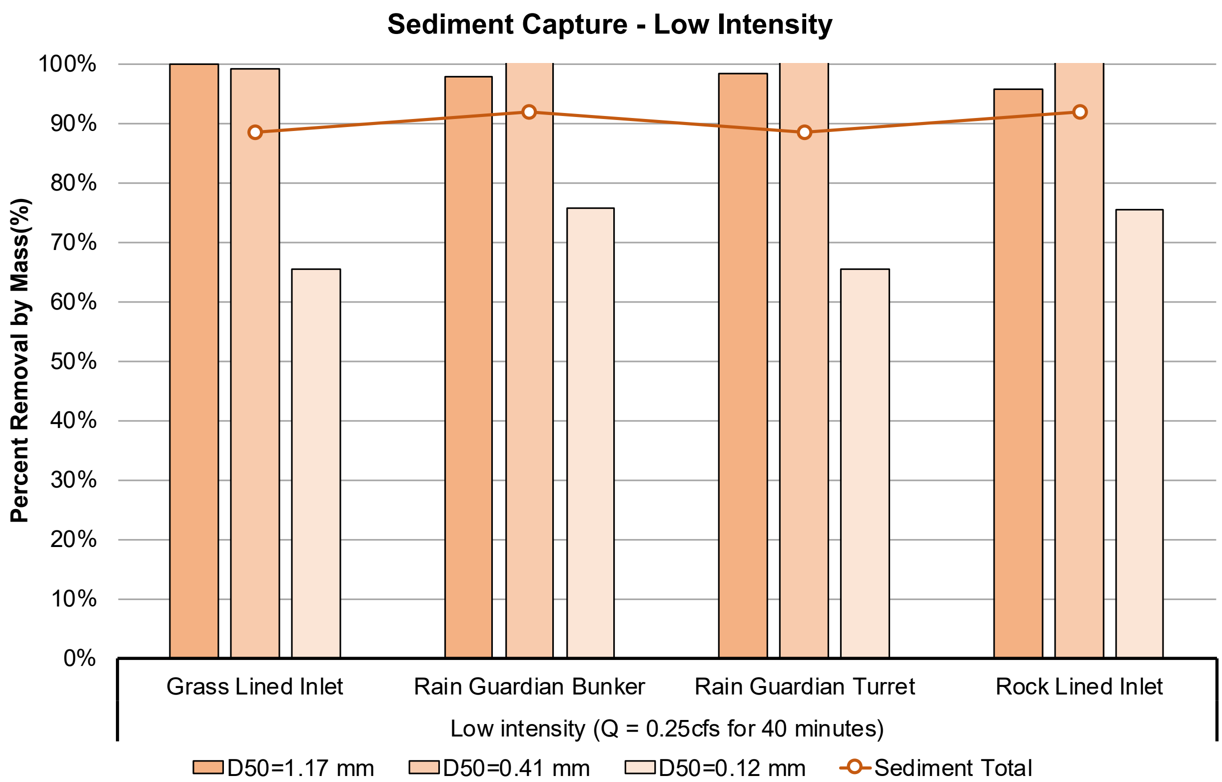


Figure 51: Sediment capture by percent for design volume low intensity tests (Q = 0.25cfs, duration = 40 minutes).

The purpose of pretreatment is to reduce the maintenance burden on primary treatment practices (i.e., bioretention) by capturing gross solids and 25% of the sediment > 100µm (MPCA 2017a). As shown in Figure 19, approximately 90% of the fine sediment fraction used in testing is between than 0.1mm (100 µm) and 0.2 mm. As shown in Figure 51, 65 – 80% of this fine sediment fraction was captured by all four pretreatment practices for low intensity tests. When all three sediment fractions are summed, 88 – 95% of the sediment mass was captured by the pretreatment practices.

Thus, these pretreatment practices exceed the goal set by the MPCA for these simulated flow conditions.

Due to the high velocity of the water, and short length and flexibility of the grass, it was unclear whether the GLI would be able to capture sediment effectively. As shown in Figure 51, over 90% of the total sediment was captured in the GLI for low intensity tests. This data was corroborated by visual observations of a significant accumulation of sediment on the grass during testing (Figure 52). This accumulation was most evident near the seam between sod sections, but sediment accumulation was observed throughout the GLI.

Figure 52. Sediment accumulation near the horizontal seam between sod sections in the GLI. Flow was right to left.

The Rain Guardian Bunker and Turret both captured approximately 90% of the test sediment, most of which was captured within the chamber of the devices (data in Appendix A). Some sediment was also captured on the surface grate in association with gross solids (primarily leaves), and some sediment was deposited downstream of the screen wall on the concrete base pad. The sediment downstream of the screen wall likely didn't flow through the screen, but rather flowed over the screen water during high water conditions and settled on the pad.

5.1.1.2 High intensity (Q = 0.50cfs for 20 minutes)

Sediment capture for the tests designed to simulate the design storage volume of the bioretention practice (600 cubic feet for Anoka) for high intensity flow conditions is shown in Figure 53. In general, all pretreatment practices captured at least 95% of the coarse sediment fraction (D_{50} = 1.17mm) mass and the medium sediment fraction (D_{50} = 0.41mm) mass, except for the grass lined inlet (GLI) which only captured 80% of the medium sediment fraction (D_{50} = 0.41mm). The pretreatment practices also captured 30 – 40% of the fine sediment fraction (D_{50} = 0.12mm).

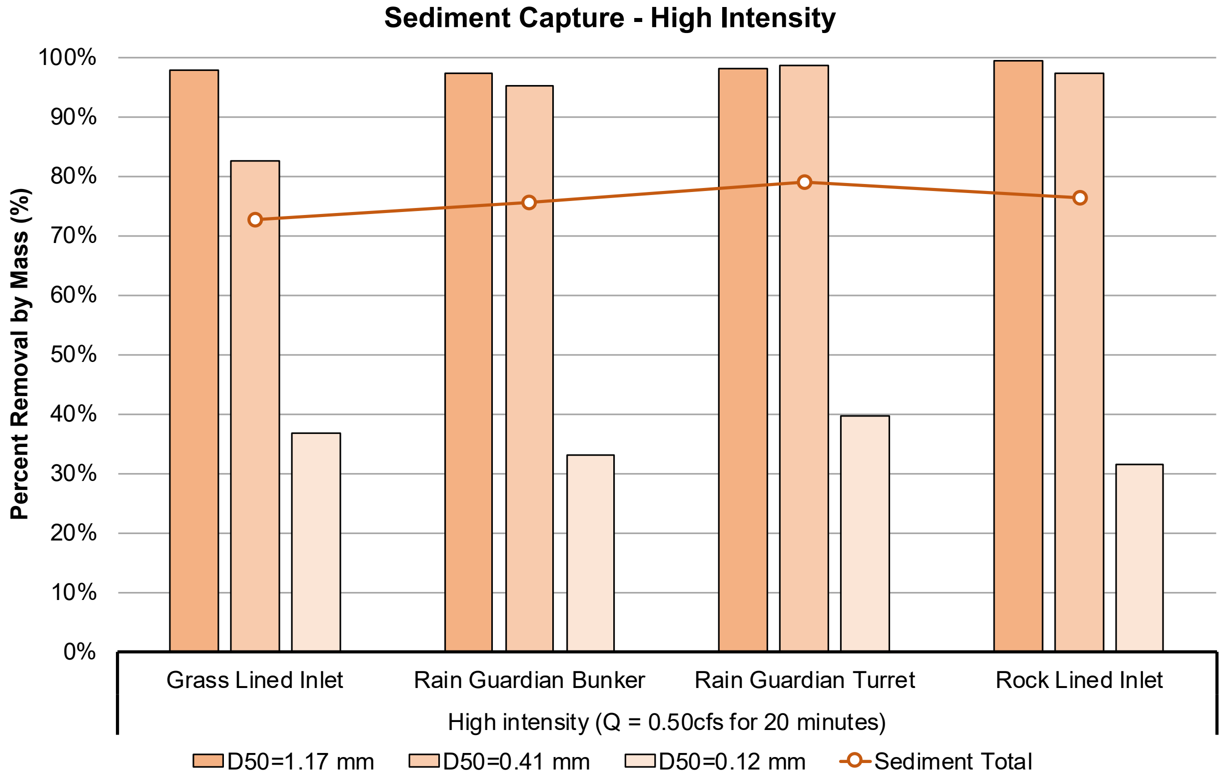


Figure 53: Sediment capture by percent for design volume high intensity tests (Q = 0.50cfs, duration = 20 minutes).

For all practices and all sediment fractions, less sediment was captured in the high intensity tests (Figure 53) compared to the low intensity tests (Figure 51). This is expected because higher flow creates more turbulence, more mixing, and shorter residence time within the pretreatment practice, and likely causes more overflow from the pretreatment practice into the primary practice (i.e., bioretention). All practices did, however, capture greater than 30% of the fine sediment fraction and at least 70% of the total sediment mass, which exceeds the goal of 25% capture of sediment > 100µm (MPCA 2017a).

5.1.2 Gross Solids Capture

5.1.2.1 Low Intensity (Q = 0.25cfs for 40 minutes)

Gross solids capture for the design volume low intensity test is shown in Figure 54. The RGB, RGT, and RLI captured over 98% of the mass of forks and leaves. The GLI, however, only captured 8% of the forks and 3% of the leaves. For the wood dowels, approximately 40% of the mass was captured by the GLI and the RGB; approximately 60% by the RGT; and over 80% captured by the RLI. Of the gross solids used in this testing, the wood dowels best represent floatables because they remained floating on the water surface throughout the duration of most tests. Overall, gross solids were captured at 20% (GLI), 80% (RGB), 85% (RGT), or 95% (RLI).

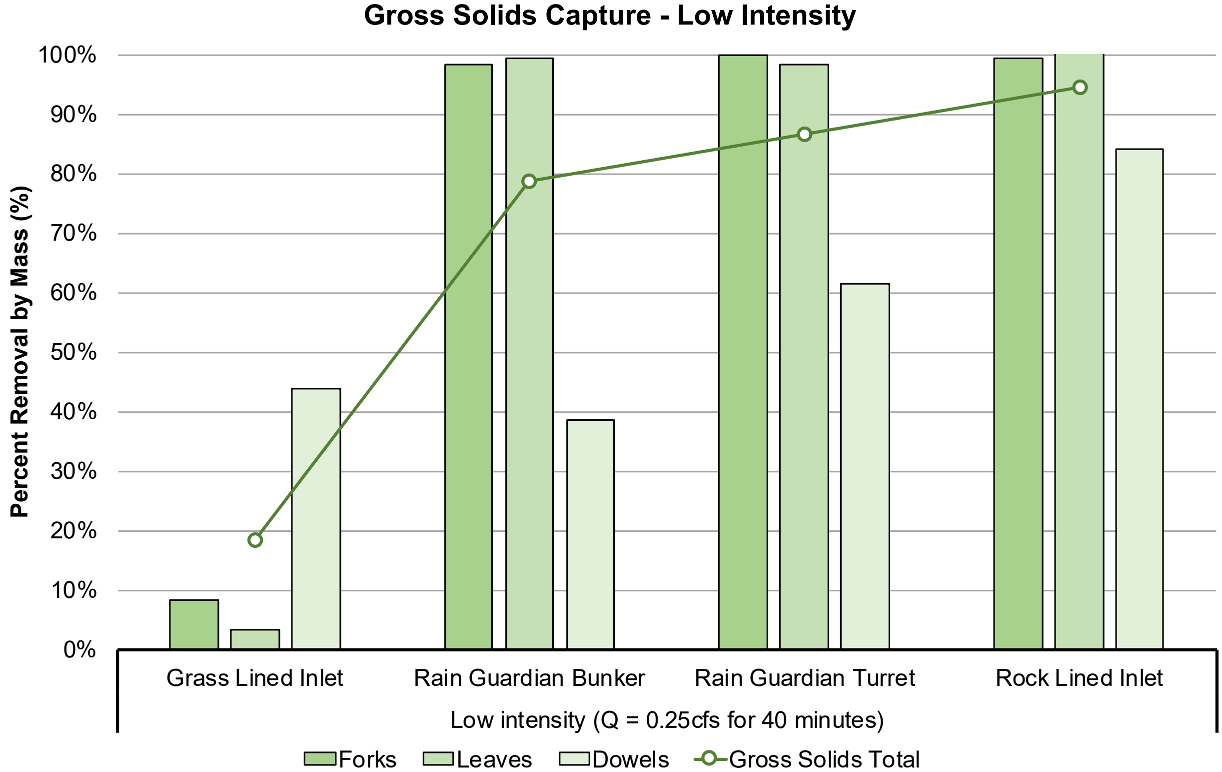


Figure 54: Gross solids capture by percent for design volume low intensity tests (Q = 0.25cfs, duration = 40 minutes).

While the GLI was shown to capture sediment (Figure 51 & Figure 53), it is evident from Figure 54 that GLIs are not effective at capturing gross solids. This is consistent with the design of GLIs in that there is no physical mechanism for gross solids to be captured. The short length and flexibility of lawn grass is not enough to capture and retain debris. While it appears from Figure 54 that the GLI captured over 40% of the wood dowels, field observations revealed that these dowels were floating on the water surface and deposited on the GLI as the water in the bioretention was drained (Figure 55). Without the corral, it is likely these dowels would have been dispersed throughout the bioretention and would not have been “captured” by the GLI.

The Rain Guardian Bunker and Turret captured 80% and 85% of the gross solids, respectively (Figure 54). Most of the gross solids were captured on the surface grate and nearly all of the remaining gross solids were captured within the chamber (data in Appendix A). A small fraction (2 – 4%) of gross solids were captured on the concrete pad downstream of the screen wall (data in Appendix A).

Figure 55: Capture of gross solids on grass lined inlet. Note wood dowels floating on water surface above the GLI near the downstream boundary with the corral. These dowels were deposited on the GLI during drawdown and counted as "captured."

5.1.2.2 High Intensity (Q = 0.50cfs for 20 minutes)

Gross solids capture by the pretreatment practices during the high intensity test is shown in Figure 56. The RGB and RGT captured over 95% of the forks, 55 – 75% of the leaves, and 30 – 45% of the dowels in high intensity tests. The RLI captured 80% of the forks, 25% of the leaves, and 65% of the dowels. The GLI captured 10% of the forks, less than 5% of the leaves, and 70% of the wood dowels. Overall, gross solids were captured at 30% (GLI), 60% (RGB and RLI), and 70% (RGT).

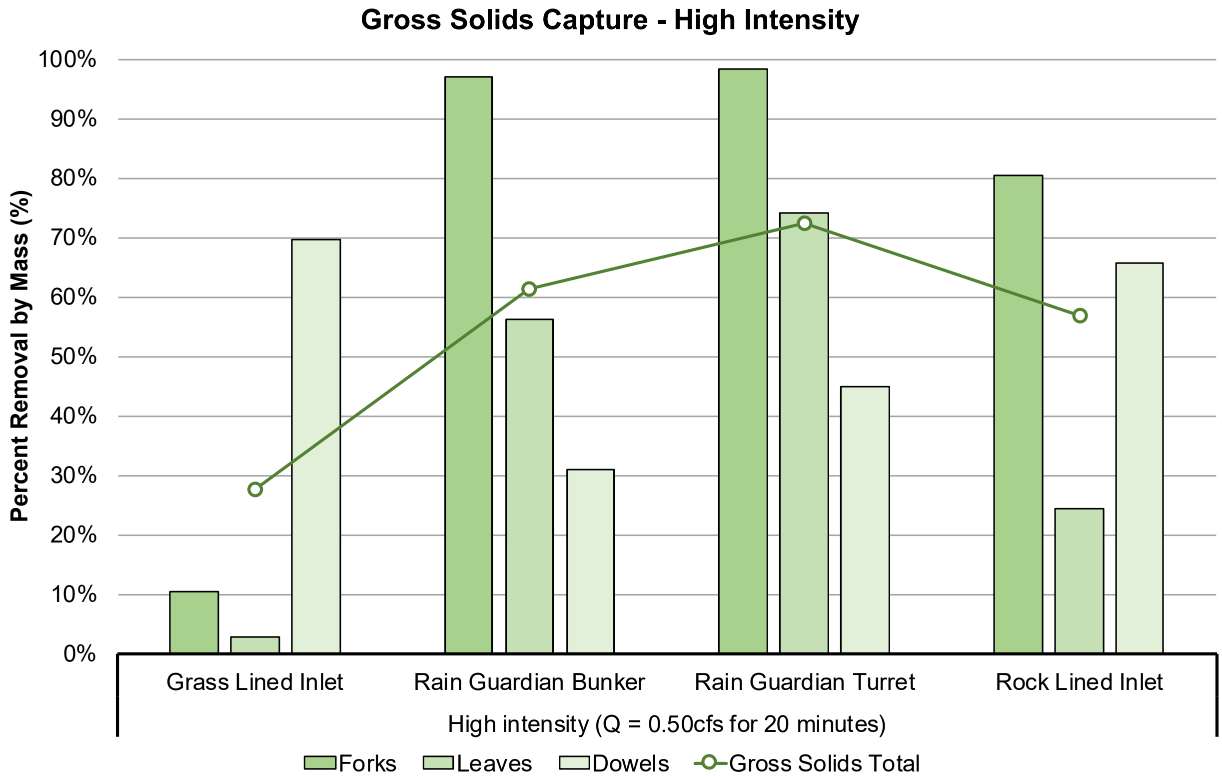


Figure 56: Gross solids capture by percent for design storage volume tests, Q = 0.50cfs, duration = 20 minutes.

In addition to the flow rate (and likely flow velocity), a primary difference between the low intensity and high intensity tests at the Anoka site (GLI, RGB, RGT, RLI) is the water depth within the bioretention cell, and subsequently the proportion of the pretreatment practice that was inundated by backwater. For the sloped practices (GLI, RLI), this meant that water, sediment, and gross solids that were carried into the practice by high velocity supercritical flow were intercepted by a standing pool at some point along the slope of the pretreatment practice. This point occurred near the bottom edge of the GLI and RLI for the low intensity tests, and near the upper edge during the high intensity tests. In other words, the GLI and RLI were mostly exposed during low intensity such that rocks and even some grass were emergent through the flow. Conversely, most of the rock and grass were fully submerged during high intensity flow. Thus, emergent rocks were able to intercept and capture gross solids during the low intensity tests but gross solids were carried further downstream during the high intensity tests, as shown in Figure 57. During the low intensity tests on the RLI, it was observed that the accumulation of gross solids (Figure 57) also created a “debris filter” that intercepted and captured sediment among the gross solids.

Figure 57. Rock lined inlet after testing at 0.25cfs for 40 minutes (left) and 0.50cfs for 20 minutes (right).

It was also observed during testing that sediment was deposited (likely by settling) in the RLI just downstream of the point of inundation, likely due to the energy dissipation caused by the pool. The effect of this inundation from backwater is further illustrated by the apparent increase in dowel capture by the GLI from the low intensity tests (45% dowel capture) to the high intensity tests (70% dowel capture). As previously discussed, dowels "captured" by the GLI were actually deposited on the GLI during the drawdown phase after the tests were complete, not as a result of the GLI physically retaining the dowels. Because more of the GLI was inundated by backwater during the high intensity tests, more dowels were deposited during drawdown.

During the high intensity tests, the Rain Guardian Bunker and Turret captured 60% and 70% gross solids, respectively. Similar to the low intensity tests, most of the gross solids were captured on the surface grate and nearly all of the remaining gross solids were captured within the chamber (data in Appendix A).

5.2 BLOOMINGTON SITE: IN-LINE SHALLOW SUMP GRIT CHAMBER

A primary difference between the Anoka and Bloomington field sites is the size of the primary treatment, the bioretention practice. In Anoka, the bioretention practice could hold approximately 600 cubic feet of runoff, whereas the bioretention in Bloomington could hold approximately 119 cubic feet of runoff. Thus, the Bloomington bioretention required a lesser flow rate (Q = 0.06cfs, duration = 30 minutes for low intensity; Q = 0.12cfs, duration = 15 minutes for high intensity) to allow for tests with a similar test duration as Anoka. Subsequently, less sediment and gross solid mass were used so that the solids concentration was similar between tests. Though every effort was made to create field tests that would be comparable between the different sites, the results from Anoka are not directly comparable to the results from Bloomington.

Field testing in Bloomington included additional tests beyond the design volume, inducing bypass of the pretreatment practice. Because the shallow sump grit chamber installed in Bloomington is constructed in-line, it is expected that performance will be affected under bypass conditions because turbulence could resuspend previously captured sediment and gross solids, allowing them to exit the pretreatment chamber and be delivered downstream. By contrast, the sites in Anoka were all designed as off-line systems such that if the flow volume exceeded the design volume, then excess water, sediment, and gross solids would simply pass by the pretreatment and bioretention without interacting with previously captured sediment or gross solids, which is an advantage of the off-line design.

Sediment capture by the shallow sump grit chamber for the design volume tests and the bypass tests is shown in Figure 58. For the design volume tests ((a) and (b) in Figure 58), the overall sediment capture decreases from 95% to 90% primarily because fine sediment (D_{50} = 0.12mm) capture decreases from 80% to 65%. As previously discussed, this is not surprising because as the intensity increases the residence time decreases and thus more sediment is carried through the pretreatment practice into the bioretention. From test (b) to (c), the flow rate remains the same, but the duration is doubled to allow in-line bypass of the pretreatment practice to occur. As noted in Figure 58, bypass began at 15 minutes after the test began and continued through the full duration (40 minutes). The performance is nearly identical between the design volume test (b) and the bypass test (c) at the same flow rate. Thus, in-line bypass of the pretreatment practice at this flow rate does not appear to affect sediment capture performance.

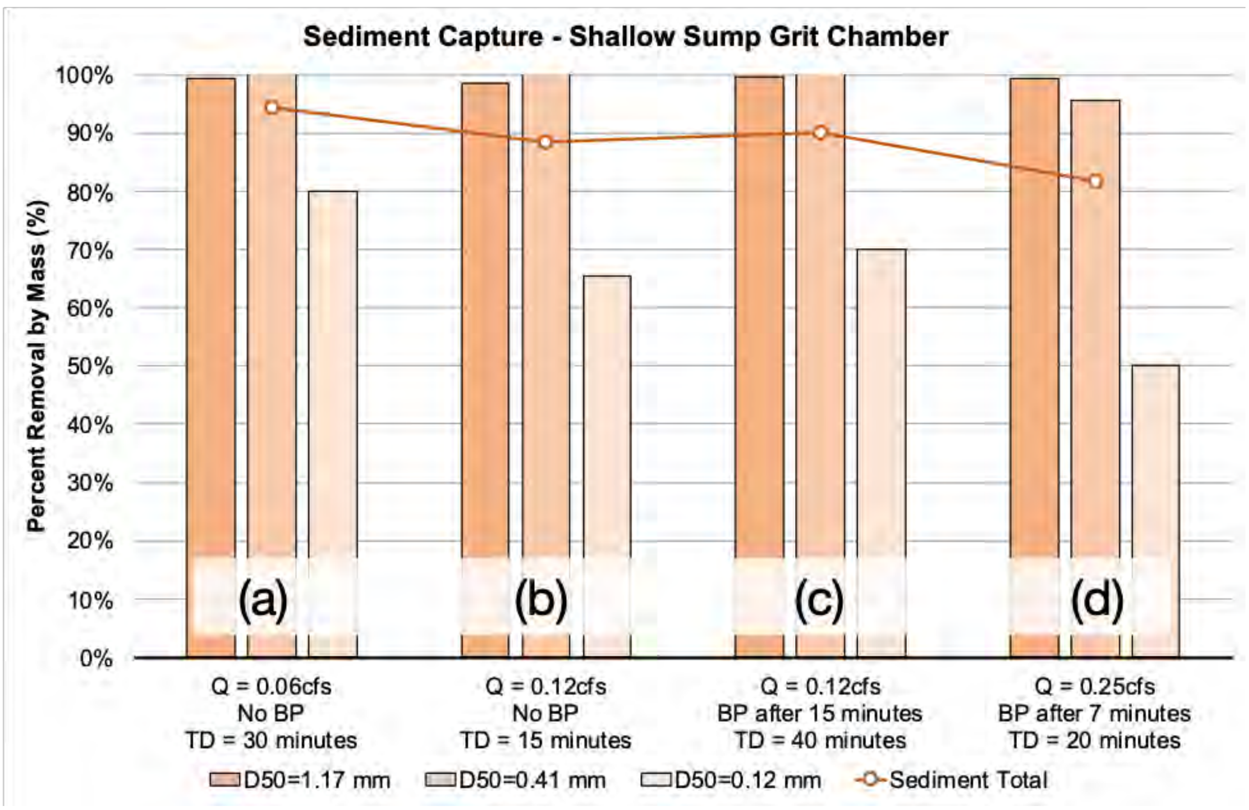


Figure 58: Sediment capture by the shallow sump grit chamber for two design volume tests* (a) *Q = 0.06cfs for 30 minutes and* (b) *Q = 0.12cfs for 15 minutes; and two bypass tests* (c) *Q = 0.12cfs for 40 minutes and* (d) *Q = 0.25cfs for 20 minutes. BP = Bypass; TD = Total Duration.

The increase in intensity from (c) to (d) resulted in a decrease in performance from 90% overall sediment capture to 80%, which can be associated with a decrease in medium sediment (D_{50} = 0.41mm) capture (100% to 95%) and fine sediment (D_{50} = 0.12mm) capture (70% to 50%). This was expected due to a reduction in residence time within the pretreatment practice and an increase in turbulence which could resuspend previously captured sediment.

Approximately 75% of fine sediment (D_{50} = 0.12mm) was either captured in the shallow sump grit chamber or not fed for the design volume and bypass tests for the same flow rate (Q = 0.12cfs) while 25% was either delivered to the bioretention or bypassed the in-line shallow sump grit chamber in the bypass test (10%), as shown in Figure 59. In the test of the shallow sump grit chamber with the highest flow rate (Q = 0.25cfs), approximately 16% of the fine sediment bypassed the in-line chamber.

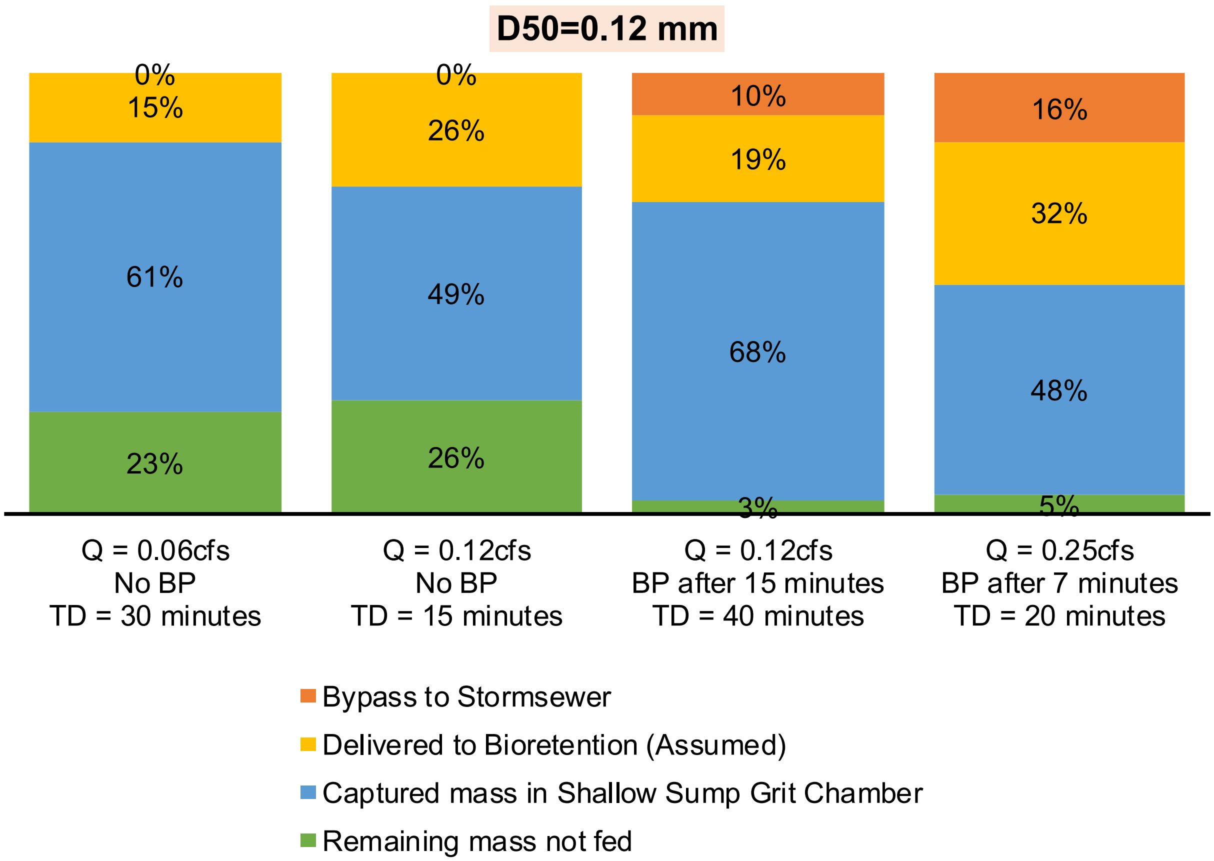


Figure 59: Fine sediment (D_{50} = 0.12mm) capture and bypass by the shallow sump grit chamber for four tests.

Gross solids capture by the shallow sump grit chamber for the design volume tests and the bypass tests is shown in Figure 60. The decrease in gross solids capture between the low and high intensity design volume tests ((a) and (b) in Figure 60) is expected due to the increase in mixing and decrease in residence time within the shallow sump grit chamber, resulting in export of gross solids from the pretreatment and into the bioretention. Capture performance for forks remained nearly the same, but leaf capture decreased from 90% to 65% and dowel capture decreased from 55% to 45%. Inducing bypass in the shallow sump grit chamber by increasing the duration but maintaining the same flow ((b) to (c)) resulted in a decrease of gross solids capture from 70% to 60%, primarily because dowel capture decreased from 45% capture in the design volume test (no bypass) to 15% in the bypass test (Figure 60). When the intensity of the bypass test was increased (test (c) to (d)), gross solids captured decreased again from 60% overall capture to below 40% capture due to reduction in capture efficiency for all three gross solids types.

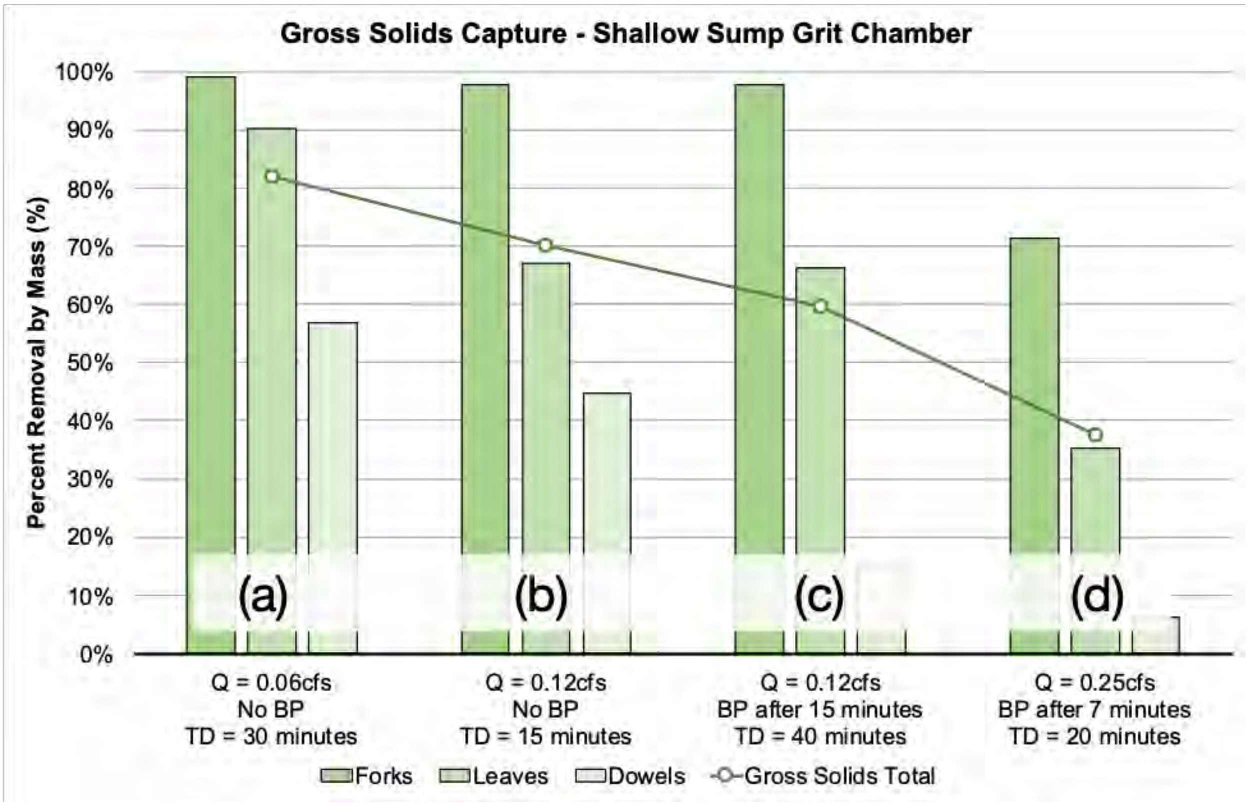


Figure 60: Gross solids by the shallow sump grit chamber for two design volume tests* (a) *Q = 0.06cfs for 30 minutes and* (b) *Q = 0.12cfs for 15 minutes; and two bypass tests* (c) *Q = 0.12cfs for 40 minutes and* (d) *Q = 0.25cfs for 20 minutes. BP = Bypass; TD = Total Duration.

Approximately 66-67% of the leaves were captured in the shallow sump grit chamber during the design volume and bypass tests for the same flow rate (Q = 0.12cfs), as shown in Figure 61. Of the remaining 33-34% of leaves that was untreated, 21% bypassed the in-line shallow sump grit chamber in the bypass test. The amount that bypassed increased to 74% for wooden dowels (data not shown) because there is no mechanism within the in-line shallow sump grit chamber to capture floatables. Thus most of the dowels flowed over the top of the grate when the water level was above the grate elevation.

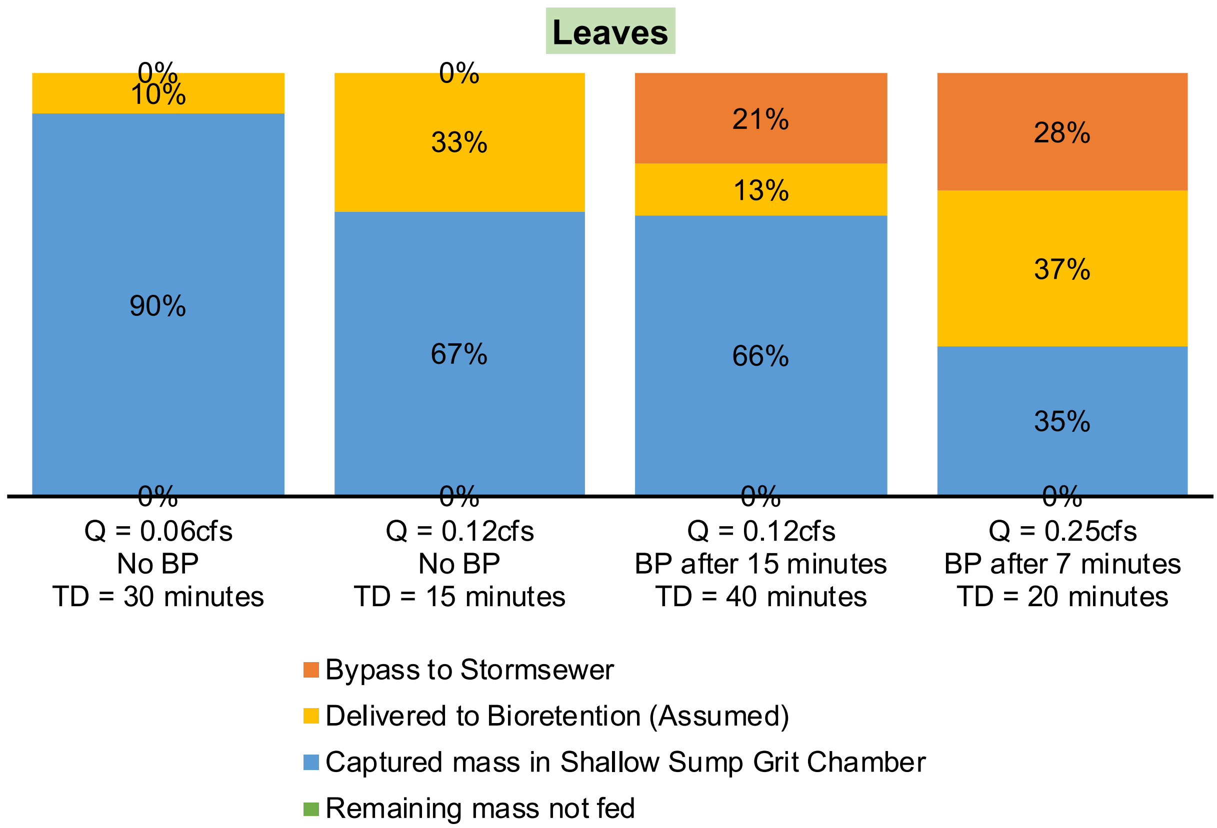


Figure 61: Leaves capture and bypass by the shallow sump grit chamber for four tests.

5.3 ERROR AND UNCERTAINTY

The nature of field testing is such that not all components or uncertainty can be measured. For this project, the sediment that was delivered to the bioretention was only quantified for tests of the GLI. However, the sediment that was captured on the GLI was not quantified, and thus a mass balance could not be completed. For all other tests, the sediment delivered to the bioretention was not quantified, and thus a mass balance could not be completed. For gross solids, the use of the corral and collection of gross solids from all locations allowed for a mass balance to be completed for some tests. Mass balance errors for gross solids were less than 5%.

In addition, precision was quantified using the relative percent difference (RPD) calculation as described above. The RPD was calculated for all tests in which two replicate tests were conducted (see Table 2). The average RPD for these ten pairs of replicates are reported for each sediment fraction and gross solids type used in testing, as shown in Table 6.

Table 6: Average Relative Percent Difference (RPD) for sediment and gross solids tests (n = 10).

	Initial Mass added to Pretreatment	**Captured Mass in Pretreatment**	**Percent Removal**
D50=1.17 mm	2.9%	3.2%	1.4%
D50=0.41 mm	2.4%	5.0%	2.8%
D50=0.12 mm	2.6%	20.4%	19.0%
Sediment Total =	2.4%	5.9%	4.6%
Forks	0.6%	22.7%	22.8%
Leaves	0.1%	24.5%	24.5%
Dowels	0.3%	26.0%	26.1%
Gross Solids Total =	0.2%	10.5%	10.4%
Sediment + Gross Solids =	1.9%	4.5%	3.6%

5.4 MAINTENANCE CONSIDERATIONS

This project was limited by time and funding to measure the sediment and gross solids capture performance of five pretreatment practices for bioretention, each at two flow intensities and two replicates for each test. To provide an adequate comparison between practices, each practice was freshly installed and cleaned prior to every test and replicate. Thus, the accumulation of sediment and gross solids from multiple sequential tests was not measured as part of this project. Further research is needed to determine the recommended maintenance frequency based on performance. However, the following observations can be made from the testing that was conducted.

5.4.1 Grass Lined Inlet (GLI)

The GLI did not capture gross solids, so maintenance to remove gross solids from the pretreatment is expected to be minimal. These gross solids are expected to accumulate within the bioretention practice, however, and maintenance would be necessary to remove them. The GLI collected a substantial amount of sediment during the tests. It is expected that this sediment would continue to accumulate, effectively increasing the soil elevation wherever sediment is deposited. If the GLI is mowed as part of maintenance, the grass height will be determined by the soil elevation, and thus the GLI is expected to increase in elevation over time as sediment accumulates. The amount of sediment that was accumulated was approximately equal to ½ of the grass height. Thus, it is possible that only a few storms could “fill” the capacity of the GLI. This phenomenon has been observed by stormwater professionals, resulting in a common design practice of including a 2 to 4-inch drop in elevation from the back of curb to the top of the GLI to allow for sediment accumulation. To maintain a GLI, the grass, sediment, and likely the topsoil will need to be removed and replaced to restore the GLI to the original design elevation. This level of maintenance is effectively the same cost as constructing a brand new GLI. Of the pretreatment practices tested in this study, the GLI is likely among the most difficult and costly to maintain.

5.4.2 Rain Garden Bunker (RGB)

The RGB collected sediment and gross solids in all tests. Collecting the sediment and gross solids to calculate performance was similar to the maintenance recommendations for the RGB, though the test sediment and gross solids were carefully collected for quantification. The accumulation of sediment and gross solids within the RGB was minimal compared to the storage capacity. Also, the chamber and screen wall design of the RGB suggest that gross solids and sediment would be protected from resuspension during high intensity flow conditions, though data to support this was not collected as part of this study.

Access to the sediment and gross solids within the RGB was simple, and accumulation of sediment and gross solids with the RGB is easily visible from the road. This is an advantage because visual inspection of the RGB is quick and could be completed by homeowners, or by staff from a vehicle. In addition, the permeable screen wall allows stored water to filter out of the bunker when runoff ceases, resulting in a dry chamber between runoff events. This prevents mosquito breeding and obnoxious odors and allows the bunker to be cleaned with a shovel by homeowners or minimally trained staff.

It is anticipated that the RGB could collect and store several storms of sediment and gross solids before maintenance is needed, though it is impossible to predict from this project how frequently maintenance will be needed and the capture performance as sediment and gross solids accumulate. Of the pretreatment practices tested in this study, the RGB is likely among the easiest to maintain.

5.4.3 Rain Garden Turret (RGT)

Similar to the RGB, the RGT collected sediment and gross solids in all tests. Collecting the sediment and gross solids to calculate performance was similar to the maintenance recommendations for the RGT, though the test sediment and gross solids were carefully collected for quantification. The accumulation of sediment and gross solids within the RGT was minimal compared to the storage capacity. Also, the chamber and screen wall design of the RGT suggest that gross solids and sediment would be protected from resuspension during high intensity runoff events, though data to support this was not collected as part of this study.

Access to the sediment and gross solids was not as simple as the RGB because the top grates of the RGT used during testing were larger and heavier than those of the RGB. Since testing, the grates used on the RGT have been replaced with fiberglass grates that are substantially less weight. Thus maintenance of the RGT is expected to be at least as simple as the RGB. Accumulation of sediment and gross solids with the RGT is easily visible from the road. This is an advantage because visual inspection of the RGT is quick and could be completed by homeowners, or by staff from a vehicle. In addition, the permeable screen wall allows stored water to filter out of the turret when runoff ceases, resulting in a dry chamber between runoff events. This prevents mosquito breeding and obnoxious odors and allows the turret to be cleaned with a shovel by homeowners or minimally trained staff.

It is anticipated that the RGT could collect and store several storms of sediment and gross solids before maintenance is needed, though it is impossible to predict from this project how frequently maintenance will be needed and the capture performance as sediment and gross solids accumulate. Of the pretreatment practices tested in this study, the RGT is likely among the easiest to maintain.

5.4.4 Rock Lined Inlet (RLI)

The RLI captured sediment and gross solids in all tests, though fewer gross solids were captured in the high intensity test. It was apparent from the field tests that the RLI does not have much capacity to store captured gross solids (see Figure 62), though sediment could accumulate in the large pore spaces between the individual rocks (see Figure 63).

Figure 62. Rock lined inlet after testing at 0.25 cfs for 40 minutes (left) and 0.50 cfs for 20 minutes (right).

Figure 63. Sediment remaining on geotextile when rocks were removed from RLI.

Sediment that is collected within the pore spaces of the RLI may be protected from high intensity storms, but the storage capacity within the pores is minimal and may become filled within a few storms. In addition, it is expected that gross solids that may be captured during low intensity storms would become mobilized and potentially washed out of the RLI during high intensity runoff events. There is no mechanism to protect collected gross solids.

Maintenance of the RLI consists of removing the rocks and either washing them onsite or installing new washed rocks as replacement. In addition, sediment and gross solids that may have accumulated within the RLI need to be removed. During testing, the rocks needed to be washed and the geotextile fabric beneath the rocks needed to be cleaned so that all the captured sediment could be quantified. Field maintenance of a RLI is anticipated to be similarly time and labor intensive. This level of maintenance is effectively the same cost as constructing a brand new RLI. Of the pretreatment practices tested in this study, the RLI is likely among the most difficult and costly to maintain.

5.4.5 Shallow Sump Grit Chamber (BDV and BBP)

The shallow sump grit chamber collected sediment and gross solids in all tests, including tests in which bypass was induced (though not as well). Collecting the sediment and gross solids to calculate performance was similar to the maintenance procedures for the shallow sump, though the test sediment and gross solids were carefully collected for quantification. The accumulation of sediment and gross solids within the shallow sump was minimal compared to the storage capacity. Though the shallow sump is relatively similar in dimension to the RGB, sediment and gross solids collected in the shallow sump are less protected compared to the off-line design of the RGB because the shallow sump is installed in-line with the gutter. Bypass tests were not conducted on both devices, so a quantitative comparison of bypass conditions cannot be made. During bypass testing of the shallow sump, however, sediment was captured while gross solids were released and delivered downstream.

Access to the sediment and gross solids within the shallow sump was simple, though the shallow sump is not easily visible from the surface and could be easily missed or forgotten. Visual inspection therefore requires access to the sump, likely removal of the surface grate, and inspection of the accumulated sediment. In addition, the saturated nature of the sump makes visual observation of the sediment depth challenging. It is possible that sediment depth could be measured with a staff gauge through the slots in the grate, though this method may be inaccurate. It is anticipated that the shallow sump could collect and store several storms of sediment and gross solids before maintenance is needed, though it is impossible to predict from this project how frequently maintenance will be needed and the capture performance as sediment and gross solids accumulate. Of the pretreatment practices tested in this study, the shallow sump is likely to be moderately easy to maintain.

CHAPTER 6: CONCLUSIONS

Though little guidance is available for pretreatment practices, many are installed throughout our urban landscapes because they are required as part of installation for many primary treatment practices. A benchmark for performance is set forth by the Minnesota Pollution Control Agency: capture of gross solids and 25% of sediment greater than 100µm. Five pretreatment practices for bioretention were assessed for sediment and gross solids capture by field testing at the design storage volume and two different intensities. Three sediment sizes, a coarse sediment (D_{50} = 1.17mm), a medium sediment (D_{50} = 0.41mm), and a fine sediment (D_{50} = 0.12mm) and three types of gross solids (plastic forks, synthetic leaves, and wood dowels) were added throughout the duration of each test.

All five pretreatment practices captured greater than 88% of the total sediment and greater than 65% of the fine sediment fraction (D_{50} = 0.12mm) in the low intensity tests (design volume filled in 40 minutes). During the high intensity tests (design volume filled in 20 minutes), all practices captured greater than 70% of the total sediment mass and greater than 30% of the fine sediment fraction, which exceeds the criterion of 25% of sediment greater than 100µm. Thus, all five pretreatment practices were able to achieve the goal when tested from a clean initial condition. The performance and maintenance needed for long-term operation of these pretreatment practices was not measured in this project.

Four of the five pretreatment practices captured 75% of the gross solids during low intensity tests and more than 55% of the gross solids during high intensity tests. The grass lined inlet captured the least gross solids; 20% during low intensity and 30% during high intensity. Inundation of the grass lined inlet during the high intensity tests resulted in floating wood dowels being deposited on the grass lined inlet surface after the test was complete. Though these are reported as "capture" as part of this study, these would likely not be captured during actual operation of a grass lined inlet.

Additional design volume and bypass tests were conducted on an in-line shallow sump grit chamber to determine if resuspension of sediment and gross solids could be measured. During these tests, overall sediment captured decreased from 95% during low intensity design volume tests down to 80% capture during high intensity bypass tests. Gross solids capture decreased from greater than 80% to below 40%. Thus, bypass at these flow rates had minimal effect on the sediment, but measurable effect on the gross solids performance.

Though at least four of the five pretreatment practices performed similarly in terms of sediment and gross solids capture, only three out of the five appear to be simple to inspect and maintain. When maintenance is required, the grass lined inlet and rock lined inlet likely require the same amount of effort and cost to maintain them as would be needed to install them (i.e., initial construction cost = maintenance cost). The grass lined inlet and rock lined inlet are likely among the most difficult and costly to maintain.

To maintain the Rain Guardian Bunker, Rain Guardian Turret, and shallow sump grit chamber, one would need to remove the top grate and either shovel or hydro-vac the collected sediment and gross solids from within the collection chamber. The Bunker and Turret are both easily visible from the street and the permeable screen wall in the bunker and the turret allows for a dry chamber between runoff events. The shallow sump grit chamber is hidden underground, which makes assessing sediment accumulation depth more challenging. Of the pretreatment practices tested in this study, the Bunker and Turret are likely among the easiest to maintain, and the shallow sump grit chamber is likely to be moderately easy to maintain.

CHAPTER 7: LESSONS LEARNED & FUTURE RESEARCH

Though the authors have conducted field testing prior to this study, the uniqueness of the practices (pretreatment for bioretention) and site conditions produced many unknowns and several lessons were learned through the field-testing process. The primary lesson learned is that compared to field testing, laboratory testing can be more accurate, more cost-effective, and a better method for comparing multiple practices side-by-side under identical conditions. Below are several reasons to support this observation:

- **Laboratory testing is not weather dependent:** field testing can only be conducted during dry-weather conditions, with an antecedent dry period prior to testing. Several opportunities for testing were lost, and results delayed due to poor weather conditions. Laboratory testing could have been completed on consecutive days, regardless of weather or season.
- **Field testing requires more pre-test preparation and post-test cleanup:** Field testing required gathering, loading, transporting, and deploying numerous pieces of equipment prior to any tests being conducted. In addition, the site needed to be prepared and cleaned prior to testing. After testing was complete, the site had to be restored to operating condition and all equipment had to be gathered, loaded, transported back to and stored at St. Anthony Falls Laboratory. The amount of time necessary for pre-test prep and post-test cleanup for field testing is equivalent to at least one additional test per test day.
- **Laboratory testing is more accurate:** Testing in the laboratory can be controlled more accurately than field testing. Water flow rate, volume, water level control, sediment and gross solid application, and sediment and gross solid collection are all more consistent and more accurate from test-to-test and device to device with laboratory testing. One key benefit of laboratory testing for this type of project is that every component of the water and pollutant mass balance can be measured effectively, accurately, and efficiently. Thus, error can be accurately assessed and reported with all measurements.
- **Laboratory testing is a more direct comparison:** Laboratory testing allows for different devices to be tested under identical conditions with the ability to conduct multiple test replicates. In addition to identical input conditions, laboratory testing allows for scaling of devices so that each device is the appropriate size in comparison to other devices.
- **Laboratory testing is more robust:** Laboratory testing is rarely limited by water supply, sediment feed rate, or gross solids application. Laboratory testing for pretreatment practices could be conducted with any number of storm events up to and exceeding the 100-year event. In addition, laboratory testing can be conducted to simulate infiltration and backwater conditions to exactly mimic field conditions but are more consistent and repeatable between tests and devices compared to field testing.
- **Laboratory testing is more efficient:** Typically in laboratory testing all the equipment is on-hand, all staff and personnel are on-site, and the analytical facilities are in-house. Thus, conducting experiments, repeating replicates, analyzing samples, and changing test conditions are all more time- and cost-efficient.

