Crosby Brook Restoration Study
Brattleboro, VT

November 25, 2014

Crosby Brook Restoration

Funding

VT Agency of Transportation (VTrans)
Transportation Enhancement Grant

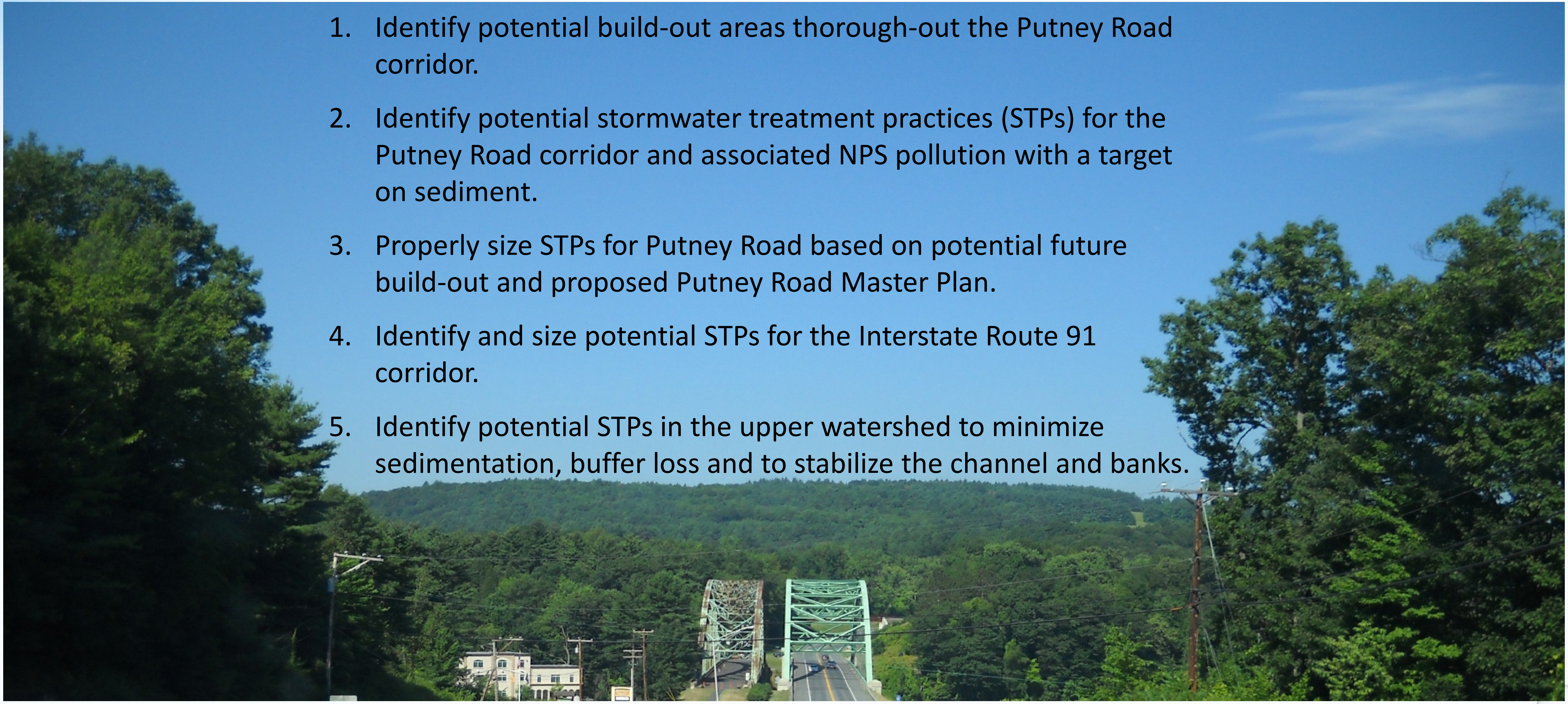
Key Stakeholders

VT Dept. of Environmental Conservation
VT Agency of Transportation
Town of Brattleboro

Project Overview

- Crosby Brook is located in Brattleboro, VT.
- On the 303(d) list and is impaired for sediment pollution and habitat alteration due sedimentation, channelization and buffer loss.
- Identified as a Class B/Coldwater Fish Habitat
- An extension of prior work performed by the Windham County Conservation District (Stream Geomorphic Assessment)

Project Goals



1. Identify potential build-out areas thorough-out the Putney Road corridor.
2. Identify potential stormwater treatment practices (STPs) for the Putney Road corridor and associated NPS pollution with a target on sediment.
3. Properly size STPs for Putney Road based on potential future build-out and proposed Putney Road Master Plan.
4. Identify and size potential STPs for the Interstate Route 91 corridor.
5. Identify potential STPs in the upper watershed to minimize sedimentation, buffer loss and to stabilize the channel and banks.

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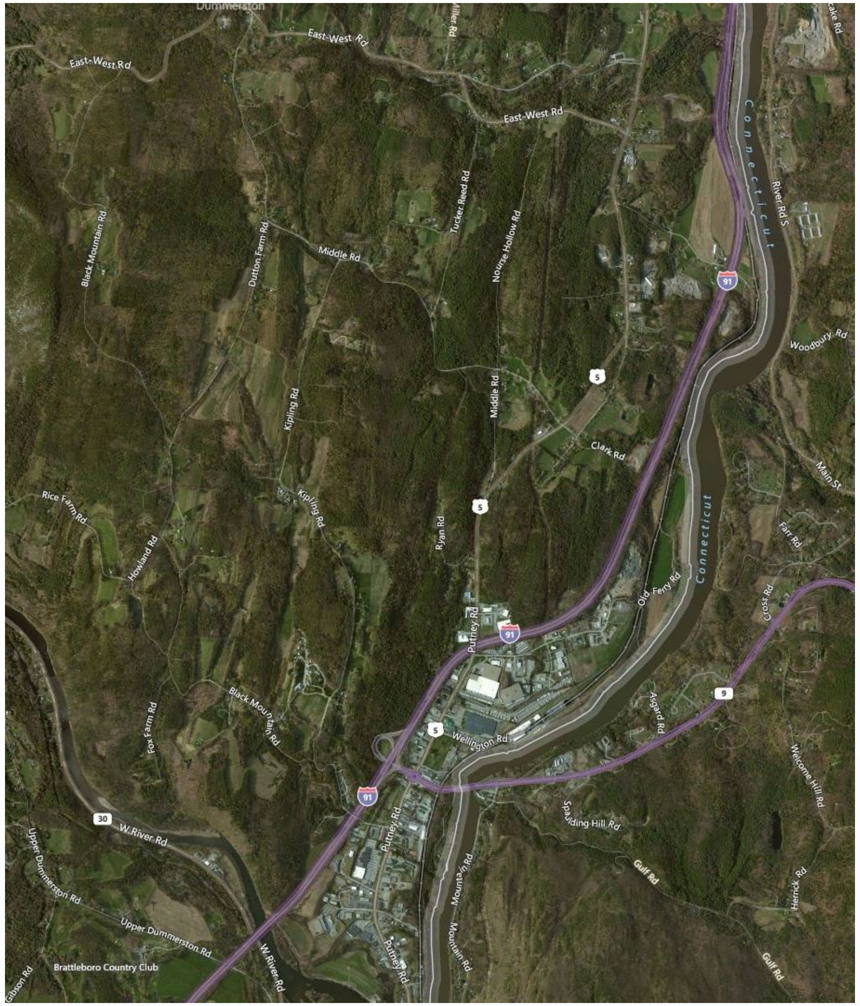
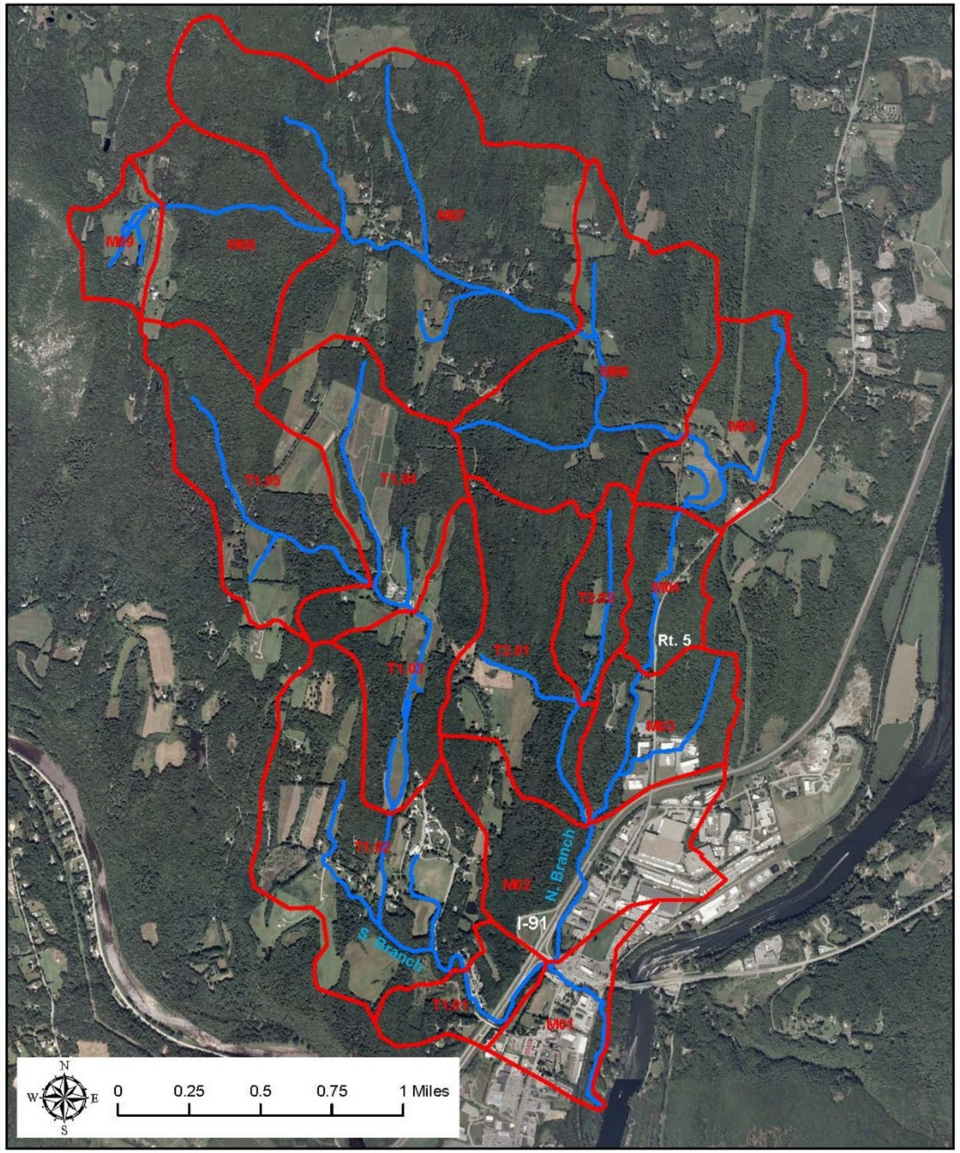
Crosby Brook



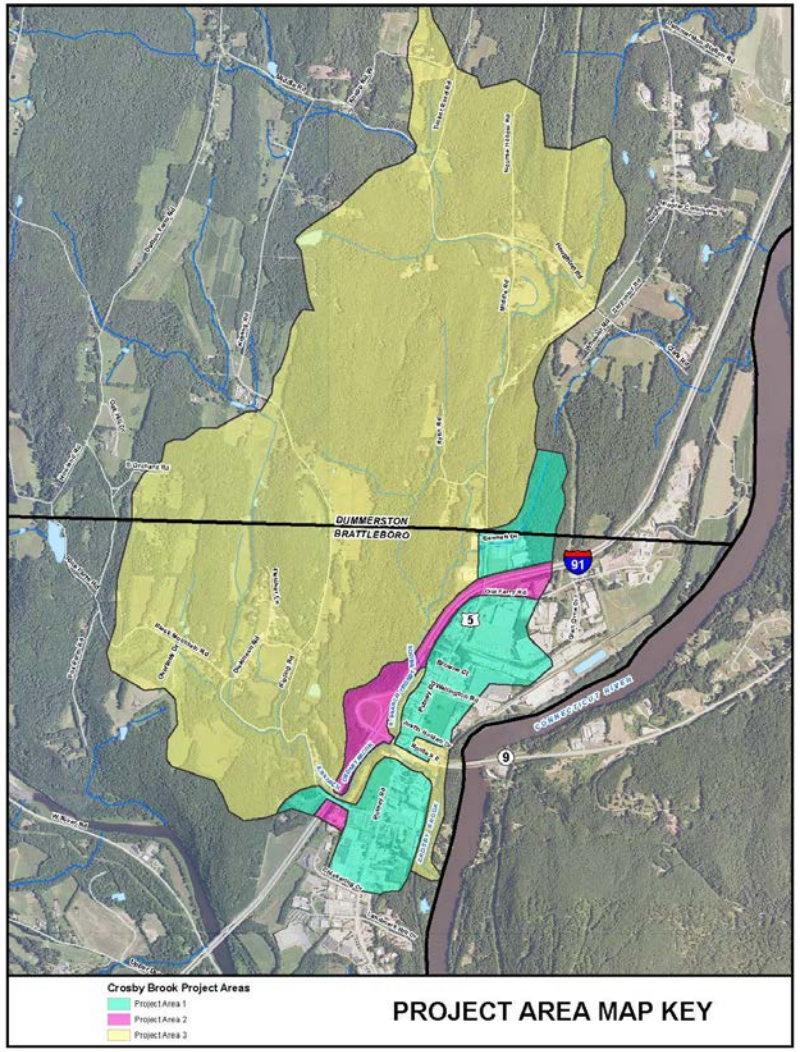
- Coldwater fish habitat (brook trout).
- Two separate branches;
- North main branch is approx. 2 miles long;
- South main branch is approx. 4 miles long;
- The two branches join, to the west of the Route 9 and Route 5 round-about;
- The last leg of the brook flows through a busy urbanized area for approx. ½ mile prior to discharge into the Connecticut River;

Crosby Brook Watershed



- 6 square miles;
- Lower watershed highly developed with a mix of residential and commercial properties;
- Upper watershed mainly forested with some agricultural and residential land uses;
- This study primarily focused on a 350 acre portion of the watershed.

Crosby Brook Project Areas



- Project Area 1 – Putney Road Corridor (Routes 5 & 9)
- Project Area 2 – Interstate Route 91 Corridor
- Project Area 3 – Upper Watershed

Crosby Brook Project Area 1

- Route 5 & Route 9
- Approx. 240 acres
- Urbanized with commercial properties
- Approx. 40% impervious

Crosby Brook Project Area 2

- Interstate Route 91
- Approx. 110 acres
- Mainly paved roads with grassed areas
- Approx. 15% impervious

Crosby Brook Project Area 3

- Route 9, Black Mountain Road and Middle Road
- Approx. 750 acres
- Low density residential, meadows, agriculture and forested areas
- Less than 1% impervious

Targeted Pollutants and Sources

Project Area 1

- Sediment loading from parking lots and roadways
- Loss of buffers due to encroachment and development
- Control of peak flows and high velocity runoff from large impervious areas to minimize erosion

Project Area 2

- Sediment & salt loading from the highway
- Control of peak flows and high velocity runoff from large impervious areas to minimize erosion

Project Area 3

- Sediment loading from bank erosion and mass failures
- Sediment loading from local roadway drainage
- Sediment loading and channel degradation due to culvert restrictions
- Loss of wildlife passage and limited buffers

STP Overview

1. STP Identification – Location and Type
2. STP Sizing & Pollutant Reductions
3. STP Selection – Ranking Process
4. STP Recommendations – Highest Ranked Sites

STP Identification

- STPs were identified for each of the three project areas and STP type, sizing and selection process based on the project area:

1. Project Area 1 - Highly urbanized – large open areas

   STP Types – Infiltration basins, gravel wetlands & treatment trains

   STP Sizing – VT Stormwater Manual

   STP Ranking – Feasibility & Cost Effectiveness of TSS Removal

2. Project Area 2 – Linear transportation corridor – lots of wet areas & narrow open areas

   STP Types – Infiltration swales, wet ponds & filtering systems

   STP Sizing – VT Stormwater Manual

   STP Ranking – Feasibility & Cost Effectiveness of TSS Removal

3. Project Area 3 – Highly un-developed – encroachment on buffers at crossings & erosion

   STP Types – Culvert improvements, buffer zones & stabilization

   STP Sizing – Based on channel width or size of erosion / issue

   STP Ranking – Size and Scale of the project

STP Identification

STP potential locations and types were selected based on available information:

- Field Reviews
- Resource Area Reviews
- Detailed Plan Reviews

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STP Identification

STP Types & Constraints

STP types were selected based on the potential location and any site constraints observed during field investigations & plan reviews:

- Land use
- Available Space
- Potential utility conflicts
- Location of bedrock
- Underlying Soils
- Shallow groundwater
- Maintenance access issues

