SUBWATERSHED MANAGEMENT PLAN FOR BELLINGHAM, MA- APPENDICES

Appendix A - Modeling Results

Modeling Results- Scenario 0

ID	Name	Total Area (ac)	Total Impervious Area (ac)	Existing Phosphorus Load (lb/yr)	RDA Site?	Assigned BMP Type	BMP Design Storm (in)	BMP Design Height (ft)	BMP Design Depth (ft)	BMP Area (sq. ft.)	BMP Treatment Volume (cu. ft.)	Phosphorus Reduction (%)	Phosphorus Load Removed (lb/yr)	Estimated BMP Cost ($)	Estimated Land Cost ($)	Total Cost ($)	($/lb/yr) Phosphorus Removed	($/ac) Acres Treated
DD1-A	Bellingham Plaza LLC (parking)	4.49	4.11	9.28	Yes	Bioret	0.38	0.75	3	4,168	5,418	50.9%	4.73	108,358	0	108,358	22,932	27,588
DD1-B	Bellingham Plaza LLC (roof)	3.12	1.60	3.86	Yes	ITrench	0.24	0	3	1,086	1,408	50.9%	1.97	22,527	0	22,527	11,449	14,114
DD2	26 Main St. Bell Rlt	4.48	2.75	6.52	Yes	Bioret	0.38	0.75	3	2,863	3,722	50.9%	3.32	74,438	0	74,438	22,426	27,588
DD3	Roman Catholic Church	30.51	2.20	7.86	Yes	Bioret	0.38	2	0	3,624	4,832	50.9%	4.00	72,487	0	72,487	18,115	20,691
O16	East of Mill Street	2.17	1.53	3.05	No	None	n/a	n/a	n/a	n/a	n/a	0.0%	0.00	0	0	0	0	0
O18-A	Park on North Main St and Mendon St	23.51	9.49	21.33	No	IBasin	0.36	4	0	9,260	12,721	73.5%	15.68	76,324	0	76,324	4,867	7,854
O18-B	Park on North Main St and Mendon St	6.52	2.34	6.31	No	Raingdn	0.23	0.75	0	3,526	2,048	58.1%	3.66	15,362	0	15,362	4,193	6,326
O18-C	Park on North Main St and Mendon St	4.49	1.45	2.89	No	Bioret	0.20	0.75	3	852	1,108	34.0%	0.98	16,620	0	16,620	16,890	10,890
O18-D	Park on North Main St and Mendon St	1.75	1.46	3.33	No	None	n/a	n/a	n/a	n/a	n/a	0.0%	0.00	0	0	0	0	0
O18-E	Park on North Main St and Mendon St	1.15	0.70	1.54	No	None	n/a	n/a	n/a	n/a	n/a	0.0%	0.00	0	0	0	0	0
O2	Edgehill Ln - cul-de-sac	1.68	0.49	0.76	No	None	n/a	n/a	n/a	n/a	n/a	0.0%	0.00	0	0	0	0	0
O20	Behind Rail intersects w/ North Main St	10.15	1.12	2.54	No	None	n/a	n/a	n/a	n/a	n/a	0.0%	0.00	0	0	0	0	0
O21	Rose Avenue	4.48	1.44	2.59	No	None	n/a	n/a	n/a	n/a	n/a	0.0%	0.00	0	0	0	0	0
O22	Judy Ln - cul-de-sac	2.62	0.86	1.52	No	None	n/a	n/a	n/a	n/a	n/a	0.0%	0.00	0	0	0	0	0
O24	Municipal Center	0.68	0.68	0.62	No	ITrench	0.48	2	0	615	1,125	79.5%	0.49	13,502	0	13,502	27,599	20,918
O24-A	Municipal Center	0.11	0.11	0.10	No	Raingdn	0.70	0.75	0	270	269	85.7%	0.09	2,020	0	2,020	23,586	18,982
O25	Famous Pizza parking lot	1.00	0.99	1.82	No	None	n/a	n/a	n/a	n/a	n/a	0.0%	0.00	0	0	0	0	0
O26	North Main Street	0.36	0.32	0.29	No	None	n/a	n/a	n/a	n/a	n/a	0.0%	0.00	0	0	0	0	0
O28	Municipal Center	2.98	2.19	4.37	No	IBasin	0.48	2	0	4,048	3,703	85.7%	3.75	22,215	0	22,215	5,927	10,459
O28-A	Walgreens	1.91	1.88	2.55	No	IChamber	0.66	0	3	2,215	4,306	85.6%	2.19	0	0	0	0	0
O29	Auto Dealer on North Main St	2.48	0.97	1.87	No	None	n/a	n/a	n/a	n/a	n/a	0.0%	0.00	0	0	0	0	0
O4	Woodside Ln - cul-de-sac	1.95	0.58	0.99	No	IBasin	0.21	2	0	671	475	58.1%	0.58	570	0	570	987	924
O5	Centerville Ln - cul-de-sac	4.95	1.29	2.78	No	IBasin	0.27	2	0	1,535	1,404	72.2%	2.01	1,685	0	1,685	838	1,195
O6	Toni and Jamie Dr - cul-de-sac	4.92	1.15	1.49	No	IBasin	0.61	1	0	7,559	2,825	85.1%	1.27	3,390	0	3,390	2,669	2,638
S1	Natural area north of River Brook Rd	4.70	0.63	0.92	No	None	n/a	n/a	n/a	n/a	n/a	0.0%	0.00	0	0	0	0	0
S2	Riverbrook Road - Rail tracks	17.47	5.07	8.26	No	None	n/a	n/a	n/a	n/a	n/a	0.0%	0.00	0	0	0	0	0
S3	Riverine buffer zone	61.20	7.16	15.30	No	None	n/a	n/a	n/a	n/a	n/a	0.0%	0.00	0	0	0	0	0
S4	Thayer St/Creek Central	26.97	5.57	11.06	No	IBasin	0.28	2	0	9,007	6,369	64.3%	7.11	38,216	0	38,216	5,376	6,006
S5	Undeveloped area north of Depot St	3.89	0.29	0.81	No	None	n/a	n/a	n/a	n/a	n/a	0.0%	0.00	0	0	0	0	0
	TOTALS	236.70	60.43	126.65								40.9%	51.82	467,715	0	467,715	9,026	7,063

ID	Name	Total Area (ac)	Total Impervious Area (ac)	Existing Phosphorus Load (lb/yr)	RDA Site?	Assigned BMP Type	BMP Design Storm (in)	BMP Design Height (ft)	BMP Design Depth (ft)	BMP A rea (sq. ft.)	BMP Treatment Volume (cu. ft.)	Phosphorus Reduction (%)	Phosphorus Load Removed (lb/yr)	Estimated BMP Cost ($)	Estimated Land Cost at $2/ft2 ($)	Total Cost ($)	($/lb/yr) Phosphorus Removed	($/ac) Acres Treated
DD1-A	Bellingham Plaza LLC (parking)	4.49	4.11	9.28	Yes	Bioret	0.02	0.75	3	265	345	4.8%	0.44	6,892	0	6,892	15,519	1,755
DD1-B	Bellingham Plaza LLC (roof)	3.12	1.60	3.86	Yes	ITrench	0.14	0	3	638	511	34.8%	1.34	13,237	0	13,237	9,856	8,294
DD2	26 Main St. Bell Rlt	4.48	2.75	6.52	Yes	Bioret	0.02	0.75	3	136	176	3.6%	0.23	3,527	0	3,527	15,177	1,307
DD3	Roman Catholic Church	30.51	2.20	7.86	Yes	Bioret	0.17	2	0	1,584	2,111	29.2%	2.29	31,672	0	31,672	13,814	9,041
O16	East of Mill Street	2.17	1.53	3.05	No	IBasin	0.20	2	0	1,508	1,005	55.5%	1.69	6,397	4,523	10,920	6,457	7,332
O18-A	Park on North Main St and Mendon St	23.51	9.49	21.33	No	IBasin	0.27	4	0	6,915	9,220	64.4%	13.74	56,999	0	56,999	4,149	5,866
O18-B	Park on North Main St and Mendon St	6.52	2.34	6.31	No	Raingdn	0.27	0.75	0	4,113	2,056	61.5%	3.88	17,918	0	17,918	4,618	7,379
O18-C	Park on North Main St and Mendon St	4.49	1.45	2.89	No	Bioret	0.07	0.75	3	285	370	13.2%	0.38	5,553	0	5,553	14,502	3,638
O18-D	Park on North Main St and Mendon St	1.75	1.46	3.33	No	IBasin	0.41	4	0	1,315	1,753	85.2%	2.84	12,477	3,945	16,423	5,782	11,726
O18-E	Park on North Main St and Mendon St	1.15	0.70	1.54	No	IBasin	0.24	4	0	378	504	72.5%	1.12	3,589	1,135	4,724	4,217	6,895
O2	Edgehill Ln - cul-de-sac	1.68	0.49	0.76	No	IBasin	0.11	2	0	288	192	39.6%	0.30	1,223	865	2,087	6,904	3,948
O20	Behind Rail intersects w/ North Main St	10.15	1.12	2.54	No	IBasin	0.24	4	0	827	1,102	72.3%	1.84	7,844	2,480	10,324	5,615	6,825
O21	Rose Avenue	4.48	1.44	2.59	No	IBasin	0.27	2	0	1,643	1,096	72.0%	1.87	6,013	4,930	10,943	5,862	7,209
O22	Judy Ln - cul-de-sac	2.62	0.86	1.52	No	IBasin	0.15	2	0	675	450	46.5%	0.71	1,911	2,026	3,937	5,573	4,350
O24	Municipal Center	0.68	0.68	0.62	No	ITrench	0.02	2	0	20	27	4.5%	0.03	440	0	440	15,889	681
O24-A	Municipal Center	0.11	0.11	0.10	No	Raingdn	0.41	0.75	0	157	79	72.6%	0.07	1,174	0	1,174	16,190	11,034
O25	Famous Pizza parking lot	1.00	0.99	1.82	No	IBasin	0.13	2	0	499	333	49.6%	0.90	2,737	1,496	4,234	4,703	4,481
O26	North Main Street	0.36	0.32	0.29	No	None	n/a	n/a	n/a	n/a	n/a	0.0%	0.00	0	0	0	0	1
O28	Municipal Center	2.98	2.19	4.37	No	IBasin	0.29	2	0	2,466	1,644	73.4%	3.21	13,535	0	13,535	4,213	6,372
O28-A	Walgreens	1.91	1.88	2.55	No	IChamber	0.66	0	3	2,215	2,658	85.6%	2.19	0	0	0	0	0
O29	Auto Dealer on North Main St	2.48	0.97	1.87	No	IBasin	0.17	2	0	689	460	56.8%	1.06	3,783	2,068	5,851	5,494	5,865
O4	Woodside Ln - cul-de-sac	1.95	0.58	0.99	No	IBasin	1.05	2	0	3,325	2,217	95.3%	0.95	2,821	0	2,821	2,981	4,577
O5	Centerville Ln - cul-de-sac	4.95	1.29	2.78	No	IBasin	0.82	2	0	4,570	3,046	95.6%	2.66	5,016	0	5,016	1,886	3,558
O6	Toni and Jamie Dr - cul-de-sac	4.92	1.15	1.49	No	IBasin	0.84	1	0	10,426	3,475	91.2%	1.36	4,677	0	4,677	3,434	3,638
S1	Natural area north of River Brook Rd	4.70	0.63	0.92	No	ITrench	0.02	0	3	41	33	4.5%	0.04	644	124	768	18,478	961
S2	Riverbrook Road - Rail tracks	17.47	5.07	8.26	No	ITrench	0.00	0	3	0	0	0.0%	0.00	10	1	10	10	100
S3	Riverine buffer zone	61.20	7.16	15.30	No	None	n/a	n/a	n/a	n/a	n/a	0.0%	0.00	0	0	0	0	0
S4	Thayer St/Creek Central	26.97	5.57	11.06	No	IBasin	0.20	2	0	6,373	4,249	55.1%	6.10	27,039	0	27,039	4,434	4,250
S5	Undeveloped area north of Depot St	3.89	0.29	0.81	No	IBasin	0.26	2	0	475	317	70.2%	0.57	2,608	1,426	4,034	7,086	8,787
	TOTALS	236.70	60.43	126.65								40.9%	51.82	239,731	25,020	264,745	5,109	4,006

