Mill River Freshwater Tidal Marshes:
2008 Vegetation Monitoring

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As part of the ongoing evaluation of the lower Mill River corridor and the potential environmental effects of public water supply withdrawals, the South Central Connecticut Regional Water Authority (RWA) conducts annual monitoring of plant communities in the freshwater tidal marsh. This marsh, created in part by downstream tide gates belonging to the City of New Haven, is an unusual vegetation type that contributes significantly to the biological diversity and wildlife populations in the lower Mill River and East Rock Park.

The Water Authority's Environmental Study Team (EST), in its 1999 assessment of potential impacts of the proposed treatment plant, recommended that vegetation in the marsh be monitored annually or biennially, both prior to construction of the plant to provide baseline data and after the plant is placed in operation. Data from these vegetation studies, along with monitoring of soil salinity, river flow, water quality, and aquatic life in the lower Mill River, will be used to evaluate environmental impacts of treatment plant operation.

The new treatment plant was placed in operation on April 20, 2005. Prior to the operation of this plant, baseline data were collected from 1998 through 2004 (J. L. Rogers and P. Sharp 2005: "2004 Vegetation Monitoring in the Mill River Freshwater Tidal Marshes: A Summary of Six Years of Baseline Data Collection," prepared for the South Central Connecticut Regional Water Authority). The baseline sampling provided information on variation in plant communities in the marsh during six years (no monitoring was performed in 1999) when there were no withdrawals for water-supply use. Vegetation sampling was repeated in September 2005 following the initiation of treatment plant operation, and continues to be performed annually in late summer. Soil water salinity measurements are made in spring and again in the summer from three monitoring wells on each transect, installed in September 2000.

Vegetation Sampling Methods

Penni Sharp and Vincent Kay conducted quantitative vegetation sampling of the Mill River marshes on September 8 and 9, 2008. Monitoring in most previous years was performed between September 7 and September 25, except in 2000 when the site was sampled in mid-August. Sampling dates for each year are listed in Table 1 on page 4.

Vegetation sampling is conducted along two permanent transects. The upstream or northern transect, MR-N, is about 2,000 feet below the Whitney dam, just south of the East Rock Park footbridge and about 700 feet north of the East Rock Road bridge. This transect passes through one of the largest and most varied parts of the marsh. The downstream transect, MR-S, passes through a narrower and less varied marsh community about 300 feet south of the East Rock Road bridge.

The permanent transect at each site is approximately perpendicular to the river with permanent marker stakes placed every 5 meters along the transect. Transect MR-N is 100 m in length, but only 18 of the surveyed stakes are sampled regularly; the stake at the upland

origin of the transect is outside the tidal area, while the two stakes closest to the river are typically inundated and can be sampled only during unusually low flow conditions. Transect MR-S is 55 m long and ends at a low levee at the river; since it does not extend into the typically inundated low marsh along the river's edge, all 12 stakes are sampled regularly. Vegetation sampling is performed by extending 5-meter sampling chains south from each stake, perpendicular to the permanent transect. A dowel rod is inserted into the vegetation at 0.5 m. intervals along the sampling chain, for a total of 10 sampling points per chain, and all species touching the rod (or an imaginary upward extension of it) are recorded. Maps of these transects, and a detailed description of the methodology, appear in the report by Lee Rogers included in the *Lake Whitney Water Treatment Plant Environmental Evaluation: Volume Two* (January 1999).

Results

Precipitation and Soil Conditions

Precipitation in the lower Mill River during the 2008 growing season (April-October) was unusually high overall (see Table 1). During the growing season, monthly rainfall totals ranged from a low of 3.67 inches in May and October to a high of 11.06 inches in September. A total of 34.89 inches of precipitation fell during this period, the highest since the Mill River monitoring project began in 1998. The annual total of 71.99 inches of precipitation is the highest on record during the 97 years that the RWA has measured rainfall. Month-by-month precipitation data for the last ten years since sampling began appear in Appendix A, Table A-1.

Withdrawals from Lake Whitney, guided by the Management Plan, are intended to protect downstream and upstream environmental resources. Daily withdrawals during the spring high-rainfall period generally ranged from about 4.5 to 8.5 million gallons per day (mgd) of the maximum 15 mgd allowed in 2008. From early May to early August, withdrawals ranged between 3 and 5 mgd *(the current once per week operation of the treatment plant did not commence until Oct 22, 2008).* Lake Whitney levels remained above spillway level for all of 2008, and downstream flows remained above 10 mgd throughout the year.

