Organization for the Assabet River

Water Quality Monitoring Program
Final Report - Summer 2000

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Acknowledgments

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Abstract

In 2000 the Organization for the Assabet River monitored water quality in the Assabet River between June and October, continuing to build the database of water quality information, which informs OAR's advocacy for the river. Although hydrologic conditions were not as extreme as they had been in the summer of 1999, dissolved oxygen (DO) and nutrient concentrations indicative of eutrophication were again found throughout the river.

Although dissolved oxygen concentrations were generally higher than in July 1999, five sites in July 2000 still failed to meet the Massachusetts Class B water quality standard of 5.0 mg/L DO. Very high and very low dissolved oxygen concentrations, both of which damage fish habitat, were again recorded in the Ben Smith and Powdermill Impoundments. The diurnal changes in DO were largest in the surface (~1.0 ft) and shallow mid-layers (1.0 - 4.5 ft) of the two impoundments. High nutrient concentrations were measured all along the river, with the highest concentrations found in the upper reaches. Non-point sources may be significant contributors to the nutrient loads in the river at higher flows, off-setting the potential decreases in nutrient concentration from increased dilution of the point sources.

Because nutrient concentrations are so high in the Assabet, control and remediation must be approached on multiple fronts: reduce both point and non-point nutrient inputs to the river, protect baseflow, and assess sediment conditions. A fishable, swimmable Assabet River would be a valuable asset to the communities in its watershed.

Introduction

The Massachusetts Department of Environmental Protection (DEP) lists all sections of the Assabet River on the 303(d) List of Waters as failing to meet water quality standards (Class B warm water standards listed in Table 3). The river suffers primarily from eutrophication caused by excess nutrients entering the river. These excess nutrients, phosphorus in particular, fuel nuisance algal and aquatic plant growth which interfere directly with recreational use of the river and cause large daily variations in the concentration of dissolved oxygen in the water, making the river poor habitat for aquatic life. When the algae and plants decay, they generate strong sewage-like odors and lower dissolved oxygen levels in the river.

During dry weather, the majority of these nutrients come from the seven wastewater treatment plants that discharge treated effluent into the Assabet River. During wet weather, non-point sources may account for a large proportion of the nutrient load to the river. Recycling of nutrients trapped in river sediments also contribute to the river's surfeit of nutrients. Dams have altered the river's hydrology, creating large, slow moving sections where nutrient-rich sediments have accumulated over many years. Such sediment accumulations become important long-term, internal sources of pollutants, which keep cycling phosphorus into the water column and are difficult to eliminate. The river's eutrophication problem is exacerbated by low flows, providing insufficient dilution of the wastewater treatment plant effluents.

Since 1992, OAR has collected baseline water quality data documenting the overall condition of the river. The information generated by OAR's water quality program helped to raise awareness throughout the watershed about the Assabet's nutrient problem, to point to the need for stricter phosphorus limits in the waste water treatment plant's NPDES permits, to make a strong case for a Total Maximum Daily Loading (TMDL) study, and to indicate the need for a groundwater model of the upper Assabet.

The TMDL study is particularly relevant to OAR's water quality monitoring program in several ways. OAR's 2000 water quality program has provided additional data that may be used in the TMDL nutrient modeling of the river. After the TMDL recommendations for controlling nutrient loads are implemented, OAR's program will continue to monitor the overall condition of the river.

The goals of OAR's 2000 water quality monitoring program were and continue to be:

(1) Understand long-term trends in the river's condition, assess whether the river meets Massachusetts Surface Water Quality Standards for Class B waters, and assess the impact of any changes in management of point and non-point pollution sources.
(2) Provide sound scientific information to evaluate and, where appropriate, support or challenge regulatory decisions.
(3) Provide water quality data useful in modeling nutrient loadings in the Assabet River as a part of the ongoing Total Maximum Daily Loading study.
(4) Identify problem spots for further investigation by OAR or other appropriate agencies or organizations.
(5) Promote stewardship of the river by increasing the number of volunteers participating in the program and expanding public knowledge of the program and its findings.

In support of these goals, a Quality Assurance Program Plan (OAR, 2000) documenting OAR's sampling methods and quality control measures was submitted to the EPA; EPA approved OAR's QAPP in April 2000. The QAPP is currently being updated for the 2001 monitoring season. Water quality data collected under the approved QAPP may be used by EPA and DEP in making regulatory decisions and in modeling for the TMDL phase two study.

Methods

Twenty-three trained volunteers and two OAR staff members monitored water quality at 26 stations along the main stem and at one station on Nashoba Brook, the largest tributary of the Assabet (Figure 1, Table 1). Sites are designated by rivermiles above the confluence of the Assabet and Sudbury Rivers at Egg Rock in Concord. Monitoring (bottle samples, *in-situ* measurements, gage readings and observations) was performed one weekend (5:00 am - 9:00 am) each month in June, July, August, and September. In October, only *in-situ* measurements (see Table 2) were taken. Staff gages were read weekly at Cox Street, Hudson, and Damonmill, Concord. Flow and stage readings from the USGS gage at Maynard were downloaded from the USGS web page twice a week.

In 2000, there were two changes from previous years:

(1) Three nutrient sampling sites were relocated from above a dam (26.3, 25.3, 6.5 and 4.7) to app. 100 ft. below the same dam (26.2, 25.2, 6.3, and 4.4) for safer access to the river and to ensure that samples are taken from well-mixed sections of the river.

(2) Depth profiles of *in-situ* parameters (Table 2) were measured in four impounded sections of the river. Sites 26.3 and 25.3 are in small impoundments behind the Sawmill dam at Route 20, Northborough, and the Woodside dam at Allen Street, Northborough, respectively. Both 26.3 and 25.3 were sampled at single locations on Saturday morning of the sampling weekend. Sites 8.8 and 6.7 are in the larger impoundments behind the Ben Smith dam near Rte 117, Maynard, and the Powdermill dam at Old High Street, Acton, respectively. Both 8.8 and 6.7 were sampled using the YSI meters from a canoe. *In-situ* readings were taken at multiple depths at five sites within each impoundment on Sunday morning of the sampling weekend. The sites chosen within the impoundments (Figures 2 and 3) are representative of their various conditions: open water/channel, embayment or backwater, among rooted aquatic plants, under duckweed cover (or where the duckweed is likely to accumulate). Afternoon profiles were taken in August in the Ben Smith and Powdermill Impoundments, to assess diurnal variation.