Modeling Results- Scenario 2

ID	Name	Total Area (ac)	Total Impervious Area (ac)	Existing Phosphorus Load (lb/yr)	RDA Site?	Assigned BMP Type	BMP Design Storm (in)	BMP Design Height (ft)	BMP Design Depth (ft)	BMP Area (ft2)	BMP Treatment Volume (ft3)	Phosphorus Reduction (%)	Phosphorus Load Removed (lb/yr)	Estimated BMP Cost ($)	Estimated Land Cost at $2/ft2 ($)	Total Cost ($)	($/lb/yr) Phosphorus Removed	($/ac) Acres Treated
DD1-A	Bellingham Plaza LLC (parking)	4.49	4.11	9.28	Yes	Bioret	0.38	0.75	3	3,024	2,716	59.1%	5.49	21,725	0	21,725	3,960	5,531
DD1-B	Bellingham Plaza LLC (roof)	3.12	1.60	3.86	Yes	ITrench	0.15	0	3	1,456	944	51.2%	1.98	7,550	0	7,550	3,815	4,730
DD2	26 Main St. Bell Rlt	4.48	2.75	6.52	Yes	Bioret	0.38	0.75	3	3,002	2,252	64.0%	4.17	18,014	0	18,014	4,319	6,676
DD3	Roman Catholic Church	30.51	2.20	7.86	Yes	Bioret	0.38	2	0	1,613	2,150	29.6%	2.33	32,257	0	32,257	13,862	9,207
O16	East of Mill Street	2.17	1.53	3.05	No	None	n/a	n/a	n/a	n/a	n/a	0.0%	0.00	0	0	0	0	0
O18-A	Park on North Main St and Mendon St	23.51	9.49	21.33	No	IBasin	0.35	4	0	5,255	7,219	57.8%	12.34	43,313	0	43,313	3,510	4,457
O18-B	Park on North Main St and Mendon St	6.52	2.34	6.31	No	Raingdn	0.20	0.75	0	8,127	2,361	61.2%	3.86	14,164	0	14,164	3,668	5,833
O18-C	Park on North Main St and Mendon St	4.49	1.45	2.89	No	Bioret	0.20	0.75	3	294	382	13.6%	0.39	5,724	0	5,724	14,502	3,751
O18-D	Park on North Main St and Mendon St	1.75	1.46	3.33	No	IBasin	0.00	4	0	381	603	51.1%	1.70	3,617	1,144	4,761	2,796	3,399
O18-E	Park on North Main St and Mendon St	1.15	0.70	1.54	No	IBasin	0.00	4	0	370	585	71.9%	1.11	3,510	1,110	4,620	4,160	6,744
O2	Edgehill Ln - cul-de-sac	1.68	0.49	0.76	No	None	n/a	n/a	n/a	n/a	n/a	0.0%	0.00	0	0	0	0	0
O20	Behind Rail intersects w/ North Main St	10.15	1.12	2.54	No	IBasin	0.00	4	0	483	764	54.8%	1.39	4,583	1,449	6,032	4,332	3,988
O21	Rose Avenue	4.48	1.44	2.59	No	None	n/a	n/a	n/a	n/a	n/a	0.0%	0.00	0	0	0	0	0
O22	Judy Ln - cul-de-sac	2.62	0.86	1.52	No	None	n/a	n/a	n/a	n/a	n/a	0.0%	0.00	0	0	0	0	0
O24	Municipal Center	0.68	0.68	0.62	No	ITrench	0.35	2	0	464	425	57.9%	0.36	2,548	0	2,548	7,149	3,947
O24-A	Municipal Center	0.11	0.11	0.10	No	None	n/a	n/a	n/a	n/a	n/a	0.0%	0.00	0	0	0	0	0
O25	Famous Pizza parking lot	1.00	0.99	1.82	No	None	n/a	n/a	n/a	n/a	n/a	0.0%	0.00	0	0	0	0	0
O26	North Main Street	0.36	0.32	0.29	No	None	n/a	n/a	n/a	n/a	n/a	0.0%	0.00	2	2	4	0	13
O28	Municipal Center	2.98	2.19	4.37	No	IBasin	0.35	2	0	2,146	1,963	69.2%	3.03	11,779	0	11,779	3,891	5,546
O28-A	Walgreens	1.91	1.88	2.55	No	IChamber	0.41	0	3	2,215	4,306	85.6%	2.19	0	0	0	0	0
O29	Auto Dealer on North Main St	2.48	0.97	1.87	No	IBasin	0.00	2	0	231	422	43.4%	0.81	3,165	692	3,857	4,739	3,866
O4	Woodside Ln - cul-de-sac	1.95	0.58	0.99	No	IBasin	0.20	2	0	2,924	2,067	93.6%	0.93	2,481	0	2,481	2,670	4,024
O5	Centerville Ln - cul-de-sac	4.95	1.29	2.78	No	IBasin	0.20	2	0	4,603	4,211	95.7%	2.66	5,053	0	5,053	1,898	3,584
O6	Toni and Jamie Dr - cul-de-sac	4.92	1.15	1.49	No	IBasin	0.54	1	0	8,488	3,173	88.0%	1.31	3,807	0	3,807	2,898	2,962
S1	Natural area north of River Brook Rd	4.70	0.63	0.92	No	ITrench	0.00	0	3	54	71	7.7%	0.07	529	163	693	9,777	866
S2	Riverbrook Road - Rail tracks	17.47	5.07	8.26	No	None	n/a	n/a	n/a	n/a	n/a	0.0%	0.00	0	0	0	0	0
S3	Riverine buffer zone	61.20	7.16	15.30	No	None	0.00	0.5	3	0	39,739	0.0%	0.00	0	0	0	0	0
S4	Thayer St/Creek Central	26.97	5.57	11.06	No	IBasin	0.26	2	0	5,694	4,027	51.5%	5.70	24,159	0	24,159	4,240	3,797
S5	Undeveloped area north of Depot St	3.89	0.29	0.81	No	None	n/a	n/a	n/a	n/a	n/a	0.0%	0.00	0	0	0	0	0
	TOTALS	236.70	60.43	126.65								40.9%	51.82	207,980	4,560	212,536	4,101	3,210

APPENDIX B: TECHNICAL INFORMATION

CRWA's Modeling Analysis

CRWA used computer modeling to develop the stormwater management plan for the entire study area. Modeling allowed us to assess the phosphorus reduction potential of various design scenarios for the study area (See Section: Modeling Analysis). This section contains technical details on certain relevant aspects of the modeling process, including CRWA's methodology for sizing and costing stormwater control units. NEI developed the schematic designs for the ten drainage areas presented in the Proposed Stormwater Management Design section. CRWA, in modeling the study area, and NEI, in developing the designs calculated the size and cost of stormwater control units sizes independently using the same water quality volume but with two different methods. NEI's methodology is discussed in the following section.