Groundwater in the transect monitoring wells was sampled on April 7 and July 9, 2008, during both high and low tide conditions. Monitoring well data for 2008 and for the three preceding years (2005 was a very dry year whereas 2006 and 2007 had high rainfall) are included in Appendix A, Table A2. Salinity in the Mill River adjacent to the transects during July generally remains around 0.1 parts per thousand (ppt), but in 2008 it reached 0.3-0.4 ppt in MR-N during the April sampling period. The unusually high ground water salinity of 0.4 ppt was measured in April 2008 (low tide) in the monitoring well number 3 at site MR-N. Salinity of 0.3 ppt was recorded in the same well on the same date at high tide. All other ground water measurements remained at 0.1-0.2 ppt. In previous years, peak soil-water salinity measurements reached 0.4-0.5 ppt in 2001 and as high as 0.7 ppt in 2002. In late summer low freshwater flow conditions, surface salinities in the adjacent river can reach 11 ppt or greater. These higher salinities are generally due to seasonal low flows that are unlikely to inundate the marsh, and they therefore have little or no effect on soil water

salinities. Throughout the study, however, soil-water salinity has remained below 0.5 ppt as an annual average, considered the limit of tolerance for freshwater marsh plants.

2008 Vegetation Monitoring Results

Vegetation monitoring results in 2008, along with those obtained during the baseline years, are summarized in the tables below. Table 1 shows the total number of species and total percent cover measured on each transect during the ten years of sampling. Percent cover is the percentage of all points sampled at which a species occurred. Total percent cover, obtained by adding the percent cover for all species, is generally more than 100 percent, because several species are encountered at a single sampling point. Table 1 also shows growing-season precipitation conditions. For purposes of this table, rainfall more than 2 inches below the long-term growing-season average of 23 inches was considered "low," 21-25 inches "normal," and above 25 inches "high." Since the time of sampling could also affect species distribution, the approximate sampling dates are also included in the table.

Table 1
Mill River Freshwater Tidal Marsh
Total Cover and Number of Species on Each Transect, 1998-2008

Year	Sampling date	Growing-season Rainfall (Apr.-Sept.)	Transect MR-N			Transect MR-S		
			Total Cover		Total # spp.	Total Cover		Total # spp.
			Percent	Rank		Percent	Rank	
1998	9/21	26.18" - high	215.6	10	31	228.3	10	23
2000	8/18	27.99" - high	259.4	9	29	244.2	9	17
2001	9/24	20.25" - low	359.4	2	40	258.3	7	27
2002	9/24	24.15" - average	315.0	4	28	279.0	6	23
2003	9/25	27.58" - high	290.0	8	31	256.7	8	21
2004	9/7	24.29" - average	366.7	1	26	338.3	2	17
2005	9/20	16.79" - low	348.3	3	32	359.2	1	27
2006	9/18-19	29.50" - high	314.4	5	32	291.6	5	35
2007	9/19-20	22.51" - average	306.1	6	33	322.5	3	25
2008	9/8-9	34.89" – high	300.5	7	36	299.2	4	31

Changes in cover by selected plant species over the past decade are shown in Table 2 for site MR-N and Table 3 for site MR-S. These tables indicate the dominant species of the herb and shrub strata in 2008. Dominants are those species that collectively make up more than half the total percent cover for that stratum of the community. Percent cover by several other common species that may have been dominant or subdominant in past years' samples are also included in these tables.