Table 1: OAR Sampling Sites - Summer 2000

OAR Site #	OAR Site Description	Water Quality Data Collected		
		YSI readings[a]	Bottle Samples[b]	Stage/ Flow
A1	gage at outflow or in impoundment			X
31.0	by Maynard St. bridge, Westboro	X	X	
Sassacus	off the end of Sassacus Dr.	X		
30.1	by Rte 9 East bridge, Westborough	X	X	
29.0	Milk Street, Westborough	X	X	
28.0	by School Street bridge, Northborough	X	X	
26.3	above the dam at Rte 20, Northborough	X		
26.2	below the dam at Rte 20, Northborough	X	X	
25.3	from Allen Street bridge, above dam, Northboro	X		
25.2	below the Allen Street dam, Northborough	X	X	
24.2	by Boundary Street bridge, Northb./Marlb.	X	X	
23.8	above dam off Robin Hill Road, Marlboro	X	X	
22.0	by Bridge St. bridge, Berlin	X	X	
19.6	by Chapin Road bridge, Hudson	X	X	
18.2	below Rte 85 bridge, Hudson center	X	X	
16.2	by Cox Street bridge, Hudson	X	X	X
14.4	below Gleasondale dam Rte 62, Stow	X	X	
13.4	by Sudbury Road bridge, Stow	X	X	
9.5	by White Pond Rd. bridge, Stow	X	X	
8.8	Ben Smith Impoundment, Maynard	X		
7.7	by USGS gage, Rte 62, Maynard	X	X	X
6.7	Powdermill Impoundment, Acton/Maynard	X		
6.5	from Old High St. bridge at dam, Acton	X		
6.3	above Rte 62 near Acton Ford, Acton	X	X	
4.7	above old dam @ Damonmill., Concord[c]	X	X	
4.4	from Rte 62 bridge @ Damonmill, Concord	X	X	X
3.3	by Rte 62 bridge near Donut Shoppe, Concord	X	X	
2.6	by Rte 2 bridge east of Assabet Ave., Concord	X	X	
T2.9	Nashoba Brook, by Comm. Ave. bridge, Concord	X	X	
1.0	below Dakins Brook, off Lowell Rd., Concord	X	X	

[a] YSI readings: temperature, DO, pH, conductivity, and oxidation/reduction potential
[b] Bottle Samples: TSS, BOD5, TP, ortho-P, TKN, nitrates, and ammonia
[c] Site 4.7 used only in June 2000, in July the sampling site was moved downstream to site 4.4

Figure 1: Assabet River Watershed and Sampling Sites 2000

Figure 2: Sampling Locations within the Ben Smith Impoundment (8.8), Maynard

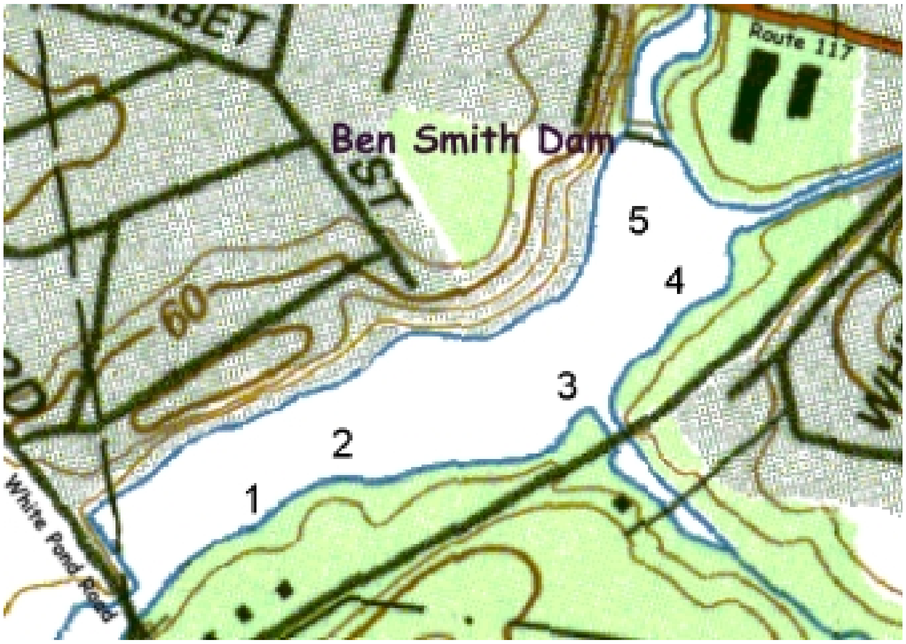


Figure 3: Sampling Locations within the Powdermill Impoundment (6.7), Acton

Samples for nutrients and suspended solids, were taken using bottles supplied by the laboratories and were stored in the dark on ice during transport from the field to the lab. Samples to be analysed by Thorstensen Laboratory were delivered to the laboratory within 4 hours. Total phosphorus samples to be analysed by the Environmental Analysis Laboratory were frozen within 4 hours of sampling and delivered to the lab within 8 weeks (holding time for the frozen samples is up to one year). Temperature, dissolved oxygen, pH, conductivity, and oxidation/reduction potential measurements were taken using multi-function YSI-6920 or YSI-6820 meters. To ensure that samples were representative of the bulk flow of the river in wadeable free-running sections, bottle samples and YSI readings were taken from the main flow of the river at mid-depth. Where the river was not wadeable (sites 26.3, 25.3, 8.8, 6.7 and 6.5) *in-situ* measurements were taken in the top, middle and bottom layers by sampling from a bridge or canoe using a 50-foot cable extension for the YSI meter. YSI readings from the several depths are reported as averages when there is no significant difference among the readings. At ten percent of the sites during each sampling event, duplicate field samples were taken and are reported here as an average of the original sample and the field duplicate. At ten percent of the sites during each sampling event, field blanks of distilled water were taken. Table 2 summarizes the parameters measured, laboratory methods and equipment used. A detailed description of sampling methods and quality control measures is available in the QAPP (OAR, 2000).

Table 2: Sampling and Analysis Methods

Parameter	Sample Type	Analysis Method #	Measurement Range/Detection Limits	Sampling Equipment	Laboratory
Temperature	*in-situ*	---	-5 - 45° C	YSI 6920	---
pH	*in-situ*	---	0 to 14 units	YSI 6920	---
Dissolved oxygen	*in-situ*	---	0 - 50 mg/L	YSI 6920	---
Conductivity	*in-situ*	---	0 to 100 mS/cm	YSI 6920	---
Oxid./reduction potential	*in-situ*	---	-999 to 999 mV	YSI 6920	---
Total Suspended Solids (TSS)	grab	EPA 160.2[a]	> 1.0 mg/L	bottle	Thorstensen Laboratory Inc.
Total Phosphorus (Thorstensen)	grab	EPA 365.2	0.01 - 1.0 mg/L	bottle	Thorstensen Laboratory Inc.
Total Phosphorus (Env. Labs)	grab	4500-P E [b]	0.003 - 0.5mg/L	bottle	Environmental Analysis Lab, UMass Amherst
ortho – Phosphate	grab	EPA 365.2	0.01 - 1.0mg/L	bottle	Thorstensen Laboratory Inc.
Total Kjeldahl Nitrogen	grab	EPA 351.3	0.05 - 100 mg/L	bottle	Thorstensen Laboratory Inc.
Nitrates	grab	EPA 352.1	0.01 - 10 mg/L	bottle	Thorstensen Laboratory Inc.
Ammonia	grab	EPA 350.3	0.03 - 10 mg/L	bottle	Thorstensen Laboratory Inc.

[a] USEPA, 1983.
[b] American Public Health Association, 1995.

Water quality measurements were compared with the Massachusetts Water Quality Standards for Class B warm waters (Table 3). All segments of the Assabet are designated Class B warm waters. For nutrient concentrations (where the Massachusetts Class B standard is narrative) results were compared with suggested trophic status boundaries (Table 4) in EPA Draft Nutrient Criteria Technical Guidance Manual: Rivers and Streams (EPA, 1999) and EPA Nutrient Criteria Technical Guidance Manual: Lakes and Reservoirs (EPA, 2000).