Calculating Existing Phosphorus Loads for Modeling Analysis

Phosphorus loads were developed by TetraTech (2009) specifically for 2005 land use categories. Although these export coefficients are slightly different from the Upper/Middle Charles TMDL coefficients (CRWA, 2009), which were based on the 1999 land use data, they preserve the total calibrated stormwater TMDL load. Our project ignored small variations in phosphorus loading across soil types. The land-use based export coefficients, multiplied by the pervious and impervious areas within each land use in each drainage area, yielded the estimated total phosphorus load for the study area under existing conditions.

Treatment of Existing Stormwater Control Units

CRWA investigated all existing stormwater control units that were accessible. CRWA determined that only one drainage area had a functioning stormwater control unit which was constructed after the completion of the Upper/Middle Nutrient TMDL study. Any control unit constructed prior to 2000 would be considered part of the TMDL "base conditions" and could not be counted as helping the Town reach their reduction goal. Drainage area O-28 has an underground infiltration chamber. Based on this system design and type, we estimated the system to achieve a 41% phosphorus removal rate for the drainage area it serves. As this is an existing installed system, the volume of water the system is treating (expressed as a depth over the contributing area) was fixed in both optimization scenarios.

Size Calculations

CRWA used the removal performance curves developed TetraTech (2009) to determine the phosphorus removal efficiencies as a function of the stormwater control volume. CRWA modified the approach used in this project from the one used in the Franklin assessment (ref??) based on a clarification by US-EPA on these curves. US-EPA has stated that the horizontal axis (expressed as a depth over the contributing area) is not the water quality volume rather it is the physical stormwater volume. In the Franklin project, we calculated the water quality volume directly from the curves. In this project we calculated the physical volume then estimated the water quality volume by adding back the estimated two-hour infiltration volume based on the Massachusetts Static Method (MA-DEP,

Table 6. BMP Sizing Formulas

BMP	Drain Time (days)	Porosity (-)	Area (A1)	S	Area (A2)	S
Bioretention	2	0.4	WQD * DA / (Dw+Dm*n)	1	WQD * DA * [Dm/ { Ksat* (0.5*Dw+Dm) *T }]	3
Green Streets	2	0.4	WQD * DA / (Dw+Dm*n)	1	WQD * DA * [Dm/ { Ksat* (0.5*Dw+Dm) *T }]	3
Gravel Wetland	-	0.4	WQD * DA / (Dw+Dm*n)	1	0.0035 * DA	4
Infiltration Basin	3	-	WQD * DA / (Dw+Ksat*2/24)	2	WQD * DA / (T*Ksat)	5
Infiltration Chamber	3	-	WQD * DA / (Dm*n+Ksat*2/24)	2	WQD * DA / (T*Ksat)	5
Infiltration Trench	3	0.45	WQD * DA / (Dm*n+Ksat*2/24)	2	WQD * DA / (T*Ksat)	5
Rain Garden	1	-	WQD * DA / (Dw+Ksat*2/24)	2	WQD * DA / (T*Ksat)	5

Sources (S):
1 = storage formula
2 = storage formula with 2 hours of infiltration using simple dynamic method from MA-DEP(2008)
3 = bioretention formula using Darcy's law (need ref)
4 = area formula (VT-ANR, 2002)
5 = drainage time formula

Definitions:
A = BMP area (ft2) = maximum(A1, A2)
DA = drainage area (ft2)
Dw = water depth (ft)
Dm = media depth (ft)
Ksat = saturated hydraulic conductivity (infiltration=soil, biofiltration/green streets=media)
T = design drainage time (d)
WQD = design water quality depth (ft)

Table 7. BMP Unit Costs and Cost Factors

BMP	Cost ($/ft^3)
Dry Pond	2
Wet Pond	3
Gravel Wetland	8
Infiltration Basin	4
Infiltration Trench	8
Infiltration Chamber	12
Rain Garden	5
Bioretention	10
Green Street	15
Water Quality Swale	8

BMP Type	Cost Factor
Outlet modifications	0.1
New BMP in undeveloped area	1
New BMP in partially developed area	1.5
New BMP in developed area	2
Insitu BMP retrofit of dry systems	2
Insitu BMP retrofit of wet systems	3

1999). The two volumes only differ for infiltration systems. The water quality volume was then for subsequent sizing and cost calculations like the Franklin project.

The physical area of the stormwater control was determined as the maximum of two area calculations (A1 and A2, see Table 3). The bioretention system area was determined as the maximum of the area from a common sizing formula based on Darcy's Law and the area required to store the entire design volume. For infiltration systems, first area was determined using the Massachusetts Static Method (MA-DEP, 1999) (area required to store the design volume allowing for two hours of infiltration) and an a second area that allows a three-day drainage recovery time. Rain gardens used a shallow infiltration basin design with a one day recovery time. stormwater controls The final surface area of the stormwater control was estimated by multiplying the water quality area by a flood storage factor that varies from one to three depending on the estimated area required for flood control. These area calculations were only used to see if the stormwater control could be located on the available space at the site.

Stormwater Control Cost Calculations

Unit costs of new stormwater controls were estimated from literature sources as the cost per water quality volume treated. Design costs (5-35%) were ignored as they are usually a fixed percentage of the total construction cost. Adjustment factors (0.3-2) were used to convert these costs from new site construction to retrofit site costs with the assumption that retrofitting highly developed, dense properties may be more costly than placing stormwater controls on new or sparsely developed sites. Retrofit costs may be higher (factors>1.0) if sites are more constrained for machinery and there are utilities (pipes, cables etc) present on or near the site. A simple retrofit using an outlet modification had a very low factor (0.3). The construction cost for each stormwater control was determined from the water quality volume (ft3), unit cost ($/ft3), and the cost factor (0.3-2). Land cost for stormwater controls requiring a land purchase (proposed site is on private property) was determined from unit land costs ($2/ft2) for current land sales in Bellingham and the land areas for the controls were estimated as 1.5 times the physical area of the stormwater control unit. The total cost for retrofitting the Bellingham study area the sum of the individual stormwater control costs for all units chosen to meet the 41% target phosphorus load reduction.

Table 8. BMP Unit Costs and Cost Factors

BMP	Cost ($/ft³)
Dry Pond	2
Wet Pond	3
Gravel Wetland	8
Infiltration Basin	4
Infiltration Trench	8
Infiltration Chamber	12
Rain Garden	5
Bioretention	10
Green Street	15
Water Quality Swale	8

BMP Type	Cost Factor
Outlet modifications	0.1
New BMP in undeveloped area	1
New BMP in partially developed area	1.5
New BMP in developed area	2
Insitu BMP retrofit of dry systems	2
Insitu BMP retrofit of wet systems	3