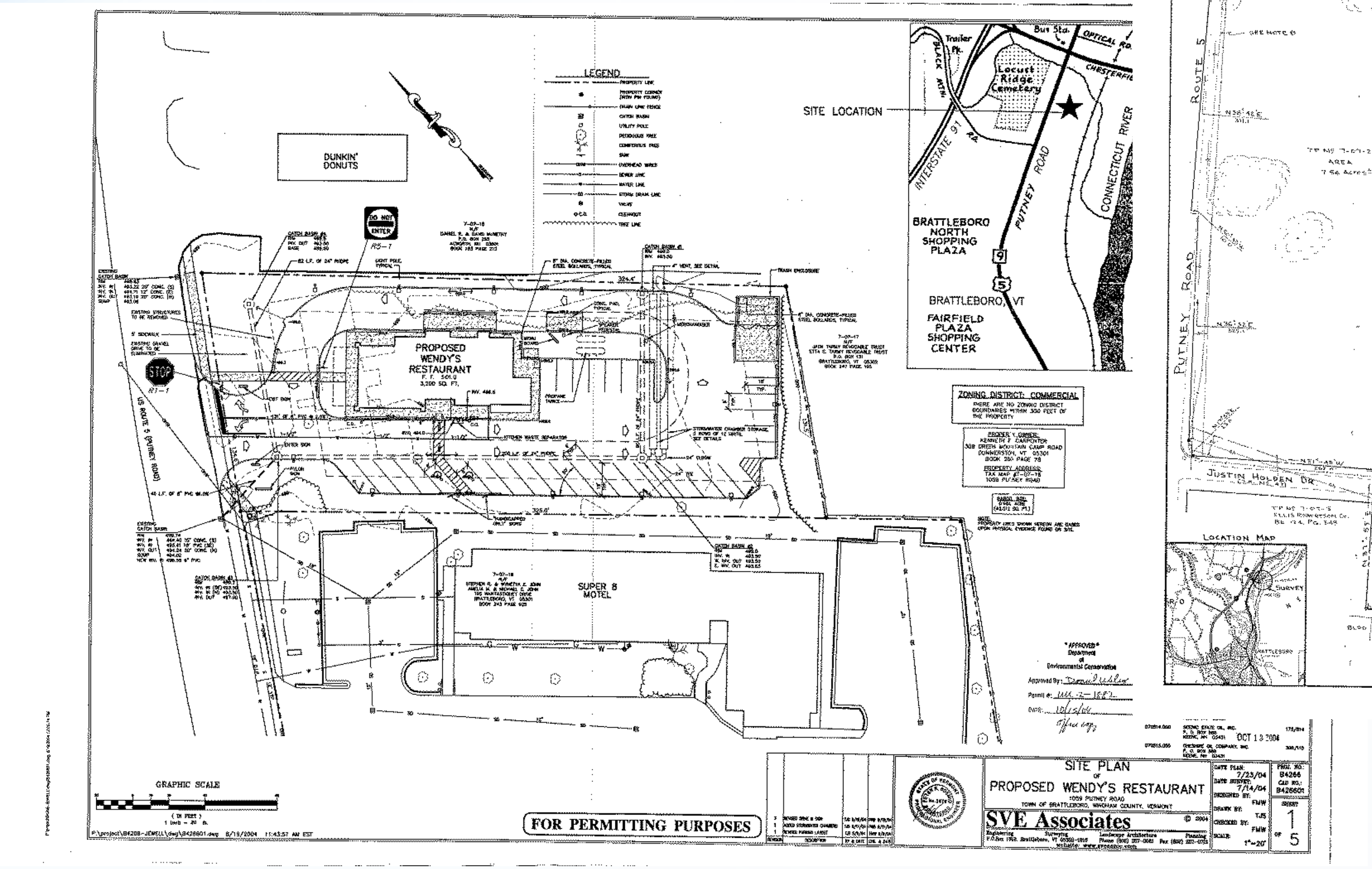
Table A.1. Land Use Matrix

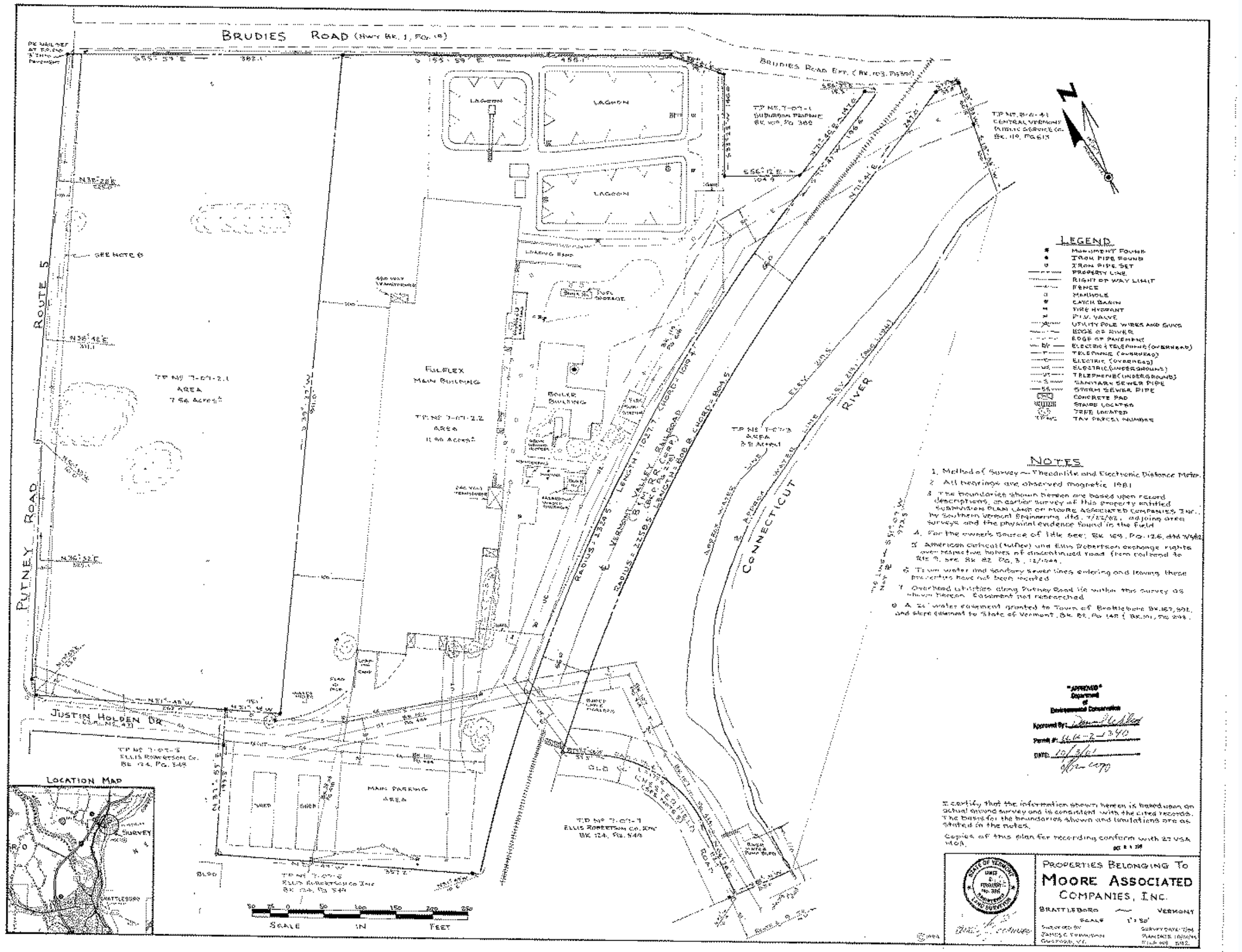
STP Group	STP Design	Rural	Residential	Roads and Highways	Commercial/ High Density	Hotspots	Ultra Urban
Pond	Micropool ED	○	○	○	◗	①	●
	Wet Pond	○	○	○	◗	①	●
	Wet ED Pond	○	○	○	◗	①	●
	Multiple Pond	○	○	◗	◗	①	●
	Pocket Pond	○	◗	○	◗	●	●
Wetland	Shallow Marsh	○	○	◗	◗	①	●
	ED Wetland	○	○	◗	◗	①	●
	Pond/Wetland	○	○	◗	◗	①	●
	Gravel Wetland	○	◗	○	○	①	●
Infiltration	Infiltration Trench	◗	○	○	○	●	◗
	Shallow I-Basin	◗	○	◗	◗	●	◗
Filters	Surface Sand Filter	●	◗	○	○	②	○
	Underground SF	●	●	◗	○	○	○
	Perimeter SF	●	●	◗	○	○	○
	Organic SF	●	◗	○	○	②	○
	Bioretention	○	○	○	○	②	○
Open Channels	Dry Swale	○	◗	○	◗	②	◗
	Wet Swale	○	●	○	●	●	●
	Grass Channel	○	◗	○	◗	②	◗
Detention*	Pond/Vault	○	○	○	○	①	●

○: Yes. Good option in most cases.
◗: Depends. Suitable under certain conditions, or may be used to treat a portion of the site.
●: No. Seldom or never suitable.
①: Acceptable option, but may require a pond liner to reduce risk of groundwater contamination.
②: Acceptable option, if not designed as an exfilter. (An exfilter is a conventional stormwater filter without an underdrain system. The filtered volume ultimately infiltrates into the underlying soils.)
*: The pond/vault is not an acceptable stand-alone water quality STP.

STP Identification

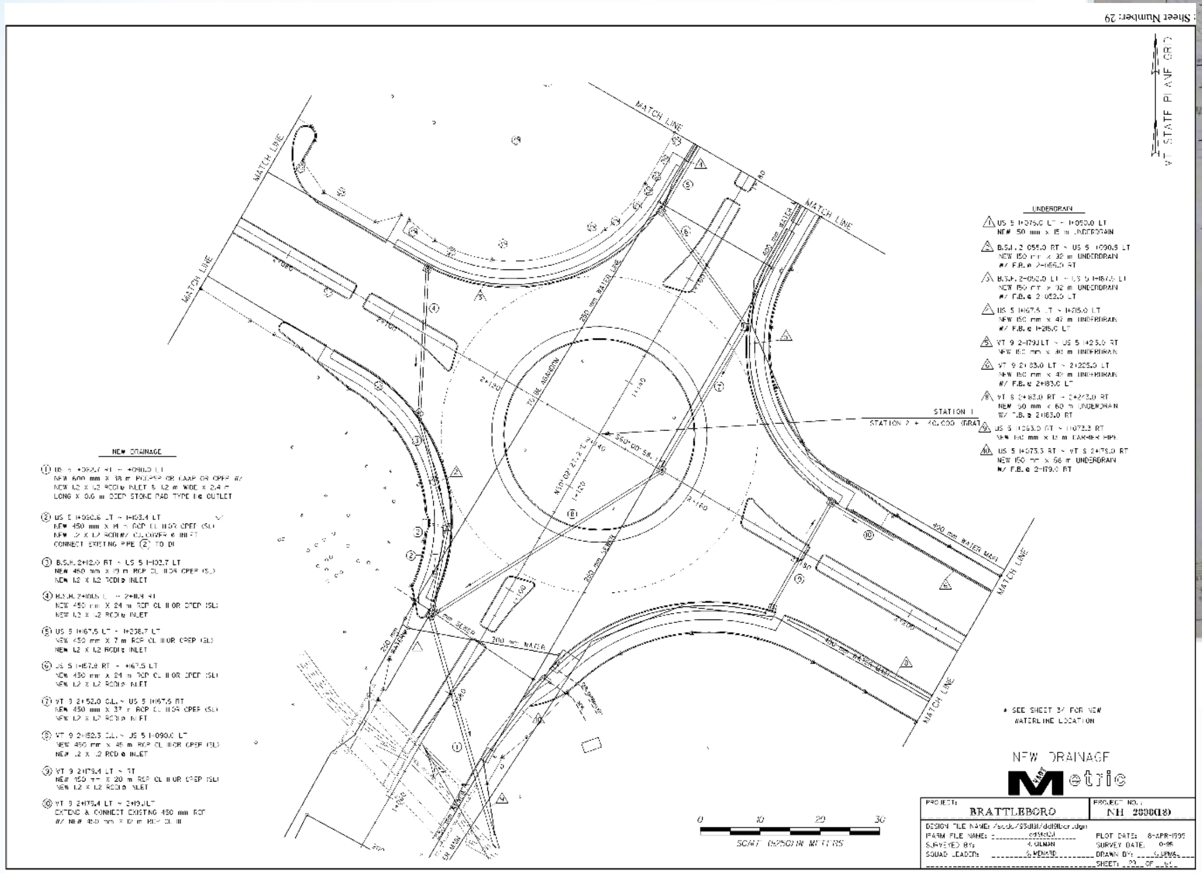
STP Location based on Available Space & Existing Town / Private Infrastructure

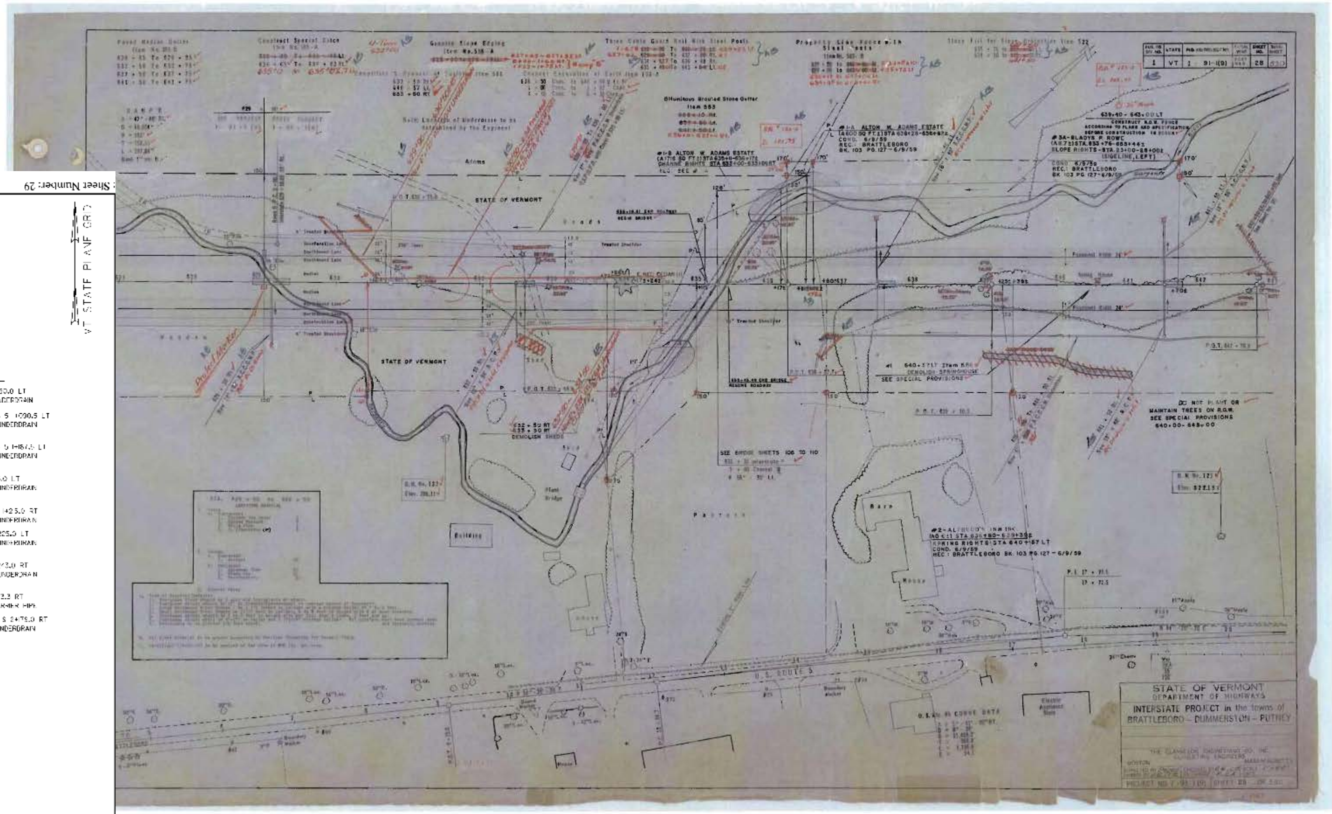




STP Identification

STP Location based on Existing Highway Infrastructure

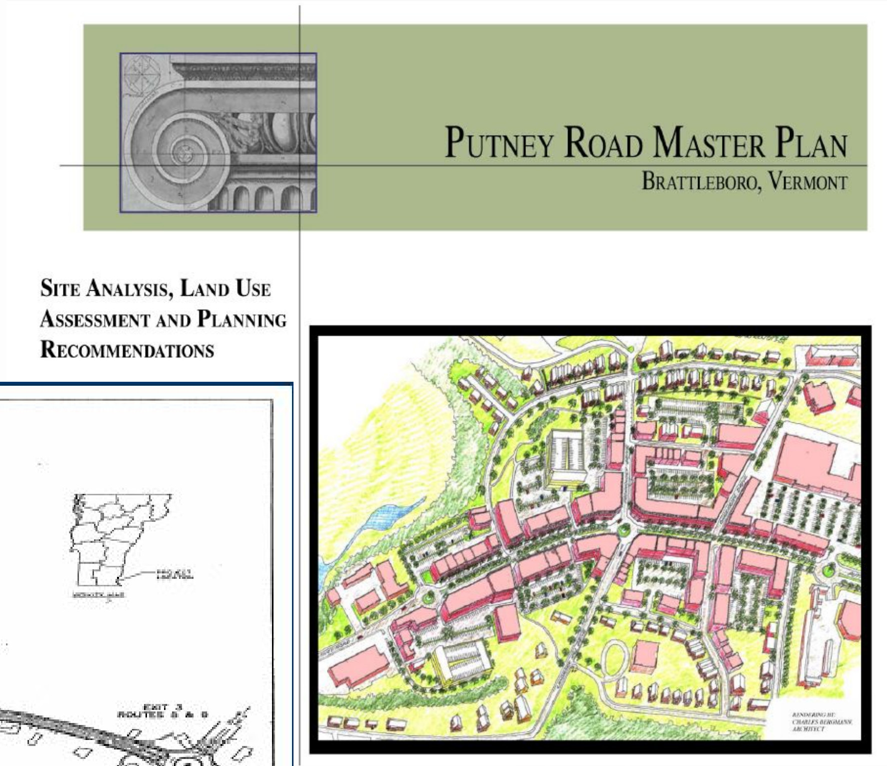


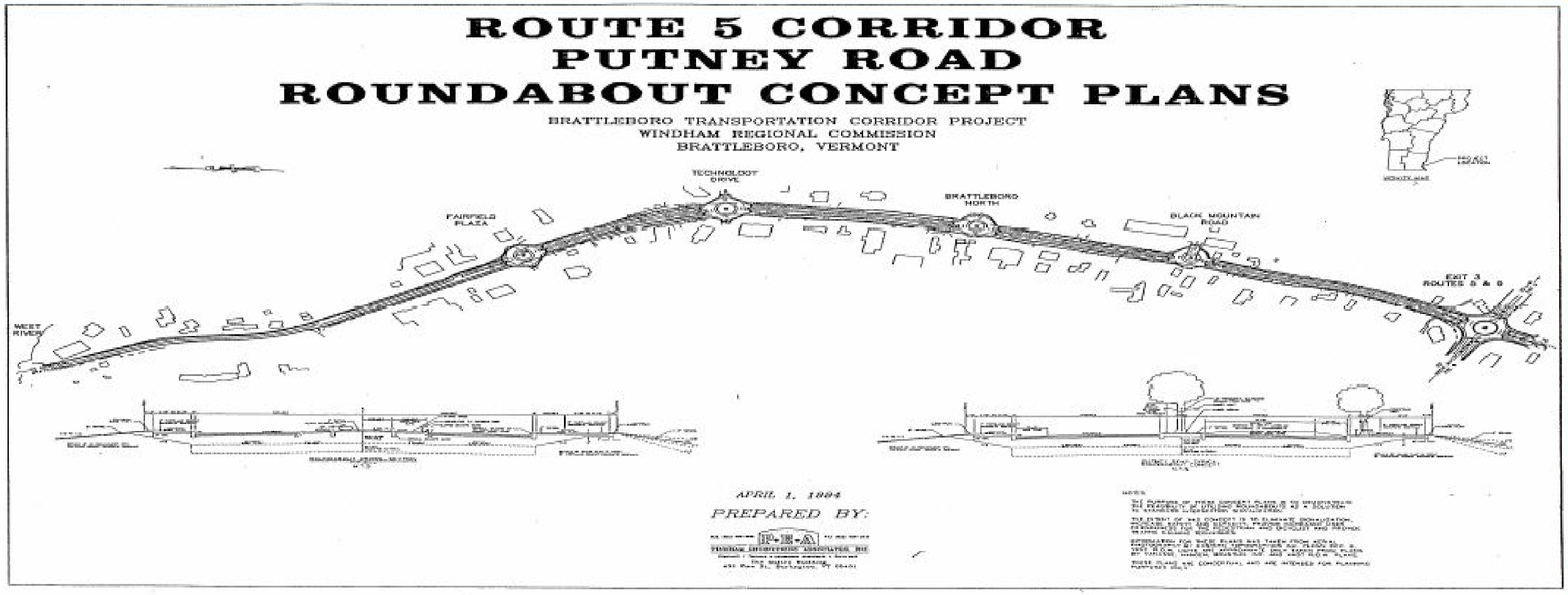


STP Identification

STP Location and Type based on:

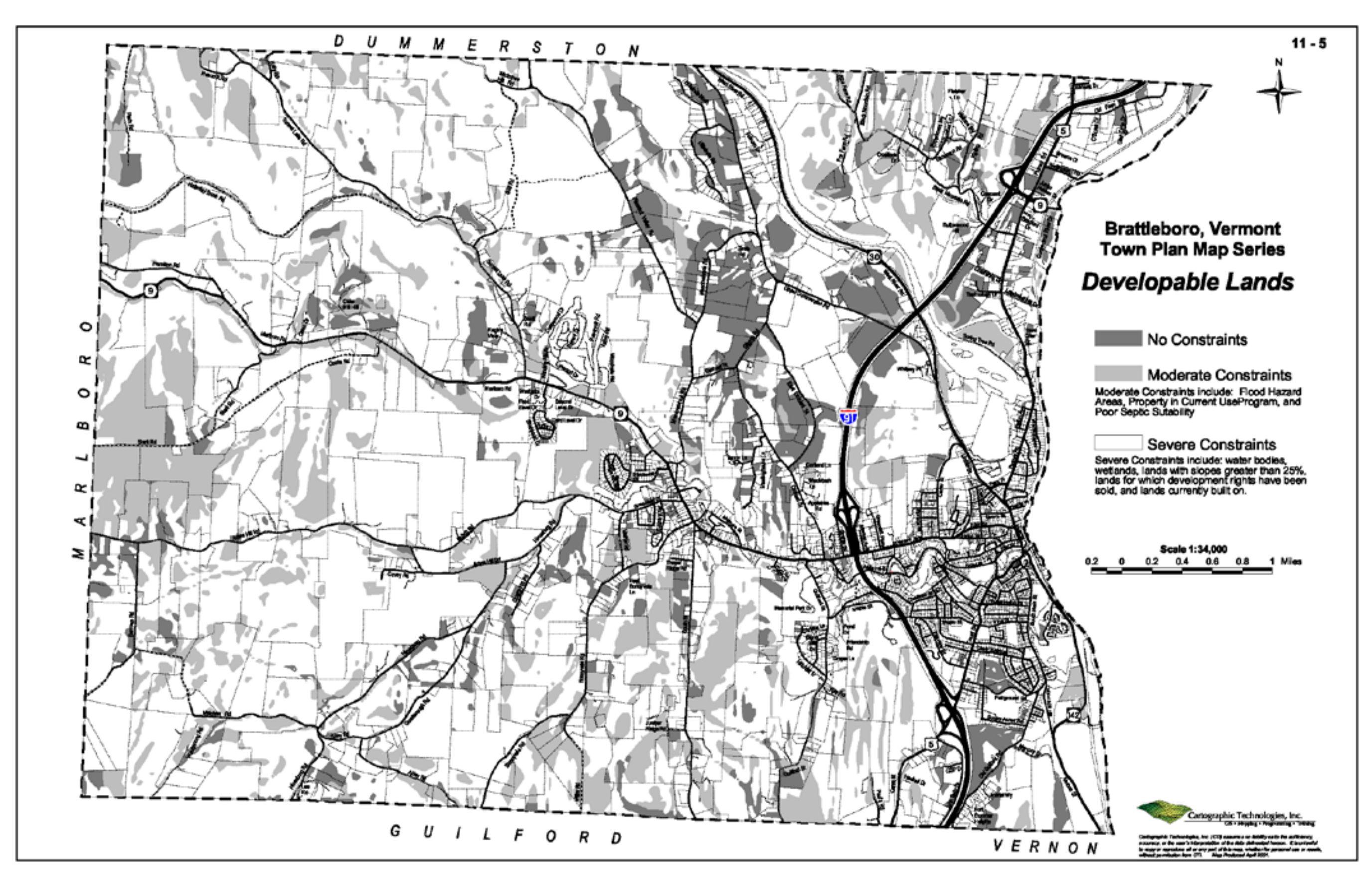
- Proposed Roadway Infrastructure
- Putney Road Master Plan