Table 2[1]
Percent Cover of Principal Species – Transect MR-N

Species (* dominant in 2008)	Year (Growing Season Precipitation)								
	2008 (high)	2007 (avg.)	2006 (high)	2005 (low)	2004 (avg.)	2003 (high)	2002 (avg.)	2001 (low)	2000 (high)
HERBS									
**Typha angustifolia*	46.7	50.0	51.7	57.2	46.7	44.4	47.2	51.7	46.7
**Lythrum salicaria*	28.3	35.6	31.7	31.7	30.6	15.6	20.6	17.2	17.8
**Impatiens capensis*	55.6	33.9	10.6	34.4	66.7	40.6	45.0	42.8	23.3
Thelypteris palustris	13.9	15.6	12.2	20.0	14.4	16.7	13.3	17.8	11.1
Leersia oryzoides	1.7	13.3	21.7	30.6	22.2	11.1	8.9	11.7	3.3
**Polygonum sagittatum*	17.2	12.8	6.7	13.9	20.0	1.7	0.0	10.6	0.0
Polygonum hydropiper	2.2	10.6	3.3	4.4	12.2	3.9	3.9	4.4	0.0
Onoclea sensibilis	8.3	10.0	11.1	8.9	6.1	8.3	5.6	7.2	7.2
Cuscuta gronovii	4.4	7.6	0.0	4.4	8.9	5.0	1.1	3.9	0.0
Bohemeria cylindrica	7.8	6.1	9.4	6.1	15.6	6.7	5.6	10.6	5.0
Pilea pumila	1.7	5.8	1.7	1.1	5.0	0.0	0.0	0.0	0.0
Peltandra viginica	5.0	5.0	4.4	6.7	7.2	6.1	2.8	3.9	3.3
Mikania scandens	6.7	4.4	47.8	24.4	15.6	30.6	48.3	28.9	21.7
Polygonum arifolium	5.0	1.7	6.1	2.8	2.2	2.2	0.6	2.8	3.3
Bidens connata	0.6	0.6	2.8	6.7	0.0	0.0	0.0	0.0	0.0
SHRUBS									
**Cornus amomum*	52.2	45.6	41.7	37.8	46.1	40.6	45.6	37.8	47.2
Hibiscus moscheutos	5.6	8.9	10.6	9.4	6.1	7.8	5.0	5.0	5.0
Viburnum dentatum	5.6	7.2	11.7	14.4	8.3	20.0	20.0	25.6	17.8
Cephlanthus occidentalis	1.7	2.8	2.8	3.3	0.0	5.6	2.8	5.0	3.3

[1] 1998 Data has been omitted from Table 2 and Table 3 due to lack of space. All data is included in the tables in the Appendices

Table 3
Percent Cover of Principal Species – Transect MR-S

Species (* dominant in 2008)	Year (Growing Season Precipitation)								
	2008 (high)	2007 (avg.)	2006 (high)	2005 (low)	2004 (avg.)	2003 (high)	2002 (avg.)	2001 (low)	2000 (high)
HERBS									
**Impatiens capensis*	57.5	64.2	21.7	48.3	74.2	56.7	69.2	42.5	42.5
**Typha angustifolia*	63.3	55.8	61.7	76.7	83.3	75.0	81.7	80.0	78.3
Pilea pumila	10.8	17.5	9.2	9.2	14.2	0.0	0.0	0.0	0.0
Polygonum arifolium	6.7	17.5	6.7	15.8	21.7	12.5	0.0	8.3	0.0
**Polygonum sagittatum*	28.3	17.5	0.8	11.7	12.5	5.8	2.5	2.5	4.2
**Lythrum salicaria*	15.0	16.7	20.8	23.3	11.7	14.2	10.8	15.8	6.7
Cuscuta gronovii	0.0	16.7	0.0	11.7	2.5	0.0	4.2	8.3	0.0
Peltandra viginica	6.7	15.0	11.7	10.0	13.3	12.5	8.3	8.3	10.8
Leersia oryzoides	9.2	11.7	9.2	2.5	0.0	2.5	0.8	2.5	8.3
**Mikania scandens*	25.0	10.0	50.0	45.8	33.3	21.7	31.7	28.3	35.8
Bohemeria cylindrica	9.2	9.2	5.8	10.0	13.3	6.7	5.8	5.8	5.8
Apios americana	4.2	2.5	5.0	1.7	0.0	0.0	0.0	0.8	0.8
Polygonum hydropiper	0.8	1.5	5.0	0.8	0.0	0.0	0.0	0.0	0.0
SHRUBS									
**Viburnum dentatum*	12.5	18.3	20.8	15.0	11.7	12.5	11.7	10.0	14.2
Cornus amomum	5.8	10.0	10.8	12.5	12.5	9.2	5.0	8.3	8.3
Lindera benzoin	0.8	4.2	5.0	5.8	5.8	4.2	4.2	4.2	7.5
Hibiscus moscheutos	1.7	1.7	2.5	5.0	6.7	3.3	5.0	4.2	4.2

Complete vegetation monitoring results for 2008 are presented in Appendix B, along with a description of the plant communities on each transect. Appendix tables N (MR-N transect) and S (MR-S transect) show the data collected on the north and south transects, respectively. These tables illustrate the zonation in the marshes, providing a profile of the two marsh areas. The marshes are subdivided into zones based on topography and vegetation, as described in the vegetation report in the *Lake Whitney Water Treatment Plant Environmental Evaluation: Volume Two* (Rogers 1999).

Percent cover of all species encountered on the transects during 2008 and the nine previous years of sampling is included in Appendix C. For each transect, this information is arranged both in decreasing order of percent cover in 2008 and alphabetically by scientific name. Since the Whitney treatment plant went online in April 2005, monitoring for the years 1998 and 2000-2004 provides an extended period of baseline data.

