Level I Water Quality Inventory – Minute Man NHP

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Executive Summary

In association with the Baseline Water Quality Data Inventory and Analysis Program of the NPS-Water Resources Division we conducted a Level I water quality inventory for Minute Man NHP (MIMA). The goal was to sample water quality parameters for key water bodies within park boundaries, identify key water resource management issues at each park and recommend appropriate long-term monitoring strategies.

There are continuing water quality concerns in the Park that may affect the water resources therein. The primary concern is the possibility of nutrient loading to critical wetland habitats by adjacent residential and industrial activities. In addition, there are small agricultural operations that may have localized effects on critical habitat from fertilizer runoff, pesticide runoff, and alteration of land cover.

During 1999, a forty-year drought severely limited surface water flow and standing water levels. Watershed levels for the entire catch basin were reduced and discharge rates on the Concord River during the mid summer reached 0.16 m^3 sec^{-1}, representing the second lowest reading in 17 years. One of the intermittent streams had no water in them for the entire sampling period and the Mill Brook was dry from June to August. The minimal freshwater inputs probably had a significant effect on water quality during the summer. This effect, which cannot be quantified in a four-season study, should be kept in mind.

The water quality of all water bodies is moderate but reveals a vulnerability of both wetlands (MIMA-4 and MIMA-5) to increased nutrient loading. Although nutrient loading levels are presently mesotrophic, the shallowness of these water bodies make them susceptible to further changes in watershed loading due to changes in adjacent land use. Such increases in nutrient watershed loading can lead to water quality degradation.

Because of these concerns, we would recommend periodic monitoring of critical water quality parameters to track changes in environmental conditions. A minimum effort would consist of sampling in the early spring and late summer for bottom dissolved oxygen, pH and dissolved nutrients at MIMA-4. MIMA-4 is a wetland in the interior of the park and is representative of a more critical and unimpacted wetland habitat. MIMA-5 is

a wetland that may be significantly affected by the adjacent park residence, groundwater input from Hanscom and road runoff. These parameters would not give a comprehensive survey of the ecological condition of both palustrine water bodies. Instead it would serve as an early warning system that would alert Park resource managers to a sudden change in trophic level or a degradation of water quality.

Introduction

Minute Man NHP (MIMA) is a historic corridor park comprised of two main units in Concord, Lincoln and Lexington Massachusetts located 8 km from Boston. The North Bridge unit contains the Park headquarters and is on either side of the Concord River centered on the Old North Bridge. The Battle Road Unit runs along either side of Route 2a and follows the old Revolutionary War retreat path. A third small unit (the Wayside Unit) was not considered for this study. The approximate dimensions of the park are 9.6 km by 0.8 – 2.4 km (See Figure 1).

Water resources, except for the Concord River, are composed of numerous forested, shrubby and herbaceous wetlands, and several small brooks. The associated habitat was described in Thompson and Jenkins (1992). The dominant wetlands by area consist of red maple swamps with a highbush blueberry shrub layer. Two of the Level I sites typify this habitat type. The three other significant wetland habitats consist of:

1. narrow-leaved emergent marsh, dominated by blue joint (*Calamagrostis canadensis*),
2. shrub swamp wetland, dominated by silky dogwood (*Cornus amomum*) and speckled alder (*Alnus rugosa*) and the
3. robust emergent marsh dominated by broad-leaved cattail (*Typha latifolia*).

At least one of the sample sites is an emergent marsh – shrub swamp complex. The Concord River basin is dominated by riverine buttonbush dominated wetlands successively invaded by purple loosestrife.

The entire Park falls within the Boston Area Bedrock Formation as described in Godfrey et al 1996. Bedrock in this area is composed of gneiss, schist and granite with sedimentary rocks like sand and siltstone. The immediate area is rolling coastal plain with stony glacial tills and glacial sands and gravels (Thompson and Jenkins 1992). These deposits result in relative large-grained soil deposits that allow rapid groundwater transport.