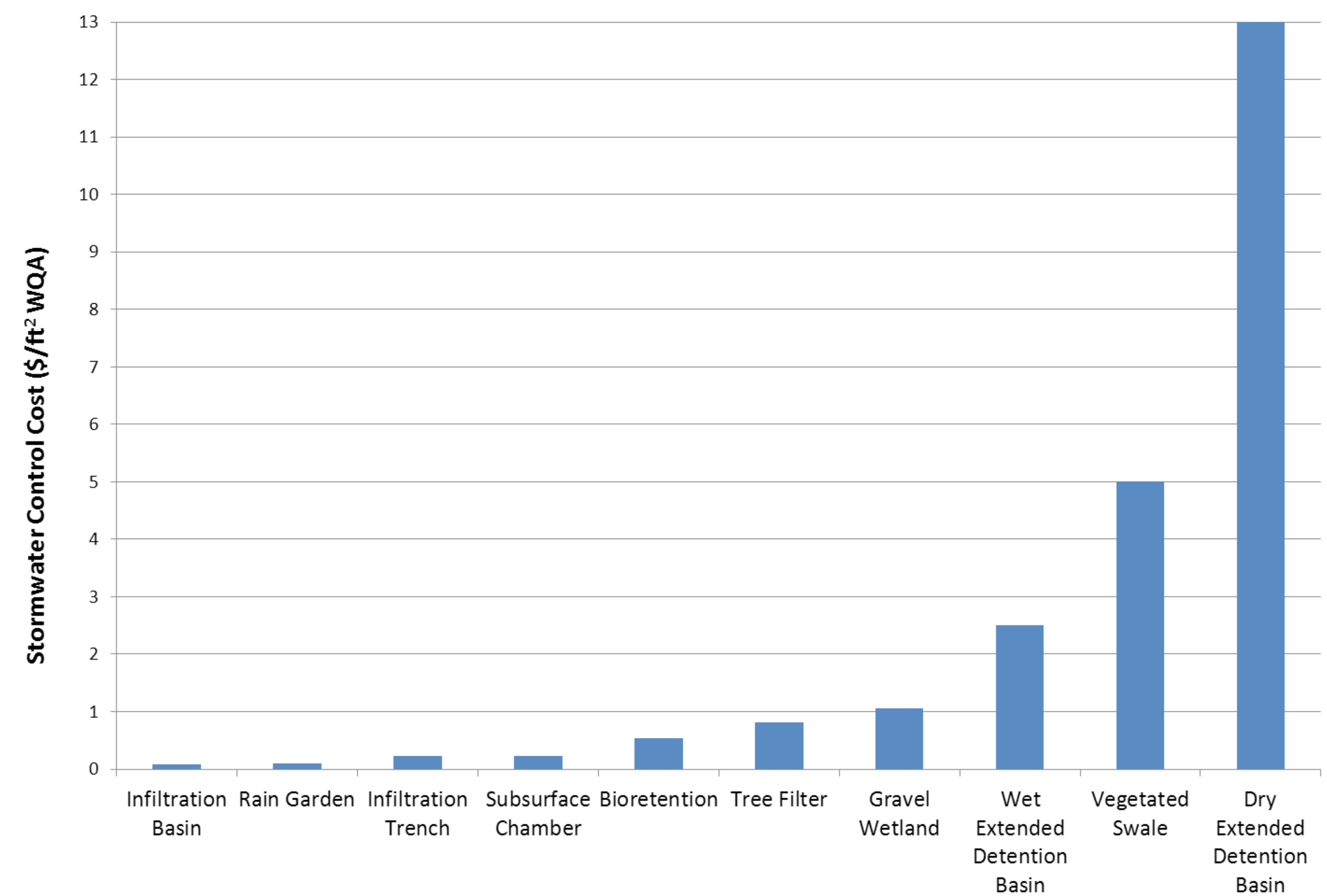


Figure 14. Relative Costs of Stormwater Controls for 65% Phosphorus Removal

Stormwater Control Cost Calculations by NEI

As opposed to CRWA's mehtodology of estimating unit costs of new stormwater controls from literature sources as the cost per water quality volume treated. NEI provided costs based on design specifications for each individual stormwater control. Table 8 summarizes the costs for each stormwater control for each individual priority sites.

DD1-A **Bellingham Plaza LLC**

Parking Lot Drainage Area: Bioretention Basins

	Unit Cost	Unit	Quantity	Total Cost
Bioretention Basin	$ 9.46	sf	8990	$ 85,035
12" CPP Pipe	$ 17.19	lf	130	$ 2,235
Area Drains (OCS)	$ 2,173.61	ea	6	$ 13,042
			Total	$ 100,311

DD1-B **Bellingham Plaza LLC**

Roof Drainage Area: Infiltration Trenches (2' x 2')

	Unit Cost	Unit	Quantity	Total Cost
Inf. Trenches	$ 5.33	sf	1500	$ 7,993
			Total	$ 7,993

O18 A **North Main Street: Infiltration Basin w/ Sediment Forebay**

	Unit Cost	Unit	Quantity	Total Cost
Infiltration Basin	$ 2.68	sf	7960	$ 21,335
12" CPP Pipe	$ 17.19	lf	140	$ 2,407
Area Drain (OCS)	$ 2,173.61	ea	1	$ 2,174
			Total	$ 23,742

O18 B **Town Park on North Main Street: Bioretention Basin**

	Unit Cost	Unit	Quantity	Total Cost
Bioretention Basin	$ 3.98	sf	3840	$ 15,279
12" CPP Pipe	$ 17.19	lf	335	$ 5,759
Area Drains (OCS)	$ 2,173.61	ea	2	$ 4,347
			Total	$ 25,385

O18 C **South Main Street: Bioretention Basin**

	Unit Cost	Unit	Quantity	Total Cost
Bioretention Basin	$ 9.46	sf	1410	$ 13,337
12" CPP Pipe	$ 17.19	lf	263	$ 4,521
Area Drains (OCS)	$ 2,173.61	ea	1	$ 2,174
			Total	$ 20,032

O24 **Town Hall Rear: Infiltration Trench (3' x 4')**

	Unit Cost	Unit	Quantity	Total Cost
Inf. Trench	$ 9.56	sf	820	$ 7,837
			Total	$ 7,837

O24A **Town Hall Rear: Rain Garden**

	Unit Cost	Unit	Quantity	Total Cost
Rain Garden	$ 3.98	sf	420	$ 1,671
			Total	$ 1,671

O28 **Town Hall Front: Infiltration Basins w/ Sediment Forebays**

	Unit Cost	Unit	Quantity	Total Cost
Infiltration Basin-3'	$ 2.68	sf	1302	$ 3,490
Infiltration Basin-4'	$ 2.88	sf	1806	$ 5,206
12" CPP Pipe	$ 17.19	lf	200	$ 3,438
Area Drain (OCS)	$ 2,173.61	ea	2	$ 4,347
			Total	$ 12,133

O6 **Tonie and Jamie Drive: Basin Retrofit w/ Sediment Forebay**

	Unit Cost	Unit	Quantity	Total Cost
Basin Retrofit	$ 2.07	sf	7170	$ 14,868
			Total	$ 14,868

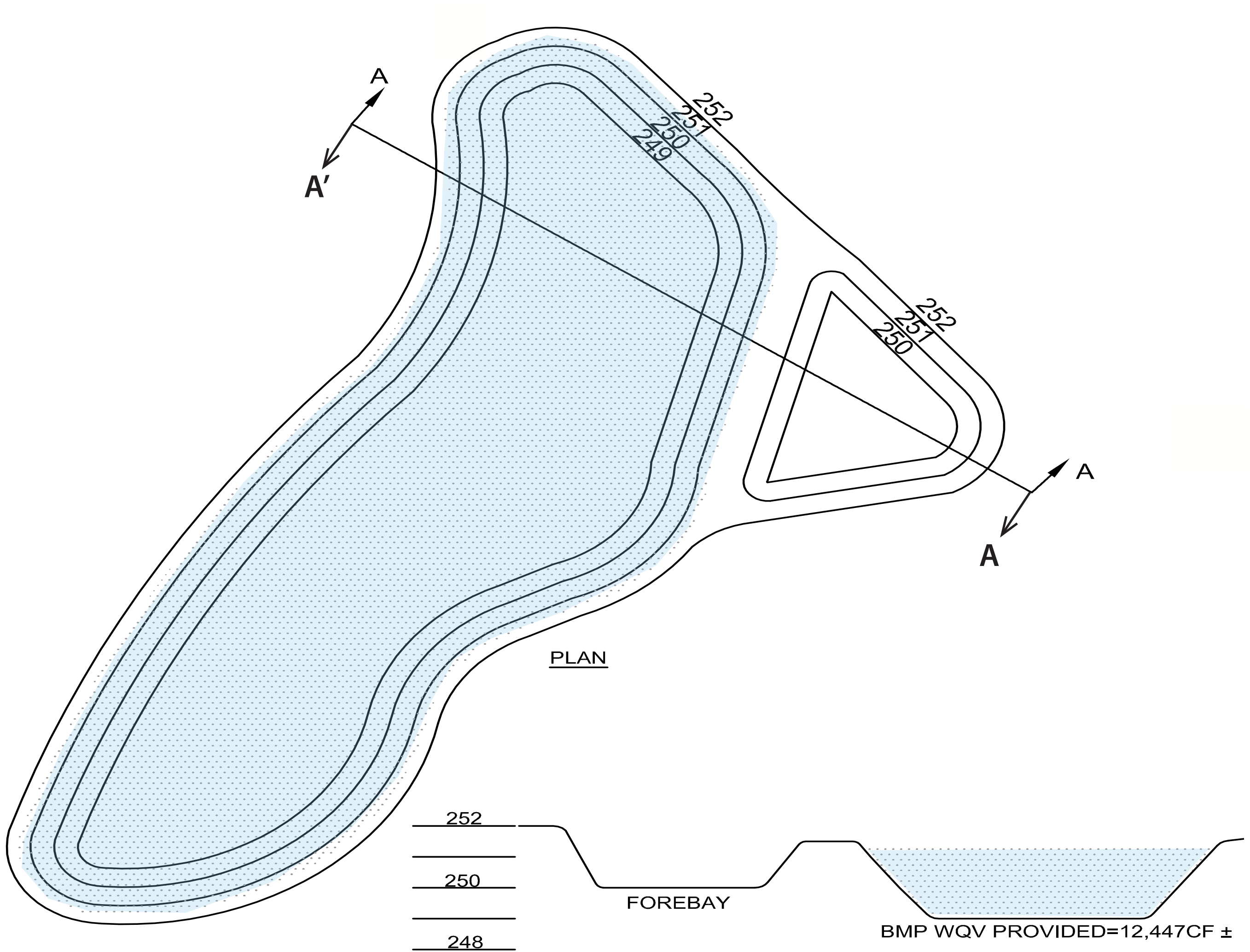
S4 **Thayer Street/Creek Central: Infiltration Basin w/ Sediment**

	Unit Cost	Unit	Quantity	Total Cost
Infiltration Basin	$ 2.68	sf	5100	$ 13,669
12" CPP Pipe	$ 17.19	lf	66	$ 1,135
Headwall (OCS)	$ 3,600.00	ea	1	$ 3,600
			Total	$ 14,804

Table 9. BMP Cost Information by drainage area.
Data supplied by NEI.