The large decrease in the climbing composite *Mikania scandens* observed in 2007 persisted during 2008 at MR-N. This annual vine, generally found clambering over narrow-leaved cattails (*Typha angustifolia*) in the marshes, reached a near-peak in 2006, but in 2007 it fell to the lowest percent cover that has been observed during the study, less than a fifth of its previous year cover (see Tables 2 and 3). Although there was a slight increase in 2008 at MR-N, it remains in very low numbers when compared to previous years. At MR-S, it has rebounded somewhat from last year and at 25 percent cover is close to what had been observed in past years. This plant is closely associated with the cattails. At MR-N, cattail cover of 46.7 percent was near the average for the study. During 2007, the cattail cover of 55.8 percent at MR-S was the lowest yet observed in this study. Cattail cover at MR-S increased somewhat during the 2008 monitoring and was tallied at 63.3 percent.

Also notable was the continued dominance in cover by spotted jewelweed (*Impatiens capensis*) at both sites. Percent cover was slightly lower at both sites compared to the highest levels of 2007, but the species was well within the range previously observed. This annual is extremely variable from year to year at all the sites we have studied. The parasitic vine dodder (*Cuscuta gronovii*), which favors the succulent jewelweed as a host plant, showed a marked decrease in cover compared with 2007. At MR-S, it did not appear at any of the sample points. Perhaps the high rainfall during the growing season created conditions unfavorable to this parasitic species.

At transect MR-N, none of the species was outside the range observed during the baseline period (see Table 2). Purple loosestrife (*Lythrum salicaria*), which has shown a steady increase at this site from its 1998 cover of 7.2 percent to its 35.6 percent cover in 2007, showed a decline this year to 28.3 percent.

At transect MR-S, percent cover of two of the species exceeded the range observed during the baseline period (see Table 3). These included arrow-leaved tearthumb (*Polygonum sagittatum*), a climbing vine armed with dense prickles and rice-cut grass (*Leersia oryzoides*). Purple loosestrife cover in 2008 decreased from that in the previous three years (see Table 3).

Shrub cover at MR-N has shown steady increase since the study was initiated, in particular silky dogwood (*Cornus amomum*), which showed its highest percent cover on record in 2008. At both sites, northern arrowwood (*Viburnum dentatum*), remained within the previously observed range. However, swamp rosemallow (*Hibiscus moscheutos*) at site MR-S has decreased in cover over the past few years, from 6.7 percent in 2004 to a low of 1.7 percent in both 2007 and 2008. It also showed a decline at MR-N where its percent cover was 5.6 in 2008, down from 8.9 in 2007 and 10.6 in 2006.

Discussion

Species Diversity and Total Plant Cover

Figures 1 and 2, and Tables 1, 2, and 3 illustrate the variability in the structure of the marsh communities from year to year. The total number of species in a plant community is an indication of its structure and complexity. A complex, diverse plant community generally is a richer wildlife habitat than an area with fewer species because the complex community can fill more of the requirements of a variety of animal species. The same is true for other functional values of wetlands such as groundwater retention, water quality effects, soil stabilization, etc. As shown in Table 1, the transect at MR-N, the more complex of our two marsh sites, has yielded 26 to 40 plant species in 1998-2008; 36 species sampled in 2008 is near the top of this range. At MR-S, the number of species from 1998 through 2005 ranged from 17 to 27, but in 2006, the number of species reached 35. This increase was largely due to the presence on the transect of just one or two individuals of several species that constitute a very minor part of the overall community. It is likely that this was simply a statistical anomaly that does not indicate any long-term trend. The 31 species observed in 2008 was within the upper middle range.

Figure 1 - Lower Mill River Marsh Vegetation Survey - North Transect (MRN)