Table 3: Massachusetts DEP Class B Water Quality Standards*

Parameter	**Standard**
Dissolved oxygen	5.0 mg/l and 60% saturation
pH	6.5 – 8.3 for inland waters
Nutrients	“control cultural eutrophication”
Temperature	28.3° C and $\Delta < 2.8°$ C
Solids	Not impair use, cause aesthetically objectionable conditions, impair benthic biota, or degrade the chemical composition of the bottom

* MADEP. 1993. Massachusetts Surface Water Quality Standards - 314 CMR 4.00 1993

Table 4: Trophic Classification Boundaries

System	**Parameter**	**Oligotrophic - mesotrophic boundary (mg/L)**	**Mesotrophic - eutrophic boundary (mg/L)**
Rivers and Streams	Total Phosphorus *	0.025	0.075
	Total Nitrogen *	0.70	1.50
Lakes and Impoundments	Total Phosphorus **	0.01	0.02

* adapted from USEPA, 1999.
** adapted from USEPA. 2000.

Results and Discussion

Monthly summary statistics and averages for the upper and lower reaches of the running sections of the river are presented in Table 5. Statistics for impounded sections of the river are presented in Table 6. Individual parameters are discussed below. Full monthly summaries of the water quality data are attached in the Appendix.

Reaches and Impoundments

For the purposes of data analysis, the river is divided into an upper and a lower reach for the running sections of the river (those not immediately behind an dam), and impounded sections. Site 7.7 (Route 62, Maynard) was selected as the dividing point between the upper and lower reaches of the river because the nutrient concentrations, nitrates in particular, are markedly lower below site 7.7 and because flow is measured at the USGS Maynard gage at this site. The upper reach of the river is from site 30.1 (Route 9, Westborough) to site 7.7 (Route 62, Maynard). The lower reach of the river is from site 7.7 (Route 62, Maynard) to site 1.0 (near the outlet of Dakins Brook, Concord). Sites 31.0 and T2.9 are reported separately. Site 31.0 (Maynard Street, Westborough), the site nearest the headwaters of the Assabet and above the first wastewater treatment plant discharge, is the least impacted. Site T2.9 is on Nashoba Brook, Concord, between Warners Pond and the Assabet River; Nashoba Brook is the Assabet’s largest tributary.

There are impoundments along the Assabet River above the dams at: Route 20, Northborough; Allen Street, Northborough; Route 85, Hudson; Gleasondale, Stow; Route

Table 5: Reach Statistics

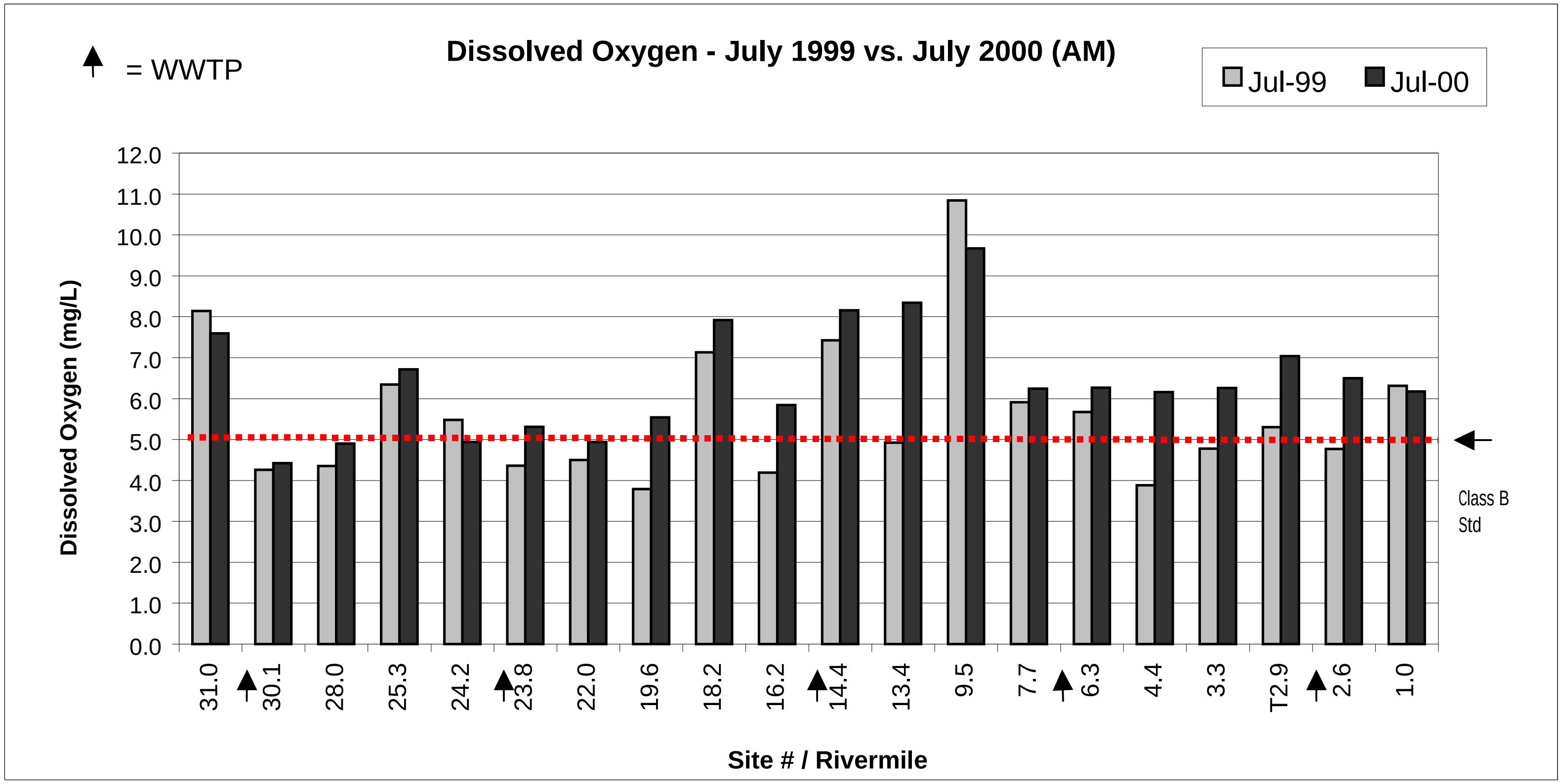
				Statistics and Reach Averages (morning measurements on running river sections)													
Dates	Site #	Sample/Reach Locations [a]	Statistic	Water Temp (C)	DO (mg/L)	DO % Sat	pH	TSS (mg/L)	Total P (mg/L)	ortho-P (mg/L)	Nitrates (mg/L)	Ammonia (mg/L)	TKN (mg/L)	Available Nitrogen	Available N:P	Total N	Total N:P
17-Jun-00	all	All	Maximum	23.3	9.02	99.5	6.99	21.0	0.20	0.16	1.0	0.33	1.9	1.0	89.0	2.7	23.3
	all	All	Minimum	19.4	4.56	50.1	6.21	5.0	0.03	<0.01	0.5	0.08	0.06	0.6	5.1	0.7	7.8
	31.0	Maynard St., Westboro	Single Reading	23.3	8.47	99.4	6.99	19.0	0.03	<0.01	0.64	0.09	0.10	0.7	73.0	0.7	23.3
	30.1 - 7.7	Rte 9 to Maynard Gage	Average	20.4	7.29	80.7	6.41	14.0	0.15	0.11	0.73	0.13	1.04	0.9	8.2	1.8	12.1
	7.7 - 1.0	Maynard Gage to Dakins	Average	20.4	7.98	88.5	6.63	13.6	0.14	0.10	0.83	0.09	0.58	0.9	21.0	1.4	10.9
	T2.9	Nashoba Brook, Concord	Single Reading	20.8	8.28	92.5	6.72	5.0	0.06	<0.01	0.81	0.08	0.45	0.9	89.0	1.3	21.0
15-Jul-00	all	All	Maximum	24.8	9.67	116.8	7.70	41.0	0.86	0.86	5.60	0.20	2.00	5.7	215.0	7.1	142.0
	all	All	Minimum	18.3	3.77	41.9	6.66	5.0	0.02	0.01	0.13	0.04	0.72	0.2	6.2	1.6	8.3
	31.0	Maynard St., Westboro	Single Reading	18.3	7.59	80.7	7.19	19.0	0.02	0.02	2.10	0.05	0.74	2.2	215.0	2.8	142.0
	30.1 - 7.7	Rte 9 to Maynard Gage	Average	21.7	6.37	73.2	7.07	14.9	0.34	0.30	2.93	0.09	1.11	3.0	14.4	4.0	13.8
	7.7 - 1.0	Maynard Gage to Dakins	Average	23.7	6.27	74.0	7.16	7.5	0.13	0.10	1.01	0.07	0.98	1.1	10.9	2.0	15.2
	T2.9	Nashoba Brook, Concord	Single Reading	23.4	7.04	82.7	7.03	7.0	0.04	0.01	0.13	0.05	0.98	0.2	18.0	1.1	27.8
19-Aug-00	all	All	Maximum	20.2	9.22	101.0	7.21	16.5	0.60	0.55	4.0	0.24	1.7	4.2	41.0	5.3	77.0
	all	All	Minimum	17.8	5.39	57.8	6.63	2.0	<0.01	<0.01	0.24	0.05	0.53	0.3	7.6	0.8	8.8
	31.0	Maynard St., Westboro	Single Reading	18.8	8.76	94.2	7.21	10.5	<0.01	<0.01	0.24	0.05	0.50	0.3	29.0	0.8	77.0
	30.1 - 7.7	Rte 9 to Maynard Gage	Average	18.9	7.36	79.4	6.91	9.1	0.25	0.20	2.14	0.12	1.12	2.3	14.2	3.3	15.5
	7.7 - 1.0	Maynard Gage to Dakins	Average	19.8	8.35	91.6	7.07	5.7	0.10	0.07	1.15	0.09	0.90	1.2	17.7	2.1	20.0
	T2.9	Nashoba Brook, Concord	Single Reading	19.3	8.17	88.7	6.86	6.0	0.04	0.01	0.32	0.09	0.87	0.4	41.0	1.2	29.8
16-Sep-00	all	All	Maximum	19.7	9.08	93.1	7.33	12.0	0.70	0.69	6.8	0.15	2.40	7.0	108.0	9.2	48.0
	all	All	Minimum	13.6	4.86	50.7	6.65	2.0	0.03	<0.01	0.20	0.08	0.92	0.3	8.1	1.2	9.6
	31.0	Maynard St., Westboro	Single Reading	13.6	9.08	87.3	7.33	7.0	0.04	<0.01	1.00	0.08	0.92	1.1	108.0	1.9	48.0
	30.1 - 7.7	Rte 9 to Maynard Gage	Average	17.7	6.77	71.1	6.91	5.5	0.34	0.27	3.50	0.12	1.40	3.7	17.3	4.9	16.4
	7.7 - 1.0	Maynard Gage to Dakins	Average	19.1	7.70	83.3	7.19	5.8	0.12	0.07	1.40	0.12	1.50	1.5	22.7	2.9	23.8
	T2.9	Nashoba Brook, Concord	Single Reading	19.2	7.57	82.1	7.00	5.0	0.03	0.02	0.20	0.08	1.00	0.3	14.0	1.2	40.0
21-Oct-00	all	All	Maximum	15.5	10.59	98.2	7.27										
	all	All	Minimum	9.2	5.57	52.0	6.75										
	31.0	Maynard St., Westboro	Single Reading	9.2	8.28	72.1	7.03										
	30.1 - 7.7	Rte 9 to Maynard Gage	Average	11.4	8.32	76.2	6.96										
	7.7 - 1.0	Maynard Gage to Dakins	Average	11.2	9.74	88.8	6.98										
	T2.9	Nashoba Brook, Concord	Single Reading	--	--	--	--										