In association with the Baseline Water Quality Data Inventory and Analysis Program of the NPS-Water Resources Division has assembled existing water quality data sets in most Park Units. MIMA was found to have depauperate water quality databases' thereby requiring Level I water quality inventories. As defined by the NPS Inventory and Monitoring Program, a Level I water

quality inventory includes sampling basic water quality parameters for key water bodies within park boundaries. Key water bodies are either those essential to the cultural, historical or natural resources management themes of the park or those that provide habitat for rare plants or animals.

The purpose of this study is to collect water quality data at MIMA to meet the Level I needs. Moreover, this study identified key water quality management issues at each park, recommending appropriate long-term water quality monitoring strategies.

Water resource issues

The primary water quality concern is the possibility of nutrient loading to critical wetland habitats by adjacent residential and industrial activities. Concord and Lexington are moderate to high-density municipalities whose communities can be expected to contribute significant amounts of nutrients to the ground water from municipal and individual septic systems and road runoff. Concord, the population center closest to the sample sites, has about seventy percent of their households on individual septic systems. Forty percent of these septic systems are older than 20 years, increasing the likelihood of their disproportionate contribution to watershed nutrient loading (Concord DPW 2000). Lincoln is a low-density municipality with minimum housing lot sizes. Land use activities peculiar to these developments (such as landscaping and lawn maintenance) can also contribute significant levels of nutrients to the ground water. Lincoln is also the location of the Hanscom Air Force Base and Hanscom Air Field (a civil air field) and a number of streams drain these complexes and may contribute significant contaminants. Finally, there are small agricultural operations that may have localized effects on critical habitat from fertilizer runoff, pesticide use, and alteration of land cover. Overall, nitrogen loading to the Concord River watershed was estimated in 1993 at 4.5 mg/l (GEC 1994).

Sample locations

Minute Man NHP is located near Boston, in a highly developed residential and industrial watershed. Six sites were chosen: 1) the Concord River - MIMA-1, 2) Mill Brook - MIMA-2, 3) Elm Brook - MIMA-3, 4) a palustrine wetland associated with the Elm Brook watershed – MIMA-4, 5) an un-named brook flowing from Hanscom Air Force Base – MIMA-5 and

6) an un-named pond fed by streams flowing from Hanscom (see Figure 1). A seventh site, Folly Pond, has been monitored in the past because of historic activities at this site. Past monitoring at this site revealed no contamination in surface waters and obviates the need for including this site in the present study. 1999 was the year of a 40-year drought, water tables throughout the park were reduced. The un-named brook, and other brooks of similar nature in the park, dried up in 1999. Because several target sites did not contain water in 1999, only following five sites were tested:

Concord River at Old North Bridge -- The North Bridge Unit of MIMA is located on the Concord River. Immediately upstream of the park, the Concord River is formed at the confluence of the Sudbury and Assabet Rivers. USGS gauging stations are located on the Sudbury River, several kilometers upstream of the North Bridge before its confluence with the Assabet/Concord, and many kilometers downstream on the Concord River in Lowell (near its' discharge to the Merrimack River). Land use within the Sudbury, Assabet, and upper Concord River watersheds is highly residential/suburban. The Concord River displayed concentrations that exceeded the EPA level of concern for dissolved oxygen, pH and dissolved copper (NPS Water Resources Division 1996).

Mill Brook -- Mill Brook flows through the Battle Road Unit, is associated with the Concord River basin, and a portion of the Mill Brook headwaters lie within MIMA. Sources of water quality degradation include road runoff and limited agriculture.

Elm Brook -- The headwaters of Elm Brook lie just outside the MIMA boundary. Elm Brook contains some of the parks' more extensive wetlands (mostly an emergent marsh – shrub swamp complex). Sources of water quality degradation include road runoff and limited agriculture.

Palustrine wetland -- Numerous permanent and intermittent palustrine wetlands are distributed throughout the Park. One of these wetlands, a complex of palustrine forested, palustrine scrub-shrub, palustrine emergent and palustrine open water, has been identified as an important site for monitoring, and may be representative of the water quality status of wetlands within the park. This wetland is a red maple/white cedar swamp with a shrub layer of buttonbush and high bush blueberry and various herbaceous species. It is contained within the Elm Brook sub-watershed.