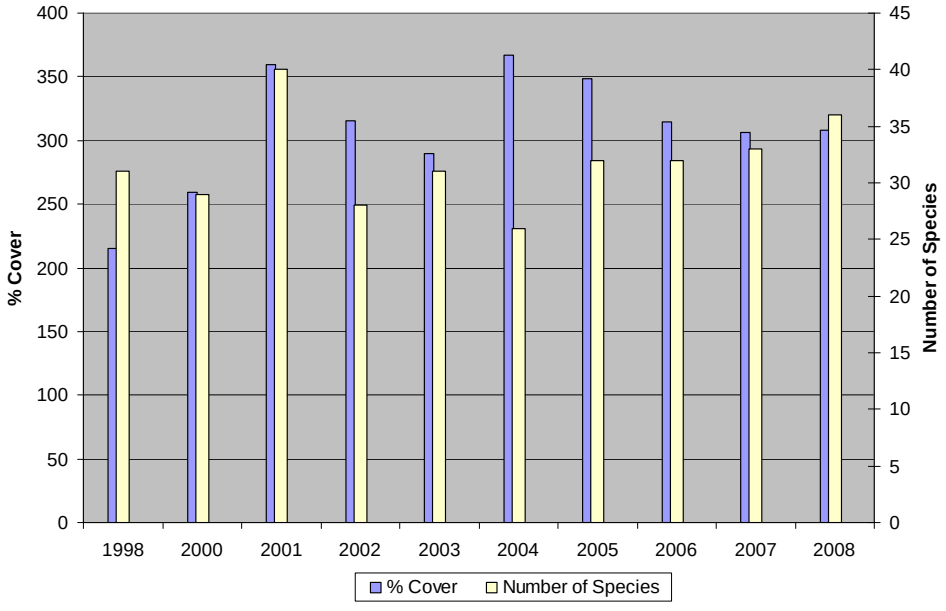
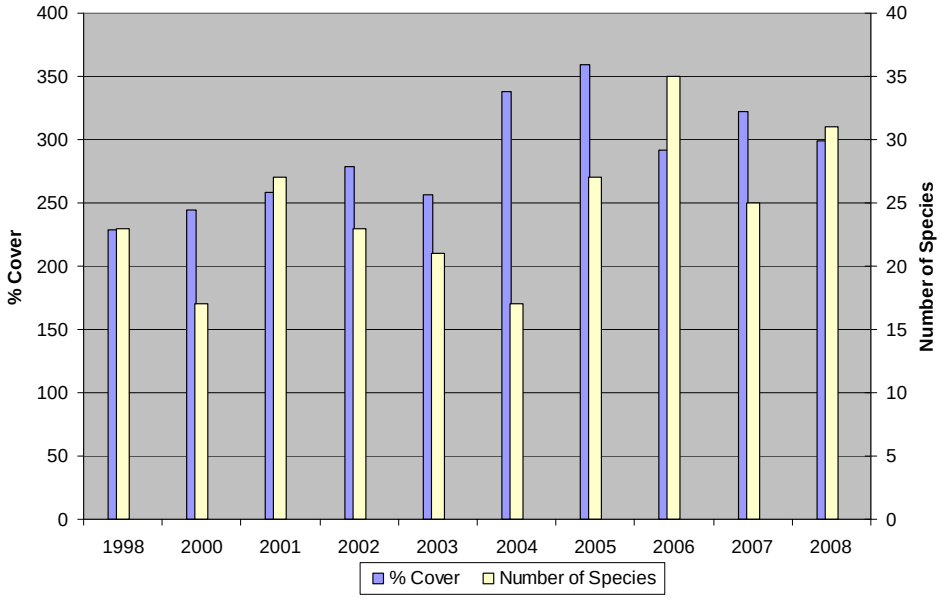


Figure 2 - Lower Mill River Vegetation Survey - South Transect (MRS)



Total plant cover is another indicator of complexity and overall health in a plant community since it reflects the presence of multiple species at each sampling point. Cover by each individual species is the percentage of total sampling points along the transect at which the species is found. These typically sum to more than 100 percent cover because several species are usually found at a sampling point. As Table 1 shows, total cover was generally highest in years of low to normal rainfall and lower in the years when growing-season precipitation was above normal. However, 2006, the wettest year, was anomalous in having both higher cover and greater species diversity than are typical in a year of high rainfall. Generally, diversity and cover are higher in relatively dry growing season because species that prefer dryer conditions can move deeper into the marsh while more hydric species persevere in the wettest areas. In 2008, cover and diversity at both transects were typical of what would be expected in a season of above average precipitation.

Herbaceous and Shrub Cover

The upper and middle marsh communities at both of the Mill River marsh sites are mosaics of herbaceous emergent marsh species intermixed with shrub thickets; intermittently submerged herbaceous species are dominant in the lower marsh zone which is more frequently inundated by tides. Shrubs tend to occur in drier portions of the marsh that are rarely flooded. The wetter parts of the Mill River marsh are dominated by narrow-leaved cattails (*Typha angustifolia*), but include a mixture of many other herbaceous species. The principal thicket-forming shrub species are silky dogwood (*Cornus amomum*) and northern arrowwood (*Viburnum dentatum*). Because the shrub areas support very little species diversity, a long-term increase in shrub areas at the expense of herbaceous area could indicate not only that the marsh is becoming drier, but that its complexity and diversity are reduced.