There are several specific observations from this project that may improve future field or laboratory testing of pretreatment practices:

- The gas powered three-inch semi-trash pump that was used to drain the basin was difficult to regulate because of its size, constant need to be adjusted, and intermittent flow operation for the basin that was studied.
- During testing of the grass lined inlet, grass blades and very fine soil particles made processing solids samples challenging. Pre-rinsing removed most of these organics, but

they could not be eliminated. Synthetic grass may have been more manageable, repeatable, and easier to clean.

- For the grass lined inlet and rock lined inlet testing, processing the geotextile and associated sediment and gross solids was time-consuming and challenging. It required removing, re-setting, and processing and required more labor than processing the samples from other practices.
- For the grass lined inlet testing, sediment built up near the centerline and along the seam of the sod. If the test were repeated without cleanout or replacing the sod, the settling patterns would likely be different as the capacity is filled. Between storms, roots may grow up into the deposited sediment, changing the shape of the inlet as well.
- For the rock lined inlet testing, sediment (coarse and medium) accumulated under and around the rocks. If multiple tests were performed sequentially without cleanout, the space under and between rocks would fill quickly.
- For the bypass testing, pre-cleaning and collecting sediment from the gutter, and setting up, sealing, and removing the geotextile basket in the downstream catch basin added significantly to the time required to run a test. These tests required approximately twice as much time as the other tests.

These lessons learned inform future research about field testing, laboratory testing, and pretreatment practices. While this project produced a quantitative performance comparison of pretreatment practices for bioretention, there are several other questions about the performance and maintenance of pretreatment practices that still need to be addressed, potentially as future research:

- **How frequently should pretreatment practices be maintained?** It was clear that all five pretreatment practices in this study captured sediment and gross solids. How quickly these practices fill with sediment and solids, or how performance is affected by accumulated sediment and gross solids was not measured. Thus, the optimal frequency of maintenance is still unknown. A study using several sequential "storms" could be used to determine when maintenance is most cost-effective for each practice.
- **How should pretreatment practices be designed or sized?** This study showed that all five pretreatment practices captured more than 30% of sediment greater than 100µm, but it did not determine if the sizing and design of these practices is optimal. Often, pretreatment practices are "sized" based on the space available or are a one-size-fits-all device. With an understanding of treatment mechanisms and performance, a study on various sizes and aspect ratios for several different pretreatment practices could determine optimal sizing criteria that would balance cost, storage capacity for sediment and gross solids, and maintenance frequency.
- **How do other pretreatment practices compare?** These five pretreatment practices are just a few of the most common practices in Minnesota, but there are others here and from other parts of the world. A study to compare the short and long-term performance of these various pretreatment practices could provide a robust pretreatment toolbox for stormwater professionals to use.
- **Are pretreatment practices cost-effective?** A common assumption is that pretreatment practices reduce the overall life-cycle costs of stormwater treatment practices by simplifying maintenance and reducing the maintenance needed in primary treatment practices (e.g., bioretention). While this study has shown that pretreatment practices are effective at capturing sediment and gross solids, it is unclear how the long-term life-cycle costs of maintaining pretreatment practices compares to the life-cycle costs of maintaining primary treatment practices. In addition, it is unknown how the use of pretreatment practices actually reduces the maintenance of primary treatment practices. For example, a

small pretreatment chamber that is effective at capturing sediment and gross solids may need more frequent maintenance. A study is needed to compare the estimated costs of maintaining primary treatment practices against the estimated costs of maintaining pretreatment practices in combination with primary treatment practices.

CHAPTER 8: REFERENCES

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CHAPTER 9: APPENDIX

9.1 PROCEDURE

Prep at lab

1. Pre-weigh, package, and label dry sediment and gross solids
2. Set and record sediment feeder rate
3. Ready supplies and tools and load into truck

Setup in field

1. Set up meter and hose. For the first run, find the valve setting (number of turns) to get the target flow rate.
2. Place flow distributor and break tank.
3. Set up generator and sediment feeder, fuel and test.
4. Place pre-weighed sediment in feeder, feed sediment to the tube end, set feed rate, and cover feeder, check feed rate if needed.
5. Place gross solids in clean water 5-gallon bucket to hydrate.
6. Prepare notebook, camera, video camera
7. Set up staff gauge(s)
8. Set up drain sump, pump intake, and discharge to storm drain.
9. Clean pretreatment entrance
10. For the first run of the day, run total volume of clear water to saturate the bioretention basin. (A flushing run was used after each new sod installation for the grass lined inlet).

Test Run

1. Record time when water flow begins
2. Record time when sediment begins (feeder on)
3. Feed sediment at determined rate
4. Feed gross solids by hand from bucket, approximately paced
5. Periodically check flow rate and adjust if needed
6. Periodically record depth on staff gauge
7. Take photos and/or video
8. Stop sediment feed and water at volume target (600 cubic feet in Anoka), OR maximum water level (bypass level) reached. Record time.

Cleanup in field

1. Possible sediment locations are Not Fed (in feeder or bucket or transition area between feeder and basin), Pretreatment Area (captured), Beyond Pretreatment (passed, not captured).
2. Label all collected material with date, run number, collector's initials
3. Collect floating gross solids if they are likely to move
4. Drain or pump out rain garden at a rate low enough so that materials do not move from the pretreatment device.
5. Collect accessible gross solids by hand, into clean storage container. Label storage container or bag with date, time, run number, or other identifying information.

6. Collect accessible sediment with a scoop, rinse through screen to capture gross solids, place sediment into container.
7. Use wet-dry vac with rinse water from a hose or sprayer to clean up remaining sediment, rinse vac through screen into container
8. Decant clear water from sediment storage container by tipping to side over a #325 sieve, being very careful not to lose any sediment grains.
9. Prepare for next test or restore pretreatment and bioretention basin.

<u>Processing at lab</u>

1. Carefully rinse off and collect sand from gross solids, geotextiles, bags, buckets, etc.
2. Maintain labeling through process – keep Not Fed separate from Captured in pretreatment separate from Passing
3. Transfer sediment to drying pans, place in oven overnight
4. Place screens with gross solids in oven overnight
5. Weigh gross solids batch
6. Separate and weigh gross solids components
7. Weigh sediment batch
8. Sieve and weigh sediment components
9. Label and store sediment for further analysis or discard

9.2 TEST DATA

Table 7: Raw flow, volume, and water depth data from field testing.

Designation	Date	Start Time	[1]Sediment Feed Duration (minutes)	[2]Pre-flush + Flowrate Adjustment (ft^3)	Total Volume (ft^3)	Average Flowrate (cfs)	[3,4]Estimated Maximum Water Depth (nearest 5mm)
GLI-025-A	6/12/18	11:21	39.57	364.2	599.6	0.253	140
GLI-025-B	6/15/18	11:25	39.97	322.4	600.0	0.250	140
GLI-050-A	6/12/18	13:57	20.10	339.9	601.0	0.498	180
GLI-050-B	6/15/18	9:29	20.18	346.0	600.6	0.496	200
RGB-025-A	6/29/18	9:58	39.45	323.0	600.5	0.254	175
RGB-025-B	7/16/18	12:09	40.03	39.7	600.0	0.250	180
RGB-050-A	6/29/18	11:56	20.97	36.2	601.1	0.478	245
RGB-050-B	6/29/18	13:41	19.72	56.9	581.5	0.492	255
RGT-025-A	7/10/18	12:45	39.27	38.9	599.5	0.254	200
RGT-025-B	7/16/18	10:04	39.45	339.7	600.3	0.254	215
RGT-050-A	7/10/18	11:02	20.22	400.7	601.1	0.496	230
RGT-050-B	7/10/18	14:27	20.70	70.5	600.4	0.483	265
RLI-025-A	5/31/18	11:37	40.33	1.5	609.2	0.252	no data
RLI-025-B	6/4/18	13:31	39.40	41.1	604.3	0.256	205
RLI-050-A	6/4/18	9:36	20.80	404.5	601.0	0.482	240
RLI-050-B	6/4/18	11:40	20.10	203.0	600.9	0.498	290
BDV-006-A	10/23/18	14:09	28.51	362.6	108.2	0.063	305
BDV-006-B	10/24/18	9:34	30.73	175.2	115.5	0.063	305
BDV-012-A	10/24/18	11:20	14.82	4.4	112.5	0.127	305
BDV-012-B	10/24/18	12:42	15.11	3.7	113.6	0.125	305
BBP-012-A	10/30/18	11:19	40.27	259.7	303.0	0.125	380
BBP-025-A	10/30/18	14:11	19.66	7.5	296.6	0.251	395

[1]Bypass (full basin) time 15.18 minutes BBP-012-A, 7.25 minutes BBP-025-A

[2]Larger flushing volumes were typical of the first test in any day to pre-wet the basin.

[3]Reference point for Anoka (RLI, GLI, RGB, RGT) is concrete base slab = basin bottom.

[4]Reference point for Bloomington (BDV, BBP) is estimated basin bottom, ~1 inch below pipe inverts.

Table 8: Raw mass data for Grass Lined Inlet (GLI) field tests

Mass data for GLI-025-A

	(a) Initial Mass (g)	(b) Mass Not Fed (g)	(c) Influent to Pretreatment (g)	(d) Untreated by Pretreatment (Captured in Bioretention) (g)	(e) Captured in Pretreatment (Assumed) (g)	(f) Percent Removal (%)
[1] D50=1.17 mm	939.39	56.33	883.06	0.95	882.11	99.9%
[2] D50=0.41 mm	939.44	33.62	905.82	2.87	902.95	99.7%
[3] D50=0.12 mm	939.39	63.74	875.65	176.37	699.28	79.9%
Sediment Total =	2818.22	153.69	2664.53	180.19	2484.34	93.2%
[A] leaves	226.61	0	226.61	218.14	8.47	3.7%
[B] dowels	226.03	0	226.03	139.57	86.46	38.3%
[C] forks	227.43	0	227.43	216.72	10.71	4.7%
Gross Solids Total =	680.07	0	680.07	574.43	105.64	15.5%
Sediment + Gross Solids =	3498.29	153.69	3344.6	754.62	2589.98	77.4%

Mass data for GLI-025-B

	(a) Initial Mass (g)	(b) Mass Not Fed (g)	(c) Influent to Pretreatment (g)	(d) Untreated by Pretreatment (Captured in Bioretention) (g)	(e) Captured in Pretreatment (Assumed) (g)	(f) Percent Removal (%)
[1] D50=1.17 mm	939.4	33.39	906.01	0.65	905.36	99.9%
[2] D50=0.41 mm	939.46	40.84	898.62	12.63	885.99	98.6%
[3] D50=0.12 mm	939.48	59.81	879.67	428.67	451	51.3%
Sediment Total =	2818.34	134.04	2684.3	441.95	2242.35	83.5%
[A] leaves	226.65	0	226.65	220.26	6.39	2.8%
[B] dowels	226.53	0	226.53	113.96	112.57	49.7%
[C] forks	225.88	0	225.88	199.28	26.6	11.8%
Gross Solids Total =	679.06	0	679.06	533.5	145.56	21.4%
Sediment + Gross Solids =	3497.4	134.04	3363.36	975.45	2387.91	71.0%

Mass data for Average of two replicates (GLI-025-A & GLI-025-B)

	(a) Initial Mass (g)	(b) Mass Not Fed (g)	(c) Influent to Pretreatment (g)	(d) Untreated by Pretreatment (Captured in Bioretention) (g)	(e) Captured in Pretreatment (Assumed) (g)	(f) Percent Removal (%)
[1] D50=1.17 mm	939.395	44.86	894.535	0.8	893.735	99.9%
[2] D50=0.41 mm	939.45	37.23	902.22	7.75	894.47	99.1%
[3] D50=0.12 mm	939.435	61.775	877.66	302.52	575.14	65.5%
Sediment Total =	2818.28	143.865	2674.415	311.07	2363.345	88.4%
[A] leaves	226.63	0	226.63	219.2	7.43	3.3%
[B] dowels	226.28	0	226.28	126.765	99.515	44.0%
[C] forks	226.655	0	226.655	208	18.655	8.2%
Gross Solids Total =	679.565	0	679.565	553.965	125.6	18.5%
Sediment + Gross Solids =	3497.845	143.865	3353.98	865.035	2488.945	74.2%

Note: ***a - b = c*** ***c - d = e*** ***e ÷ c = f***

Table 8: Raw mass data for Grass Lined Inlet (GLI) field tests (cont'd)

Mass data for GLI-050-A

	(a) Initial Mass (g)	(b) Mass Not Fed (g)	(c) Influent to Pretreatment (g)	(d) Untreated by Pretreatment (Captured in Bioretention) (g)	(e) Captured in Pretreatment (Assumed) (g)	(f) Percent Removal (%)
[1] D50=1.17 mm	939.4	26.61	912.79	35.41	877.38	96.1%
[2] D50=0.41 mm	939.47	21.35	918.12	179.93	738.19	80.4%
[3] D50=0.12 mm	939.46	42.92	896.54	546.4	350.14	39.1%
Sediment Total =	2818.33	90.88	2727.45	761.74	1965.71	72.1%
[A] leaves	226.53	0	226.53	217.11	9.42	4.2%
[B] dowels	226.9	0	226.9	76.82	150.08	66.1%
[C] forks	226.01	0	226.01	215.37	10.64	4.7%
Gross Solids Total =	679.44	0	679.44	509.3	170.14	25.0%
Sediment + Gross Solids =	3497.77	90.88	3406.89	1271.04	2135.85	62.7%

Mass data for GLI-050-B

	(a) Initial Mass (g)	(b) Mass Not Fed (g)	(c) Influent to Pretreatment (g)	(d) Untreated by Pretreatment (Captured in Bioretention) (g)	(e) Captured in Pretreatment (Assumed) (g)	(f) Percent Removal (%)
[1] D50=1.17 mm	939.39	26.57	912.82	7.39	905.43	99.2%
[2] D50=0.41 mm	939.43	22.48	916.95	138.82	778.13	84.9%
[3] D50=0.12 mm	939.5	40.35	899.15	588.9	310.25	34.5%
Sediment Total =	2818.32	89.4	2728.92	735.11	1993.81	73.1%
[A] leaves	226.5	0	226.5	223.21	3.29	1.5%
[B] dowels	227	0	227	60.52	166.48	73.3%
[C] forks	226.65	0	226.65	189.82	36.83	16.2%
Gross Solids Total =	680.15	0	680.15	473.55	206.6	30.4%
Sediment + Gross Solids =	3498.47	89.4	3409.07	1208.66	2200.41	64.5%

Mass data for Average of two replicates (GLI-050-A & GLI-050-B)

	(a) Initial Mass (g)	(b) Mass Not Fed (g)	(c) Influent to Pretreatment (g)	(d) Untreated by Pretreatment (Captured in Bioretention) (g)	(e) Captured in Pretreatment (Assumed) (g)	(f) Percent Removal (%)
[1] D50=1.17 mm	939.395	26.59	912.805	21.4	891.405	97.7%
[2] D50=0.41 mm	939.45	21.915	917.535	159.375	758.16	82.6%
[3] D50=0.12 mm	939.48	41.635	897.845	567.65	330.195	36.8%
Sediment Total =	2818.325	90.14	2728.185	748.425	1979.76	72.6%
[A] leaves	226.515	0	226.515	220.16	6.355	2.8%
[B] dowels	226.95	0	226.95	68.67	158.28	69.7%
[C] forks	226.33	0	226.33	202.595	23.735	10.5%
Gross Solids Total =	679.795	0	679.795	491.425	188.37	27.7%
Sediment + Gross Solids =	3498.12	90.14	3407.98	1239.85	2168.13	63.6%

Note: ***a - b = c*** ***c - d = e*** ***e ÷ c = f***

Table 9: Raw mass data for Rain Guardian Bunker (RGB) field tests

Mass data for RGB-025-A

	(a) Initial Mass (g)	(b) Mass Not Fed (g)	(c) Influent to Pretreatment (g)	(d) Captured on Surface Grate (g)	(e) Captured in Chamber (g)	(f) Captured on Screen wall (g)	(g) Deposited Downstream of Screen Wall (g)	(h) Captured in Pretreatment (g)	(i) Percent Removal (%)
[1] D50=1.17 mm	939.39	49.13	890.26	52.43	813.06	0	1.6	867.09	97.4%
[2] D50=0.41 mm	939.4	46.91	892.49	64.19	824.66	1.16	13.74	903.75	101.3%
[3] D50=0.12 mm	939.41	71.2	868.21	106.06	387.36	17.96	181.21	692.59	79.8%
Sediment Total =	2818.2	167.24	2650.96	222.68	2025.08	19.12	196.55	2463.43	92.9%
[A] leaves	226.58	0	226.58	144.96	80.94	0	0.24	226.14	99.8%
[B] dowels	226.66	0	226.66	41.52	34.36	1.16	15.79	92.83	41.0%
[C] forks	226.17	0	226.17	157.86	68.2	0	0	226.06	100.0%
Gross Solids Total =	679.41	0	679.41	344.34	183.5	1.16	16.03	545.03	80.2%
Sediment + Gross Solids =	3497.61	167.24	3330.37	567.02	2208.58	20.28	212.58	3008.46	90.3%

Mass data for RGB-025-B

	(a) Initial Mass (g)	(b) Mass Not Fed (g)	(c) Influent to Pretreatment (g)	(d) Captured on Surface Grate (g)	(e) Captured in Chamber (g)	(f) Captured on Screen wall (g)	(g) Deposited Downstream of Screen Wall (g)	(h) Captured in Pretreatment (g)	(i) Percent Removal (%)
[1] D50=1.17 mm	939.39	43.87	895.52	11.34	864.42	0.01	1.27	877.04	97.9%
[2] D50=0.41 mm	939.44	44.11	895.33	10.03	876.91	2.01	20.49	909.44	101.6%
[3] D50=0.12 mm	939.44	68	871.44	14.59	419.35	22.66	167.99	624.59	71.7%
Sediment Total =	2818.27	155.98	2662.29	35.96	2160.68	24.68	189.75	2411.07	90.6%
[A] leaves	226.58	0	226.58	86.43	137.83	0	0	224.26	99.0%
[B] dowels	226.14	0	226.14	10.84	20.65	18.98	31.82	82.29	36.4%
[C] forks	226.14	0	226.14	144.38	74.75	0	0	219.13	96.9%
Gross Solids Total =	678.86	0	678.86	241.65	233.23	18.98	31.82	525.68	77.4%
Sediment + Gross Solids =	3497.13	155.98	3341.15	277.61	2393.91	43.66	221.57	2936.75	87.9%

Mass data for Average of two replicates (RGB-025-A & RGB-025-B)

	(a) Initial Mass (g)	(b) Mass Not Fed (g)	(c) Influent to Pretreatment (g)	(d) Captured on Surface Grate (g)	(e) Captured in Chamber (g)	(f) Captured on Screen wall (g)	(g) Deposited Downstream of Screen Wall (g)	(h) Captured in Pretreatment (g)	(i) Percent Removal (%)
[1] D50=1.17 mm	939.39	46.5	892.89	31.885	838.74	0.005	1.435	872.065	97.7%
[2] D50=0.41 mm	939.42	45.51	893.91	37.11	850.785	1.585	17.115	906.595	101.4%
[3] D50=0.12 mm	939.425	69.6	869.825	60.325	403.355	20.31	174.6	658.59	75.7%
Sediment Total =	2818.235	161.61	2656.625	129.32	2092.88	21.9	193.15	2437.25	91.7%
[A] leaves	226.58	0	226.58	115.695	109.385	0	0.12	225.2	99.4%
[B] dowels	226.4	0	226.4	26.18	27.505	10.07	23.805	87.56	38.7%
[C] forks	226.155	0	226.155	151.12	71.475	0	0	222.595	98.4%
Gross Solids Total =	679.135	0	679.135	292.995	208.365	10.07	23.925	535.355	78.8%
Sediment + Gross Solids =	3497.37	161.61	3335.76	422.315	2301.245	31.97	217.075	2972.605	89.1%

Note: $a - b = c$ $d + e + f + g = h$ $h \div c = i$

Table 9: Raw mass data for Rain Guardian Bunker (RGB) field tests (cont'd)

Mass data for RGB-050-A

	(a) Initial Mass (g)	(b) Mass Not Fed (g)	(c) Influent to Pretreatment (g)	(d) Captured on Surface Grate (g)	(e) Captured in Chamber (g)	(f) Captured on Screen wall (g)	(g) Deposited Downstream of Screen Wall (g)	(h) Captured in Pretreatment (g)	(i) Percent Removal (%)
[1] D50=1.17 mm	939.42	5.81	933.61	7.26	866.56	0.92	34.84	909.58	97.4%
[2] D50=0.41 mm	939.42	7.81	931.61	3.43	815.62	4.81	85.67	909.53	97.6%
[3] D50=0.12 mm	939.41	28.72	910.69	10.55	194.38	31.24	99.19	335.36	36.8%
Sediment Total =	2818.25	42.34	2775.91	21.24	1876.56	36.97	219.7	2154.47	77.6%
[A] leaves	226.51	0	226.51	95.91	18.28	0	6.48	120.67	53.3%
[B] dowels	226.54	0	226.54	31.99	39.23	2.49	10.2	83.91	37.0%
[C] forks	226.93	0	226.93	158.44	52.84	0	13.08	224.36	98.9%
Gross Solids Total =	679.98	0	679.98	286.34	110.35	2.49	29.76	428.94	63.1%
Sediment + Gross Solids =	3498.23	42.34	3455.89	307.58	1986.91	39.46	249.46	2583.41	74.8%

Mass data for RGB-050-B

	(a) Initial Mass (g)	(b) Mass Not Fed (g)	(c) Influent to Pretreatment (g)	(d) Captured on Surface Grate (g)	(e) Captured in Chamber (g)	(f) Captured on Screen wall (g)	(g) Deposited Downstream of Screen Wall (g)	(h) Captured in Pretreatment (g)	(i) Percent Removal (%)
[1] D50=1.17 mm	939.39	29.68	909.71	4.96	817.57	0.85	61.72	885.1	97.3%
[2] D50=0.41 mm	939.39	30.72	908.67	3.21	681.73	6.55	151.81	843.3	92.8%
[3] D50=0.12 mm	939.42	56.82	882.6	9.69	121.11	26.33	99.59	256.72	29.1%
Sediment Total =	2818.2	117.22	2700.98	17.86	1620.41	33.73	313.12	1985.12	73.5%
[A] leaves	226.55	0	226.55	109.64	14.29	0	10.53	134.46	59.4%
[B] dowels	225.38	0	225.38	22.97	11.35	0	21.41	55.73	24.7%
[C] forks	225.55	0	225.55	145.74	53.3	0	15.87	214.91	95.3%
Gross Solids Total =	677.48	0	677.48	278.35	78.94	0	47.81	405.1	59.8%
Sediment + Gross Solids =	3495.68	117.22	3378.46	296.21	1699.35	33.73	360.93	2390.22	70.7%

Mass data for Average of two replicates (RGB-050-A & RGB-050-B)

	(a) Initial Mass (g)	(b) Mass Not Fed (g)	(c) Influent to Pretreatment (g)	(d) Captured on Surface Grate (g)	(e) Captured in Chamber (g)	(f) Captured on Screen wall (g)	(g) Deposited Downstream of Screen Wall (g)	(h) Captured in Pretreatment (g)	(i) Percent Removal (%)
[1] D50=1.17 mm	939.405	17.745	921.66	6.11	842.065	0.885	48.28	897.34	97.4%
[2] D50=0.41 mm	939.405	19.265	920.14	3.32	748.675	5.68	118.74	876.415	95.2%
[3] D50=0.12 mm	939.415	42.77	896.645	10.12	157.745	28.785	99.39	296.04	33.0%
Sediment Total =	2818.225	79.78	2738.445	19.55	1748.485	35.35	266.41	2069.795	75.6%
[A] leaves	226.53	0	226.53	102.775	16.285	0	8.505	127.565	56.3%
[B] dowels	225.96	0	225.96	27.48	25.29	1.245	15.805	69.82	30.9%
[C] forks	226.24	0	226.24	152.09	53.07	0	14.475	219.635	97.1%
Gross Solids Total =	678.73	0	678.73	282.345	94.645	1.245	38.785	417.02	61.4%
Sediment + Gross Solids =	3496.955	79.78	3417.175	301.895	1843.13	36.595	305.195	2486.815	72.8%

Note: $a - b = c$ $d + e + f + g = h$ $h \div c = i$

Table 10: Raw mass data for Rain Guardian Turret (RGT) field tests

Mass data for RGT-025-A

	(a) Initial Mass (g)	(b) Mass Not Fed (g)	(c) Influent to Pretreatment (g)	(d) Captured on Surface Grate (g)	(e) Captured in Chamber (g)	(f) Captured on Screen wall (g)	(g) Deposited Downstream of Screen Wall (g)	(h) Captured in Pretreatment (g)	(i) Percent Removal (%)
[1] D50=1.17 mm	939.4	49.6	889.8	41.89	830.44	0.06	0.4	872.79	98.1%
[2] D50=0.41 mm	939.38	42.75	896.63	53.55	850.01	0.53	1.04	905.13	100.9%
[3] D50=0.12 mm	939.45	66.17	873.28	66.26	423.99	9.86	40.05	540.16	61.9%
Sediment Total =	2818.23	158.52	2659.71	161.7	2104.44	10.45	41.49	2318.08	87.2%
[A] leaves	226.44	0	226.44	156.02	68.56	0	0	224.58	99.2%
[B] dowels	226.53	0	226.53	33.84	102.76	0	7.81	144.41	63.7%
[C] forks	226.63	0	226.63	163.25	63.34	0	0	226.59	100.0%
Gross Solids Total =	679.6	0	679.6	353.11	234.66	0	7.81	595.58	87.6%
Sediment + Gross Solids =	3497.83	158.52	3339.31	514.81	2339.1	10.45	49.3	2913.66	87.3%

Mass data for RGT-025-B

	(a) Initial Mass (g)	(b) Mass Not Fed (g)	(c) Influent to Pretreatment (g)	(d) Captured on Surface Grate (g)	(e) Captured in Chamber (g)	(f) Captured on Screen wall (g)	(g) Deposited Downstream of Screen Wall (g)	(h) Captured in Pretreatment (g)	(i) Percent Removal (%)
[1] D50=1.17 mm	939.4	39.48	899.92	37.74	847.07	0	0.04	884.85	98.3%
[2] D50=0.41 mm	939.4	50.78	888.62	40.19	853.52	0.76	2.34	896.81	100.9%
[3] D50=0.12 mm	939.43	74.66	864.77	56.32	455.93	13.98	68.81	595.04	68.8%
Sediment Total =	2818.23	164.92	2653.31	134.25	2156.52	14.74	71.19	2376.7	89.6%
[A] leaves	226.63	0	226.63	148.04	73.37	0	0	221.41	97.7%
[B] dowels	226.56	0	226.56	51.14	61.56	0	22	134.7	59.5%
[C] forks	226.74	0	226.74	195.38	31.28	0	0	226.66	100.0%
Gross Solids Total =	679.93	0	679.93	394.56	166.21	0	22	582.77	85.7%
Sediment + Gross Solids =	3498.16	164.92	3333.24	528.81	2322.73	14.74	93.19	2959.47	88.8%

Mass data for Average of two replicates (RGT-025-A & RGT-025-B)

	(a) Initial Mass (g)	(b) Mass Not Fed (g)	(c) Influent to Pretreatment (g)	(d) Captured on Surface Grate (g)	(e) Captured in Chamber (g)	(f) Captured on Screen wall (g)	(g) Deposited Downstream of Screen Wall (g)	(h) Captured in Pretreatment (g)	(i) Percent Removal (%)
[1] D50=1.17 mm	939.4	44.54	894.86	39.815	838.755	0.03	0.22	878.82	98.2%
[2] D50=0.41 mm	939.39	46.765	892.625	46.87	851.765	0.645	1.69	900.97	100.9%
[3] D50=0.12 mm	939.44	70.415	869.025	61.29	439.96	11.92	54.43	567.6	65.3%
Sediment Total =	2818.23	161.72	2656.51	147.975	2130.48	12.595	56.34	2347.39	88.4%
[A] leaves	226.535	0	226.535	152.03	70.965	0	0	222.995	98.4%
[B] dowels	226.545	0	226.545	42.49	82.16	0	14.905	139.555	61.6%
[C] forks	226.685	0	226.685	179.315	47.31	0	0	226.625	100.0%
Gross Solids Total =	679.765	0	679.765	373.835	200.435	0	14.905	589.175	86.7%
Sediment + Gross Solids =	3497.995	161.72	3336.275	521.81	2330.915	12.595	71.245	2936.565	88.0%

Note: $a - b = c$ $d + e + f + g = h$ $h \div c = i$

Table 10: Raw mass data for Rain Guardian Turret (RGT) field tests (cont'd)

Mass data for RGT-050-A

	(a) Initial Mass (g)	(b) Mass Not Fed (g)	(c) Influent to Pretreatment (g)	(d) Captured on Surface Grate (g)	(e) Captured in Chamber (g)	(f) Captured on Screen wall (g)	(g) Deposited Downstream of Screen Wall (g)	(h) Captured in Pretreatment (g)	(i) Percent Removal (%)
[1] D50=1.17 mm	939.41	29.75	909.66	0.62	893.67	0.12	0.21	894.62	98.3%
[2] D50=0.41 mm	939.41	49.28	890.13	0.41	848.9	5.45	17.35	872.11	98.0%
[3] D50=0.12 mm	939.42	63.97	875.45	1.81	264.01	13.09	15.33	294.24	33.6%
Sediment Total =	2818.24	143	2675.24	2.84	2006.58	18.66	32.89	2060.97	77.0%
[A] leaves	226.66	0	226.66	106.01	70.33	0	0	176.34	77.8%
[B] dowels	226.01	0	226.01	68.96	48.46	0	3.69	121.11	53.6%
[C] forks	227.28	0	227.28	179.27	47.96	0	0	227.23	100.0%
Gross Solids Total =	679.95	0	679.95	354.24	166.75	0	3.69	524.68	77.2%
Sediment + Gross Solids =	3498.19	143	3355.19	357.08	2173.33	18.66	36.58	2585.65	77.1%

Mass data for RGT-050-B

	(a) Initial Mass (g)	(b) Mass Not Fed (g)	(c) Influent to Pretreatment (g)	(d) Captured on Surface Grate (g)	(e) Captured in Chamber (g)	(f) Captured on Screen wall (g)	(g) Deposited Downstream of Screen Wall (g)	(h) Captured in Pretreatment (g)	(i) Percent Removal (%)
[1] D50=1.17 mm	939.39	6.47	932.92	0.08	909.56	0.06	0.35	910.05	97.5%
[2] D50=0.41 mm	939.4	9.54	929.86	0.6	907.4	2.82	10.26	921.08	99.1%
[3] D50=0.12 mm	939.42	31.88	907.54	8.17	346.17	11.08	48.43	413.85	45.6%
Sediment Total =	2818.21	47.89	2770.32	8.85	2163.13	13.96	59.04	2244.98	81.0%
[A] leaves	226.55	0	226.55	121.14	37.82		0.69	159.65	70.5%
[B] dowels	226.5	0	226.5	58.62	10.77	1.09	11.26	81.74	36.1%
[C] forks	226.94	0	226.94	189.97	21.25		7.89	219.11	96.5%
Gross Solids Total =	679.99	0	679.99	369.73	69.84	1.09	19.84	460.5	67.7%
Sediment + Gross Solids =	3498.2	47.89	3450.31	378.58	2232.97	15.05	78.88	2705.48	78.4%

Mass data for Average of two replicates (RGT-050-A & RGT-050-B)

	(a) Initial Mass (g)	(b) Mass Not Fed (g)	(c) Influent to Pretreatment (g)	(d) Captured on Surface Grate (g)	(e) Captured in Chamber (g)	(f) Captured on Screen wall (g)	(g) Deposited Downstream of Screen Wall (g)	(h) Captured in Pretreatment (g)	(i) Percent Removal (%)
[1] D50=1.17 mm	939.4	18.11	921.29	0.35	901.615	0.09	0.28	902.335	97.9%
[2] D50=0.41 mm	939.405	29.41	909.995	0.505	878.15	4.135	13.805	896.595	98.5%
[3] D50=0.12 mm	939.42	47.925	891.495	4.99	305.09	12.085	31.88	354.045	39.7%
Sediment Total =	2818.225	95.445	2722.78	5.845	2084.855	16.31	45.965	2152.975	79.1%
[A] leaves	226.605	0	226.605	113.575	54.075	0	0.345	167.995	74.1%
[B] dowels	226.255	0	226.255	63.79	29.615	0.545	7.475	101.425	44.8%
[C] forks	227.11	0	227.11	184.62	34.605	0	3.945	223.17	98.3%
Gross Solids Total =	679.97	0	679.97	361.985	118.295	0.545	11.765	492.59	72.4%
Sediment + Gross Solids =	3498.195	95.445	3402.75	367.83	2203.15	16.855	57.73	2645.565	77.7%

Note: $a - b = c$ $d + e + f + g = h$ $h \div c = i$

Table 11: Raw mass data for Rock Lined Inlet (RLI) field tests

Mass data for RLI-025-A

	(a) Initial Mass (g)	(b) Mass Not Fed (g)	(c) Influent to Pretreatment (g)	(d) Captured in Pretreatment (g)	(e) Percent Removal (%)
[1] D50=1.17 mm	939.44	11.04	928.4	852.8	91.9%
[2] D50=0.41 mm	939.44	14.18	925.26	988.41	106.8%
[3] D50=0.12 mm	939.42	41.08	898.34	551.64	61.4%
Sediment Total =	2818.3	66.3	2752	2392.85	86.9%
[A] leaves	225.87	0	225.87	228.31	101.1%
[B] dowels	226.65	0	226.65	223.77	98.7%
[C] forks	227.32	2.71	224.61	224.7	100.0%
Gross Solids Total =	679.84	2.71	677.13	676.78	99.9%
Sediment + Gross Solids =	3498.14	69.01	3429.13	3069.63	89.5%

Mass data for RLI-025-B

	(a) Initial Mass (g)	(b) Mass Not Fed (g)	(c) Influent to Pretreatment (g)	(d) Captured in Pretreatment (g)	(e) Percent Removal (%)
[1] D50=1.17 mm	939.44	43.59	895.85	890.27	99.4%
[2] D50=0.41 mm	939.4	38.17	901.23	906.71	100.6%
[3] D50=0.12 mm	939.42	76.36	863.06	776.8	90.0%
Sediment Total =	2818.26	158.12	2660.14	2573.78	96.8%
[A] leaves	226.48	0	226.48	225.54	99.6%
[B] dowels	226.82	0	226.82	157.55	69.5%
[C] forks	227.15	0	227.15	224.5	98.8%
Gross Solids Total =	680.45	0	680.45	607.59	89.3%
Sediment + Gross Solids =	3498.71	158.12	3340.59	3181.37	95.2%

Mass data for Average of two replicates (RLI-025-A & RLI-025-B)

	(a) Initial Mass (g)	(b) Mass Not Fed (g)	(c) Influent to Pretreatment (g)	(d) Captured in Pretreatment (g)	(e) Percent Removal (%)
[1] D50=1.17 mm	939.44	27.315	912.125	871.535	95.5%
[2] D50=0.41 mm	939.42	26.175	913.245	947.56	103.8%
[3] D50=0.12 mm	939.42	58.72	880.7	664.22	75.4%
Sediment Total =	2818.28	112.21	2706.07	2483.315	91.8%
[A] leaves	226.175	0	226.175	226.925	100.3%
[B] dowels	226.735	0	226.735	190.66	84.1%
[C] forks	227.235	1.355	225.88	224.6	99.4%
Gross Solids Total =	680.145	1.355	678.79	642.185	94.6%
Sediment + Gross Solids =	3498.425	113.565	3384.86	3125.5	92.3%

Note: $a - b = c$ $d \div c = e$

Table 11: Raw mass data for Rock Lined Inlet (RLI) field tests (cont'd)

Mass data for RLI-050-A

	(a) Initial Mass (g)	(b) Mass Not Fed (g)	(c) Influent to Pretreatment (g)	(d) Captured in Pretreatment (g)	(e) Percent Removal (%)
[1] D50=1.17 mm	939.42	7.83	931.59	924.06	99.2%
[2] D50=0.41 mm	939.45	9.67	929.78	926.81	99.7%
[3] D50=0.12 mm	939.47	29.06	910.41	311.76	34.2%
Sediment Total =	2818.34	46.56	2771.78	2162.63	78.0%
[A] leaves	226.97	0	226.97	79.64	35.1%
[B] dowels	225.99	0	225.99	121.98	54.0%
[C] forks	226.31	0	226.31	194.69	86.0%
Gross Solids Total =	679.27	0	679.27	396.31	58.3%
Sediment + Gross Solids =	3497.61	46.56	3451.05	2558.94	74.1%

Mass data for RLI-050-B

	(a) Initial Mass (g)	(b) Mass Not Fed (g)	(c) Influent to Pretreatment (g)	(d) Captured in Pretreatment (g)	(e) Percent Removal (%)
[1] D50=1.17 mm	939.4	55.48	883.92	877.56	99.3%
[2] D50=0.41 mm	939.42	38.38	901.04	853.68	94.7%
[3] D50=0.12 mm	939.45	50.72	888.73	256.66	28.9%
Sediment Total =	2818.27	144.58	2673.69	1987.9	74.4%
[A] leaves	226.54	0	226.54	30.98	13.7%
[B] dowels	225.79	0	225.79	174.85	77.4%
[C] forks	224.68	0	224.68	168.46	75.0%
Gross Solids Total =	677.01	0	677.01	374.29	55.3%
Sediment + Gross Solids =	3495.28	144.58	3350.7	2362.19	70.5%

Mass data for Average of two replicates (RLI-050-A & RLI-050-B)

	(a) Initial Mass (g)	(b) Mass Not Fed (g)	(c) Influent to Pretreatment (g)	(d) Captured in Pretreatment (g)	(e) Percent Removal (%)
[1] D50=1.17 mm	939.41	31.655	907.755	900.81	99.2%
[2] D50=0.41 mm	939.435	24.025	915.41	890.245	97.3%
[3] D50=0.12 mm	939.46	39.89	899.57	284.21	31.6%
Sediment Total =	2818.305	95.57	2722.735	2075.265	76.2%
[A] leaves	226.755	0	226.755	55.31	24.4%
[B] dowels	225.89	0	225.89	148.415	65.7%
[C] forks	225.495	0	225.495	181.575	80.5%
Gross Solids Total =	678.14	0	678.14	385.3	56.8%
Sediment + Gross Solids =	3496.445	95.57	3400.875	2460.565	72.4%

Note: $a - b = c$ $d \div c = e$

Table 12: Raw mass data for Shallow Sump Grit Chamber Design Volume (BDV) field tests

Mass data for BDV-006-A

	(a) Initial Mass (g)	(b) Mass Not Fed (g)	(c) Influent to Pretreatment (g)	(d) Captured in Pretreatment (g)	(e) Percent Removal (%)
[1] D50=1.17 mm	259.91	46.19	213.72	212.4	99.4%
[2] D50=0.41 mm	259.93	48.51	211.42	221.12	104.6%
[3] D50=0.12 mm	259.99	56.15	203.84	166.19	81.5%
Sediment Total =	779.83	150.85	628.98	599.71	95.3%
[A] leaves	56.56	0	56.56	51.68	91.4%
[B] dowels	56.41	0	56.41	24.03	42.6%
[C] forks	55.79	0	55.79	55.77	100.0%
Gross Solids Total =	168.76	0	168.76	131.48	77.9%
Sediment + Gross Solids =	948.59	150.85	797.74	731.19	91.7%

Mass data for BDV-006-B

	(a) Initial Mass (g)	(b) Mass Not Fed (g)	(c) Influent to Pretreatment (g)	(d) Captured in Pretreatment (g)	(e) Percent Removal (%)
[1] D50=1.17 mm	259.91	65.02	194.89	193.53	99.3%
[2] D50=0.41 mm	259.87	66.29	193.58	199.66	103.1%
[3] D50=0.12 mm	259.99	64.99	195	152.5	78.2%
Sediment Total =	779.77	196.3	583.47	545.69	93.5%
[A] leaves	56.52	0	56.52	50.24	88.9%
[B] dowels	56.34	0	56.34	40.13	71.2%
[C] forks	56.62	0	56.62	55.58	98.2%
Gross Solids Total =	169.48	0	169.48	145.95	86.1%
Sediment + Gross Solids =	949.25	196.3	752.95	691.64	91.9%

Mass data for Average of two replicates (BDV-006-A & BDV-006-B)

	(a) Initial Mass (g)	(b) Mass Not Fed (g)	(c) Influent to Pretreatment (g)	(d) Captured in Pretreatment (g)	(e) Percent Removal (%)
[1] D50=1.17 mm	259.91	55.605	204.305	202.965	99.3%
[2] D50=0.41 mm	259.9	57.4	202.5	210.39	103.9%
[3] D50=0.12 mm	259.99	60.57	199.42	159.345	79.9%
Sediment Total =	779.8	173.575	606.225	572.7	94.5%
[A] leaves	56.54	0	56.54	50.96	90.1%
[B] dowels	56.375	0	56.375	32.08	56.9%
[C] forks	56.205	0	56.205	55.675	99.1%
Gross Solids Total =	169.12	0	169.12	138.715	82.0%
Sediment + Gross Solids =	948.92	173.575	775.345	711.415	91.8%

Note: ***a - b = c*** ***d ÷ c = e***

Table 12: Raw mass data for Shallow Sump Grit Chamber Design Volume (BDV) field tests (cont'd)

Mass data for BDV-012-A

	(a) Initial Mass (g)	(b) Mass Not Fed (g)	(c) Influent to Pretreatment (g)	(d) Captured in Pretreatment (g)	(e) Percent Removal (%)
[1] D50=1.17 mm	259.95	55.47	204.48	199.91	97.8%
[2] D50=0.41 mm	259.92	56.29	203.63	206.53	101.4%
[3] D50=0.12 mm	259.81	72.99	186.82	122.23	65.4%
Sediment Total =	779.68	184.75	594.93	528.67	88.9%
[A] leaves	56.53	0	56.53	36.83	65.2%
[B] dowels	56.16	0	56.16	25.84	46.0%
[C] forks	58.54	0	58.54	58.52	100.0%
Gross Solids Total =	171.23	0	171.23	121.19	70.8%
Sediment + Gross Solids =	950.91	184.75	766.16	649.86	84.8%

Mass data for BDV-012-B

	(a) Initial Mass (g)	(b) Mass Not Fed (g)	(c) Influent to Pretreatment (g)	(d) Captured in Pretreatment (g)	(e) Percent Removal (%)
[1] D50=1.17 mm	259.91	57.86	202.05	200.41	99.2%
[2] D50=0.41 mm	259.95	54.5	205.45	203.89	99.2%
[3] D50=0.12 mm	260.02	61.74	198.28	130.12	65.6%
Sediment Total =	779.88	174.1	605.78	534.42	88.2%
[A] leaves	56.6	0	56.6	39.02	68.9%
[B] dowels	56.87	0	56.87	24.68	43.4%
[C] forks	57.82	0	57.82	55.2	95.5%
Gross Solids Total =	171.29	0	171.29	118.9	69.4%
Sediment + Gross Solids =	951.17	174.1	777.07	653.32	84.1%

Mass data for Average of two replicates (BDV-012-A & BDV-012-B)

	(a) Initial Mass (g)	(b) Mass Not Fed (g)	(c) Influent to Pretreatment (g)	(d) Captured in Pretreatment (g)	(e) Percent Removal (%)
[1] D50=1.17 mm	259.93	56.665	203.265	200.16	98.5%
[2] D50=0.41 mm	259.935	55.395	204.54	205.21	100.3%
[3] D50=0.12 mm	259.915	67.365	192.55	126.175	65.5%
Sediment Total =	779.78	179.425	600.355	531.545	88.5%
[A] leaves	56.565	0	56.565	37.925	67.0%
[B] dowels	56.515	0	56.515	25.26	44.7%
[C] forks	58.18	0	58.18	56.86	97.7%
Gross Solids Total =	171.26	0	171.26	120.045	70.1%
Sediment + Gross Solids =	951.04	179.425	771.615	651.59	84.4%

Note: ***a - b = c*** ***d ÷ c = e***

Table 13: Raw mass data for Shallow Sump Grit Chamber Bypass (BBP) field tests

Mass data for BBP-012

	(a) Initial Mass (g)	(b) Mass Not Fed (g)	(c) Influent to Pretreatment (g)	(d) Deposited on Bypass Gutter (g)	(e) Captured in Downstream Bypass Grate (g)	(f) Captured in Pretreatment (g)	(g) Percent Removal (%)
[1] D50=1.17 mm	486.4	6.1	480.3	0.0	0.1	478.2	99.6%
[2] D50=0.41 mm	486.4	5.3	481.1	0.1	0.6	483.3	100.4%
[3] D50=0.12 mm	486.8	16.2	470.6	23.2	23.3	329.1	69.9%
Sediment Total =	**1,459.6**	**27.6**	**1,432.0**	**23.3**	**24.0**	**1,290.6**	**90.1%**
[A] leaves	113.4	0.0	113.4	0.0	24.2	75.1	66.2%
[B] dowels	113.5	0.0	113.5	0.0	83.8	17.1	15.1%
[C] forks	114.4	0.0	114.4	0.0	2.6	111.8	97.7%
Gross Solids Total =	**341.4**	**0.0**	**341.4**	**0.0**	**110.5**	**204.0**	**59.8%**
Sediment + Gross Solids =	***1,801.0***	***27.6***	***1,773.4***	***23.3***	***134.5***	***1,494.6***	***84.3%***

Mass data for BBP-025

	(a) Initial Mass (g)	(b) Mass Not Fed (g)	(c) Influent to Pretreatment (g)	(d) Deposited on Bypass Gutter (g)	(e) Captured in Downstream Bypass Grate (g)	(f) Captured in Pretreatment (g)	(g) Percent Removal (%)
[1] D50=1.17 mm	486.4	26.0	460.4	0.1	0.1	457.8	99.4%
[2] D50=0.41 mm	486.4	17.7	468.7	0.4	3.1	447.7	95.5%
[3] D50=0.12 mm	486.4	22.4	464.1	20.8	55.4	232.1	50.0%
Sediment Total =	**1,459.2**	**66.0**	**1,393.2**	**21.3**	**58.6**	**1,137.6**	**81.7%**
[A] leaves	113.2	0.0	113.2	0.0	31.6	39.9	35.2%
[B] dowels	113.7	0.0	113.7	0.0	84.1	7.0	6.2%
[C] forks	112.4	0.0	112.4	0.0	29.5	80.1	71.3%
Gross Solids Total =	**339.3**	**0.0**	**339.3**	**0.0**	**145.1**	**127.0**	**37.4%**
Sediment + Gross Solids =	***1,798.5***	***66.0***	***1,732.5***	***21.3***	***203.7***	***1,264.6***	***73.0%***

Note: ***a - b = c*** ***d + e = f*** ***f ÷ c = g***

Appendix D – Massachusetts Stormwater Checklist

Massachusetts Department of Environmental Protection
Bureau of Resource Protection - Wetlands Program
Checklist for Stormwater Report

A. Introduction

Important: When filling out forms on the computer, use only the tab key to move your cursor - do not use the return key.

A Stormwater Report must be submitted with the Notice of Intent permit application to document compliance with the Stormwater Management Standards. The following checklist is NOT a substitute for the Stormwater Report (which should provide more substantive and detailed information) but is offered here as a tool to help the applicant organize their Stormwater Management documentation for their Report and for the reviewer to assess this information in a consistent format. As noted in the Checklist, the Stormwater Report must contain the engineering computations and supporting information set forth in Volume 3 of the Massachusetts Stormwater Handbook. The Stormwater Report must be prepared and certified by a Registered Professional Engineer (RPE) licensed in the Commonwealth.

The Stormwater Report must include:

- The Stormwater Checklist completed and stamped by a Registered Professional Engineer (see page 2) that certifies that the Stormwater Report contains all required submittals.[1] This Checklist is to be used as the cover for the completed Stormwater Report.
- Applicant/Project Name
- Project Address
- Name of Firm and Registered Professional Engineer that prepared the Report
- Long-Term Pollution Prevention Plan required by Standards 4-6
- Construction Period Pollution Prevention and Erosion and Sedimentation Control Plan required by Standard 8[2]
- Operation and Maintenance Plan required by Standard 9

In addition to all plans and supporting information, the Stormwater Report must include a brief narrative describing stormwater management practices, including environmentally sensitive site design and LID techniques, along with a diagram depicting runoff through the proposed BMP treatment train. Plans are required to show existing and proposed conditions, identify all wetland resource areas, NRCS soil types, critical areas, Land Uses with Higher Potential Pollutant Loads (LUHPPL), and any areas on the site where infiltration rate is greater than 2.4 inches per hour. The Plans shall identify the drainage areas for both existing and proposed conditions at a scale that enables verification of supporting calculations.

As noted in the Checklist, the Stormwater Management Report shall document compliance with each of the Stormwater Management Standards as provided in the Massachusetts Stormwater Handbook. The soils evaluation and calculations shall be done using the methodologies set forth in Volume 3 of the Massachusetts Stormwater Handbook.

To ensure that the Stormwater Report is complete, applicants are required to fill in the Stormwater Report Checklist by checking the box to indicate that the specified information has been included in the Stormwater Report. If any of the information specified in the checklist has not been submitted, the applicant must provide an explanation. The completed Stormwater Report Checklist and Certification must be submitted with the Stormwater Report.

[1] The Stormwater Report may also include the Illicit Discharge Compliance Statement required by Standard 10. If not included in the Stormwater Report, the Illicit Discharge Compliance Statement must be submitted prior to the discharge of stormwater runoff to the post-construction best management practices.

[2] For some complex projects, it may not be possible to include the Construction Period Erosion and Sedimentation Control Plan in the Stormwater Report. In that event, the issuing authority has the discretion to issue an Order of Conditions that approves the project and includes a condition requiring the proponent to submit the Construction Period Erosion and Sedimentation Control Plan before commencing any land disturbance activity on the site.

Checklist for Stormwater Report

B. Stormwater Checklist and Certification

The following checklist is intended to serve as a guide for applicants as to the elements that ordinarily need to be addressed in a complete Stormwater Report. The checklist is also intended to provide conservation commissions and other reviewing authorities with a summary of the components necessary for a comprehensive Stormwater Report that addresses the ten Stormwater Standards.