O18A NORTH MAIN STREET: INFILTRATION BASIN

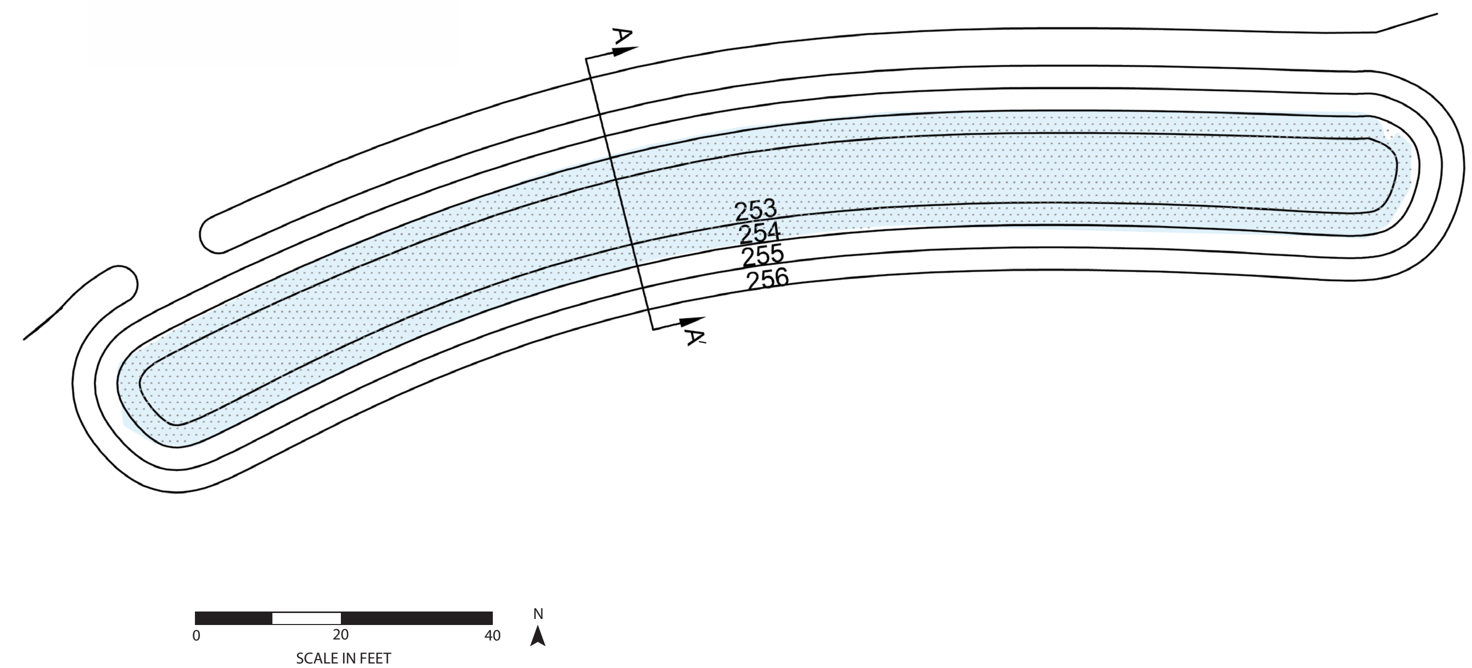
Infiltration Basin Plan

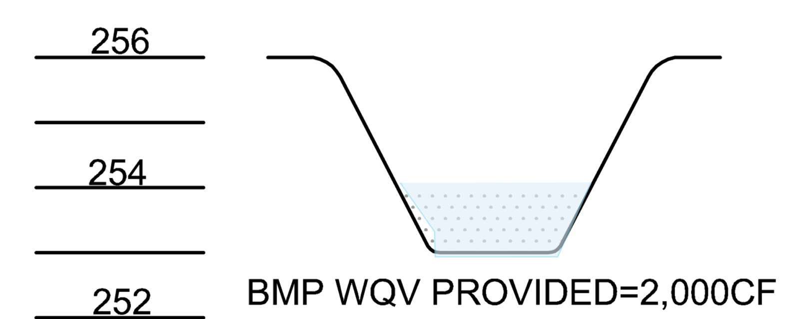


Section A - A'

O18 B TOWN COMMONS: RAIN GARDEN

Rain Garden Plan



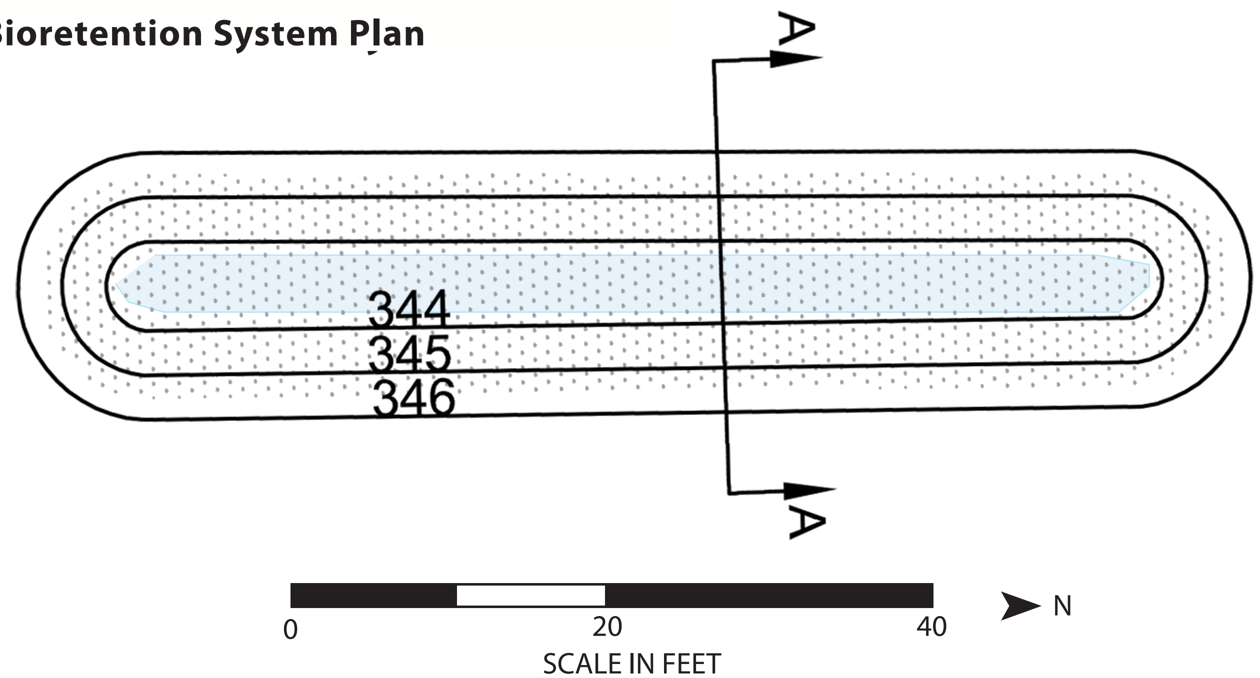


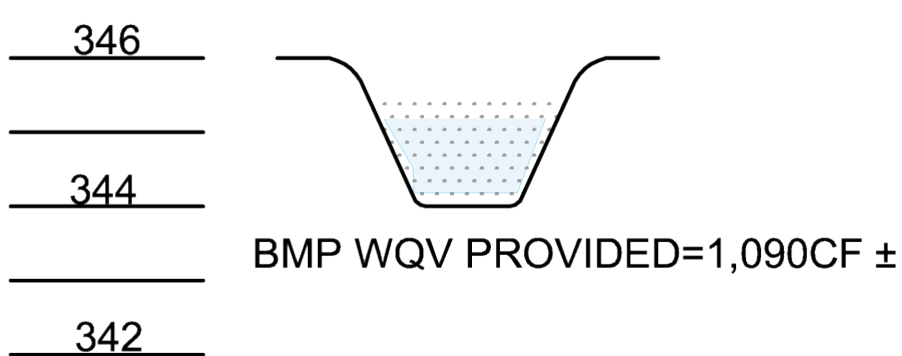
Section A - A'

Details provided by Nitsch Engineering

O18 C TOWN COMMONS: BIORETENTION SYSTEM

Bioretention System Plan

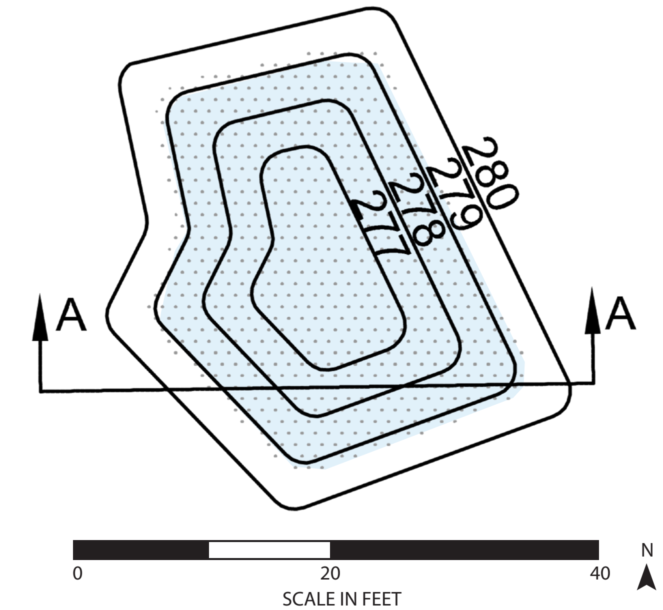


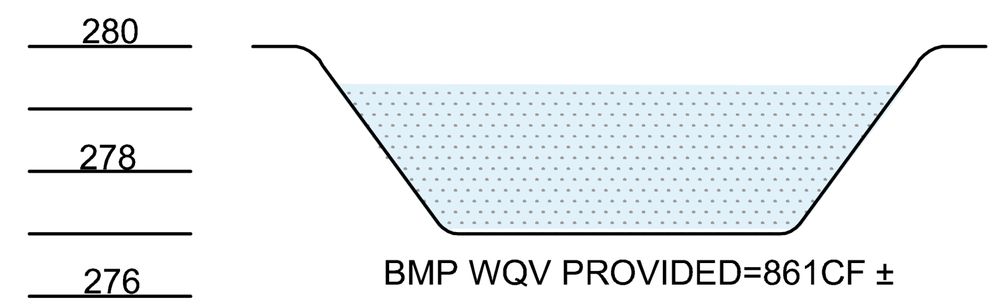


Section A - A'

