Technical Memorandum TM 81-3

CONTINUOUS TEMPERATURE DATA AT THREE LOCATIONS ON THE SQUANNACOOK RIVER, NASHUA RIVER WATERSHED

DWM Control Number: CN 134.0

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April 2005

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TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

INTRODUCTION AND OBJECTIVES

Automated, continuous temperature monitors can be used to collect large data sets of surface water temperature in order to determine statistics such as maximum, minimum, and mean daily temperatures. These statistics can help to 1) assess the possibility of exceedances of Massachusetts Surface Water Quality Standards (SWQS) and subsequently perform Aquatic Life designated use determinations, 2) assist in the classification determination of unlisted waterbodies for inclusion in the SWQS (i.e. cold water vs. warm water fishery); 3) examine the timing of diurnal temperature fluctuations with regard to natural occurrences such as rain events and canopy cover; and 4) determine the impacts, if any, associated with National Pollutant Discharge Elimination System (NPDES) discharges or water withdrawals.

A brief study of temperatures in the Squannacook River was undertaken by MA DEP's Division of Watershed Management during the late summer 2003. The study and its data quality objectives were included as part of DWM's 2003 quality assurance project plan entitled, *Quality Assurance Project Plan 2003 MADEP-DWM Monitoring in the Blackstone, Chicopee, Connecticut and Nashua Watersheds* (CN127.0). The objective of the temperature survey was to evaluate whether or not water quality standards for a Cold Water Fishery were being met in the river upstream from the Hollingsworth & Vose Company wastewater discharge.

Optic Stowaway® temperature sensors were deployed from August 4 to September 16, 2003 at the following three locations on the Squannacook River (Figure 1).
1) Approximately 200 feet downstream from Route 13, Townsend, off the left bank.
2) Approximately 150 feet downstream from South Street and Harbor Pond, Townsend, off the right bank.
3) Off the west side of Townsend Road (directly across from Candice Lane), Groton, off the right bank.

All sensors were deployed in flowing water with canopy cover sufficient enough to avoid direct sun exposure. A duplicate sensor was also deployed at the Townsend Road station for quality control purposes.

BACKGROUND

The Squannacook River runs 14.3 miles from the confluence with Mason and Willard Brooks in Townsend to its confluence with the Nashua River at the Shirley/Groton/Ayer town lines. The upper 10.7 miles of the river from its headwaters to the Hollingsworth & Vose Company NPDES discharge is classified as a Class B, Cold Water Fishery and Outstanding Resource Water. The lower 3.6 miles, downstream from the discharge, is classified as a Class B, Warm Water Fishery. The entire subwatershed of the Squannacook River is approximately 71 square miles and extends into Southern New Hampshire. The Massachusetts portion of the subwatershed is approximately 55 square miles with the three top land uses consisting of 75% forest, 12% residential and 5% agriculture. The Massachusetts Department of Fish and Game has requested that the lower portion of the Squannacook River (downstream from the Hollingsworth & Vose discharge) be reclassified as a Cold Water Fishery in the next version of the SWQS.

The Hollingsworth & Vose Company manufactures technical, filter, and specialty papers, nonwovens, and advanced composites and is permitted to discharge treated process wastewater, filter backwash water and non-contact cooling water via one outfall to the Squannacook River. The permit imposes effluent limits for BOD_5, total suspended solids, total zinc and pH. There is no temperature limit in the current NPDES permit for Hollingworth & Vose.