Un-named pond -- This pond consists of an open basin fringed with red maple stands. The shore is cleared of vegetation on the western and southern shoreline. There is a residence for park employees next to the pond. This pond is partly fed by streams running out of Hanscom Air Force Base.

Existing water quality data

The Water Resources Division produced a water quality scoping report (USDOI 1996). The Concord River station was found to significant levels of total nitrogen and phosphorus concomitant with a river moving through a population center and probably due to the municipal wastewater plant in Concord Center. It found moderately good water quality at the stream that was nearest in hydrological characteristics to those found in the Park (Hobbs Brook, Lincoln). However, no sample sites were located in the Park. The US Geological Survey has water gauging stations in at the Concord River in Concord, MA and the Sudbury River in Saxonville, MA.

PROTOCOL

Sampling plan

The objective of this water quality-monitoring program is not to assemble a comprehensive database, but rather to obtain a baseline of environmental variables. Should degrading trends in these fundamental variables be noted, then management should implement a more comprehensive program to clearly assess the problem.

Once a season, from October 1998 to October 1999, samples were collected from all monitoring sites that contained surface water. Samples were collected in the fall (October - November 1998), winter (January - February 1999), spring (March - April 1999) and summer (July - August 1999). Parameters were sampled at Minute Man NHP as outlined in Table 1.

Table 1. Sampling parameters for each station

Station	GPS Coordinates	Sampling Parameters

Concord River (MIMA-1)	306786.4/ 4704561.6	Alkalinity, conductivity, total and dissolved nutrients, dissolved oxygen, pH, turbidity, temperature, VOC
Mill Brook (MIMA-2)	308992.8/ 4703362.1	Alkalinity, conductivity, total and dissolved nutrients, dissolved oxygen, pH, temperature, discharge
Elm Brook (MIMA-3)	310592.8/ 4702744.3	Alkalinity, conductivity, total and dissolved oxygen, pH, temperature, discharge
Palustrine wetland (MIMA-4)	310972.1/ 4702672	Alkalinity, conductivity, total and dissolved nutrients, dissolved oxygen, pH, temperature, water level
Un-named wetland (MIMA-5)	313522.2/ 4702158.4	Alkalinity, conductivity, total and dissolved nutrients, dissolved oxygen, pH, temperature, water level

Field sample collection techniques

Dissolved oxygen, pH, temperature, conductivity and turbidity was measured at all stations with a Hydrolab Mini-Sonde. Only the Concord River was deep enough to allow for surface to bottom profiles. Discrete water samples were collected at all stations 0.25 m below the surface with a Kemmerer bottle.

For alkalinity, 60-ml sample bottles were filled to overflowing, capped and placed on ice for transport to the CACO laboratory. A one-liter bottle was collected and placed on ice for transport to the CACO laboratory for the chlorophyll a samples. Triplicate 20-ml aliquots were collected in pre-cleaned test tubes and fixed with persulfate oxidizing reagent and transported to the CACO laboratory for total nitrogen and phosphorus analysis. Sixty-ml sample bottles for dissolved nutrients were filled with water filtered through 0.4-micrometer Millipore filters, preserved with 2 N hydrochloric acid and iced for transport to CACO. All samples were kept in the dark at 4^{o}C until analysis preparation was completed. Nutrient samples were not analyzed for four to six months because of mechanical and logistical problems at the CACO laboratory that has since been resolved.

Analytical techniques

Field methods: A Hydrolab that was calibrated according to manufacturers methods before each sample trip collected dissolved oxygen, pH, temperature, conductivity and turbidity. Water levels were established and monitored using the Hydrolab depth recorder.

Laboratory methods: All laboratory analyses were performed at the North Atlantic Coastal Laboratory at the Cape Cod national Seashore.

Alkalinity: Measurement was taken by potentiometric titration using bromcresol indicator (APHA 1992).

Chlorophyll a: The water samples were filtered through a Whatman GFF filter. The filter was ground up and extracted with acetone. The chlorophyll levels in the acetone extract were then measured on a spectrophotometer (Lorenzen 1966).