O28C TOWN HALL FRONT: INFILTRATION BASINS

Infiltration Basin North of Town Hall: Plan View



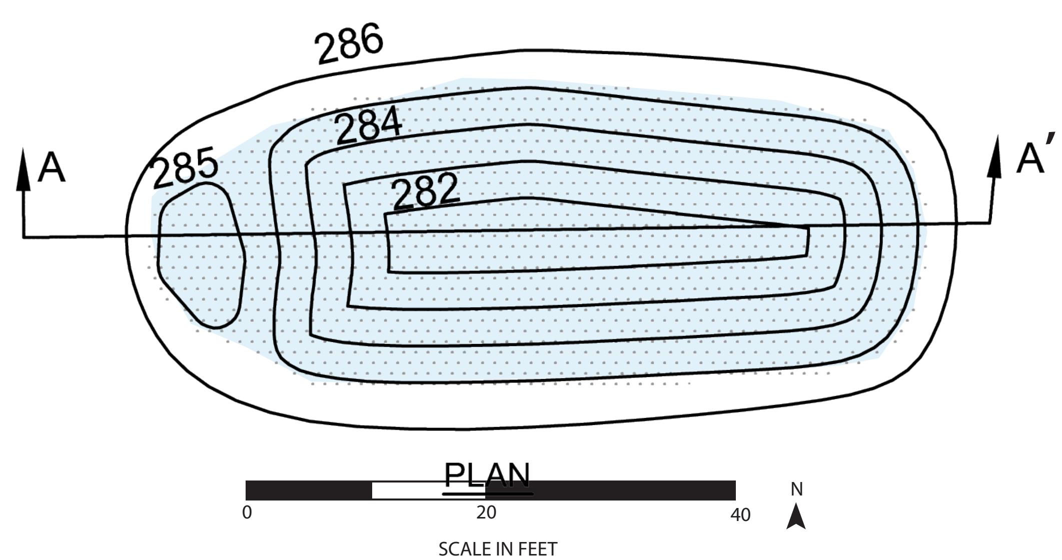


Section A-A'

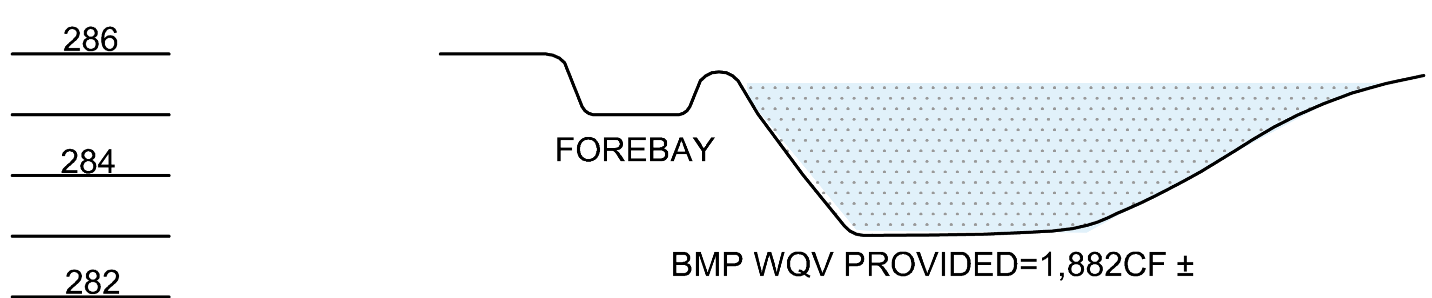
Details provided by Nitsch Engineering

O28 TOWN HALL REAR: INFILTRATION TRENCH

Infiltration Basin South of Town Hall: Plan View

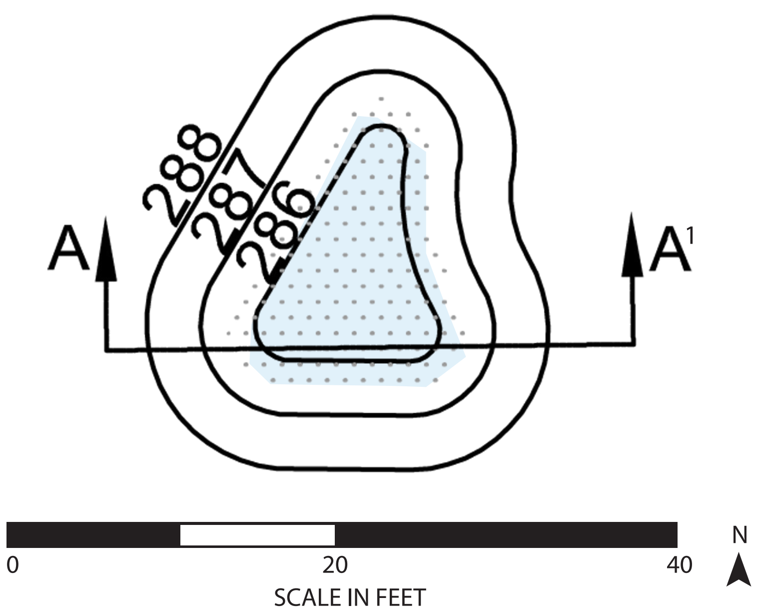


Section A-A’



O24A TOWN HALL REAR: RAIN GARDEN

Rain Garden Plan



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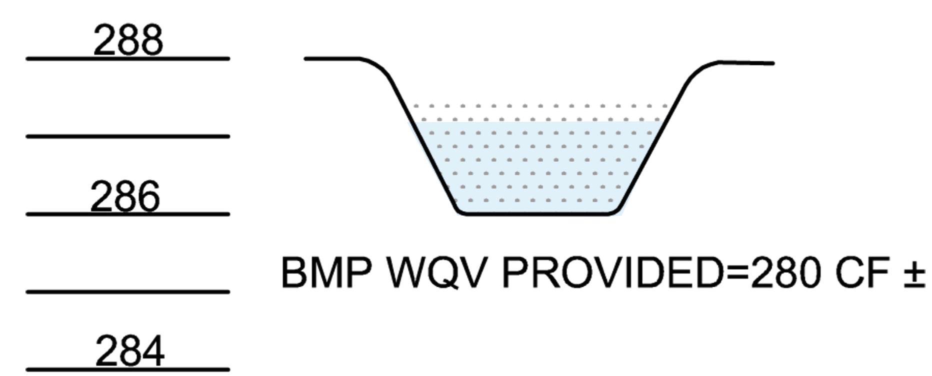
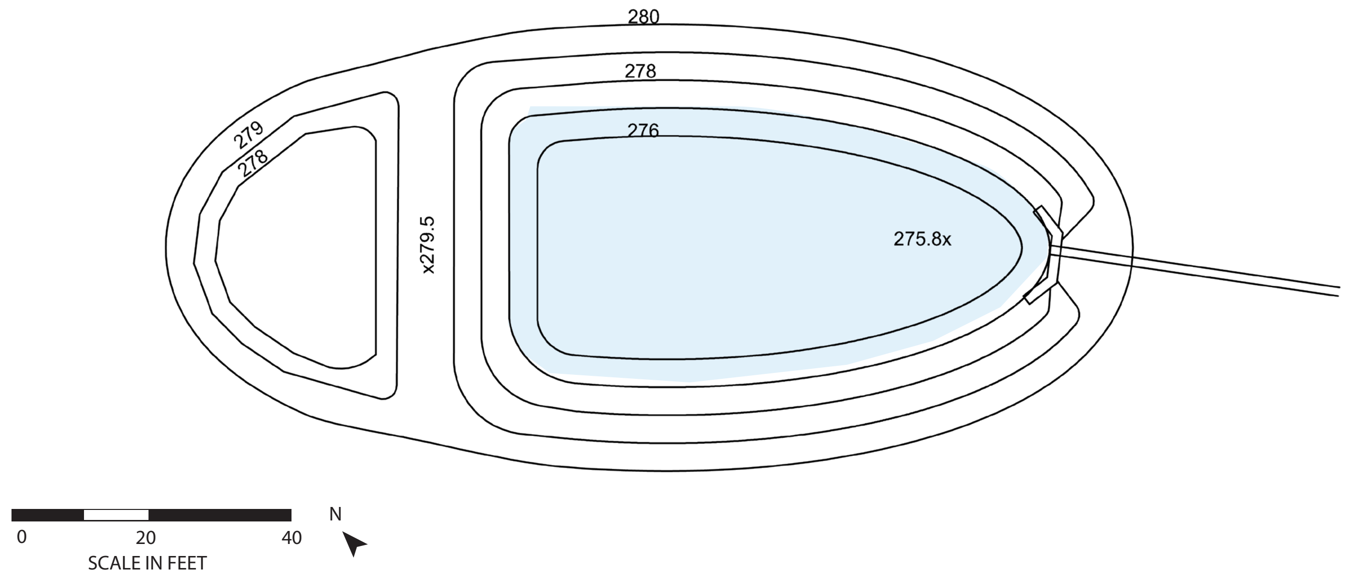