Note: Because stormwater requirements vary from project to project, it is possible that a complete Stormwater Report may not include information on some of the subjects specified in the Checklist. If it is determined that a specific item does not apply to the project under review, please note that the item is not applicable (N.A.) and provide the reasons for that determination.

A complete checklist must include the Certification set forth below signed by the Registered Professional Engineer who prepared the Stormwater Report.

Registered Professional Engineer's Certification

I have reviewed the Stormwater Report, including the soil evaluation, computations, Long-term Pollution Prevention Plan, the Construction Period Erosion and Sedimentation Control Plan (if included), the Long-term Post-Construction Operation and Maintenance Plan, the Illicit Discharge Compliance Statement (if included) and the plans showing the stormwater management system, and have determined that they have been prepared in accordance with the requirements of the Stormwater Management Standards as further elaborated by the Massachusetts Stormwater Handbook. I have also determined that the information presented in the Stormwater Checklist is accurate and that the information presented in the Stormwater Report accurately reflects conditions at the site as of the date of this permit application.

Registered Professional Engineer Block and Signature

9-14-22
COMMONWEALTH OF MASSACHUSETTS
KATIE L. ENRIGHT
CIVIL
No. 46111
REGISTERED PROFESSIONAL ENGINEER

9/14/22

Signature and Date

Checklist

Project Type: Is the application for new development, redevelopment, or a mix of new and redevelopment?

☒ New development

☐ Redevelopment

☐ Mix of New Development and Redevelopment

Checklist (continued)

LID Measures: Stormwater Standards require LID measures to be considered. Document what environmentally sensitive design and LID Techniques were considered during the planning and design of the project:

☒ No disturbance to any Wetland Resource Areas

☒ Site Design Practices (e.g. clustered development, reduced frontage setbacks)

☐ Reduced Impervious Area (Redevelopment Only)

☐ Minimizing disturbance to existing trees and shrubs

☐ LID Site Design Credit Requested:

- ☐ Credit 1
- ☐ Credit 2
- ☐ Credit 3

☒ Use of "country drainage" versus curb and gutter conveyance and pipe

☐ Bioretention Cells (includes Rain Gardens)

☐ Constructed Stormwater Wetlands (includes Gravel Wetlands designs)

☐ Treebox Filter

☐ Water Quality Swale

☒ Grass Channel

☐ Green Roof

☐ Other (describe): ____________________

Standard 1: No New Untreated Discharges

☒ No new untreated discharges

☒ Outlets have been designed so there is no erosion or scour to wetlands and waters of the Commonwealth

☒ Supporting calculations specified in Volume 3 of the Massachusetts Stormwater Handbook included.

Checklist (continued)

Standard 2: Peak Rate Attenuation

☐ Standard 2 waiver requested because the project is located in land subject to coastal storm flowage and stormwater discharge is to a wetland subject to coastal flooding.

☐ Evaluation provided to determine whether off-site flooding increases during the 100-year 24-hour storm.

☒ Calculations provided to show that post-development peak discharge rates do not exceed pre-development rates for the 2-year and 10-year 24-hour storms. If evaluation shows that off-site flooding increases during the 100-year 24-hour storm, calculations are also provided to show that post-development peak discharge rates do not exceed pre-development rates for the 100-year 24-hour storm.

Standard 3: Recharge

☒ Soil Analysis provided.

☒ Required Recharge Volume calculation provided.

☐ Required Recharge volume reduced through use of the LID site Design Credits.

☒ Sizing the infiltration, BMPs is based on the following method: Check the method used.

☒ Static ☐ Simple Dynamic ☐ Dynamic Field[1]

☒ Runoff from all impervious areas at the site discharging to the infiltration BMP.

☐ Runoff from all impervious areas at the site is *not* discharging to the infiltration BMP and calculations are provided showing that the drainage area contributing runoff to the infiltration BMPs is sufficient to generate the required recharge volume.

☒ Recharge BMPs have been sized to infiltrate the Required Recharge Volume.

☐ Recharge BMPs have been sized to infiltrate the Required Recharge Volume *only* to the maximum extent practicable for the following reason:

- ☐ Site is comprised solely of C and D soils and/or bedrock at the land surface
- ☐ M.G.L. c. 21E sites pursuant to 310 CMR 40.0000
- ☐ Solid Waste Landfill pursuant to 310 CMR 19.000
- ☐ Project is otherwise subject to Stormwater Management Standards only to the maximum extent practicable.

☒ Calculations showing that the infiltration BMPs will drain in 72 hours are provided.

☐ Property includes a M.G.L. c. 21E site or a solid waste landfill and a mounding analysis is included.

[1] 80% TSS removal is required prior to discharge to infiltration BMP if Dynamic Field method is used.

Checklist (continued)

Standard 3: Recharge (continued)

☒ The infiltration BMP is used to attenuate peak flows during storms greater than or equal to the 10-year 24-hour storm and separation to seasonal high groundwater is less than 4 feet and a mounding analysis is provided.

☒ Documentation is provided showing that infiltration BMPs do not adversely impact nearby wetland resource areas.

Standard 4: Water Quality

The Long-Term Pollution Prevention Plan typically includes the following:

- Good housekeeping practices;
- Provisions for storing materials and waste products inside or under cover;
- Vehicle washing controls;
- Requirements for routine inspections and maintenance of stormwater BMPs;
- Spill prevention and response plans;
- Provisions for maintenance of lawns, gardens, and other landscaped areas;
- Requirements for storage and use of fertilizers, herbicides, and pesticides;
- Pet waste management provisions;
- Provisions for operation and management of septic systems;
- Provisions for solid waste management;
- Snow disposal and plowing plans relative to Wetland Resource Areas;
- Winter Road Salt and/or Sand Use and Storage restrictions;
- Street sweeping schedules;
- Provisions for prevention of illicit discharges to the stormwater management system;
- Documentation that Stormwater BMPs are designed to provide for shutdown and containment in the event of a spill or discharges to or near critical areas or from LUHPPL;
- Training for staff or personnel involved with implementing Long-Term Pollution Prevention Plan;
- List of Emergency contacts for implementing Long-Term Pollution Prevention Plan.

☒ A Long-Term Pollution Prevention Plan is attached to Stormwater Report and is included as an attachment to the Wetlands Notice of Intent.

☒ Treatment BMPs subject to the 44% TSS removal pretreatment requirement and the one inch rule for calculating the water quality volume are included, and discharge:

- ☐ is within the Zone II or Interim Wellhead Protection Area
- ☐ is near or to other critical areas
- ☒ is within soils with a rapid infiltration rate (greater than 2.4 inches per hour)
- ☐ involves runoff from land uses with higher potential pollutant loads.

☐ The Required Water Quality Volume is reduced through use of the LID site Design Credits.

☒ Calculations documenting that the treatment train meets the 80% TSS removal requirement and, if applicable, the 44% TSS removal pretreatment requirement, are provided.

Checklist (continued)

Standard 4: Water Quality (continued)

☒ The BMP is sized (and calculations provided) based on:

- ☒ The ½" or 1" Water Quality Volume or
- ☒ The equivalent flow rate associated with the Water Quality Volume and documentation is provided showing that the BMP treats the required water quality volume.

☒ The applicant proposes to use proprietary BMPs, and documentation supporting use of proprietary BMP and proposed TSS removal rate is provided. This documentation may be in the form of the propriety BMP checklist found in Volume 2, Chapter 4 of the Massachusetts Stormwater Handbook and submitting copies of the TARP Report, STEP Report, and/or other third party studies verifying performance of the proprietary BMPs.

☐ A TMDL exists that indicates a need to reduce pollutants other than TSS and documentation showing that the BMPs selected are consistent with the TMDL is provided.

Standard 5: Land Uses With Higher Potential Pollutant Loads (LUHPPLs)

☐ The NPDES Multi-Sector General Permit covers the land use and the Stormwater Pollution Prevention Plan (SWPPP) has been included with the Stormwater Report.

☒ The NPDES Multi-Sector General Permit covers the land use and the SWPPP will be submitted ***prior to*** the discharge of stormwater to the post-construction stormwater BMPs.

☐ The NPDES Multi-Sector General Permit does ***not*** cover the land use.

☐ LUHPPLs are located at the site and industry specific source control and pollution prevention measures have been proposed to reduce or eliminate the exposure of LUHPPLs to rain, snow, snow melt and runoff, and been included in the long term Pollution Prevention Plan.

☐ All exposure has been eliminated.

☐ All exposure has ***not*** been eliminated and all BMPs selected are on MassDEP LUHPPL list.

☐ The LUHPPL has the potential to generate runoff with moderate to higher concentrations of oil and grease (e.g. all parking lots with >1000 vehicle trips per day) and the treatment train includes an oil grit separator, a filtering bioretention area, a sand filter or equivalent.

Standard 6: Critical Areas

☐ The discharge is near or to a critical area and the treatment train includes only BMPs that MassDEP has approved for stormwater discharges to or near that particular class of critical area.

☐ Critical areas and BMPs are identified in the Stormwater Report.

Checklist (continued)

Standard 7: Redevelopments and Other Projects Subject to the Standards only to the maximum extent practicable

☐ The project is subject to the Stormwater Management Standards only to the maximum Extent Practicable as a:

- ☐ Limited Project
- ☐ Small Residential Projects: 5-9 single family houses or 5-9 units in a multi-family development provided there is no discharge that may potentially affect a critical area.
- ☐ Small Residential Projects: 2-4 single family houses or 2-4 units in a multi-family development with a discharge to a critical area
- ☐ Marina and/or boatyard provided the hull painting, service and maintenance areas are protected from exposure to rain, snow, snow melt and runoff
- ☐ Bike Path and/or Foot Path
- ☐ Redevelopment Project
- ☐ Redevelopment portion of mix of new and redevelopment.

☐ Certain standards are not fully met (Standard No. 1, 8, 9, and 10 must always be fully met) and an explanation of why these standards are not met is contained in the Stormwater Report.

☐ The project involves redevelopment and a description of all measures that have been taken to improve existing conditions is provided in the Stormwater Report. The redevelopment checklist found in Volume 2 Chapter 3 of the Massachusetts Stormwater Handbook may be used to document that the proposed stormwater management system (a) complies with Standards 2, 3 and the pretreatment and structural BMP requirements of Standards 4-6 to the maximum extent practicable and (b) improves existing conditions.

Standard 8: Construction Period Pollution Prevention and Erosion and Sedimentation Control

A Construction Period Pollution Prevention and Erosion and Sedimentation Control Plan must include the following information:

- Narrative;
- Construction Period Operation and Maintenance Plan;
- Names of Persons or Entity Responsible for Plan Compliance;
- Construction Period Pollution Prevention Measures;
- Erosion and Sedimentation Control Plan Drawings;
- Detail drawings and specifications for erosion control BMPs, including sizing calculations;
- Vegetation Planning;
- Site Development Plan;
- Construction Sequencing Plan;
- Sequencing of Erosion and Sedimentation Controls;
- Operation and Maintenance of Erosion and Sedimentation Controls;
- Inspection Schedule;
- Maintenance Schedule;
- Inspection and Maintenance Log Form.

☒ A Construction Period Pollution Prevention and Erosion and Sedimentation Control Plan containing the information set forth above has been included in the Stormwater Report.

Appendix E – Wrentham Board of Health Stormwater Checklist

Commonwealth of Massachusetts

Town of Wrentham

Board of Health

79 South Street, Wrentham, MA 02093

REGULATION FOR STORM WATER AND RUNOFF MANAGEMENT
APPLICATION FOR A CERTIFICATE OF APPROVAL

Date: 09/09/2022	Property Description:
Street Address: 1139 West Street	Map & Parcel Map G-03 Block 1 Lot 14
Project Type: *(subdivision, site plan, other)* Site Plan (Senior Living Community)	Name of Project: *(optional)* Sheldon West
APPLICANT INFORMATION	
Name of Applicant: Sheldon West, LLC. (Chris Cahill)	Address of Applicant: 480 Turnpike Street South Easton, MA 02375
Telephone Number: 978-265-2100	Email Address: chriscahill@aol.com
PROPERTY OWNER INFORMATION	
Property Owner Name: John Hasenjaeger	Address of Property Owner: 23 Pinnacle Drive East Walpole, MA 02032
Telephone Number:	Email Address:
ENGINEER OF RECORD INFORMATION	
Name of Engineer: Howard Stein Hudson (Katie Enright)	Address: 114 Turnpike Road, Suite 2C Chelmsford, MA 01824
Telephone Number: 978-844-5251	Email Address: kenright@hshassoc.com

SUBMISSION REQUIREMENTS

Submit the required fee to the Board of Health Office, 79 South Street, Wrentham, MA 02093.
Application Fee: $275

53G Engineering Peer Review Fee: $2,500 (Note: This fee is the initial required deposit. Once the application has been reviewed by the peer reviewer a more detailed cost estimate will be provided) Please pay in two separate checks, both made payable to the Town of Wrentham.

Submit two (2) printed copies of **all required documents as listed below** to the Board of Health Office, 79 South Street, Wrentham, MA 02093.

Submit electronic (PDF) copies of all required documents as listed below to the following:
One PDF copy to ebugbee@wrentham.gov One PDF copy to thouston@pscpc.com Peer review consultant for the Board of Health, Thomas Houston, Professional Services Corporation*

*Appeals to 53G Consultant: I hereby request that the selection of a peer review consultant under M.G.L. Ch. 44 §53G be reviewed by the Board during the first public meeting. The grounds for any appeal of a consultant shall be limited to claims that the consultant selected has a conflict of interest or does not posses the minimum required qualifications. All costs associated with the peer review are to be borne by the Applicant, not the Town. Costs shall be per standard company billing rates, unless otherwise specified. If this box remains unchecked it shall be deemed as acceptable of the peer review consultant chosen by the Board, and peer review work on the application may proceed to the first public meeting, if the need is determined after review by staff." ☐

REQUIRED DOCUMENTS

_x_ Copies of this "Application for a Certificate of Approval" with original signatures including the stormwater checklist as provided on the following pages and also including an attachment describing the stormwater management system and Best Management Practices (BMPs).

_x_ Copies of all required plans, 24-inches by-36 inches, signed and sealed by a Massachusetts Civil Professional Engineer (PE).

_x_ Reduced printed copies all of the required plans, 11-inches by-17 inches, signed and sealed by a Massachusetts Civil Professional Engineer (PE) inserted in mailing envelopes.

_x_ Copies of (1)Stormwater Management Report and Calculations, (2) DEP Checklist Stormwater Report, (3) Construction Phase Operations and Maintenance Plan and Sedimentation and Erosion Control Plan, and (4) Long Term Operation and Maintenance Plan that are signed and sealed by a Massachusetts Civil Professional Engineer (PE).

Applicant's Signature:

____

Date:

____

II. SUBMITTAL REGULATIONS AND REQUIREMENTS FOR SUBDIVISION PLANS, SITE PLANS, OR OTHER TYPES OF PROJECT PLANS

Any applicant, who seeks review comments for a subdivision plan, site plan, or other project plan submitted to the Wrentham Board of Health for review and approval, shall have the project designer complete the checklist below and follow the requirements that are herein described. The project designer is also referred to any additional applicable Board of Health regulations that are available at the Board of Health Office.

Any plan and related documents being submitted for review by the Board of Health and/or its agent, regardless of whether such information is being referred as part of a subdivision, site plan, or special permit process, shall be signed and stamped by a Professional Engineer, Registered in the Commonwealth of Massachusetts.

No plan shall be deemed to be "**SUBMITTED**" under Board of Health regulations, until (1) an application has been completely executed, (2) two copies of all the required plans, calculations, and other required documents, have been submitted, (3) the required fee has been paid, and (4) a copy of this executed guidelines checklist has been submitted.

All submittal items required by the Planning Board shall be included in the submittal to the Board of Health.

The Plan Content shall include all applicable items required by the Zoning By-Law, Planning Board Regulations, as well as those required by the Board of Health.

The following in checklist format lists additional design regulation:

_X_ Designer shall have a copy of the Board of Health Stormwater and Runoff Management Regulations

_X_ Hydrologic Report shall be prepared which is stamped and signed by a Professional Engineer, Registered in Commonwealth of Massachusetts, and includes a Table of Contents and has sequentially numbered pages throughout, and is based upon the methodology of the United States Department of Agriculture (USDA), Natural Resources Soil Conservation Service (NRSCS).

_X_ Any Zone II of the public water supply or other nitrogen sensitive or limiting area shall be clearly designated and defined.

_X_ Proposed system shall be analyzed for the 2-inch storm, and the 2-year, 10-year, 50-year and 100-year storm events as established from data of the Northeast Regional Climate Center.

_X_ Both volume and rate of runoff amounts shall be calculated for pre- and post conditions. A clear, tabular summary of results shall be prepared providing this data for the existing condition, the developed condition without flow attenuation, and the developed condition with flow attenuation.

_X_ Existing site impervious area provided.

_X_ Proposed site impervious area provided.

_X_ Separate overlays shall be included of pre- and post- development watershed catchment areas, including the soil types, hydrologic categories, CN values of the NRSCS, and the Time of Concentration flow paths and design points delineated.

_X_ Best Management Practices shall be provided for removal of contaminants from the peak runoff from the 2-inch storm. Specific calculations shall be prepared.

_X_ High groundwater determinations shall be made in the areas of any detention or infiltration basins based upon soil morphology or by use of an adjustment provided by or otherwise approved by the Board of Health based upon the methodology of Frimpter. The location of all test holes and monitor wells shall be shown, including elevation of top of monitor well, elevation of ground, date of water level readings (should usually be taken between the 22nd and 29th of the month), and groundwater adjustment used with supporting data, where applicable.

Hydrology Calculations

X The methodology of the NRSCS shall be used.

N/A Overall watershed contour map at a scale of 1 inch = 500 feet or larger. This typically may extend outside the boundary of the project. Show Tc, CN, and Drainage Area for each sub-area on the map. Indicate relevant structures.

N/A Large-scale map at a scale of 1 inch = 100 feet or larger, showing different soils within each sub-area boundary, which may also be used to delineate drainage areas. Show Tc calculation and path used for each sub-area.

X CN value calculations and work sheets shall be included.

X Times of Concentration calculations and work sheets shall be included. Note that sheet flow components should not exceed 50 feet and are usually less.

X Hydrographs shall be printed out and show data and a 2D graphical representation for pre- and post-development conditions.

X A tabular sheet showing stage-discharge-storage volumes for detention/retention facilities, along with supporting calculations shall be submitted. Include drawings of structures and cross-sections showing elevations and dimensions used in the calculations.

X Tabular sheet showing stormwater flow rates and volumes generated prior to development, for the development without attenuation, and the final discharge.

General Basin Design Requirements

X Plan of basin at scale of 1 inch = 20 feet provided.

X 20-scale Cross-Section view of basin showing detail of design features and underlying profiles of high groundwater, existing grade, proposed grade, soil strata, and impervious/bedrock layers. All test holes and borings also shown in appropriate perspective.

X Geometric Design follows both Board of Health requirements and DEP Stormwater Handbook. Note that 4:1 side slopes are required on basin interiors and a 10-foot safety bench is required. The width of the top of the containment berm must be at least 10 feet wide.

X Water depth shall not exceed 3 feet.

X Minimum of 12 inches of freeboard provided.

X Emergency spillway shall be provided.

X A Maintenance Plan shall be submitted.

Dry and Extended Detention Basins

N/A Extended detention provides 24-hour average detention for 2-inch and 2-year storms as calculated by plug-flow method.

N/A Inlet and outlet separation has been maximized.

N/A Inlet energy dissipater and forebay is provided.

N/A Maintenance access has been provided.

N/A Multi-stage outlet provided as required.

N/A Ten-year storm shall empty in 24 hours maximum.

N/A 100-year storm shall empty in 72 hours maximum.

Infiltration Structure

X Soil hydraulic conductivity shall be based upon field borehole permeability tests.

X Complete Boring Logs and Details of Calculations shall be submitted.

X Elevation of high ground water, elevation of underlying impervious layer (ledge or clay), and saturated thickness of underlying aquifer has been determined.

X Mounding of groundwater shall be considered in the design.

X An infiltration structure for a 2-inch storm will have a minimum of 2 feet of vertical clearance (preferably 4 feet) to the high ground water with consideration of the groundwater mound.

X Ten-year storm will empty (infiltrate) in 24 hours maximum.

X 100-year storm will empty (infiltrate) in 72 hours maximum.

N/A Underground Infiltration Facilities shall be preceded by an Innovative/Alternative stormwater quality enhancement system that has had its performance verified by the Massachusetts Strategic Envirotechnology Partnership (STEP). Such I/A systems shall be required for all underground infiltration facilities. Units shall be designed to accept the flow rate from a 20-inch NRCS Type 3 rainfall without by-pass.

III. OPERATION AND MAINTENANCE PLAN

X Are stormwater facilities to be publicly or privately owned and maintained? The stormwater management system shall have an operation and maintenance plan satisfactory to the Board of Health in accordance with Mass DEP guidelines and good engineering practice to ensure that systems function as designed. For stormwater facilities that are not publicly owned or maintained, the Board of Health shall require that an agreement shall be executed, subject to the approval of the Board of Health, for perpetual maintenance and operation of the stormwater system in order to guarantee the regular maintenance, repair and replacement of any or all components as necessary.

IV. RESPONSIBILITY

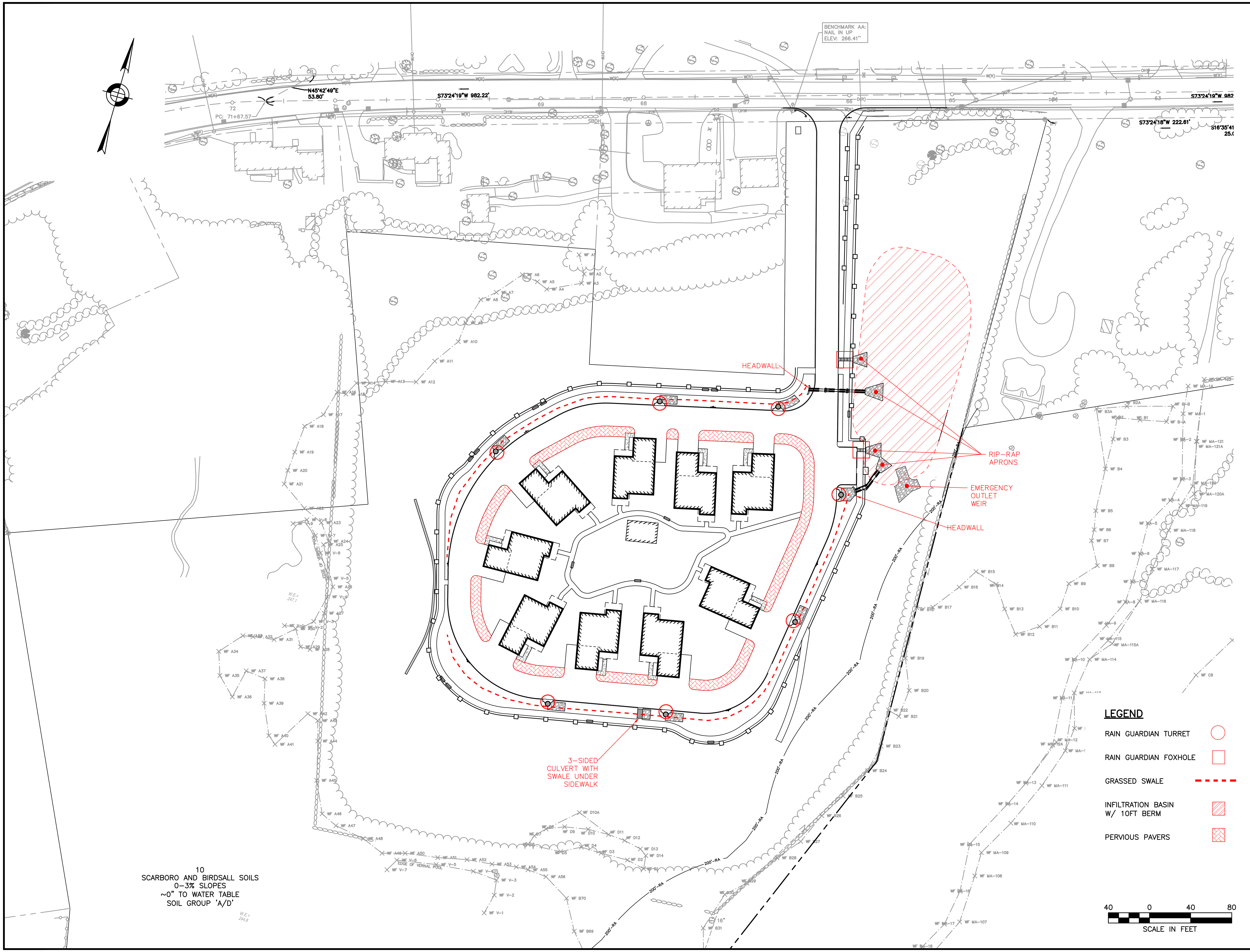
It is the ultimate responsibility of the design engineer to assure that the storm water system design is in full compliance with all applicable laws and regulations, and that all stormwater facility construction products are designed and installed in accordance with manufacturer's recommendations and/or requirements.

Name of Registered Engineer completing this checklist.

(print) Katie Enright Reg. # 46111

Signature: Katie Enright Date: 9/14/22

Appendix F – BMP Map



9/8/2022 L:\19227\West St - CURRENT\19227 - Drainage.dwg
Last Saved by: KLABRIE
Printed by: Kristen LaBrie

HOWARD STEIN HUDSON
114 Turnpike Road, Suite 2C
Chelmsford, MA 01824
www.hshassoc.com

PREPARED FOR:

SHELDON WEST, LLC
480 TURNPIKE STREET
SOUTH EASTON, MA 02375

SHELDON WEST
1139 WEST STREET
WRENTHAM, MA 02093
NORFOLK COUNTY

REVISIONS:

NO	BY	DATE	DESCRIPTION
1	KL	9/9/22	PEER REVIEW

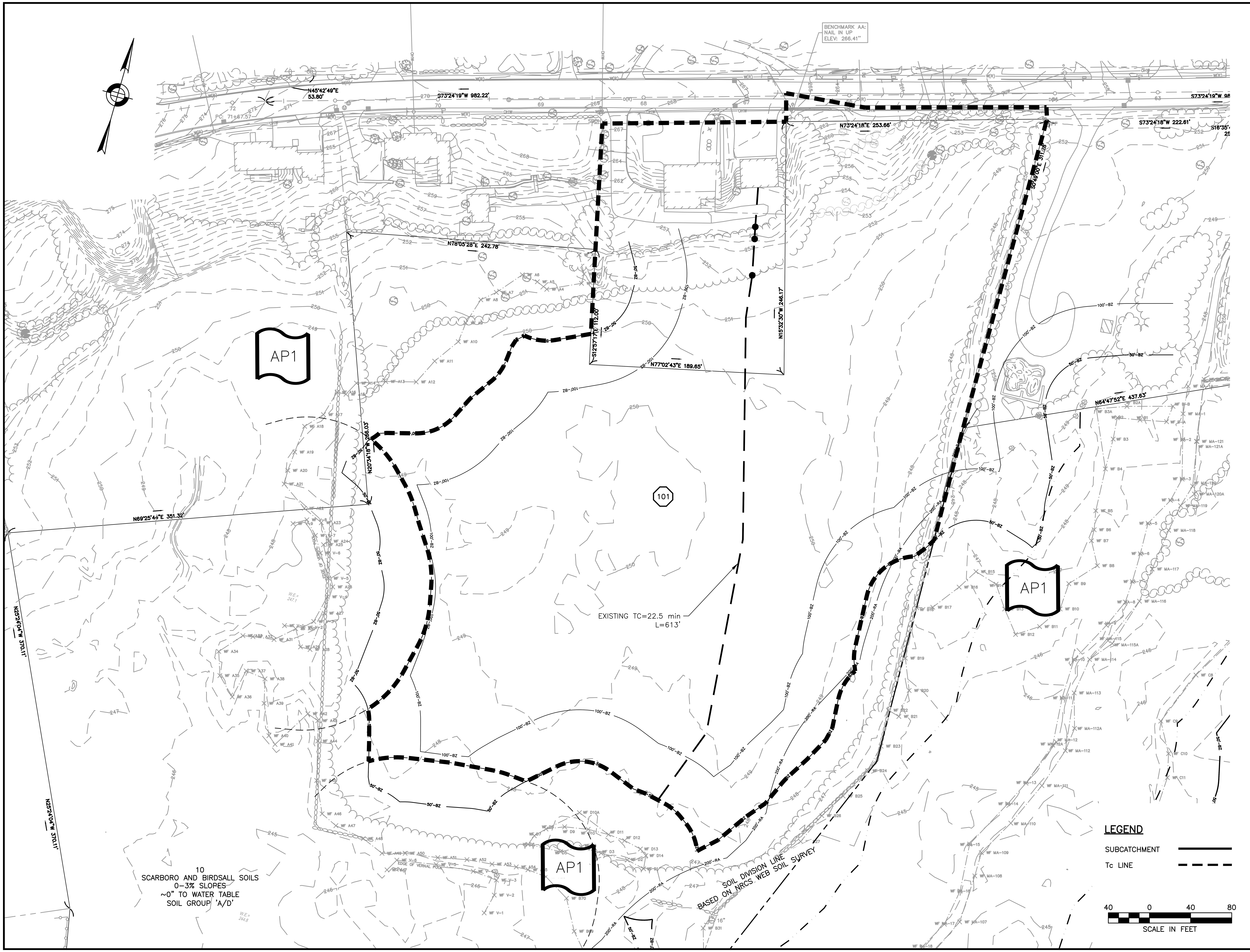
SITE PLAN

BMP MAP

DATE:	APRIL 11, 2022
PROJECT NUMBER:	19227.01
DESIGNED BY:	KL
DRAWN BY:	KL/NC
CHECKED BY:	KE

1

Appendix G – Pre and Post Drainage Maps



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SOUTH EASTON, MA 02375

SHELDON WEST

1139 WEST STREET
WRENTHAM, MA 02093
NORFOLK COUNTY

REVISIONS:

NO	BY	DATE	DESCRIPTION
1	KL	9/13/22	PEER REVIEW

SITE PLAN

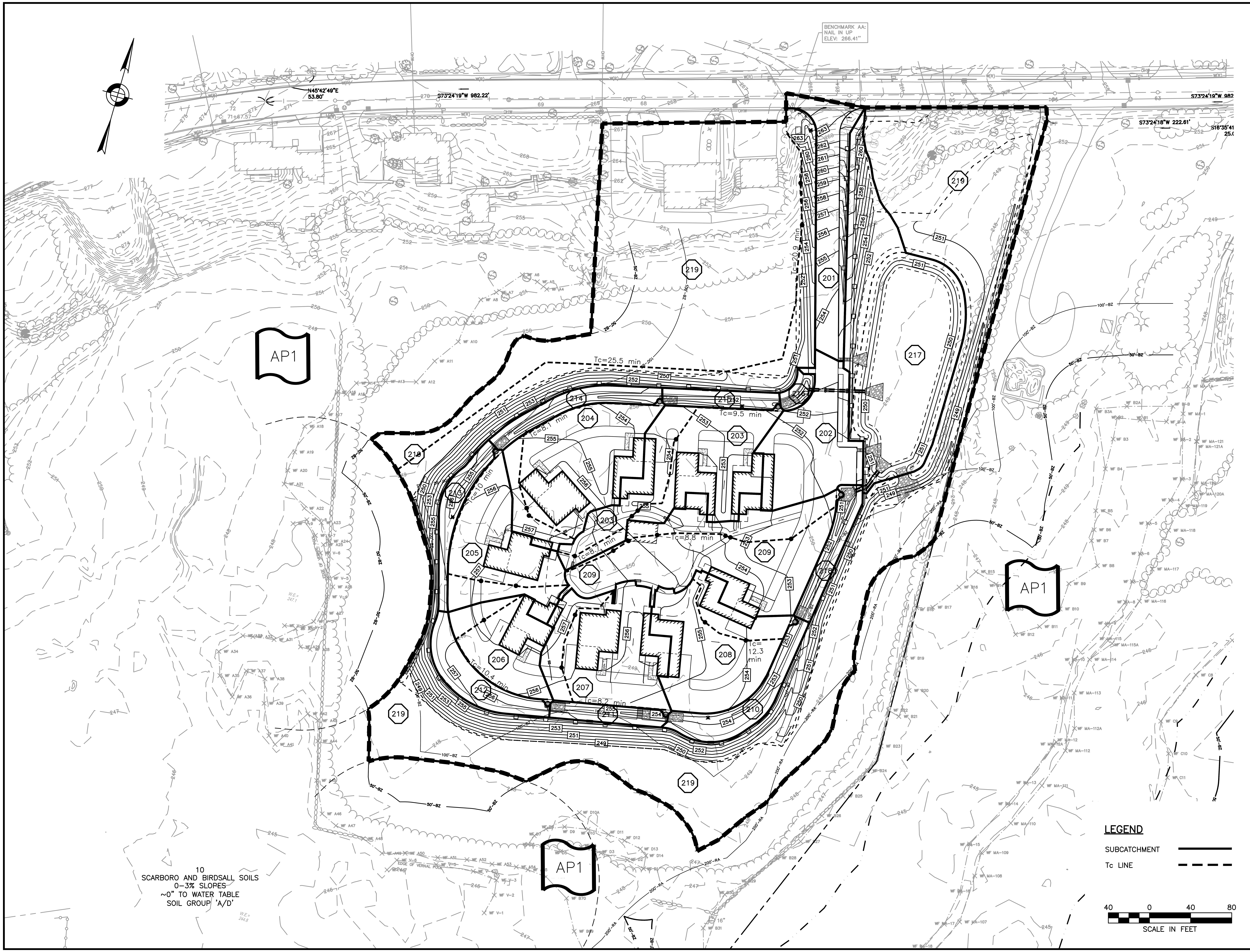
PRE DEVELOPMENT DRAINAGE MAP

DATE:	APRIL 11, 2022
PROJECT NUMBER:	19227.01
DESIGNED BY:	KL/MB
DRAWN BY:	KL/MB/NC
CHECKED BY:	KE

1

SHEET 1 OF 2

9/12/2022 L:\19227\West St - CURRENT\19227 - Drainage.dwg
Last Saved by: KLABRIE
Printed by: Kristen LaBrie



HOWARD STEIN HUDSON
114 Turnpike Road, Suite 2C
Chelmsford, MA 01824
www.hshassoc.com

PREPARED FOR:

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480 TURNPIKE STREET
SOUTH EASTON, MA 02375

SHELDON WEST
1139 WEST STREET
WRENTHAM, MA 02093
NORFOLK COUNTY

REVISIONS:

NO	BY	DATE	DESCRIPTION
1	KL	9/13/22	PEER REVIEW

SITE
PLAN

POST DEVELOPMENT
DRAINAGE MAP

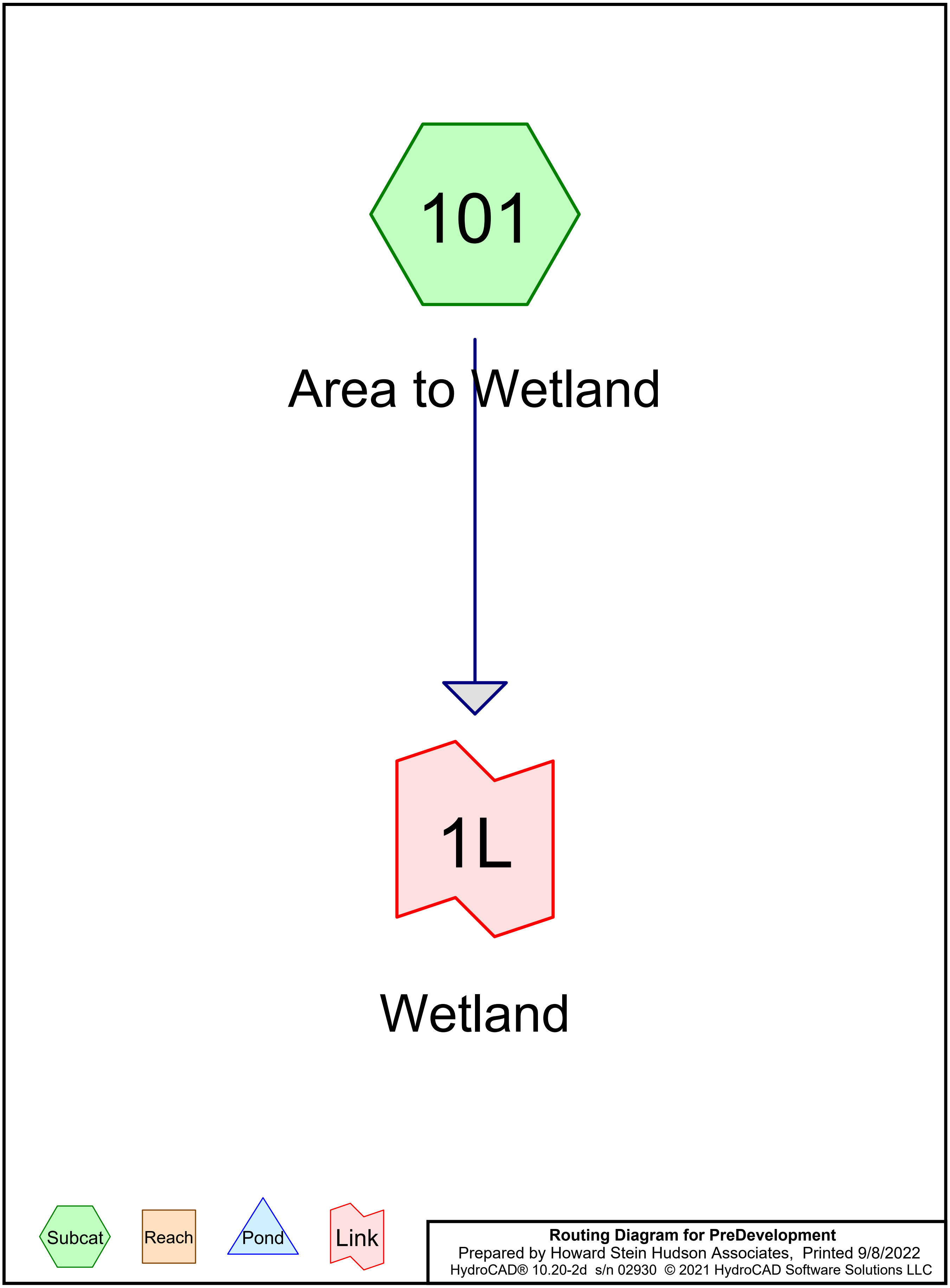
DATE:	APRIL 11, 2022
PROJECT NUMBER:	19227.01
DESIGNED BY:	KL/MB
DRAWN BY:	KL/MB/NC
CHECKED BY:	KE

2

SHEET 2 OF 2

9/12/2022 L:\19227\West St - CURRENT\19227 - Drainage.dwg
Last Saved by: KLABRIE
Printed by: Kristen LaBrie

Appendix H – HydroCAD, Stage Storage and Hydrographs



Routing Diagram for PreDevelopment
Prepared by Howard Stein Hudson Associates, Printed 9/8/2022

Project Notes

Rainfall events imported from "19227 - Post Dev_West St.hcp"
Rainfall events imported from "Atlas-14-Rain.txt" for 441 MA Franklin

Rainfall Events Listing

Event#	Event Name	Storm Type	Curve	Mode	Duration (hours)	B/B	Depth (inches)	AMC
1	2-Inch	NRCC 24-hr	C	Default	24.00	1	2.00	2
2	2-Year	NRCC 24-hr	C	Default	24.00	1	3.02	2
3	10-Year	NRCC 24-hr	C	Default	24.00	1	4.33	2
4	50-Year	NRCC 24-hr	C	Default	24.00	1	6.22	2
5	100-Year	NRCC 24-hr	C	Default	24.00	1	7.29	2

Area Listing (all nodes)

Area (sq-ft)	CN	Description (subcatchment-numbers)
255,194	39	>75% Grass cover, Good, HSG A (101)
8,602	98	Paved parking, HSG A (101)
3,293	98	Roofs, HSG A (101)
25,857	30	Woods, Good, HSG A (101)
292,946	**41**	**TOTAL AREA**

Soil Listing (all nodes)

Area (sq-ft)	Soil Group	Subcatchment Numbers
292,946	HSG A	101
0	HSG B	
0	HSG C	
0	HSG D	
0	Other	
292,946		**TOTAL AREA**

Ground Covers (all nodes)

HSG-A (sq-ft)	HSG-B (sq-ft)	HSG-C (sq-ft)	HSG-D (sq-ft)	Other (sq-ft)	Total (sq-ft)	Ground Cover	Su Nu
255,194	0	0	0	0	255,194	>75% Grass cover, Good	
8,602	0	0	0	0	8,602	Paved parking	
3,293	0	0	0	0	3,293	Roofs	
25,857	0	0	0	0	25,857	Woods, Good	
292,946	**0**	**0**	**0**	**0**	**292,946**	**TOTAL AREA**	

Time span=0.00-24.00 hrs, dt=0.05 hrs, 481 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 101: Area to Wetland Runoff Area=292,946 sf 4.06% Impervious Runoff Depth=0.00"
Flow Length=282' Tc=14.5 min CN=41 Runoff=0.00 cfs 0 cf

Link 1L: Wetland Inflow=0.00 cfs 0 cf
Primary=0.00 cfs 0 cf

Total Runoff Area = 292,946 sf Runoff Volume = 0 cf Average Runoff Depth = 0.00"
95.94% Pervious = 281,051 sf 4.06% Impervious = 11,895 sf

Summary for Subcatchment 101: Area to Wetland

[45] Hint: Runoff=Zero

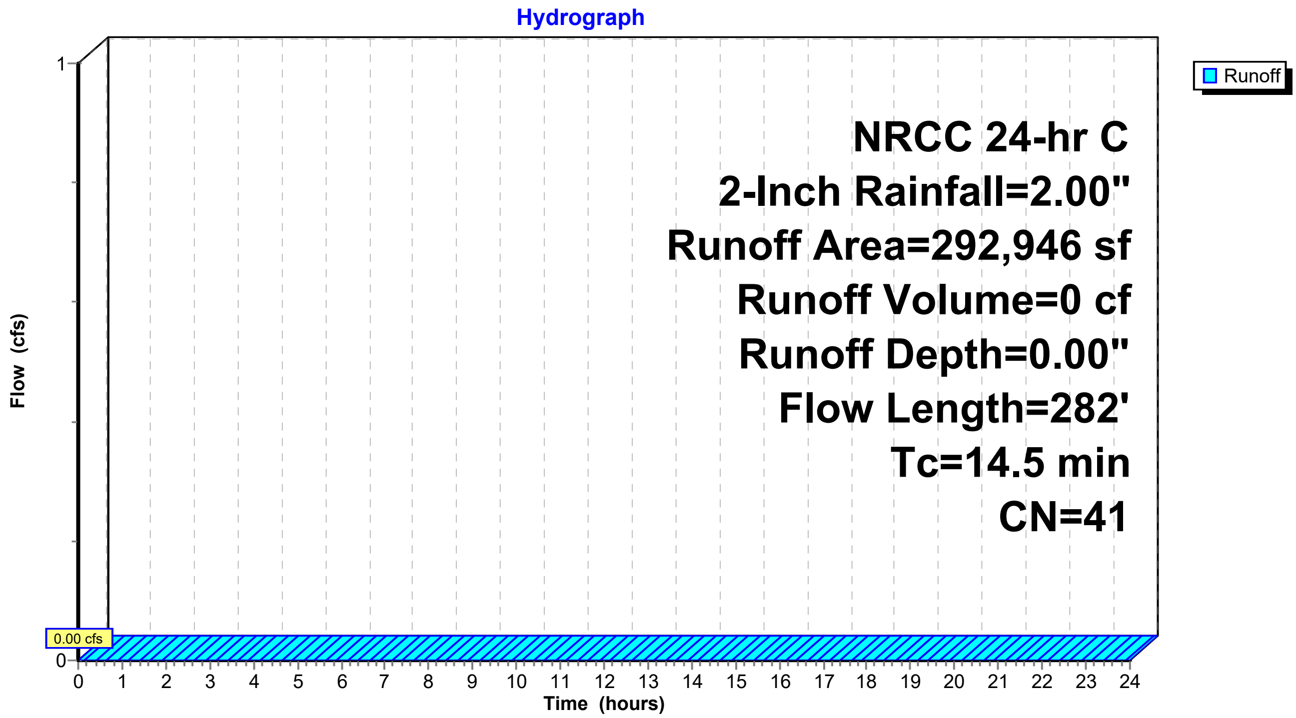
Runoff = 0.00 cfs @ 0.00 hrs, Volume= 0 cf, Depth= 0.00"
Routed to Link 1L : Wetland

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
NRCC 24-hr C 2-Inch Rainfall=2.00"

Area (sf)	CN	Description
255,194	39	>75% Grass cover, Good, HSG A
25,857	30	Woods, Good, HSG A
8,602	98	Paved parking, HSG A
3,293	98	Roofs, HSG A
292,946	41	Weighted Average
281,051		95.94% Pervious Area
11,895		4.06% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
8.4	35	0.1000	0.07		**Sheet Flow,** Woods: Dense underbrush n= 0.800 P2= 3.27"
1.7	15	0.0330	0.14		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.27"
3.1	194	0.0220	1.04		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
1.3	38	0.0100	0.50		**Shallow Concentrated Flow,** Woodland Kv= 5.0 fps
14.5	282	Total			

Subcatchment 101: Area to Wetland

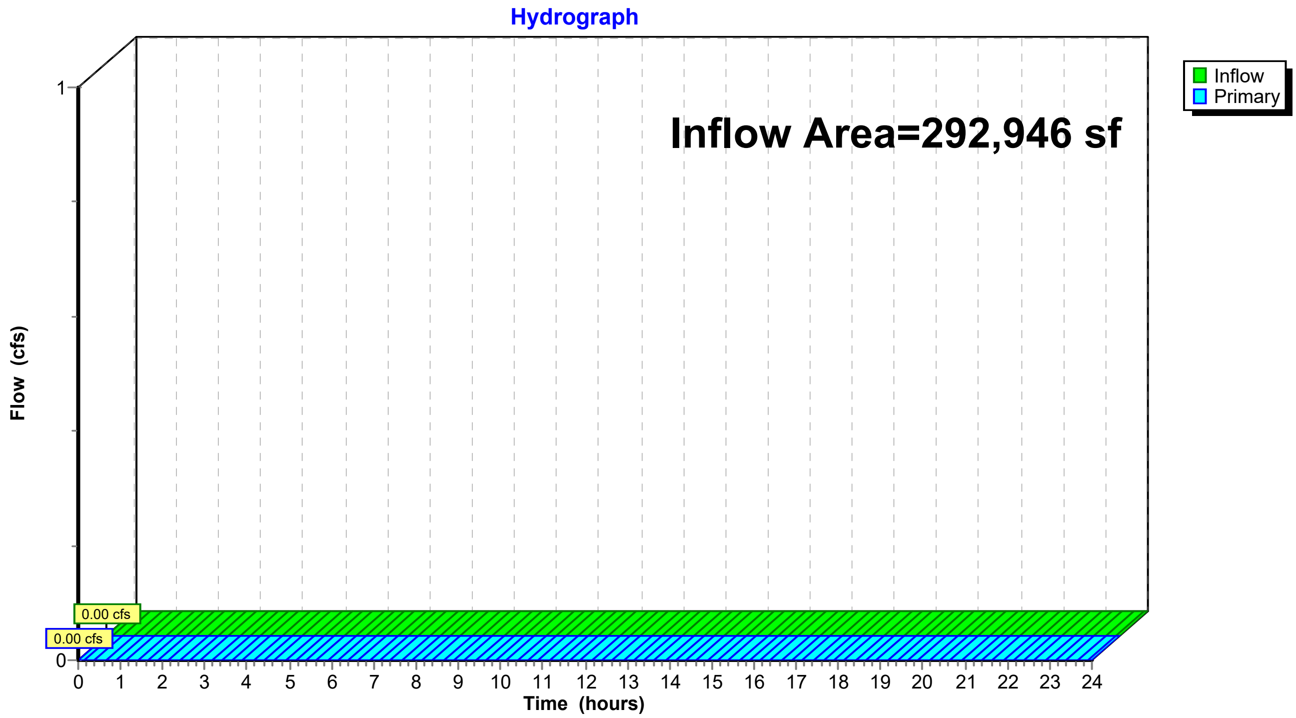


Summary for Link 1L: Wetland

Inflow Area = 292,946 sf, 4.06% Impervious, Inflow Depth = 0.00" for 2-Inch event
Inflow = 0.00 cfs @ 0.00 hrs, Volume= 0 cf
Primary = 0.00 cfs @ 0.00 hrs, Volume= 0 cf, Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs

Link 1L: Wetland



Time span=0.00-24.00 hrs, dt=0.05 hrs, 481 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 101: Area to Wetland Runoff Area=292,946 sf 4.06% Impervious Runoff Depth>0.00"
Flow Length=282' Tc=14.5 min CN=41 Runoff=0.00 cfs 31 cf

Link 1L: Wetland Inflow=0.00 cfs 31 cf
Primary=0.00 cfs 31 cf

Total Runoff Area = 292,946 sf Runoff Volume = 31 cf Average Runoff Depth = 0.00"
95.94% Pervious = 281,051 sf 4.06% Impervious = 11,895 sf

Summary for Subcatchment 101: Area to Wetland

[73] Warning: Peak may fall outside time span

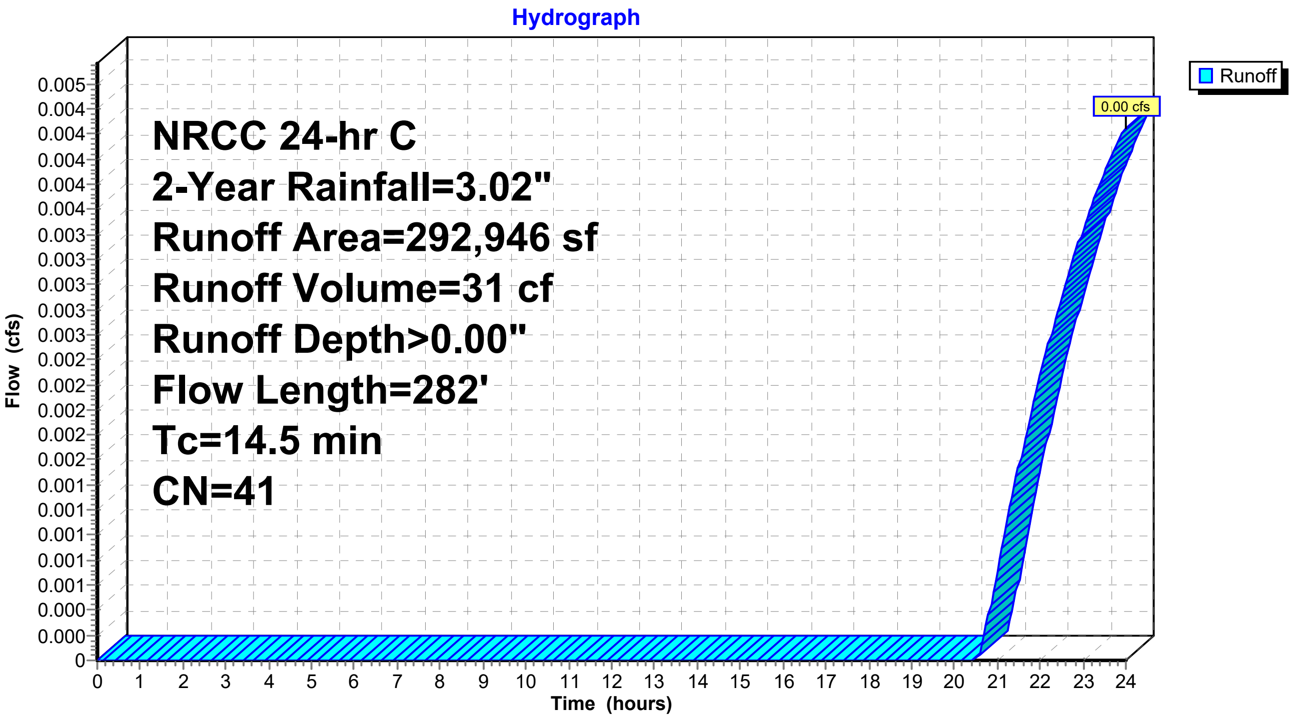
Runoff = 0.00 cfs @ 24.00 hrs, Volume= 31 cf, Depth> 0.00"
Routed to Link 1L : Wetland