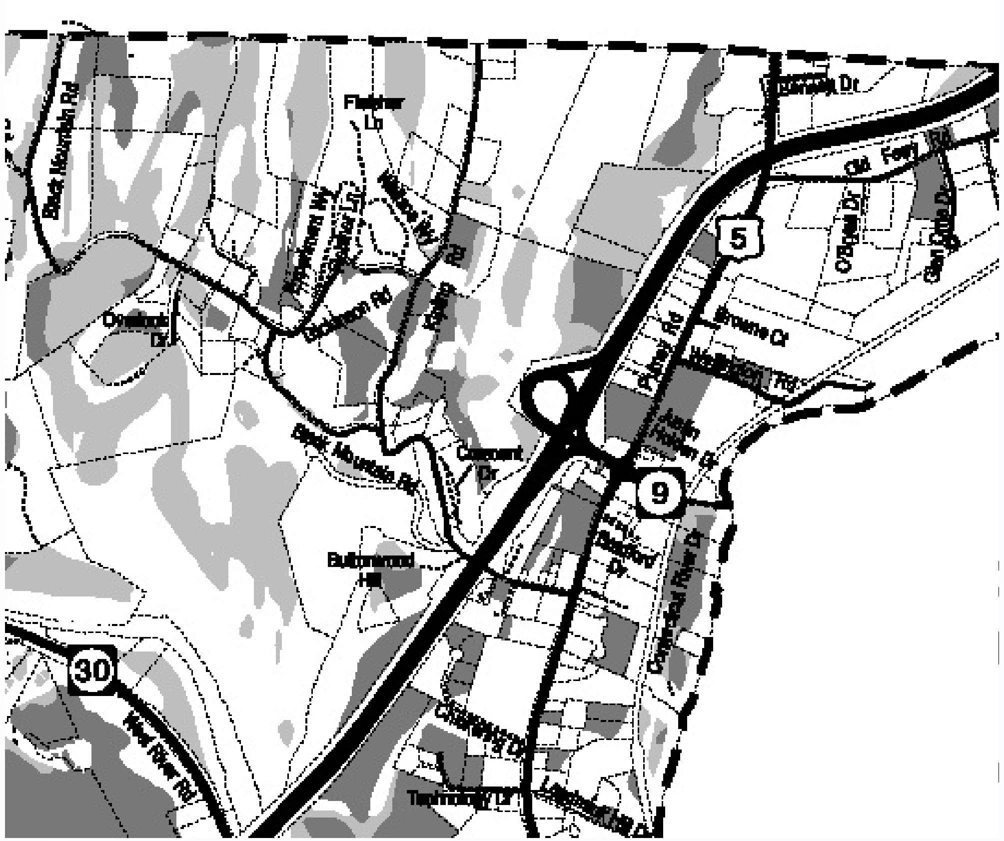




STP Identification

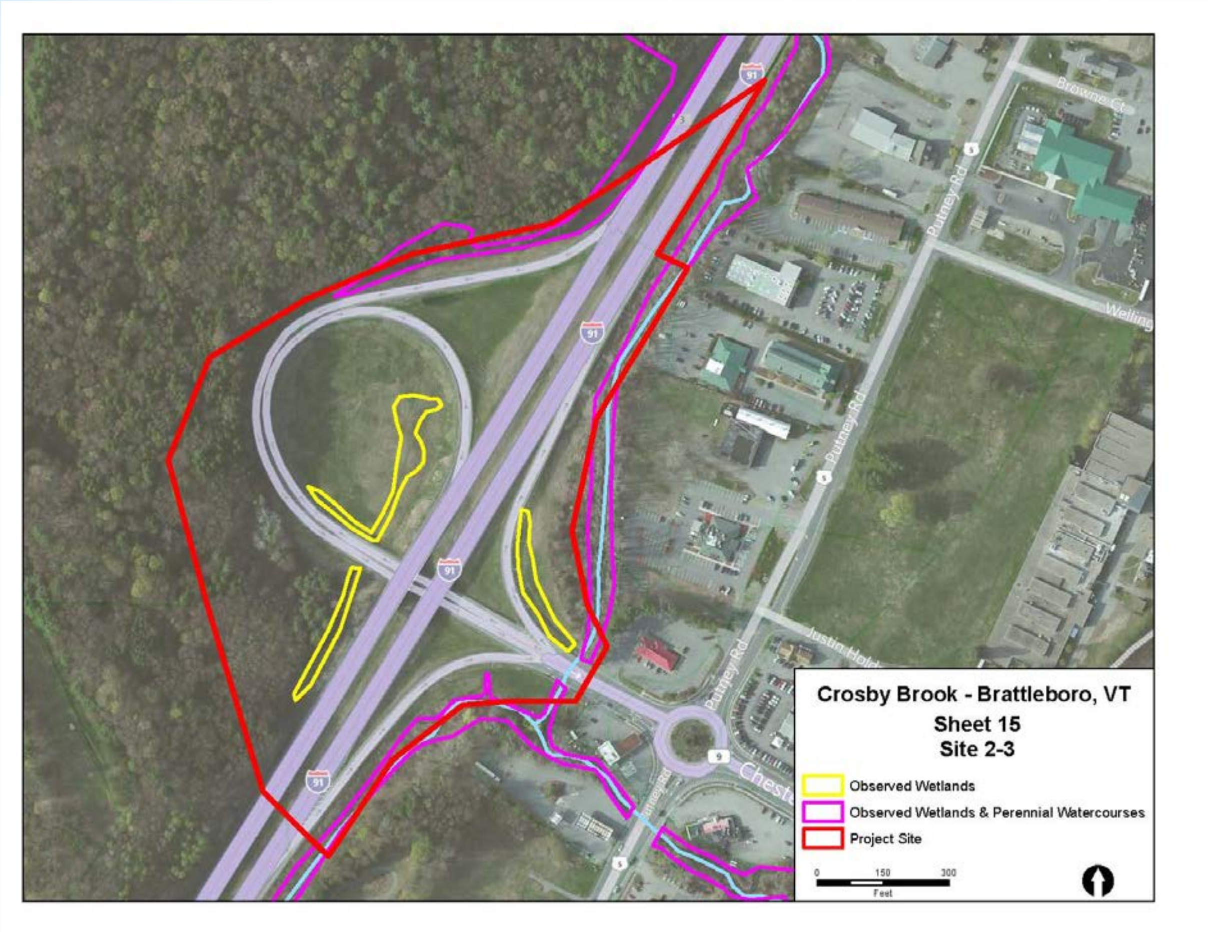
STP Location based on Potential Build-out Areas





STP Identification

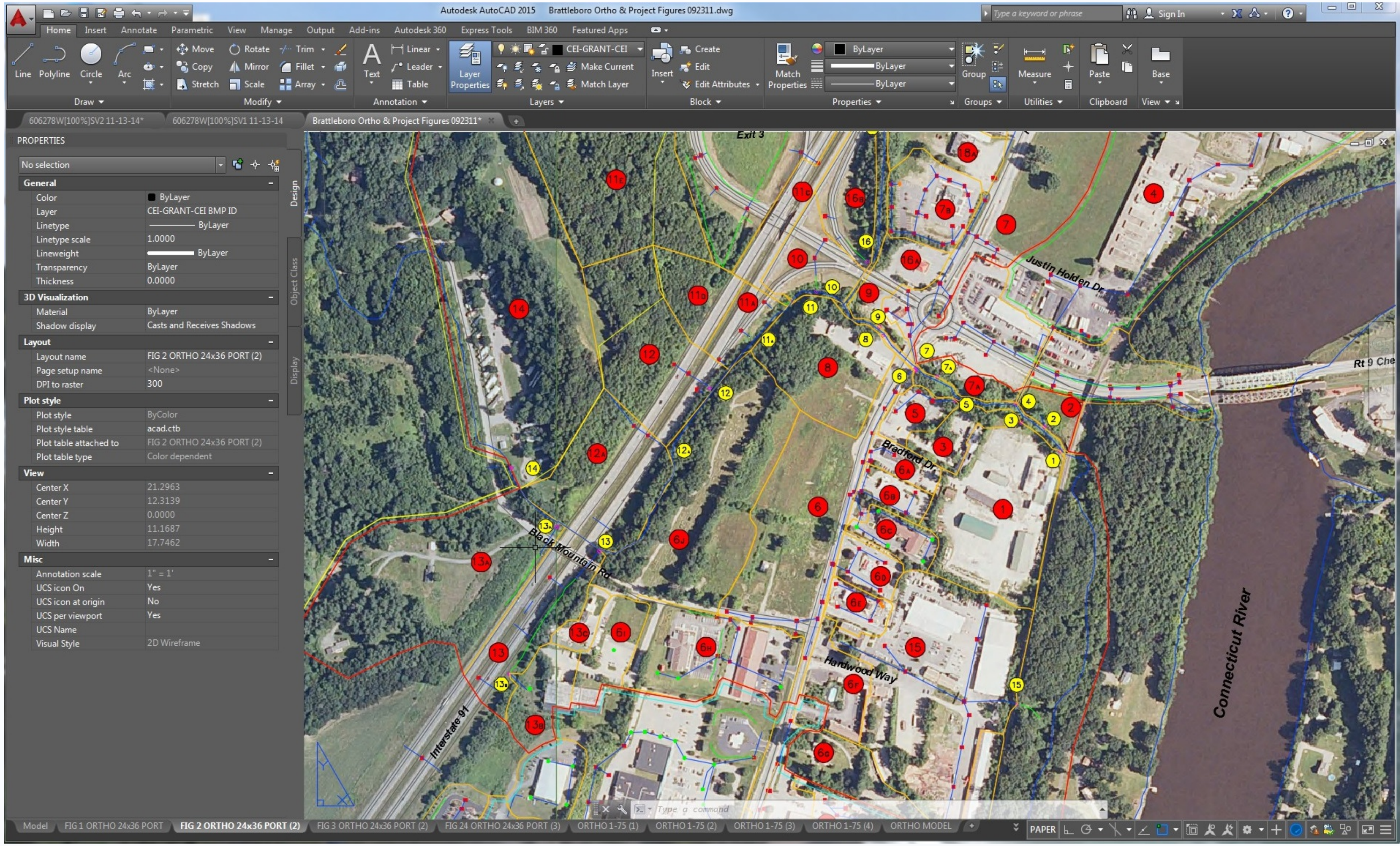
STP Location and Type based on Resource Area Delineations & Potential Impacts



STP Identification

STP Location and Type based on Subwatershed Delineations & Potential Drainage Connections

- Potential for a sub-watershed area to drain to an STP site;
- Potential for drainage systems to be diverted;
- Review of existing drainage connections
- Locations of outfalls



STP Identification

Culvert replacements & stabilization areas in Study Area 3 were based on information from previous geomorphic assessments

Crosby Brook Phase 2
Stream Geomorphic Assessment Summary

July 21, 2008

Prepared by:

Evan P. Fitzgerald, Principal Watershed Scientist

Fitzgerald Environmental Associates, LLC.

Applied Watershed Science & Ecology

Prepared for:

Appendix B - Phase 2 Reach Summary Statistics

Reach/ Segment	Stream Type	Dominant Bed Material	Bedform	STD*	Reference Stream Type†	Reference Bed Material†	Reference Bedform†	RHA Score	RHA Condition	RGA Score	RGA Condition	Reach Sensitivity	CEM**	CEM** Stage
M01-A	A	Gravel	Step-Pool	No				0.70	Good	0.74	Good	High	F	I
M01-B	C	Sand	Riffle-Pool	No				0.42	Fair	0.41	Fair	Very High	F	II
M02	F	Gravel	Plane Bed	Yes	C	Gravel	Riffle-Pool	0.34	Poor	0.33	Poor	Extreme	F	II
M03	C	Gravel	Riffle-Pool	No				0.63	Fair	0.48	Fair	Very High	F	III
M04	C	Gravel	Riffle-Pool	No				0.72	Good	0.68	Good	High	F	I
M05	E	Gravel	Riffle-Pool	No				0.57	Fair	0.64	Good	High	F	IV
M06-A	C	Gravel	Riffle-Pool	No				0.71	Good	0.61	Fair	Very High	F	II
M06-B	B	Cobble	Step-Pool	No				0.73	Good	0.68	Good	Moderate	F	II
M06-C	C	Gravel	Riffle-Pool	No				0.73	Good	0.66	Good	High	F	I
T1.01	F	Gravel	Plane Bed	Yes	C	Gravel	Riffle-Pool	0.53	Fair	0.38	Fair	Extreme	F	II
T1.02-A	C	Gravel	Riffle-Pool	No				0.63	Fair	0.45	Fair	Very High	F	II
T1.02-B	F	Gravel	Step-Pool	Yes	B	Cobble	Step-Pool	0.48	Fair	0.34	Poor	Extreme	F	II
T1.02-C	A	Bedrock	Step-Pool	No				0.86	Reference	0.85	Reference	Very Low	F	I
T1.02-D	E	Sand	Riffle-Pool	No				0.62	Fair	0.60	Fair	Very High	F	II
T1.02-E	B	Gravel	Plane Bed	No				0.72	Good	0.79	Good	Moderate	F	I
T1.03	E	Sand	Dune-Ripple	No				0.62	Fair	0.61	Fair	Very High	F	II
							Mean:	0.62		0.58				
							Max:	0.86		0.85				
							Min:	0.34		0.33				

* STD = Stream Type Departure
** CEM = Channel Evolution Model
† = Assessed Reference Condition Prior to Stream Type Departure

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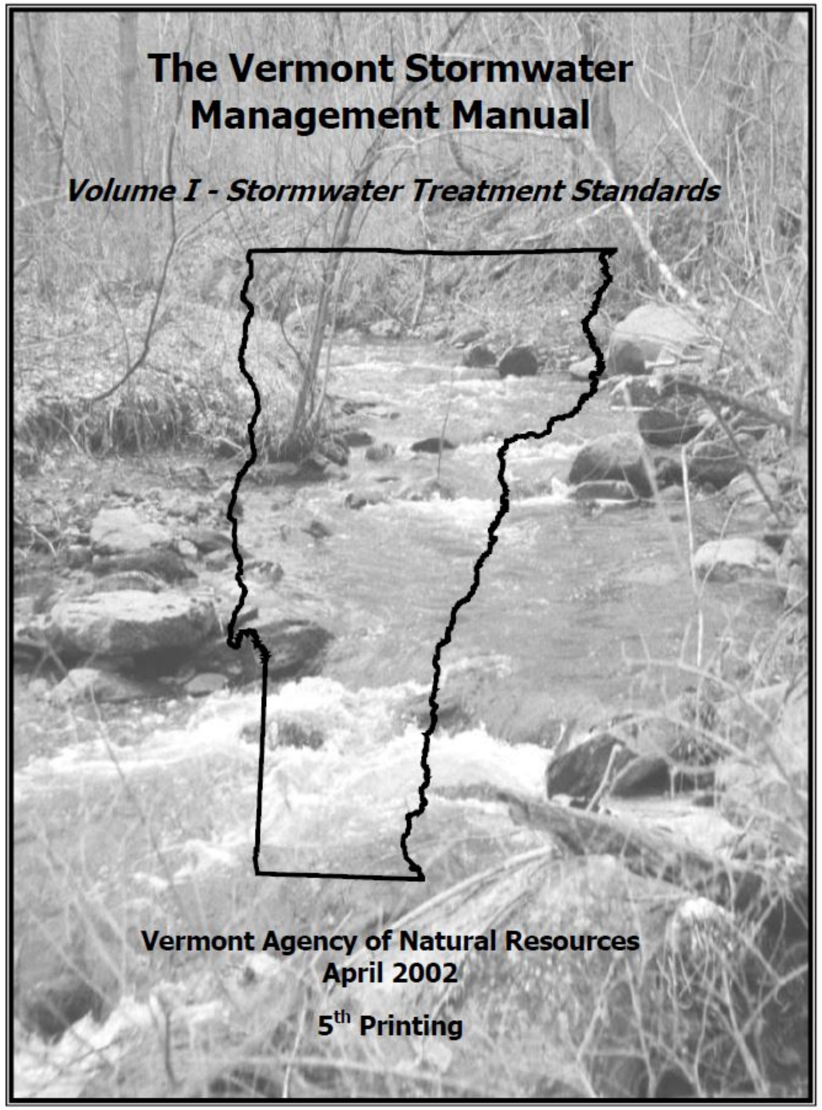
STP Sizing – Project Areas 1 & 2



Stormwater Management Manual STP Sizing Standards

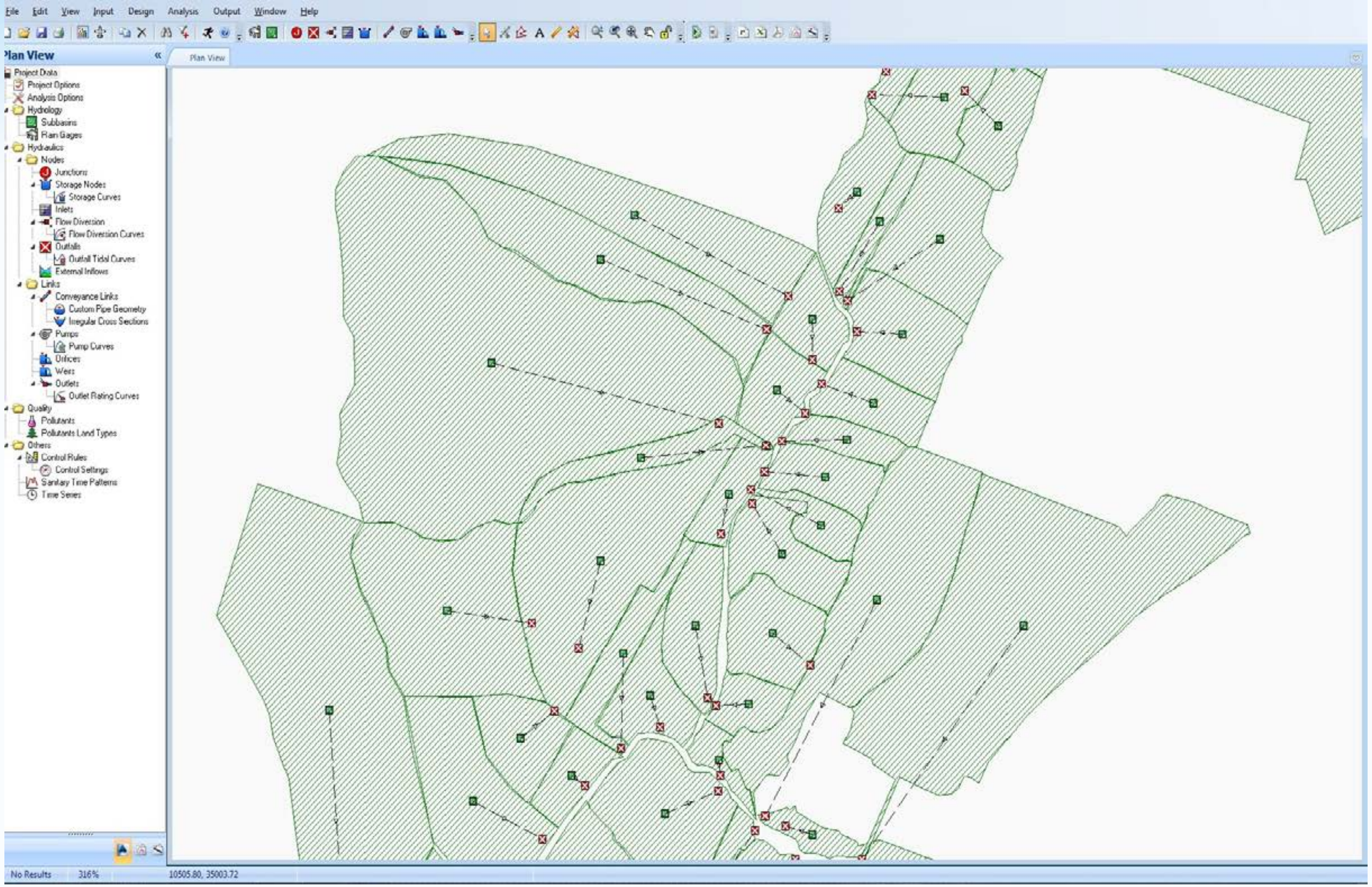
Volume Sizing for Peak Flow Attenuation

- Channel Protection
- Overbank Protection
- Spillway sized for 100-year

Volume Sizing for Stormwater Treatment

- Water Quality Volume
- Pre-Treatment Volume
- Recharge Volume

STP Sizing– Project Areas 1 & 2
Autodesk Storm & Sanitary Analysis (SSA) Model



$$A = A_1 + A_2 + A_3 + A_4 + A_5$$

$$CN = \frac{1}{A}\left[A_1(CN_1) + A_2(CN_2) + A_3(CN_3) + A_4(CN)_4 + A_5(CN)_5\right]$$

Time of Concentration

TOC Method : SCS TR-55

Sheet Flow Equation :

Tc = (0.007 * ((n * Lf)^0.8)) / ((P^0.5) * (Sf^0.4))

Where :

Tc = Time of Concentration (hr)
n = Manning's roughness
Lf = Flow Length (ft)
P = 2 yr, 24 hr Rainfall (inches)
Sf = Slope (ft/ft)

Shallow Concentrated Flow Equation :

V = 16.1345 * (Sf^0.5) (unpaved surface)
V = 20.3282 * (Sf^0.5) (paved surface)
V = 15.0 * (Sf^0.5) (grassed waterway surface)
V = 10.0 * (Sf^0.5) (nearly bare & untilled surface)
V = 9.0 * (Sf^0.5) (cultivated straight rows surface)
V = 7.0 * (Sf^0.5) (short grass pasture surface)
V = 5.0 * (Sf^0.5) (woodland surface)
V = 2.5 * (Sf^0.5) (forest w/heavy litter surface)
Tc = (Lf / V) / (3600 sec/hr)

Where:

Tc = Time of Concentration (hr)
Lf = Flow Length (ft)
V = Velocity (ft/sec)
Sf = Slope (ft/ft)

Channel Flow Equation :

V = (1.49 * (R^(2/3)) * (Sf^0.5)) / n
R = Aq / Wp
Tc = (Lf / V) / (3600 sec/hr)

Where :

Tc = Time of Concentration (hr)
Lf = Flow Length (ft)
R = Hydraulic Radius (ft)
Aq = Flow Area (ft²)
Wp = Wetted Perimeter (ft)
V = Velocity (ft/sec)
Sf = Slope (ft/ft)
n = Manning's roughness

STP Sizing– Project Areas 1 & 2 Peak Flows

Subbasin : OF-10 Rt 91 Exit 3 NB Off ramp

Composite Curve Number

Soil/Surface Description	Area (acres)	Soil Group	Curve Number
> 75% grass cover, Good	1.57	A	39.00
Paved roads with curbs & sewers	0.54	A	98.00
Composite Area & Weighted CN	2.11		54.08

Time of Concentration

Sheet Flow Computations	Subarea A	Subarea B	Subarea C
Manning's Roughness :	0.01	0.00	0.00
Flow Length (ft) :	100	0.00	0.00
Slope (%) :	2	0.00	0.00
2 yr, 24 hr Rainfall (in) :	2.70	0.00	0.00
Velocity (ft/sec) :	1.36	0.00	0.00
Computed Flow Time (min) :	1.22	0.00	0.00

Shallow Concentrated Flow Computations	Subarea A	Subarea B	Subarea C
Flow Length (ft) :	50	50	0.00
Slope (%) :	2	2	0.00
Surface Type :	Paved	;sed wate	Unpaved
Velocity (ft/sec) :	2.87	2.12	0.00
Computed Flow Time (min) :	0.29	0.39	0.00