[a] Excluding impoundment sites: 26.3, 25.3, 8.8, and 6.7.

Table 6: Impoundment Statistics

				Statistics and Impoundment Averages (all depths averaged)						
Dates	Site #	Impoundment Location	Statistic	Water Temp (°C)	DO (mg/L)	DO % Sat	pH	Cond. (µS/cm)	ORP	Total Depth (ft)
17-Jun-00	all	All	Maximum	24.4	7.55	87.7	6.48	478	-15.5	2.5
	all	All	Minimum	20.1	5.20	58.0	6.10	263	247	12.5
	26.3	above Rte 20 dam, Northboro	Average	20.7	5.20	58.0	6.34	478	183	2.5
	25.3	above Allen St. dam, Northboro	Average	20.1	8.02	87.8	6.47	413	190	6.0
	8.8	Ben Smith Impound., Maynard	Average	22.1	7.21	81.9	6.06	--	216	5.4
	6.7	Powdermill Impound., Acton	Average	20.5	7.83	87.1	6.50	263	230	9.0
15-16 July 00	all	All	Maximum	24.8	11.91	143.0	6.86	760	176	13.0
	all	All	Minimum	20.5	0.46	5.0	8.53	354	-241	3.0
	26.3	above Rte 20 dam, Northboro	Average	20.5	5.16	57.4	6.91	760	124	2.0
	25.3	above Allen St. dam, Northboro	Average	21.2	6.73	76.0	7.05	693	82	4.0
	8.8	Ben Smith Impound., Maynard	Average	23.2	6.19	72.9	7.12	430	68	6.5
	6.7	Powdermill Impound., Acton	Average	24.0	6.36	75.8	7.25	444	66	4.4
19-20 August 00 Morning (4 - 8 am)	all	All	Maximum	20.5	8.76	97.7	7.02	650	172	12.8
	all	All	Minimum	17.9	3.61	44.9	6.38	176	-80	3.2
	26.3	above Rte 20 dam, Northboro	Average	18.8	5.21	56.0	6.79	650	30	4.0
	25.3	above Allen St. dam, Northboro	Average	17.9	7.93	83.6	7.00	493	9	4.0
	8.8	Ben Smith Impound., Maynard	Average	20.0	7.60	84.5	6.76	334	114	5.8
	6.7	Powdermill Impound., Acton	Average	20.0	7.76	85.4	6.95	362	11	6.6
19-20 August 00 Afternoon (4 - 7 pm)	all	All	Maximum	23.4	13.98	159.4	8.62	473	55	12.5
	all	All	Minimum	18.2	2.53	26.8	6.53	186	-100	3.0
	26.3	above Rte 20 dam, Northboro	Average	--	--	--	--	--	--	--
	25.3	above Allen St. dam, Northboro	Average	--	--	--	--	--	--	--
	8.8	Ben Smith Impound., Maynard	Average	21.5	9.65	110.0	7.14	341	-27	7.4
	6.7	Powdermill Impound., Acton	Average	21.6	9.84	112.0	7.66	358	-27	5.9
16-17 Sept 00	all	All	Maximum	18.1	7.59	78.7	7.26	522	117	12+
	all	All	Minimum	16.9	5.45	57.1	6.77	320	35	3.0
	26.3	above Rte 20 dam, Northboro	Average	16.9	5.53	57.1	6.70	331	110	3.0
	25.3	above Allen St. dam, Northboro	Average	17.0	7.57	78.4	6.93	321	92	5.0
	8.8	Ben Smith Impound., Maynard	Average	17.8	5.58	58.9	6.92	513	73	6.6
	6.7	Powdermill Impound., Acton	Average	18.2	6.57	69.7	7.00	444	80	6.7
21-22 Oct 00	all	All	Maximum	12.1	8.87	81.2	6.92	450	356	12+
	all	All	Minimum	11.0	5.51	51.4	6.67	312	-53	3.0
	26.3	above Rte 20 dam, Northboro	Average	12.3	6.29	58.9	6.96	556	269	3.0
	25.3	above Allen St. dam, Northboro	Average	11.1	8.66	78.8	7.09	450	241	4.5
	8.8	Ben Smith Impound., Maynard	Average	11.5	7.85	72.2	6.79	351	234	6.2
	6.7	Powdermill Impound., Acton	Average	11.7	8.12	74.9	6.85	337	196	5.8