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
NRCC 24-hr C 2-Year Rainfall=3.02"

Area (sf)	CN	Description
255,194	39	>75% Grass cover, Good, HSG A
25,857	30	Woods, Good, HSG A
8,602	98	Paved parking, HSG A
3,293	98	Roofs, HSG A
292,946	41	Weighted Average
281,051		95.94% Pervious Area
11,895		4.06% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
8.4	35	0.1000	0.07		**Sheet Flow,** Woods: Dense underbrush n= 0.800 P2= 3.27"
1.7	15	0.0330	0.14		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.27"
3.1	194	0.0220	1.04		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
1.3	38	0.0100	0.50		**Shallow Concentrated Flow,** Woodland Kv= 5.0 fps
14.5	282	Total			

Subcatchment 101: Area to Wetland

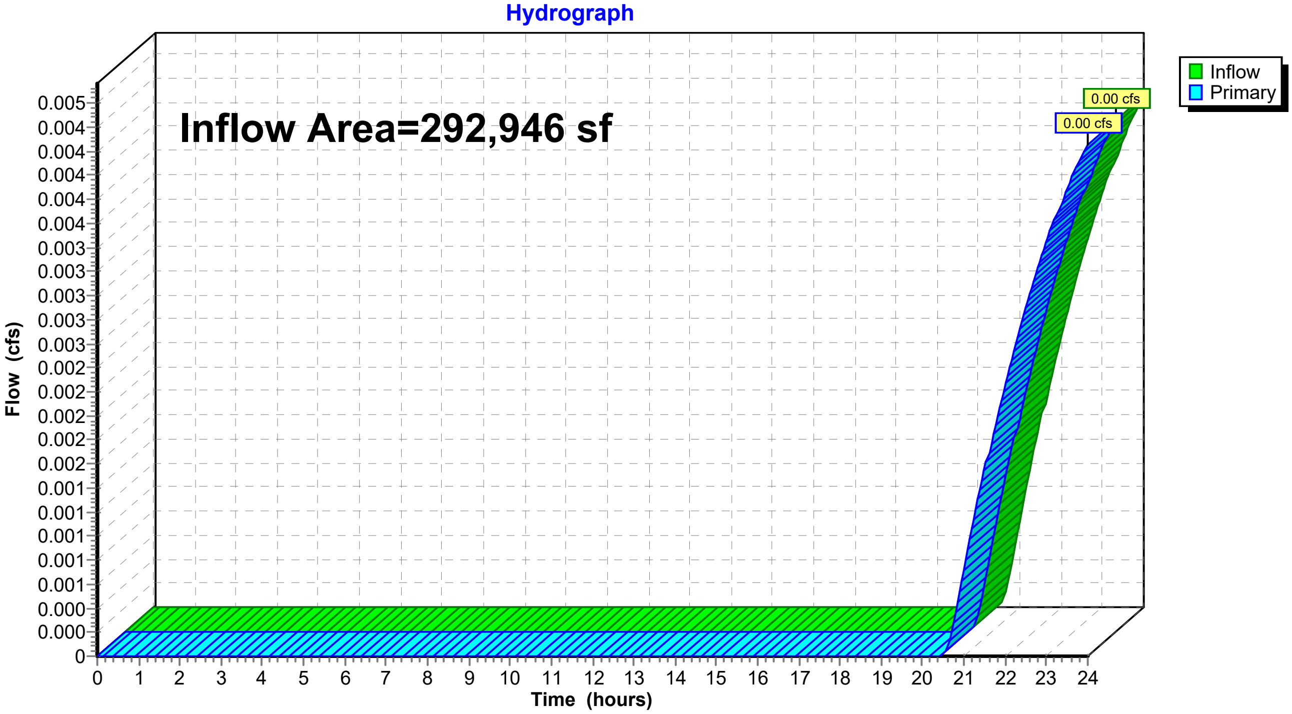


Summary for Link 1L: Wetland

Inflow Area = 292,946 sf, 4.06% Impervious, Inflow Depth > 0.00" for 2-Year event
Inflow = 0.00 cfs @ 24.00 hrs, Volume= 31 cf
Primary = 0.00 cfs @ 24.00 hrs, Volume= 31 cf, Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs

Link 1L: Wetland



Time span=0.00-24.00 hrs, dt=0.05 hrs, 481 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment101: Area to Wetland Runoff Area=292,946 sf 4.06% Impervious Runoff Depth>0.13"
Flow Length=282' Tc=14.5 min CN=41 Runoff=0.11 cfs 3,207 cf

Link 1L: Wetland Inflow=0.11 cfs 3,207 cf
Primary=0.11 cfs 3,207 cf

Total Runoff Area = 292,946 sf Runoff Volume = 3,207 cf Average Runoff Depth = 0.13"
95.94% Pervious = 281,051 sf 4.06% Impervious = 11,895 sf

Summary for Subcatchment 101: Area to Wetland

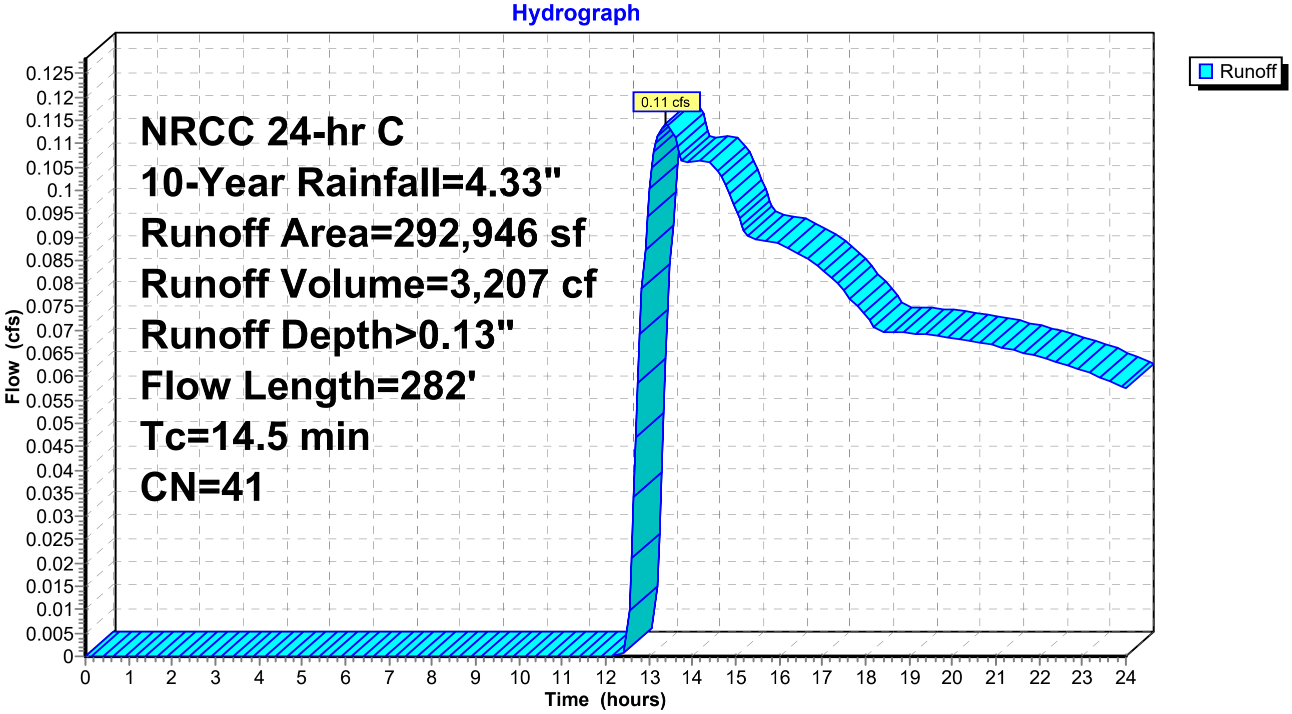
Runoff = 0.11 cfs @ 13.40 hrs, Volume= 3,207 cf, Depth> 0.13"
Routed to Link 1L : Wetland

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
NRCC 24-hr C 10-Year Rainfall=4.33"

Area (sf)	CN	Description
255,194	39	>75% Grass cover, Good, HSG A
25,857	30	Woods, Good, HSG A
8,602	98	Paved parking, HSG A
3,293	98	Roofs, HSG A
292,946	41	Weighted Average
281,051		95.94% Pervious Area
11,895		4.06% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
8.4	35	0.1000	0.07		**Sheet Flow,**
					Woods: Dense underbrush n= 0.800 P2= 3.27"
1.7	15	0.0330	0.14		**Sheet Flow,**
					Grass: Short n= 0.150 P2= 3.27"
3.1	194	0.0220	1.04		**Shallow Concentrated Flow,**
					Short Grass Pasture Kv= 7.0 fps
1.3	38	0.0100	0.50		**Shallow Concentrated Flow,**
					Woodland Kv= 5.0 fps
14.5	282	Total			

Subcatchment 101: Area to Wetland

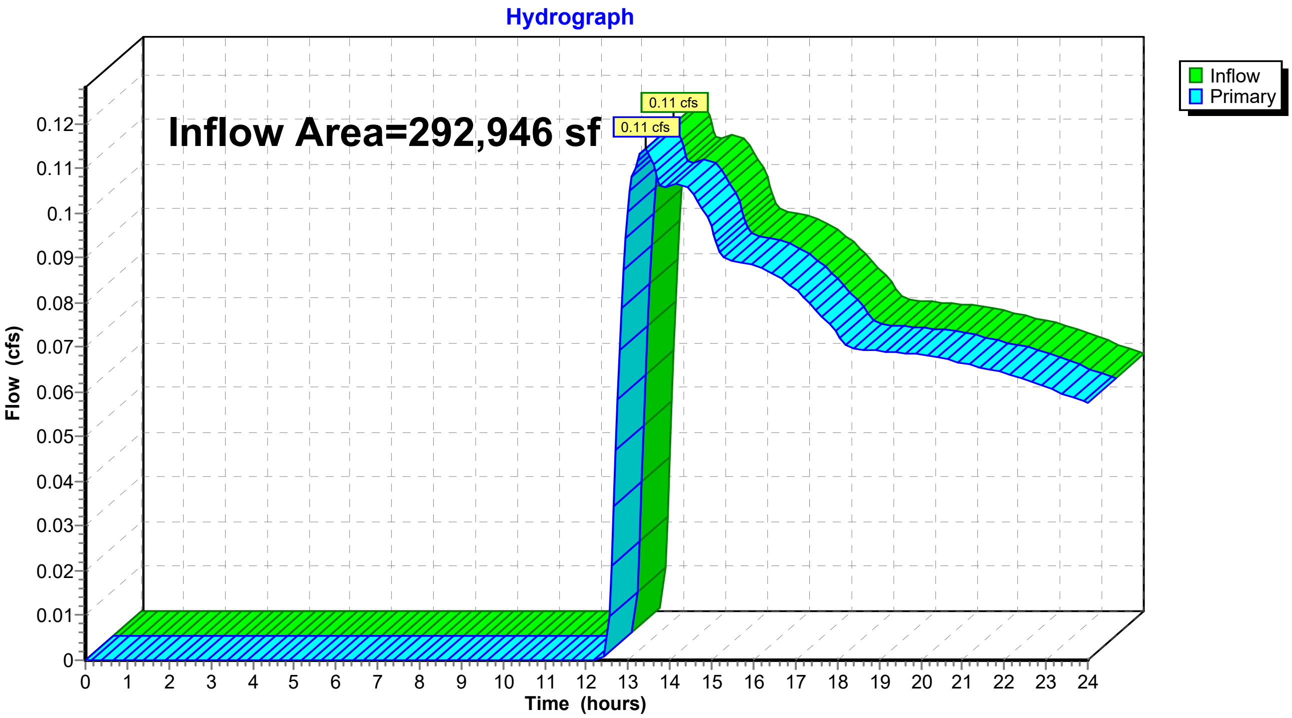


Summary for Link 1L: Wetland

Inflow Area =	292,946 sf,	4.06% Impervious,	Inflow Depth > 0.13"	for 10-Year event	
Inflow =	0.11 cfs @	13.40 hrs,	Volume=	3,207 cf	
Primary =	0.11 cfs @	13.40 hrs,	Volume=	3,207 cf,	Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs

Link 1L: Wetland



Time span=0.00-24.00 hrs, dt=0.05 hrs, 481 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 101: Area to Wetland Runoff Area=292,946 sf 4.06% Impervious Runoff Depth>0.63"
Flow Length=282' Tc=14.5 min CN=41 Runoff=1.81 cfs 15,260 cf

Link 1L: Wetland Inflow=1.81 cfs 15,260 cf
Primary=1.81 cfs 15,260 cf

Total Runoff Area = 292,946 sf Runoff Volume = 15,260 cf Average Runoff Depth = 0.63"
95.94% Pervious = 281,051 sf 4.06% Impervious = 11,895 sf

Summary for Subcatchment 101: Area to Wetland

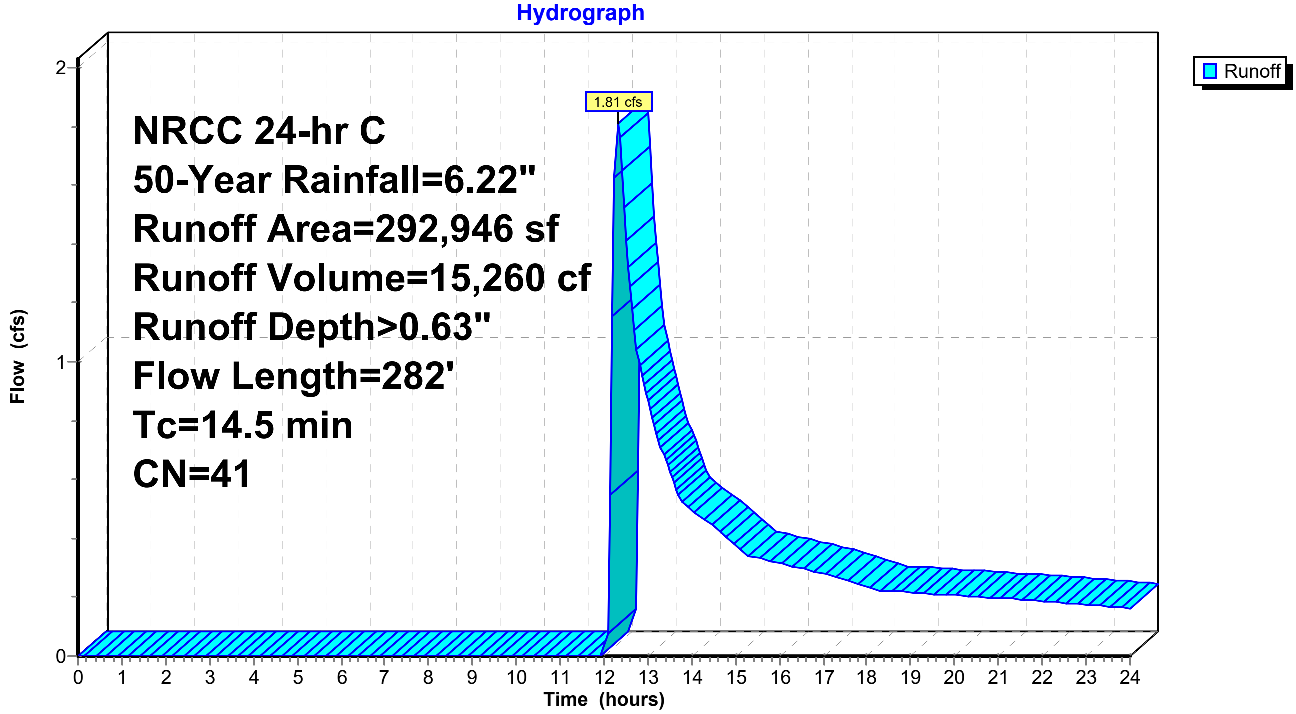
Runoff = 1.81 cfs @ 12.32 hrs, Volume= 15,260 cf, Depth> 0.63"
Routed to Link 1L : Wetland

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
NRCC 24-hr C 50-Year Rainfall=6.22"

Area (sf)	CN	Description
255,194	39	>75% Grass cover, Good, HSG A
25,857	30	Woods, Good, HSG A
8,602	98	Paved parking, HSG A
3,293	98	Roofs, HSG A
292,946	41	Weighted Average
281,051		95.94% Pervious Area
11,895		4.06% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
8.4	35	0.1000	0.07		**Sheet Flow,** Woods: Dense underbrush n= 0.800 P2= 3.27"
1.7	15	0.0330	0.14		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.27"
3.1	194	0.0220	1.04		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
1.3	38	0.0100	0.50		**Shallow Concentrated Flow,** Woodland Kv= 5.0 fps
14.5	282	Total			

Subcatchment 101: Area to Wetland

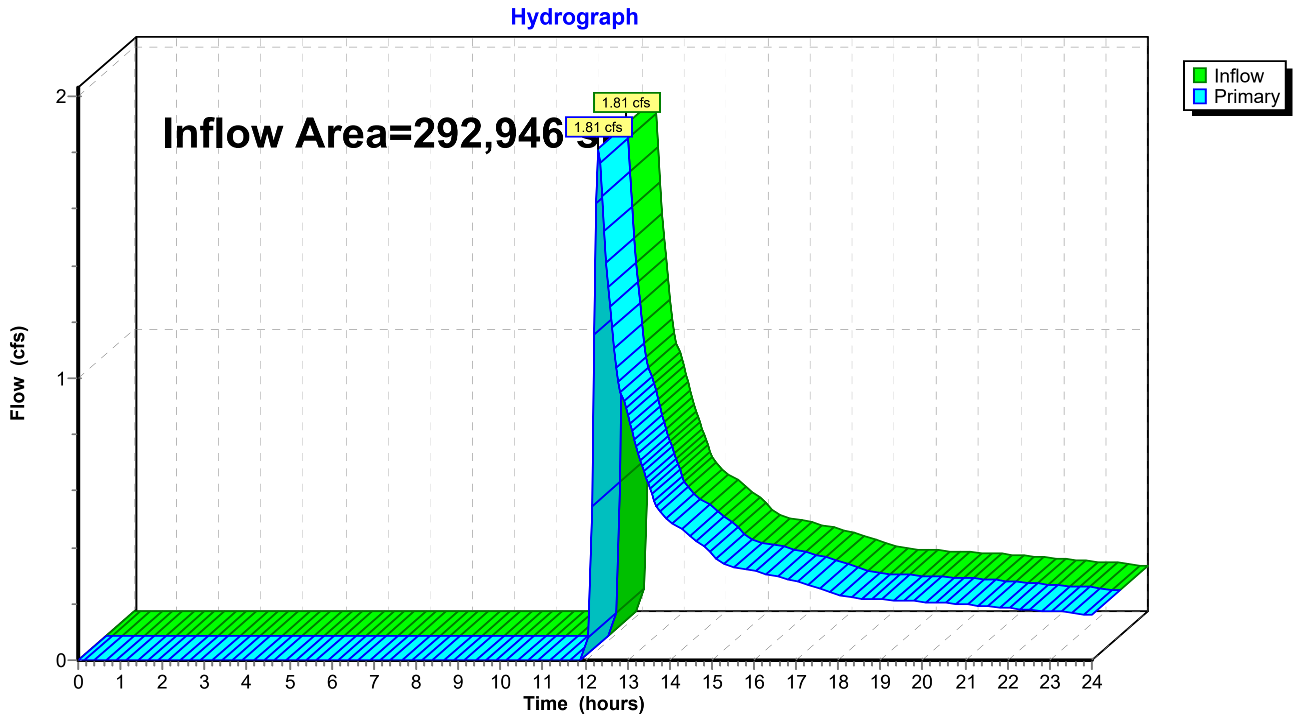


Summary for Link 1L: Wetland

Inflow Area =	292,946 sf,	4.06% Impervious,	Inflow Depth > 0.63"	for 50-Year event	
Inflow =	1.81 cfs @	12.32 hrs, Volume=	15,260 cf		
Primary =	1.81 cfs @	12.32 hrs, Volume=	15,260 cf,	Atten= 0%,	Lag= 0.0 min

Primary outflow = Inflow, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs

Link 1L: Wetland



Time span=0.00-24.00 hrs, dt=0.05 hrs, 481 points
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Stor-Ind+Trans method - Pond routing by Stor-Ind method

Subcatchment 101: Area to Wetland Runoff Area=292,946 sf 4.06% Impervious Runoff Depth>1.03"
Flow Length=282' Tc=14.5 min CN=41 Runoff=4.26 cfs 25,109 cf

Link 1L: Wetland Inflow=4.26 cfs 25,109 cf
Primary=4.26 cfs 25,109 cf

Total Runoff Area = 292,946 sf Runoff Volume = 25,109 cf Average Runoff Depth = 1.03"
95.94% Pervious = 281,051 sf 4.06% Impervious = 11,895 sf

Summary for Subcatchment 101: Area to Wetland

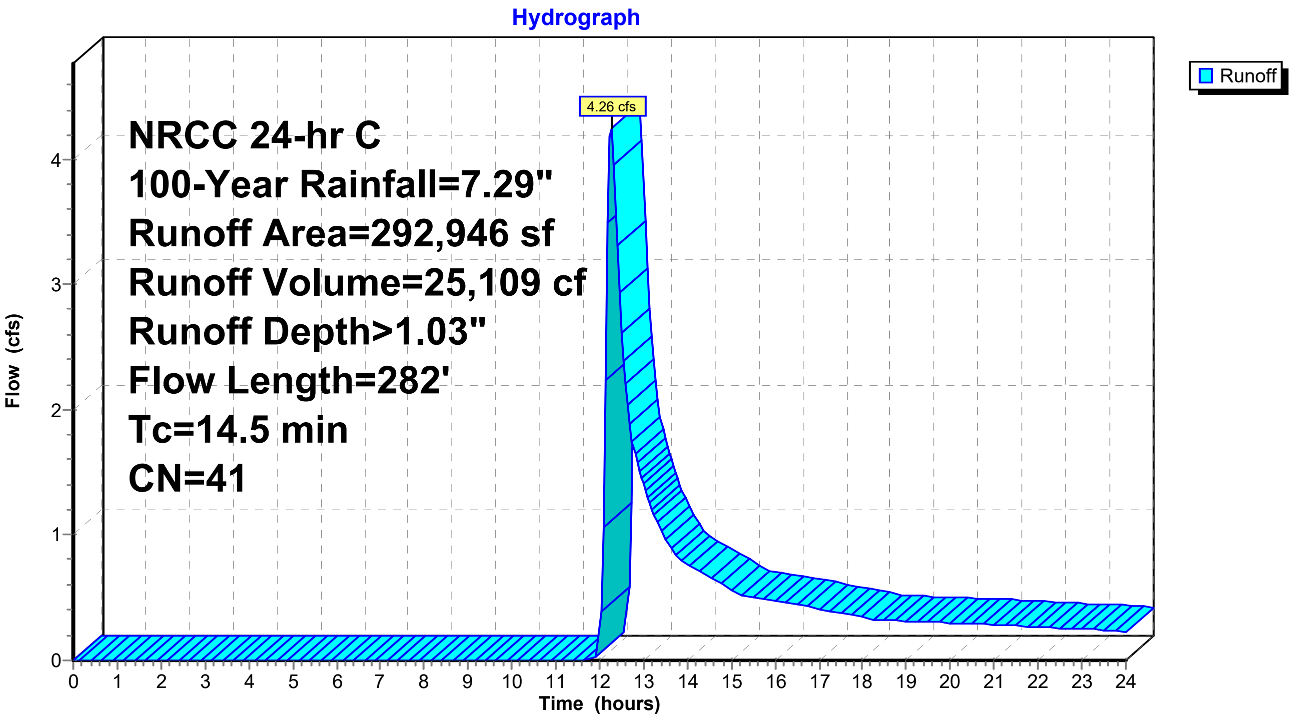
Runoff = 4.26 cfs @ 12.27 hrs, Volume= 25,109 cf, Depth> 1.03"
Routed to Link 1L : Wetland

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs
NRCC 24-hr C 100-Year Rainfall=7.29"

Area (sf)	CN	Description
255,194	39	>75% Grass cover, Good, HSG A
25,857	30	Woods, Good, HSG A
8,602	98	Paved parking, HSG A
3,293	98	Roofs, HSG A
292,946	41	Weighted Average
281,051		95.94% Pervious Area
11,895		4.06% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
8.4	35	0.1000	0.07		**Sheet Flow,** Woods: Dense underbrush n= 0.800 P2= 3.27"
1.7	15	0.0330	0.14		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.27"
3.1	194	0.0220	1.04		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
1.3	38	0.0100	0.50		**Shallow Concentrated Flow,** Woodland Kv= 5.0 fps
14.5	282	Total			

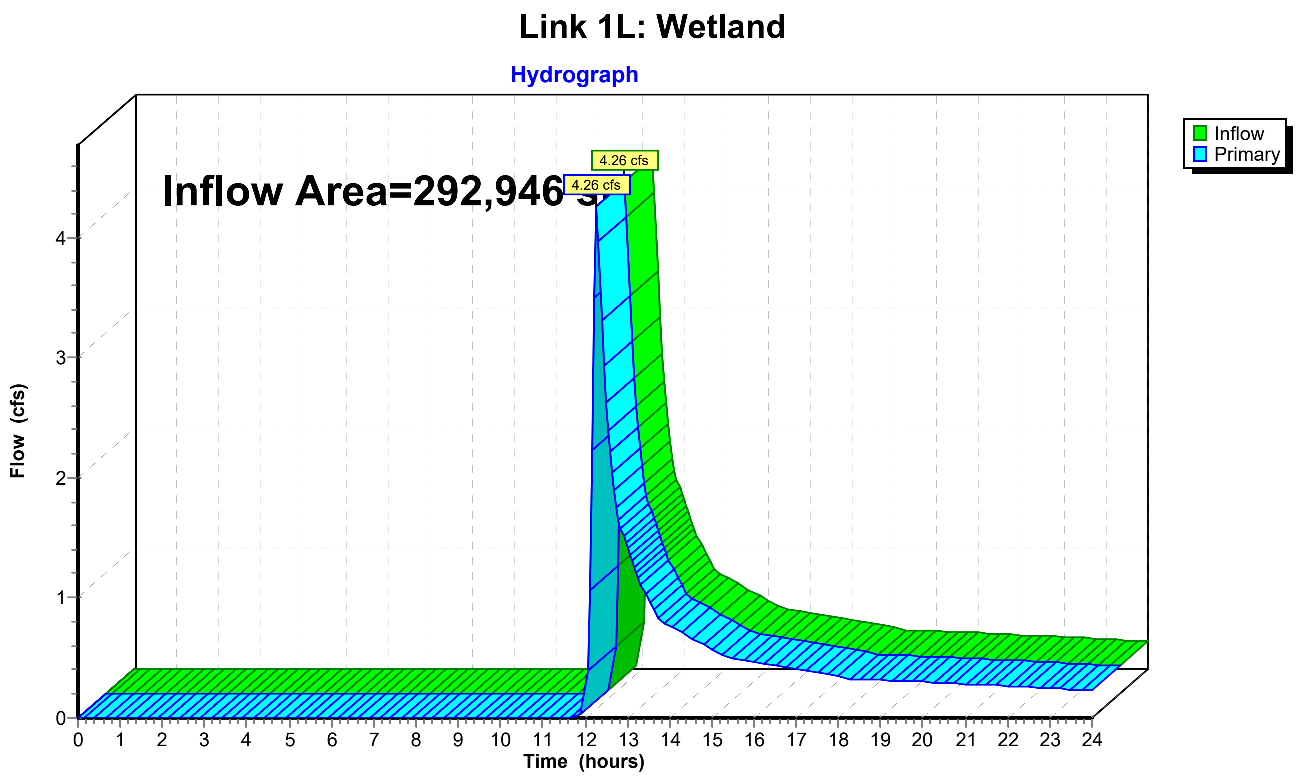
Subcatchment 101: Area to Wetland

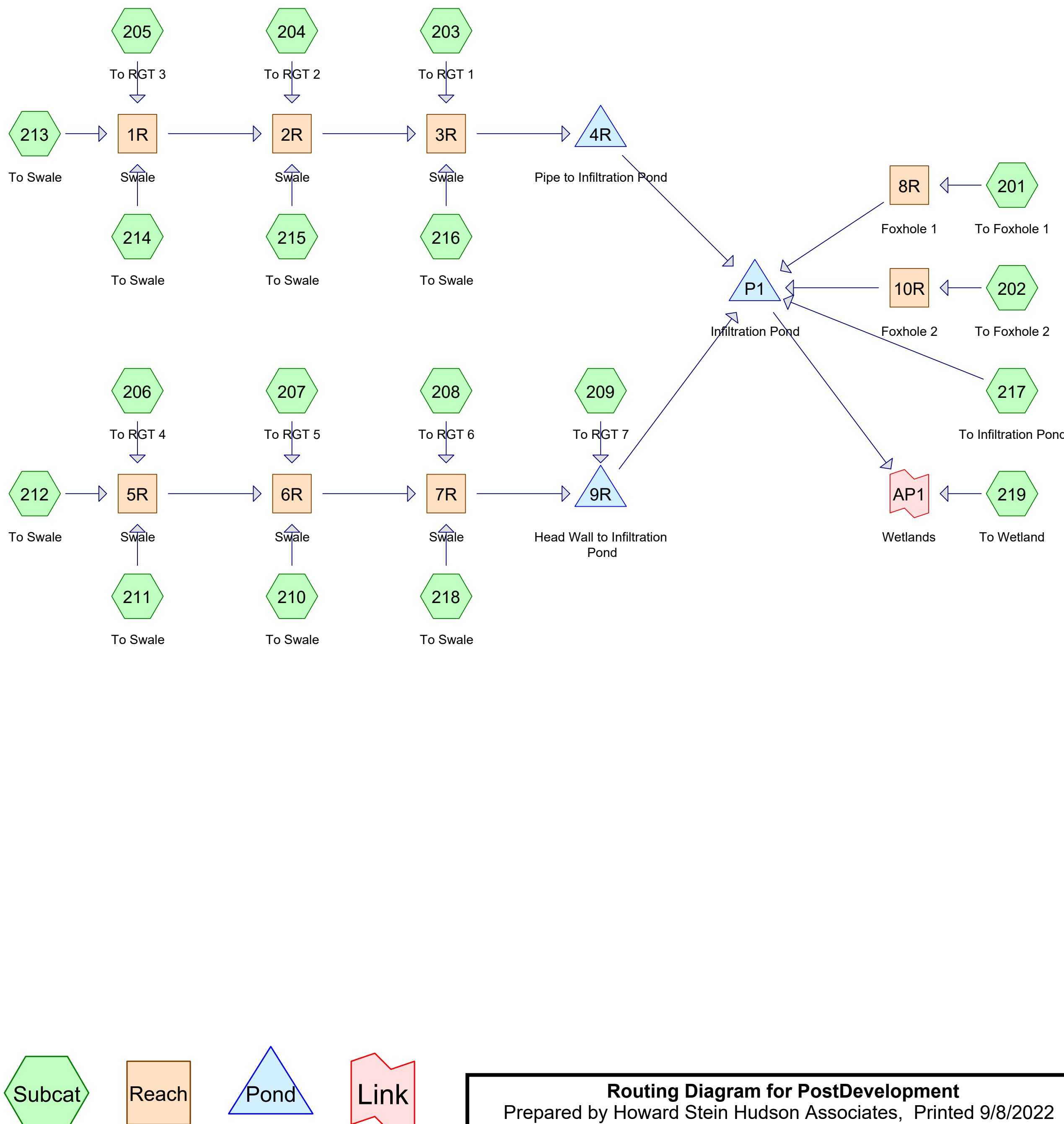


Summary for Link 1L: Wetland

Inflow Area =	292,946 sf,	4.06% Impervious,	Inflow Depth > 1.03"	for 100-Year event	
Inflow =	4.26 cfs @	12.27 hrs, Volume=	25,109 cf		
Primary =	4.26 cfs @	12.27 hrs, Volume=	25,109 cf,	Atten= 0%,	Lag= 0.0 min

Primary outflow = Inflow, Time Span= 0.00-24.00 hrs, dt= 0.05 hrs





Routing Diagram for PostDevelopment
Prepared by Howard Stein Hudson Associates, Printed 9/8/2022
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Project Notes

Rainfall events imported from "PreDevelopment.hcp"
Rainfall events imported from "PreDevelopment.hcp"

Rainfall Events Listing

Event#	Event Name	Storm Type	Curve	Mode	Duration (hours)	B/B	Depth (inches)	AMC
1	2-Inch	NRCC 24-hr	C	Default	24.00	1	2.00	2
2	2-Year	NRCC 24-hr	C	Default	24.00	1	3.02	2
3	10-Year	NRCC 24-hr	C	Default	24.00	1	4.33	2
4	50-Year	NRCC 24-hr	C	Default	24.00	1	6.22	2
5	100-Year	NRCC 24-hr	C	Default	24.00	1	7.29	2

Area Listing (all nodes)

Area (sq-ft)	CN	Description (subcatchment-numbers)
173,889	39	>75% Grass cover, Good, HSG A (201, 202, 203, 204, 205, 206, 207, 208, 209, 210, 211, 212, 213, 214, 215, 216, 217, 218, 219)
65,683	98	Paved parking, HSG A (201, 202, 203, 204, 205, 206, 207, 208, 209, 210, 211, 212, 213, 214, 215, 216, 217, 218, 219)
23,006	98	Roofs, HSG A (202, 203, 204, 205, 206, 207, 208, 209, 219)
13,731	98	Water Surface, 0% imp, HSG A (217)
16,637	32	Woods/grass comb., Good, HSG A (219)
292,946	**59**	**TOTAL AREA**

Soil Listing (all nodes)

Area (sq-ft)	Soil Group	Subcatchment Numbers
292,946	HSG A	201, 202, 203, 204, 205, 206, 207, 208, 209, 210, 211, 212, 213, 214, 215, 216, 217, 218, 219
0	HSG B	
0	HSG C	
0	HSG D	
0	Other	
292,946		**TOTAL AREA**

Ground Covers (all nodes)

HSG-A (sq-ft)	HSG-B (sq-ft)	HSG-C (sq-ft)	HSG-D (sq-ft)	Other (sq-ft)	Total (sq-ft)	Ground Cover	S N
173,889	0	0	0	0	173,889	>75% Grass cover, Good	
65,683	0	0	0	0	65,683	Paved parking	
23,006	0	0	0	0	23,006	Roofs	
13,731	0	0	0	0	13,731	Water Surface, 0% imp	
16,637	0	0	0	0	16,637	Woods/grass comb., Good	
292,946	**0**	**0**	**0**	**0**	**292,946**	**TOTAL AREA**	

Pipe Listing (all nodes)

Line#	Node Number	In-Invert (feet)	Out-Invert (feet)	Length (feet)	Slope (ft/ft)	n	Width (inches)	Diam/Height (inches)	Inside-Fill (inches)
1	8R	253.28	252.53	14.3	0.0524	0.013	22.0	4.5	0.0
2	10R	251.90	251.15	8.4	0.0893	0.013	22.0	4.5	0.0
3	4R	250.00	249.72	55.0	0.0051	0.012	0.0	12.0	0.0
4	9R	250.50	250.00	29.8	0.0168	0.020	0.0	15.0	0.0

Time span=0.00-24.00 hrs, dt=0.01 hrs, 2401 points x 3
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Dyn-Stor-Ind method - Pond routing by Dyn-Stor-Ind method

Subcatchment201: To Foxhole 1 Runoff Area=8,236 sf 77.20% Impervious Runoff Depth>0.79"
Tc=6.0 min CN=85 Runoff=0.19 cfs 545 cf

Subcatchment202: To Foxhole 2 Runoff Area=9,659 sf 79.19% Impervious Runoff Depth>0.85"
Tc=6.0 min CN=86 Runoff=0.24 cfs 682 cf

Subcatchment203: To RGT 1 Runoff Area=14,593 sf 62.69% Impervious Runoff Depth>0.41"
Flow Length=301' Tc=9.5 min CN=76 Runoff=0.13 cfs 501 cf

Subcatchment204: To RGT 2 Runoff Area=14,048 sf 64.46% Impervious Runoff Depth>0.45"
Flow Length=270' Slope=0.0150 '/' Tc=8.1 min CN=77 Runoff=0.15 cfs 523 cf

Subcatchment205: To RGT 3 Runoff Area=10,291 sf 73.21% Impervious Runoff Depth>0.65"
Flow Length=246' Tc=10.0 min CN=82 Runoff=0.16 cfs 554 cf

Subcatchment206: To RGT 4 Runoff Area=6,868 sf 84.23% Impervious Runoff Depth>1.03"
Flow Length=191' Tc=10.4 min CN=89 Runoff=0.17 cfs 587 cf

Subcatchment207: To RGT 5 Runoff Area=12,173 sf 63.90% Impervious Runoff Depth>0.45"
Flow Length=229' Tc=8.2 min CN=77 Runoff=0.13 cfs 453 cf

Subcatchment208: To RGT 6 Runoff Area=11,957 sf 63.77% Impervious Runoff Depth>0.45"
Flow Length=151' Tc=12.3 min CN=77 Runoff=0.11 cfs 444 cf

Subcatchment209: To RGT 7 Runoff Area=18,588 sf 45.75% Impervious Runoff Depth>0.15"
Flow Length=297' Tc=8.8 min CN=66 Runoff=0.02 cfs 237 cf

Subcatchment210: To Swale Runoff Area=3,987 sf 30.88% Impervious Runoff Depth>0.03"
Tc=6.0 min CN=57 Runoff=0.00 cfs 10 cf

Subcatchment211: To Swale Runoff Area=1,897 sf 38.32% Impervious Runoff Depth>0.09"
Tc=6.0 min CN=62 Runoff=0.00 cfs 14 cf

Subcatchment212: To Swale Runoff Area=3,761 sf 28.72% Impervious Runoff Depth>0.02"
Tc=6.0 min CN=56 Runoff=0.00 cfs 7 cf

Subcatchment213: To Swale Runoff Area=2,571 sf 42.94% Impervious Runoff Depth>0.12"
Tc=6.0 min CN=64 Runoff=0.00 cfs 25 cf

Subcatchment214: To Swale Runoff Area=2,962 sf 36.53% Impervious Runoff Depth>0.07"
Tc=6.0 min CN=61 Runoff=0.00 cfs 18 cf

Subcatchment215: To Swale Runoff Area=1,912 sf 35.83% Impervious Runoff Depth>0.06"
Tc=6.0 min CN=60 Runoff=0.00 cfs 10 cf

Subcatchment216: To Swale Runoff Area=807 sf 25.90% Impervious Runoff Depth>0.01"
Tc=6.0 min CN=54 Runoff=0.00 cfs 1 cf

Subcatchment217: To Infiltration Pond Runoff Area=25,006 sf 6.05% Impervious Runoff Depth>0.38"
Tc=6.0 min CN=75 Runoff=0.24 cfs 792 cf

Subcatchment218: To Swale Runoff Area=2,577 sf 33.41% Impervious Runoff Depth>0.05"
Tc=6.0 min CN=59 Runoff=0.00 cfs 11 cf

Subcatchment219: To Wetland Runoff Area=141,053 sf 7.63% Impervious Runoff Depth=0.00"
Flow Length=492' Tc=21.0 min CN=43 Runoff=0.00 cfs 0 cf

Reach 1R: Swale Avg. Flow Depth=0.09' Max Vel=1.03 fps Inflow=0.16 cfs 598 cf
n=0.030 L=175.0' S=0.0137 '/' Capacity=40.09 cfs Outflow=0.15 cfs 595 cf

Reach 2R: Swale Avg. Flow Depth=0.14' Max Vel=1.09 fps Inflow=0.29 cfs 1,128 cf
n=0.030 L=115.0' S=0.0087 '/' Capacity=31.92 cfs Outflow=0.28 cfs 1,125 cf

Reach 3R: Swale Avg. Flow Depth=0.17' Max Vel=2.12 fps Inflow=0.41 cfs 1,627 cf
n=0.030 L=32.0' S=0.0313 '/' Capacity=48.70 cfs Outflow=0.41 cfs 1,626 cf

Reach 5R: Swale Avg. Flow Depth=0.10' Max Vel=0.99 fps Inflow=0.17 cfs 607 cf
n=0.030 L=146.0' S=0.0110 '/' Capacity=35.84 cfs Outflow=0.17 cfs 606 cf

Reach 6R: Swale Avg. Flow Depth=0.14' Max Vel=1.11 fps Inflow=0.29 cfs 1,069 cf
n=0.030 L=151.0' S=0.0093 '/' Capacity=32.96 cfs Outflow=0.28 cfs 1,065 cf

Reach 7R: Swale Avg. Flow Depth=0.15' Max Vel=1.28 fps Inflow=0.38 cfs 1,520 cf
n=0.030 L=140.0' S=0.0107 '/' Capacity=35.44 cfs Outflow=0.38 cfs 1,516 cf

Reach 8R: Foxhole 1 Avg. Flow Depth=0.04' Max Vel=2.82 fps Inflow=0.19 cfs 545 cf
22.0" x 4.5" Box Pipe n=0.013 L=14.3' S=0.0524 '/' Capacity=5.21 cfs Outflow=0.19 cfs 545 cf

Reach 10R: Foxhole 2 Avg. Flow Depth=0.04' Max Vel=3.63 fps Inflow=0.24 cfs 682 cf
22.0" x 4.5" Box Pipe n=0.013 L=8.4' S=0.0893 '/' Capacity=6.80 cfs Outflow=0.24 cfs 682 cf

Pond 4R: Pipe to Infiltration Pond Peak Elev=250.25' Storage=11 cf Inflow=0.41 cfs 1,626 cf
12.0" Round Culvert x 2.00 n=0.012 L=55.0' S=0.0051 '/' Outflow=0.41 cfs 1,625 cf

Pond 9R: Head Wall to Infiltration Pond Peak Elev=250.72' Storage=33 cf Inflow=0.40 cfs 1,753 cf
15.0" Round Culvert x 2.00 n=0.020 L=29.8' S=0.0168 '/' Outflow=0.39 cfs 1,747 cf

Pond P1: Infiltration Pond Peak Elev=249.51' Storage=64 cf Inflow=1.24 cfs 5,391 cf
Discarded=1.23 cfs 5,388 cf Primary=0.00 cfs 0 cf Outflow=1.23 cfs 5,388 cf

Link AP1: Wetlands Inflow=0.00 cfs 0 cf
Primary=0.00 cfs 0 cf

Total Runoff Area = 292,946 sf Runoff Volume = 5,412 cf Average Runoff Depth = 0.22"
69.73% Pervious = 204,257 sf 30.27% Impervious = 88,689 sf

Summary for Subcatchment 201: To Foxhole 1

Runoff = 0.19 cfs @ 12.13 hrs, Volume= 545 cf, Depth> 0.79"
Routed to Reach 8R : Foxhole 1

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 2-Inch Rainfall=2.00"

Area (sf)	CN	Description
6,358	98	Paved parking, HSG A
1,878	39	>75% Grass cover, Good, HSG A
8,236	85	Weighted Average
1,878		22.80% Pervious Area
6,358		77.20% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Summary for Subcatchment 202: To Foxhole 2

Runoff = 0.24 cfs @ 12.13 hrs, Volume= 682 cf, Depth> 0.85"
Routed to Reach 10R : Foxhole 2

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 2-Inch Rainfall=2.00"

Area (sf)	CN	Description
7,031	98	Paved parking, HSG A
2,010	39	>75% Grass cover, Good, HSG A
618	98	Roofs, HSG A
9,659	86	Weighted Average
2,010		20.81% Pervious Area
7,649		79.19% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Summary for Subcatchment 203: To RGT 1

Runoff = 0.13 cfs @ 12.18 hrs, Volume= 501 cf, Depth> 0.41"
Routed to Reach 3R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 2-Inch Rainfall=2.00"

Area (sf)	CN	Description
5,212	98	Paved parking, HSG A
5,444	39	>75% Grass cover, Good, HSG A
3,937	98	Roofs, HSG A
14,593	76	Weighted Average
5,444		37.31% Pervious Area
9,149		62.69% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.3	17	0.0190	0.92		**Sheet Flow, Sidewalk** Smooth surfaces n= 0.011 P2= 3.02"
6.6	70	0.0280	0.18		**Sheet Flow, Grass** Grass: Short n= 0.150 P2= 3.02"
0.1	8	0.0100	2.03		**Shallow Concentrated Flow, Sidewalk** Paved Kv= 20.3 fps
1.5	90	0.0200	0.99		**Shallow Concentrated Flow, Grass** Short Grass Pasture Kv= 7.0 fps
1.0	116	0.0100	2.03		**Shallow Concentrated Flow, Road** Paved Kv= 20.3 fps
9.5	301	Total			

Summary for Subcatchment 204: To RGT 2

Runoff = 0.15 cfs @ 12.16 hrs, Volume= 523 cf, Depth> 0.45"
Routed to Reach 2R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 2-Inch Rainfall=2.00"

Area (sf)	CN	Description
5,526	98	Paved parking, HSG A
4,993	39	>75% Grass cover, Good, HSG A
3,529	98	Roofs, HSG A
14,048	77	Weighted Average
4,993		35.54% Pervious Area
9,055		64.46% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.5	50	0.0150	0.13		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.02"
0.2	8	0.0150	0.86		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
1.4	212	0.0150	2.49		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
8.1	270	Total			

Summary for Subcatchment 205: To RGT 3

Runoff = 0.16 cfs @ 12.18 hrs, Volume= 554 cf, Depth> 0.65"
Routed to Reach 1R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 2-Inch Rainfall=2.00"

Area (sf)	CN	Description
5,110	98	Paved parking, HSG A
2,757	39	>75% Grass cover, Good, HSG A
2,424	98	Roofs, HSG A
10,291	82	Weighted Average
2,757		26.79% Pervious Area
7,534		73.21% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
7.6	50	0.0100	0.11		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.02"
1.1	34	0.0050	0.49		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
1.3	162	0.0100	2.03		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
10.0	246	Total			

Summary for Subcatchment 206: To RGT 4

Runoff = 0.17 cfs @ 12.18 hrs, Volume= 587 cf, Depth> 1.03"
Routed to Reach 5R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 2-Inch Rainfall=2.00"

Area (sf)	CN	Description
4,247	98	Paved parking, HSG A
1,083	39	>75% Grass cover, Good, HSG A
1,538	98	Roofs, HSG A
6,868	89	Weighted Average
1,083		15.77% Pervious Area
5,785		84.23% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
9.4	46	0.0050	0.08		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.02"
1.0	145	0.0150	2.49		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
10.4	191	Total			

Summary for Subcatchment 207: To RGT 5

Runoff = 0.13 cfs @ 12.16 hrs, Volume= 453 cf, Depth> 0.45"
Routed to Reach 6R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 2-Inch Rainfall=2.00"

Area (sf)	CN	Description
4,249	98	Paved parking, HSG A
4,395	39	>75% Grass cover, Good, HSG A
3,529	98	Roofs, HSG A
12,173	77	Weighted Average
4,395		36.10% Pervious Area
7,778		63.90% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.7	50	0.0140	0.12		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.02"
0.7	53	0.0290	1.19		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.8	126	0.0150	2.49		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
8.2	229	Total			

Summary for Subcatchment 208: To RGT 6

Runoff = 0.11 cfs @ 12.22 hrs, Volume= 444 cf, Depth> 0.45"
Routed to Reach 7R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 2-Inch Rainfall=2.00"

Area (sf)	CN	Description
5,503	98	Paved parking, HSG A
4,332	39	>75% Grass cover, Good, HSG A
2,122	98	Roofs, HSG A
11,957	77	Weighted Average
4,332		36.23% Pervious Area
7,625		63.77% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
10.1	50	0.0050	0.08		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.02"
1.1	44	0.0090	0.66		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
1.1	57	0.0150	0.86		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
12.3	151	Total			

Summary for Subcatchment 209: To RGT 7

Runoff = 0.02 cfs @ 12.27 hrs, Volume= 237 cf, Depth> 0.15"
Routed to Pond 9R : Head Wall to Infiltration Pond

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 2-Inch Rainfall=2.00"

Area (sf)	CN	Description
6,488	98	Paved parking, HSG A
10,084	39	>75% Grass cover, Good, HSG A
2,016	98	Roofs, HSG A
18,588	66	Weighted Average
10,084		54.25% Pervious Area
8,504		45.75% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.8	50	0.0200	0.14		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.02"
0.3	18	0.0200	0.99		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.2	29	0.0200	2.87		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
1.1	69	0.0230	1.06		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.0	5	0.0100	2.03		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
1.0	60	0.0200	0.99		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.4	66	0.0150	2.49		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
8.8	297	Total			

Summary for Subcatchment 210: To Swale

Runoff = 0.00 cfs @ 16.54 hrs, Volume= 10 cf, Depth> 0.03"
Routed to Reach 6R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 2-Inch Rainfall=2.00"

Area (sf)	CN	Description
1,231	98	Paved parking, HSG A
2,756	39	>75% Grass cover, Good, HSG A
3,987	57	Weighted Average
2,756		69.12% Pervious Area
1,231		30.88% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Summary for Subcatchment 211: To Swale

Runoff = 0.00 cfs @ 12.85 hrs, Volume= 14 cf, Depth> 0.09"
Routed to Reach 5R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 2-Inch Rainfall=2.00"

Area (sf)	CN	Description
727	98	Paved parking, HSG A
1,170	39	>75% Grass cover, Good, HSG A
1,897	62	Weighted Average
1,170		61.68% Pervious Area
727		38.32% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Summary for Subcatchment 212: To Swale

Runoff = 0.00 cfs @ 21.14 hrs, Volume= 7 cf, Depth> 0.02"
Routed to Reach 5R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 2-Inch Rainfall=2.00"