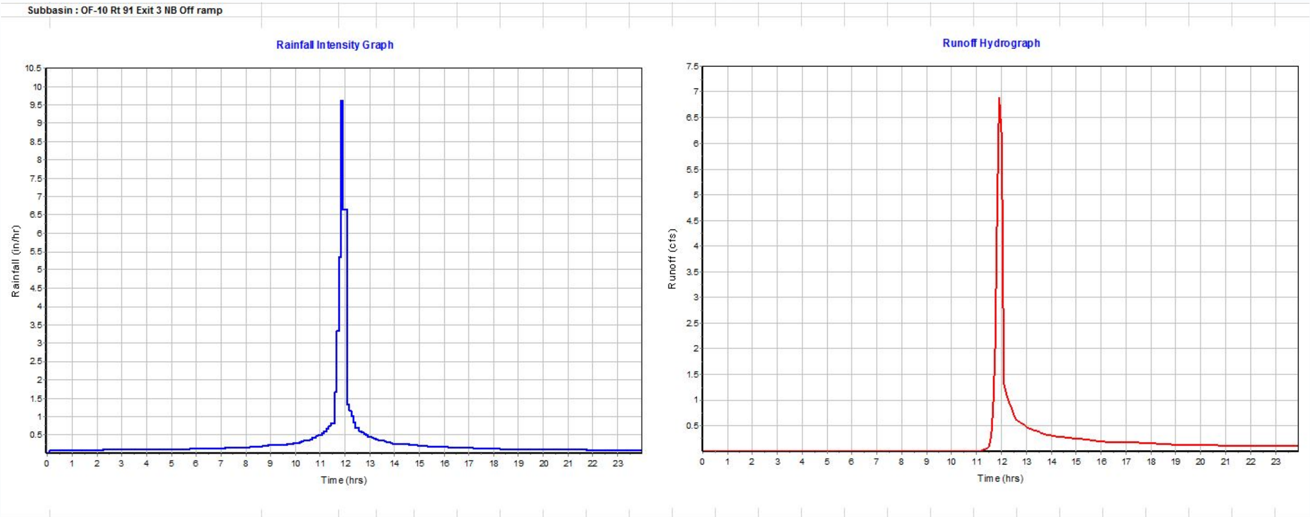
Channel Flow Computations	Subarea A	Subarea B	Subarea C
Manning's Roughness :	0.013	0.013	0.00
Flow Length (ft) :	50	76.90	0.00
Channel Slope (%) :	2	2	0.00
Cross Section Area (ft²) :	1	0.8	0.00
Wetted Perimeter (ft) :	3	3.14	0.00
Velocity (ft/sec) :	7.79	6.51	0.00
Computed Flow Time (min) :	0.11	0.20	0.00

Total TOC (min) 2.21

Subbasin Runoff Results

Total Rainfall (in)	7.00
Total Runoff (in)	2.04
Peak Runoff (cfs)	7.15
Weighted Curve Number	54.08
Time of Concentration (days hh:mm:ss)	0 00:02:13

- Determine Weighted Curve Number (CN)
- Determine Time of Concentration (Tc)
- Determine Impervious Area (IA)
- Used Higher Precipitation Design Storms



STP Sizing– Project Areas 1 & 2
Peak Flow Criteria

- CP_V – Channel Protection Volume
- OB_V – Overbank Protection Volume

Channel Protection (CP_v)	Default Criterion: CP_v = 12 hours extended detention of post-developed 1-year, 24-hour rainfall event in coldwater fish habitats (24 hr. detention in warmwater fish habitats).
Overbank Flood (Q_{p10})	Control the post-developed[2] peak discharge from the 10-year storm to 10-year pre-development[3] rates.
Extreme Storm (Q_{p100})	Control the peak discharge from the 100-year storm to 100-year pre-development rates.

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STP Sizing– Project Areas 1 & 2
Basin Volumes

Based on the VT Manual, peak flow model estimates, (USDA TR-55) and Harrington methods were used to estimate basin volumes

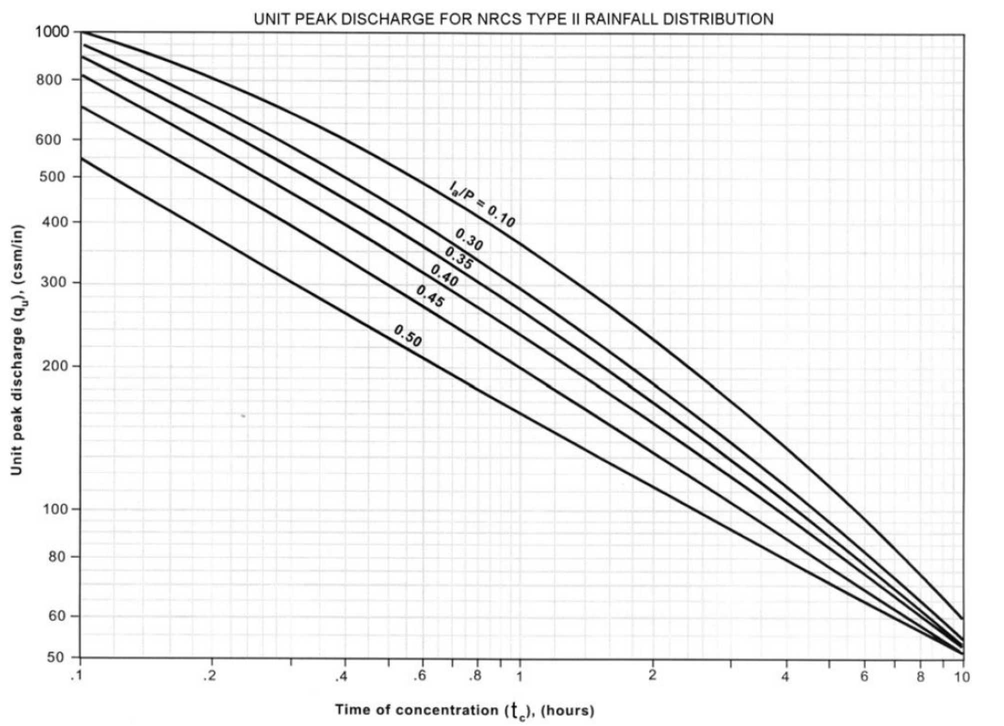

Figure 1.4 Unit Peak Discharge for Type II Rainfall Distribution (Source: NRCS, 1986)

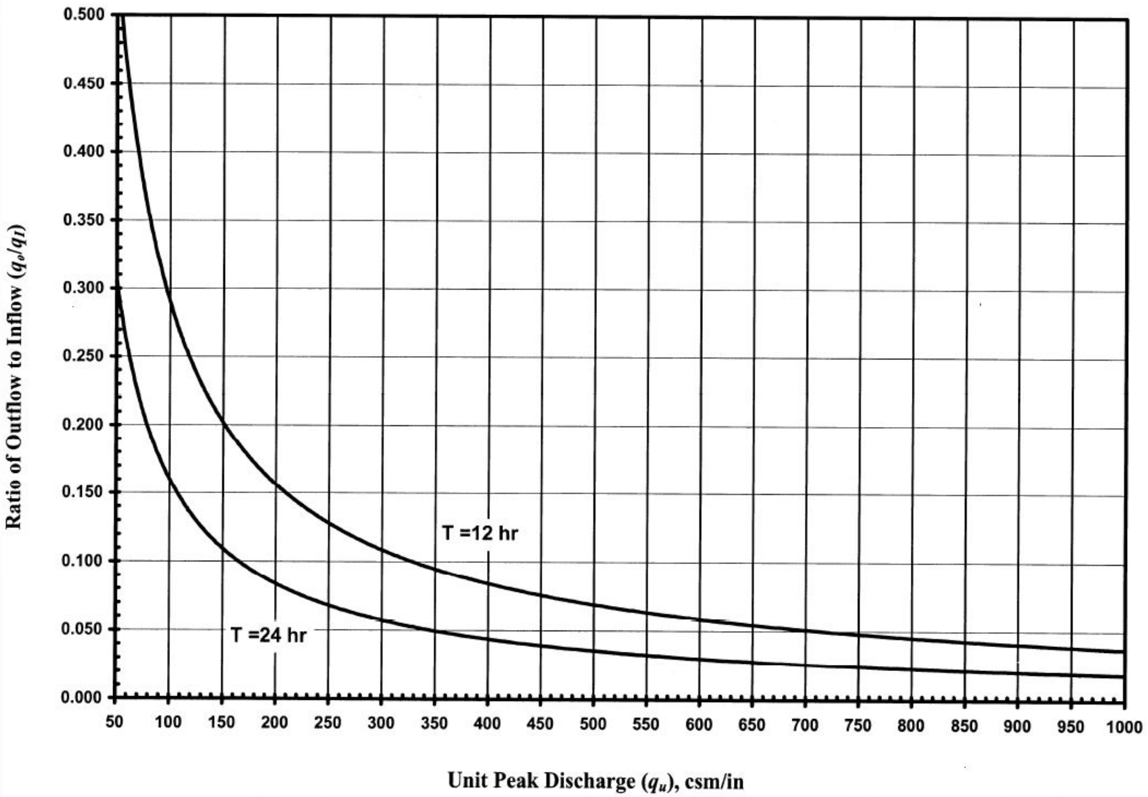

Figure 1.5 Detention Time vs. Discharge Ratios (Source: adopted from Harrington, 1987)

STP Sizing– Project Areas 1 & 2
Basin Volumes

Then using q_O/q_i, Figure 1.6 can be used to estimate V_S/V_r. For a Type II or Type III rainfall distribution, V_S/V_r can also be calculated using the following equation:

$$V_S/V_r = 0.682 - 1.43\,(q_O/q_I) + 1.64\,(q_O/q_I)^2 - 0.804\,(q_O/q_I)^3$$

Where:
- V_S = required storage volume (acre-feet)
- V_r = runoff volume (acre-feet)
- q_O = peak outflow discharge (cfs)
- Q_I = peak inflow discharge (cfs)

The required storage volume can then be calculated by:

$$V_S = \frac{(V_S/V_r)(Q_d)(A)}{12}$$

Where:
- Q_d = the developed runoff for the design storm (inches)
- A = total drainage area (acres)

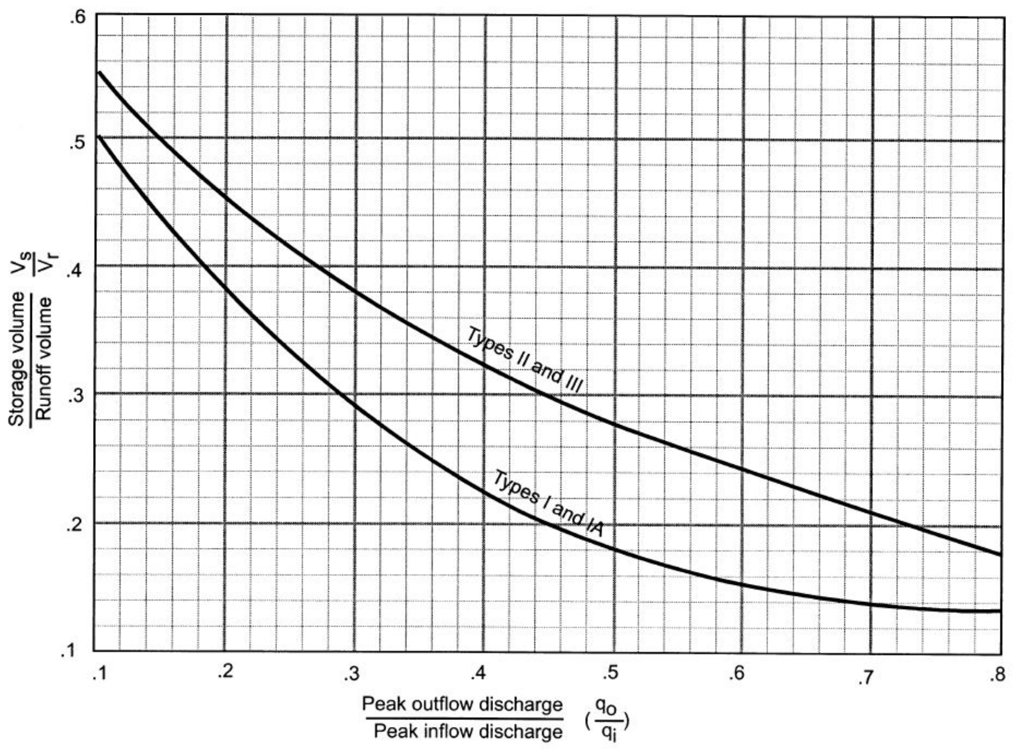

Figure 1.6 Approximate Detention Basin Routing For Rainfall Types I, IA, II, and III. (Source: NRCS, 1986)

STP Sizing– Project Areas 1 & 2 Channel Protection Volume (CPv)

CP_V –12-hr detention of 1-yr, 24-hr storm completed for each Sub-watershed

Subbasin Summary

Subbasin ID	Area (acre)	Weighted Curve Number	Total Rainfall (in)	Total Runoff (in)	Total Runoff Volume (ac-in)	Peak Runoff (cfs)	tc (hr)	S	Ia	Ia/P	Channel Protection Volume, 24 Hour Storm: qu	qo/qi	T (hrs)	Vs/Vr	Vs (acre-feet)	Vs cubic feet
OF-10 Rt 91 Exit 3 NB Off ramp	2.11	54.08	2.40	0.05	0.11	0.01	**0.037**	8.49	1.70	**0.71**	400	0.04	24	0.627	0.006	260
OF-11A Rt 91 NB / S Exit 3 Off ramp	1.32	60.86	2.40	0.16	0.22	0.23	**0.032**	6.43	1.29	**0.54**	500	0.03	24	0.641	0.012	504
OF-11B Rt 91 Exit 3 SB On/Off Clover Leaf	9.29	67.37	2.40	0.33	3.03	3.65	**0.110**	4.84	0.97	**0.40**	800	0.025	24	0.647	0.163	7115
OF-11C Rt 91 Exit 3 SB Overpass	1.85	68.68	2.40	0.37	0.68	0.91	**0.061**	4.56	0.91	**0.38**	810	0.025	24	0.647	0.036	1590
OF-11D Rt 91 SB / S Exit 3	2.12	40.70	2.40	0.00	0.00	0.00	**0.058**	14.57	2.91	**1.21**	100	0.15	24	0.502	0.000	0
OF-11E Upper Watershed RT 91 Clover Leaf	8.13	30.00	2.40	0.00	0.00	0.00	**0.340**	23.33	4.67	**1.94**	80	0.16	24	0.492	0.000	0
OF-12 Rt 91 S of Exit 3	5.47	40.32	2.40	0.00	0.00	0.00	**0.059**	14.80	2.96	**1.23**	100	0.15	24	0.502	0.000	0
OF-12A Rt 91 N of Black MT Rd Overpass	4.87	49.90	2.40	0.02	0.07	0.01	**0.060**	10.04	2.01	**0.84**	200	0.08	24	0.578	0.004	153
OF-13 Rt 91 S Black Mt Rd Overpass	3.50	74.96	2.40	0.59	2.07	3.16	**0.059**	3.34	0.67	**0.28**	980	0.02	24	0.654	0.113	4909
OF-16B Rt 91 Exit 3 NB On ramp	2.44	44.42	2.40	0.00	0.00	0.00	**0.039**	12.51	2.50	**1.04**	200	0.08	24	0.578	0.000	0
OF-17 Rt 91 N Exit 3 / Steakout	1.32	58.65	2.40	0.12	0.16	0.09	**0.059**	7.05	1.41	**0.59**	400	0.04	24	0.627	0.008	367
OF-20A Rt 91 SB Exit Offramp	1.76	67.33	2.40	0.33	0.57	0.78	**0.046**	4.85	0.97	**0.40**	800	0.025	24	0.647	0.031	1342
OF-20B Upper Watershed Rt 91 Exit 3	29.54	70.00	2.40	0.41	12.05	9.18	**0.395**	4.29	0.86	**0.36**	400	0.04	24	0.627	0.630	27452
OF-22A Rt 91 N of Exit 3	1.80	73.13	2.40	0.52	0.93	1.37	**0.060**	3.67	0.73	**0.31**	950	0.02	24	0.654	0.051	2217
OF-22B Upper Watershed Rt 91	6.22	70.00	2.40	0.41	2.54	1.93	**0.395**	4.29	0.86	**0.36**	400	0.04	24	0.627	0.133	5781
OF-25A Rt 91 S of Crosby Crossing	1.58	72.25	2.40	0.49	0.77	1.10	**0.060**	3.84	0.77	**0.32**	970	0.02	24	0.654	0.042	1825
OF-25B Upper Watershed Rt 91	7.30	70.00	2.40	0.41	2.98	2.27	**0.395**	4.29	0.86	**0.36**	400	0.04	24	0.627	0.156	6786
OF-26A Rt 91 N of Crosby Cross	0.95	63.18	2.40	0.22	0.20	0.24	**0.051**	5.83	1.17	**0.49**	550	0.035	24	0.634	0.011	472
OF-27 Rt 91 N of Crosby Cross	2.39	51.10	2.40	0.02	0.05	0.01	**0.050**	9.57	1.91	**0.80**	360	0.055	24	0.608	0.003	121
OF-28A Rt 91 N Exit 3 / E Hampton	2.64	53.97	2.40	0.05	0.14	0.01	**0.052**	8.53	1.71	**0.71**	400	0.04	24	0.627	0.007	313
OF-28B Upper Watershed Rt 91	2.67	39.00	2.40	0.00	0.00	0.00	**0.429**	15.64	3.13	**1.30**	180	0.1	24	0.555	0.000	0
OF-29 Rt 91 SW of Putney Bridge	6.42	54.54	2.40	0.06	0.38	0.04	**0.046**	8.34	1.67	**0.69**	410	0.045	24	0.621	0.020	853
OF-35 Rt 91 NE of Putney Bridge	9.49	76.68	2.40	0.66	6.30	10.38	**0.038**	3.04	0.61	**0.25**	950	0.02	24	0.654	0.343	14958

STP Sizing– Project Areas 1 & 2
Overbank Protection Volume (OBv)

Ob_V – 10yr – 24hr storm completed for each Sub-watershed

Subbasin Summary

Subbasin ID	Area (acre)	Weighted Curve Number	Total Rainfall (in)	Total Runoff (in)	Total Runoff Volume (ac-in)	Peak Runoff (cfs)	tc (hr)	S	Ia	Ia/P	Overbank Flood Volume 24 Hour Storm qu	qo/qi	T	Vs/Vr	Vs (acre-feet)	Vs (cubic feet)
OF-10 Rt 91 Exit 3 NB Off ramp	2.11	54.08	4.10	0.53	1.12	1.54	**0.037**	8.49	1.70	**0.41**	800	0.025	24	0.647	0.060	2630
OF-11A Rt 91 NB / S Exit 3 Off ramp	1.32	60.86	4.10	0.86	1.13	1.77	**0.032**	6.43	1.29	**0.31**	950	0.02	24	0.654	0.062	2688
OF-11B Rt 91 Exit 3 SB On/Off Clover Leaf	9.29	67.37	4.10	1.23	11.43	16.41	**0.110**	4.84	0.97	**0.24**	995	0.02	24	0.654	0.623	27128
OF-11C Rt 91 Exit 3 SB Overpass	1.85	68.68	4.10	1.31	2.43	3.89	**0.061**	4.56	0.91	**0.22**	995	0.02	24	0.654	0.132	5758
OF-11D Rt 91 SB / S Exit 3	2.12	40.70	4.10	0.09	0.19	0.02	**0.058**	14.57	2.91	**0.71**	290	0.06	24	0.602	0.009	413
OF-11E Upper Watershed RT 91 Clover Leaf	8.13	30.00	4.10	0.00	0.00	0.00	**0.340**	23.33	4.67	**1.14**	150	0.11	24	0.543	0.000	0
OF-12 Rt 91 S of Exit 3	5.47	40.32	4.10	0.08	0.44	0.05	**0.059**	14.80	2.96	**0.72**	290	0.06	24	0.602	0.022	968
OF-12A Rt 91 N of Black MT Rd Overpass	4.87	49.90	4.10	0.36	1.76	1.96	**0.060**	10.04	2.01	**0.49**	560	0.03	24	0.641	0.094	4086
OF-13 Rt 91 S Black Mt Rd Overpass	3.50	74.96	4.10	1.74	6.08	10.07	**0.059**	3.34	0.67	**0.16**	1000	0.02	24	0.654	0.332	14446
OF-16B Rt 91 Exit 3 NB On ramp	2.44	44.42	4.10	0.18	0.44	0.20	**0.039**	12.51	2.50	**0.61**	320	0.05	24	0.614	0.023	983
OF-17 Rt 91 N Exit 3 / Steakout	1.32	58.65	4.10	0.74	0.98	1.36	**0.059**	7.05	1.41	**0.34**	910	0.02	24	0.654	0.054	2331
OF-20A Rt 91 SB Exit Offramp	1.76	67.33	4.10	1.23	2.16	3.54	**0.046**	4.85	0.97	**0.24**	995	0.02	24	0.654	0.118	5120
OF-20B Upper Watershed Rt 91 Exit 3	29.54	70.00	4.10	1.40	41.27	39.85	**0.395**	4.29	0.86	**0.21**	995	0.02	24	0.654	2.250	97992
OF-22A Rt 91 N of Exit 3	1.80	73.13	4.10	1.61	2.89	4.76	**0.060**	3.67	0.73	**0.18**	1000	0.02	24	0.654	0.158	6873
OF-22B Upper Watershed Rt 91	6.22	70.00	4.10	1.40	8.69	8.39	**0.395**	4.29	0.86	**0.21**	990	0.02	24	0.654	0.474	20637
OF-25A Rt 91 S of Crosby Crossing	1.58	72.25	4.10	1.55	2.44	4.00	**0.060**	3.84	0.77	**0.19**	990	0.02	24	0.654	0.133	5800
OF-25B Upper Watershed Rt 91	7.30	70.00	4.10	1.40	10.20	9.85	**0.395**	4.29	0.86	**0.21**	990	0.02	24	0.654	0.556	24224
OF-26A Rt 91 N of Crosby Cross	0.95	63.18	4.10	0.98	0.93	1.44	**0.051**	5.83	1.17	**0.28**	970	0.02	24	0.654	0.051	2215
OF-27 Rt 91 N of Crosby Cross	2.39	51.10	4.10	0.41	0.97	1.19	**0.050**	9.57	1.91	**0.47**	600	0.025	24	0.647	0.052	2284
OF-28A Rt 91 N Exit 3 / E Hampton	2.64	53.97	4.10	0.53	1.39	1.84	**0.052**	8.53	1.71	**0.42**	750	0.02	24	0.654	0.076	3291
OF-28B Upper Watershed Rt 91	2.67	39.00	4.10	0.06	0.15	0.02	**0.429**	15.64	3.13	**0.76**	280	0.06	24	0.602	0.008	333
OF-29 Rt 91 SW of Putney Bridge	6.42	54.54	4.10	0.55	3.53	4.79	**0.046**	8.34	1.67	**0.41**	790	0.02	24	0.654	0.192	8380
OF-35 Rt 91 NE of Putney Bridge	9.49	76.68	4.10	1.87	17.71	30.37	**0.038**	3.04	0.61	**0.15**	1000	0.02	24	0.654	0.965	42036