Figure 4: Dissolved Oxygen Concentrations in Free-Flowing Sections (July 99 vs. July 00)



62/117 (Ben Smith dam), Maynard; Route 62 (Powdermill dam), Acton. *In-situ* measurements were taken in all of the impoundments except Rte 85, Hudson.

Flow

River flow, as measured at the UGSG gage in Maynard, were approximately 2 - 10 times higher in the summer of 2000 than in the corresponding months in 1999 (Table 7). Except for July 2000, flows this summer were near or above the mean monthly flow.

Table 7: Flows in 1999 and 2000

	Flow at USGS Maynard Gage (cfs)		
Month	1999	2000	Mean Monthly [a]
June	24	260	153
July	14	43	73.4
August	20	90	61.7
September	51	120	63.3
October	Not tested	88	91.7

[a] based on 57 years of record at the USGS gage in Maynard

Temperature and pH

Dissolved oxygen, temperature, pH, conductivity, and oxidation-reduction potential (ORP) measurements were taken in June, July, August, September, and October between 4am - 8am, when daily dissolved oxygen concentrations are expected to be at their lowest.

Temperatures in running sections ranged from 9.2 - 24.8 ° C, meeting the water quality standard of 28.3 ° C for Class B warm waters. However, in October the temperature change between sites 31.0 and 30.1 (above and below the Westborough waste water treatment plant) exceeded the water quality standard, a change of > 2.8° C. pH measurements in running sections ranged from 6.21 to 7.70 units, which met the Class B standards.

Temperatures in the impoundments were generally warmer, from 11.0 to 24.8 ° C. In the impoundments, pHs ranged from 6.10 - 8.62. Site 6.7-4 in the Powdermill Impoundment was above the Class B pH standard (pH 8.3) during the July morning and August afternoon samplings. Site 6.7-4 is over a shallow mud bar covered with abundant rooted vegetation and the high pH is likely associated with high photosynthetic activity.

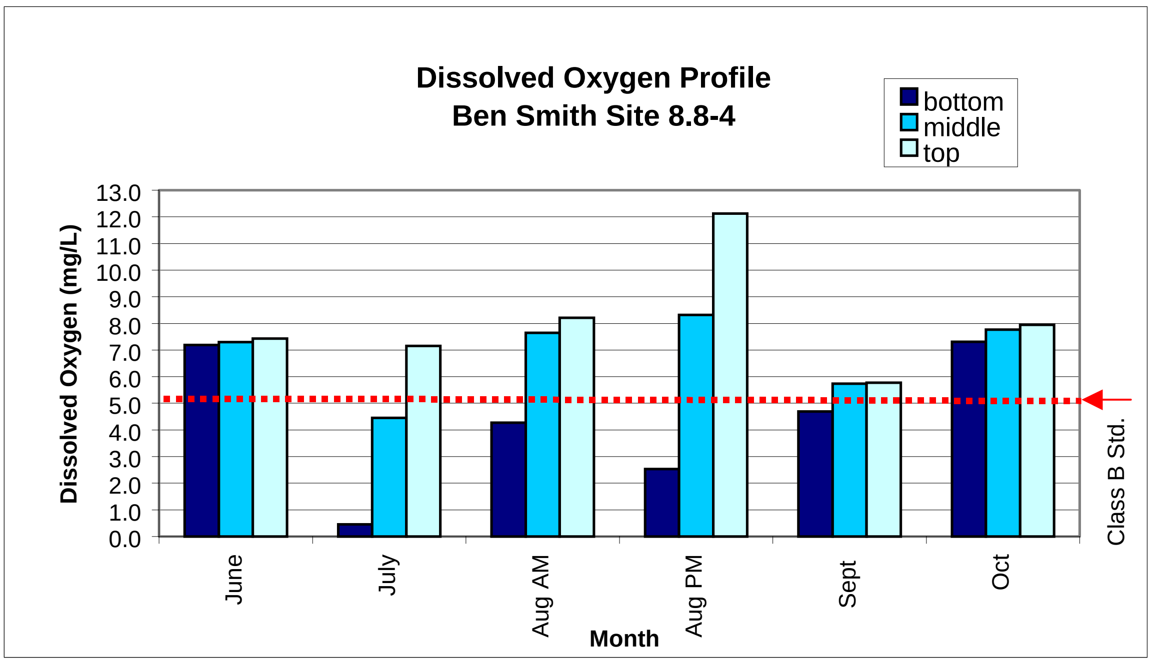
Dissolved Oxygen

Dissolved oxygen (DO) concentrations are generally at their lowest between 5 am - 8 am after plant and microbial respiration has been removing oxygen from the water column during the night. Low morning concentrations and large diurnal variations in DO indicate eutrophic conditions. Morning DO concentrations in the free-flowing sections ranged from 4.56 - 9.02 mg/L in June, 3.77 - 9.67 mg/L in July, 5.39 - 9.22 mg/L in August, 4.86 - 9.08 mg/L in September, and 5.57 - 10.59 mg/L in October. DO concentrations failed to meet water quality standards (5.0 mg/L DO and 60% saturation) at one site in June and at five sites in July.

Figure 4, shows the distribution of morning DO concentrations in free-flowing sections in July 2000, when river flows were the lowest for the summer, compared with DO concentrations in July 1999. Although dissolved oxygen concentrations were generally higher than they had been in July 1999, five sites in July 2000 still failed to meet the Massachusetts Class B water quality standard of 5.0 mg/L DO.

Morning DO concentrations in the impoundments (sites 26.3, 25.3, 8.8, and 6.7 all depths) ranged from 5.20 -7.55 mg/L in June, 0.46 - 11.91 mg/L in July, 3.61 - 8.76 mg/L in August, 5.45 - 7.59 mg/L in September, and 5.51 - 8.87 mg/L in October. Site 8.8-4, the deepest site sampled in the Ben Smith Impoundment shows consistent stratification of DO over depth from July to September (Figure 5). This site is in the main channel of the impoundment and had little plant growth over the summer.