Dissolved nutrients: Dissolved inorganic nutrients (nitrate, nitrite, ammonia and phosphate) were determined colorimetrically on a Lachat autoanalyzer (American Public Health Association 1992; Lachat Instruments 1993,1994).

Total nitrogen and phosphorus: Total nitrogen and phosphorus were determined simultaneously by potassium persulfate digestions followed by colorimetric analysis on the Lachat autoanalyzer (Valderrama 1981).

Volatile organic compounds: VOCs were analyzed at the Barnstable County laboratory. They were measured by purge and trap, packed column Gas Chromatography-Mass Spectrophotometry (American Public Health Association 1992). Samples were collected once during the study at MIMA-1 and MIMA-3 to gauge background levels in the Concord River and to determine possible contamination from Hanscom Air Base runoff.

Data management and Archiving

All collected data was entered in the Environmental Protection Agency's national water quality database, STORET.

Results

All results were compared to the state water quality standards, the EPA standards and water body classifications associated with ambient nutrient levels. Massachusetts water quality standards (Division of Water Pollution Control, 314 CMR) are based on functional attributes of water bodies. These standards associate their water quality with the watershed in which they are contained. The Concord River, by this estimation, is a Class B Warm Water Fishery and Treated Water Supply subject to the Class B contaminant levels shown in Table 2. All wetlands within the park are designated Class B Outstanding Resource Waters and are subject to the same limits. When specific contaminants aren't mentioned, they are under the purview of EPA water quality standards. As there are no state minimum nutrient loading standards, we will employ a lake trophic classification scheme (Wetzel 1985). This will allow us to evaluate the potential for significant nutrient loading from watershed sources (see Table 1) although it would be an imperfect comparison for brook and wetland habitats.

During 1999, a forty-year drought severely limited surface water flow and standing water levels. Watershed levels for the entire catch basin were reduced and discharge rates on the Concord River during the mid summer reached 0.16 m^3 sec^{-1}, representing the second lowest reading in 17 years (USGS 2000). One of the intermittent streams had no water in them for the entire sampling period and the Mill Brook was dry from June to August. The minimal freshwater inputs probably had a significant effect on water quality during the summer. This effect, which cannot be quantified in a four-season study, should be kept in mind.

The Concord River site (MIMA-1) showed water quality parameters that fell within minimum standards for Class B Warm Water (see Table 2). The chlorophyll, total N and P levels were representative of a mesotrophic water body. These values are lower than those measured during a water survey in 1972-1973, which revealed total N levels associated with eutrophic conditions. This difference in nitrogen levels may represent the construction of the Concord Center municipal wastewater plant with a resulting reduction of nitrogenous waste input. The maximum values occurred in June when the drought may have reduced flow levels and decreased dilution of the sewage plant effluent. Total VOC measured on June 12 2000 showed levels of all

VOC species below minimum detection limits by the Barnstable County Health Laboratory.

The Mill Brook site (MIMA-2) revealed water quality parameters that fell within minimum standards for Class B Outstanding Resource Waters except for October of 1999 (see Table 2). Oxygen levels dropped to 23% and total P levels were at a maximum of 13.11 mg l^{-1}. The summer's drought was followed in October by substantial rain. This precipitation may have increased runoff of particulates and phosphorus accumulated during the drought, thus increasing oxygen demand from particulate bed load and phosphorus loading. The limited sample size precludes definitive conclusions about long-term water quality trends. However, water quality parameters at this site are likely influenced by those factors (such as precipitation, land use patterns, etc.) that affect runoff and ground water transport.

The Elm Brook site (MIMA-3) revealed water quality parameters that fell within minimum standards for Class B Outstanding Resource Waters (see Table 2). Seasonal variability of these parameters appeared to fall with natural ranges. Water quality overall seems to be good in this water body. Total VOC measured on June 12 2000 showed levels of all VOC species below minimum detection limits by the Barnstable County Health Laboratory. Again, the water quality at this site is dependent on surface water flow rates and influenced by any episodic factors that affect runoff and ground water transport.