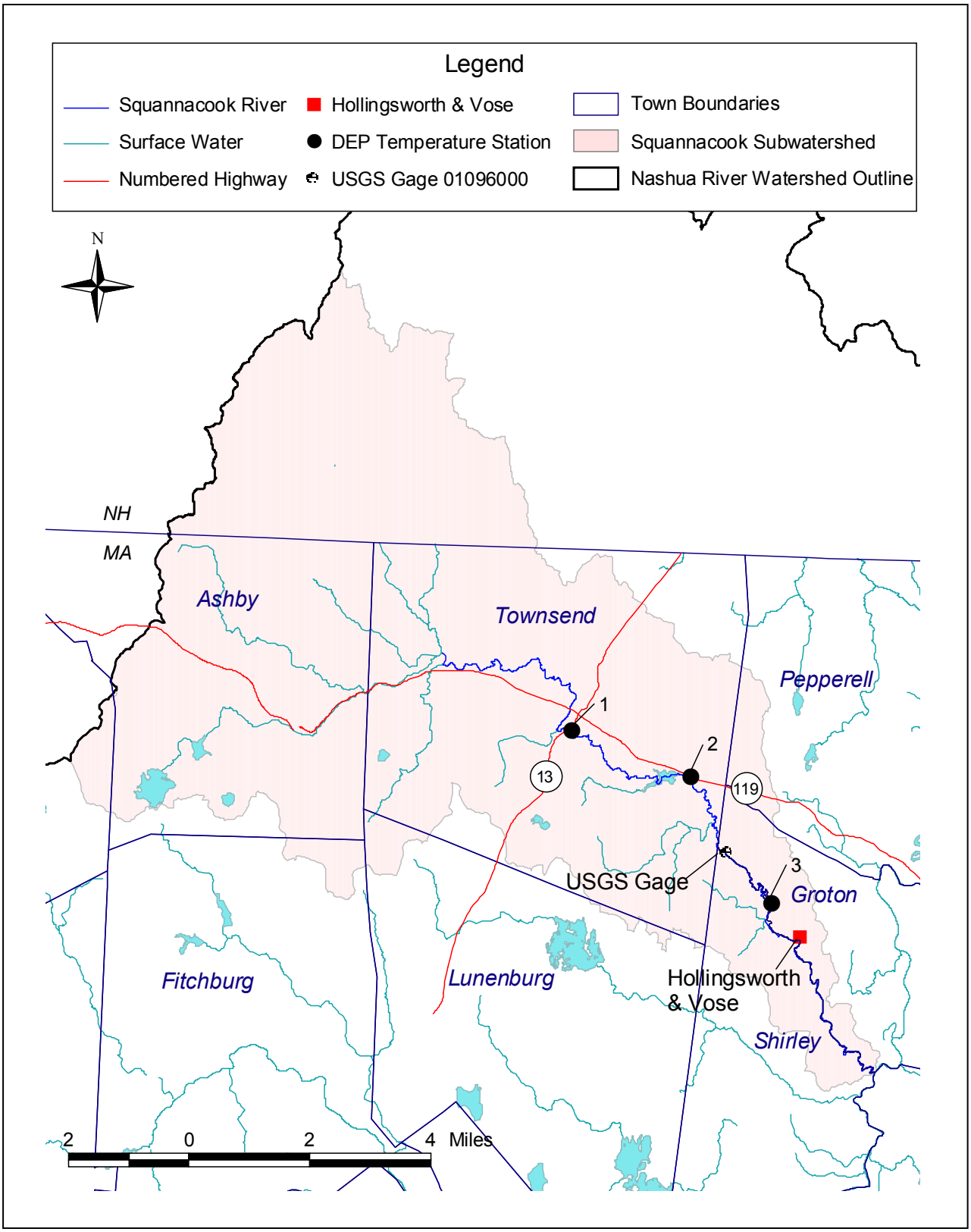

Figure 1. Locations of temperature sensors on the Squannacook River.

MATERIALS AND METHODS

The following materials and procedures were used in this project (excerpted with edits from CN103.0 Draft Standard Operating Procedure *Continuous Temperature Monitoring*).

Sensing and Data Retrieval Equipment: Optic Stowaway® Temp sensors, optic shuttle, optic base station and BoxCar® Pro software (Onset Computer Corp.). The 6" long, sealed polycarbonate optic sensors were initially launched (data logging initiated) using the BoxCar® program loaded on a DWM PC, and tested for logging capability and accuracy. All sensors were deemed fit to use and were re-launched prior to placement in rigid plastic tubes for field use. At the same time, the optic shuttle (used for field downloading without a laptop) and the optic base station (for data transmittal from a sensor or the shuttle to the PC) were also tested. The BoxCar® program was also tested and used to look for any potential software problems and none were found. After placement in the plastic tubes, the sensors were anchored at representative river locations at each of the three stations.