Figure 5: Dissolved Oxygen Profile, Ben Smith Impoundment Site 8.8-4

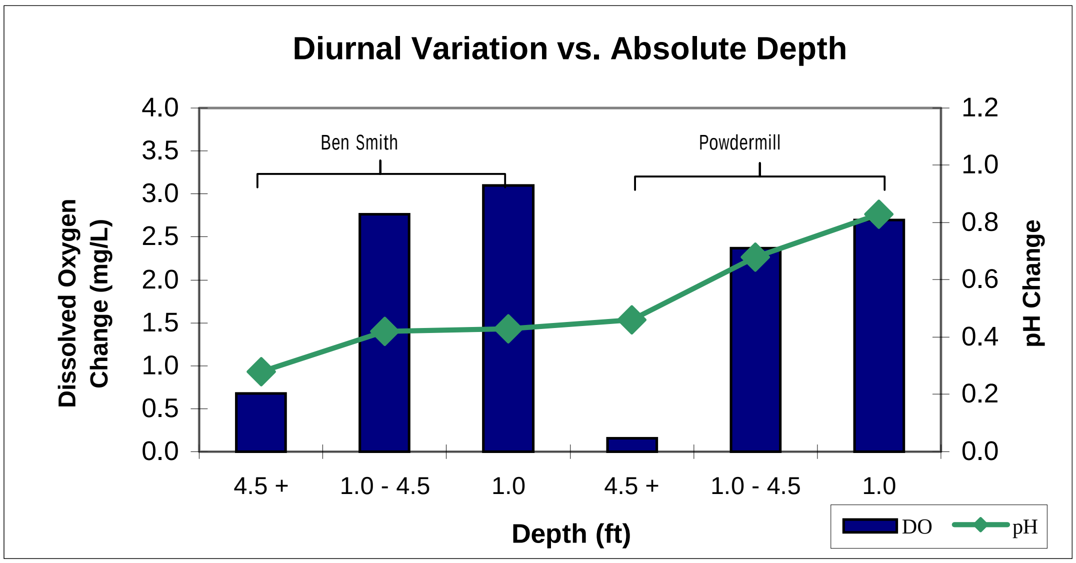


Although conditions were not as extreme as they had been in summer 1999, very high and very low dissolved oxygen concentrations, both of which damage fish habitat, were again recorded in the Ben Smith and Powdermill Impoundments. Dissolved oxygen concentrations in excess of 125% saturation are considered dangerous to fish (Behar 1996). DO concentrations over 125% saturation were measured in the surface waters (~ 1.0 ft) of Ben Smith sites 3, 4 and 5 and Powdermill site 4 in the August afternoon survey. DO concentrations below the Class B standard (5.0 mg/L) were measured in the bottom layers (>4.5 ft.) at Ben Smith sites 4 and 5 in July, August and September, and in the bottom layer of Powdermill site 4 in September.

Diurnal Variation

In August, morning and afternoon *in-situ* measurements were taken to assess diurnal variation in the Ben Smith and Powdermill Impoundments. The most significant diurnal changes measured were in dissolved oxygen, pH, and temperature. The diurnal changes were largest in the surface (~1.0 ft) and shallow mid-layers (1.0 - 4.5 ft) of the two impoundments. Changes (averaged over the five sampling sites in each impoundment) in dissolved oxygen and pH are shown for three depth ranges in Figure 6. Changes in temperature ranged from 0 -3.4 ° C; changes in DO ranged from -1.7 - 5.2 mg/L; changes in pH ranged from -0.03 - 1.68. The largest changes in pH were generally associated with the largest swings in DO and were likely due to photosynthetic activity.

Figure 6: Diurnal Variation vs. Depth



Nutrients

Summary statistics for nutrient and solids concentrations are in Table 5. Figures 7 - 10 show typical distributions of nutrient concentrations along the river in July 2000 compared with July 1999. In general, the nutrient concentrations in 2000 were again in the eutrophic or hyper-eutrophic ranges and were higher in the upper reach of the river than in the lower reach. Nutrient concentrations at site 31.0 (Maynard St., Westborough) and T.2.9 on Nashoba Brook were generally in the mesotrophic range.

Concentrations of total phosphorus (which represents both the dissolved and particulate phosphorus in the water column) tended to be highest in the upper reaches of the river where dilution of the wastewater treatment plant effluent by baseflow was the least (Figure 7). All sites except 31.0 (Maynard St., Westborough) and T2.9 (Nashoba Brook) exceeded 0.075 mg/L total phosphorus, the phosphorus threshold for eutrophication of rivers, on all dates tested. Concentrations of ortho-phosphorus, which represents the available phosphorus in the water column, ranged from <0.01 - 0.86 mg/L along the river.

Nitrogen species concentrations were also high. Total nitrogen (TN, calculated as the sum of TKN and nitrates concentrations) concentrations were consistently ~1 - 4.5 times higher in the upper reach of the river than in the lower reach. TN concentrations exceeded 1.5 mg/L, the TN threshold for eutrophication, on each date tested at all but a few sites. Available nitrogen (the sum of nitrates and ammonia) represents the fraction of nitrogen readily available for uptake by plants. Available nitrogen ranged from 0.29 - 6.95 mg/L along the river. Nitrate concentrations ranged from 0.24 - 6.8 mg/L and ammonia concentrations ranged from 0.04 - 0.33 mg/L along the river.

Comparison of Nutrient Concentrations in July 1999 and 2000

Although river flows were significantly higher and nutrient concentrations were generally lower in the summer of 2000 than they had been in 1999 (see Table 7), nutrient concentrations were still in the eutrophic and hypereutrophic ranges. Non-point sources may be significant contributors to the nutrient loads in the river at higher flows, off-setting the potential decreases in nutrient concentration from increased dilution of the point sources.

Figures 7 - 10 show typical nutrient concentrations along the river in July ‘00 compared with July ‘99. Total and ortho-phosphorus concentrations were significantly lower in 2000 all along the river: TP was an average of 32% lower and ortho-P was an average of 21% lower than in July ‘99. So, although flows three times higher in July ’00, phosphorus concentrations in the river were not reduced by 66%. This suggests the reduction in nutrient concentrations gained by increased dilution of the wastewater treatment plant effluent were offset by increases in non-point source phosphorus loads.

In the upper reach, total nitrogen and available nitrogen concentrations were generally lower in 2000 than in 1999, but in the lower reach concentrations were higher starting at site 9.6. Site 9.6 is just below the long impounded stretch between the Gleasondale dam and White Pond Road. This difference between upper and lower reaches could be attributed to slightly lower water temperatures, higher flushing rates, and slower plant growth leading to lower uptake of nitrogen species in the impounded sections in 2000. Although OAR did not undertake a macrophyte assessment in this study, ENSR reported (ENSR 2000) that total biomass values and density levels observed during their Summer 2000 survey of the six major impoundments were smaller than those in their Summer 1999 survey.