In the Mill River marshes, cattail cover at both sites has decreased over the past few years. At MR-N (Table 2), cattails in 2007 remained within the range observed during the baseline period before the water treatment plant was placed in service. At MR-S (Table 3), however, cattail cover reached new lows in both 2006 and 2007. There was an increase in cattail cover during 2008, but cover remains slightly below the baseline levels. Future changes should be evaluated carefully as there may be a long-term decline in cattails in this part of the marsh. Slightly higher marsh elevation at MR-N and the fact that the cattail community is less well established may have contributed to the different effects on the two marsh communities.

Cover by Introduced Wetland Species

Invasion by non-native species has become a serious problem in some wetland areas. Two of the most widespread invasive species are the tall reed *Phragmites australis* and the showy perennial, purple loosestrife (*Lythrum salicaria*). These species can spread extensively in a marsh community, especially one that has been disturbed or stressed, replacing most of the native vegetation. This produces a much less complex and varied marsh that is unable to support diverse wildlife.

Purple loosestrife has show a long-term increase at both sites. At MR-N, this species had an initial baseline cover of 7.2 percent in 1998 and reached a high of 35.6 percent in 2007. Fortunately, its percent cover this year was reduced to 28.3 percent. At MR-S, loosestrife cover was 0.8 percent in 1998 and reached a peak of 23.3 percent in 2005. During the next two years, it declined to 16.7 percent and declined further in 2008 to 15.0 percent. The trend of increasing loosestrife cover was evident during the baseline period (1998-2004) and does not appear to have accelerated since the water treatment plant was placed in service.

No common reed (*Phragmites australis*) occurs on the Mill River transects. There are isolated patches of this species within the marsh, primarily where dredging, draining, or pollution by storm sewer outfalls has occurred. We have found no evidence that these areas are expanding following annual qualitative surveys of the patches.

Conclusions

There is some evidence from several years of vegetation sampling that freshwater tidal marshes in the lower Mill River are undergoing gradual changes. The gradual invasion by purple loosestrife, the increase in shrub cover, and the decrease in cattail cover at site MR-S could eventually result in an overall loss of diversity and wildlife habitat value of these marshes. Since the Whitney water treatment plant has only been in operation since 2005 and the changes in the plant communities have been occurring at least since 1998, these changes do not appear to indicate environmental impacts due to treatment plant operation. This is further supported by the fact that downstream flows have not been seriously affected and average groundwater salinities remain well below 0.5 ppt. It is possible that future operations could play a role in accelerating changes in marsh plant communities, so continued monitoring is needed to ensure that withdrawal management and mitigation measures are adequate and effective.

Mill River Freshwater Tidal Marshes

Appendices

Appendix A: Precipitation and Salinity in the Mill River Marshes

Table A1: Lake Whitney Precipitation, 1998 - 2008

Table A2: Groundwater Monitoring Well Data, 2004-2008

Appendix B: Transect Descriptions and 2008 Vegetation Monitoring Results

1. **MR-N Transect**

   Table N: Mill River Freshwater Tidal Marsh Vegetation, North Site (MR-N) – Frequency by Species and Zone: 2008

2. **MR-S Transect**

   Table S: Mill River Freshwater Tidal Marsh Vegetation, South Site (MR-S) – Frequency by Species and Zone: 2008