The palustrine wetland site (MIMA-4) revealed water quality parameters that fell outside minimum standards for Class B Outstanding Resource Waters (see Table 2) in October 1998 and June 1999. Negative alkalinities are expected in these water bodies dominated by humic-rich litter on the bottom. pH and oxygen values were below Class B standards for these sample periods. Chlorophyll a was above the eutrophic level in June 1999. Total N represented the highest level shown at any of the sites for this study and could account for the chlorophyll peak observed at this time. In addition, the higher oxygen demand could result in a decreased pH. The higher conductivity and variable pH indicate the higher ionic composition (partly due to organic acids and humics) that is typical of these wetlands. A greater concern is the seasonal levels of dissolved nitrogen, implying substantial input. Although the pigment peaks may be due to nitrogen loading from the surrounding communities, it is equally likely that nutrient

regeneration from decomposing leaf litter on the floor of the wetland could account for the these observed values. The source of these nutrients cannot be pinpointed without a hydrological analysis of groundwater flow. More baseline data is needed to ascertain whether June levels are indicative of a seasonally stressed habitat or an artifact of a drought year.

The unnamed pond site (MIMA-5) revealed water quality parameters that fell outside minimum standards for Class B Outstanding Resource Waters (see Table 2) in October 1998 and June 1999. Oxygen levels fell below Class B standards for every sampling period except in January 1999. pH in October 1998 fell out of the Class B standard range as well. Chlorophyll a was consistently near or above mesotrophic classification. For the purposes of interpretation, it is necessary to note that this pond is actually a palustrine wetland. As was observed in the other wetland site (MIMA-4), the trends in oxygen, pH and chlorophyll are expected because of the high natural nutrient regeneration rates. The larger chlorophyll, oxygen demand and pH drops in this basin may be a result of a lack of the shrubby undergrowth in this basin.

It has been found that undergrowth in palustrine wetlands can reduce nutrient levels in the water column (Mann and Wetzel 2000). At MIMA-5, the absence of emergent vegetation could allow nutrient levels to accumulate and lead to phytoplankton blooms. The alternate source of elevated nutrient levels could be the septic system of the park residence adjacent to and upslope to MIMA-5. However, this sampling program was for too short a period to determine the significance of this nutrient source. Because of the potential for nutrient input from the residence as well as the state highway adjacent to the pond, this water body is vulnerable to further water quality degradation from increased watershed nutrient input.

Conclusions

The water quality of all water bodies is moderate but reveals a vulnerability of two wetlands (MIMA-4 and MIMA-5) to increased nutrient loading. Although nutrient loading levels are presently mesotrophic, the shallowness of these water bodies makes them susceptible to further changes in watershed-related nutrient loading due to changes in adjacent land use. Such increases in this source of nutrient loading can lead to water quality degradation.

Because of these concerns, we would recommend periodic monitoring of critical water quality parameters to track changes in environmental conditions. A minimum effort would consist of sampling in the early spring and late summer for bottom dissolved oxygen, pH and dissolved nutrients at MIMA-4 and MIMA-5. MIMA-4 is a wetland in the interior of the park and is representative of a more critical and unimpacted wetland habitat. MIMA-5 is a wetland that may be significantly affected by the adjacent park residence, groundwater input from Hanscom and road runoff. Unlike the other water bodies sampled, the large majority of the Concord River falls outside of park boundaries. Thus, water quality conditions outlined in this report are indicative of land use conditions outside the purview of Park managers. Because of this, water quality monitoring in the Concord River is not recommended.

These parameters would not give a comprehensive survey of the ecological condition of both palustrine water bodies (MIMA-4 and MIMA-5). Instead it would serve as an early warning system that would alert Park resource managers to a sudden change in trophic level or a degradation of water quality.