Area (sf)	CN	Description
1,080	98	Paved parking, HSG A
2,681	39	>75% Grass cover, Good, HSG A
3,761	56	Weighted Average
2,681		71.28% Pervious Area
1,080		28.72% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Summary for Subcatchment 213: To Swale

Runoff = 0.00 cfs @ 12.54 hrs, Volume= 25 cf, Depth> 0.12"
Routed to Reach 1R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 2-Inch Rainfall=2.00"

Area (sf)	CN	Description
1,104	98	Paved parking, HSG A
1,467	39	>75% Grass cover, Good, HSG A
2,571	64	Weighted Average
1,467		57.06% Pervious Area
1,104		42.94% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Summary for Subcatchment 214: To Swale

Runoff = 0.00 cfs @ 12.95 hrs, Volume= 18 cf, Depth> 0.07"
Routed to Reach 1R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 2-Inch Rainfall=2.00"

Area (sf)	CN	Description
1,082	98	Paved parking, HSG A
1,880	39	>75% Grass cover, Good, HSG A
2,962	61	Weighted Average
1,880		63.47% Pervious Area
1,082		36.53% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Summary for Subcatchment 215: To Swale

Runoff = 0.00 cfs @ 13.25 hrs, Volume= 10 cf, Depth> 0.06"
Routed to Reach 2R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 2-Inch Rainfall=2.00"

Area (sf)	CN	Description
685	98	Paved parking, HSG A
1,227	39	>75% Grass cover, Good, HSG A
1,912	60	Weighted Average
1,227		64.17% Pervious Area
685		35.83% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Summary for Subcatchment 216: To Swale

[73] Warning: Peak may fall outside time span

Runoff = 0.00 cfs @ 23.06 hrs, Volume= 1 cf, Depth> 0.01"
Routed to Reach 3R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 2-Inch Rainfall=2.00"

Area (sf)	CN	Description
598	39	>75% Grass cover, Good, HSG A
209	98	Paved parking, HSG A
807	54	Weighted Average
598		74.10% Pervious Area
209		25.90% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Summary for Subcatchment 217: To Infiltration Pond

Runoff = 0.24 cfs @ 12.14 hrs, Volume= 792 cf, Depth> 0.38"
Routed to Pond P1 : Infiltration Pond

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 2-Inch Rainfall=2.00"

Area (sf)	CN	Description
9,762	39	>75% Grass cover, Good, HSG A
1,513	98	Paved parking, HSG A
13,731	98	Water Surface, 0% imp, HSG A
25,006	75	Weighted Average
23,493		93.95% Pervious Area
1,513		6.05% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Summary for Subcatchment 218: To Swale

Runoff = 0.00 cfs @ 14.34 hrs, Volume= 11 cf, Depth> 0.05"
Routed to Reach 7R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 2-Inch Rainfall=2.00"

Area (sf)	CN	Description
861	98	Paved parking, HSG A
1,716	39	>75% Grass cover, Good, HSG A
2,577	59	Weighted Average
1,716		66.59% Pervious Area
861		33.41% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Summary for Subcatchment 219: To Wetland

[45] Hint: Runoff=Zero

Runoff = 0.00 cfs @ 0.00 hrs, Volume= 0 cf, Depth= 0.00"
Routed to Link AP1 : Wetlands

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 2-Inch Rainfall=2.00"

Area (sf)	CN	Description
7,467	98	Paved parking, HSG A
113,656	39	>75% Grass cover, Good, HSG A
16,637	32	Woods/grass comb., Good, HSG A
3,293	98	Roofs, HSG A
141,053	43	Weighted Average
130,293		92.37% Pervious Area
10,760		7.63% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
9.6	50	0.1600	0.09		**Sheet Flow,** Woods: Dense underbrush n= 0.800 P2= 3.02"
0.4	41	0.1000	1.58		**Shallow Concentrated Flow,** Woodland Kv= 5.0 fps
11.0	401	0.0075	0.61		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
21.0	492	Total			

Summary for Reach 1R: Swale

Inflow Area = 15,824 sf, 61.43% Impervious, Inflow Depth > 0.45" for 2-Inch event
Inflow = 0.16 cfs @ 12.18 hrs, Volume= 598 cf
Outflow = 0.15 cfs @ 12.21 hrs, Volume= 595 cf, Atten= 5%, Lag= 1.8 min
Routed to Reach 2R : Swale

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 1.03 fps, Min. Travel Time= 2.8 min
Avg. Velocity = 0.40 fps, Avg. Travel Time= 7.3 min

Peak Storage= 26 cf @ 12.21 hrs
Average Depth at Peak Storage= 0.09' , Surface Width= 1.93'
Bank-Full Depth= 1.50' Flow Area= 7.9 sf, Capacity= 40.09 cfs

1.50' x 1.50' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 2.5 '/' Top Width= 9.00'
Length= 175.0' Slope= 0.0137 '/'
Inlet Invert= 254.40', Outlet Invert= 252.00'

Summary for Reach 2R: Swale

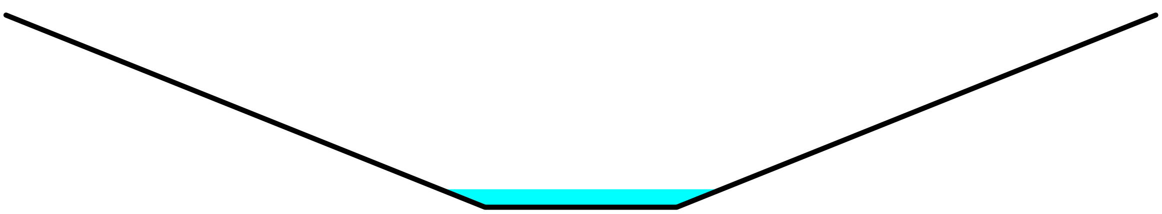
[62] Hint: Exceeded Reach 1R OUTLET depth by 0.05' @ 12.19 hrs

Inflow Area = 31,784 sf, 61.23% Impervious, Inflow Depth > 0.43" for 2-Inch event
Inflow = 0.29 cfs @ 12.18 hrs, Volume= 1,128 cf
Outflow = 0.28 cfs @ 12.20 hrs, Volume= 1,125 cf, Atten= 2%, Lag= 1.3 min
Routed to Reach 3R : Swale

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 1.09 fps, Min. Travel Time= 1.8 min
Avg. Velocity = 0.42 fps, Avg. Travel Time= 4.6 min

Peak Storage= 30 cf @ 12.20 hrs
Average Depth at Peak Storage= 0.14' , Surface Width= 2.20'
Bank-Full Depth= 1.50' Flow Area= 7.9 sf, Capacity= 31.92 cfs

1.50' x 1.50' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 2.5 '/' Top Width= 9.00'
Length= 115.0' Slope= 0.0087 '/'
Inlet Invert= 252.00', Outlet Invert= 251.00'



Summary for Reach 3R: Swale

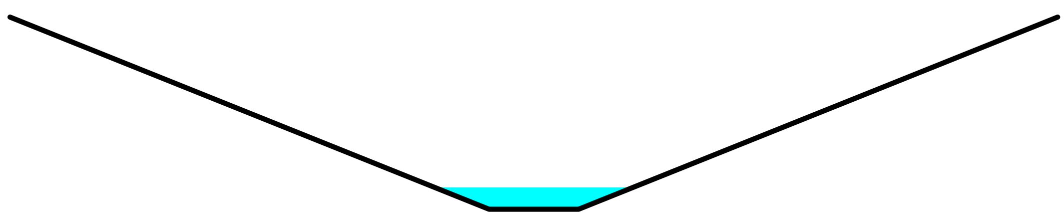
[62] Hint: Exceeded Reach 2R OUTLET depth by 0.03' @ 12.17 hrs

Inflow Area = 47,184 sf, 61.08% Impervious, Inflow Depth > 0.41" for 2-Inch event
Inflow = 0.41 cfs @ 12.20 hrs, Volume= 1,627 cf
Outflow = 0.41 cfs @ 12.20 hrs, Volume= 1,626 cf, Atten= 0%, Lag= 0.2 min
Routed to Pond 4R : Pipe to Infiltration Pond

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 2.12 fps, Min. Travel Time= 0.3 min
Avg. Velocity = 0.88 fps, Avg. Travel Time= 0.6 min

Peak Storage= 6 cf @ 12.20 hrs
Average Depth at Peak Storage= 0.17' , Surface Width= 1.56'
Bank-Full Depth= 1.50' Flow Area= 6.7 sf, Capacity= 48.70 cfs

0.70' x 1.50' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 2.5 '/' Top Width= 8.20'
Length= 32.0' Slope= 0.0313 '/'
Inlet Invert= 251.00', Outlet Invert= 250.00'



Summary for Reach 5R: Swale

Inflow Area = 12,526 sf, 60.61% Impervious, Inflow Depth > 0.58" for 2-Inch event
Inflow = 0.17 cfs @ 12.18 hrs, Volume= 607 cf
Outflow = 0.17 cfs @ 12.21 hrs, Volume= 606 cf, Atten= 4%, Lag= 1.5 min
Routed to Reach 6R : Swale

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 0.99 fps, Min. Travel Time= 2.5 min
Avg. Velocity = 0.36 fps, Avg. Travel Time= 6.8 min

Peak Storage= 24 cf @ 12.21 hrs
Average Depth at Peak Storage= 0.10' , Surface Width= 1.98'
Bank-Full Depth= 1.50' Flow Area= 7.9 sf, Capacity= 35.84 cfs

1.50' x 1.50' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 2.5 '/' Top Width= 9.00'
Length= 146.0' Slope= 0.0110 '/'
Inlet Invert= 255.00', Outlet Invert= 253.40'

Summary for Reach 6R: Swale

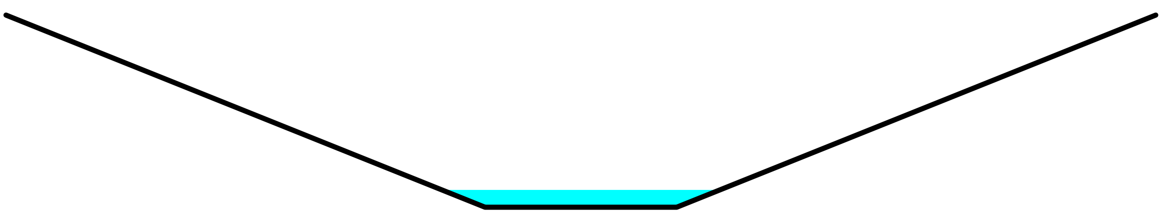
[62] Hint: Exceeded Reach 5R OUTLET depth by 0.04' @ 12.22 hrs

Inflow Area = 28,686 sf, 57.87% Impervious, Inflow Depth > 0.45" for 2-Inch event
Inflow = 0.29 cfs @ 12.18 hrs, Volume= 1,069 cf
Outflow = 0.28 cfs @ 12.21 hrs, Volume= 1,065 cf, Atten= 4%, Lag= 1.6 min
Routed to Reach 7R : Swale

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 1.11 fps, Min. Travel Time= 2.3 min
Avg. Velocity = 0.39 fps, Avg. Travel Time= 6.5 min

Peak Storage= 38 cf @ 12.21 hrs
Average Depth at Peak Storage= 0.14' , Surface Width= 2.18'
Bank-Full Depth= 1.50' Flow Area= 7.9 sf, Capacity= 32.96 cfs

1.50' x 1.50' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 2.5 '/' Top Width= 9.00'
Length= 151.0' Slope= 0.0093 '/'
Inlet Invert= 253.40', Outlet Invert= 252.00'



Summary for Reach 7R: Swale

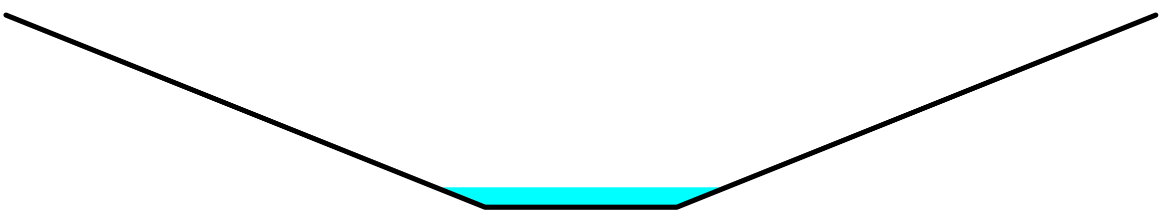
[62] Hint: Exceeded Reach 6R OUTLET depth by 0.03' @ 12.30 hrs

Inflow Area = 43,220 sf, 58.04% Impervious, Inflow Depth > 0.42" for 2-Inch event
Inflow = 0.38 cfs @ 12.21 hrs, Volume= 1,520 cf
Outflow = 0.38 cfs @ 12.23 hrs, Volume= 1,516 cf, Atten= 2%, Lag= 1.3 min
Routed to Pond 9R : Head Wall to Infiltration Pond

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 1.28 fps, Min. Travel Time= 1.8 min
Avg. Velocity = 0.46 fps, Avg. Travel Time= 5.1 min

Peak Storage= 41 cf @ 12.23 hrs
Average Depth at Peak Storage= 0.15' , Surface Width= 2.27'
Bank-Full Depth= 1.50' Flow Area= 7.9 sf, Capacity= 35.44 cfs

1.50' x 1.50' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 2.5 '/' Top Width= 9.00'
Length= 140.0' Slope= 0.0107 '/'
Inlet Invert= 252.00', Outlet Invert= 250.50'



Summary for Reach 8R: Foxhole 1

[52] Hint: Inlet/Outlet conditions not evaluated

Inflow Area = 8,236 sf, 77.20% Impervious, Inflow Depth > 0.79" for 2-Inch event
Inflow = 0.19 cfs @ 12.13 hrs, Volume= 545 cf
Outflow = 0.19 cfs @ 12.14 hrs, Volume= 545 cf, Atten= 0%, Lag= 0.1 min
Routed to Pond P1 : Infiltration Pond

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 2.82 fps, Min. Travel Time= 0.1 min
Avg. Velocity = 0.81 fps, Avg. Travel Time= 0.3 min

Peak Storage= 1 cf @ 12.14 hrs
Average Depth at Peak Storage= 0.04' , Surface Width= 1.83'
Bank-Full Depth= 0.38' Flow Area= 0.7 sf, Capacity= 5.21 cfs

22.0" W x 4.5" H Box Pipe
n= 0.013 Concrete, trowel finish
Length= 14.3' Slope= 0.0524 '/'
Inlet Invert= 253.28', Outlet Invert= 252.53'

Summary for Reach 10R: Foxhole 2

[52] Hint: Inlet/Outlet conditions not evaluated

Inflow Area = 9,659 sf, 79.19% Impervious, Inflow Depth > 0.85" for 2-Inch event
Inflow = 0.24 cfs @ 12.13 hrs, Volume= 682 cf
Outflow = 0.24 cfs @ 12.13 hrs, Volume= 682 cf, Atten= 0%, Lag= 0.0 min
Routed to Pond P1 : Infiltration Pond

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 3.63 fps, Min. Travel Time= 0.0 min
Avg. Velocity = 1.04 fps, Avg. Travel Time= 0.1 min

Peak Storage= 1 cf @ 12.13 hrs
Average Depth at Peak Storage= 0.04' , Surface Width= 1.83'
Bank-Full Depth= 0.38' Flow Area= 0.7 sf, Capacity= 6.80 cfs

22.0" W x 4.5" H Box Pipe
n= 0.013 Concrete, trowel finish
Length= 8.4' Slope= 0.0893 '/'
Inlet Invert= 251.90', Outlet Invert= 251.15'

Summary for Pond 4R: Pipe to Infiltration Pond

[62] Hint: Exceeded Reach 3R OUTLET depth by 0.08' @ 12.22 hrs

Inflow Area = 47,184 sf, 61.08% Impervious, Inflow Depth > 0.41" for 2-Inch event
Inflow = 0.41 cfs @ 12.20 hrs, Volume= 1,626 cf
Outflow = 0.41 cfs @ 12.20 hrs, Volume= 1,625 cf, Atten= 0%, Lag= 0.3 min
Primary = 0.41 cfs @ 12.20 hrs, Volume= 1,625 cf
Routed to Pond P1 : Infiltration Pond

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Peak Elev= 250.25' @ 12.20 hrs Surf.Area= 62 sf Storage= 11 cf

Plug-Flow detention time= 0.9 min calculated for 1,624 cf (100% of inflow)
Center-of-Mass det. time= 0.5 min (901.8 - 901.2)

Volume	Invert	Avail.Storage	Storage Description
#1	250.00'	620 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
250.00	22	0	0
251.00	181	102	102
252.00	855	518	620

Device	Routing	Invert	Outlet Devices
#1	Primary	250.00'	**12.0" Round Culvert X 2.00** L= 55.0' Ke= 0.500 Inlet / Outlet Invert= 250.00' / 249.72' S= 0.0051 '/' Cc= 0.900 n= 0.012 Corrugated PP, smooth interior, Flow Area= 0.79 sf

Primary OutFlow Max=0.41 cfs @ 12.20 hrs HW=250.25' TW=249.51' (Dynamic Tailwater)
↑—**1=Culvert** (Barrel Controls 0.41 cfs @ 1.98 fps)

Summary for Pond 9R: Head Wall to Infiltration Pond

[62] Hint: Exceeded Reach 7R OUTLET depth by 0.07' @ 12.30 hrs

Inflow Area = 61,808 sf, 54.35% Impervious, Inflow Depth > 0.34" for 2-Inch event
Inflow = 0.40 cfs @ 12.23 hrs, Volume= 1,753 cf
Outflow = 0.39 cfs @ 12.25 hrs, Volume= 1,747 cf, Atten= 1%, Lag= 0.9 min
Primary = 0.39 cfs @ 12.25 hrs, Volume= 1,747 cf
Routed to Pond P1 : Infiltration Pond

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Peak Elev= 250.72' @ 12.25 hrs Surf.Area= 179 sf Storage= 33 cf

Plug-Flow detention time= 3.8 min calculated for 1,747 cf (100% of inflow)
Center-of-Mass det. time= 2.1 min (904.0 - 901.9)

Volume	Invert	Avail.Storage	Storage Description
#1	250.50'	288 cf	**Custom Stage Data (Irregular)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Perim. (feet)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)	Wet.Area (sq-ft)
250.50	121	75.8	0	0	121
251.00	269	116.2	95	95	740
251.50	517	131.6	193	288	1,050

Device	Routing	Invert	Outlet Devices
#1	Primary	250.50'	**15.0" Round Culvert X 2.00** L= 29.8' RCP, groove end w/headwall, Ke= 0.200 Inlet / Outlet Invert= 250.50' / 250.00' S= 0.0168 '/' Cc= 0.900 n= 0.020 Corrugated PE, corrugated interior, Flow Area= 1.23 sf

Primary OutFlow Max=0.39 cfs @ 12.25 hrs HW=250.72' TW=249.51' (Dynamic Tailwater)
↑—**1=Culvert** (Barrel Controls 0.39 cfs @ 2.06 fps)

Summary for Pond P1: Infiltration Pond

Inflow Area = 151,893 sf, 51.31% Impervious, Inflow Depth > 0.43" for 2-Inch event
Inflow = 1.24 cfs @ 12.17 hrs, Volume= 5,391 cf
Outflow = 1.23 cfs @ 12.18 hrs, Volume= 5,388 cf, Atten= 1%, Lag= 1.0 min
Discarded = 1.23 cfs @ 12.18 hrs, Volume= 5,388 cf
Primary = 0.00 cfs @ 0.00 hrs, Volume= 0 cf
Routed to Link AP1 : Wetlands

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Peak Elev= 249.51' @ 12.18 hrs Surf.Area= 10,439 sf Storage= 64 cf

Plug-Flow detention time= 0.9 min calculated for 5,386 cf (100% of inflow)
Center-of-Mass det. time= 0.7 min (894.1 - 893.5)

Volume	Invert	Avail.Storage	Storage Description
#1	249.50'	28,409 cf	**Custom Stage Data (Irregular)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Perim. (feet)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)	Wet.Area (sq-ft)
249.50	10,423	450.6	0	0	10,423
250.00	11,803	469.4	5,553	5,553	11,818
251.00	13,731	494.5	12,755	18,308	13,803
251.70	15,140	512.1	10,101	28,409	15,256

Device	Routing	Invert	Outlet Devices
#1	Primary	250.70'	**10.0' long x 19.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63
#2	Discarded	249.50'	**8.270 in/hr Exfiltration over Surface area** Conductivity to Groundwater Elevation = 247.00' Phase-In= 0.01'

Discarded OutFlow Max=1.23 cfs @ 12.18 hrs HW=249.51' (Free Discharge)
└─**2=Exfiltration** (Controls 1.23 cfs)

Primary OutFlow Max=0.00 cfs @ 0.00 hrs HW=249.50' TW=0.00' (Dynamic Tailwater)
└─**1=Broad-Crested Rectangular Weir** (Controls 0.00 cfs)

Summary for Link AP1: Wetlands

Inflow Area = 292,946 sf, 30.27% Impervious, Inflow Depth = 0.00" for 2-Inch event
Inflow = 0.00 cfs @ 0.00 hrs, Volume= 0 cf
Primary = 0.00 cfs @ 0.00 hrs, Volume= 0 cf, Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs

Time span=0.00-24.00 hrs, dt=0.01 hrs, 2401 points x 3
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Dyn-Stor-Ind method - Pond routing by Dyn-Stor-Ind method

Subcatchment201: To Foxhole 1 Runoff Area=8,236 sf 77.20% Impervious Runoff Depth>1.60"
Tc=6.0 min CN=85 Runoff=0.39 cfs 1,100 cf

Subcatchment202: To Foxhole 2 Runoff Area=9,659 sf 79.19% Impervious Runoff Depth>1.68"
Tc=6.0 min CN=86 Runoff=0.47 cfs 1,350 cf

Subcatchment203: To RGT 1 Runoff Area=14,593 sf 62.69% Impervious Runoff Depth>1.03"
Flow Length=301' Tc=9.5 min CN=76 Runoff=0.37 cfs 1,247 cf

Subcatchment204: To RGT 2 Runoff Area=14,048 sf 64.46% Impervious Runoff Depth>1.08"
Flow Length=270' Slope=0.0150 '/' Tc=8.1 min CN=77 Runoff=0.40 cfs 1,267 cf

Subcatchment205: To RGT 3 Runoff Area=10,291 sf 73.21% Impervious Runoff Depth>1.39"
Flow Length=246' Tc=10.0 min CN=82 Runoff=0.36 cfs 1,193 cf

Subcatchment206: To RGT 4 Runoff Area=6,868 sf 84.23% Impervious Runoff Depth>1.91"
Flow Length=191' Tc=10.4 min CN=89 Runoff=0.32 cfs 1,095 cf

Subcatchment207: To RGT 5 Runoff Area=12,173 sf 63.90% Impervious Runoff Depth>1.08"
Flow Length=229' Tc=8.2 min CN=77 Runoff=0.35 cfs 1,098 cf

Subcatchment208: To RGT 6 Runoff Area=11,957 sf 63.77% Impervious Runoff Depth>1.08"
Flow Length=151' Tc=12.3 min CN=77 Runoff=0.29 cfs 1,077 cf

Subcatchment209: To RGT 7 Runoff Area=18,588 sf 45.75% Impervious Runoff Depth>0.55"
Flow Length=297' Tc=8.8 min CN=66 Runoff=0.22 cfs 855 cf

Subcatchment210: To Swale Runoff Area=3,987 sf 30.88% Impervious Runoff Depth>0.25"
Tc=6.0 min CN=57 Runoff=0.01 cfs 83 cf

Subcatchment211: To Swale Runoff Area=1,897 sf 38.32% Impervious Runoff Depth>0.41"
Tc=6.0 min CN=62 Runoff=0.02 cfs 64 cf

Subcatchment212: To Swale Runoff Area=3,761 sf 28.72% Impervious Runoff Depth>0.22"
Tc=6.0 min CN=56 Runoff=0.01 cfs 70 cf

Subcatchment213: To Swale Runoff Area=2,571 sf 42.94% Impervious Runoff Depth>0.48"
Tc=6.0 min CN=64 Runoff=0.03 cfs 102 cf

Subcatchment214: To Swale Runoff Area=2,962 sf 36.53% Impervious Runoff Depth>0.37"
Tc=6.0 min CN=61 Runoff=0.02 cfs 92 cf

Subcatchment215: To Swale Runoff Area=1,912 sf 35.83% Impervious Runoff Depth>0.34"
Tc=6.0 min CN=60 Runoff=0.01 cfs 54 cf

Subcatchment216: To Swale Runoff Area=807 sf 25.90% Impervious Runoff Depth>0.18"
Tc=6.0 min CN=54 Runoff=0.00 cfs 12 cf

Subcatchment217: To Infiltration Pond Runoff Area=25,006 sf 6.05% Impervious Runoff Depth>0.97"
Tc=6.0 min CN=75 Runoff=0.69 cfs 2,025 cf

Subcatchment218: To Swale Runoff Area=2,577 sf 33.41% Impervious Runoff Depth>0.31"
Tc=6.0 min CN=59 Runoff=0.01 cfs 66 cf

Subcatchment219: To Wetland Runoff Area=141,053 sf 7.63% Impervious Runoff Depth>0.01"
Flow Length=492' Tc=21.0 min CN=43 Runoff=0.01 cfs 111 cf

Reach 1R: Swale Avg. Flow Depth=0.15' Max Vel=1.41 fps Inflow=0.40 cfs 1,386 cf
n=0.030 L=175.0' S=0.0137 '/' Capacity=40.09 cfs Outflow=0.39 cfs 1,382 cf

Reach 2R: Swale Avg. Flow Depth=0.24' Max Vel=1.49 fps Inflow=0.78 cfs 2,703 cf
n=0.030 L=115.0' S=0.0087 '/' Capacity=31.92 cfs Outflow=0.77 cfs 2,699 cf

Reach 3R: Swale Avg. Flow Depth=0.29' Max Vel=2.80 fps Inflow=1.13 cfs 3,957 cf
n=0.030 L=32.0' S=0.0313 '/' Capacity=48.70 cfs Outflow=1.13 cfs 3,956 cf

Reach 5R: Swale Avg. Flow Depth=0.14' Max Vel=1.24 fps Inflow=0.34 cfs 1,229 cf
n=0.030 L=146.0' S=0.0110 '/' Capacity=35.84 cfs Outflow=0.33 cfs 1,226 cf

Reach 6R: Swale Avg. Flow Depth=0.22' Max Vel=1.45 fps Inflow=0.67 cfs 2,408 cf
n=0.030 L=151.0' S=0.0093 '/' Capacity=32.96 cfs Outflow=0.65 cfs 2,402 cf

Reach 7R: Swale Avg. Flow Depth=0.26' Max Vel=1.70 fps Inflow=0.95 cfs 3,545 cf
n=0.030 L=140.0' S=0.0107 '/' Capacity=35.44 cfs Outflow=0.94 cfs 3,539 cf

Reach 8R: Foxhole 1 Avg. Flow Depth=0.06' Max Vel=3.71 fps Inflow=0.39 cfs 1,100 cf
22.0" x 4.5" Box Pipe n=0.013 L=14.3' S=0.0524 '/' Capacity=5.21 cfs Outflow=0.39 cfs 1,100 cf

Reach 10R: Foxhole 2 Avg. Flow Depth=0.05' Max Vel=4.72 fps Inflow=0.47 cfs 1,350 cf
22.0" x 4.5" Box Pipe n=0.013 L=8.4' S=0.0893 '/' Capacity=6.80 cfs Outflow=0.47 cfs 1,350 cf

Pond 4R: Pipe to Infiltration Pond Peak Elev=250.43' Storage=24 cf Inflow=1.13 cfs 3,956 cf
12.0" Round Culvert x 2.00 n=0.012 L=55.0' S=0.0051 '/' Outflow=1.13 cfs 3,955 cf

Pond 9R: Head Wall to Infiltration Pond Peak Elev=250.87' Storage=64 cf Inflow=1.14 cfs 4,394 cf
15.0" Round Culvert x 2.00 n=0.020 L=29.8' S=0.0168 '/' Outflow=1.13 cfs 4,386 cf

Pond P1: Infiltration Pond Peak Elev=249.58' Storage=802 cf Inflow=3.44 cfs 12,816 cf
Discarded=2.10 cfs 12,812 cf Primary=0.00 cfs 0 cf Outflow=2.10 cfs 12,812 cf

Link AP1: Wetlands Inflow=0.01 cfs 111 cf
Primary=0.01 cfs 111 cf

Total Runoff Area = 292,946 sf Runoff Volume = 12,961 cf Average Runoff Depth = 0.53"
69.73% Pervious = 204,257 sf 30.27% Impervious = 88,689 sf

Summary for Subcatchment 201: To Foxhole 1

Runoff = 0.39 cfs @ 12.13 hrs, Volume= 1,100 cf, Depth> 1.60"
Routed to Reach 8R : Foxhole 1

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 2-Year Rainfall=3.02"

Area (sf)	CN	Description
6,358	98	Paved parking, HSG A
1,878	39	>75% Grass cover, Good, HSG A
8,236	85	Weighted Average
1,878		22.80% Pervious Area
6,358		77.20% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Summary for Subcatchment 202: To Foxhole 2

Runoff = 0.47 cfs @ 12.13 hrs, Volume= 1,350 cf, Depth> 1.68"
Routed to Reach 10R : Foxhole 2

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 2-Year Rainfall=3.02"

Area (sf)	CN	Description
7,031	98	Paved parking, HSG A
2,010	39	>75% Grass cover, Good, HSG A
618	98	Roofs, HSG A
9,659	86	Weighted Average
2,010		20.81% Pervious Area
7,649		79.19% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Summary for Subcatchment 203: To RGT 1

Runoff = 0.37 cfs @ 12.17 hrs, Volume= 1,247 cf, Depth> 1.03"
Routed to Reach 3R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 2-Year Rainfall=3.02"

Area (sf)	CN	Description
5,212	98	Paved parking, HSG A
5,444	39	>75% Grass cover, Good, HSG A
3,937	98	Roofs, HSG A
14,593	76	Weighted Average
5,444		37.31% Pervious Area
9,149		62.69% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.3	17	0.0190	0.92		**Sheet Flow, Sidewalk** Smooth surfaces n= 0.011 P2= 3.02"
6.6	70	0.0280	0.18		**Sheet Flow, Grass** Grass: Short n= 0.150 P2= 3.02"
0.1	8	0.0100	2.03		**Shallow Concentrated Flow, Sidewalk** Paved Kv= 20.3 fps
1.5	90	0.0200	0.99		**Shallow Concentrated Flow, Grass** Short Grass Pasture Kv= 7.0 fps
1.0	116	0.0100	2.03		**Shallow Concentrated Flow, Road** Paved Kv= 20.3 fps
9.5	301	Total			

Summary for Subcatchment 204: To RGT 2

Runoff = 0.40 cfs @ 12.16 hrs, Volume= 1,267 cf, Depth> 1.08"
Routed to Reach 2R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 2-Year Rainfall=3.02"

Area (sf)	CN	Description
5,526	98	Paved parking, HSG A
4,993	39	>75% Grass cover, Good, HSG A
3,529	98	Roofs, HSG A
14,048	77	Weighted Average
4,993		35.54% Pervious Area
9,055		64.46% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.5	50	0.0150	0.13		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.02"
0.2	8	0.0150	0.86		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
1.4	212	0.0150	2.49		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
8.1	270	Total			

Summary for Subcatchment 205: To RGT 3

Runoff = 0.36 cfs @ 12.18 hrs, Volume= 1,193 cf, Depth> 1.39"
Routed to Reach 1R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 2-Year Rainfall=3.02"

Area (sf)	CN	Description
5,110	98	Paved parking, HSG A
2,757	39	>75% Grass cover, Good, HSG A
2,424	98	Roofs, HSG A
10,291	82	Weighted Average
2,757		26.79% Pervious Area
7,534		73.21% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
7.6	50	0.0100	0.11		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.02"
1.1	34	0.0050	0.49		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
1.3	162	0.0100	2.03		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
10.0	246	Total			

Summary for Subcatchment 206: To RGT 4

Runoff = 0.32 cfs @ 12.18 hrs, Volume= 1,095 cf, Depth> 1.91"
Routed to Reach 5R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 2-Year Rainfall=3.02"

Area (sf)	CN	Description
4,247	98	Paved parking, HSG A
1,083	39	>75% Grass cover, Good, HSG A
1,538	98	Roofs, HSG A
6,868	89	Weighted Average
1,083		15.77% Pervious Area
5,785		84.23% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
9.4	46	0.0050	0.08		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.02"
1.0	145	0.0150	2.49		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
10.4	191	Total			

Summary for Subcatchment 207: To RGT 5

Runoff = 0.35 cfs @ 12.16 hrs, Volume= 1,098 cf, Depth> 1.08"
Routed to Reach 6R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 2-Year Rainfall=3.02"

Area (sf)	CN	Description
4,249	98	Paved parking, HSG A
4,395	39	>75% Grass cover, Good, HSG A
3,529	98	Roofs, HSG A
12,173	77	Weighted Average
4,395		36.10% Pervious Area
7,778		63.90% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.7	50	0.0140	0.12		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.02"
0.7	53	0.0290	1.19		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.8	126	0.0150	2.49		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
8.2	229	Total			

Summary for Subcatchment 208: To RGT 6

Runoff = 0.29 cfs @ 12.21 hrs, Volume= 1,077 cf, Depth> 1.08"
Routed to Reach 7R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 2-Year Rainfall=3.02"

Area (sf)	CN	Description
5,503	98	Paved parking, HSG A
4,332	39	>75% Grass cover, Good, HSG A
2,122	98	Roofs, HSG A
11,957	77	Weighted Average
4,332		36.23% Pervious Area
7,625		63.77% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
10.1	50	0.0050	0.08		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.02"
1.1	44	0.0090	0.66		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
1.1	57	0.0150	0.86		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
12.3	151	Total			

Summary for Subcatchment 209: To RGT 7

Runoff = 0.22 cfs @ 12.17 hrs, Volume= 855 cf, Depth> 0.55"
Routed to Pond 9R : Head Wall to Infiltration Pond

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 2-Year Rainfall=3.02"

Area (sf)	CN	Description
6,488	98	Paved parking, HSG A
10,084	39	>75% Grass cover, Good, HSG A
2,016	98	Roofs, HSG A
18,588	66	Weighted Average
10,084		54.25% Pervious Area
8,504		45.75% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.8	50	0.0200	0.14		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.02"
0.3	18	0.0200	0.99		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.2	29	0.0200	2.87		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
1.1	69	0.0230	1.06		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.0	5	0.0100	2.03		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
1.0	60	0.0200	0.99		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.4	66	0.0150	2.49		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
8.8	297	Total			

Summary for Subcatchment 210: To Swale

Runoff = 0.01 cfs @ 12.17 hrs, Volume= 83 cf, Depth> 0.25"
Routed to Reach 6R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 2-Year Rainfall=3.02"

Area (sf)	CN	Description
1,231	98	Paved parking, HSG A
2,756	39	>75% Grass cover, Good, HSG A
3,987	57	Weighted Average
2,756		69.12% Pervious Area
1,231		30.88% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Summary for Subcatchment 211: To Swale

Runoff = 0.02 cfs @ 12.15 hrs, Volume= 64 cf, Depth> 0.41"
Routed to Reach 5R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 2-Year Rainfall=3.02"

Area (sf)	CN	Description
727	98	Paved parking, HSG A
1,170	39	>75% Grass cover, Good, HSG A
1,897	62	Weighted Average
1,170		61.68% Pervious Area
727		38.32% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Summary for Subcatchment 212: To Swale

Runoff = 0.01 cfs @ 12.18 hrs, Volume= 70 cf, Depth> 0.22"
Routed to Reach 5R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 2-Year Rainfall=3.02"

Area (sf)	CN	Description
1,080	98	Paved parking, HSG A
2,681	39	>75% Grass cover, Good, HSG A
3,761	56	Weighted Average
2,681		71.28% Pervious Area
1,080		28.72% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Summary for Subcatchment 213: To Swale

Runoff = 0.03 cfs @ 12.14 hrs, Volume= 102 cf, Depth> 0.48"
Routed to Reach 1R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 2-Year Rainfall=3.02"

Area (sf)	CN	Description
1,104	98	Paved parking, HSG A
1,467	39	>75% Grass cover, Good, HSG A
2,571	64	Weighted Average
1,467		57.06% Pervious Area
1,104		42.94% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Summary for Subcatchment 214: To Swale

Runoff = 0.02 cfs @ 12.15 hrs, Volume= 92 cf, Depth> 0.37"
Routed to Reach 1R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 2-Year Rainfall=3.02"

Area (sf)	CN	Description
1,082	98	Paved parking, HSG A
1,880	39	>75% Grass cover, Good, HSG A
2,962	61	Weighted Average
1,880		63.47% Pervious Area
1,082		36.53% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Summary for Subcatchment 215: To Swale

Runoff = 0.01 cfs @ 12.15 hrs, Volume= 54 cf, Depth> 0.34"
Routed to Reach 2R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 2-Year Rainfall=3.02"

Area (sf)	CN	Description
685	98	Paved parking, HSG A
1,227	39	>75% Grass cover, Good, HSG A
1,912	60	Weighted Average
1,227		64.17% Pervious Area
685		35.83% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Summary for Subcatchment 216: To Swale

Runoff = 0.00 cfs @ 12.54 hrs, Volume= 12 cf, Depth> 0.18"
Routed to Reach 3R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 2-Year Rainfall=3.02"

Area (sf)	CN	Description
598	39	>75% Grass cover, Good, HSG A
209	98	Paved parking, HSG A
807	54	Weighted Average
598		74.10% Pervious Area
209		25.90% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Summary for Subcatchment 217: To Infiltration Pond

Runoff = 0.69 cfs @ 12.14 hrs, Volume= 2,025 cf, Depth> 0.97"
Routed to Pond P1 : Infiltration Pond

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 2-Year Rainfall=3.02"

Area (sf)	CN	Description
9,762	39	>75% Grass cover, Good, HSG A
1,513	98	Paved parking, HSG A
13,731	98	Water Surface, 0% imp, HSG A
25,006	75	Weighted Average
23,493		93.95% Pervious Area
1,513		6.05% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Summary for Subcatchment 218: To Swale

Runoff = 0.01 cfs @ 12.16 hrs, Volume= 66 cf, Depth> 0.31"
Routed to Reach 7R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 2-Year Rainfall=3.02"

Area (sf)	CN	Description
861	98	Paved parking, HSG A
1,716	39	>75% Grass cover, Good, HSG A
2,577	59	Weighted Average
1,716		66.59% Pervious Area
861		33.41% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Summary for Subcatchment 219: To Wetland

[73] Warning: Peak may fall outside time span

Runoff = 0.01 cfs @ 23.73 hrs, Volume= 111 cf, Depth> 0.01"
Routed to Link AP1 : Wetlands

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 2-Year Rainfall=3.02"

Area (sf)	CN	Description
7,467	98	Paved parking, HSG A
113,656	39	>75% Grass cover, Good, HSG A
16,637	32	Woods/grass comb., Good, HSG A
3,293	98	Roofs, HSG A
141,053	43	Weighted Average
130,293		92.37% Pervious Area
10,760		7.63% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
9.6	50	0.1600	0.09		**Sheet Flow,** Woods: Dense underbrush n= 0.800 P2= 3.02"
0.4	41	0.1000	1.58		**Shallow Concentrated Flow,** Woodland Kv= 5.0 fps
11.0	401	0.0075	0.61		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
21.0	492	Total			

Summary for Reach 1R: Swale

Inflow Area = 15,824 sf, 61.43% Impervious, Inflow Depth > 1.05" for 2-Year event
Inflow = 0.40 cfs @ 12.17 hrs, Volume= 1,386 cf
Outflow = 0.39 cfs @ 12.19 hrs, Volume= 1,382 cf, Atten= 3%, Lag= 1.4 min
Routed to Reach 2R : Swale

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 1.41 fps, Min. Travel Time= 2.1 min
Avg. Velocity = 0.48 fps, Avg. Travel Time= 6.0 min

Peak Storage= 48 cf @ 12.19 hrs
Average Depth at Peak Storage= 0.15' , Surface Width= 2.23'
Bank-Full Depth= 1.50' Flow Area= 7.9 sf, Capacity= 40.09 cfs

1.50' x 1.50' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 2.5 '/' Top Width= 9.00'
Length= 175.0' Slope= 0.0137 '/'
Inlet Invert= 254.40', Outlet Invert= 252.00'

Summary for Reach 2R: Swale

[62] Hint: Exceeded Reach 1R OUTLET depth by 0.10' @ 12.18 hrs

Inflow Area = 31,784 sf, 61.23% Impervious, Inflow Depth > 1.02" for 2-Year event
Inflow = 0.78 cfs @ 12.17 hrs, Volume= 2,703 cf
Outflow = 0.77 cfs @ 12.19 hrs, Volume= 2,699 cf, Atten= 2%, Lag= 0.9 min
Routed to Reach 3R : Swale

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 1.49 fps, Min. Travel Time= 1.3 min
Avg. Velocity = 0.52 fps, Avg. Travel Time= 3.7 min

Peak Storage= 59 cf @ 12.19 hrs
Average Depth at Peak Storage= 0.24' , Surface Width= 2.72'
Bank-Full Depth= 1.50' Flow Area= 7.9 sf, Capacity= 31.92 cfs

1.50' x 1.50' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 2.5 '/' Top Width= 9.00'
Length= 115.0' Slope= 0.0087 '/'
Inlet Invert= 252.00', Outlet Invert= 251.00'

Summary for Reach 3R: Swale

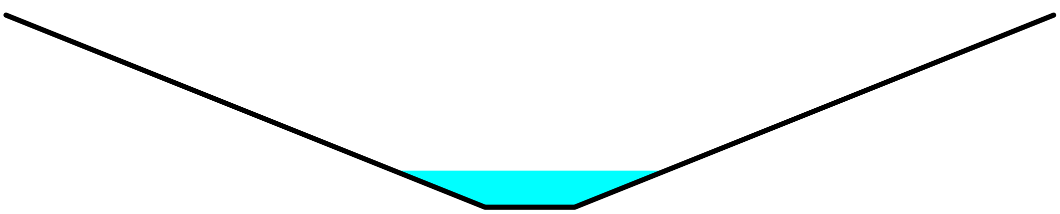
[62] Hint: Exceeded Reach 2R OUTLET depth by 0.04' @ 12.16 hrs

Inflow Area = 47,184 sf, 61.08% Impervious, Inflow Depth > 1.01" for 2-Year event
Inflow = 1.13 cfs @ 12.18 hrs, Volume= 3,957 cf
Outflow = 1.13 cfs @ 12.18 hrs, Volume= 3,956 cf, Atten= 0%, Lag= 0.1 min
Routed to Pond 4R : Pipe to Infiltration Pond

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 2.80 fps, Min. Travel Time= 0.2 min
Avg. Velocity = 1.08 fps, Avg. Travel Time= 0.5 min

Peak Storage= 13 cf @ 12.18 hrs
Average Depth at Peak Storage= 0.29' , Surface Width= 2.13'
Bank-Full Depth= 1.50' Flow Area= 6.7 sf, Capacity= 48.70 cfs

0.70' x 1.50' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 2.5 '/' Top Width= 8.20'
Length= 32.0' Slope= 0.0313 '/'
Inlet Invert= 251.00', Outlet Invert= 250.00'



Summary for Reach 5R: Swale

Inflow Area = 12,526 sf, 60.61% Impervious, Inflow Depth > 1.18" for 2-Year event
Inflow = 0.34 cfs @ 12.18 hrs, Volume= 1,229 cf
Outflow = 0.33 cfs @ 12.20 hrs, Volume= 1,226 cf, Atten= 3%, Lag= 1.3 min
Routed to Reach 6R : Swale

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 1.24 fps, Min. Travel Time= 2.0 min
Avg. Velocity = 0.41 fps, Avg. Travel Time= 6.0 min

Peak Storage= 39 cf @ 12.20 hrs
Average Depth at Peak Storage= 0.14' , Surface Width= 2.21'
Bank-Full Depth= 1.50' Flow Area= 7.9 sf, Capacity= 35.84 cfs

1.50' x 1.50' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 2.5 '/' Top Width= 9.00'
Length= 146.0' Slope= 0.0110 '/'
Inlet Invert= 255.00', Outlet Invert= 253.40'

Summary for Reach 6R: Swale

[62] Hint: Exceeded Reach 5R OUTLET depth by 0.08' @ 12.19 hrs

Inflow Area = 28,686 sf, 57.87% Impervious, Inflow Depth > 1.01" for 2-Year event
Inflow = 0.67 cfs @ 12.17 hrs, Volume= 2,408 cf
Outflow = 0.65 cfs @ 12.19 hrs, Volume= 2,402 cf, Atten= 3%, Lag= 1.2 min
Routed to Reach 7R : Swale

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 1.45 fps, Min. Travel Time= 1.7 min
Avg. Velocity = 0.48 fps, Avg. Travel Time= 5.3 min

Peak Storage= 68 cf @ 12.19 hrs
Average Depth at Peak Storage= 0.22' , Surface Width= 2.60'
Bank-Full Depth= 1.50' Flow Area= 7.9 sf, Capacity= 32.96 cfs

1.50' x 1.50' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 2.5 '/' Top Width= 9.00'
Length= 151.0' Slope= 0.0093 '/'
Inlet Invert= 253.40', Outlet Invert= 252.00'

Summary for Reach 7R: Swale

[62] Hint: Exceeded Reach 6R OUTLET depth by 0.05' @ 12.27 hrs

Inflow Area = 43,220 sf, 58.04% Impervious, Inflow Depth > 0.98" for 2-Year event
Inflow = 0.95 cfs @ 12.20 hrs, Volume= 3,545 cf
Outflow = 0.94 cfs @ 12.21 hrs, Volume= 3,539 cf, Atten= 1%, Lag= 1.0 min
Routed to Pond 9R : Head Wall to Infiltration Pond

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 1.70 fps, Min. Travel Time= 1.4 min
Avg. Velocity = 0.56 fps, Avg. Travel Time= 4.1 min

Peak Storage= 77 cf @ 12.21 hrs
Average Depth at Peak Storage= 0.26' , Surface Width= 2.79'
Bank-Full Depth= 1.50' Flow Area= 7.9 sf, Capacity= 35.44 cfs

1.50' x 1.50' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 2.5 '/' Top Width= 9.00'
Length= 140.0' Slope= 0.0107 '/'
Inlet Invert= 252.00', Outlet Invert= 250.50'

Summary for Reach 8R: Foxhole 1

[52] Hint: Inlet/Outlet conditions not evaluated

Inflow Area = 8,236 sf, 77.20% Impervious, Inflow Depth > 1.60" for 2-Year event
Inflow = 0.39 cfs @ 12.13 hrs, Volume= 1,100 cf
Outflow = 0.39 cfs @ 12.13 hrs, Volume= 1,100 cf, Atten= 0%, Lag= 0.0 min
Routed to Pond P1 : Infiltration Pond

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 3.71 fps, Min. Travel Time= 0.1 min
Avg. Velocity = 0.99 fps, Avg. Travel Time= 0.2 min

Peak Storage= 1 cf @ 12.13 hrs
Average Depth at Peak Storage= 0.06' , Surface Width= 1.83'
Bank-Full Depth= 0.38' Flow Area= 0.7 sf, Capacity= 5.21 cfs

22.0" W x 4.5" H Box Pipe
n= 0.013 Concrete, trowel finish
Length= 14.3' Slope= 0.0524 '/'
Inlet Invert= 253.28', Outlet Invert= 252.53'

Summary for Reach 10R: Foxhole 2

[52] Hint: Inlet/Outlet conditions not evaluated

Inflow Area = 9,659 sf, 79.19% Impervious, Inflow Depth > 1.68" for 2-Year event
Inflow = 0.47 cfs @ 12.13 hrs, Volume= 1,350 cf
Outflow = 0.47 cfs @ 12.13 hrs, Volume= 1,350 cf, Atten= 0%, Lag= 0.0 min
Routed to Pond P1 : Infiltration Pond

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 4.72 fps, Min. Travel Time= 0.0 min
Avg. Velocity = 1.25 fps, Avg. Travel Time= 0.1 min

Peak Storage= 1 cf @ 12.13 hrs
Average Depth at Peak Storage= 0.05' , Surface Width= 1.83'
Bank-Full Depth= 0.38' Flow Area= 0.7 sf, Capacity= 6.80 cfs

22.0" W x 4.5" H Box Pipe
n= 0.013 Concrete, trowel finish
Length= 8.4' Slope= 0.0893 '/'
Inlet Invert= 251.90', Outlet Invert= 251.15'

Summary for Pond 4R: Pipe to Infiltration Pond

[62] Hint: Exceeded Reach 3R OUTLET depth by 0.14' @ 12.20 hrs

Inflow Area = 47,184 sf, 61.08% Impervious, Inflow Depth > 1.01" for 2-Year event
Inflow = 1.13 cfs @ 12.18 hrs, Volume= 3,956 cf
Outflow = 1.13 cfs @ 12.19 hrs, Volume= 3,955 cf, Atten= 0%, Lag= 0.3 min
Primary = 1.13 cfs @ 12.19 hrs, Volume= 3,955 cf
Routed to Pond P1 : Infiltration Pond

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Peak Elev= 250.43' @ 12.19 hrs Surf.Area= 90 sf Storage= 24 cf

Plug-Flow detention time= 0.7 min calculated for 3,955 cf (100% of inflow)
Center-of-Mass det. time= 0.4 min (872.3 - 871.9)

Volume	Invert	Avail.Storage	Storage Description
#1	250.00'	620 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
250.00	22	0	0
251.00	181	102	102
252.00	855	518	620

Device	Routing	Invert	Outlet Devices
#1	Primary	250.00'	**12.0" Round Culvert X 2.00** L= 55.0' Ke= 0.500 Inlet / Outlet Invert= 250.00' / 249.72' S= 0.0051 '/' Cc= 0.900 n= 0.012 Corrugated PP, smooth interior, Flow Area= 0.79 sf

Primary OutFlow Max=1.13 cfs @ 12.19 hrs HW=250.43' TW=249.55' (Dynamic Tailwater)
└─**1=Culvert** (Barrel Controls 1.13 cfs @ 2.58 fps)

Summary for Pond 9R: Head Wall to Infiltration Pond

[62] Hint: Exceeded Reach 7R OUTLET depth by 0.12' @ 12.22 hrs

Inflow Area = 61,808 sf, 54.35% Impervious, Inflow Depth > 0.85" for 2-Year event
Inflow = 1.14 cfs @ 12.21 hrs, Volume= 4,394 cf
Outflow = 1.13 cfs @ 12.22 hrs, Volume= 4,386 cf, Atten= 1%, Lag= 0.7 min
Primary = 1.13 cfs @ 12.22 hrs, Volume= 4,386 cf
Routed to Pond P1 : Infiltration Pond

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Peak Elev= 250.87' @ 12.22 hrs Surf.Area= 226 sf Storage= 64 cf