Sensor Housing and Anchoring Assembly: Each sensor was placed in a 9-12" long, 2" O.D. ABS plastic pipe with glued, PVC caps on both ends for protection. Several ¾" holes were drilled into each pipe section so each assembly would sink. Prior to gluing the caps, a small, round rock was placed inside each pipe to reduce buoyancy and guarantee submergence. The caps were numbered (1-4) to keep track of which sensors were at which locations. Approximate 10-15' long, 1/8" diameter, flexible steel cables were swage-fitted to each pipe (on one end) and attached to the top loop of 18" long steel screw anchors.

Field Deployment: At each station, the anchors were hand-screwed into a stable streambank at the water's edge (near the sampling location). The cable was hidden as much as possible and the pipe containing the sensor allowed to drift downstream and sink below the water surface. All locations and placements were selected to be representative of typical river conditions. The pipe number, station name and number, exact time and other relevant field data were documented in a field notebook.

NIST-traceable accuracy checks: A hand-held digital thermometer (Eutechnics 4400 Series) traceable to a NIST-certified thermometer was used in the field to check sensor accuracy at deployment and at retrieval. Based on manufacturer specifications, the Eutechnics thermometer is accurate within 0-50° C to +/- 0.015°C (plus probe tolerance). The resolution is listed as 0.01°C; with a one-year probe drift of +/- 0.010°C.

Data Validation: Several tasks were performed to validate the data. Raw data via the Boxcar® software were reviewed for obvious errors. The data records for each deployment were censored as appropriate to discard inappropriate and problematic data (i.e. those data not logged as intended). Excel data files, spreadsheets and charts were briefly reviewed for errors in values, equations and presentation. All data were rounded for reporting purposes to the tenths digit, reflecting the lack of confidence in the hundredths place. A chart comparing readings from the duplicate temperature sensor vs. an original temperature sensor, deployed at station 3, is displayed in Figure 2.

Data Management and Analysis: All temperature data files are stored electronically at the DWM office in Worcester, MA (w:dwm/sop/datalog/temperature). Data were uploaded and viewed using the BoxCar® Pro 4 software (Onset Computer Corp.), then exported to MS Excel for validation, analysis, and graphics. Data were analyzed both for the "total" deployment period (minus any censored and clipped data), as well as for a selected "maximum mean-monthly" period (6 August through 4 September 2003). For each time period, standard statistics were calculated for each station's data set using the same time interval. Where appropriate, data were related to temperature thresholds, such as those contained in the Massachusetts Surface Water Quality Standards (e.g. 20°C).

Figure 2. Comparison of original vs. duplicate temperature sensors at Station 3.

RESULTS AND DISCUSSION

Analysis of the 2003 Squannacook River temperature data set has been presented for two date ranges:

1. The portion of deployment (40 days) for which data is available for a complete calendar day (15-minute readings totaling 96 readings per every 24 hours from 12:15 am August 6, 2003 to 12:00 am September 15, 2003); and

2. The first 30 days (15-minute readings totaling 96 readings per every 24 hours from 12:15 am August 6, 2003 to 12:00 am September 5, 2003) representing a period with which to calculate a mean monthly temperature.

The SWQS define Cold Water Fisheries as “waters in which the maximum mean monthly temperature generally does not exceed 68°F (20°C) and, when other ecological factors are favorable (such as habitat), are capable of supporting a year-round population of cold water stenothermal aquatic life such as trout”. A preliminary review of the 40-day data set showed that highest daily average temperatures, and temperatures that exceeded the 20°C standard, occurred during the month of August (Table 1); therefore, the first 30 days were used to calculate the highest mean monthly (30-day) temperature for the entire data set. All daily average temperatures in September were less than 20°C. Mean daily discharge data from the USGS gage on the Squannacook River and maximum and minimum air temperatures and total daily precipitation from the NOAA weather station at the Fitchburg airport are also presented in Table 1 (USGS 2003 and NOAA 2005). The gage is located approximately half way between the South Street (Station 2) and Townsend Road (Station 3) stations.