Details provided by Nitsch Engineering

 Appendix C - Details

O6 TONI AND JAMIE DRIVE: BASIN RETROFIT

Basin Plan



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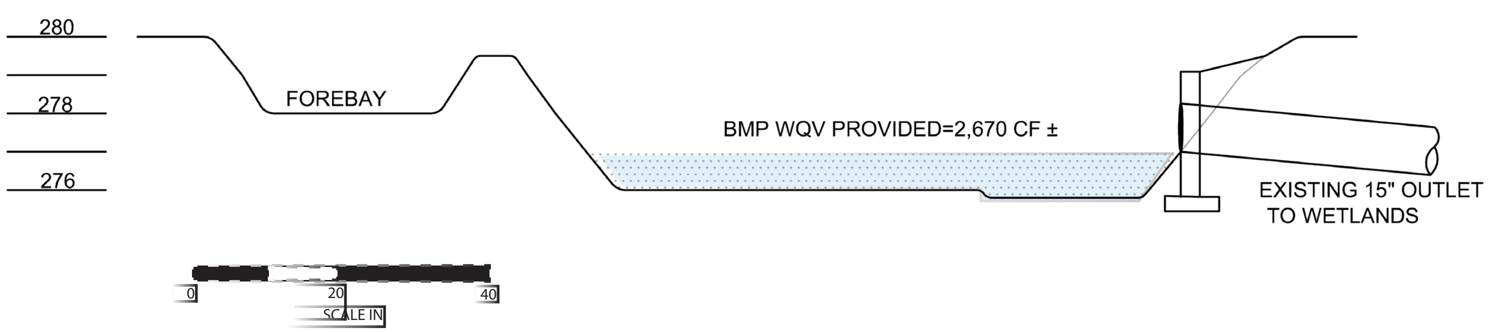
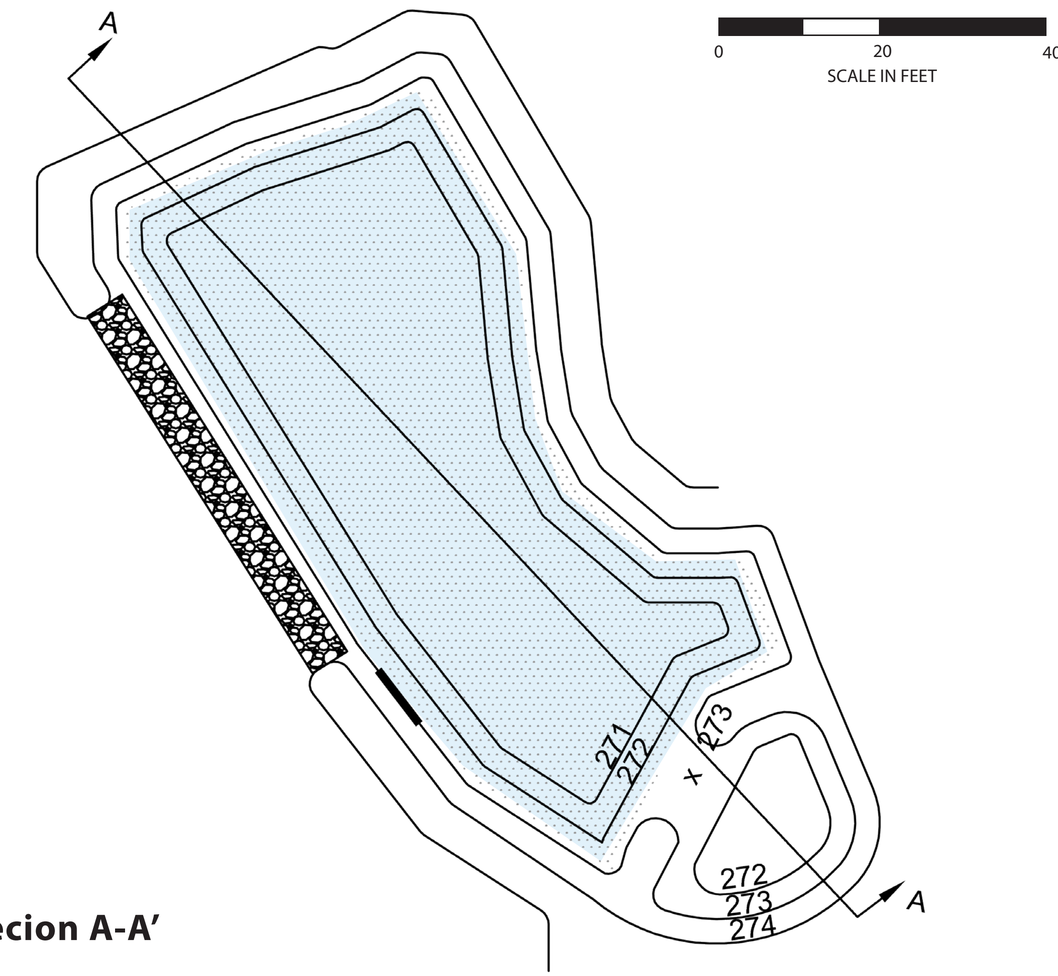


S4 THAYER ST/CREEK CENTRAL: INFILTRATION BASIN

Basin Plan



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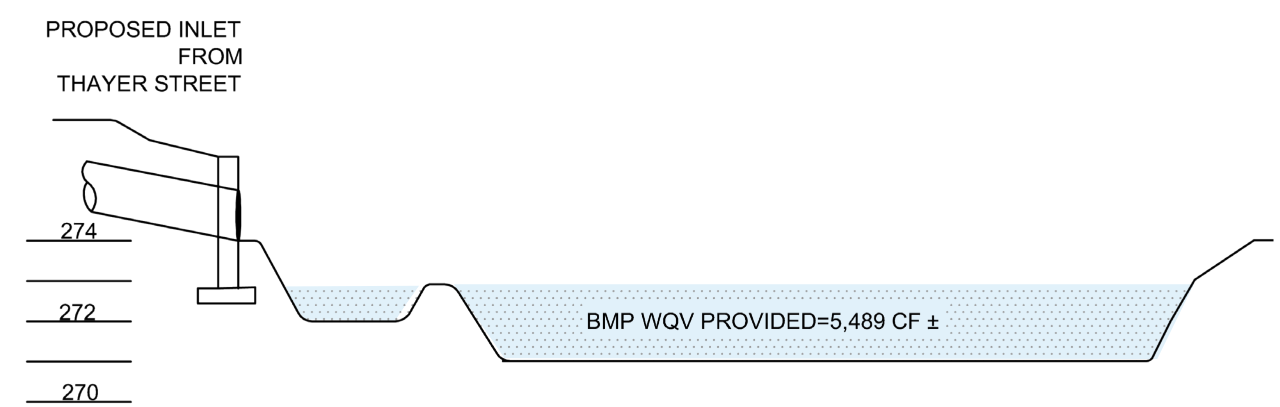
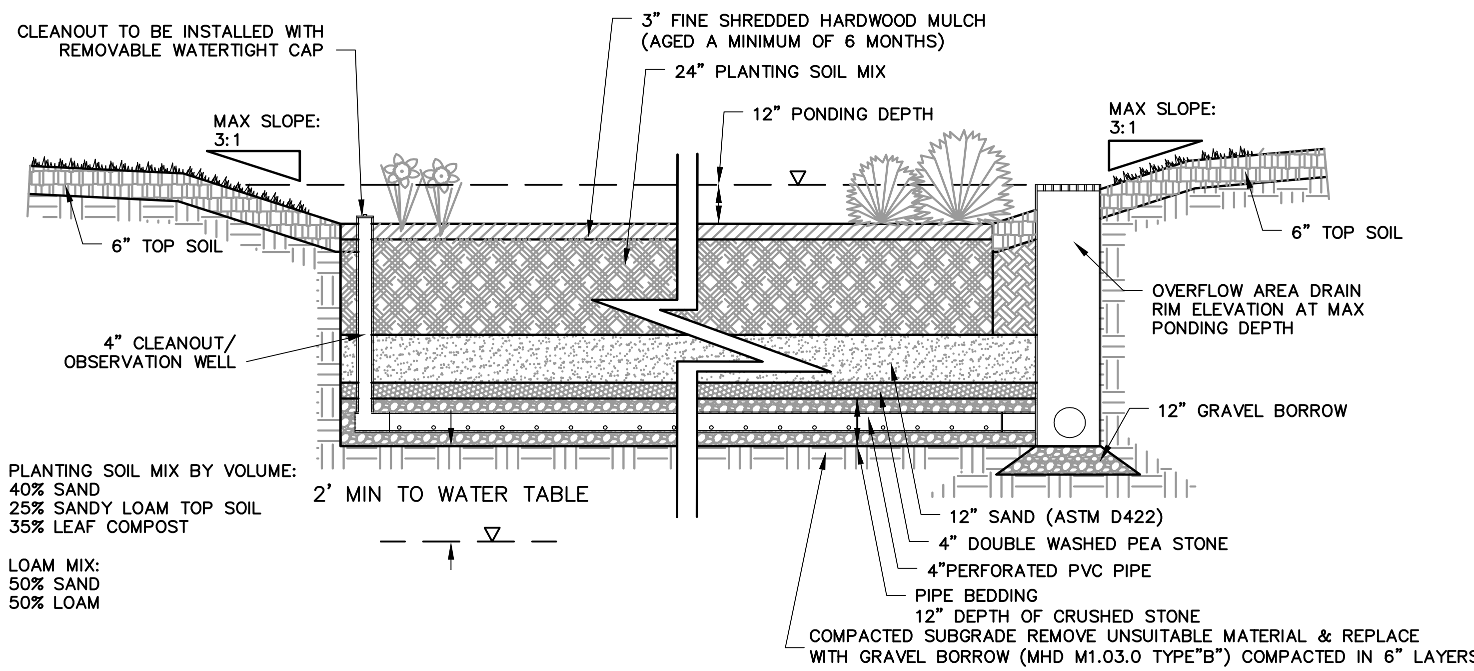