Appendix C: Vegetation Sampling Data, 1998 - 2008

1. **MR-N Transect**

   List of Species by Percent Cover in 2008

   Alphabetical List of Species and Percent Cover

2. **MR-S Transect**

   List of Species by Percent Cover in 2008

   Alphabetical List of Species and Percent Cover

Appendix A
Precipitation and Salinity in the Mill River Marshes

Table A1
Lake Whitney Precipitation, 1998-2008

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	G.S.*
1998	5.00	4.69	5.59	3.98	5.51	8.30	1.11	4.92	2.36	3.23	1.81	0.95	47.45	26.18
1999	6.85	4.76	3.90	1.50	2.75	0.32	1.22	3.42	7.05	3.86	2.91	2.41	40.95	16.26
2000	2.44	1.89	4.14	4.68	3.31	5.95	7.04	2.72	4.29	0.44	4.45	2.41	43.76	27.99
2001	1.62	2.05	7.29	1.53	5.32	4.26	2.87	3.43	2.84	1.18	1.03	2.18	35.60	20.25
2002	1.67	1.27	4.09	3.45	5.56	3.35	1.90	3.16	6.73	4.20	4.15	4.06	43.59	24.15
2003	1.47	2.48	4.13	2.92	4.11	6.57	1.57	5.47	6.94	5.36	2.18	3.62	46.82	27.58
2004	1.38	2.09	3.08	5.77	2.69	0.88	2.95	4.52	7.48	1.97	3.19	3.27	39.27	24.29
2005	3.61	2.31	3.16	6.14	1.31	2.68	2.83	1.35	2.48	14.03	3.90	4.25	48.05	16.79
2006	5.70	2.42	0.55	6.46	6.35	5.87	3.54	5.08	2.20	6.58	4.73	2.88	52.36	29.50
2007	3.64	1.28	5.71	10.17	1.47	3.39	3.54	2.36	1.58	3.80	2.00	N/A	N/A	22.51
2008	2.44	11.16	7.23	6.06	3.67	4.23	3.98	5.89	11.06	3.67	4.58	8.02	71.99	34.89
10-yr Aver.	***3.08***	***3.17***	***4.33***	***4.87***	***3.65***	***3.75***	***3.14***	***3.74***	***5.27***	***4.51***	***3.32***	***3.99***	***46.82***	***24.42***
95-yr Aver.	**3.63**	**3.30**	**4.37**	**4.24**	**3.93**	**3.60**	**3.62**	**3.97**	**3.78**	**3.72**	**4.02**	**4.03**	**46.21**	**23.14**

***** Growing season precipitation, April through September.

Table A2
Groundwater Monitoring Well Data, 2005-2008

	2005				2006				2007			
	4/8/05 (high flow)		7/21/05 (low flow)		4/27/06 (high flow)		7/12/06 (low flow)		5/11/07 (high flow)		7/12/07 (low flow)	
Monitor well	**Low tide**	**High tide**	**Low tide**	**High tide**	**Low tide**	**High tide**	**Low tide**	**High tide**	**Low tide**	**High tide**	**Low tide**	**High tide**
MRN-1	0.2	0.2	0.2	0.1	0.2	0.2	0.1	0.1	0.2	0.2	0.1	0.1
MRN-2	0.1	0.1	0.2	0.2	0.1	0.2	0.2	0.2	0.1	0.1	0.2	0.2
MRN-3	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1
River@ MR-N	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1
MRS-1	0.1	0.1	0.1	0.2	0.1	0.1	0.2	0.2	0.2	0.1	0.1	0.1
MRS-2	0.1	0.1	0.2	0.2	0.1	0.1	0.2	0.2	0.1	0.1	0.2	0.1
MRS-3	0.1	0.1	0.3	0.1	0.1	0.4	0.2	0.1	0.2	0.1	0.4	0.4
River@ MR-S	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.3

Table A2, cont.
Groundwater Monitoring Well Data, 2005-2008

	2008			
	4/7/08 (high flow)		7/9/08 (low flow)	
Monitor well	**Low tide**	**High tide**	**Low tide**	**High tide**
MRN-1	0.1	0.1	0.1	0.1
MRN-2	0.1	0.1	0.2	0.2
MRN-3	0.4	0.3	0.2	0.2
River@ MR-N	0.1	0.1	0.1	0.1
MRS-1	0.1	0.1	0.1	0.1
MRS-2	0.1	0.1	0.1	0.2
MRS-3	0.2	0.1	0.2	0.2
River@ MR-S	0.1	0.1	0.1	0.1

Appendix B
Transect Descriptions and 2008 Vegetation Monitoring Results

MR-N Transect

The upstream or northern transect, MR-N, is about 2,000 feet below the Whitney dam, just south of the East Rock Park footbridge and about 700 feet north of the East Rock Road bridge. This transect passes through one of the largest and most varied parts of the marsh. As surveyed, the transect is about 100 meters long; approximately 75 meters of this length passes through high marsh, a mosaic of shrubs and emergent marsh (primarily cattails), which is seasonally or occasionally flooded but not subject to daily tidal inundations. About 25 meters of low marsh bordering the river is alternately flooded and exposed as a result of daily tidal fluctuations in the river; portions of the low marsh are often inaccessible due to flooding by tidal action or high river flows. On transect MR-N, sampling begins at the second stake, since the stake at the origin of the transect is located within a swale with little vegetation other than canopy trees overhanging from the adjacent upland forest. A total of 18 stakes are sampled, for a total of 18 chains and 180 sampling points; two additional stakes were installed and surveyed on the riverward end of this transect but are typically inundated and have not been accessible for sampling.