Plug-Flow detention time= 2.5 min calculated for 4,384 cf (100% of inflow)
Center-of-Mass det. time= 1.5 min (878.0 - 876.6)

Volume	Invert	Avail.Storage	Storage Description
#1	250.50'	288 cf	**Custom Stage Data (Irregular)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Perim. (feet)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)	Wet.Area (sq-ft)
250.50	121	75.8	0	0	121
251.00	269	116.2	95	95	740
251.50	517	131.6	193	288	1,050

Device	Routing	Invert	Outlet Devices
#1	Primary	250.50'	**15.0" Round Culvert X 2.00** L= 29.8' RCP, groove end w/headwall, Ke= 0.200 Inlet / Outlet Invert= 250.50' / 250.00' S= 0.0168 '/' Cc= 0.900 n= 0.020 Corrugated PE, corrugated interior, Flow Area= 1.23 sf

Primary OutFlow Max=1.13 cfs @ 12.22 hrs HW=250.87' TW=249.56' (Dynamic Tailwater)
↑—**1=Culvert** (Barrel Controls 1.13 cfs @ 2.76 fps)

Summary for Pond P1: Infiltration Pond

Inflow Area = 151,893 sf, 51.31% Impervious, Inflow Depth > 1.01" for 2-Year event
Inflow = 3.44 cfs @ 12.16 hrs, Volume= 12,816 cf
Outflow = 2.10 cfs @ 12.31 hrs, Volume= 12,812 cf, Atten= 39%, Lag= 8.8 min
Discarded = 2.10 cfs @ 12.31 hrs, Volume= 12,812 cf
Primary = 0.00 cfs @ 0.00 hrs, Volume= 0 cf
Routed to Link AP1 : Wetlands

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Peak Elev= 249.58' @ 12.31 hrs Surf.Area= 10,628 sf Storage= 802 cf

Plug-Flow detention time= 1.8 min calculated for 12,806 cf (100% of inflow)
Center-of-Mass det. time= 1.7 min (869.2 - 867.5)

Volume	Invert	Avail.Storage	Storage Description
#1	249.50'	28,409 cf	**Custom Stage Data (Irregular)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Perim. (feet)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)	Wet.Area (sq-ft)
249.50	10,423	450.6	0	0	10,423
250.00	11,803	469.4	5,553	5,553	11,818
251.00	13,731	494.5	12,755	18,308	13,803
251.70	15,140	512.1	10,101	28,409	15,256

Device	Routing	Invert	Outlet Devices
#1	Primary	250.70'	**10.0' long x 19.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63
#2	Discarded	249.50'	**8.270 in/hr Exfiltration over Surface area** Conductivity to Groundwater Elevation = 247.00' Phase-In= 0.01'

Discarded OutFlow Max=2.10 cfs @ 12.31 hrs HW=249.58' (Free Discharge)
└─**2=Exfiltration** (Controls 2.10 cfs)

Primary OutFlow Max=0.00 cfs @ 0.00 hrs HW=249.50' TW=0.00' (Dynamic Tailwater)
└─**1=Broad-Crested Rectangular Weir** (Controls 0.00 cfs)

Summary for Link AP1: Wetlands

Inflow Area = 292,946 sf, 30.27% Impervious, Inflow Depth > 0.00" for 2-Year event
Inflow = 0.01 cfs @ 23.73 hrs, Volume= 111 cf
Primary = 0.01 cfs @ 23.73 hrs, Volume= 111 cf, Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs

Time span=0.00-24.00 hrs, dt=0.01 hrs, 2401 points x 3
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Dyn-Stor-Ind method - Pond routing by Dyn-Stor-Ind method

Subcatchment201: To Foxhole 1 Runoff Area=8,236 sf 77.20% Impervious Runoff Depth>2.75"
Tc=6.0 min CN=85 Runoff=0.65 cfs 1,888 cf

Subcatchment202: To Foxhole 2 Runoff Area=9,659 sf 79.19% Impervious Runoff Depth>2.84"
Tc=6.0 min CN=86 Runoff=0.79 cfs 2,288 cf

Subcatchment203: To RGT 1 Runoff Area=14,593 sf 62.69% Impervious Runoff Depth>1.99"
Flow Length=301' Tc=9.5 min CN=76 Runoff=0.74 cfs 2,419 cf

Subcatchment204: To RGT 2 Runoff Area=14,048 sf 64.46% Impervious Runoff Depth>2.07"
Flow Length=270' Slope=0.0150 '/' Tc=8.1 min CN=77 Runoff=0.78 cfs 2,422 cf

Subcatchment205: To RGT 3 Runoff Area=10,291 sf 73.21% Impervious Runoff Depth>2.48"
Flow Length=246' Tc=10.0 min CN=82 Runoff=0.63 cfs 2,128 cf

Subcatchment206: To RGT 4 Runoff Area=6,868 sf 84.23% Impervious Runoff Depth>3.13"
Flow Length=191' Tc=10.4 min CN=89 Runoff=0.51 cfs 1,790 cf

Subcatchment207: To RGT 5 Runoff Area=12,173 sf 63.90% Impervious Runoff Depth>2.07"
Flow Length=229' Tc=8.2 min CN=77 Runoff=0.68 cfs 2,098 cf

Subcatchment208: To RGT 6 Runoff Area=11,957 sf 63.77% Impervious Runoff Depth>2.07"
Flow Length=151' Tc=12.3 min CN=77 Runoff=0.57 cfs 2,059 cf

Subcatchment209: To RGT 7 Runoff Area=18,588 sf 45.75% Impervious Runoff Depth>1.28"
Flow Length=297' Tc=8.8 min CN=66 Runoff=0.59 cfs 1,989 cf

Subcatchment210: To Swale Runoff Area=3,987 sf 30.88% Impervious Runoff Depth>0.77"
Tc=6.0 min CN=57 Runoff=0.07 cfs 254 cf

Subcatchment211: To Swale Runoff Area=1,897 sf 38.32% Impervious Runoff Depth>1.04"
Tc=6.0 min CN=62 Runoff=0.05 cfs 165 cf

Subcatchment212: To Swale Runoff Area=3,761 sf 28.72% Impervious Runoff Depth>0.71"
Tc=6.0 min CN=56 Runoff=0.06 cfs 224 cf

Subcatchment213: To Swale Runoff Area=2,571 sf 42.94% Impervious Runoff Depth>1.16"
Tc=6.0 min CN=64 Runoff=0.08 cfs 249 cf

Subcatchment214: To Swale Runoff Area=2,962 sf 36.53% Impervious Runoff Depth>0.98"
Tc=6.0 min CN=61 Runoff=0.08 cfs 243 cf

Subcatchment215: To Swale Runoff Area=1,912 sf 35.83% Impervious Runoff Depth>0.93"
Tc=6.0 min CN=60 Runoff=0.05 cfs 148 cf

Subcatchment216: To Swale Runoff Area=807 sf 25.90% Impervious Runoff Depth>0.62"
Tc=6.0 min CN=54 Runoff=0.01 cfs 42 cf

Subcatchment217: To Infiltration Pond Runoff Area=25,006 sf 6.05% Impervious Runoff Depth>1.91"
Tc=6.0 min CN=75 Runoff=1.40 cfs 3,990 cf

Subcatchment218: To Swale Runoff Area=2,577 sf 33.41% Impervious Runoff Depth>0.87"
Tc=6.0 min CN=59 Runoff=0.06 cfs 187 cf

Subcatchment219: To Wetland Runoff Area=141,053 sf 7.63% Impervious Runoff Depth>0.19"
Flow Length=492' Tc=21.0 min CN=43 Runoff=0.10 cfs 2,180 cf

Reach 1R: Swale Avg. Flow Depth=0.21' Max Vel=1.74 fps Inflow=0.78 cfs 2,619 cf
n=0.030 L=175.0' S=0.0137 '/' Capacity=40.09 cfs Outflow=0.76 cfs 2,614 cf

Reach 2R: Swale Avg. Flow Depth=0.35' Max Vel=1.82 fps Inflow=1.56 cfs 5,183 cf
n=0.030 L=115.0' S=0.0087 '/' Capacity=31.92 cfs Outflow=1.54 cfs 5,177 cf

Reach 3R: Swale Avg. Flow Depth=0.40' Max Vel=3.36 fps Inflow=2.29 cfs 7,638 cf
n=0.030 L=32.0' S=0.0313 '/' Capacity=48.70 cfs Outflow=2.29 cfs 7,637 cf

Reach 5R: Swale Avg. Flow Depth=0.20' Max Vel=1.50 fps Inflow=0.61 cfs 2,178 cf
n=0.030 L=146.0' S=0.0110 '/' Capacity=35.84 cfs Outflow=0.60 cfs 2,174 cf

Reach 6R: Swale Avg. Flow Depth=0.32' Max Vel=1.78 fps Inflow=1.33 cfs 4,527 cf
n=0.030 L=151.0' S=0.0093 '/' Capacity=32.96 cfs Outflow=1.30 cfs 4,520 cf

Reach 7R: Swale Avg. Flow Depth=0.37' Max Vel=2.08 fps Inflow=1.90 cfs 6,766 cf
n=0.030 L=140.0' S=0.0107 '/' Capacity=35.44 cfs Outflow=1.88 cfs 6,757 cf

Reach 8R: Foxhole 1 Avg. Flow Depth=0.08' Max Vel=4.54 fps Inflow=0.65 cfs 1,888 cf
22.0" x 4.5" Box Pipe n=0.013 L=14.3' S=0.0524 '/' Capacity=5.21 cfs Outflow=0.65 cfs 1,888 cf

Reach 10R: Foxhole 2 Avg. Flow Depth=0.07' Max Vel=5.75 fps Inflow=0.79 cfs 2,288 cf
22.0" x 4.5" Box Pipe n=0.013 L=8.4' S=0.0893 '/' Capacity=6.80 cfs Outflow=0.79 cfs 2,288 cf

Pond 4R: Pipe to Infiltration Pond Peak Elev=250.64' Storage=47 cf Inflow=2.29 cfs 7,637 cf
12.0" Round Culvert x 2.00 n=0.012 L=55.0' S=0.0051 '/' Outflow=2.28 cfs 7,634 cf

Pond 9R: Head Wall to Infiltration Pond Peak Elev=251.06' Storage=112 cf Inflow=2.45 cfs 8,746 cf
15.0" Round Culvert x 2.00 n=0.020 L=29.8' S=0.0168 '/' Outflow=2.43 cfs 8,736 cf

Pond P1: Infiltration Pond Peak Elev=249.85' Storage=3,803 cf Inflow=7.00 cfs 24,536 cf
Discarded=2.47 cfs 24,529 cf Primary=0.00 cfs 0 cf Outflow=2.47 cfs 24,529 cf

Link AP1: Wetlands Inflow=0.10 cfs 2,180 cf
Primary=0.10 cfs 2,180 cf

Total Runoff Area = 292,946 sf Runoff Volume = 26,763 cf Average Runoff Depth = 1.10"
69.73% Pervious = 204,257 sf 30.27% Impervious = 88,689 sf

Summary for Subcatchment 201: To Foxhole 1

Runoff = 0.65 cfs @ 12.13 hrs, Volume= 1,888 cf, Depth> 2.75"
Routed to Reach 8R : Foxhole 1

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 10-Year Rainfall=4.33"

Area (sf)	CN	Description
6,358	98	Paved parking, HSG A
1,878	39	>75% Grass cover, Good, HSG A
8,236	85	Weighted Average
1,878		22.80% Pervious Area
6,358		77.20% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Summary for Subcatchment 202: To Foxhole 2

Runoff = 0.79 cfs @ 12.13 hrs, Volume= 2,288 cf, Depth> 2.84"
Routed to Reach 10R : Foxhole 2

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 10-Year Rainfall=4.33"

Area (sf)	CN	Description
7,031	98	Paved parking, HSG A
2,010	39	>75% Grass cover, Good, HSG A
618	98	Roofs, HSG A
9,659	86	Weighted Average
2,010		20.81% Pervious Area
7,649		79.19% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Summary for Subcatchment 203: To RGT 1

Runoff = 0.74 cfs @ 12.17 hrs, Volume= 2,419 cf, Depth> 1.99"
Routed to Reach 3R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 10-Year Rainfall=4.33"

Area (sf)	CN	Description
5,212	98	Paved parking, HSG A
5,444	39	>75% Grass cover, Good, HSG A
3,937	98	Roofs, HSG A
14,593	76	Weighted Average
5,444		37.31% Pervious Area
9,149		62.69% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.3	17	0.0190	0.92		**Sheet Flow, Sidewalk** Smooth surfaces n= 0.011 P2= 3.02"
6.6	70	0.0280	0.18		**Sheet Flow, Grass** Grass: Short n= 0.150 P2= 3.02"
0.1	8	0.0100	2.03		**Shallow Concentrated Flow, Sidewalk** Paved Kv= 20.3 fps
1.5	90	0.0200	0.99		**Shallow Concentrated Flow, Grass** Short Grass Pasture Kv= 7.0 fps
1.0	116	0.0100	2.03		**Shallow Concentrated Flow, Road** Paved Kv= 20.3 fps
9.5	301	Total			

Summary for Subcatchment 204: To RGT 2

Runoff = 0.78 cfs @ 12.16 hrs, Volume= 2,422 cf, Depth> 2.07"
Routed to Reach 2R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 10-Year Rainfall=4.33"

Area (sf)	CN	Description
5,526	98	Paved parking, HSG A
4,993	39	>75% Grass cover, Good, HSG A
3,529	98	Roofs, HSG A
14,048	77	Weighted Average
4,993		35.54% Pervious Area
9,055		64.46% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.5	50	0.0150	0.13		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.02"
0.2	8	0.0150	0.86		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
1.4	212	0.0150	2.49		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
8.1	270	Total			

Summary for Subcatchment 205: To RGT 3

Runoff = 0.63 cfs @ 12.17 hrs, Volume= 2,128 cf, Depth> 2.48"
Routed to Reach 1R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 10-Year Rainfall=4.33"

Area (sf)	CN	Description
5,110	98	Paved parking, HSG A
2,757	39	>75% Grass cover, Good, HSG A
2,424	98	Roofs, HSG A
10,291	82	Weighted Average
2,757		26.79% Pervious Area
7,534		73.21% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
7.6	50	0.0100	0.11		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.02"
1.1	34	0.0050	0.49		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
1.3	162	0.0100	2.03		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
10.0	246	Total			

Summary for Subcatchment 206: To RGT 4

Runoff = 0.51 cfs @ 12.18 hrs, Volume= 1,790 cf, Depth> 3.13"
Routed to Reach 5R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 10-Year Rainfall=4.33"

Area (sf)	CN	Description
4,247	98	Paved parking, HSG A
1,083	39	>75% Grass cover, Good, HSG A
1,538	98	Roofs, HSG A
6,868	89	Weighted Average
1,083		15.77% Pervious Area
5,785		84.23% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
9.4	46	0.0050	0.08		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.02"
1.0	145	0.0150	2.49		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
10.4	191	Total			

Summary for Subcatchment 207: To RGT 5

Runoff = 0.68 cfs @ 12.16 hrs, Volume= 2,098 cf, Depth> 2.07"
Routed to Reach 6R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 10-Year Rainfall=4.33"

Area (sf)	CN	Description
4,249	98	Paved parking, HSG A
4,395	39	>75% Grass cover, Good, HSG A
3,529	98	Roofs, HSG A
12,173	77	Weighted Average
4,395		36.10% Pervious Area
7,778		63.90% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.7	50	0.0140	0.12		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.02"
0.7	53	0.0290	1.19		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.8	126	0.0150	2.49		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
8.2	229	Total			

Summary for Subcatchment 208: To RGT 6

Runoff = 0.57 cfs @ 12.20 hrs, Volume= 2,059 cf, Depth> 2.07"
Routed to Reach 7R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 10-Year Rainfall=4.33"

Area (sf)	CN	Description
5,503	98	Paved parking, HSG A
4,332	39	>75% Grass cover, Good, HSG A
2,122	98	Roofs, HSG A
11,957	77	Weighted Average
4,332		36.23% Pervious Area
7,625		63.77% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
10.1	50	0.0050	0.08		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.02"
1.1	44	0.0090	0.66		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
1.1	57	0.0150	0.86		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
12.3	151	Total			

Summary for Subcatchment 209: To RGT 7

Runoff = 0.59 cfs @ 12.17 hrs, Volume= 1,989 cf, Depth> 1.28"
Routed to Pond 9R : Head Wall to Infiltration Pond

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 10-Year Rainfall=4.33"

Area (sf)	CN	Description
6,488	98	Paved parking, HSG A
10,084	39	>75% Grass cover, Good, HSG A
2,016	98	Roofs, HSG A
18,588	66	Weighted Average
10,084		54.25% Pervious Area
8,504		45.75% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.8	50	0.0200	0.14		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.02"
0.3	18	0.0200	0.99		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.2	29	0.0200	2.87		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
1.1	69	0.0230	1.06		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.0	5	0.0100	2.03		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
1.0	60	0.0200	0.99		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.4	66	0.0150	2.49		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
8.8	297	Total			

Summary for Subcatchment 210: To Swale

Runoff = 0.07 cfs @ 12.14 hrs, Volume= 254 cf, Depth> 0.77"
Routed to Reach 6R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 10-Year Rainfall=4.33"

Area (sf)	CN	Description
1,231	98	Paved parking, HSG A
2,756	39	>75% Grass cover, Good, HSG A
3,987	57	Weighted Average
2,756		69.12% Pervious Area
1,231		30.88% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Summary for Subcatchment 211: To Swale

Runoff = 0.05 cfs @ 12.14 hrs, Volume= 165 cf, Depth> 1.04"
Routed to Reach 5R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 10-Year Rainfall=4.33"

Area (sf)	CN	Description
727	98	Paved parking, HSG A
1,170	39	>75% Grass cover, Good, HSG A
1,897	62	Weighted Average
1,170		61.68% Pervious Area
727		38.32% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Summary for Subcatchment 212: To Swale

Runoff = 0.06 cfs @ 12.14 hrs, Volume= 224 cf, Depth> 0.71"
Routed to Reach 5R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 10-Year Rainfall=4.33"

Area (sf)	CN	Description
1,080	98	Paved parking, HSG A
2,681	39	>75% Grass cover, Good, HSG A
3,761	56	Weighted Average
2,681		71.28% Pervious Area
1,080		28.72% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Summary for Subcatchment 213: To Swale

Runoff = 0.08 cfs @ 12.14 hrs, Volume= 249 cf, Depth> 1.16"
Routed to Reach 1R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 10-Year Rainfall=4.33"

Area (sf)	CN	Description
1,104	98	Paved parking, HSG A
1,467	39	>75% Grass cover, Good, HSG A
2,571	64	Weighted Average
1,467		57.06% Pervious Area
1,104		42.94% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Summary for Subcatchment 214: To Swale

Runoff = 0.08 cfs @ 12.14 hrs, Volume= 243 cf, Depth> 0.98"
Routed to Reach 1R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 10-Year Rainfall=4.33"

Area (sf)	CN	Description
1,082	98	Paved parking, HSG A
1,880	39	>75% Grass cover, Good, HSG A
2,962	61	Weighted Average
1,880		63.47% Pervious Area
1,082		36.53% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Summary for Subcatchment 215: To Swale

Runoff = 0.05 cfs @ 12.14 hrs, Volume= 148 cf, Depth> 0.93"
Routed to Reach 2R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 10-Year Rainfall=4.33"

Area (sf)	CN	Description
685	98	Paved parking, HSG A
1,227	39	>75% Grass cover, Good, HSG A
1,912	60	Weighted Average
1,227		64.17% Pervious Area
685		35.83% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Summary for Subcatchment 216: To Swale

Runoff = 0.01 cfs @ 12.15 hrs, Volume= 42 cf, Depth> 0.62"
Routed to Reach 3R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 10-Year Rainfall=4.33"

Area (sf)	CN	Description
598	39	>75% Grass cover, Good, HSG A
209	98	Paved parking, HSG A
807	54	Weighted Average
598		74.10% Pervious Area
209		25.90% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Summary for Subcatchment 217: To Infiltration Pond

Runoff = 1.40 cfs @ 12.13 hrs, Volume= 3,990 cf, Depth> 1.91"
Routed to Pond P1 : Infiltration Pond

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 10-Year Rainfall=4.33"

Area (sf)	CN	Description
9,762	39	>75% Grass cover, Good, HSG A
1,513	98	Paved parking, HSG A
13,731	98	Water Surface, 0% imp, HSG A
25,006	75	Weighted Average
23,493		93.95% Pervious Area
1,513		6.05% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Summary for Subcatchment 218: To Swale

Runoff = 0.06 cfs @ 12.14 hrs, Volume= 187 cf, Depth> 0.87"
Routed to Reach 7R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 10-Year Rainfall=4.33"

Area (sf)	CN	Description
861	98	Paved parking, HSG A
1,716	39	>75% Grass cover, Good, HSG A
2,577	59	Weighted Average
1,716		66.59% Pervious Area
861		33.41% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Summary for Subcatchment 219: To Wetland

Runoff = 0.10 cfs @ 13.13 hrs, Volume= 2,180 cf, Depth> 0.19"
Routed to Link AP1 : Wetlands

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 10-Year Rainfall=4.33"

Area (sf)	CN	Description
7,467	98	Paved parking, HSG A
113,656	39	>75% Grass cover, Good, HSG A
16,637	32	Woods/grass comb., Good, HSG A
3,293	98	Roofs, HSG A
141,053	43	Weighted Average
130,293		92.37% Pervious Area
10,760		7.63% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
9.6	50	0.1600	0.09		**Sheet Flow,** Woods: Dense underbrush n= 0.800 P2= 3.02"
0.4	41	0.1000	1.58		**Shallow Concentrated Flow,** Woodland Kv= 5.0 fps
11.0	401	0.0075	0.61		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
21.0	492	Total			

Summary for Reach 1R: Swale

Inflow Area = 15,824 sf, 61.43% Impervious, Inflow Depth > 1.99" for 10-Year event
Inflow = 0.78 cfs @ 12.16 hrs, Volume= 2,619 cf
Outflow = 0.76 cfs @ 12.18 hrs, Volume= 2,614 cf, Atten= 2%, Lag= 1.1 min
Routed to Reach 2R : Swale

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 1.74 fps, Min. Travel Time= 1.7 min
Avg. Velocity = 0.57 fps, Avg. Travel Time= 5.1 min

Peak Storage= 76 cf @ 12.18 hrs
Average Depth at Peak Storage= 0.21' , Surface Width= 2.57'
Bank-Full Depth= 1.50' Flow Area= 7.9 sf, Capacity= 40.09 cfs

1.50' x 1.50' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 2.5 '/' Top Width= 9.00'
Length= 175.0' Slope= 0.0137 '/'
Inlet Invert= 254.40', Outlet Invert= 252.00'

Summary for Reach 2R: Swale

[62] Hint: Exceeded Reach 1R OUTLET depth by 0.14' @ 12.17 hrs

Inflow Area = 31,784 sf, 61.23% Impervious, Inflow Depth > 1.96" for 10-Year event
Inflow = 1.56 cfs @ 12.16 hrs, Volume= 5,183 cf
Outflow = 1.54 cfs @ 12.18 hrs, Volume= 5,177 cf, Atten= 1%, Lag= 0.8 min
Routed to Reach 3R : Swale

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 1.82 fps, Min. Travel Time= 1.1 min
Avg. Velocity = 0.61 fps, Avg. Travel Time= 3.2 min

Peak Storage= 97 cf @ 12.18 hrs
Average Depth at Peak Storage= 0.35' , Surface Width= 3.27'
Bank-Full Depth= 1.50' Flow Area= 7.9 sf, Capacity= 31.92 cfs

1.50' x 1.50' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 2.5 '/' Top Width= 9.00'
Length= 115.0' Slope= 0.0087 '/'
Inlet Invert= 252.00', Outlet Invert= 251.00'

Summary for Reach 3R: Swale

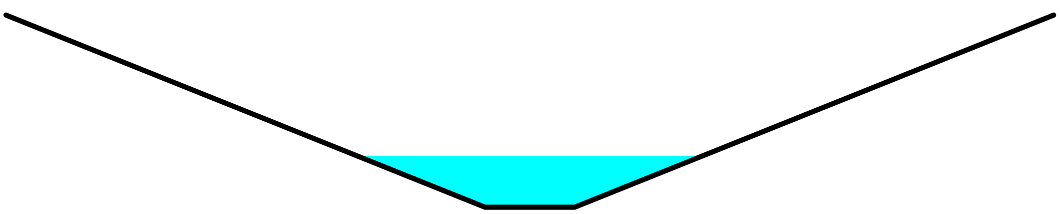
[62] Hint: Exceeded Reach 2R OUTLET depth by 0.05' @ 12.13 hrs

Inflow Area = 47,184 sf, 61.08% Impervious, Inflow Depth > 1.94" for 10-Year event
Inflow = 2.29 cfs @ 12.17 hrs, Volume= 7,638 cf
Outflow = 2.29 cfs @ 12.18 hrs, Volume= 7,637 cf, Atten= 0%, Lag= 0.1 min
Routed to Pond 4R : Pipe to Infiltration Pond

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 3.36 fps, Min. Travel Time= 0.2 min
Avg. Velocity = 1.25 fps, Avg. Travel Time= 0.4 min

Peak Storage= 22 cf @ 12.18 hrs
Average Depth at Peak Storage= 0.40' , Surface Width= 2.70'
Bank-Full Depth= 1.50' Flow Area= 6.7 sf, Capacity= 48.70 cfs

0.70' x 1.50' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 2.5 '/' Top Width= 8.20'
Length= 32.0' Slope= 0.0313 '/'
Inlet Invert= 251.00', Outlet Invert= 250.00'



Summary for Reach 5R: Swale

Inflow Area = 12,526 sf, 60.61% Impervious, Inflow Depth > 2.09" for 10-Year event
Inflow = 0.61 cfs @ 12.17 hrs, Volume= 2,178 cf
Outflow = 0.60 cfs @ 12.18 hrs, Volume= 2,174 cf, Atten= 2%, Lag= 1.1 min
Routed to Reach 6R : Swale

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 1.50 fps, Min. Travel Time= 1.6 min
Avg. Velocity = 0.47 fps, Avg. Travel Time= 5.2 min

Peak Storage= 59 cf @ 12.18 hrs
Average Depth at Peak Storage= 0.20' , Surface Width= 2.50'
Bank-Full Depth= 1.50' Flow Area= 7.9 sf, Capacity= 35.84 cfs

1.50' x 1.50' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 2.5 '/' Top Width= 9.00'
Length= 146.0' Slope= 0.0110 '/'
Inlet Invert= 255.00', Outlet Invert= 253.40'

Summary for Reach 6R: Swale

[62] Hint: Exceeded Reach 5R OUTLET depth by 0.12' @ 12.18 hrs

Inflow Area = 28,686 sf, 57.87% Impervious, Inflow Depth > 1.89" for 10-Year event
Inflow = 1.33 cfs @ 12.16 hrs, Volume= 4,527 cf
Outflow = 1.30 cfs @ 12.18 hrs, Volume= 4,520 cf, Atten= 2%, Lag= 1.0 min
Routed to Reach 7R : Swale

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 1.78 fps, Min. Travel Time= 1.4 min
Avg. Velocity = 0.56 fps, Avg. Travel Time= 4.5 min

Peak Storage= 111 cf @ 12.18 hrs
Average Depth at Peak Storage= 0.32' , Surface Width= 3.09'
Bank-Full Depth= 1.50' Flow Area= 7.9 sf, Capacity= 32.96 cfs

1.50' x 1.50' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 2.5 '/' Top Width= 9.00'
Length= 151.0' Slope= 0.0093 '/'
Inlet Invert= 253.40', Outlet Invert= 252.00'

Summary for Reach 7R: Swale

[62] Hint: Exceeded Reach 6R OUTLET depth by 0.07' @ 12.26 hrs

Inflow Area = 43,220 sf, 58.04% Impervious, Inflow Depth > 1.88" for 10-Year event
Inflow = 1.90 cfs @ 12.18 hrs, Volume= 6,766 cf
Outflow = 1.88 cfs @ 12.20 hrs, Volume= 6,757 cf, Atten= 1%, Lag= 0.9 min
Routed to Pond 9R : Head Wall to Infiltration Pond

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 2.08 fps, Min. Travel Time= 1.1 min
Avg. Velocity = 0.66 fps, Avg. Travel Time= 3.5 min

Peak Storage= 127 cf @ 12.20 hrs
Average Depth at Peak Storage= 0.37' , Surface Width= 3.36'
Bank-Full Depth= 1.50' Flow Area= 7.9 sf, Capacity= 35.44 cfs

1.50' x 1.50' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 2.5 '/' Top Width= 9.00'
Length= 140.0' Slope= 0.0107 '/'
Inlet Invert= 252.00', Outlet Invert= 250.50'

Summary for Reach 8R: Foxhole 1

[52] Hint: Inlet/Outlet conditions not evaluated

Inflow Area = 8,236 sf, 77.20% Impervious, Inflow Depth > 2.75" for 10-Year event
Inflow = 0.65 cfs @ 12.13 hrs, Volume= 1,888 cf
Outflow = 0.65 cfs @ 12.13 hrs, Volume= 1,888 cf, Atten= 0%, Lag= 0.0 min
Routed to Pond P1 : Infiltration Pond

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 4.54 fps, Min. Travel Time= 0.1 min
Avg. Velocity = 1.14 fps, Avg. Travel Time= 0.2 min

Peak Storage= 2 cf @ 12.13 hrs
Average Depth at Peak Storage= 0.08' , Surface Width= 1.83'
Bank-Full Depth= 0.38' Flow Area= 0.7 sf, Capacity= 5.21 cfs

22.0" W x 4.5" H Box Pipe
n= 0.013 Concrete, trowel finish
Length= 14.3' Slope= 0.0524 '/'
Inlet Invert= 253.28', Outlet Invert= 252.53'

Summary for Reach 10R: Foxhole 2

[52] Hint: Inlet/Outlet conditions not evaluated

Inflow Area = 9,659 sf, 79.19% Impervious, Inflow Depth > 2.84" for 10-Year event
Inflow = 0.79 cfs @ 12.13 hrs, Volume= 2,288 cf
Outflow = 0.79 cfs @ 12.13 hrs, Volume= 2,288 cf, Atten= 0%, Lag= 0.0 min
Routed to Pond P1 : Infiltration Pond

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 5.75 fps, Min. Travel Time= 0.0 min
Avg. Velocity = 1.44 fps, Avg. Travel Time= 0.1 min

Peak Storage= 1 cf @ 12.13 hrs
Average Depth at Peak Storage= 0.07' , Surface Width= 1.83'
Bank-Full Depth= 0.38' Flow Area= 0.7 sf, Capacity= 6.80 cfs

22.0" W x 4.5" H Box Pipe
n= 0.013 Concrete, trowel finish
Length= 8.4' Slope= 0.0893 '/'
Inlet Invert= 251.90', Outlet Invert= 251.15'

Summary for Pond 4R: Pipe to Infiltration Pond

[62] Hint: Exceeded Reach 3R OUTLET depth by 0.24' @ 12.19 hrs

Inflow Area = 47,184 sf, 61.08% Impervious, Inflow Depth > 1.94" for 10-Year event
Inflow = 2.29 cfs @ 12.18 hrs, Volume= 7,637 cf
Outflow = 2.28 cfs @ 12.18 hrs, Volume= 7,634 cf, Atten= 0%, Lag= 0.3 min
Primary = 2.28 cfs @ 12.18 hrs, Volume= 7,634 cf
Routed to Pond P1 : Infiltration Pond

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Peak Elev= 250.64' @ 12.18 hrs Surf.Area= 124 sf Storage= 47 cf

Plug-Flow detention time= 0.6 min calculated for 7,634 cf (100% of inflow)
Center-of-Mass det. time= 0.4 min (851.8 - 851.4)

Volume	Invert	Avail.Storage	Storage Description
#1	250.00'	620 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
250.00	22	0	0
251.00	181	102	102
252.00	855	518	620

Device	Routing	Invert	Outlet Devices
#1	Primary	250.00'	**12.0" Round Culvert X 2.00** L= 55.0' Ke= 0.500 Inlet / Outlet Invert= 250.00' / 249.72' S= 0.0051 '/' Cc= 0.900 n= 0.012 Corrugated PP, smooth interior, Flow Area= 0.79 sf

Primary OutFlow Max=2.28 cfs @ 12.18 hrs HW=250.64' TW=249.70' (Dynamic Tailwater)
└─**1=Culvert** (Barrel Controls 2.28 cfs @ 3.06 fps)

Summary for Pond 9R: Head Wall to Infiltration Pond

[62] Hint: Exceeded Reach 7R OUTLET depth by 0.19' @ 12.20 hrs

Inflow Area = 61,808 sf, 54.35% Impervious, Inflow Depth > 1.70" for 10-Year event
Inflow = 2.45 cfs @ 12.19 hrs, Volume= 8,746 cf
Outflow = 2.43 cfs @ 12.20 hrs, Volume= 8,736 cf, Atten= 1%, Lag= 0.6 min
Primary = 2.43 cfs @ 12.20 hrs, Volume= 8,736 cf
Routed to Pond P1 : Infiltration Pond

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Peak Elev= 251.06' @ 12.20 hrs Surf.Area= 294 sf Storage= 112 cf

Plug-Flow detention time= 1.9 min calculated for 8,736 cf (100% of inflow)
Center-of-Mass det. time= 1.2 min (858.1 - 856.9)

Volume	Invert	Avail.Storage	Storage Description
#1	250.50'	288 cf	**Custom Stage Data (Irregular)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Perim. (feet)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)	Wet.Area (sq-ft)
250.50	121	75.8	0	0	121
251.00	269	116.2	95	95	740
251.50	517	131.6	193	288	1,050

Device	Routing	Invert	Outlet Devices
#1	Primary	250.50'	**15.0" Round Culvert X 2.00** L= 29.8' RCP, groove end w/headwall, Ke= 0.200 Inlet / Outlet Invert= 250.50' / 250.00' S= 0.0168 '/' Cc= 0.900 n= 0.020 Corrugated PE, corrugated interior, Flow Area= 1.23 sf

Primary OutFlow Max=2.43 cfs @ 12.20 hrs HW=251.06' TW=249.73' (Dynamic Tailwater)
↑—**1=Culvert** (Barrel Controls 2.43 cfs @ 3.37 fps)

Summary for Pond P1: Infiltration Pond

Inflow Area = 151,893 sf, 51.31% Impervious, Inflow Depth > 1.94" for 10-Year event
Inflow = 7.00 cfs @ 12.16 hrs, Volume= 24,536 cf
Outflow = 2.47 cfs @ 12.42 hrs, Volume= 24,529 cf, Atten= 65%, Lag= 15.7 min
Discarded = 2.47 cfs @ 12.42 hrs, Volume= 24,529 cf
Primary = 0.00 cfs @ 0.00 hrs, Volume= 0 cf
Routed to Link AP1 : Wetlands

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Peak Elev= 249.85' @ 12.42 hrs Surf.Area= 11,377 sf Storage= 3,803 cf

Plug-Flow detention time= 8.2 min calculated for 24,519 cf (100% of inflow)
Center-of-Mass det. time= 8.0 min (856.4 - 848.5)

Volume	Invert	Avail.Storage	Storage Description
#1	249.50'	28,409 cf	**Custom Stage Data (Irregular)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Perim. (feet)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)	Wet.Area (sq-ft)
249.50	10,423	450.6	0	0	10,423
250.00	11,803	469.4	5,553	5,553	11,818
251.00	13,731	494.5	12,755	18,308	13,803
251.70	15,140	512.1	10,101	28,409	15,256

Device	Routing	Invert	Outlet Devices
#1	Primary	250.70'	**10.0' long x 19.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63
#2	Discarded	249.50'	**8.270 in/hr Exfiltration over Surface area** Conductivity to Groundwater Elevation = 247.00' Phase-In= 0.01'

Discarded OutFlow Max=2.47 cfs @ 12.42 hrs HW=249.85' (Free Discharge)
└─**2=Exfiltration** (Controls 2.47 cfs)

Primary OutFlow Max=0.00 cfs @ 0.00 hrs HW=249.50' TW=0.00' (Dynamic Tailwater)
└─**1=Broad-Crested Rectangular Weir** (Controls 0.00 cfs)

Summary for Link AP1: Wetlands

Inflow Area = 292,946 sf, 30.27% Impervious, Inflow Depth > 0.09" for 10-Year event
Inflow = 0.10 cfs @ 13.13 hrs, Volume= 2,180 cf
Primary = 0.10 cfs @ 13.13 hrs, Volume= 2,180 cf, Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs

Time span=0.00-24.00 hrs, dt=0.01 hrs, 2401 points x 3
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Dyn-Stor-Ind method - Pond routing by Dyn-Stor-Ind method

Subcatchment201: To Foxhole 1 Runoff Area=8,236 sf 77.20% Impervious Runoff Depth>4.50"
Tc=6.0 min CN=85 Runoff=1.04 cfs 3,092 cf

Subcatchment202: To Foxhole 2 Runoff Area=9,659 sf 79.19% Impervious Runoff Depth>4.61"
Tc=6.0 min CN=86 Runoff=1.24 cfs 3,713 cf

Subcatchment203: To RGT 1 Runoff Area=14,593 sf 62.69% Impervious Runoff Depth>3.56"
Flow Length=301' Tc=9.5 min CN=76 Runoff=1.32 cfs 4,332 cf

Subcatchment204: To RGT 2 Runoff Area=14,048 sf 64.46% Impervious Runoff Depth>3.66"
Flow Length=270' Slope=0.0150 '/' Tc=8.1 min CN=77 Runoff=1.37 cfs 4,290 cf

Subcatchment205: To RGT 3 Runoff Area=10,291 sf 73.21% Impervious Runoff Depth>4.18"
Flow Length=246' Tc=10.0 min CN=82 Runoff=1.05 cfs 3,585 cf

Subcatchment206: To RGT 4 Runoff Area=6,868 sf 84.23% Impervious Runoff Depth>4.94"
Flow Length=191' Tc=10.4 min CN=89 Runoff=0.79 cfs 2,826 cf

Subcatchment207: To RGT 5 Runoff Area=12,173 sf 63.90% Impervious Runoff Depth>3.66"
Flow Length=229' Tc=8.2 min CN=77 Runoff=1.19 cfs 3,717 cf

Subcatchment208: To RGT 6 Runoff Area=11,957 sf 63.77% Impervious Runoff Depth>3.66"
Flow Length=151' Tc=12.3 min CN=77 Runoff=1.00 cfs 3,647 cf

Subcatchment209: To RGT 7 Runoff Area=18,588 sf 45.75% Impervious Runoff Depth>2.60"
Flow Length=297' Tc=8.8 min CN=66 Runoff=1.25 cfs 4,024 cf

Subcatchment210: To Swale Runoff Area=3,987 sf 30.88% Impervious Runoff Depth>1.81"
Tc=6.0 min CN=57 Runoff=0.20 cfs 600 cf

Subcatchment211: To Swale Runoff Area=1,897 sf 38.32% Impervious Runoff Depth>2.24"
Tc=6.0 min CN=62 Runoff=0.12 cfs 354 cf

Subcatchment212: To Swale Runoff Area=3,761 sf 28.72% Impervious Runoff Depth>1.72"
Tc=6.0 min CN=56 Runoff=0.18 cfs 540 cf

Subcatchment213: To Swale Runoff Area=2,571 sf 42.94% Impervious Runoff Depth>2.42"
Tc=6.0 min CN=64 Runoff=0.18 cfs 518 cf

Subcatchment214: To Swale Runoff Area=2,962 sf 36.53% Impervious Runoff Depth>2.15"
Tc=6.0 min CN=61 Runoff=0.18 cfs 531 cf

Subcatchment215: To Swale Runoff Area=1,912 sf 35.83% Impervious Runoff Depth>2.06"
Tc=6.0 min CN=60 Runoff=0.11 cfs 329 cf

Subcatchment216: To Swale Runoff Area=807 sf 25.90% Impervious Runoff Depth>1.56"
Tc=6.0 min CN=54 Runoff=0.03 cfs 105 cf

Subcatchment217: To Infiltration Pond Runoff Area=25,006 sf 6.05% Impervious Runoff Depth>3.47"
Tc=6.0 min CN=75 Runoff=2.52 cfs 7,221 cf

Subcatchment218: To Swale Runoff Area=2,577 sf 33.41% Impervious Runoff Depth>1.98"
Tc=6.0 min CN=59 Runoff=0.15 cfs 424 cf

Subcatchment219: To Wetland Runoff Area=141,053 sf 7.63% Impervious Runoff Depth>0.75"
Flow Length=492' Tc=21.0 min CN=43 Runoff=1.09 cfs 8,799 cf

Reach 1R: Swale Avg. Flow Depth=0.29' Max Vel=2.07 fps Inflow=1.38 cfs 4,634 cf
n=0.030 L=175.0' S=0.0137 '/' Capacity=40.09 cfs Outflow=1.35 cfs 4,626 cf

Reach 2R: Swale Avg. Flow Depth=0.48' Max Vel=2.15 fps Inflow=2.81 cfs 9,245 cf
n=0.030 L=115.0' S=0.0087 '/' Capacity=31.92 cfs Outflow=2.78 cfs 9,236 cf

Reach 3R: Swale Avg. Flow Depth=0.52' Max Vel=3.92 fps Inflow=4.13 cfs 13,673 cf
n=0.030 L=32.0' S=0.0313 '/' Capacity=48.70 cfs Outflow=4.13 cfs 13,671 cf

Reach 5R: Swale Avg. Flow Depth=0.27' Max Vel=1.77 fps Inflow=1.06 cfs 3,721 cf
n=0.030 L=146.0' S=0.0110 '/' Capacity=35.84 cfs Outflow=1.04 cfs 3,715 cf

Reach 6R: Swale Avg. Flow Depth=0.43' Max Vel=2.10 fps Inflow=2.40 cfs 8,033 cf
n=0.030 L=151.0' S=0.0093 '/' Capacity=32.96 cfs Outflow=2.37 cfs 8,022 cf

Reach 7R: Swale Avg. Flow Depth=0.51' Max Vel=2.45 fps Inflow=3.46 cfs 12,094 cf
n=0.030 L=140.0' S=0.0107 '/' Capacity=35.44 cfs Outflow=3.43 cfs 12,082 cf

Reach 8R: Foxhole 1 Avg. Flow Depth=0.10' Max Vel=5.42 fps Inflow=1.04 cfs 3,092 cf
22.0" x 4.5" Box Pipe n=0.013 L=14.3' S=0.0524 '/' Capacity=5.21 cfs Outflow=1.04 cfs 3,091 cf

Reach 10R: Foxhole 2 Avg. Flow Depth=0.10' Max Vel=6.84 fps Inflow=1.24 cfs 3,713 cf
22.0" x 4.5" Box Pipe n=0.013 L=8.4' S=0.0893 '/' Capacity=6.80 cfs Outflow=1.24 cfs 3,713 cf

Pond 4R: Pipe to Infiltration Pond Peak Elev=250.93' Storage=89 cf Inflow=4.13 cfs 13,671 cf
12.0" Round Culvert x 2.00 n=0.012 L=55.0' S=0.0051 '/' Outflow=4.11 cfs 13,668 cf

Pond 9R: Head Wall to Infiltration Pond Peak Elev=251.30' Storage=197 cf Inflow=4.64 cfs 16,106 cf
15.0" Round Culvert x 2.00 n=0.020 L=29.8' S=0.0168 '/' Outflow=4.61 cfs 16,092 cf

Pond P1: Infiltration Pond Peak Elev=250.36' Storage=9,878 cf Inflow=12.69 cfs 43,786 cf
Discarded=3.14 cfs 43,775 cf Primary=0.00 cfs 0 cf Outflow=3.14 cfs 43,775 cf

Link AP1: Wetlands Inflow=1.09 cfs 8,799 cf
Primary=1.09 cfs 8,799 cf

Total Runoff Area = 292,946 sf Runoff Volume = 52,647 cf Average Runoff Depth = 2.16"
69.73% Pervious = 204,257 sf 30.27% Impervious = 88,689 sf

Summary for Subcatchment 201: To Foxhole 1

Runoff = 1.04 cfs @ 12.13 hrs, Volume= 3,092 cf, Depth> 4.50"
Routed to Reach 8R : Foxhole 1

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 50-Year Rainfall=6.22"

Area (sf)	CN	Description
6,358	98	Paved parking, HSG A
1,878	39	>75% Grass cover, Good, HSG A
8,236	85	Weighted Average
1,878		22.80% Pervious Area
6,358		77.20% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Summary for Subcatchment 202: To Foxhole 2

Runoff = 1.24 cfs @ 12.13 hrs, Volume= 3,713 cf, Depth> 4.61"
Routed to Reach 10R : Foxhole 2

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 50-Year Rainfall=6.22"

Area (sf)	CN	Description
7,031	98	Paved parking, HSG A
2,010	39	>75% Grass cover, Good, HSG A
618	98	Roofs, HSG A
9,659	86	Weighted Average
2,010		20.81% Pervious Area
7,649		79.19% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Summary for Subcatchment 203: To RGT 1

Runoff = 1.32 cfs @ 12.17 hrs, Volume= 4,332 cf, Depth> 3.56"
Routed to Reach 3R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 50-Year Rainfall=6.22"

Area (sf)	CN	Description
5,212	98	Paved parking, HSG A
5,444	39	>75% Grass cover, Good, HSG A
3,937	98	Roofs, HSG A
14,593	76	Weighted Average
5,444		37.31% Pervious Area
9,149		62.69% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.3	17	0.0190	0.92		**Sheet Flow, Sidewalk** Smooth surfaces n= 0.011 P2= 3.02"
6.6	70	0.0280	0.18		**Sheet Flow, Grass** Grass: Short n= 0.150 P2= 3.02"
0.1	8	0.0100	2.03		**Shallow Concentrated Flow, Sidewalk** Paved Kv= 20.3 fps
1.5	90	0.0200	0.99		**Shallow Concentrated Flow, Grass** Short Grass Pasture Kv= 7.0 fps
1.0	116	0.0100	2.03		**Shallow Concentrated Flow, Road** Paved Kv= 20.3 fps
9.5	301	Total			

Summary for Subcatchment 204: To RGT 2

Runoff = 1.37 cfs @ 12.15 hrs, Volume= 4,290 cf, Depth> 3.66"
Routed to Reach 2R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 50-Year Rainfall=6.22"

Area (sf)	CN	Description
5,526	98	Paved parking, HSG A
4,993	39	>75% Grass cover, Good, HSG A
3,529	98	Roofs, HSG A
14,048	77	Weighted Average
4,993		35.54% Pervious Area
9,055		64.46% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.5	50	0.0150	0.13		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.02"
0.2	8	0.0150	0.86		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
1.4	212	0.0150	2.49		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
8.1	270	Total			

Summary for Subcatchment 205: To RGT 3

Runoff = 1.05 cfs @ 12.17 hrs, Volume= 3,585 cf, Depth> 4.18"
Routed to Reach 1R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 50-Year Rainfall=6.22"

Area (sf)	CN	Description
5,110	98	Paved parking, HSG A
2,757	39	>75% Grass cover, Good, HSG A
2,424	98	Roofs, HSG A
10,291	82	Weighted Average
2,757		26.79% Pervious Area
7,534		73.21% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
7.6	50	0.0100	0.11		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.02"
1.1	34	0.0050	0.49		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
1.3	162	0.0100	2.03		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
10.0	246	Total			

Summary for Subcatchment 206: To RGT 4

Runoff = 0.79 cfs @ 12.18 hrs, Volume= 2,826 cf, Depth> 4.94"
Routed to Reach 5R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 50-Year Rainfall=6.22"

Area (sf)	CN	Description
4,247	98	Paved parking, HSG A
1,083	39	>75% Grass cover, Good, HSG A
1,538	98	Roofs, HSG A
6,868	89	Weighted Average
1,083		15.77% Pervious Area
5,785		84.23% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
9.4	46	0.0050	0.08		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.02"
1.0	145	0.0150	2.49		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
10.4	191	Total			

Summary for Subcatchment 207: To RGT 5

Runoff = 1.19 cfs @ 12.16 hrs, Volume= 3,717 cf, Depth> 3.66"
Routed to Reach 6R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 50-Year Rainfall=6.22"

Area (sf)	CN	Description
4,249	98	Paved parking, HSG A
4,395	39	>75% Grass cover, Good, HSG A
3,529	98	Roofs, HSG A
12,173	77	Weighted Average
4,395		36.10% Pervious Area
7,778		63.90% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.7	50	0.0140	0.12		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.02"
0.7	53	0.0290	1.19		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.8	126	0.0150	2.49		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
8.2	229	Total			

Summary for Subcatchment 208: To RGT 6

Runoff = 1.00 cfs @ 12.20 hrs, Volume= 3,647 cf, Depth> 3.66"
Routed to Reach 7R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 50-Year Rainfall=6.22"

Area (sf)	CN	Description
5,503	98	Paved parking, HSG A
4,332	39	>75% Grass cover, Good, HSG A
2,122	98	Roofs, HSG A
11,957	77	Weighted Average
4,332		36.23% Pervious Area
7,625		63.77% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
10.1	50	0.0050	0.08		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.02"
1.1	44	0.0090	0.66		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
1.1	57	0.0150	0.86		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
12.3	151	Total			

Summary for Subcatchment 209: To RGT 7

Runoff = 1.25 cfs @ 12.16 hrs, Volume= 4,024 cf, Depth> 2.60"
Routed to Pond 9R : Head Wall to Infiltration Pond

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 50-Year Rainfall=6.22"

Area (sf)	CN	Description
6,488	98	Paved parking, HSG A
10,084	39	>75% Grass cover, Good, HSG A
2,016	98	Roofs, HSG A
18,588	66	Weighted Average
10,084		54.25% Pervious Area
8,504		45.75% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.8	50	0.0200	0.14		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.02"
0.3	18	0.0200	0.99		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.2	29	0.0200	2.87		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
1.1	69	0.0230	1.06		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.0	5	0.0100	2.03		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
1.0	60	0.0200	0.99		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.4	66	0.0150	2.49		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
8.8	297	Total			

Summary for Subcatchment 210: To Swale

Runoff = 0.20 cfs @ 12.14 hrs, Volume= 600 cf, Depth> 1.81"
Routed to Reach 6R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 50-Year Rainfall=6.22"

Area (sf)	CN	Description
1,231	98	Paved parking, HSG A
2,756	39	>75% Grass cover, Good, HSG A
3,987	57	Weighted Average
2,756		69.12% Pervious Area
1,231		30.88% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Summary for Subcatchment 211: To Swale

Runoff = 0.12 cfs @ 12.14 hrs, Volume= 354 cf, Depth> 2.24"
Routed to Reach 5R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 50-Year Rainfall=6.22"

Area (sf)	CN	Description
727	98	Paved parking, HSG A
1,170	39	>75% Grass cover, Good, HSG A
1,897	62	Weighted Average
1,170		61.68% Pervious Area
727		38.32% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Summary for Subcatchment 212: To Swale

Runoff = 0.18 cfs @ 12.14 hrs, Volume= 540 cf, Depth> 1.72"
Routed to Reach 5R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 50-Year Rainfall=6.22"