STP Sizing– Project Areas 1 & 2
Water Quality Volume (WQv)

The following equation shall be used to determine the water quality storage volume (WQ_v) (in acre-feet of storage):

$$WQ_v = \frac{(P)\,(R_v)\,(A)}{12}$$

where:

- WQ_v = water quality volume (in acre-feet)
- P = 90% Rainfall Event (0.9 inches across Vermont)
- R_v = volumetric runoff coefficient equal to: [0.05 + 0.009(I)], where I is a whole number percent impervious cover at the site (ex. 25, not .25)
- A = site area (in acres)

Subbasin Summary

Subbasin ID	Water Quality Volume								
	Area (acre)	Imp Area	P (in)	% Imp (%)	% Imp (decimal)	Runoff Coeff (Rv)	WQv (acre-feet)	WQv (cu ft)	WQv (acre-in)
OF-10 Rt 91 Exit 3 NB Off ramp	2.11	0.54	0.90	26%	25.56	0.28	0.04	1933	0.53
OF-11A Rt 91 NB / S Exit 3 Off ramp	1.32	0.49	0.90	37%	37.05	0.38	0.04	1657	0.46
OF-11B Rt 91 Exit 3 SB On/Off Clover Leaf	9.29	1.06	0.90	11%	11.41	0.15	0.11	4634	1.28
OF-11C Rt 91 Exit 3 SB Overpass	1.85	0.56	0.90	30%	30.29	0.32	0.04	1949	0.54
OF-11D Rt 91 SB / S Exit 3	2.12	0.27	0.90	13%	12.72	0.16	0.03	1141	0.31
OF-11E Upper Watershed RT 91 Clover Leaf	8.13	0	0.90	0%	0.00	0.05	0.03	1329	0.37
OF-12 Rt 91 S of Exit 3	5.47	0.69	0.90	13%	12.61	0.16	0.07	2923	0.81
OF-12A Rt 91 N of Black MT Rd Overpass	4.87	0.88	0.90	18%	18.08	0.21	0.08	3383	0.93
OF-13 Rt 91 S Black Mt Rd Overpass	3.50	2.11	0.90	60%	60.31	0.59	0.16	6776	1.87
OF-16B Rt 91 Exit 3 NB On ramp	2.44	0.38	0.90	16%	15.61	0.19	0.03	1515	0.42
OF-17 Rt 91 N Exit 3 / Steakout	1.32	0.44	0.90	33%	33.30	0.35	0.03	1510	0.42
OF-20A Rt 91 SB Exit Offramp	1.76	0.41	0.90	23%	23.33	0.26	0.03	1493	0.41
OF-20B Upper Watershed Rt 91 Exit 3	29.54	0	0.90	0%	0.00	0.05	0.11	4826	1.33
OF-22A Rt 91 N of Exit 3	1.80	0.59	0.90	33%	32.80	0.35	0.05	2029	0.56
OF-22B Upper Watershed Rt 91	6.22	0	0.90	0%	0.00	0.05	0.02	1016	0.28
OF-25A Rt 91 S of Crosby Crossing	1.58	0.48	0.90	30%	30.41	0.32	0.04	1669	0.46
OF-25B Upper Watershed Rt 91	7.30	0	0.90	0%	0.00	0.05	0.03	1193	0.33
OF-26A Rt 91 N of Crosby Cross	0.95	0.56	0.90	59%	59.02	0.58	0.04	1802	0.50
OF-27 Rt 91 N of Crosby Cross	2.39	0.49	0.90	21%	20.51	0.23	0.04	1831	0.50
OF-28A Rt 91 N Exit 3 / E Hampton	2.64	0.67	0.90	25%	25.37	0.28	0.06	2401	0.66
OF-28B Upper Watershed Rt 91	2.67	0	0.90	0%	0.00	0.05	0.01	436	0.12
OF-29 Rt 91 SW of Putney Bridge	6.42	1.69	0.90	26%	26.34	0.29	0.14	6017	1.66
OF-35 Rt 91 NE of Putney Bridge	9.49	2.78	0.90	29%	29.30	0.31	0.22	9724	2.68

STP Sizing– Project Areas 1 & 2
Pre-Treatment Volume (Prev)

- Pre-treatment volume varies based on STP type
- For conceptual sizing purposes, used 10% of the water quality volume.

Subbasin Summary

Subbasin ID	Area (acre)	Weighted Curve Number	Pre-Treatment Volume: Pre-Treat coeff (in)	Imp Area (acre)	Pre-Treat Volume (acre-in)	Pre-Treat Volume (acre-feet)	Pre-Treat Volume (cu ft)
OF-10 Rt 91 Exit 3 NB Off ramp	2.11	54.08	0.1	0.54	0.054	0.005	196
OF-11A Rt 91 NB / S Exit 3 Off ramp	1.32	60.86	0.1	0.49	0.049	0.004	178
OF-11B Rt 91 Exit 3 SB On/Off Clover Leaf	9.29	67.37	0.1	1.06	0.106	0.009	385
OF-11C Rt 91 Exit 3 SB Overpass	1.85	68.68	0.1	0.56	0.056	0.005	203
OF-11D Rt 91 SB / S Exit 3	2.12	40.70	0.1	0.27	0.027	0.002	98
OF-11E Upper Watershed RT 91 Clover Leaf	8.13	30.00	0.1	0	0	0.000	0
OF-12 Rt 91 S of Exit 3	5.47	40.32	0.1	0.69	0.069	0.006	250
OF-12A Rt 91 N of Black MT Rd Overpass	4.87	49.90	0.1	0.88	0.088	0.007	319
OF-13 Rt 91 S Black Mt Rd Overpass	3.50	74.96	0.1	2.11	0.211	0.018	766
OF-16B Rt 91 Exit 3 NB On ramp	2.44	44.42	0.1	0.38	0.038	0.003	138
OF-17 Rt 91 N Exit 3 / Steakout	1.32	58.65	0.1	0.44	0.044	0.004	160
OF-20A Rt 91 SB Exit Offramp	1.76	67.33	0.1	0.41	0.041	0.003	149
OF-20B Upper Watershed Rt 91 Exit 3	29.54	70.00	0.1	0	0	0.000	0
OF-22A Rt 91 N of Exit 3	1.80	73.13	0.1	0.59	0.059	0.005	214
OF-22B Upper Watershed Rt 91	6.22	70.00	0.1	0	0	0.000	0
OF-25A Rt 91 S of Crosby Crossing	1.58	72.25	0.1	0.48	0.048	0.004	174
OF-25B Upper Watershed Rt 91	7.30	70.00	0.1	0	0	0.000	0
OF-26A Rt 91 N of Crosby Cross	0.95	63.18	0.1	0.56	0.056	0.005	203
OF-27 Rt 91 N of Crosby Cross	2.39	51.10	0.1	0.49	0.049	0.004	178
OF-28A Rt 91 N Exit 3 / E Hampton	2.64	53.97	0.1	0.67	0.067	0.006	243
OF-28B Upper Watershed Rt 91	2.67	39.00	0.1	0	0	0.000	0
OF-29 Rt 91 SW of Putney Bridge	6.42	54.54	0.1	1.69	0.169	0.014	613
OF-35 Rt 91 NE of Putney Bridge	9.49	76.68	0.1	2.78	0.278	0.023	1009

VTrans Working to Get You There — Vermont Agency of Transportation

VERMONT DEPARTMENT OF ENVIRONMENTAL CONSERVATION

STP Sizing– Project Areas 1 & 2
Recharge Volume (Rev)

The Percent Volume Method calculation is as follows:

$$Re_v = (F)(A)(I)/12$$

Where: Re_v = Recharge volume (acre-feet)

F = Recharge factor (inches)

Hydrologic Soil Group	Recharge Factor (F)
A	0.40
B	0.25
C	0.10
D	waived

A = Site area (in acres)

I = Site imperviousness (expressed as a decimal percent)

Subbasin Summary

Subbasin ID	Recharge Volume						
	Total Area (acre)	Soils	Recharge coeff (in)	% Imp	Rev (acre-in)	Rev (acre-feet)	Rev (cu ft)
OF-10 Rt 91 Exit 3 NB Off ramp	2.11	A	0.4	26%	0.22	0.018	784
OF-11A Rt 91 NB / S Exit 3 Off ramp	1.32	A	0.4	37%	0.20	0.016	711
OF-11B Rt 91 Exit 3 SB On/Off Clover Leaf	9.29	B	0.25	11%	0.27	0.022	962
OF-11C Rt 91 Exit 3 SB Overpass	1.85	A	0.4	30%	0.22	0.019	813
OF-11D Rt 91 SB / S Exit 3	2.12	A	0.4	13%	0.11	0.009	392
OF-11E Upper Watershed RT 91 Clover Leaf	8.13	C	0.1	0%	0.00	0.000	0
OF-12 Rt 91 S of Exit 3	5.47	A	0.4	13%	0.28	0.023	1002
OF-12A Rt 91 N of Black MT Rd Overpass	4.87	A	0.4	18%	0.35	0.029	1278
OF-13 Rt 91 S Black Mt Rd Overpass	3.50	B	0.25	60%	0.53	0.044	1915
OF-16B Rt 91 Exit 3 NB On ramp	2.44	A	0.4	16%	0.15	0.013	552
OF-17 Rt 91 N Exit 3 / Steakout	1.32	A	0.4	33%	0.18	0.015	639
OF-20A Rt 91 SB Exit Offramp	1.76	B	0.25	23%	0.10	0.009	372
OF-20B Upper Watershed Rt 91 Exit 3	29.54	C	0.1	0%	0.00	0.000	0
OF-22A Rt 91 N of Exit 3	1.80	B	0.25	33%	0.15	0.012	535
OF-22B Upper Watershed Rt 91	6.22	B	0.25	0%	0.00	0.000	0
OF-25A Rt 91 S of Crosby Crossing	1.58	B	0.25	30%	0.12	0.010	436
OF-25B Upper Watershed Rt 91	7.30	B	0.25	0%	0.00	0.000	0
OF-26A Rt 91 N of Crosby Cross	0.95	A	0.4	59%	0.22	0.019	813
OF-27 Rt 91 N of Crosby Cross	2.39	A	0.4	21%	0.20	0.016	711
OF-28A Rt 91 N Exit 3 / E Hampton	2.64	A	0.4	25%	0.27	0.022	973
OF-28B Upper Watershed Rt 91	2.67	A	0.4	0%	0.00	0.000	0
OF-29 Rt 91 SW of Putney Bridge	6.42	A	0.4	26%	0.68	0.056	2454
OF-35 Rt 91 NE of Putney Bridge	9.49	B	0.25	29%	0.70	0.058	2523

STP Sizing– Project Areas 1 & 2 Results

Available STP volume versus Sizing Criteria

	STP #1.1	Total Area (acre)	Treated Percent	Treated Area (acre)	12 hr- CPv Volume (cu.ft.)	Total Imp Area (acre)	Treated Imp Area (acre)	WQ Volume (cu.ft.)	Soils Group	Re Volume (cu.ft.)	Pre-Treat Volume (cu.ft.)	Sanded Area (acre)	Sand Load (cu.ft.)	24 hr -OB Volume (cu.ft.)	Assumed Weir Ht. (ft)	Peak Flow 100 yr (cfs)	Weir Length (ft)
59	OF-6D McDonalds	0.97	100%	0.965	3593	0.8	0.80	2510	B	726	290	0.00	27	7364	1.0	9.0	3
60	OF-6E KFC Taco Bell	1.00	25%	0.249	928	0.87	0.22	680	B	197	79	0.04	7	1902	1.0	2.3	1
61	OF-6F Americas Best Inn	1.83	100%	1.832	6820	1.26	1.26	4004	B	1143	457	0.15	46	13979	1.0	17.0	5
22	BO-OF-6 Current House	2.11	25%	0.528	19	0.12	0.03	175	A	44	11	0.00	0	263	1.0	0.6	0
23	BO-OF-6 New Development 1	1.26	50%	0.630	608	0.68	0.34	1103	B	309	123	0.00	9	2126	1.0	3.4	1
24	BO-OF-6 New Development 2	2.66	50%	1.328	1281	1.44	0.72	2334	A	1045	261	0.00	20	4480	1.0	7.1	2
25	BO-OF-6-Current Putney Road	2.29	60%	1.372	3791	1.80	1.08	3400	B	980	392	1.08	60	8705	1.0	11.8	4
8	BO-OF-15 Current Commercial / Indu	8.73	60%	5.236	19491	6.43	3.86	12199	A	5602	1400	0.16	191	39953	1.0	47.9	15
9	BO-OF-15 New Development 15	2.58	50%	1.289	1244	1.39	0.70	2254	A	1009	252	0.00	19	4351	1.0	6.9	2
15	OF-15 Commercial / Industrial	11.31	0%	0.000	0	7.36	0.00	0	B	0	0	0.00	0	0	1.0	0.0	0
	STP #1.1	34.73		13.43	37773	22.15	9.00	28658		11055	3267	1.43	380	83123		106.1	34

	STP #1.1															
	Decription	TYPE	Length	Width	Area	Area	Depth		Volume							
BMP 1	Infiltration Pond	POND	0.00	0.00		7500.00	4.50		33750						100 YR	Spillway
BMP 2	Wetpond	POND	0.00	0.00		9000.00	5.00		45000	Pre	WQv	REv	CPv	Obv	Peak	Length
BMP 3	Gravel Wetland	TRENCH	100.00	50.00		5000.00	2.00		3000	(cu.ft.)	(cu.ft.)	(cu.ft.)	(cu.ft.)	(cu.ft.)	(cfs)	(ft)
BMP 4			0.00	0.00		0.00			0	3267	28658	11055	37773	83123	106.1	34
				Total Area		Avg Depth	3.83	Volume	81750	2502%	285%	739%	216%	98%		

STPv falls shy of Obv

STPv meets REv

STPv meets WQv, CPv

STP Sizing– Project Areas 1 & 2

Treated areas and associated property owners:

STP #1.1 Subwatersheds	Area (acres)	Imp Area (acres)					
BO-OF-6 Current House	0.528	0.03					
BO-OF-6 New Development 1	0.630	0.34					
BO-OF-6 New Development 2	1.328	0.72					
BO-OF-6-Current Putney Road	1.372	1.08					
OF-6D McDonalds	0.965	0.80					
OF-6E KFC Taco Bell	0.249	0.22					
OF-6F Americas Best Inn	1.832	1.26					
BO-OF-15 Current Commercial / Industrial	5.236	3.86					
BO-OF-15 New Development 15	1.289	0.70					
Total =	13.43	9.00					
Area Breakdown	**Area**	**Area**		**% Total Area**		**% Imp Area**	
Putney Rd	**1.37**	**1.08**	Putney Rd	10%		12%	
Other Town Roads	**0.35**	**0.35**	Other Town Roads	3%		4%	
Route 91	**0.00**	**0.00**	Route 91	0%		0%	
Total Private	**11.71**	**7.57**	Total Private	87%		84%	
					% Private		% Private
Private - Currently Developed	**8.46**	**5.82**	Current	63%	72%	65%	77%
Private - Potential Buildout	**3.25**	**1.76**	Potential Buildout	24%	28%	19%	23%

Treat a mix of public and private lands

STP Pollutant Reduction – Project Areas 1 & 2
STP Pollutant Removal

Table A.5. STP Selection: Pollutant Removal Matrix

Practice	TSS [%]	TP [%]	TN [%]	Metals[1] [%]	Bacteria [%]	Hydrocarbons [%]
Wet Ponds	80	51	33	62	70	81[2]
Stormwater Wetlands	76	49	30	42	78[2]	85[2]
Filtering Practices	86	59	38	69	37[2]	84[2]
Infiltration Practices[3]	95[2]	80	51	99[2]	N/A	N/A
Open Channels[4]	81	34	84[2]	70	N/A	62[2]
Quantity Control Ponds[2, 5]	3	19	5	7.5	78	N/A

1. Average of zinc and copper. Only zinc for infiltration
2. Based on fewer than five data points (i.e., independent monitoring studies)
3. Includes porous pavement, which is not on the list of approved practices for Vermont. At this time, there are no known field studies that have measured sediment removal in infiltration trenches. However, it can logically be presumed that a properly operating infiltration trench will remove nearly 100% of the TSS load associated with the design treatment volume.
4. Higher removal rates for dry swales.
5. Quantity control ponds (a.k.a. dry detention basins or vaults) do not meet the WQ_v requirement and must be used in conjunction with acceptable water quality STPs.

N/A: Data not available

Removals represent median values from Winer (2000)

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STP Pollutant Reduction – Project Areas 1 & 2 Pollutant Load

The Simple Method - Pollutant Reduction Model

Example Pollutant Loading Estimates

No.	Watershed Name	Landuse ID	Landuse	Area (acres)	Sanded?	Sanded Area (acres)	% Impervious	Runoff (in)	Pretreatment (0.1"/ Imp. acre) cf	Treatment (1"/ Imp. acre) cf	Annual Runoff (cf)	Annual TSS (lbs)	Annual TP (lbs)	Annual TN (lbs)	Annual FC (billion colonies)
1	Paved Roadway	8	Roadway/Parking Lot	1.870	Yes	1.870	80	31.2	543	5,430	211,687	6,545	7.25	18.5	102.1
2	Woods	2	Forested	1.000	No	0.000	5	3.8	18.2	182	13,966	44	0.10	1.5	1.2
3	Commercial	1	Commercial	10.550	Yes	7.130	85	33.0	3,255.2	32,552	1,264,072	26,919	25.97	233.7	1,649.9
							0	0.0	0.0	0	0	0	0.00	0.0	0.0
							0	0.0	0	0	0	0	0.00	0.0	0.0
Total				13.420		9.000			**3,816**	**38,164**	**1,489,725**	**33,509**	**33.3**	**253.7**	**1,753.2**

Landuse[1]	Landuse ID (used for v-lookup)	% Impervious	(C) TSS (mg/l)	(C) TP (mg/l)	(C) TN (mg/l)	*Fecal Coliform (colonies/100 mL)	Landuse
Commercial	1	85	77	0.33	2.97	4600	Commercial
Forested	2	5	51	0.11	1.78	300	Forested
Open Urban Land	3	9	51	0.11	1.74	300	Open Urban Land
Residential-High Density	4	40	100	0.4	2.2	7000	Residential-High Density
Residential-Low Density	5	10	100	0.4	2.2	7000	Residential-Low Density
Residential-Med. Density	6	30	100	0.4	2.2	7000	Residential-Med. Density
Industrial	7	75	149	0.32	3.97	2400	Industrial
Roadway/Parking Lot	8	80	172	0.55	1.4	1700	Roadway/Parking Lot
Pasture	9	5	145	0.37	5.98	300	Pasture

[1] High density residential (<1/4 acre lots); Medium density residential (1/4 to 1/2 acre lots); Low density residential (>1 acre lots); Multifamily (>7 dwellings per acre).