Figure 7: Total Phosphorus

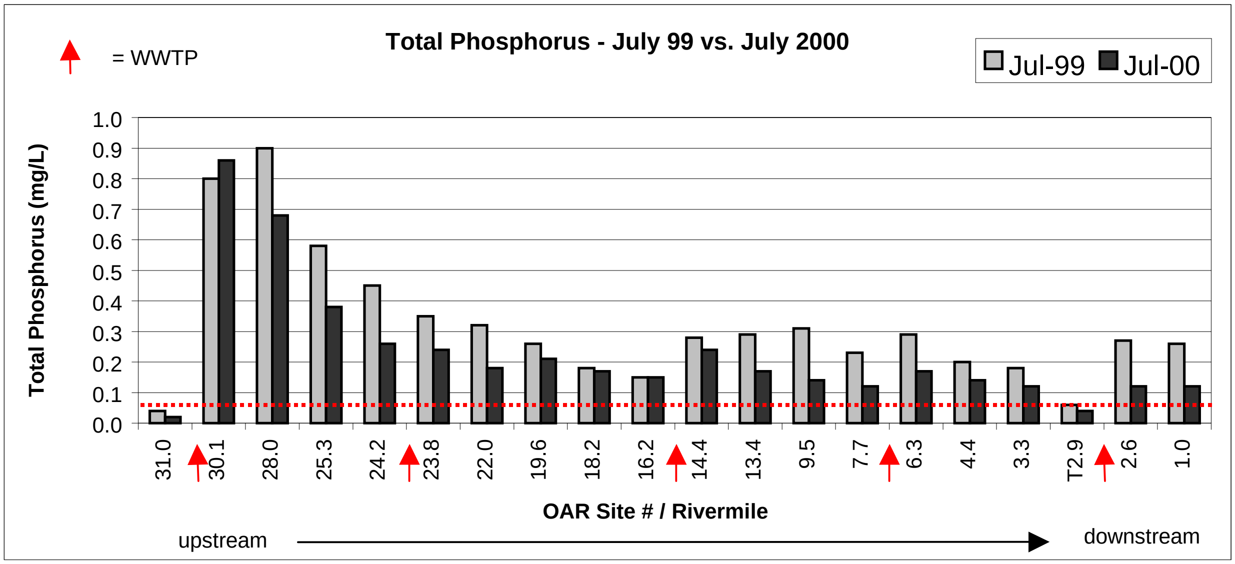


Figure 8: ortho-Phosphate

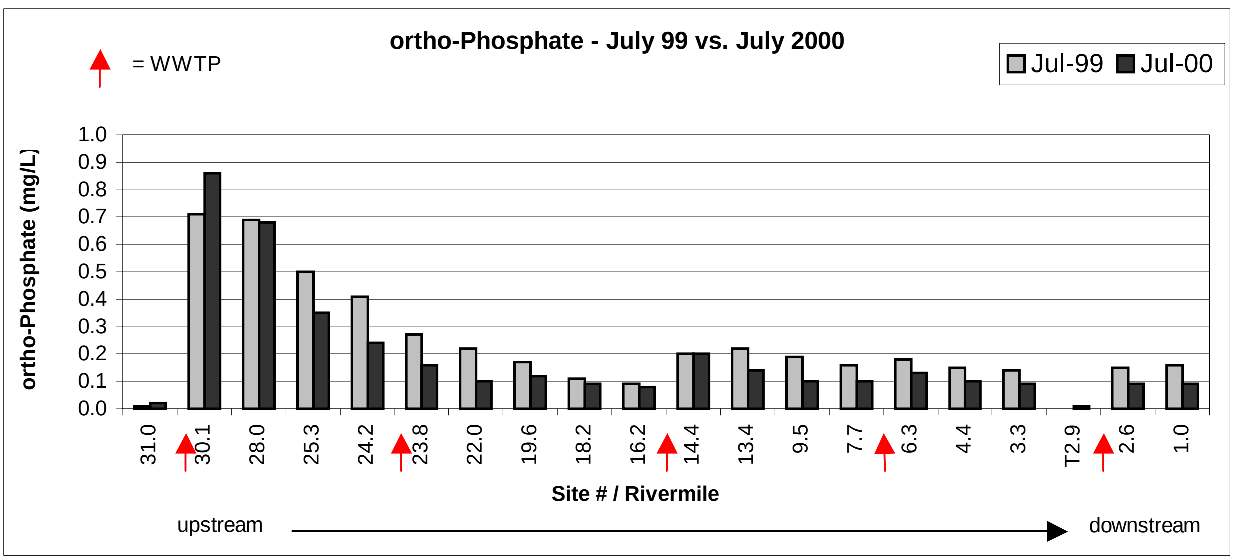


Figure 9: Total Nitrogen

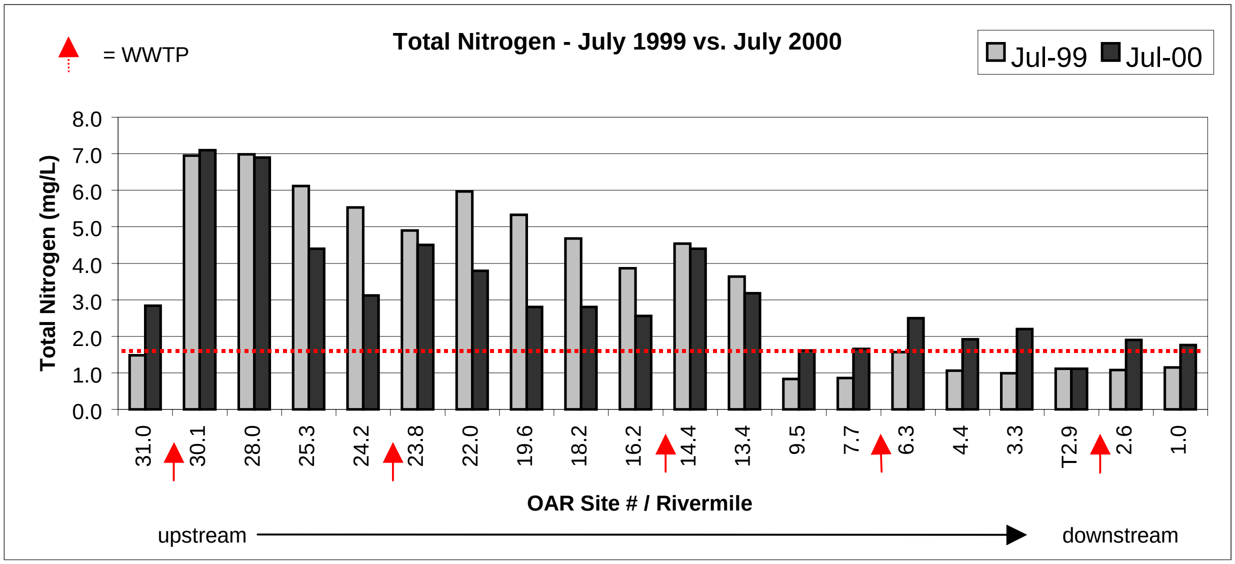
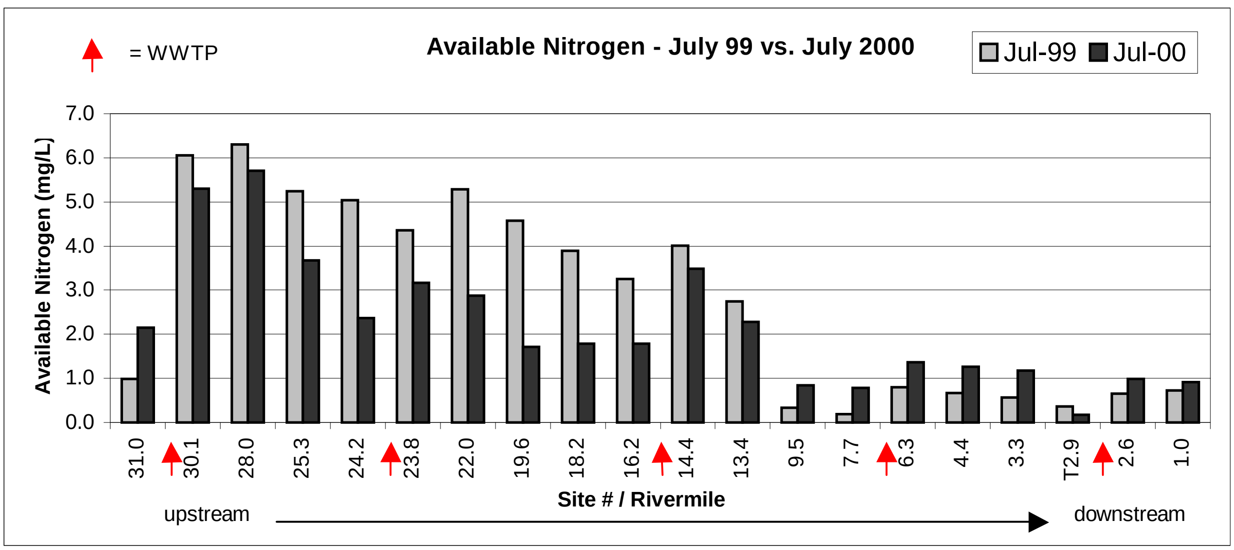