Area (sf)	CN	Description
1,080	98	Paved parking, HSG A
2,681	39	>75% Grass cover, Good, HSG A
3,761	56	Weighted Average
2,681		71.28% Pervious Area
1,080		28.72% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Summary for Subcatchment 213: To Swale

Runoff = 0.18 cfs @ 12.14 hrs, Volume= 518 cf, Depth> 2.42"
Routed to Reach 1R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 50-Year Rainfall=6.22"

Area (sf)	CN	Description
1,104	98	Paved parking, HSG A
1,467	39	>75% Grass cover, Good, HSG A
2,571	64	Weighted Average
1,467		57.06% Pervious Area
1,104		42.94% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Summary for Subcatchment 214: To Swale

Runoff = 0.18 cfs @ 12.14 hrs, Volume= 531 cf, Depth> 2.15"
Routed to Reach 1R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 50-Year Rainfall=6.22"

Area (sf)	CN	Description
1,082	98	Paved parking, HSG A
1,880	39	>75% Grass cover, Good, HSG A
2,962	61	Weighted Average
1,880		63.47% Pervious Area
1,082		36.53% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Summary for Subcatchment 215: To Swale

Runoff = 0.11 cfs @ 12.14 hrs, Volume= 329 cf, Depth> 2.06"
Routed to Reach 2R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 50-Year Rainfall=6.22"

Area (sf)	CN	Description
685	98	Paved parking, HSG A
1,227	39	>75% Grass cover, Good, HSG A
1,912	60	Weighted Average
1,227		64.17% Pervious Area
685		35.83% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Summary for Subcatchment 216: To Swale

Runoff = 0.03 cfs @ 12.14 hrs, Volume= 105 cf, Depth> 1.56"
Routed to Reach 3R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 50-Year Rainfall=6.22"

Area (sf)	CN	Description
598	39	>75% Grass cover, Good, HSG A
209	98	Paved parking, HSG A
807	54	Weighted Average
598		74.10% Pervious Area
209		25.90% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Summary for Subcatchment 217: To Infiltration Pond

Runoff = 2.52 cfs @ 12.13 hrs, Volume= 7,221 cf, Depth> 3.47"
Routed to Pond P1 : Infiltration Pond

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 50-Year Rainfall=6.22"

Area (sf)	CN	Description
9,762	39	>75% Grass cover, Good, HSG A
1,513	98	Paved parking, HSG A
13,731	98	Water Surface, 0% imp, HSG A
25,006	75	Weighted Average
23,493		93.95% Pervious Area
1,513		6.05% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Summary for Subcatchment 218: To Swale

Runoff = 0.15 cfs @ 12.14 hrs, Volume= 424 cf, Depth> 1.98"
Routed to Reach 7R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 50-Year Rainfall=6.22"

Area (sf)	CN	Description
861	98	Paved parking, HSG A
1,716	39	>75% Grass cover, Good, HSG A
2,577	59	Weighted Average
1,716		66.59% Pervious Area
861		33.41% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Summary for Subcatchment 219: To Wetland

Runoff = 1.09 cfs @ 12.39 hrs, Volume= 8,799 cf, Depth> 0.75"
Routed to Link AP1 : Wetlands

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 50-Year Rainfall=6.22"

Area (sf)	CN	Description
7,467	98	Paved parking, HSG A
113,656	39	>75% Grass cover, Good, HSG A
16,637	32	Woods/grass comb., Good, HSG A
3,293	98	Roofs, HSG A
141,053	43	Weighted Average
130,293		92.37% Pervious Area
10,760		7.63% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
9.6	50	0.1600	0.09		**Sheet Flow,** Woods: Dense underbrush n= 0.800 P2= 3.02"
0.4	41	0.1000	1.58		**Shallow Concentrated Flow,** Woodland Kv= 5.0 fps
11.0	401	0.0075	0.61		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
21.0	492	Total			

Summary for Reach 1R: Swale

Inflow Area = 15,824 sf, 61.43% Impervious, Inflow Depth > 3.51" for 50-Year event
Inflow = 1.38 cfs @ 12.16 hrs, Volume= 4,634 cf
Outflow = 1.35 cfs @ 12.17 hrs, Volume= 4,626 cf, Atten= 2%, Lag= 1.0 min
Routed to Reach 2R : Swale

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 2.07 fps, Min. Travel Time= 1.4 min
Avg. Velocity = 0.65 fps, Avg. Travel Time= 4.5 min

Peak Storage= 115 cf @ 12.17 hrs
Average Depth at Peak Storage= 0.29' , Surface Width= 2.97'
Bank-Full Depth= 1.50' Flow Area= 7.9 sf, Capacity= 40.09 cfs

1.50' x 1.50' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 2.5 '/' Top Width= 9.00'
Length= 175.0' Slope= 0.0137 '/'
Inlet Invert= 254.40', Outlet Invert= 252.00'

Summary for Reach 2R: Swale

[62] Hint: Exceeded Reach 1R OUTLET depth by 0.19' @ 12.17 hrs

Inflow Area = 31,784 sf, 61.23% Impervious, Inflow Depth > 3.49" for 50-Year event
Inflow = 2.81 cfs @ 12.16 hrs, Volume= 9,245 cf
Outflow = 2.78 cfs @ 12.17 hrs, Volume= 9,236 cf, Atten= 1%, Lag= 0.7 min
Routed to Reach 3R : Swale

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 2.15 fps, Min. Travel Time= 0.9 min
Avg. Velocity = 0.70 fps, Avg. Travel Time= 2.7 min

Peak Storage= 149 cf @ 12.17 hrs
Average Depth at Peak Storage= 0.48' , Surface Width= 3.90'
Bank-Full Depth= 1.50' Flow Area= 7.9 sf, Capacity= 31.92 cfs

1.50' x 1.50' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 2.5 '/' Top Width= 9.00'
Length= 115.0' Slope= 0.0087 '/'
Inlet Invert= 252.00', Outlet Invert= 251.00'

Summary for Reach 3R: Swale

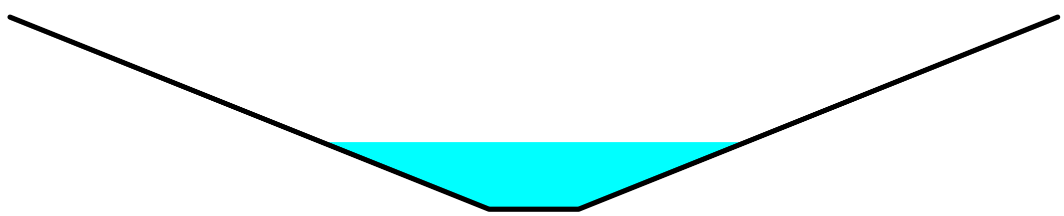
[62] Hint: Exceeded Reach 2R OUTLET depth by 0.05' @ 12.07 hrs

Inflow Area = 47,184 sf, 61.08% Impervious, Inflow Depth > 3.48" for 50-Year event
Inflow = 4.13 cfs @ 12.17 hrs, Volume= 13,673 cf
Outflow = 4.13 cfs @ 12.17 hrs, Volume= 13,671 cf, Atten= 0%, Lag= 0.1 min
Routed to Pond 4R : Pipe to Infiltration Pond

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 3.92 fps, Min. Travel Time= 0.1 min
Avg. Velocity = 1.42 fps, Avg. Travel Time= 0.4 min

Peak Storage= 34 cf @ 12.17 hrs
Average Depth at Peak Storage= 0.52' , Surface Width= 3.32'
Bank-Full Depth= 1.50' Flow Area= 6.7 sf, Capacity= 48.70 cfs

0.70' x 1.50' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 2.5 '/' Top Width= 8.20'
Length= 32.0' Slope= 0.0313 '/'
Inlet Invert= 251.00', Outlet Invert= 250.00'



Summary for Reach 5R: Swale

Inflow Area = 12,526 sf, 60.61% Impervious, Inflow Depth > 3.56" for 50-Year event
Inflow = 1.06 cfs @ 12.16 hrs, Volume= 3,721 cf
Outflow = 1.04 cfs @ 12.17 hrs, Volume= 3,715 cf, Atten= 2%, Lag= 1.0 min
Routed to Reach 6R : Swale

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 1.77 fps, Min. Travel Time= 1.4 min
Avg. Velocity = 0.54 fps, Avg. Travel Time= 4.5 min

Peak Storage= 86 cf @ 12.17 hrs
Average Depth at Peak Storage= 0.27' , Surface Width= 2.85'
Bank-Full Depth= 1.50' Flow Area= 7.9 sf, Capacity= 35.84 cfs

1.50' x 1.50' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 2.5 '/' Top Width= 9.00'
Length= 146.0' Slope= 0.0110 '/'
Inlet Invert= 255.00', Outlet Invert= 253.40'

Summary for Reach 6R: Swale

[62] Hint: Exceeded Reach 5R OUTLET depth by 0.16' @ 12.17 hrs

Inflow Area = 28,686 sf, 57.87% Impervious, Inflow Depth > 3.36" for 50-Year event
Inflow = 2.40 cfs @ 12.16 hrs, Volume= 8,033 cf
Outflow = 2.37 cfs @ 12.17 hrs, Volume= 8,022 cf, Atten= 2%, Lag= 0.8 min
Routed to Reach 7R : Swale

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 2.10 fps, Min. Travel Time= 1.2 min
Avg. Velocity = 0.65 fps, Avg. Travel Time= 3.9 min

Peak Storage= 170 cf @ 12.17 hrs
Average Depth at Peak Storage= 0.43' , Surface Width= 3.67'
Bank-Full Depth= 1.50' Flow Area= 7.9 sf, Capacity= 32.96 cfs

1.50' x 1.50' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 2.5 '/' Top Width= 9.00'
Length= 151.0' Slope= 0.0093 '/'
Inlet Invert= 253.40', Outlet Invert= 252.00'

Summary for Reach 7R: Swale

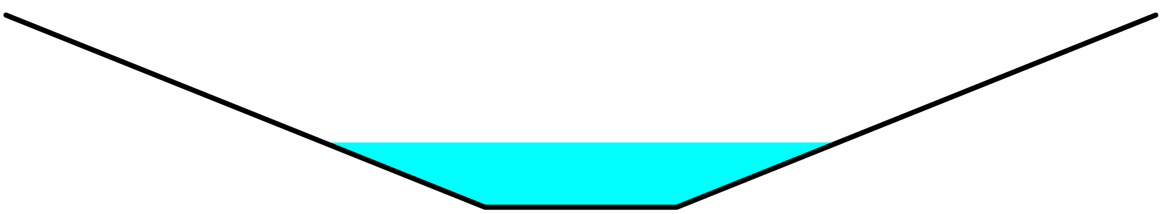
[62] Hint: Exceeded Reach 6R OUTLET depth by 0.09' @ 12.26 hrs

Inflow Area = 43,220 sf, 58.04% Impervious, Inflow Depth > 3.36" for 50-Year event
Inflow = 3.46 cfs @ 12.18 hrs, Volume= 12,094 cf
Outflow = 3.43 cfs @ 12.19 hrs, Volume= 12,082 cf, Atten= 1%, Lag= 0.7 min
Routed to Pond 9R : Head Wall to Infiltration Pond

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 2.45 fps, Min. Travel Time= 1.0 min
Avg. Velocity = 0.78 fps, Avg. Travel Time= 3.0 min

Peak Storage= 196 cf @ 12.19 hrs
Average Depth at Peak Storage= 0.51' , Surface Width= 4.03'
Bank-Full Depth= 1.50' Flow Area= 7.9 sf, Capacity= 35.44 cfs

1.50' x 1.50' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 2.5 '/' Top Width= 9.00'
Length= 140.0' Slope= 0.0107 '/'
Inlet Invert= 252.00', Outlet Invert= 250.50'



Summary for Reach 8R: Foxhole 1

[52] Hint: Inlet/Outlet conditions not evaluated

Inflow Area = 8,236 sf, 77.20% Impervious, Inflow Depth > 4.50" for 50-Year event
Inflow = 1.04 cfs @ 12.13 hrs, Volume= 3,092 cf
Outflow = 1.04 cfs @ 12.13 hrs, Volume= 3,091 cf, Atten= 0%, Lag= 0.0 min
Routed to Pond P1 : Infiltration Pond

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 5.42 fps, Min. Travel Time= 0.0 min
Avg. Velocity = 1.32 fps, Avg. Travel Time= 0.2 min

Peak Storage= 3 cf @ 12.13 hrs
Average Depth at Peak Storage= 0.10' , Surface Width= 1.83'
Bank-Full Depth= 0.38' Flow Area= 0.7 sf, Capacity= 5.21 cfs

22.0" W x 4.5" H Box Pipe
n= 0.013 Concrete, trowel finish
Length= 14.3' Slope= 0.0524 '/'
Inlet Invert= 253.28', Outlet Invert= 252.53'

Summary for Reach 10R: Foxhole 2

[52] Hint: Inlet/Outlet conditions not evaluated

Inflow Area = 9,659 sf, 79.19% Impervious, Inflow Depth > 4.61" for 50-Year event
Inflow = 1.24 cfs @ 12.13 hrs, Volume= 3,713 cf
Outflow = 1.24 cfs @ 12.13 hrs, Volume= 3,713 cf, Atten= 0%, Lag= 0.0 min
Routed to Pond P1 : Infiltration Pond

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 6.84 fps, Min. Travel Time= 0.0 min
Avg. Velocity = 1.66 fps, Avg. Travel Time= 0.1 min

Peak Storage= 2 cf @ 12.13 hrs
Average Depth at Peak Storage= 0.10' , Surface Width= 1.83'
Bank-Full Depth= 0.38' Flow Area= 0.7 sf, Capacity= 6.80 cfs

22.0" W x 4.5" H Box Pipe
n= 0.013 Concrete, trowel finish
Length= 8.4' Slope= 0.0893 '/'
Inlet Invert= 251.90', Outlet Invert= 251.15'

Summary for Pond 4R: Pipe to Infiltration Pond

[62] Hint: Exceeded Reach 3R OUTLET depth by 0.41' @ 12.18 hrs

Inflow Area = 47,184 sf, 61.08% Impervious, Inflow Depth > 3.48" for 50-Year event
Inflow = 4.13 cfs @ 12.17 hrs, Volume= 13,671 cf
Outflow = 4.11 cfs @ 12.18 hrs, Volume= 13,668 cf, Atten= 0%, Lag= 0.4 min
Primary = 4.11 cfs @ 12.18 hrs, Volume= 13,668 cf
Routed to Pond P1 : Infiltration Pond

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Peak Elev= 250.93' @ 12.18 hrs Surf.Area= 170 sf Storage= 89 cf

Plug-Flow detention time= 0.5 min calculated for 13,662 cf (100% of inflow)
Center-of-Mass det. time= 0.4 min (834.0 - 833.6)

Volume	Invert	Avail.Storage	Storage Description
#1	250.00'	620 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
250.00	22	0	0
251.00	181	102	102
252.00	855	518	620

Device	Routing	Invert	Outlet Devices
#1	Primary	250.00'	**12.0" Round Culvert X 2.00** L= 55.0' Ke= 0.500 Inlet / Outlet Invert= 250.00' / 249.72' S= 0.0051 '/' Cc= 0.900 n= 0.012 Corrugated PP, smooth interior, Flow Area= 0.79 sf

Primary OutFlow Max=4.11 cfs @ 12.18 hrs HW=250.93' TW=250.01' (Dynamic Tailwater)
└─**1=Culvert** (Barrel Controls 4.11 cfs @ 3.51 fps)

Summary for Pond 9R: Head Wall to Infiltration Pond

[62] Hint: Exceeded Reach 7R OUTLET depth by 0.30' @ 12.20 hrs

Inflow Area = 61,808 sf, 54.35% Impervious, Inflow Depth > 3.13" for 50-Year event
Inflow = 4.64 cfs @ 12.18 hrs, Volume= 16,106 cf
Outflow = 4.61 cfs @ 12.19 hrs, Volume= 16,092 cf, Atten= 1%, Lag= 0.7 min
Primary = 4.61 cfs @ 12.19 hrs, Volume= 16,092 cf
Routed to Pond P1 : Infiltration Pond

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Peak Elev= 251.30' @ 12.19 hrs Surf.Area= 409 sf Storage= 197 cf

Plug-Flow detention time= 1.5 min calculated for 16,092 cf (100% of inflow)
Center-of-Mass det. time= 1.0 min (840.6 - 839.6)

Volume	Invert	Avail.Storage	Storage Description
#1	250.50'	288 cf	**Custom Stage Data (Irregular)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Perim. (feet)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)	Wet.Area (sq-ft)
250.50	121	75.8	0	0	121
251.00	269	116.2	95	95	740
251.50	517	131.6	193	288	1,050

Device	Routing	Invert	Outlet Devices
#1	Primary	250.50'	**15.0" Round Culvert X 2.00** L= 29.8' RCP, groove end w/headwall, Ke= 0.200 Inlet / Outlet Invert= 250.50' / 250.00' S= 0.0168 '/' Cc= 0.900 n= 0.020 Corrugated PE, corrugated interior, Flow Area= 1.23 sf

Primary OutFlow Max=4.60 cfs @ 12.19 hrs HW=251.30' TW=250.05' (Dynamic Tailwater)
└**1=Culvert** (Barrel Controls 4.60 cfs @ 3.94 fps)

Summary for Pond P1: Infiltration Pond

Inflow Area = 151,893 sf, 51.31% Impervious, Inflow Depth > 3.46" for 50-Year event
Inflow = 12.69 cfs @ 12.16 hrs, Volume= 43,786 cf
Outflow = 3.14 cfs @ 12.54 hrs, Volume= 43,775 cf, Atten= 75%, Lag= 22.8 min
Discarded = 3.14 cfs @ 12.54 hrs, Volume= 43,775 cf
Primary = 0.00 cfs @ 0.00 hrs, Volume= 0 cf
Routed to Link AP1 : Wetlands

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Peak Elev= 250.36' @ 12.54 hrs Surf.Area= 12,473 sf Storage= 9,878 cf

Plug-Flow detention time= 20.5 min calculated for 43,756 cf (100% of inflow)
Center-of-Mass det. time= 20.3 min (851.9 - 831.6)

Volume	Invert	Avail.Storage	Storage Description
#1	249.50'	28,409 cf	**Custom Stage Data (Irregular)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Perim. (feet)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)	Wet.Area (sq-ft)
249.50	10,423	450.6	0	0	10,423
250.00	11,803	469.4	5,553	5,553	11,818
251.00	13,731	494.5	12,755	18,308	13,803
251.70	15,140	512.1	10,101	28,409	15,256

Device	Routing	Invert	Outlet Devices
#1	Primary	250.70'	**10.0' long x 19.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63
#2	Discarded	249.50'	**8.270 in/hr Exfiltration over Surface area** Conductivity to Groundwater Elevation = 247.00' Phase-In= 0.01'

Discarded OutFlow Max=3.14 cfs @ 12.54 hrs HW=250.36' (Free Discharge)
└─**2=Exfiltration** (Controls 3.14 cfs)

Primary OutFlow Max=0.00 cfs @ 0.00 hrs HW=249.50' TW=0.00' (Dynamic Tailwater)
└─**1=Broad-Crested Rectangular Weir** (Controls 0.00 cfs)

Summary for Link AP1: Wetlands

Inflow Area = 292,946 sf, 30.27% Impervious, Inflow Depth > 0.36" for 50-Year event
Inflow = 1.09 cfs @ 12.39 hrs, Volume= 8,799 cf
Primary = 1.09 cfs @ 12.39 hrs, Volume= 8,799 cf, Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs

Time span=0.00-24.00 hrs, dt=0.01 hrs, 2401 points x 3
Runoff by SCS TR-20 method, UH=SCS, Weighted-CN
Reach routing by Dyn-Stor-Ind method - Pond routing by Dyn-Stor-Ind method

Subcatchment201: To Foxhole 1 Runoff Area=8,236 sf 77.20% Impervious Runoff Depth>5.52"
Tc=6.0 min CN=85 Runoff=1.26 cfs 3,791 cf

Subcatchment202: To Foxhole 2 Runoff Area=9,659 sf 79.19% Impervious Runoff Depth>5.64"
Tc=6.0 min CN=86 Runoff=1.50 cfs 4,538 cf

Subcatchment203: To RGT 1 Runoff Area=14,593 sf 62.69% Impervious Runoff Depth>4.51"
Flow Length=301' Tc=9.5 min CN=76 Runoff=1.66 cfs 5,480 cf

Subcatchment204: To RGT 2 Runoff Area=14,048 sf 64.46% Impervious Runoff Depth>4.62"
Flow Length=270' Slope=0.0150 '/' Tc=8.1 min CN=77 Runoff=1.72 cfs 5,407 cf

Subcatchment205: To RGT 3 Runoff Area=10,291 sf 73.21% Impervious Runoff Depth>5.18"
Flow Length=246' Tc=10.0 min CN=82 Runoff=1.29 cfs 4,440 cf

Subcatchment206: To RGT 4 Runoff Area=6,868 sf 84.23% Impervious Runoff Depth>5.98"
Flow Length=191' Tc=10.4 min CN=89 Runoff=0.94 cfs 3,422 cf

Subcatchment207: To RGT 5 Runoff Area=12,173 sf 63.90% Impervious Runoff Depth>4.62"
Flow Length=229' Tc=8.2 min CN=77 Runoff=1.49 cfs 4,685 cf

Subcatchment208: To RGT 6 Runoff Area=11,957 sf 63.77% Impervious Runoff Depth>4.61"
Flow Length=151' Tc=12.3 min CN=77 Runoff=1.25 cfs 4,597 cf

Subcatchment209: To RGT 7 Runoff Area=18,588 sf 45.75% Impervious Runoff Depth>3.43"
Flow Length=297' Tc=8.8 min CN=66 Runoff=1.66 cfs 5,306 cf

Subcatchment210: To Swale Runoff Area=3,987 sf 30.88% Impervious Runoff Depth>2.50"
Tc=6.0 min CN=57 Runoff=0.29 cfs 832 cf

Subcatchment211: To Swale Runoff Area=1,897 sf 38.32% Impervious Runoff Depth>3.01"
Tc=6.0 min CN=62 Runoff=0.17 cfs 476 cf

Subcatchment212: To Swale Runoff Area=3,761 sf 28.72% Impervious Runoff Depth>2.40"
Tc=6.0 min CN=56 Runoff=0.26 cfs 753 cf

Subcatchment213: To Swale Runoff Area=2,571 sf 42.94% Impervious Runoff Depth>3.22"
Tc=6.0 min CN=64 Runoff=0.24 cfs 689 cf

Subcatchment214: To Swale Runoff Area=2,962 sf 36.53% Impervious Runoff Depth>2.91"
Tc=6.0 min CN=61 Runoff=0.25 cfs 718 cf

Subcatchment215: To Swale Runoff Area=1,912 sf 35.83% Impervious Runoff Depth>2.81"
Tc=6.0 min CN=60 Runoff=0.16 cfs 447 cf

Subcatchment216: To Swale Runoff Area=807 sf 25.90% Impervious Runoff Depth>2.21"
Tc=6.0 min CN=54 Runoff=0.05 cfs 148 cf

Subcatchment217: To Infiltration Pond Runoff Area=25,006 sf 6.05% Impervious Runoff Depth>4.40"
Tc=6.0 min CN=75 Runoff=3.18 cfs 9,168 cf

Subcatchment218: To Swale Runoff Area=2,577 sf 33.41% Impervious Runoff Depth>2.70"
Tc=6.0 min CN=59 Runoff=0.20 cfs 581 cf

Subcatchment219: To Wetland Runoff Area=141,053 sf 7.63% Impervious Runoff Depth>1.19"
Flow Length=492' Tc=21.0 min CN=43 Runoff=2.21 cfs 13,996 cf

Reach 1R: Swale Avg. Flow Depth=0.33' Max Vel=2.21 fps Inflow=1.73 cfs 5,847 cf
n=0.030 L=175.0' S=0.0137 '/' Capacity=40.09 cfs Outflow=1.70 cfs 5,839 cf

Reach 2R: Swale Avg. Flow Depth=0.54' Max Vel=2.29 fps Inflow=3.55 cfs 11,692 cf
n=0.030 L=115.0' S=0.0087 '/' Capacity=31.92 cfs Outflow=3.52 cfs 11,682 cf

Reach 3R: Swale Avg. Flow Depth=0.58' Max Vel=4.16 fps Inflow=5.22 cfs 17,311 cf
n=0.030 L=32.0' S=0.0313 '/' Capacity=48.70 cfs Outflow=5.22 cfs 17,309 cf

Reach 5R: Swale Avg. Flow Depth=0.31' Max Vel=1.89 fps Inflow=1.32 cfs 4,651 cf
n=0.030 L=146.0' S=0.0110 '/' Capacity=35.84 cfs Outflow=1.30 cfs 4,645 cf

Reach 6R: Swale Avg. Flow Depth=0.49' Max Vel=2.25 fps Inflow=3.05 cfs 10,162 cf
n=0.030 L=151.0' S=0.0093 '/' Capacity=32.96 cfs Outflow=3.00 cfs 10,150 cf

Reach 7R: Swale Avg. Flow Depth=0.57' Max Vel=2.62 fps Inflow=4.39 cfs 15,328 cf
n=0.030 L=140.0' S=0.0107 '/' Capacity=35.44 cfs Outflow=4.35 cfs 15,314 cf

Reach 8R: Foxhole 1 Avg. Flow Depth=0.12' Max Vel=5.82 fps Inflow=1.26 cfs 3,791 cf
22.0" x 4.5" Box Pipe n=0.013 L=14.3' S=0.0524 '/' Capacity=5.21 cfs Outflow=1.26 cfs 3,791 cf

Reach 10R: Foxhole 2 Avg. Flow Depth=0.11' Max Vel=7.34 fps Inflow=1.50 cfs 4,538 cf
22.0" x 4.5" Box Pipe n=0.013 L=8.4' S=0.0893 '/' Capacity=6.80 cfs Outflow=1.50 cfs 4,538 cf

Pond 4R: Pipe to Infiltration Pond Peak Elev=251.11' Storage=126 cf Inflow=5.22 cfs 17,309 cf
12.0" Round Culvert x 2.00 n=0.012 L=55.0' S=0.0051 '/' Outflow=5.16 cfs 17,305 cf

Pond 9R: Head Wall to Infiltration Pond Peak Elev=251.43' Storage=255 cf Inflow=5.97 cfs 20,620 cf
15.0" Round Culvert x 2.00 n=0.020 L=29.8' S=0.0168 '/' Outflow=5.91 cfs 20,605 cf

Pond P1: Infiltration Pond Peak Elev=250.67' Storage=13,893 cf Inflow=16.00 cfs 55,407 cf
Discarded=3.55 cfs 55,394 cf Primary=0.00 cfs 0 cf Outflow=3.55 cfs 55,394 cf

Link AP1: Wetlands Inflow=2.21 cfs 13,996 cf
Primary=2.21 cfs 13,996 cf

Total Runoff Area = 292,946 sf Runoff Volume = 69,473 cf Average Runoff Depth = 2.85"
69.73% Pervious = 204,257 sf 30.27% Impervious = 88,689 sf

Summary for Subcatchment 201: To Foxhole 1

Runoff = 1.26 cfs @ 12.13 hrs, Volume= 3,791 cf, Depth> 5.52"
Routed to Reach 8R : Foxhole 1

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 100-Year Rainfall=7.29"

Area (sf)	CN	Description
6,358	98	Paved parking, HSG A
1,878	39	>75% Grass cover, Good, HSG A
8,236	85	Weighted Average
1,878		22.80% Pervious Area
6,358		77.20% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Summary for Subcatchment 202: To Foxhole 2

Runoff = 1.50 cfs @ 12.13 hrs, Volume= 4,538 cf, Depth> 5.64"
Routed to Reach 10R : Foxhole 2

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 100-Year Rainfall=7.29"

Area (sf)	CN	Description
7,031	98	Paved parking, HSG A
2,010	39	>75% Grass cover, Good, HSG A
618	98	Roofs, HSG A
9,659	86	Weighted Average
2,010		20.81% Pervious Area
7,649		79.19% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Summary for Subcatchment 203: To RGT 1

Runoff = 1.66 cfs @ 12.17 hrs, Volume= 5,480 cf, Depth> 4.51"
Routed to Reach 3R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 100-Year Rainfall=7.29"

Area (sf)	CN	Description
5,212	98	Paved parking, HSG A
5,444	39	>75% Grass cover, Good, HSG A
3,937	98	Roofs, HSG A
14,593	76	Weighted Average
5,444		37.31% Pervious Area
9,149		62.69% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
0.3	17	0.0190	0.92		**Sheet Flow, Sidewalk** Smooth surfaces n= 0.011 P2= 3.02"
6.6	70	0.0280	0.18		**Sheet Flow, Grass** Grass: Short n= 0.150 P2= 3.02"
0.1	8	0.0100	2.03		**Shallow Concentrated Flow, Sidewalk** Paved Kv= 20.3 fps
1.5	90	0.0200	0.99		**Shallow Concentrated Flow, Grass** Short Grass Pasture Kv= 7.0 fps
1.0	116	0.0100	2.03		**Shallow Concentrated Flow, Road** Paved Kv= 20.3 fps
9.5	301	Total			

Summary for Subcatchment 204: To RGT 2

Runoff = 1.72 cfs @ 12.15 hrs, Volume= 5,407 cf, Depth> 4.62"
Routed to Reach 2R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 100-Year Rainfall=7.29"

Area (sf)	CN	Description
5,526	98	Paved parking, HSG A
4,993	39	>75% Grass cover, Good, HSG A
3,529	98	Roofs, HSG A
14,048	77	Weighted Average
4,993		35.54% Pervious Area
9,055		64.46% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.5	50	0.0150	0.13		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.02"
0.2	8	0.0150	0.86		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
1.4	212	0.0150	2.49		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
8.1	270	Total			

Summary for Subcatchment 205: To RGT 3

Runoff = 1.29 cfs @ 12.17 hrs, Volume= 4,440 cf, Depth> 5.18"
Routed to Reach 1R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 100-Year Rainfall=7.29"

Area (sf)	CN	Description
5,110	98	Paved parking, HSG A
2,757	39	>75% Grass cover, Good, HSG A
2,424	98	Roofs, HSG A
10,291	82	Weighted Average
2,757		26.79% Pervious Area
7,534		73.21% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
7.6	50	0.0100	0.11		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.02"
1.1	34	0.0050	0.49		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
1.3	162	0.0100	2.03		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
10.0	246	Total			

Summary for Subcatchment 206: To RGT 4

Runoff = 0.94 cfs @ 12.17 hrs, Volume= 3,422 cf, Depth> 5.98"
Routed to Reach 5R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 100-Year Rainfall=7.29"

Area (sf)	CN	Description
4,247	98	Paved parking, HSG A
1,083	39	>75% Grass cover, Good, HSG A
1,538	98	Roofs, HSG A
6,868	89	Weighted Average
1,083		15.77% Pervious Area
5,785		84.23% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
9.4	46	0.0050	0.08		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.02"
1.0	145	0.0150	2.49		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
10.4	191	Total			

Summary for Subcatchment 207: To RGT 5

Runoff = 1.49 cfs @ 12.15 hrs, Volume= 4,685 cf, Depth> 4.62"
Routed to Reach 6R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 100-Year Rainfall=7.29"

Area (sf)	CN	Description
4,249	98	Paved parking, HSG A
4,395	39	>75% Grass cover, Good, HSG A
3,529	98	Roofs, HSG A
12,173	77	Weighted Average
4,395		36.10% Pervious Area
7,778		63.90% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.7	50	0.0140	0.12		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.02"
0.7	53	0.0290	1.19		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.8	126	0.0150	2.49		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
8.2	229	Total			

Summary for Subcatchment 208: To RGT 6

Runoff = 1.25 cfs @ 12.20 hrs, Volume= 4,597 cf, Depth> 4.61"
Routed to Reach 7R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 100-Year Rainfall=7.29"

Area (sf)	CN	Description
5,503	98	Paved parking, HSG A
4,332	39	>75% Grass cover, Good, HSG A
2,122	98	Roofs, HSG A
11,957	77	Weighted Average
4,332		36.23% Pervious Area
7,625		63.77% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
10.1	50	0.0050	0.08		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.02"
1.1	44	0.0090	0.66		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
1.1	57	0.0150	0.86		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
12.3	151	Total			

Summary for Subcatchment 209: To RGT 7

Runoff = 1.66 cfs @ 12.16 hrs, Volume= 5,306 cf, Depth> 3.43"
Routed to Pond 9R : Head Wall to Infiltration Pond

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 100-Year Rainfall=7.29"

Area (sf)	CN	Description
6,488	98	Paved parking, HSG A
10,084	39	>75% Grass cover, Good, HSG A
2,016	98	Roofs, HSG A
18,588	66	Weighted Average
10,084		54.25% Pervious Area
8,504		45.75% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
5.8	50	0.0200	0.14		**Sheet Flow,** Grass: Short n= 0.150 P2= 3.02"
0.3	18	0.0200	0.99		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.2	29	0.0200	2.87		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
1.1	69	0.0230	1.06		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.0	5	0.0100	2.03		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
1.0	60	0.0200	0.99		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
0.4	66	0.0150	2.49		**Shallow Concentrated Flow,** Paved Kv= 20.3 fps
8.8	297	Total			

Summary for Subcatchment 210: To Swale

Runoff = 0.29 cfs @ 12.14 hrs, Volume= 832 cf, Depth> 2.50"
Routed to Reach 6R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 100-Year Rainfall=7.29"

Area (sf)	CN	Description
1,231	98	Paved parking, HSG A
2,756	39	>75% Grass cover, Good, HSG A
3,987	57	Weighted Average
2,756		69.12% Pervious Area
1,231		30.88% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Summary for Subcatchment 211: To Swale

Runoff = 0.17 cfs @ 12.13 hrs, Volume= 476 cf, Depth> 3.01"
Routed to Reach 5R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 100-Year Rainfall=7.29"

Area (sf)	CN	Description
727	98	Paved parking, HSG A
1,170	39	>75% Grass cover, Good, HSG A
1,897	62	Weighted Average
1,170		61.68% Pervious Area
727		38.32% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Summary for Subcatchment 212: To Swale

Runoff = 0.26 cfs @ 12.14 hrs, Volume= 753 cf, Depth> 2.40"
Routed to Reach 5R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 100-Year Rainfall=7.29"

Area (sf)	CN	Description
1,080	98	Paved parking, HSG A
2,681	39	>75% Grass cover, Good, HSG A
3,761	56	Weighted Average
2,681		71.28% Pervious Area
1,080		28.72% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Summary for Subcatchment 213: To Swale

Runoff = 0.24 cfs @ 12.13 hrs, Volume= 689 cf, Depth> 3.22"
Routed to Reach 1R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 100-Year Rainfall=7.29"

Area (sf)	CN	Description
1,104	98	Paved parking, HSG A
1,467	39	>75% Grass cover, Good, HSG A
2,571	64	Weighted Average
1,467		57.06% Pervious Area
1,104		42.94% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Summary for Subcatchment 214: To Swale

Runoff = 0.25 cfs @ 12.13 hrs, Volume= 718 cf, Depth> 2.91"
Routed to Reach 1R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 100-Year Rainfall=7.29"

Area (sf)	CN	Description
1,082	98	Paved parking, HSG A
1,880	39	>75% Grass cover, Good, HSG A
2,962	61	Weighted Average
1,880		63.47% Pervious Area
1,082		36.53% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Summary for Subcatchment 215: To Swale

Runoff = 0.16 cfs @ 12.14 hrs, Volume= 447 cf, Depth> 2.81"
Routed to Reach 2R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 100-Year Rainfall=7.29"

Area (sf)	CN	Description
685	98	Paved parking, HSG A
1,227	39	>75% Grass cover, Good, HSG A
1,912	60	Weighted Average
1,227		64.17% Pervious Area
685		35.83% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Summary for Subcatchment 216: To Swale

Runoff = 0.05 cfs @ 12.14 hrs, Volume= 148 cf, Depth> 2.21"
Routed to Reach 3R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 100-Year Rainfall=7.29"

Area (sf)	CN	Description
598	39	>75% Grass cover, Good, HSG A
209	98	Paved parking, HSG A
807	54	Weighted Average
598		74.10% Pervious Area
209		25.90% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Summary for Subcatchment 217: To Infiltration Pond

Runoff = 3.18 cfs @ 12.13 hrs, Volume= 9,168 cf, Depth> 4.40"
Routed to Pond P1 : Infiltration Pond

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 100-Year Rainfall=7.29"

Area (sf)	CN	Description
9,762	39	>75% Grass cover, Good, HSG A
1,513	98	Paved parking, HSG A
13,731	98	Water Surface, 0% imp, HSG A
25,006	75	Weighted Average
23,493		93.95% Pervious Area
1,513		6.05% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Summary for Subcatchment 218: To Swale

Runoff = 0.20 cfs @ 12.14 hrs, Volume= 581 cf, Depth> 2.70"
Routed to Reach 7R : Swale

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 100-Year Rainfall=7.29"

Area (sf)	CN	Description
861	98	Paved parking, HSG A
1,716	39	>75% Grass cover, Good, HSG A
2,577	59	Weighted Average
1,716		66.59% Pervious Area
861		33.41% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
6.0					**Direct Entry,**

Summary for Subcatchment 219: To Wetland

Runoff = 2.21 cfs @ 12.36 hrs, Volume= 13,996 cf, Depth> 1.19"
Routed to Link AP1 : Wetlands

Runoff by SCS TR-20 method, UH=SCS, Weighted-CN, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs
NRCC 24-hr C 100-Year Rainfall=7.29"

Area (sf)	CN	Description
7,467	98	Paved parking, HSG A
113,656	39	>75% Grass cover, Good, HSG A
16,637	32	Woods/grass comb., Good, HSG A
3,293	98	Roofs, HSG A
141,053	43	Weighted Average
130,293		92.37% Pervious Area
10,760		7.63% Impervious Area

Tc (min)	Length (feet)	Slope (ft/ft)	Velocity (ft/sec)	Capacity (cfs)	Description
9.6	50	0.1600	0.09		**Sheet Flow,** Woods: Dense underbrush n= 0.800 P2= 3.02"
0.4	41	0.1000	1.58		**Shallow Concentrated Flow,** Woodland Kv= 5.0 fps
11.0	401	0.0075	0.61		**Shallow Concentrated Flow,** Short Grass Pasture Kv= 7.0 fps
21.0	492	Total			

Summary for Reach 1R: Swale

Inflow Area = 15,824 sf, 61.43% Impervious, Inflow Depth > 4.43" for 100-Year event
Inflow = 1.73 cfs @ 12.16 hrs, Volume= 5,847 cf
Outflow = 1.70 cfs @ 12.17 hrs, Volume= 5,839 cf, Atten= 2%, Lag= 1.0 min
Routed to Reach 2R : Swale

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 2.21 fps, Min. Travel Time= 1.3 min
Avg. Velocity = 0.69 fps, Avg. Travel Time= 4.2 min

Peak Storage= 135 cf @ 12.17 hrs
Average Depth at Peak Storage= 0.33' , Surface Width= 3.16'
Bank-Full Depth= 1.50' Flow Area= 7.9 sf, Capacity= 40.09 cfs

1.50' x 1.50' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 2.5 '/' Top Width= 9.00'
Length= 175.0' Slope= 0.0137 '/'
Inlet Invert= 254.40', Outlet Invert= 252.00'

Summary for Reach 2R: Swale

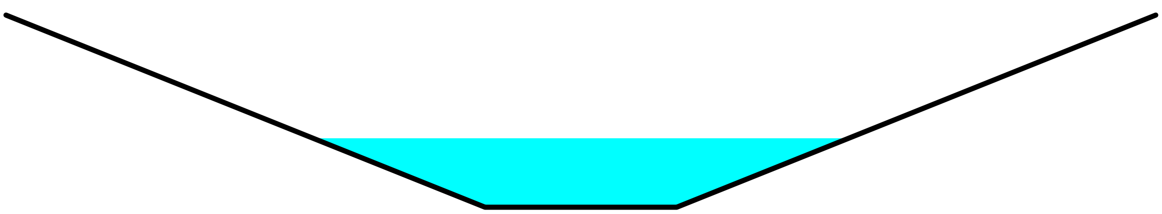
[62] Hint: Exceeded Reach 1R OUTLET depth by 0.21' @ 12.17 hrs

Inflow Area = 31,784 sf, 61.23% Impervious, Inflow Depth > 4.41" for 100-Year event
Inflow = 3.55 cfs @ 12.16 hrs, Volume= 11,692 cf
Outflow = 3.52 cfs @ 12.17 hrs, Volume= 11,682 cf, Atten= 1%, Lag= 0.6 min
Routed to Reach 3R : Swale

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 2.29 fps, Min. Travel Time= 0.8 min
Avg. Velocity = 0.75 fps, Avg. Travel Time= 2.6 min

Peak Storage= 177 cf @ 12.17 hrs
Average Depth at Peak Storage= 0.54' , Surface Width= 4.20'
Bank-Full Depth= 1.50' Flow Area= 7.9 sf, Capacity= 31.92 cfs

1.50' x 1.50' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 2.5 '/' Top Width= 9.00'
Length= 115.0' Slope= 0.0087 '/'
Inlet Invert= 252.00', Outlet Invert= 251.00'



Summary for Reach 3R: Swale

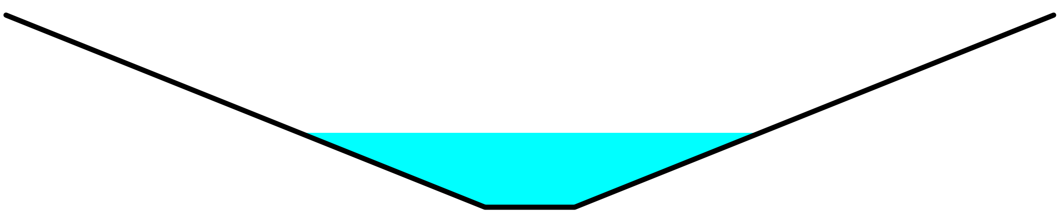
[62] Hint: Exceeded Reach 2R OUTLET depth by 0.05' @ 12.05 hrs

Inflow Area = 47,184 sf, 61.08% Impervious, Inflow Depth > 4.40" for 100-Year event
Inflow = 5.22 cfs @ 12.17 hrs, Volume= 17,311 cf
Outflow = 5.22 cfs @ 12.17 hrs, Volume= 17,309 cf, Atten= 0%, Lag= 0.1 min
Routed to Pond 4R : Pipe to Infiltration Pond

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 4.16 fps, Min. Travel Time= 0.1 min
Avg. Velocity = 1.51 fps, Avg. Travel Time= 0.4 min

Peak Storage= 40 cf @ 12.17 hrs
Average Depth at Peak Storage= 0.58' , Surface Width= 3.61'
Bank-Full Depth= 1.50' Flow Area= 6.7 sf, Capacity= 48.70 cfs

0.70' x 1.50' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 2.5 '/' Top Width= 8.20'
Length= 32.0' Slope= 0.0313 '/'
Inlet Invert= 251.00', Outlet Invert= 250.00'



Summary for Reach 5R: Swale

Inflow Area = 12,526 sf, 60.61% Impervious, Inflow Depth > 4.46" for 100-Year event
Inflow = 1.32 cfs @ 12.15 hrs, Volume= 4,651 cf
Outflow = 1.30 cfs @ 12.17 hrs, Volume= 4,645 cf, Atten= 1%, Lag= 1.0 min
Routed to Reach 6R : Swale

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 1.89 fps, Min. Travel Time= 1.3 min
Avg. Velocity = 0.58 fps, Avg. Travel Time= 4.2 min

Peak Storage= 101 cf @ 12.17 hrs
Average Depth at Peak Storage= 0.31' , Surface Width= 3.03'
Bank-Full Depth= 1.50' Flow Area= 7.9 sf, Capacity= 35.84 cfs

1.50' x 1.50' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 2.5 '/' Top Width= 9.00'
Length= 146.0' Slope= 0.0110 '/'
Inlet Invert= 255.00', Outlet Invert= 253.40'

Summary for Reach 6R: Swale

[62] Hint: Exceeded Reach 5R OUTLET depth by 0.19' @ 12.17 hrs

Inflow Area = 28,686 sf, 57.87% Impervious, Inflow Depth > 4.25" for 100-Year event
Inflow = 3.05 cfs @ 12.16 hrs, Volume= 10,162 cf
Outflow = 3.00 cfs @ 12.17 hrs, Volume= 10,150 cf, Atten= 1%, Lag= 0.8 min
Routed to Reach 7R : Swale

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 2.25 fps, Min. Travel Time= 1.1 min
Avg. Velocity = 0.70 fps, Avg. Travel Time= 3.6 min

Peak Storage= 202 cf @ 12.17 hrs
Average Depth at Peak Storage= 0.49' , Surface Width= 3.95'
Bank-Full Depth= 1.50' Flow Area= 7.9 sf, Capacity= 32.96 cfs

1.50' x 1.50' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 2.5 '/' Top Width= 9.00'
Length= 151.0' Slope= 0.0093 '/'
Inlet Invert= 253.40', Outlet Invert= 252.00'

Summary for Reach 7R: Swale

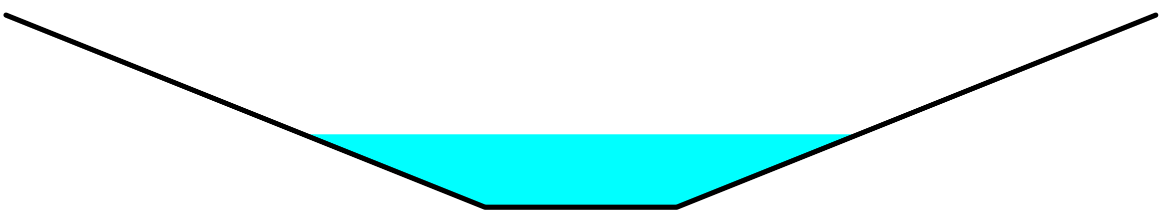
[62] Hint: Exceeded Reach 6R OUTLET depth by 0.10' @ 12.25 hrs

Inflow Area = 43,220 sf, 58.04% Impervious, Inflow Depth > 4.26" for 100-Year event
Inflow = 4.39 cfs @ 12.17 hrs, Volume= 15,328 cf
Outflow = 4.35 cfs @ 12.18 hrs, Volume= 15,314 cf, Atten= 1%, Lag= 0.7 min
Routed to Pond 9R : Head Wall to Infiltration Pond

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 2.62 fps, Min. Travel Time= 0.9 min
Avg. Velocity = 0.83 fps, Avg. Travel Time= 2.8 min

Peak Storage= 233 cf @ 12.18 hrs
Average Depth at Peak Storage= 0.57' , Surface Width= 4.35'
Bank-Full Depth= 1.50' Flow Area= 7.9 sf, Capacity= 35.44 cfs

1.50' x 1.50' deep channel, n= 0.030 Earth, grassed & winding
Side Slope Z-value= 2.5 '/' Top Width= 9.00'
Length= 140.0' Slope= 0.0107 '/'
Inlet Invert= 252.00', Outlet Invert= 250.50'



Summary for Reach 8R: Foxhole 1

[52] Hint: Inlet/Outlet conditions not evaluated

Inflow Area = 8,236 sf, 77.20% Impervious, Inflow Depth > 5.52" for 100-Year event
Inflow = 1.26 cfs @ 12.13 hrs, Volume= 3,791 cf
Outflow = 1.26 cfs @ 12.13 hrs, Volume= 3,791 cf, Atten= 0%, Lag= 0.0 min
Routed to Pond P1 : Infiltration Pond

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 5.82 fps, Min. Travel Time= 0.0 min
Avg. Velocity = 1.41 fps, Avg. Travel Time= 0.2 min

Peak Storage= 3 cf @ 12.13 hrs
Average Depth at Peak Storage= 0.12' , Surface Width= 1.83'
Bank-Full Depth= 0.38' Flow Area= 0.7 sf, Capacity= 5.21 cfs

22.0" W x 4.5" H Box Pipe
n= 0.013 Concrete, trowel finish
Length= 14.3' Slope= 0.0524 '/'
Inlet Invert= 253.28', Outlet Invert= 252.53'

Summary for Reach 10R: Foxhole 2

[52] Hint: Inlet/Outlet conditions not evaluated

Inflow Area = 9,659 sf, 79.19% Impervious, Inflow Depth > 5.64" for 100-Year event
Inflow = 1.50 cfs @ 12.13 hrs, Volume= 4,538 cf
Outflow = 1.50 cfs @ 12.13 hrs, Volume= 4,538 cf, Atten= 0%, Lag= 0.0 min
Routed to Pond P1 : Infiltration Pond

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Max. Velocity= 7.34 fps, Min. Travel Time= 0.0 min
Avg. Velocity = 1.77 fps, Avg. Travel Time= 0.1 min

Peak Storage= 2 cf @ 12.13 hrs
Average Depth at Peak Storage= 0.11' , Surface Width= 1.83'
Bank-Full Depth= 0.38' Flow Area= 0.7 sf, Capacity= 6.80 cfs

22.0" W x 4.5" H Box Pipe
n= 0.013 Concrete, trowel finish
Length= 8.4' Slope= 0.0893 '/'
Inlet Invert= 251.90', Outlet Invert= 251.15'

Summary for Pond 4R: Pipe to Infiltration Pond

[62] Hint: Exceeded Reach 3R OUTLET depth by 0.53' @ 12.19 hrs

Inflow Area = 47,184 sf, 61.08% Impervious, Inflow Depth > 4.40" for 100-Year event
Inflow = 5.22 cfs @ 12.17 hrs, Volume= 17,309 cf
Outflow = 5.16 cfs @ 12.18 hrs, Volume= 17,305 cf, Atten= 1%, Lag= 0.7 min
Primary = 5.16 cfs @ 12.18 hrs, Volume= 17,305 cf
Routed to Pond P1 : Infiltration Pond

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Peak Elev= 251.11' @ 12.18 hrs Surf.Area= 256 sf Storage= 126 cf

Plug-Flow detention time= 0.6 min calculated for 17,305 cf (100% of inflow)
Center-of-Mass det. time= 0.5 min (826.9 - 826.4)

Volume	Invert	Avail.Storage	Storage Description
#1	250.00'	620 cf	**Custom Stage Data (Prismatic)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)
250.00	22	0	0
251.00	181	102	102
252.00	855	518	620

Device	Routing	Invert	Outlet Devices
#1	Primary	250.00'	**12.0" Round Culvert X 2.00** L= 55.0' Ke= 0.500 Inlet / Outlet Invert= 250.00' / 249.72' S= 0.0051 '/' Cc= 0.900 n= 0.012 Corrugated PP, smooth interior, Flow Area= 0.79 sf

Primary OutFlow Max=5.16 cfs @ 12.18 hrs HW=251.11' TW=250.23' (Dynamic Tailwater)
└─**1=Culvert** (Barrel Controls 5.16 cfs @ 3.69 fps)