Annual Rainfall	45	inches; user specified
P_j	0.9	%; default
Sanding Rate	350	lbs/acre; default
Sanding Applications	10	times/year; default

References:

The Simple Method to Calculate Urban Stormwater Loads. Retrieved July 22, 2005 from the World Wide Web: http://www.stormwatercenter.net/monitoring%20and%20assessment/simple%20meth/simple.htm

Pollutant Loading Formulas (Simple Method Equations):

TSS, TP, TN

L = 0.226 * R * C * A

Where:

- L = Annual Load (lbs)
- R = Annual Runoff (inches)
- C = Pollutant Concentration (mg/l)
- A = Area (acres)
- 0.226 = Unit Conversion Factor

Fecal Coliform

L = .00103 * R * C * A

Where:

- L = Annual Load (Billion Colonies)
- R = Annual Runoff (inches)
- C = Pollutant Concentration (#col/100mL)
- A = Area (acres)
- 0.00103 = Unit Conversion Factor

$R = P * P_j * Rv$

Where:

- R = Annual Runoff (inches)
- P = Annual Rainfall (inches)
- P_j = % of rainfall events producing runoff
- Rv = Runoff Coefficient = 0.05+0.9 * Ia
- Ia = Impervious Fraction (%)

STP Pollutant Reduction – Project Areas 1 & 2
Pollutant Removal

The Simple Method - Pollutant Reduction Model

Example Pollutant Reduction Estimates

					BMP Removal Efficiency^				Quantity of Pollutant Removed				
No.	Watershed Name	BMP ID	BMP Type	BMP Drainage Area (acres)	TSS Removal (%)	TP Removal (%)	TN Removal (%)	Fecal Coliform Removal**(%)	Annual TSS Removed (lbs)	Annual TP Removed (lbs)	Annual TN Removed (lbs)	Annual Fecal Coliform Removed (billion colonies)	Pretreatment / Treatment
1st BMP in series													
	BMP Volume (cf) =	3,820.00	Water Quality Volume %	100%									
1	Paved Roadway	2	Plunge Pool / Forebay**	1.870	85.0%	8.0%	3.0%	12.0%	5,563	0.58	0.6	12.3	Pretreatment
2	Woods	2	Plunge Pool / Forebay**	1.000	85.0%	8.0%	3.0%	12.0%	38	0.01	0.0	0.1	Pretreatment
3	Commercial	2	Plunge Pool / Forebay**	10.550	85.0%	8.0%	3.0%	12.0%	22,882	2.08	7.0	198.0	Pretreatment
Total								**BMP Total**	**28,482**	**2.67**	**7.6**	**210.4**	
2nd BMP in series													
	BMP Volume (cf) =	38,200.00	Water Quality Volume %	100%									
1	Paved Roadway	7	Infiltration Basin	1.870	95.0%	80.0%	51.0%	90.0%	933	5.3	9.1	80.9	Treatment
2	Woods	7	Infiltration Basin	3.000	95.0%	80.0%	51.0%	90.0%	19	0.2	2.3	2.8	Treatment
3	Commercial	7	Infiltration Basin	1.500	95.0%	80.0%	51.0%	90.0%	545	2.7	16.4	185.8	Treatment
Total								**BMP Total**	**1,497**	**8.26**	**27.9**	**269.5**	
								TOTAL REMOVAL =	**29,979**	**10.9**	**35.5**	**479.9**	
								% REMOVAL =	**89.5%**	**32.8%**	**14.0%**	**27.4%**	

BMP Type	BMP ID (used for v-lookup)	TSS Removal (%)	TP Removal (%)	TN Removal (%)	Fecal Coliform Removal** (%)	Pretreatment / Treatment	BMP Type
Vegetated Swale	1	81%	34%	84%	60%	Pretreatment	Vegetated Swale
Plunge Pool / Forebay**	2	85%	8%	3%	12%	Pretreatment	Plunge Pool / Forebay**
Leaching Catch Basin**	3	95%	80%	51%	90%	Pretreatment	Leaching Catch Basin**
Wet Pond	4	80%	51%	33%	70%	Treatment	Wet Pond
Riprap Swale***	5	50%	5%	2%	5%	Pretreatment	Riprap Swale***
Raingarden	6	86%	59%	38%	37%	Treatment	Raingarden
Infiltration Basin	7	95%	80%	51%	90%	Treatment	Infiltration Basin
Infiltration Chambers**	8	95%	80%	51%	90%	Treatment	Infiltration Chambers**
Enhanced Sand Filtration****	9	86%	59%	38%	37%	Treatment	Enhanced Sand Filtration****
Gravel Wetland	10	76%	49%	30%	78%	Treatment	Gravel Wetland
Extended Detention Wetland	11	76%	49%	30%	78%	Treatment	Extended Detention Wetland

STP Sizing– Project Area 3
Sizing to Address Channel Erosion

<u>Culvert Re-sizing</u>

- Conceptual for cost purposes
- Meet ~75% of bank-full width
- More detailed study required for final sizing
- Culvert design should follow *Guidelines for the Design of Stream/Road Crossings for Passage of Aquatic Organisms in VT* prepared by the VT Department of Fish and Game

Table 2. Crosby Brook Reference Reach Characteristics

Reach	Phase 2 Data	Drainage Area (sq. mi.)	Channel Length (mi)	Channel Slope (%)	Channel Width (ft.)	Sinuosity	Valley Width§ (ft.)	Confinement Ratio	Type*	Stream Type**	Bedform†
M01	Yes	5.7	0.7	1.2	28.2	1.07	150	5.3	NW	C	Riffle-Pool
M02	Yes	3.7	0.5	0.7	23.3	1.03	227	9.7	BD	C	Riffle-Pool
M03	Yes	2.8	0.6	1.1	20.6	1.07	200	9.7	BD	C	Riffle-Pool
M04	Yes	2.6	0.6	1.4	19.9	1.10	100	5.0	NW	C	Riffle-Pool
M05	Yes	2.4	0.5	0.3	19.4	1.20	400	20.7	VB	E	Riffle-Pool
M06	Yes	2.2	0.7	2.5	18.4	1.05	150	8.1	BD	C	Riffle-Pool
M07	No	1.6	1.0	3.1	16.1	1.03	*50*	3.1	SC	B	Step-Pool
M08	No	0.5	0.7	7.4	9.4	1.00	*15*	1.6	NC	A	Step-Pool
M09	No	0.1	0.3	3.6	4.9	1.06	*25*	5.1	NW	B	Step-Pool
T1.01	Yes	1.8	0.5	1.4	17.1	1.03	120	7.0	BD	C	Riffle-Pool
T1.02	Yes	1.7	0.8	4.5	16.5	1.01	40	2.4	SC	B	Step-Pool
T1.03	Yes	1.1	0.8	0.2	13.5	1.06	381	28.2	VB	E	Dune-Ripple
T1.04	No	0.8	0.2	4.3	11.9	1.20	*40*	3.4	NC	B	Step-Pool
T1.05	No	0.4	1.0	4.9	8.9	1.03	*15*	1.7	NC	A	Step-Pool
T2.01	No	0.5	0.5	3.4	9.7	1.02	*55*	5.7	SC	B	Step-Pool
T2.02	No	0.1	0.7	4.8	5.3	1.01	*15*	2.8	SC	A	Step-Pool

* NW = Narrow; SC = Semi-confined; BD = Broad; VB = Very Broad

§ Valley Width estimated remotely for *italicized* values

** per Rosgen (1994)

† per Montgomery & Buffington (1997)

STP Sizing– Project Area 3
Sizing to Address Bank Erosion

Based on size of impacted area or erosion extent measured in the field

Figure 14. Mass failure in lower M01-B

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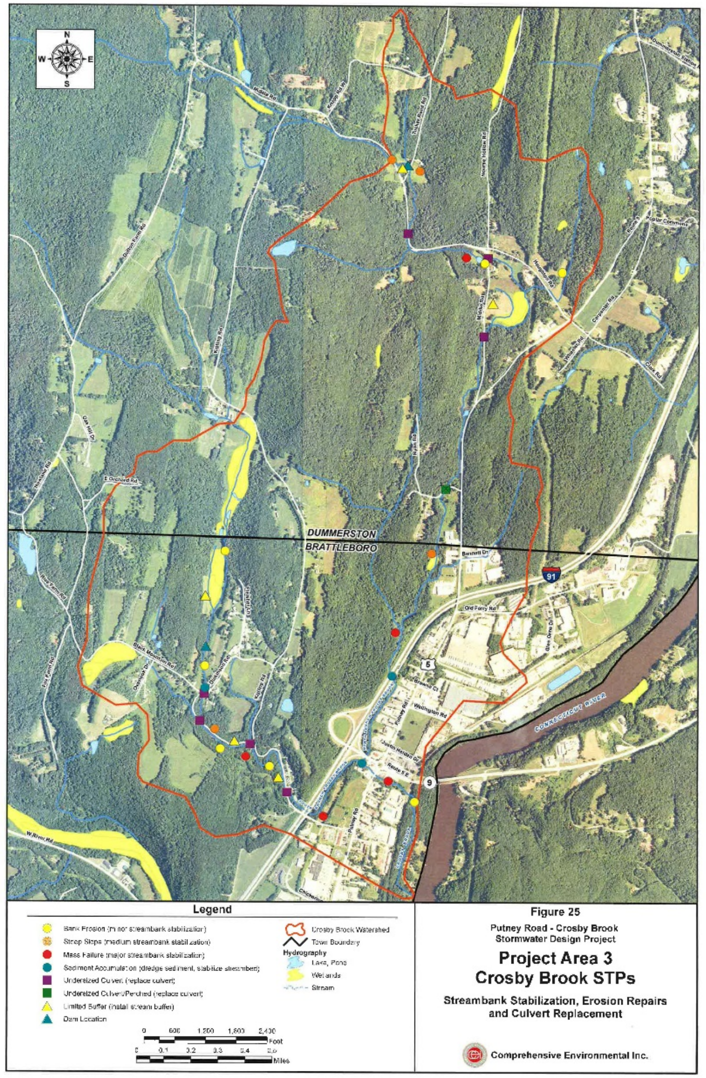
STP Ranking - Project Areas 1 & 2

Two Phased Ranking Process:

The intent was to use model results to prioritize sites based on feasibility and then rank those sites based on a more refined cost and pollutant removal estimate.

- 1st round ranked the potential STP sites based on feasibility, location and ability to meet stormwater standards.

- 2nd round ranked the STP sites based on cost-effectiveness and removal of sediment.



STP Ranking Project Areas 1 & 2
Phase 1 Ranking Criteria

- Proximity to Brook
- Sediment Accumulation & Removal
- Ease of Implementation
- Land Use
- Land Owner
- STP Sizing & Standards Compliance
- Maintenance Requirements
- Permitting Requirements

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STP Ranking - Project Areas 1 & 2
Phase 1 Ranking Criteria

Each criterion was given a range of priority points based on the importance of that criteria:

Explanation of Ranking:

Proximity to Brook: Within 50 feet = 1 ; 51 feet - 100 feet = 2 ; 101 - 200 feet = 3 ; 201 - 300 feet = 4 ; 300+ feet = 5

Direct / Indirect Discharge: Direct = 4 ; Indirect = 2

Impervious Area %: 76% - 100% = 4 ; 51% - 75% = 3 ; 26% - 50% = 2; 0% - 25% = 1

Ease of Implementation: Easy, low number of issues = 5 ; Moderate, possible equipment maneuvering/ access issues = 3 ; Difficult, expensive equipment maneuvering/ road closures = 1

Land Owner: Town / State Owned (no easements) = 3; Private (easement needed) = 1

Land Use: Commercial / Industrial = 3.5; Commercial / Highway = 3; Industrial / Highway = 2.5; Commercial / Residential = 2.5; Residential / Highway = 1.5; Commercial = 4; Industrial = 3; Highway = 2; Residential/Forested = 1

Potential STP Storm Size: 10yr -24hr plus = 3 ; 10yr -24hr = 2 ; under 10yr -24hr = 1; No STP = 0

Potential STP Recharge: 15,000 CF plus = 5 ; 10,000 - 14,999 CF = 4 ; 5,000 - 9,999 CF = 3 ; 2,000 - 4,999 CF = 2; <2,000 CF = 1 ; No STP = 0

Sediment Removal: 250 cf plus = 6; 200 - 249 cf = 5; 150 - 199 cf = 4 ; 100 - 149 = 3; 50 - 99 = 2; 0 - 49 = 1 ; No STP = 0

STP Cost: $550,000 plus = 1; $450,000 - $549,999 = 1.5; $350,000 - $449,999 = 2 ; $250,000 - $349,999 =2.5 ; $150,000 - $249,999= 3; $125,000 - $149,999 =3.5; $75,000 - $124,999 = 4; $74,999 and less = 4.5

Permit Requirements: No Permit Needed = 3 ; Possible Permit Needed = 2 ; Definitely Permit Needed = 1

Maintenance Requirements: Low frequency, easy access, easy tasks = 3 ; Moderate frequency, access issues, several tasks = 2 ; High frequency, difficult to access w/ equipment = 1

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STP Ranking - Project Areas 1 & 2
Phase 1 Ranking Process

Raw data was entered into a matrix for each potential STP location.

STP ID	Sub-basins Handled (Outfall I.D.)	Sub-basin Areas (acres)	Percent Impervious (%)	TSS Removal (cu.ft.)	Property Owner	Proximity to Brook (ft)	Permitting Required	Design Storm Handled	Land Use Type
1-8	7, 7B, 18, 18A, 19	10.6	65%	155	PRIVATE	50	POSSIBLE	10YR-24HR	COMMERCIAL
1-6	7, 7B	5.8	63%	105	PRIVATE	150	NONE	10YR-24HR	COMMERCIAL
1-7	7, 18, 19, 21, 23	9.5	69%	170	PRIVATE / STATE	500	NONE	OVER 10YR-24HR	COMMERCIAL / INDUSTRIAL
1-10	33A, 33B	21.1	68%	170	PRIVATE / STATE	625	POSSIBLE	UNDER 10YR-24HR	COMMERCIAL / INDUSTRIAL
1-3	1, 3, 5, 6, 6A, 6B, 6C, 8	13.0	56%	190	PRIVATE	75	POSSIBLE	10YR-24HR	COMMERCIAL / INDUSTRIAL
1-13	6, 6H & 15C	16.4	54%	118	STATE	625	NONE	10YR-24HR	COMMERCIAL / HIGHWAY
1-9	23, 24, 26A, 26B	10.0	56%	138	PRIVATE / STATE	50	DEFINITE	UNDER 10YR-24HR	COMMERCIAL / HIGHWAY
1-11B	37, A, 37B, 41A, 41B	19.3	32%	112	PRIVATE / TOWN	500	DEFINITE	10YR-24HR	COMMERCIAL / INDUSTRIAL
1-5	8, 9	1.7	32%	18	PRIVATE	25	DEFINITE	10YR-24HR	COMMERCIAL
1-11A	37A, 40	20.5	19%	80	PRIVATE	225	DEFINITE	UNDER 10YR-24HR	COMMERCIAL / INDUSTRIAL
1-12	14	18.1	25%	87	PRIVATE / TOWN	50	POSSIBLE	10YR-24HR	RESIDENTIAL

STP Ranking - Project Areas 1 & 2
Phase 1 Ranking Process

STP ID	Sub-basins Handled (Outfall I.D.)	Sub-basin Areas (acres)	Percent Impervious (%)	WQv Target (cu.ft.)	REv Target (cu.ft.)	CPv Target (cu.ft.)	OBv Target (cu.ft.)	STP Max Volume (cu.ft.)	TSS Removal (cu.ft.)	STP Total Costs ($)	STP Maintenance ($)	STP Total 10 yr Costs ($)
1-1	6, 6D, 6E, 6F, 15	13.4	67%	28,700	11,000	38,700	83,100	81,750	340	$655,196	$3,400	$689,196
1-4	7, 7A	7.3	56%	13,200	5,900	8,600	26,200	26,400	110	$215,259	$2,000	$235,259
1-2	6, 6H, 6I, 6J	16.2	36%	19,650	6,200	23,000	54,400	54,800	135	$296,859	$3,100	$327,859
1-8	7, 7B, 18, 18A, 19	10.6	65%	21,900	10,000	19,100	48,800	48,750	155	$397,002	$3,100	$428,002
1-6	7, 7B	5.8	63%	11,600	5,300	10,200	26,750	26,800	105	$201,920	$2,400	$225,920
1-7	7, 18, 19, 21, 23	9.5	69%	20,850	8,900	19,900	49,400	50,500	170	$427,785	$3,200	$459,785
1-10	33A, 33B	21.1	68%	45,800	13,200	57,300	130,600	94,500	170	$219,219	$5,200	$271,219
1-3	1, 3, 5, 6, 6A, 6B, 6C, 8	13.0	56%	23,650	7,550	27,100	63,000	62,900	190	$500,085	$2,600	$526,085
1-13	6, 6H & 15C	16.4	54%	28,600	11,700	24,000	36,200	28,850	118	$429,500	$3,900	$468,500
1-9	23, 24, 26A, 26B	10.0	56%	18,000	4,800	16,700	39,500	38,000	138	$319,119	$2,100	$340,119
1-11B	37, A, 37B, 41A, 41B	19.3	32%	21,100	5,600	27,950	78,000	78,000	112	$350,907	$3,300	$383,907
1-5	8, 9	1.7	32%	1,900	800	2,000	5,650	5,640	18	$59,274	$1,300	$72,274

STP sizing and pollutant reduction information was also entered into the matrix to be used for ranking analysis

STP Ranking - Project Areas 1 & 2
Ranking Costs

APPENDIX D - STP OPTIONS - COST SUMMARY TABLE

STP ID	Sub-basins Handled (Outfall I.D.)	Area	Pipe	Pipe	Structure	Structure	Pond Install	Add Excavation	Excav Cost	Added Costs	STP Const Cost ($)	Survey	Permitting	Engineering	Bid / Construction	Engineering Total Costs ($)	STP Total Costs ($)	STP Maintenance ($)	STP Total 10 yr Costs ($)
1-1	6, 6D, 6E, 6F, 15	20,500	1,200	$180,000	15	$52,500	$163,500	5,125	$3,796	$80,000	$479,796	$7,400	$0	$96,000	$72,000	$175,400	$655,196	$3,400	$689,196
1-2	6, 6H, 6I, 6J	18,250	300	$45,000	5	$17,500	$109,600	9,125	$6,759	$35,800	$214,659	$7,100	$0	$42,900	$32,200	$82,200	$296,859	$3,100	$327,859
1-3	1, 3, 5, 6, 6A, 6B, 6C, 8	14,000	950	$142,500	8	$28,000	$125,800	7,000	$5,185	$60,300	$361,785	$6,600	$5,000	$72,400	$54,300	$138,300	$500,085	$2,600	$526,085

Conceptual costs were prepared and entered into the matrix to be used for ranking analysis

The detailed cost estimates included:

Construction costs

- Piping
- Structures
- Excavation and grading
- STP installation

Planning & Engineering costs

- Survey
- Permitting
- Design
- Bid and Construction Oversight

+

Annual Maintenance Costs

- Applied for 10 years

STP Cost Summary:

STP Type	Install	Material	Total	Unit
Treatment STP	$2.00	$1.00	$3.00	per CF
Stilling Basin	$2.00	$1.50	$3.50	per CF
Sediment Forebay STP	$1.50	$1.00	$2.50	per CF
Roadside Swales & STPs	$1.50	$3.00	$4.50	per SF
Maintenance Level Spreader	$5.00	$15.00	$20.00	per SF
Riprap Spillway	$5.00	$10.00	$15.00	per SF
Riprap Infiltration STP	$3.00	$8.00	$11.00	per SF
Filter Media STP	$10.00	$20.00	$30.00	per SF
Streambank Stabilization	$3.00	$4.50	$7.50	per SF
Naturalized Bank Erosion Stabilization	$4.00	$6.00	$10.00	per SF
Steep Slope Stabilization	$2.00	$3.00	$5.00	per SF
Erosion Repair	$0.50	$1.00	$1.50	per SF
Vegetated Buffer	$2.00	$4.00	$6.00	per SF
Dredge	$1.50	$0.00	$1.50	per CF
Small Culvert Replacement	$1,000.00	$500.00	$1,500.00	per LF
Large Culvert Replacement	$3,000.00	$500.00	$3,500.00	per LF

STP Ranking - Project Areas 1 & 2
Ranking Costs

Explanation of Costs:

STP Construction Cost Estimate: Based on a combination of drainage piping, drainage structures, STP installation, additional excavation costs, potential rock excavation and supplemental costs

Pipe Costs: Linear feet of pipe times $75/lf pipe between 0-500 ft; $100/lf between 500 - 1000 ft; and $150/lf for lengths over 1000 feet

Structure Costs: Number of drainage structures needed times $2,500 per structure

STP Installation Costs: Cost to represent excavation, stabilization and installation of all standard stormwater treatment pond components: Pond Volume times $1.50/ cu.ft. for ponds less than 100,000 cu.ft. and $0.80 / cu.ft. for ponds larger than 100,000 cu.ft.

Additional Excavation Costs: Cost per cubic yard to excavate existing terrain beyond the volume required for the pond. Estimated based on area of pond and approximate cut depths to level the area prior to pond installation

Potential Rock/ Ledge Excavation Costs: Cost per cubic foot to excavate rock and ledge that could be encountered during all excavations times $5 per cubic foot of rock. Estimated based on volume of pond and volume of extra earth excavation assuming approximate ledge depths and percentage of total excavation depths

Supplemental Costs: Costs carried for supplemental work that would be required for a specific STP or location. Additional costs include liners for ponds, road re-grading, bridge retrofits, underground tanks, utility relocations and intercept swales to redirect additional runoff around STPs

STP Engineering Cost Estimate: Based on a combination of survey, permitting and engineering/design cost estimates

Survey Costs: Based on estimates to obtain topographic survey for design and permitting. Cost includes a rough base price plus a cost per acre based on the footprint of the STP

Permitting Costs: Based on estimates to perform STP permitting for state and supplemental local permitting. Costs based on historical data and past experience and depend on potential impacts to the reservoir, wetland area, surface water resources and applicable buffers.

Engineering Costs: Based on estimates to complete design, plans and specifications ready for bidding. Based on a combination of historical data, an approximate 20% of construction budget and previous design project experience. Costs do not include bidding and construction based services.