As shown in Table N, the upper marsh on transect MR-N is dominated by spotted jewelweed (*Impatiens capensis*), which gradually gives way to narrow-leaved cattail (*Typha angustifolia*), an emergent marsh plant tolerant of relatively high salinities. Cattail dominates the middle marsh, often in some years with the annual composite, climbing hemp (*Mikania scandens*). The transect then passes through a broad area where emergent marsh intermingles with shrub thickets, apparently depending on small changes in elevation; this area appears in Table N as three zones, "Shrub thicket," "Shrub/marsh" (the lowest area), and "Dogwood thicket." In the higher areas of this complex, silky dogwood (*Cornus amomum*) dominates, intermixed with several herbaceous species, including cattail, climbing hemp, jewelweed, clearweed (*Pilea pumila*), and goldenrod (*Solidago gigantea*). Swamp rosemallow (*Hibiscus moscheutos*) is also among the shrubs in this area. In the lower swale, northern arrowwood (*Viburnum dentatum* var. *recognitum*) is the dominant shrub; buttonbush (*Cephlanthus occidentalis*), a shrub highly tolerant of periodic inundation, appears in the lowest and wettest areas. Cattails (*T. angustifolia*) are absent in the low shrub/marsh, and jewelweed (*I. capensis*) is the dominant herbaceous species. As the ground rises slightly on the riverward side, there is a dense thicket of silky dogwood (*C. amomum*), again intermixed with cattails as well as jewelweed. Below this rise, the substrate descends fairly rapidly toward the river. Silky dogwood is still common on higher ground, but cattails disappear in the low marsh, which is subject to frequent tidal inundation. *Mikania scandens*, purple loosestrife (*Lythrum salicaria*), and jewelweed occur among the dogwood, but give way to arrow arum (*Peltandra virginiana*), and then (beyond stake 18) to other species tolerant of regular submersion, including arrowhead (*Sagittaria* sp.), pickerel weed (*Pontederia* sp.), and white waterlily (*Nymphaea odorata*).

Link to Table N: Mill River Freshwater Tidal Marsh Vegetation, North Site (MR-N) – Frequency by Species and Zone: 2008:
http://whitneydigs.com/Enviro/Reports/Vegetation_2008_Supplements/Supplemental_Table_N.pdf

MR-S Transect

The downstream transect, MR-S, passes through a narrower and less varied marsh community about 300 feet south of the East Rock Road bridge. This transect is about 55 meters long from upland edge to river. The high marsh, about 45 meters wide, consists primarily of cattail marsh, with shrub thickets on elevated hummocks. The remaining 10 meters of the transect is in low marsh bordering the river. For transect MR-S, sampling begins at the origin of the permanent transect (stake 1) and extends through stake 12, for a total of 12 chains and 120 sampling points.

As shown in Table S, sampling at site MR-S, begins in an area of transition between upland forest and marsh, dominated by spicebush (*Lindera benzoin*), silky dogwood (*Cornus amomum*), and multiflora rose (*Rosa multiflora*); jewelweed is the dominant herb. In the upper marsh, narrow-leaved cattail (*Typha angustifolia*) and jewelweed (*Impatiens capensis*) are dominant, while in the middle marsh, jewelweed becomes less common and cattails share dominance with climbing hemp (*Mikania scandens*), although in 2007 and 2008 the climbing hemp was reduced in overall coverage. The transect then crosses a small rise or hummock, where a few shrubs such as swamp rosemallow (*Hibiscus moscheutos*) intermix with the cattail community. Beyond this is low marsh, where cattails and jewelweed are replaced by arrow arum. The last sampling chain crosses part of a small levee adjacent to the river, where a large silver maple (*Acer saccharinum*) and other upland species occur.

Link to Table S: Mill River Freshwater Tidal Marsh Vegetation, South Site (MR-S) – Frequency by Species and Zone: 2007:
http://whitneydigs.com/Enviro/Reports/Vegetation_2008_Supplements/Supplemental_Table_S.pdf

Appendix C

Mill River Freshwater Tidal Marshes: Vegetation Sampling Data 1998-2008

Link to MR-N Transect Lists of Species & Percent Cover in 2008 (Alphabetical and by Percent Cover):
http://whitneydigs.com/Enviro/Reports/Vegetation_2008_Supplements/Supplemental_Table_MR-N.pdf

Link to MR-S Transect Lists of Species & Percent Cover in 2008 (Alphabetical and by Percent Cover):
http://whitneydigs.com/Enviro/Reports/Vegetation_2008_Supplements/Supplemental_Table_MR-S.pdf