Summary for Pond 9R: Head Wall to Infiltration Pond

[62] Hint: Exceeded Reach 7R OUTLET depth by 0.36' @ 12.20 hrs

Inflow Area = 61,808 sf, 54.35% Impervious, Inflow Depth > 4.00" for 100-Year event
Inflow = 5.97 cfs @ 12.18 hrs, Volume= 20,620 cf
Outflow = 5.91 cfs @ 12.19 hrs, Volume= 20,605 cf, Atten= 1%, Lag= 0.8 min
Primary = 5.91 cfs @ 12.19 hrs, Volume= 20,605 cf
Routed to Pond P1 : Infiltration Pond

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Peak Elev= 251.43' @ 12.19 hrs Surf.Area= 479 sf Storage= 255 cf

Plug-Flow detention time= 1.4 min calculated for 20,596 cf (100% of inflow)
Center-of-Mass det. time= 0.9 min (833.5 - 832.6)

Volume	Invert	Avail.Storage	Storage Description
#1	250.50'	288 cf	**Custom Stage Data (Irregular)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Perim. (feet)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)	Wet.Area (sq-ft)
250.50	121	75.8	0	0	121
251.00	269	116.2	95	95	740
251.50	517	131.6	193	288	1,050

Device	Routing	Invert	Outlet Devices
#1	Primary	250.50'	**15.0" Round Culvert X 2.00** L= 29.8' RCP, groove end w/headwall, Ke= 0.200 Inlet / Outlet Invert= 250.50' / 250.00' S= 0.0168 '/' Cc= 0.900 n= 0.020 Corrugated PE, corrugated interior, Flow Area= 1.23 sf

Primary OutFlow Max=5.91 cfs @ 12.19 hrs HW=251.43' TW=250.26' (Dynamic Tailwater)
└─**1=Culvert** (Barrel Controls 5.91 cfs @ 4.18 fps)

Summary for Pond P1: Infiltration Pond

Inflow Area = 151,893 sf, 51.31% Impervious, Inflow Depth > 4.38" for 100-Year event
Inflow = 16.00 cfs @ 12.16 hrs, Volume= 55,407 cf
Outflow = 3.55 cfs @ 12.58 hrs, Volume= 55,394 cf, Atten= 78%, Lag= 25.5 min
Discarded = 3.55 cfs @ 12.58 hrs, Volume= 55,394 cf
Primary = 0.00 cfs @ 0.00 hrs, Volume= 0 cf
Routed to Link AP1 : Wetlands

Routing by Dyn-Stor-Ind method, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs / 3
Peak Elev= 250.67' @ 12.58 hrs Surf.Area= 13,080 sf Storage= 13,893 cf

Plug-Flow detention time= 27.5 min calculated for 55,394 cf (100% of inflow)
Center-of-Mass det. time= 27.3 min (852.1 - 824.7)

Volume	Invert	Avail.Storage	Storage Description
#1	249.50'	28,409 cf	**Custom Stage Data (Irregular)** Listed below (Recalc)

Elevation (feet)	Surf.Area (sq-ft)	Perim. (feet)	Inc.Store (cubic-feet)	Cum.Store (cubic-feet)	Wet.Area (sq-ft)
249.50	10,423	450.6	0	0	10,423
250.00	11,803	469.4	5,553	5,553	11,818
251.00	13,731	494.5	12,755	18,308	13,803
251.70	15,140	512.1	10,101	28,409	15,256

Device	Routing	Invert	Outlet Devices
#1	Primary	250.70'	**10.0' long x 19.0' breadth Broad-Crested Rectangular Weir** Head (feet) 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 Coef. (English) 2.68 2.70 2.70 2.64 2.63 2.64 2.64 2.63
#2	Discarded	249.50'	**8.270 in/hr Exfiltration over Surface area** Conductivity to Groundwater Elevation = 247.00' Phase-In= 0.01'

Discarded OutFlow Max=3.55 cfs @ 12.58 hrs HW=250.67' (Free Discharge)
└─**2=Exfiltration** (Controls 3.55 cfs)

Primary OutFlow Max=0.00 cfs @ 0.00 hrs HW=249.50' TW=0.00' (Dynamic Tailwater)
└─**1=Broad-Crested Rectangular Weir** (Controls 0.00 cfs)

Stage-Area-Storage for Pond P1: Infiltration Pond

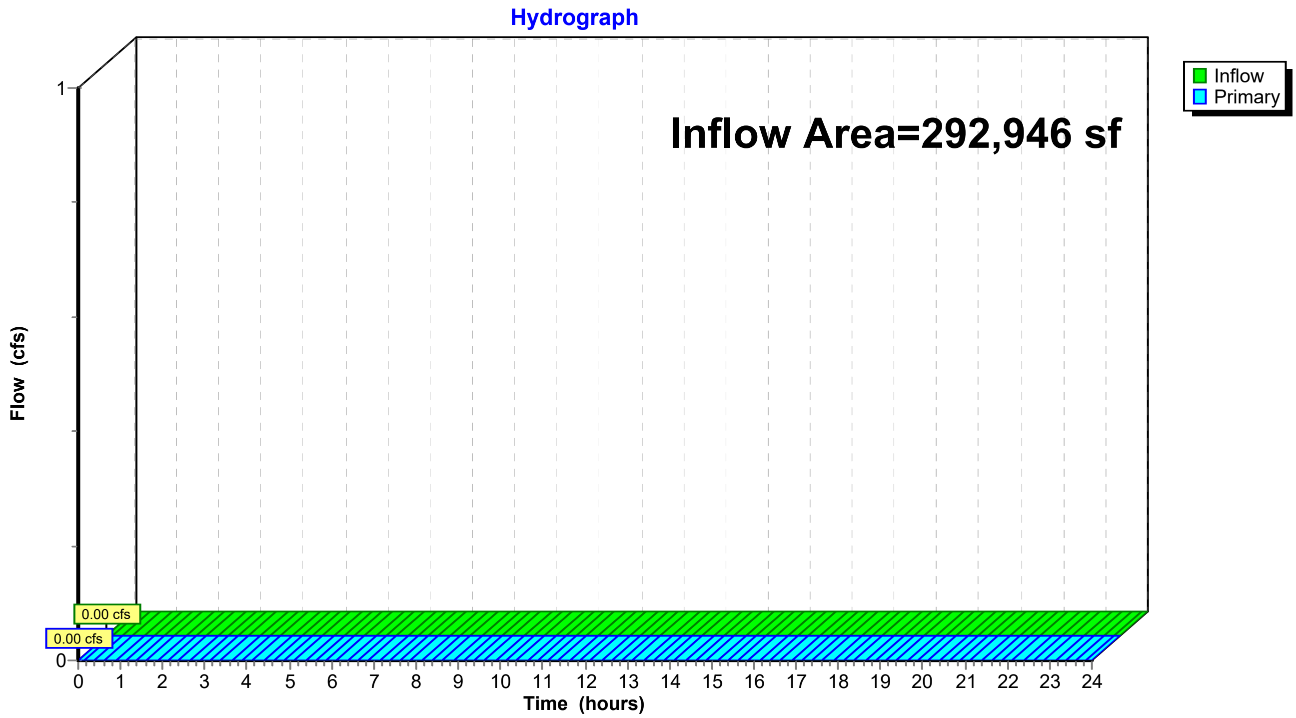
Elevation (feet)	Surface (sq-ft)	Storage (cubic-feet)
249.50	10,423	0
249.55	10,557	524
249.60	10,692	1,056
249.65	10,828	1,594
249.70	10,965	2,139
249.75	11,102	2,690
249.80	11,241	3,249
249.85	11,380	3,814
249.90	11,520	4,387
249.95	11,661	4,966
250.00	11,803	5,553
250.05	11,896	6,145
250.10	11,989	6,743
250.15	12,083	7,344
250.20	12,177	7,951
250.25	12,271	8,562
250.30	12,366	9,178
250.35	12,461	9,799
250.40	12,557	10,424
250.45	12,653	11,054
250.50	12,749	11,689
250.55	12,845	12,329
250.60	12,942	12,974
250.65	13,040	13,623
250.70	13,137	14,278
250.75	13,235	14,937
250.80	13,334	15,601
250.85	13,433	16,271
250.90	13,532	16,945
250.95	13,631	17,624
251.00	13,731	18,308
251.05	13,829	18,997
251.10	13,928	19,691
251.15	14,027	20,390
251.20	14,127	21,093
251.25	14,226	21,802
251.30	14,326	22,516
251.35	14,427	23,235
251.40	14,528	23,959
251.45	14,629	24,688
251.50	14,730	25,422
251.55	14,832	26,161
251.60	14,935	26,905
251.65	15,037	27,654
251.70	**15,140**	**28,409**

Summary for Link AP1: Wetlands

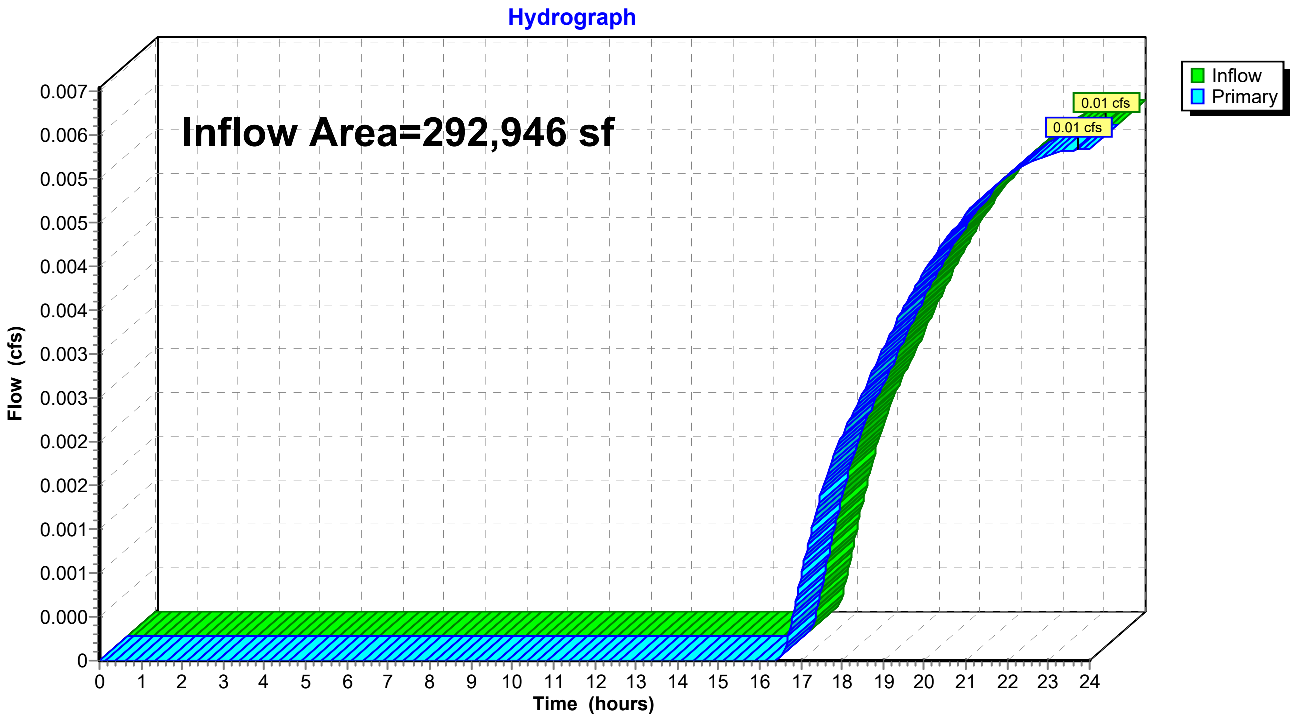
Inflow Area = 292,946 sf, 30.27% Impervious, Inflow Depth > 0.57" for 100-Year event
Inflow = 2.21 cfs @ 12.36 hrs, Volume= 13,996 cf
Primary = 2.21 cfs @ 12.36 hrs, Volume= 13,996 cf, Atten= 0%, Lag= 0.0 min

Primary outflow = Inflow, Time Span= 0.00-24.00 hrs, dt= 0.01 hrs

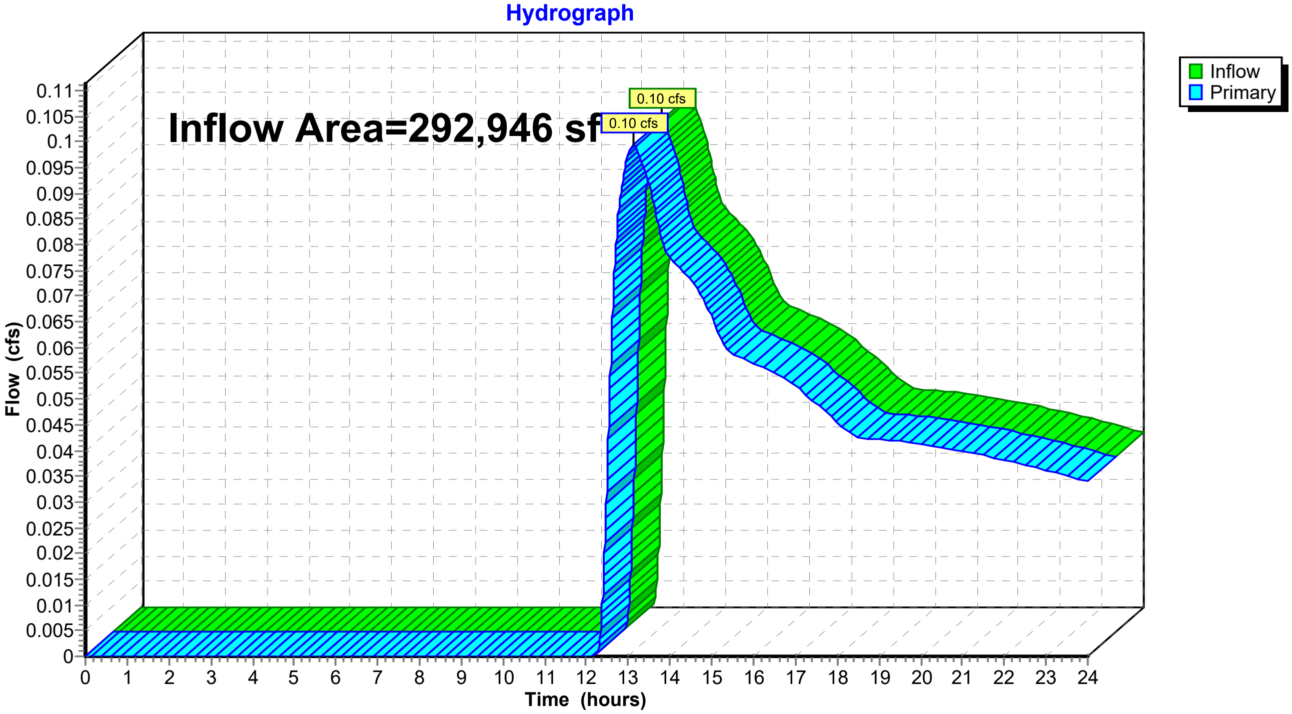
Link AP1: Wetlands



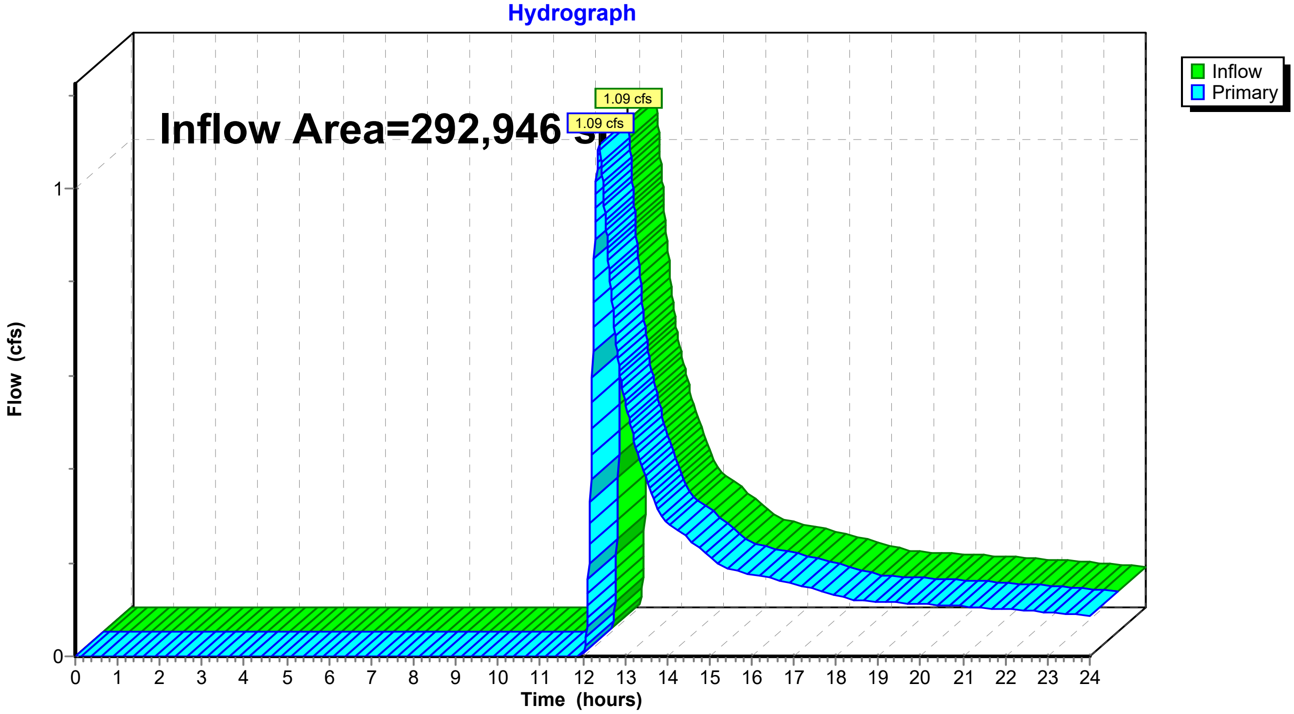
Link AP1: Wetlands



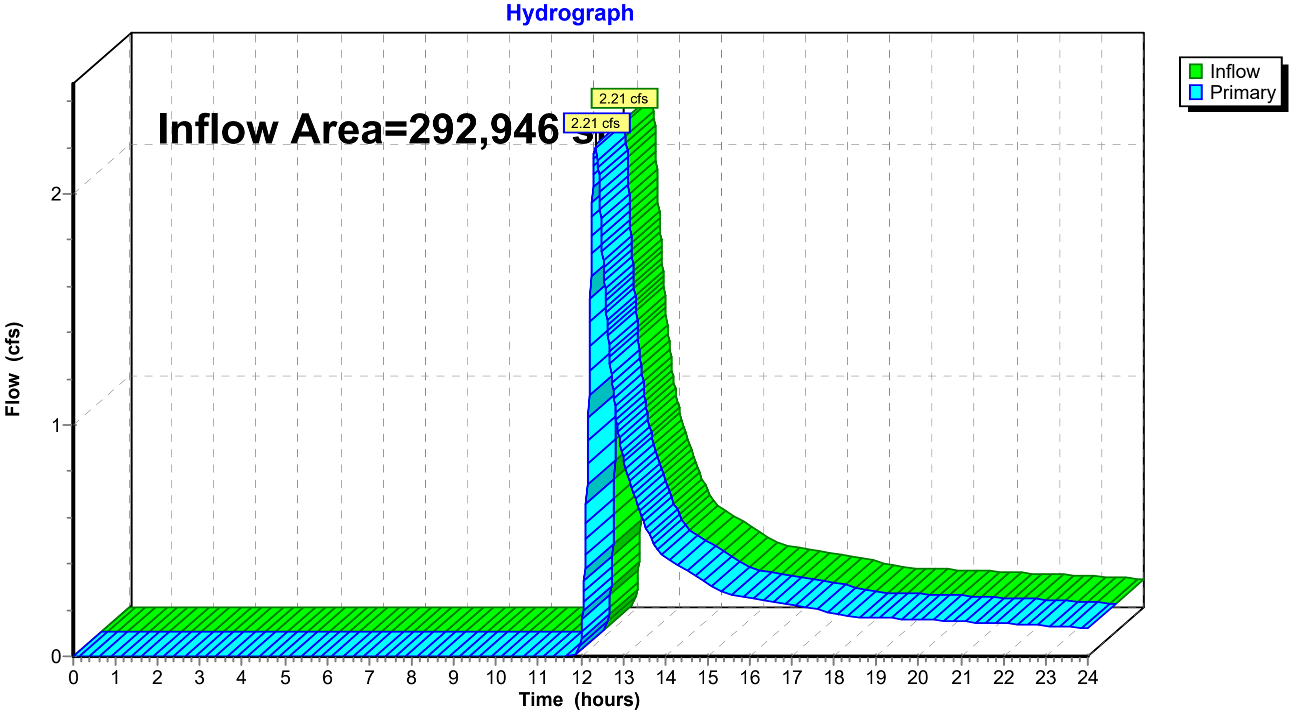
Link AP1: Wetlands



Link AP1: Wetlands

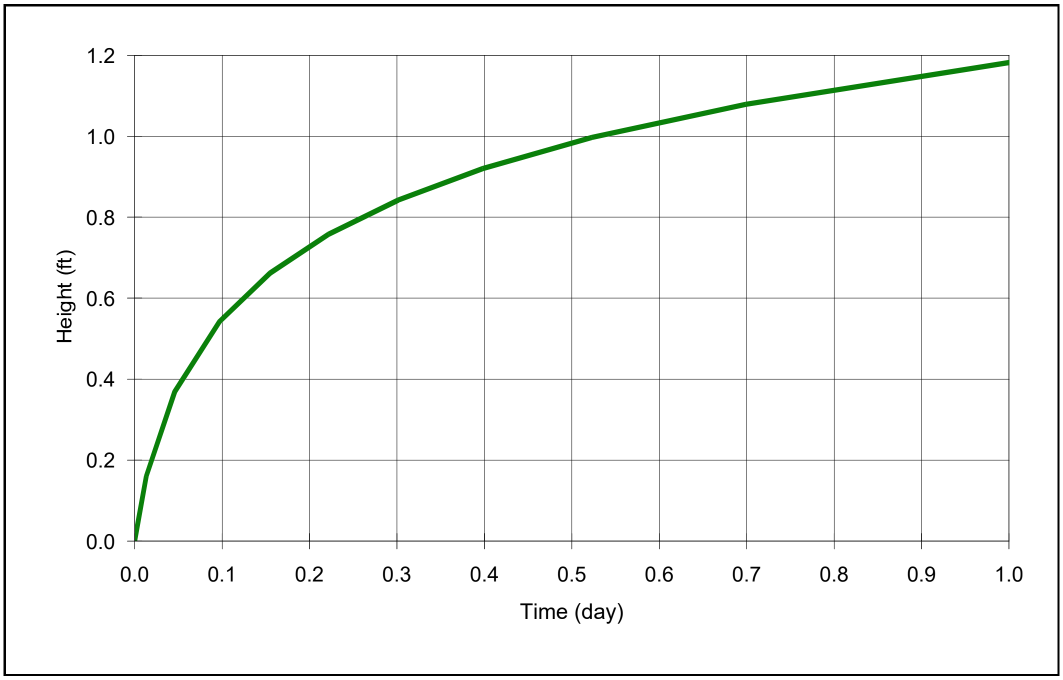


Link AP1: Wetlands



Appendix I – Mounding Calculations

Groundwater Mounding Analysis (Hantush's Method using Glover's Solution)



COMPANY: Howard Stein Hudson

PROJECT: Sheldon West

ANALYST: Kristen LaBrie

DATE: 8/19/2022 TIME: 12:18:01 PM

INPUT PARAMETERS

Application rate: 5.32 c.ft/day/sq. ft
Duration of application: 1 day
Total simulation time: 1 day
Fillable porosity: 0.35
Hydraulic conductivity: 493 ft/day
Initial saturated thickness: 35 ft
Length of application area: 189 ft
Width of application area: 63 ft
No constant head boundary used
Groundwater mounding @
X coordinate: 0 ft
Y coordinate: 0 ft
Total volume applied: 63345.24 cft

MODEL RESULTS

Time (day)	Mound Height (ft)
0	0
0	0.16
0	0.37
0.1	0.54
0.2	0.66
0.2	0.76
0.3	0.84
0.4	0.92
0.5	1
0.7	1.08
1	1.18

Appendix J – Rip-Rap Aprons Calculations

1139 West Street - Sheldon West - Wrentham, MA
HSH# 19227.01

Foxhole -1

Do=	1.833	ft
Q=	1.26	cfs (100-yr Storm)
Tw=	0.25	ft

$La=1.8Do(Q/(Do))^{5/2}+7Do$

La=	13.74	ft

$W_1=3Do$

W_1=	5.50	ft

$W_2=W_1+0.66La$

$W_{2=}$	14.66	ft

$d50=(0.02/Tw)*((Q/Do)^{4/3})$

d50=	0.05	ft
	0.58	in

Foxhole -2

Do=	1.833	ft
Q=	1.5	cfs (100-yr Storm)
Tw=	0.25	ft

$La=1.8Do(Q/(Do))^{5/2}+7Do$

La=	13.92	ft

$W_1=3Do$

W_1=	5.50	ft

$W_2=W_1+0.66La$

$W_{2=}$	14.78	ft

$d50=(0.02/Tw)*((Q/Do)^{4/3})$

d50=	0.06	ft
	0.73	in

(2) 12" Inlet

Do=	1	ft
Q=	2.58	cfs (100-yr Storm)
Tw=	0.25	ft

$La=1.8Do(Q/(Do))^{5/2}+7Do$

La=	11.64	ft

$W_1=3Do$

W_1=	3.00	ft

$W_2=W_1+0.66La$

$W_{2=}$	10.76	ft

$d50=(0.02/Tw)*((Q/Do)^{4/3})$

d50=	0.28	ft
	3.40	in

(2) 15" Inlet

Do=	1.25	ft
Q=	2.96	cfs (100-yr Storm)
Tw=	0.25	ft

$La=1.8Do(Q/(Do))^{5/2}+7Do$

La=	12.56	ft

$W_1=3Do$

W_1=	3.75	ft

$W_2=W_1+0.66La$

$W_{2=}$	12.12	ft

$d50=(0.02/Tw)*((Q/Do)^{4/3})$

d50=	0.25	ft
	3.02	in

Appendix K – Snow Storage Calculations

Snow Storage Calculations

HOWARD STEIN HUDSON
Engineers + Planners

Site Location: 1139 West Street - Wrentham, MA

Date: 09/09/2022
By: MB
Checked: KE

Snow Storage Location	Area of Location (sf)	Bottom Volume	Top Volume*	Total Volume
1	589	1178	982	2,160
2	652	1304	761	2,065
3	802	1604	1,003	2,607
4	242	484	262	746
5	582	1164	728	1,892
6	408	816	476	1,292
7	793	1586	1,454	3,040
8	342	684	428	1,112

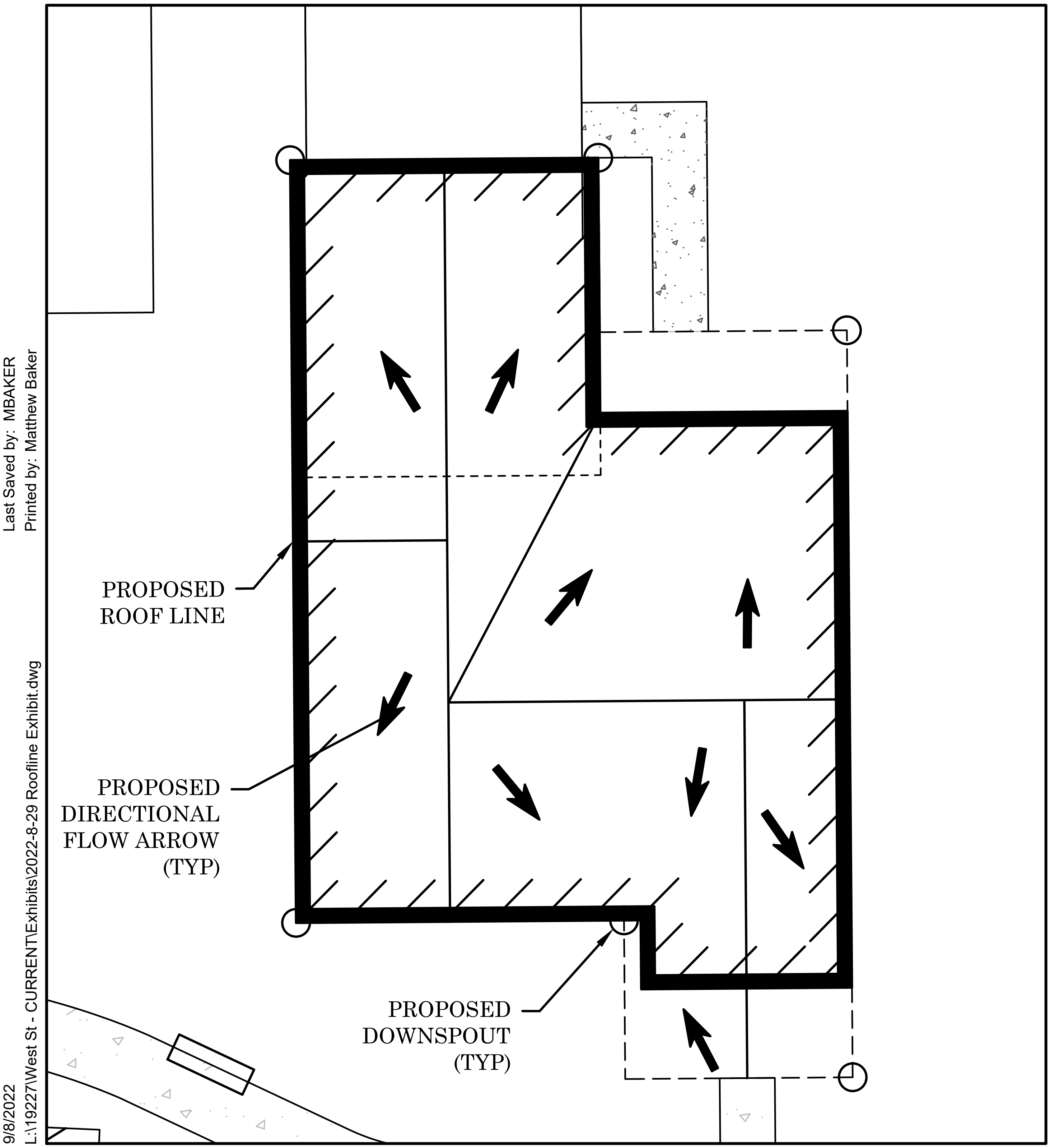
Total Volume Provided (cf)	14,912
Compaction Factor	3
Compacted Volume	**44,736**
Total Roadway Impervious Area (sf	**44,544**

* Assumes 2:1 side slopes

Storm Event (inches)		**Accumulation (cf)**
1		**3,712**
2		**7,424**
3		**11,136**
4		**14,848**
5		**18,560**
6		**22,272**
7		**25,984**
8		**29,696**
9		**33,408**
10		**37,120**
11		**40,832**
12		**44,544**
13		**48,256**
14		**51,968**

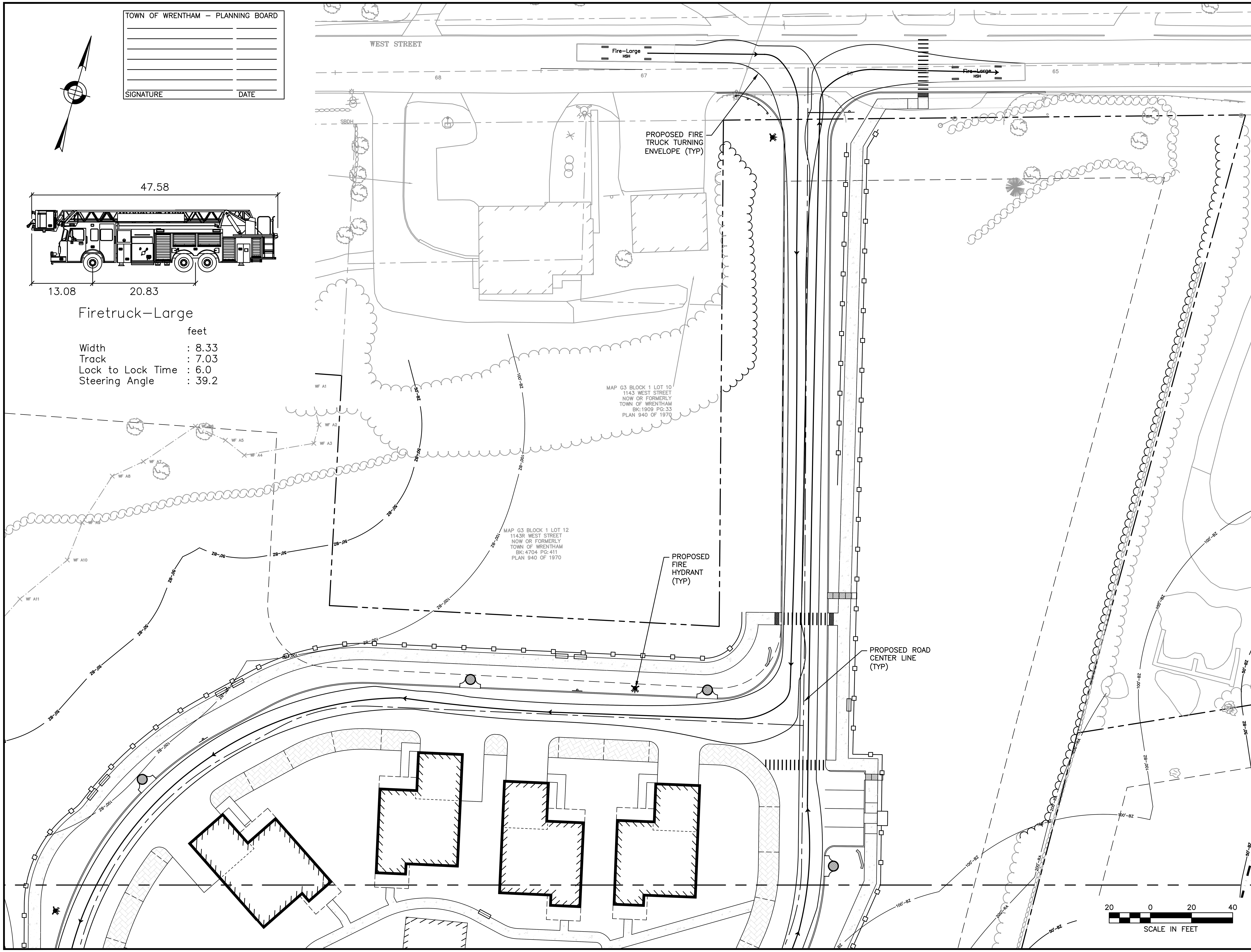
Appendix L – Down Spout Exhibit

Figure 1. *Downspout Exhibit*



Approximate Scale: 1" = 10'-0"
Date: 9/7/2022

Appendix M – Truck Turning Exhibit



HOWARD STEIN HUDSON
114 Turnpike Road, Suite 2C
Chelmsford, MA 01824
www.hshassoc.com

PREPARED FOR:
SHELDON WEST, LLC
480 TURNPIKE STREET
SOUTH EASTON, MA 02375

SHELDON WEST
1139 WEST STREET
WRENTHAM, MA 02093
NORFOLK COUNTY

REVISIONS:

NO	BY	DATE	DESCRIPTION
1	KL	9/9/22	PEER REVIEW

SITE PLAN

TRUCK TURNING PLAN SHEET 1 OF 2

DATE:	APRIL 11, 2022
PROJECT NUMBER:	19227.01
DESIGNED BY:	KL/MB
DRAWN BY:	KL/MB/NC
CHECKED BY:	KE

1.0

SHEET 1 OF 2

9/8/2022 L:\19227\West St - CURRENT\19227 - Truck Turning.dwg
Last Saved by: MBAKER
Printed by: Matthew Baker

Appendix N – Hydrologist Memo

July 28, 2022

Ms. Katie Enright, P.E.
114 Turnpike Road, Suite 2C
Chelmsford, MA 01824

Re: Infiltration Rate Opinion
20 Hancock Street and 1139 West Street
Wrentham, Massachusetts

Dear Ms. Enright:

As requested, Northeast Geoscience, Inc. (NGI) has prepared this analysis of the unconsolidated deposits at the above sites and to offer an opinion on the appropriate infiltration rate for stormwater design.

PUBLISHED HYDROGEOLOGIC INFORMATION

Published hydrogeologic maps for the area are available from the U.S. Geological Survey. The unconsolidated deposits at the sites are mapped by the USGS as glacial outwash deposits of sand and gravel (Stone et al, 2018) with estimated well yields from these deposits as high as 50 gallons per minute (gpm)(Walker & Krejmas, 1986). These characteristics are favorable for stormwater management.

PERMEABILITY TESTING

In March 2022 the unconsolidated deposits at both sites were observed in excavated test pits and monitoring wells drilled for septic system permeability testing. The samples observed were similar across the sites and consisted of stratified deposits of fine to coarse sand and gravel to depths of up to 27 feet and contained a saturated thickness of over 15 feet. These observations are in agreement with the hydrogeologic mapping conducted by the U.S. Geological Survey noted above.

Pumping tests were conducted on the monitoring wells. The wells were pumped at rates ranging from 3.3 to 6.8 gpm for approximately 40 minutes, and water level drawdown was recorded throughout the tests. Hydraulic conductivity values obtained from the tests ranged from 19.7 ft/day to 1,321 ft/day. These values are representative of moderate to highly-permeable deposits of sand and gravel.

Rising-head permeability tests (a.k.a. slug test) were conducted on well points installed within test pits on site (Bower and Rice, 1976). A slug of water was instantaneously removed from the well point and water level recovery was recorded using an electronic data logging pressure transducer. The results of the testing indicated hydraulic conductivity values of at least 1.6 ft/day. Slug tests results are generally considered order of magnitude estimates and the results are sensitive to well installation and construction and methods. The well points were installed by hand in excavated test pits that were then backfilled, disturbing the sorting and stratified natured of the in-situ deposits and reducing the overall permeability. Therefore, these permeability results should be considered highly conservative estimates. However, these results still fall within the range of fine to medium sand deposits.

Soil samples collected from split-spoon/standard penetration tests during the monitoring well installation were sieved and the data used to estimate saturated hydraulic conductivity. The data were analyzed using the spreadsheet method described by Devlin (2015). The spreadsheet calculates hydraulic conductivity by 15 different methods and produces an average and geometric mean of the results. The samples contained moderately well sorted sand. The geometric mean hydraulic conductivity value was 493 ft/day and the minimum calculated hydraulic conductivity value was 79 ft/day. These hydraulic conductivity values fall within the range of values obtained from pumping tests and also indicate moderate to highly permeable deposits of sand and gravel.

CONCLUSIONS

The visual observations of the unconsolidated deposits at the site, in-situ pumping and slug tests, and laboratory sieve analyses, all indicate that the deposits at the site correspond to the characterization provided by the U.S. Geological Survey as moderately to highly-permeable, stratified glacial outwash deposits of sand and gravel. According to the U.S. Department of Agriculture, deposits within Hydrologic Soil Group A are soils having a high infiltration rate (low runoff potential) and consisting mainly of deep, well drained to excessively drained sands or gravelly sands, with high rates of water transmission. The observations and analyses conducted at the site indicate that the deposits at the sites meet this definition.

Please do not hesitate to contact me if you have any questions.

Sincerely,
NORTHEAST GEOSCIENCE, INC.

Joel Frisch, P.G.
Senior Hydrogeologist/Principal

REFERENCES

Bouwer, H. and R.C. Rice, 1976. A slug test method for determining hydraulic conductivity of unconfined aquifers with completely or partially penetrating wells, Water Resources Research, vol. 12, no. 3, pp. 423-428.

Devlin, J.F. 2015. HydrogeoSieveXL: an Excel-based tool to estimate hydraulic conductivity from grain size analysis. Hydrogeology Journal, DOI 10.1007/s10040-015-1255-0.

Stone, J.R., Stone, B.D., DiGiacomo-Cohen, M.L., and Mabee, S.B., comps., 2018, Surficial materials of Massachusetts—A 1:24,000-scale geologic map database: U.S. Geological Survey Scientific Investigations Map 3402, 189 sheets, scale 1:24,000; index map, scale 1:250,000; 58-p. pamphlet; and geodatabase files, htt10.3133/sim3402.

Walker, E.H. & B.E. Krejmas, 1986. Water Resources of the Blackstone River Basin, Massachusetts. U.S. Geological Survey Hydraulic Atlas HA-682.

Appendix O – Traffic Safety Memo

TO:	Wrentham Planning Board	DATE:	September 6, 2022
FROM:	Keri Pyke, P.E., PTOE Melissa Restrepo	HSH PROJECT NO.:	2019227.01
SUBJECT:	Senior Adult Housing – Wrentham Safety and Sight Distance Studies		

Introduction

Howard Stein Hudson (HSH) has prepared this study to address concerns related to the proposed senior adult housing community, to be located at 20 Hancock Street (Sheldon Meadow) and 1139 West Street (Sheldon West) in Wrentham, Massachusetts. The Project consists of the construction of 25 residential homes for senior adults in two distinct communities. Two new private driveways are proposed: one off West Street, which will provide access to nine residential homes, and one off Hancock Street, which will provide access to 16 residential homes. This study provides an assessment of the safety of the proposed internal roadway at each Site as well as the proposed driveways on West and Hancock Streets. It also provides an update on the request to coordinate with the Massachusetts Department of Transportation (MassDOT) regarding sidewalks on West Street.

Sight Distance Evaluation

As previously included in the *Senior Adult Housing – Wrentham, Transportation Impact Study*, dated March 2, 2022, a field sight distance evaluation was performed on September 3, 2020, at the proposed intersection locations on West Street and Hancock Street, and a speed study was conducted with Automatic Traffic Recorder (ATR) devices along both West Street and Hancock Street over a 72-hour period between Tuesday, January 12, 2021, and Thursday, January 14, 2021. In accordance with MassDOT and American Association of State Highway and Transportation Officials (AASHTO) standards, a minimum Stopping Sight Distance (SSD) must be met to provide safe intersection operations. The SSD is the distance required by a vehicle traveling at the design speed of a roadway, on wet pavement, to stop prior to striking an obstacle in its path of travel.

Intersection Sight Distance (ISD) is another criterion that is usually measured along with SSD. ISD is the distance necessary for a vehicle on a minor approach to pull out into the traffic without impacting the travel speed of a vehicle on the major roadway. ISD guidelines are different depending on whether the vehicle pulling out from the stop-controlled approach in front of an oncoming vehicle is turning left or right (ISD guidelines are longer for left-turning vehicles since it takes additional time to cross to the opposite direction of lane of travel). ISD is not a safety requirement and relates only to the comfort of motorists traveling through an intersection. This evaluation, summarized in the sections that follow, confirmed that the measured SSD and ISD exceeds MassDOT and AASHTO requirements.

Sight Distance Measurements

The minimum SSD at an intersection is a requirement necessary to determine the safety of an intersection. SSD calculations also take into consideration grade changes along the approaching roadway; the SSD increases on a downgrade and decreases for an upgrade. The minimum required SSD for a vehicle traveling eastbound along West Street, with a posted speed limit of 40 mph, would be approximately 300 feet, due to the approximately 5% uphill grade. In the opposite direction, vehicles traveling westbound will approach at an approximately 5% downslope, increasing the minimum required SSD to approximately 340 feet. The field measurements determined the maximum available SSD from the proposed West Street/driveway intersection could exceed 600 feet in either direction, should the existing roadside foliage be cut back approximately three feet. The minimum required SSD for a vehicle traveling in either direction along Hancock Street, an assumed 25-mph roadway, is approximately 150 feet. The measured SSD exceeds this requirement with 800 feet in the northbound direction and 300 feet in the southbound direction.

The ISD measurements were taken 10 feet off the edge of the travel way to the approaching eastbound lane on West Street and the approaching southbound lane on Hancock Street. The minimum required ISD for a vehicle turning left onto the westbound travel lane on West Street is approximately 516 feet and approximately 344 feet for a vehicle turning right onto the eastbound travel lane on West Street. The measured ISD exceeds this requirement with over 600 feet in either direction. The minimum required ISD for a vehicle turning left onto the northbound travel lane on Hancock Street is approximately 331 feet and approximately 239 feet for a vehicle turning right onto the southbound travel lane on Hancock Street. The measured ISD exceeds this requirement with 360 feet in the northbound direction (turning left onto Hancock Street) and 800 feet in the southbound direction (turning right onto Hancock Street). **Table 1** summarizes the AASHTO minimum requirements with the measured sight distances on September 3, 2020, based on the posted/assumed speed limit.

Table 1. Sight Distance Analysis Summary – Posted/Assumed Speed Limit

Location	Stopping Sight Distance (SSD) – West Street and Hancock Street				Intersection Sight Distance (ISD) – Exiting Site Driveways			Sight Distance Satisfied?
	Direction of Travel	Speed (mph)	Min. Required (feet)	Measured (feet)[1]	Turning	Min. Required (feet)	Measured (feet)	
Posted/Assumed Speed Limit								
Site Driveway at West Street	EB[2] *toward Hancock St*	40	326	**750**	Left	516	**750**	**Yes**
	WB[3] *toward Arnold St*	40	281	**630**	Right	344	**630**	**Yes**
Site Driveway at Hancock Street	NB *toward West St*	25	152	**835**	Left	331	**360**	**Yes**
	SB *toward Burnt Swamp Rd*	25	152	**300**	Right	239	**800**	**Yes**

[1] *Assuming properly trimmed and maintained foliage.*
[2] *Accounting for the approximately 5% downhill grade.*
[3] *Accounting for the approximately 5% uphill grade.*

Vehicle Speed Data Collection

The vehicular speeds along West Street and Hancock Street were collected via ATR devices. The ATRs were located in the vicinity of the proposed driveways and collected continuous data over a 72-hour period between Tuesday, January 12, 2021, and Thursday, January 14, 2021. The data indicates that the three-day average 85th percentile speed along West Street is approximately 42 mph in the eastbound direction and approximately 43 mph in the westbound direction. The three-day average 85th percentile speed along Hancock Street as approximately 30 mph in the northbound direction and approximately 28 mph in the southbound direction. **Table 2** summarizes the AASHTO minimum SSD and ISD requirements based on the collected 85th percentile speeds compared to the sight distances measured on September 3, 2020.

Table 2. Sight Distance Analysis Summary – 85th Percentile Speed

Location	Stopping Sight Distance (SSD) - West Street and Hancock Street				Intersection Sight Distance (ISD) – Exiting Site Driveways			Sight Distance Satisfied?
	Direction of Travel	Speed (mph)	Min. Required (feet)	Measured (feet)[1]	Turning	Min. Required (feet)	Measured (feet)	
85th Percentile Speed								
Site Driveway at West Street	EB[2] *toward Hancock St*	42	352	**750**	Left	474	**750**	**Yes**
	WB[3] *toward Arnold St*	43	313	**630**	Right	401	**630**	**Yes**
Site Driveway at Hancock Street	NB *toward West St*	30	197	**835**	Left	331	**360**	**Yes**
	SB *toward Burnt Swamp Rd*	28	178	**300**	Right	268	**800**	**Yes**

[1] Assuming properly trimmed and maintained foliage.
[2] Accounting for the approximately 5% downhill grade.
[3] Accounting for the approximately 5% uphill grade.

Project Trip Generation

The Project is anticipated to generate approximately 17 vehicle trips during the a.m. peak hour (5 in and 12 out) and 19 vehicle trips during the p.m. peak hour (11 in and 8 out). The anticipated 17 and 19 vehicle trips during the a.m. and p.m. peak hours, respectively, will be split between the two proposed driveways and will utilize the internal private roadway on each Site, providing access to each residential home. It is important to note that these are the highest volumes the Project will generate throughout the day.

With a total of seven vehicle trips using the West Street driveway during both the a.m. and p.m. peak hours, the internal private roadway on Sheldon West is expected to experience approximately one new vehicle trip every nine minutes during both peak hours, causing little to no impact on the vehicular traffic along the driveway. Similarly, the Hancock Street driveway will experience at most 10 vehicle trips during the a.m. peak hour and 12 vehicle trips during the p.m. peak hour. The internal private roadway on Sheldon Meadow is expected to experience approximately one new vehicle trip every five to six minutes during both the peak hours.

These trips were added to the surrounding study area intersections to evaluate the traffic operations by assessing average delay experienced by vehicles at the intersections and along intersection approaches. Based on this analysis, the two proposed driveways are expected to operate with a delay of 16 seconds or lower (level of service C or better) during both the peak hours, with negligible queuing on the driveways. There is approximately 340 feet on the proposed driveway from its intersection at West Street down to the first house driveway on the internal private road. This length provides enough space for 13 cars to queue, based on an average vehicle length including space between vehicles of 25 feet. There will be nine homes located in Sheldon West. It is improbable that 13 vehicles would be queued waiting to leave the driveway at the same time.

The distance from Hancock Street to the first house's driveway is approximately 270 feet on the internal private road. This length provides enough space for 10 cars to queue, based on an average vehicle length of 25 feet. There will be 16 homes located in Sheldon Meadow. It is improbably that 10 cars would be queued waiting to leave the driveway at the same time. Based on the traffic operations analysis, each driveway is expected to experience less than 25 feet of queuing (about one car length) during both the peak hours, confirming that each driveway is designed to provide sufficient space to accommodate more vehicles than the number of vehicle trips the Project is expected to generate during the morning and evening peak hours.

Sidewalks on West Street

HSH has begun coordination with MassDOT District 5 staff regarding sidewalk installation on West Street. Although, representatives from District 5 do not want to comment formally until the Project is approved and a submittal can be made to MassDOT, HSH requested a virtual meeting to discuss the probability of installing a sidewalk on the south side of West Street and/or whether it would be more appropriate to prepare a crossing from Sheldon West to the existing sidewalk on the north side of West Street.

The addition of a sidewalk on the south side of West Street would most likely affect existing private property improvements in the right of way, require additional land takings, and constrict the curb cut at the convenience store considerably, essentially eliminating the access to parking on West Street. Based on recent improvements to the signage on West Street in the vicinity of these projects, representatives from MassDOT requested that the Project propose the appropriate crossing in proximity to the new site driveway on West Street and review the criteria for signage and/or flashing beacons relative to our traffic study and site conditions. MassDOT requested we review the existing crossing at West Street and Hancock Street as it approaches the convenience store and work within the right of way to see if it would be possible to provide a landing at the intersection to allow for a safe place for the crosswalk to end, as it currently ends within the parking lot. We look forward to filing an access permit application with MassDOT following Town Project approval to work out the details.

Conclusion

As summarized, the SSD along West Street and Hancock Street and the ISD at the Site driveways are both satisfactory based on both the assumed/posted speed limit and the collected 85th percentile speed. The internal private roadways will experience a peak between 7-12 vehicle trips during the morning and afternoon peak hours, resulting in little to no traffic impacts to the roadway network. The proposed internal private roadways along Sheldon West and Sheldon Meadow are designed to be 22 feet wide, providing ample space for the low number of vehicle trips that each Site is expected to generate.