STP Total Cost Estimate: Based on the combination of total construction costs plus engineering costs

STP Ranking - Project Areas 1 & 2
Phase 1 Ranking Results

Once criteria for each STP was complied, the priority point scores were applied and tallied to select STPs with the highest total score

STP ID	Proximity to Brook	Direct / Indirect Discharge	Impervious Area %	Ease of Implementation	Land Owner	Land Use	Potential STP Storm Size	Potential STP Recharge	Sediment Removal	STP Costs	Permit Requirements	Maintenance Requirements / Access	Priority Points	RANK
1-1	5	2	3	3	1	4	3	4	6	1	3	3	38	**1**
1-4	2	4	3	5	2	4	3	3	3	3	2	3	37	**2**
1-2	5	2	2	5	2	2.5	3	3	3	2.5	3	2	35	**3**
1-8	1	4	3	5	1	4	2	4	4	2	2	2	34	**4**
1-6	3	2	3	3	1	4	2	3	3	3	3	3	33	**5**
1-7	5	2	3	1	2	3.5	3	3	4	2	3	1	32.5	**6**
1-10	5	2	3	1	2	3.5	1	4	4	3	2	2	32.5	**7**
1-3	2	4	3	3	1	3.5	2	3	4	1	2	3	31.5	**8**
1-13	5	2	3	1	3	3	1	4	3	1.5	3	2	31.5	**9**
1-9	1	4	3	5	2	3	1	2	3	2.5	1	3	30.5	**10**
1-11B	5	2	2	3	2	3.5	2	3	3	2	1	2	30.5	**11**
1-5	1	4	2	5	1	4	2	1	1	4.5	1	3	29.5	**12**

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STP Ranking - Project Areas 1 & 2
Phase 2 Ranking Criteria

A second ranking phase was completed to compare similar STPs and potential long-term costs and benefits:

BMP Costs **divided by** **Pollutants Removed**

BMP Costs
- Permitting
- Design
- Construction
- Annual Maintenance

Pollutants Removed
- Land Type
- Land Area
- TSS Applied
- Removal Efficiency
- Annual TSS Removed

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STP Ranking - Project Areas 1 & 2
Phase 2 Ranking Process

Use Ranking Criteria:

- BMP Drainage Area
- Percent Impervious
- Land Use Types
- 10 yr. Pollutant Removal
- BMP Cost
- 10 yr. BMP Maintenance Cost

To Estimate:

$ per ton of sediment (TSS) removed

(over 10 year period)

To Select:

Top 2 BMPs per Area = Most Cost Effective

On average over a 10 year period

~ $4,000 - $5,000 per ton

STP Ranking - Project Areas 1 & 2
Phase 2 Ranking Results

Project Area 1

APPENDIX C - STP OPTIONS - RANKING SUMMARY TABLE BY AREA															
STP ID	Sub-basins Handled (Outfall I.D.)	Sub-basin Areas (acres)	Percent Impervious (%)	WQv Target (cu.ft.)	REv Target (cu.ft.)	CPv Target (cu.ft.)	OBv Target (cu.ft.)	STP Max Volume (cu.ft.)	TSS Removal (cu.ft.)	STP Total Costs ($)	STP Maintenance ($)	STP Total 10 yr Costs ($)	TSS Removal (lbs)	10 Yr TSS Removal (tons)	Cost / TSS Removal ($/ton)
1-1	6, 6D, 6E, 6F, 15	13.4	67%	28,700	11,000	38,700	83,100	81,750	340	$655,196	$3,400	$689,196	30,600	153	**$4,505**
1-4	7, 7A	7.3	56%	13,200	5,900	8,600	26,200	26,400	110	$215,259	$2,000	$235,259	9,900	50	**$4,753**

Project Area 2

APPENDIX C - STP OPTIONS - RANKING SUMMARY TABLE BY AREA															
STP ID	Sub-basins Handled (Outfall I.D.)	Sub-basin Areas (acres)	Percent Impervious (%)	WQv Target (cu.ft.)	REv Target (cu.ft.)	CPv Target (cu.ft.)	OBv Target (cu.ft.)	STP Max Volume (cu.ft.)	TSS Removal (cu.ft.)	STP Total Costs ($)	STP Maintenance ($)	STP Total 10 yr Costs ($)	TSS Removal (lbs)	10 Yr TSS Removal (tons)	Cost / TSS Removal ($/ton)
2-1	13, 13B, 13C	5.6	56%	10,100	3,100	9,900	26,000	25,800	87	$137,707	$2,400	$161,707	7,830	39	**$4,130**
2-4	20A, 22A, 22B, 25A, 25B	5.9	25%	5,200	1,400	6,700	21,300	25,500	68	$125,930	$2,400	$149,930	6,120	31	**$4,900**

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STP Ranking - Project Area 3 Undersized Culverts

Culverts with widths less than bank-full width were reviewed:

- Any undersized culverts should eventually be replaced.
- For ranking purposes, culvert projects with widths less than 33% of the bank-full channel width were selected as the highest priority to be completed under a first phase.
- Remaining undersized culverts could be replaced in 2 additional phases based on similar criteria (e.g. under 67% and remainder less than bank-full width).

Cost estimates were preformed for the top 4:

Table 3. Summary of Stream Crossings

Reach/ Seg-ment	Road Name	Road Type	Location	Struct. Height (ft)	Stream Width (ft)	Struct. Width (ft)	Struct/ Stream Width*	Flood-plain Filled?	Stream Approach
M01-B Bridge	Railroad	Rail-road	Railroad crossing just upstream of segment break.	9.5	20.0	19.0	95%	Partially	Channelized Straight
M01-B Bridge	Route 5	Paved	Route 5 crossing.	5.4	22.0	30.0	136%	Entirely	Channelized Straight
M01-B Bridge	I-91 Ramp	Paved	I-91 Exit 3 ramp.	7.0	21.8	20.0	92%	Partially	Channelized Straight
M02 Bridge	I-91	Paved	I-91 crossing (2 lanes).	4.5	23.0	25.0	109%	Partially	Mild Bend
M03 Culvert	Ryan Rd.	Gravel	Just west of intersection with Route 5.	7.0	23.8	7.0	29%	Partially	Naturally Straight
M04 Culvert	Middle Rd.	Paved	Just north of intersection with Route 5.	7.0	21.0	7.0	33%	Partially	Channelized Straight
M05 Culvert	Middle Rd.	Paved	Just south of intersection with Houghton Rd.	7.0	16.0	7.0	44%	Partially	Mild Bend
M06-B Bridge	Drive-way	Gravel	Driveway stemming from Houghton Rd mid-segment.	10.6	18.0	18.5	103%	Partially	Naturally Straight
M06-B Culvert	Hough-ton Rd.	Paved	Houghton Rd crossing upper.	7.0	16.0	9.0	56%	Partially	Mild Bend

Reach/ Seg-ment	Road Name	Road Type	Location	Struct. Height (ft)	Stream Width (ft)	Struct. Width (ft)	Struct/ Stream Width*	Flood-plain Filled?	Stream Approach
M06-C Bridge	Tucker Reed Rd.	Gravel	Just east of intersection with Houghton Rd.	5.0	18.0	6.2	34%	Partially	Mild Bend
M06-C Culvert	Hough-ton Rd.	Paved	At reach break with M07.	6.0	18.0	6.5	36%	Partially	Naturally Straight
T1.01 Culvert	I-91	Paved	I-91 crossing (2 lanes).	7.0	17.0	11.0	65%	Partially	Channelized Straight
T1.01 Culvert	Black Mtn. Rd.	Paved	Just south of intersection with Crescent Dr.	4.0	17.0	4.0	24%	Entirely	Sharp Bend
T1.02-B Arch	Black Mtn. Rd.	Gravel	Upper Black Mt Rd crossing.	4.9	17.5	7.0	40%	Partially	Naturally Straight
T1.02-D Culvert	Dickin-son Rd.	Gravel	Just east of intersection with Black Mt Rd.	3.0	9.0	3.0	33%	Partially	Mild Bend
T1.03 Bridge	NA - Trail	Trail	Lower athletic field access trail.	3.5	4.3	16.5	384%	Partially	Naturally Straight
T1.03 Culvert	NA - Trail	Trail	Access trail to SIT pond.	5.0	12.0	5.0	42%	Partially	Channelized Straight

APPENDIX D - PROJECT AREA 3 - STP OPTIONS - COST SUMMARY

STP ID	STP Type	Location Description of STP	Road Length (ft.)	Road Width (ft.)	Road Area (sq.ft.)	Culvert Length (ft.)	Culvert Opening (ft. x ft.)	Culvert Cost ($)	No. of Structures (#)	Structure Cost ($)	STP Install ($)	STP Materials ($)	Add'l Excav / Prep/ Clearing ($)	Construction Cont. Costs (30%) ($)	**STP Const. Cost ($)**	Survey Costs ($)	Permit Costs ($)	Engineering Costs ($)	Bid / Construct Oversight ($)	Engineering Total Costs ($)	**STP Total Costs ($)**
1	Replace Culvert	Northern Fork / Ryan Rd (M03) - Install new culvert to meet min 75% stream width - Exist. Culvert = 7'x7'	50.0	25.0	1250.0	50	7 x 18	$175,000	0	$0	$3,750	$5,625	$6,250	$57,200	**$247,825**	$3,100	$8,000	$49,600	$24,800	$85,500	**$333,300**
2	Replace Culvert	Northern Fork / Middle Rd (M04) - Install new culvert to meet min 75% stream width & LCBs for paved drainage - Exist. Culvert = 7'x7'	100.0	25.0	2500.0	60	7 x 16	$210,000	2	$7,000	$7,500	$11,250	$12,500	$74,500	**$322,750**	$3,300	$8,000	$64,600	$32,300	$108,200	**$431,000**
3	Replace Culvert	Southern Fork / Black Mtn. Rd (T1.01) - Install new culvert to meet min 75% stream width LCBs for paved drainage - Exist. Culvert = 4'x4'	100.0	30.0	3000.0	75	4 x 12	$112,500	2	$7,000	$9,000	$13,500	$15,000	$47,100	**$204,100**	$3,300	$8,000	$40,800	$20,400	$72,500	**$276,600**
4	Replace Culvert	Southern Fork / Dickinson Rd (T1.02-D) - Install new culvert to meet min 75% stream width - Exist. Culvert = 3'x3'	50.0	25.0	1250.0	40	3 x 7	$60,000	0	$0	$3,750	$5,625	$6,250	$22,700	**$98,325**	$3,100	$8,000	$19,700	$9,800	$40,600	**$138,900**
						225								**Totals**	**$873,000**					**Totals**	**$1,179,800**

STP Ranking - Project Area 3
Erosion & Mass Failures

Stabilization ranking was based on repair of the top 6 largest problem areas identified in the field

Cost estimates were performed:

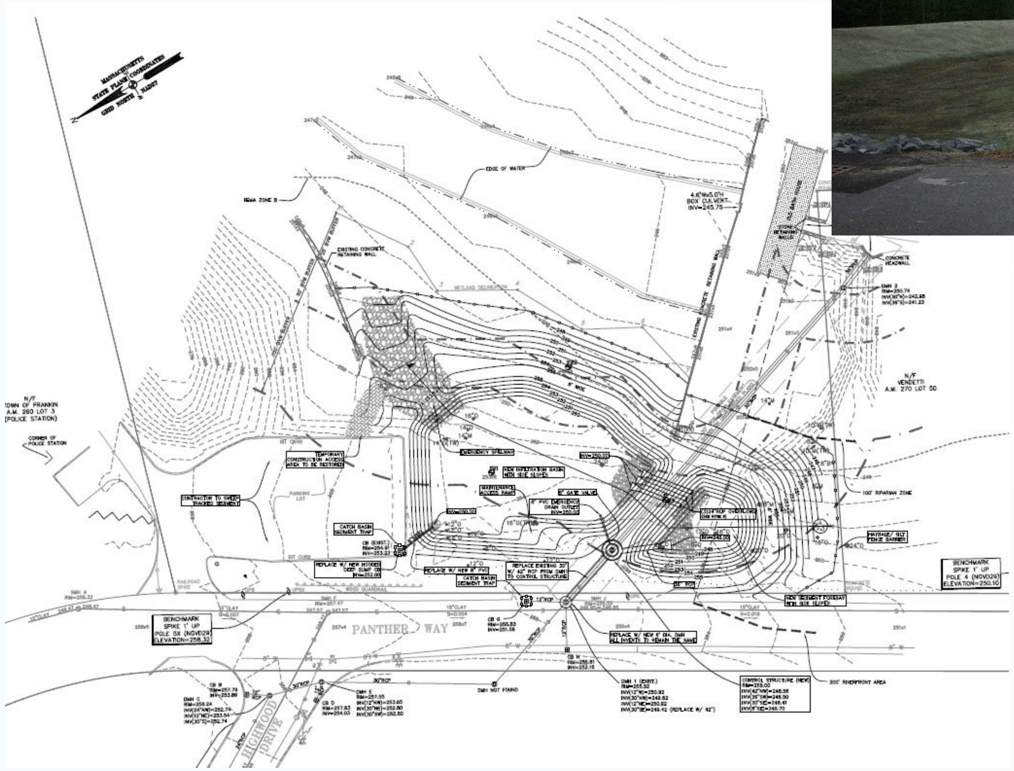
APPENDIX D - PROJECT AREA 3 - STP OPTIONS - COST SUMMARY

STP ID	STP Type	Location Description of STP	Slope Length (ft.)	Slope Width (ft.)	Slope Area (sq.ft.)	STP Install ($)	STP Materials ($)	Add'l Excav / Prep/ Clearing ($)	Construction Cont. Costs (30%) ($)	**STP Const. Cost ($)**	Survey Costs ($)	Permit Costs ($)	Engineering Costs ($)	Bid / Construct Oversight ($)	Engineering Total Costs ($)	**STP Total Costs ($)**
1	Stabilize Steep Slopes	Mass Slope Failure Southern Fork near Black Mtn. Rd - Repair erosion & stabilize slope	100.0	75.0	7500.0	$15,000	$22,500	$7,500	$13,500	**$58,500**	$3,900	$8,000	$11,700	$5,900	$29,500	**$88,000**
2	Streambank Stabilization	Steep Slope Failure Northern Fork near Route 91 northbound - Repair erosion & stabilize banks	100.0	30.0	3000.0	$9,000	$13,500	$3,000	$7,700	**$33,200**	$3,300	$8,000	$6,600	$3,300	$21,200	**$54,400**
3	Streambank Stabilization	Mass Slope Failure Northern Fork along Route 91 southbound right of way - Repair erosion & stabilize banks	75.0	50.0	3750.0	$11,250	$16,875	$3,750	$9,600	**$41,475**	$3,400	$8,000	$8,300	$4,100	$23,800	**$65,300**
4	Stabilize Steep Slopes	Steep Eroded Banks along Northern Fork near Pepsi - Repair erosion & stabilize slopes	50.0	50.0	2500.0	$5,000	$7,500	$2,500	$4,500	**$19,500**	$3,300	$8,000	$3,000	$2,500	$16,800	**$36,300**
5	Streambank Stabilization	Mass Slope Failure along Main Channel near Route 9 eastbound shoulder - Repair erosion & stabilize slope	150.0	30.0	4500.0	$13,500	$20,250	$4,500	$11,500	**$49,750**	$3,500	$8,000	$10,000	$5,000	$26,500	**$76,300**
6	Stabilize Steep Slopes	Mass Slope Failure Northern Fork near Houghton Rd - Repair erosion & stabilize slope	75.0	50.0	3750.0	$7,500	$11,250	$3,750	$6,800	**$29,300**	$3,400	$8,000	$5,900	$2,900	$20,200	**$49,500**
					25,000				Totals	$231,725					Totals	$369,800

STP Recommendations
Project Area 1

Project Area 1

- Infiltration basins
- Stormwater wetlands
- Wet ponds / multi-pond systems



STP Recommendations
Project Area 1

Project Area 1 – Routes 5 & 9

Site 1.1 – Putney Road & Private Properties

- Located on private property behind the America's Best Inn
- Re-direct runoff from an existing drainage system on Putney Road, Hardwood Way and a Private Drive

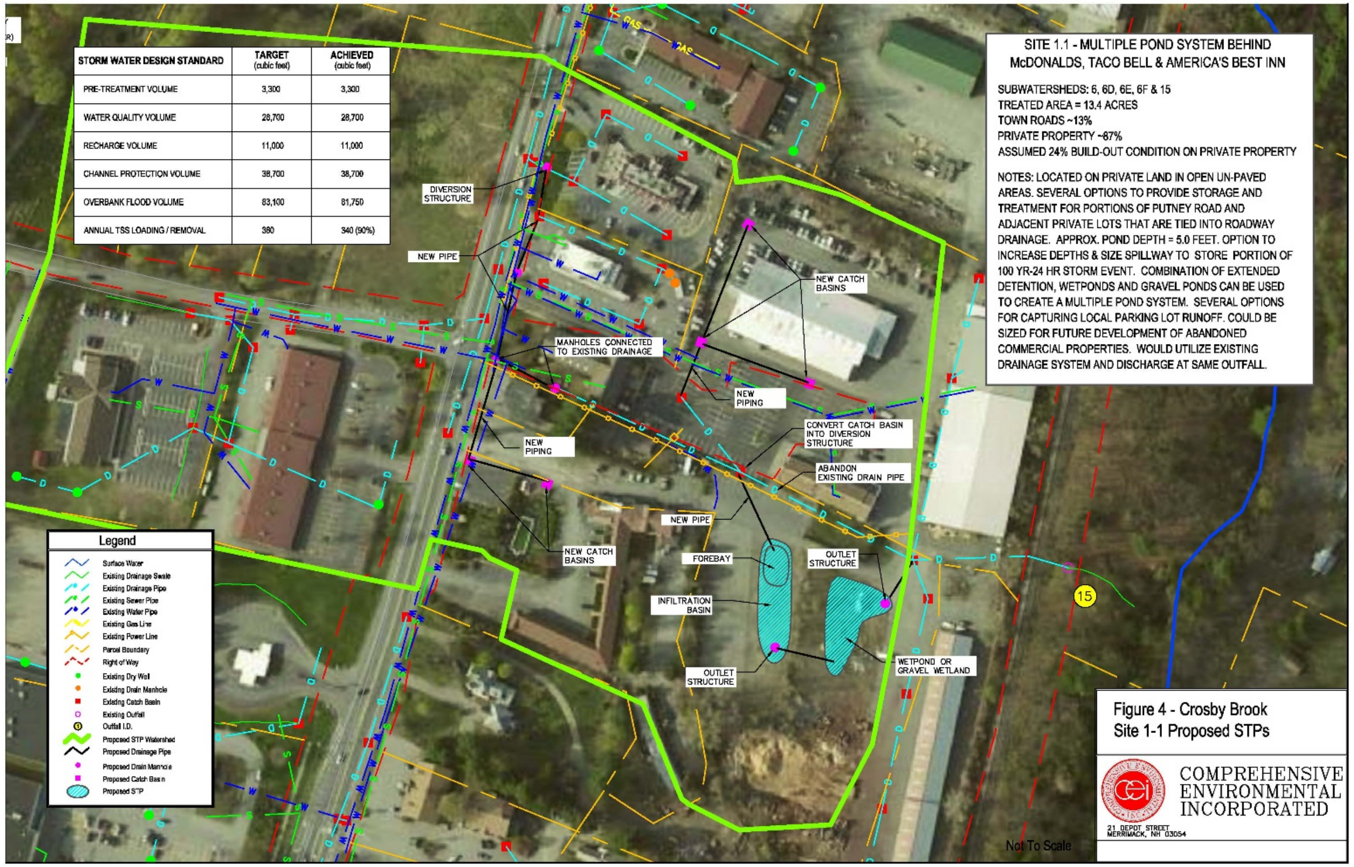
Site 1.4 – Putney Road & Route 9

- Located on private property next to the old Bickford's restaurant
- Re-direct runoff from an existing drainage system on Routes 5 and 9 that discharges at the Crosby Brook / Putney Rd bridge crossing

STP Recommendations
Project Area 1

Site 1.1

- Drainage diversion
- Stormwater wetland
- Multi-pond system



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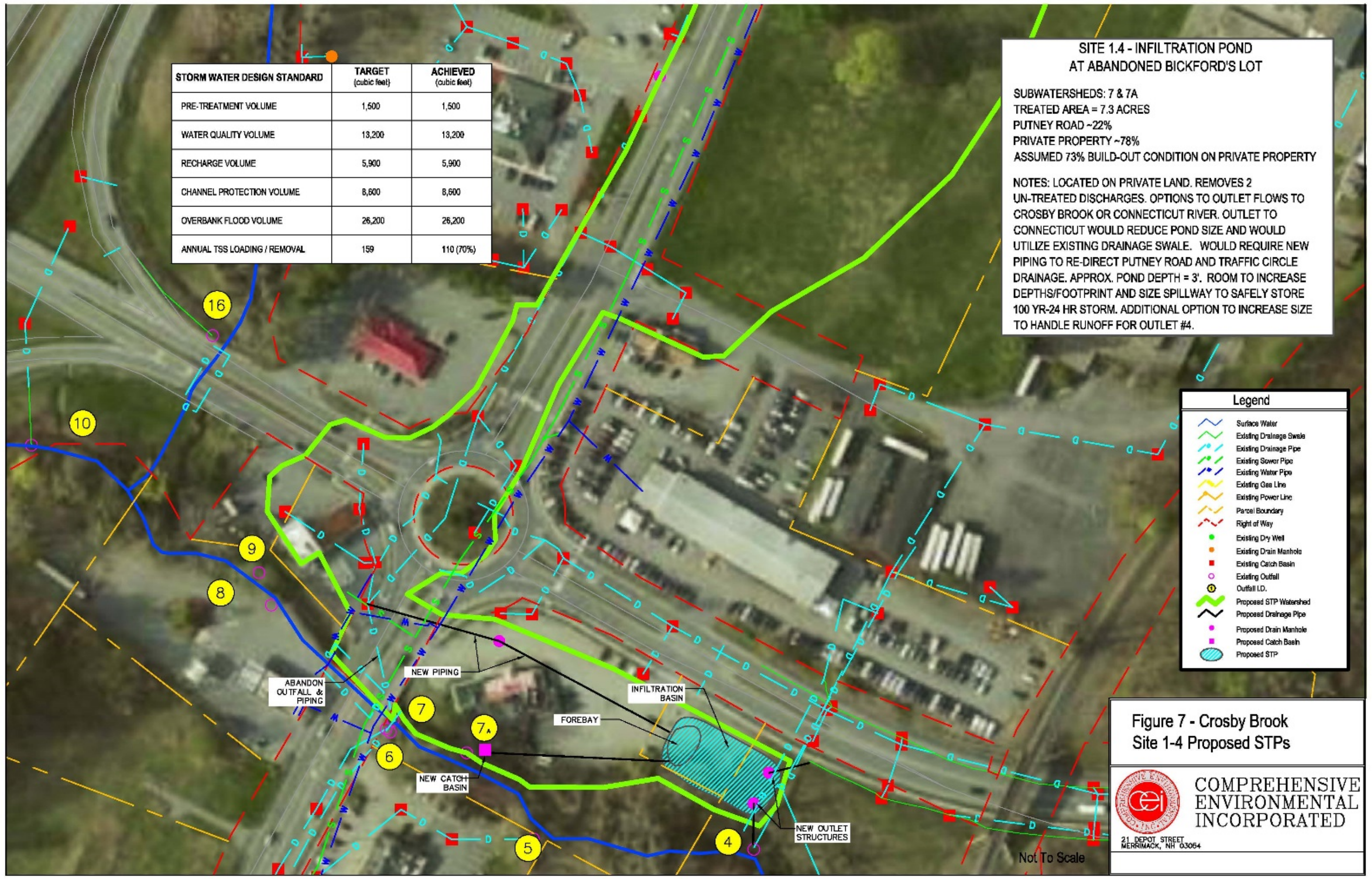
STP Recommendations
Project Area 1