Figure 10: Available Nitrogen



Conclusions

River flows in the Assabet in the summer of 2000 were near average for the 57 years of record at the USGS gage in Maynard in sharp contrast with the low flows in 1999. While river flows were higher, water temperatures slightly lower, and aquatic plant growth less in the summer of 2000 than they had been in 1999, the river still showed signs of severe eutrophication.

Low morning dissolved oxygen concentrations and large diurnal changes in DO concentration are indicative of eutrophication and may be harmful to fish and other aquatic organisms. Dissolved oxygen concentrations failed to meet the Class B standard at in June and July at several sites along the running sections of the river and in the deeper waters (>4.5 ft.) at two sites in the Ben Smith Impoundment and one site in the Powdermill Impoundment. Large diurnal changes (1.3 - 5.2 mg/L) in dissolved oxygen concentrations were measured in the shallow waters of the Ben Smith and Powdermill Impoundments.

Nutrient concentrations were lower in the summer of 2000 than in 1999, but were still in the eutrophic to hyper-eutrophic ranges, capable of supporting excess aquatic plant growth. Nutrient concentrations, both phosphorus and nitrogen species, were highest in the upper reach of the river where there is least dilution of the wastewater treatment plant effluent by natural flow. The lower nutrient concentrations in the lower half of the river may be explained by several possible factors: the larger proportion of natural flow to effluent in the river, nutrient uptake by plants during the growing season, and deposition of bound nutrients to the sediments in slow moving river sections. Non-point sources may contribute to the nutrient loads in the river at higher flows, off-setting the potential decreases in nutrient concentration from increased dilution of the point sources.

Because nutrient concentrations are so high in the Assabet, control and remediation must be approached on multiple fronts: reduce both point and non-point nutrient inputs to the river, protect baseflow, and assess sediment conditions. A fishable, swimmable Assabet River would be a valuable asset to the communities in its watershed.

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Glossary of Terms

Ammonia (NH3): a form of nitrogen available to uptake by plants and microorganisms. Sources include the breakdown of organic nitrogen in sediments and untreated sewage. Other sources of ammonia include: fertilizer, home cleaning products and food processing. While ammonia can be readily utilized by plants, high concentrations of ammonia are directly toxic to aquatic life. A secondary effect of increased ammonia occurs when bacteria oxidize the NH_3 to NO_3, a process called nitrification, consuming four atoms of oxygen for every atom of nitrogen converted. This process can dramatically lower dissolved oxygen in the water.

Baseflow: the flow of water from aquifers into the streambed. In natural systems in New England baseflow makes up most of the river flow during the summer.

Biochemical oxygen demand (BOD): oxygen required to break down organic matter and to oxidize reduced chemicals (in water or sewage). BOD provides a direct measure of the decomposition or oxidation processes in the water column. The more difficult-to-perform **sediment oxygen demand (SOD)** test measures the decomposition processes in the sediments.

Conductivity: the ability of the water to conduct a charge, which increases with increasing concentrations of charged ions in the water. Conductivity is a rough indicator of pollutants, such as untreated waste, entering the stream.

Dissolved Oxygen: the presence of oxygen gas molecules (O2) in the water. The concentration of dissolved oxygen (DO) in the water column provides a direct indication of the water's ability to support aquatic life like fish and macroinvertebrates. Aquatic plants and bacteria in the sediments remove dissolved oxygen from the water when they respire (plants respire mainly at night). Therefore, the lowest dissolved oxygen concentrations of the day occur in the early in the morning. During the day plants add oxygen to the water column through photosynthesis. Both extreme (low or high) DO concentrations and large changes in DO concentrations over the day (diurnal variation) are damaging to the habitat.

Eutrophic: abundant in nutrients and having high rates of productivity frequently resulting in oxygen depletion below the surface layer.

Mesotrophic: having a nutrient loading resulting in moderate productivity.

Nitrogen: a major nutrient supporting plant growth. Nitrogen is measured in its various forms as **nitrate (NO_3)**, **ammonia (NH_3)**, and **total Kjeldahl nitrogen (TKN**). **Total nitrogen** is calculated as the sum of TKN and nitrates. **Available nitrogen**, calculated as the sum of nitrate and ammonia, gives a measure of the nitrogen readily available for absorption by plants. Once absorbed, nitrogen is incorporated into proteins, amino acids, nucleic acids, and other molecules. Although most aquatic plant growth in rivers is limited by the availability of phosphorus, increased nitrogen availability can also lead to algal blooms.

Oligotrophic: having a small supply of nutrients, low production of organic matter, low rates of decomposition, and high dissolved oxygen in the lower layers of the water column.

Phosphorus: Plants need nutrients to grow, in particular they need a balance of phosphorus (P) and nitrogen (N). Phosphorus is measured as **total phosphorus** (TP) and **ortho-phosphate** (ortho-P; soluble inorganic phosphate, the form required by plants). In most fresh waters, the concentration of phosphorus available to plants is low enough that the plants cannot grow at their maximum rate. But in water bodies, like the Assabet, where human activities add phosphorus to the environment, the added phosphorus allows much greater growth of aquatic plants.

Oxidation/reduction potential provides a measure of the condition of the suspended solids: to what extent the organic material in them has been degraded by microorganisms.

pH: the negative log of the hydrogen ion concentration in water, a measure of the acidity of water. pH is measured on a scale from 1 to 14, with 1 being very acidic, 7 being neutral, and 14 being very basic. Extreme pHs, in either direction, can be toxic to fish and other aquatic life. pH plays role in the behavior of other pollutants such as heavy metals in the environment. High or low pH levels can be the result of acid rain/snow, chemicals entering the waterways, or algal blooms.

Total suspended solids (TSS): the amount of silt, clay, organic material and algae in the water. Sources include erosion and the solids in effluent. Once in the water column, suspended solids are transported downstream and settle gradually, along with decaying plant matter, to form thick organic-rich sediments in the slower sections of the river.

Stage and flow measure the amount of water in the river. Stage is the height of the water above the riverbed, and is read at staff gages at several points along the river. Flow measures the volume of water passing a given point in the river. Flow is measured by the USGS at their gage in Maynard and reported on the USGS web page.

Temperature affects the ecosystem in a number of ways: many organisms, especially cool water fish, are sensitive to high temperatures; the solubility of oxygen is lower in warmer water, decreasing the supply of dissolved oxygen; algae, weeds, and pathogenic microorganisms can all grow faster in warmer water.