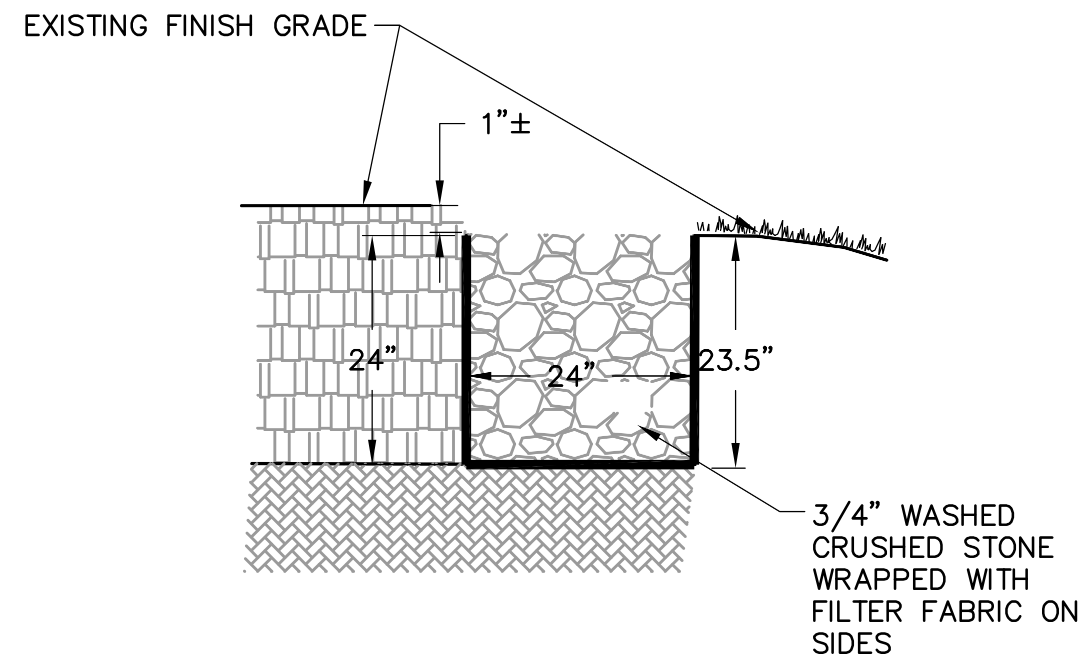
DD1-A BELLINGHAM PLAZA, LLC: BIORETENTION BASINS



RAIN GARDEN (RG)

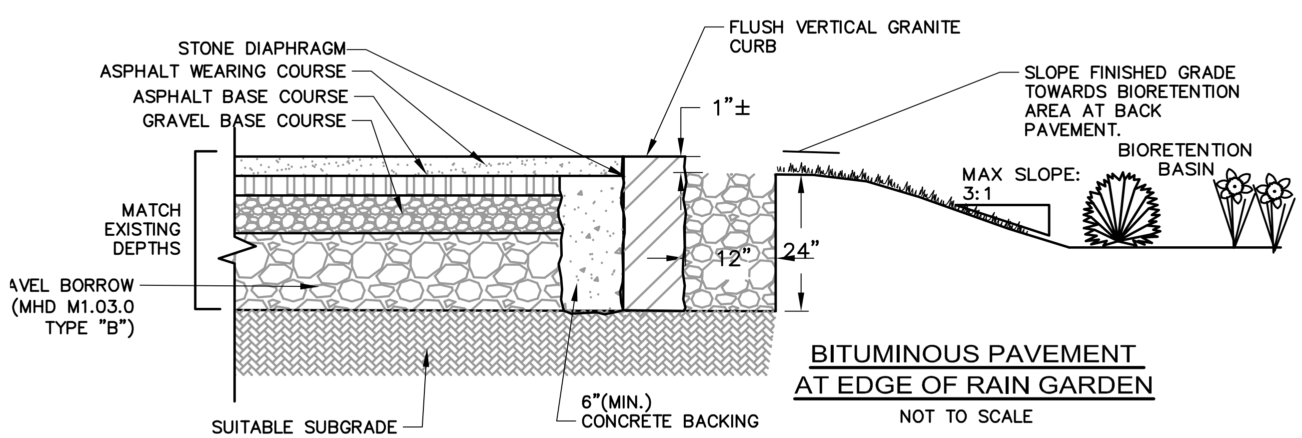
NOT TO SCALE

DD1-A BELLINGHAM PLAZA, LLC: INFILTRATION TRENCHES



INFILTRATION TRENCH (T)

NOT TO SCALE

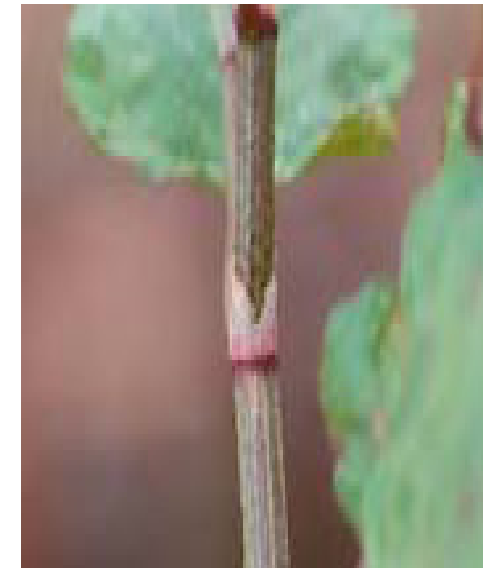


BITUMINOUS PAVEMENT AT EDGE OF RAIN GARDEN

NOT TO SCALE

Details provided by Nitsch Engineering

The following guidance for control of invasive Japanese Knotweed is excerpted from the Penn State University vegetation management fact sheet, which can be found at: http://vm.cas.psu.edu/Publications/CREP_WS_4_POLCU.pdf



Japanse Knotweed at the O6 drainage basin

Invasive species in Massachusetts are a significant threat to biodiversity, as they displace native species, cause significant changes in habitat and soil structure and exacerbate riparian erosion.

Field studies of the Bellingham subwatershed region observed the presence of several invasive plant species, most notably in the O6 Toni/Jamie Drive drainage basin, where a substantial crop of Japanese Knotweed (Fallopia japonica) threatens to overtake the wetland ecosystem adjacent to the Town Commons.

Removal of invasive Knotweed must be done programmatically; that is, cutting it once will not produce successful results. Aggressive mechanical controls, including cutting/removing plants twice monthly from April through August, should be considered in conjunction with careful integration of herbicide should be considered. Because the plant spreads easily downstream by water, it is necessary to begin control from the furthest possible upstream location. Outreach to all public and private landowners, and the community at large, will increase the success of control.

Knotweed Control Measures

To control knotweed, the rhizome system must be managed. To bring a knotweed infestation to a manageable level, multiple treatments over the course of at least two years must be implemented.

This approach relies on depletion of the reserves stored in the rhizomes in the late spring, and injury through use of systemic herbicides in the late summer. A late summer application of the herbicide glyphosate is one of the most effective treatments available. It also has the advantage of having no soil activity,reducing the risk of injury to non-target plants through root absorption, particularly in riparian forest buffer plantings. If glyphosate contacts the foliage of non-target plants, they will be injured or killed. In the state of Massachusetts, all workers involved in any aspect of handling, mixing and/or loading glyphosate products must be trained as a HANDLER or have a pesticide license.

There are many glyphosate products available. When working in riparian settings, a formulation labeled for aquatic applications is the best choice. The best-known example of this type of glyphosate product is 'Rodeo'.

There are two features that distinguish 'Rodeo' from products labeled only for terrestrial use, such as 'Roundup Pro'. 'Rodeo' has no surfactant, so you must add one; and 'Rodeo' is 1/3 more concentrated than 'Roundup Pro', so only 3/4 the product will achieve the results as a larger dose of 'Roundup'. By using a glyphosate product and surfactant labeled for aquatic settings, the risk of injury to aquatic organisms is greatly reduced. The surfactant in the 'old' Roundup (now sold as 'Roundup Original') was highly toxic to aquatic organisms. Using 'Rodeo' does not permit you to treat weeds in the water or allow you to direct spray into the water: using an aquatic-labeled product close to water simply reduces the risk to non-target aquatic organisms.

A late summer glyphosate application is much easier if the knotweed is mowed or cut around June 1. The regrowth after cutting at this date is much shorter than the original growth - 3 to 4 feet tall rather than the typical 6 to 10 feet of growth. This shorter canopy is much easier to treat with a sprayer: it is less work, and you can be much more selective in the application.

If the knotweed is not cut in June, it should be treated with glyphosate in late July, and then regrowth or missed stems should be spot treated in early September. Follow-up treatment in the second year is essential. You will probably observe 90 to 95 percent reduction in the stand, but if you don't continue to treat it, the knotweed will come back and you will need to start over. Wait until July of the second year for the follow-up treatment. If treatment takes place earlier, there is less translocation of the herbicide to the rhizomes.

Knotweed management is more complex if it's growing among trees. It must be cut earlier and more often to prevent from canopying over tree plantings. As with the single mowing approach, allow at least six weeks after the last mowing before spot treating the knotweed with glyphosate in the late summer. Knotweed may never be eradicated from your site, but it can definitely be kept at a manageable level so it does not impact biodiversity or threaten nearby resources..