Site 1.4

- Drainage diversion
- Infiltration basin



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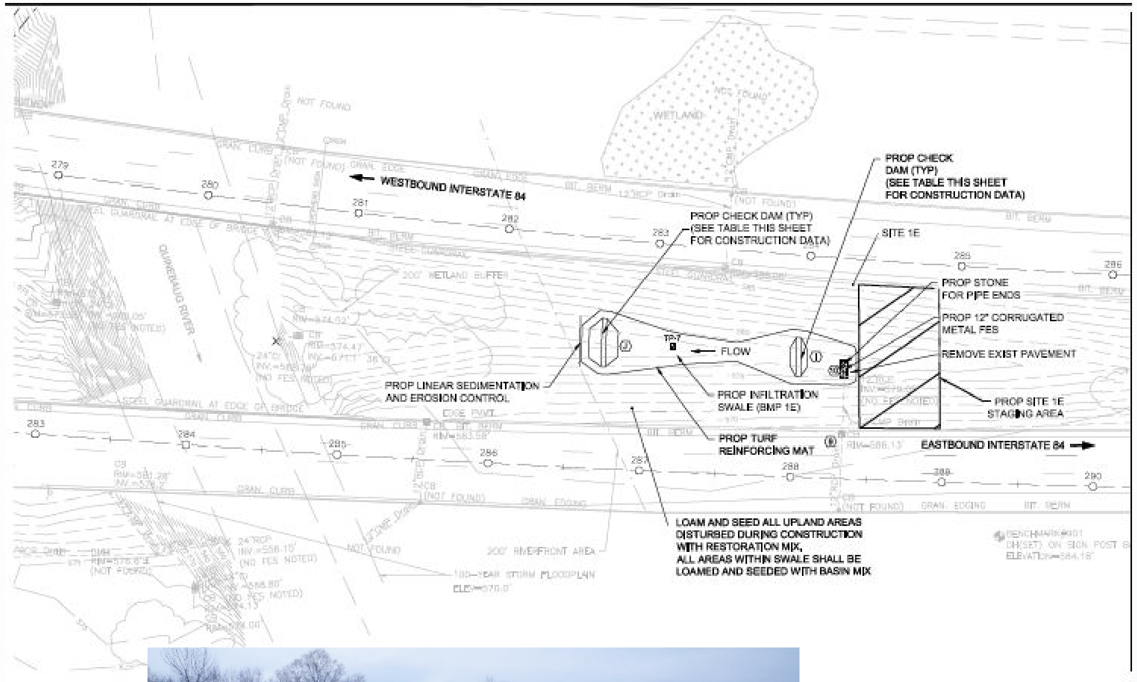
STP Recommendations
Project Area 2

Project Area 2 – Interstate Route 91

- Infiltration swales
- Stormwater wetlands
- Wet swales / dry swales
- Sand Filters



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STP Recommendations
Project Area 2

Project Area 2

Site 2.1 – Interstate Route 91 at Black Mtn. Rd

- Located in VTrans Right of Way
- Retrofit existing drainage systems on shoulders and medians

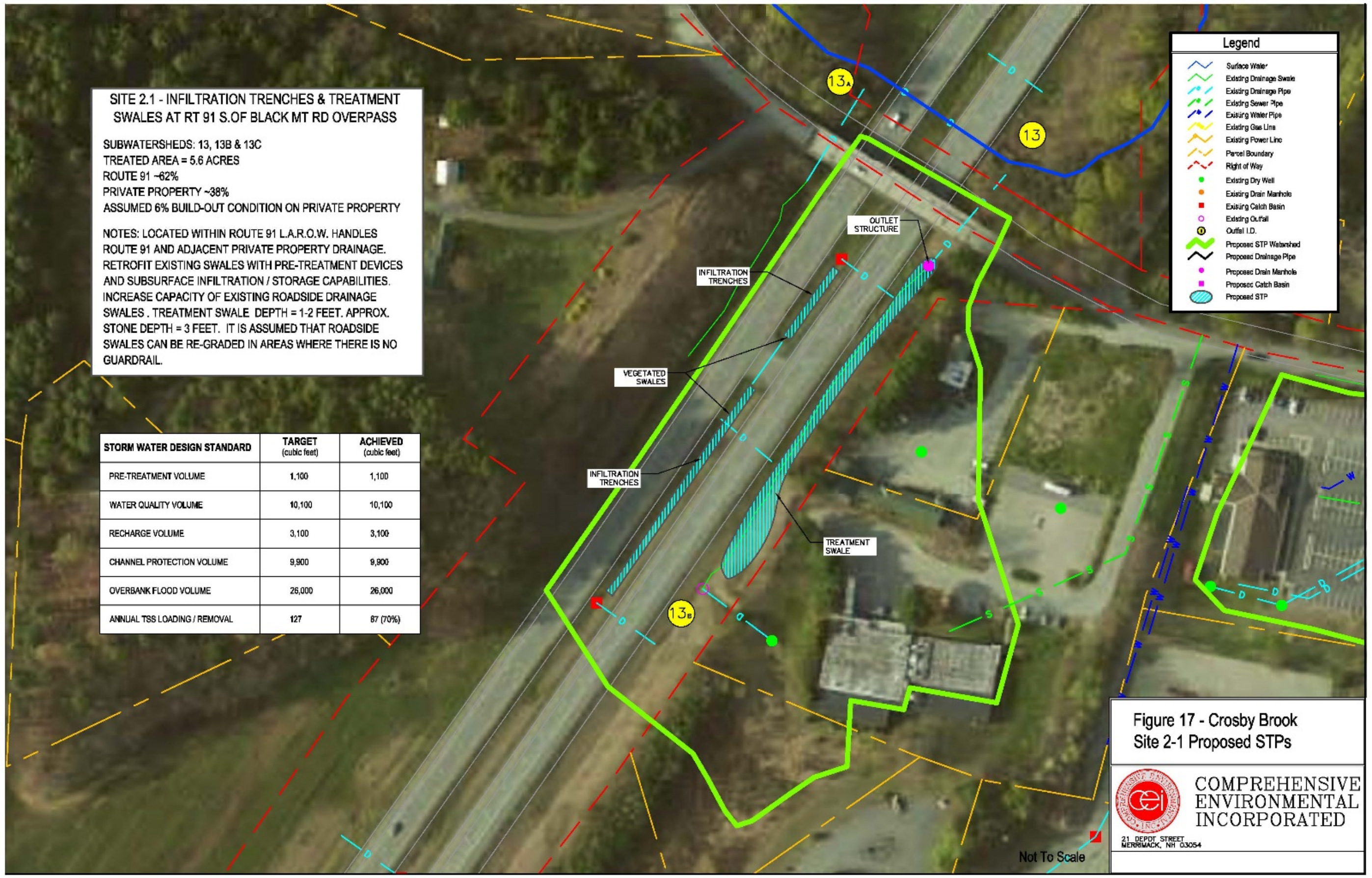
Site 2.4 – Interstate Route 91 at Exit 3

- Located in VTrans Right of Way
- Use low-points and large available space along the exit ramp to install larger STPs
- Retrofit existing drainage systems on highway medians to provide linear STPs

STP Recommendations
Project Area 2

Site 2.1

- Infiltration swales
- Dry swales with sand filters

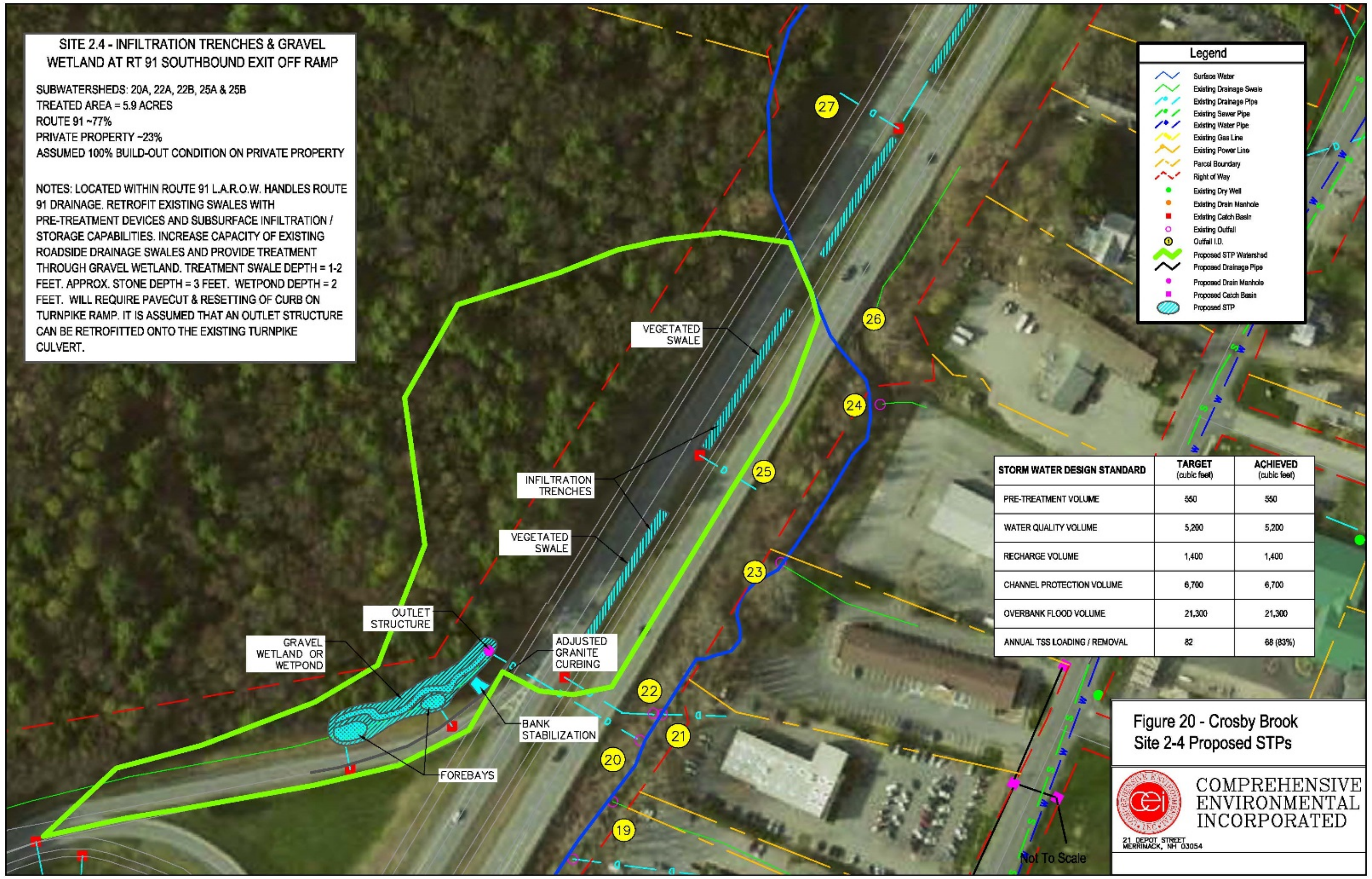


STORM WATER DESIGN STANDARD	TARGET (cubic feet)	ACHIEVED (cubic feet)
PRE-TREATMENT VOLUME	1,100	1,100
WATER QUALITY VOLUME	10,100	10,100
RECHARGE VOLUME	3,100	3,100
CHANNEL PROTECTION VOLUME	9,900	9,900
OVERBANK FLOOD VOLUME	26,000	26,000
ANNUAL TSS LOADING / REMOVAL	127	87 (70%)

STP Recommendations
Project Area 2

Site 2.4

- Stormwater wetlands
- Wet swales and sand filters



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STP Recommendations
Project Area 3

Culvert Replacement Locations

- Ryan Rd
- Middle Rd
- Black Mountain Rd
- Dickinson Rd

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STP Recommendations
Project Area 3

Culvert Replacement Designs

- Proper widths
- Proper substrate material
- Embedded or open bottom
- Roadway drainage treatment at crossings
- Improve Wildlife Passage


Guidelines for the Design of Stream/Road Crossings for Passage of Aquatic Organisms in Vermont

Kozmo Ken Bates, P.E., Kozmo, Inc.
Rich Kirn, Vermont Department of Fish and Wildlife
March, 2009

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Figure 20. Perched culvert beneath Ryan Road.

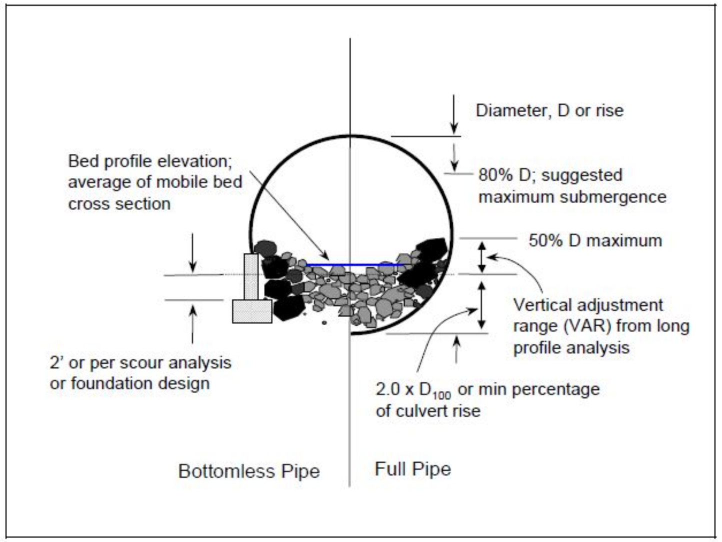
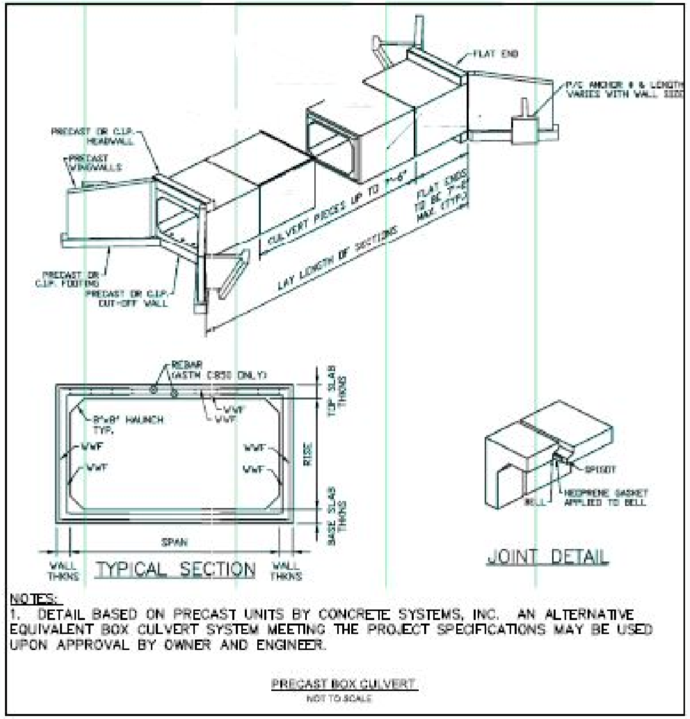
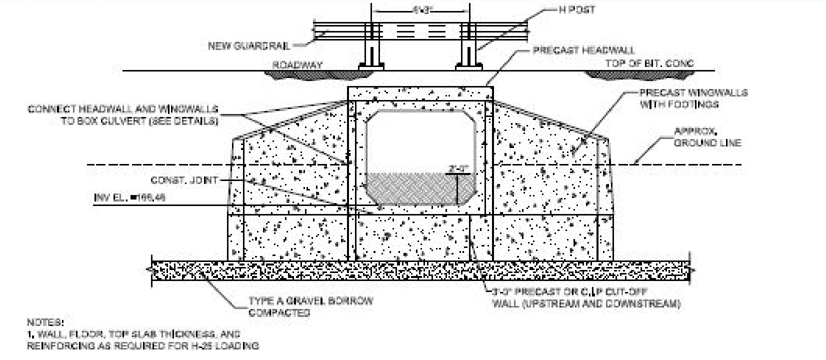


Figure 6-6. Stream simulation culvert embedment.





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STP Recommendations
Project Area 3

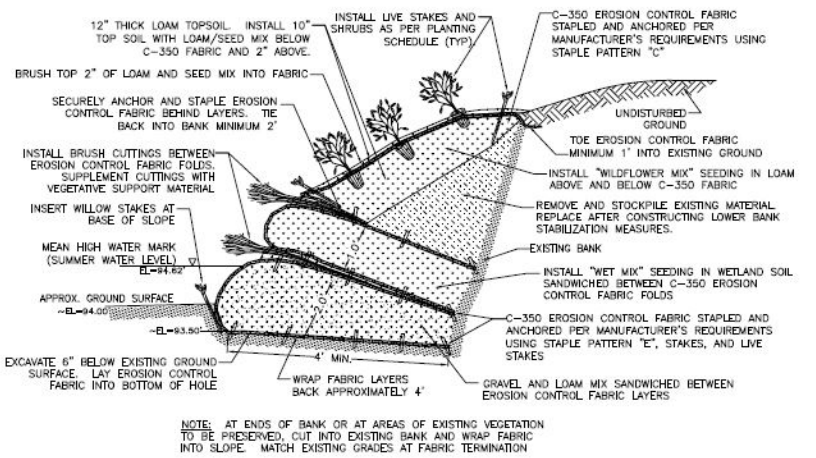
Stabilization / Erosion Repair STPs

- Mass Failures or Large Bank Erosion
- 6 locations
- 4 on the Northern Branch
- 1 on the Southern Branch
- 1 on the Main (lower) Branch

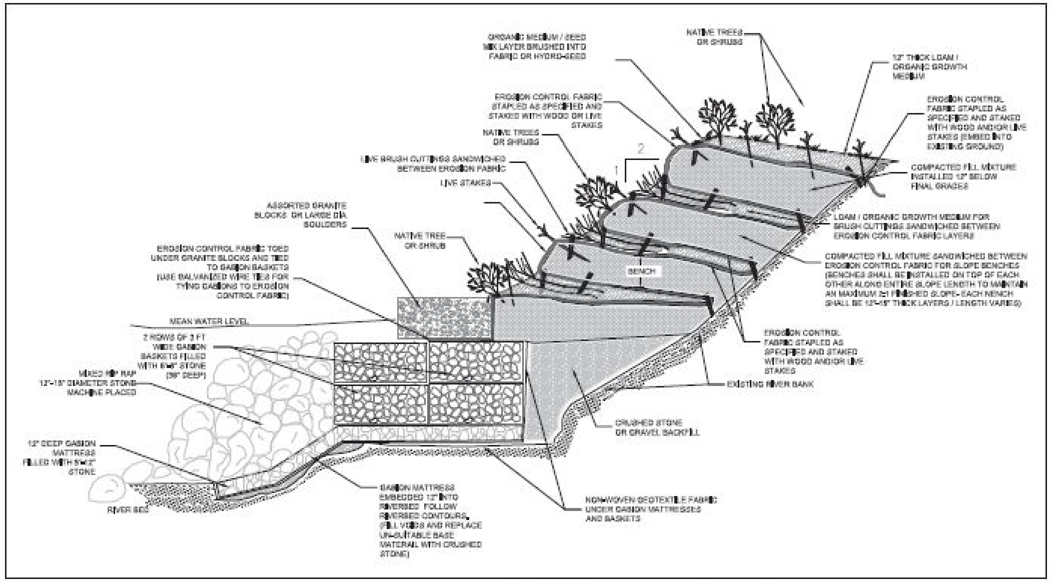
STP Recommendations
Project Area 3

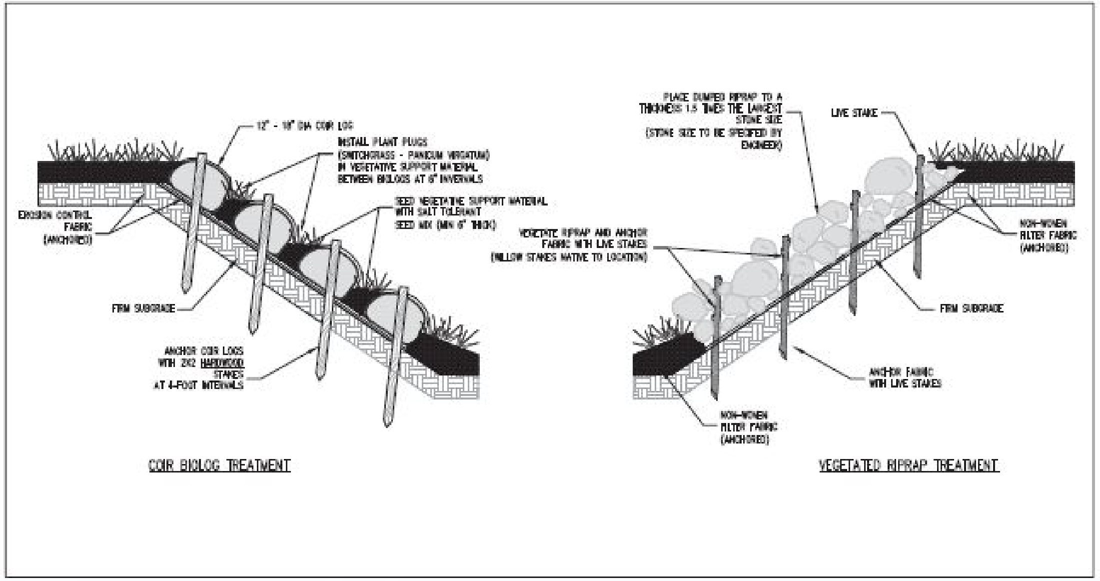
Stabilization Techniques

- Bio-engineered slope treatment
- Riprap, vegetation and coir logs
- Proper toe-of-slope selection
- Proper anchoring
- Proper reinforcement materials



Brush Layering





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We’ve crossed the bridge(s)!!

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Questions