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Table 2. Minute Man Water Quality Results At Five Level 1 Sample Locations And Massachusetts Water Quality Standards

Station	Date	pH	Bottom DO (% sat.)	Bottom DO (mg l^{-1})	Surface DO (% sat.)	Surface DO (mg l^{-1})	Secchi depth (m)	Water depth (m)	Turbidity (NTU)	Discharge (m3/sec)
Concord River	October 27, 1998	6.95	74	8.28	86	9.18	1.25	2.02		
	January 1999									
	June 9, 1999	7.11	64.2	5.44	70.6	5.91	1.2	1.25	7.9	
	August 4, 1999	7.42	80.2	6.55	83.4	6.74		1.40		
	October 21, 1999	6.58	80.9	9.13	88.1	9.87	1	2.00	1.1	
Mill Brook	October 28, 1998	6.04			12.6	1.46	0.078	0.07	76.1	0.004
	January 19, 1999	6.18			11.0	75.7		0.03	10.1	0.085
	June 1999									
	August 1999									
	October 21, 1999	6.69			23.8	2.6	0.08	0.08	0.0	
Elm Brook	October 28, 1998				82.1	9.68		0.11	5.3	0.138
	January 19, 1999				98.1	13.97		0.19		0.286
	June 9, 1999				89.7	11.19		0.17	44.2	
	August 1999									
	October 21, 1999				104.8	11.92		0.04	3.6	
Palustrine wetland	October 28, 1998	4.72			25.3	3.28		0.04	4.5	
	January 19, 1999									
	June 9, 1999	5.72			16	2.07		0.24	5.72	
	August 1999									
	October 21, 1999	6.56			53.4	6.37		0.24	0.0	
Un-named pond	October 27, 1998	5.36			26.5	2.41		0.14		
	January 19, 1999	6.67			84.6	11.91		0.01		
	June 9, 1999	5.8			22.4	1.93		0.12		
	August 1999									
	October 21, 1999	6.69			53.5	5.91		0.06		
STORET data (USDOI 1996)										
Concord River basin										

Hobbs Brook, Lincoln	1969-1971	5.9		10.5						0.03
Lake trophic classification (Wetzel 1983)										
Oligotrophic										
Mesotrophic										
Eutrophic										
Class B lake, Warm water; treated water supply		6.5-8.3			60%					

Station	Date	Alkalinity ($\mu eq\ l^{-1}$)	Chlorophyll ($\mu g\ l^{-1}$)	Specific conductivity ($\mu S\ cm^{-1}$)	dissolved NO3 (μM)	Dissolved NH4 (μM)	Total N ($\mu M\ NO_3$)	Total P ($\mu M\ PO_4$)
Concord River	October 27, 1998	22.85		301	3.94	76.84	43.71	2.40
	January 1999							
	June 9, 1999	34.6	12.85	372			141.67	3.45
	August 4, 1999	31.9	1.335	465	32.62	4.39	40.30	2.94
	October 21, 1999	20	3.82	340	45.6	4.21	44.76	1.73
Mill Brook	October 28, 1998	29.05		211	2.17	26.43	34.22	6.22
	January 19, 1999	7.15		108	16.97	51.08		
	June 1999							
	August 1999							
	October 21, 1999	40.45	0.57	377	1.84	6.56	41.75	13.11
Elm Brook	October 28, 1998	21.35			25.86	2.28	25.80	1.04
	January 19, 1999	3.75			19.79	57.68		
	June 9, 1999	16.65						
	August 1999							
	October 21, 1999	8.35	2.79	2.79			25.07	1.22
Palustrine wetland	October 28, 1998	-0.95		227		16.54	53.18	
	January 19, 1999				2.18			
	June 9, 1999	-1.15	120.7	328			148.04	
	August 1999							
	October 21, 1999		1.67	239	2.18		37.67	0.61
Un-named pond	October 27, 1998	10.65	5.27	863			53.458	4.90
	January 19, 1999	0.55	4.87	457				

	June 9, 1999			2000			77.08	1.91
	August 1999							
	October 21, 1999	9.5	7.15	237	2.25	2.25	50.54	2.73
STORET data (USDOI 1996)								
Concord River	1972-1973						1330	159
Hobbs Brook, Lincoln	1969-1971	6.5				300	40	60
Lake trophic classification (Wetzel 1983)								
Oligotrophic			1.7				661	8.0
Mesotrophic			4.7				752	26.7
Eutrophic			14.3				1875	84.4
Class B lake, warm water, treated water supply								

Figure 1. Minute Man NHP Sample Locations