A comparison between stations shows that average daily temperatures peak (24.4°C) at the Station 2 downstream from South Street (Figure 3). This station is located downstream from Harbor Pond. One possibility for this observance is that surface temperatures in the pond elevate as the sun heats up the slower moving water, thereby elevating river temperatures downstream as the warmer surface pond water flows over the dam.

Table 1. Average Daily Temperatures; Daily Mean Discharge; Total Precipitation and Maximum and Minimum Air Temperatures.

Date	Station 1 Temperature (°C)	Station 2 Temperature (°C)	Station 3 Temperature (°C)	Discharge (cfs)	Total Precipitation (inches)	Max / Min Air Temperature (°C)
08/06/03	21.1	22.6	22.2	67	0.05	85 / 69
08/07/03	21.3	22.8	22.6	54	0.34	81 / 67
08/08/03	20.7	22.6	22.4	55	0.48	78 / 67
08/09/03	20.8	22.7	22.4	59	trace	82 / 70
08/10/03	21.6	23.1	23.0	54	0.23	84 / 73
08/11/03	21.9	23.4	23.2	47	0.02	86 / 72
08/12/03	21.8	23.4	23.3	41	0.73	82 / 69
08/13/03	21.9	23.8	23.3	46	0.43	87 / 70
08/14/03	**22.2**	23.5	23.5	54	0	88 / 66
08/15/03	22.0	23.9	23.6	45	0.01	88 / 65
08/16/03	21.9	24.3	**23.7**	35	0	87 / 67
08/17/03	21.3	23.4	23.4	31	0	76 / 63
08/18/03	20.3	22.7	22.4	30	0.11	75 / 63
08/19/03	19.9	23.0	21.7	28	0	85 / 63
08/20/03	20.2	23.1	21.8	26	0	88 / 61
08/21/03	20.8	24.1	22.6	25	0	88 / 67
08/22/03	21.1	**24.4**	23.0	25	0.39	90* / 66
08/23/03	20.8	23.2	22.9	31	0	80 / 54
08/24/03	18.9	21.4	21.3	29	0	74 / 45*
08/25/03	17.9	20.9	20.1	24	trace	80 / 59
08/26/03	18.3	21.5	20.0	23	0	82 / 58
08/27/03	19.3	22.4	20.9	21	0	85 / 61
08/28/03	18.9	21.9	21.0	19	0	74 / 53
08/29/03	17.7	21.5	20.2	18	trace	81 / 49
08/30/03	18.3	22.0	20.1	17	0	81 / 54
08/31/03	17.4	20.3	19.6	16	0	71 / 47
09/01/03	16.4	19.7	19.1	16	0.02	68 / 53
09/02/03	15.9	18.7	18.3	18	0.33	65 / 58
09/03/03	15.8	18.3	17.8	18	0.30	70 / 57
09/04/03	15.8	18.1	17.6	22	0.18	67 / 57
09/05/03	16.3	18.0	17.7	24	0.01	75 / 55
09/06/03	16.4	18.3	17.9	23	0	75 / 50
09/07/03	16.2	19.0	17.7	21	trace	81 / 52
09/08/03	17.0	19.6	18.2	20	0	73 / 53
09/09/03	16.4	18.8	18.0	18	0	66 / 47
09/10/03	15.3	18.4	17.3	17	0	77 / 44
09/11/03	15.5	18.8	17.0	15	0	76 / 53
09/12/03	15.7	19.0	17.1	15	0	72 / 52
09/13/03	15.6	18.9	17.1	14	0	75 / 53
09/14/03	16.2	19.8	17.6	14	trace	83* / 61

* indicates an extreme for the month
Bold indicates peak average daily temperature.

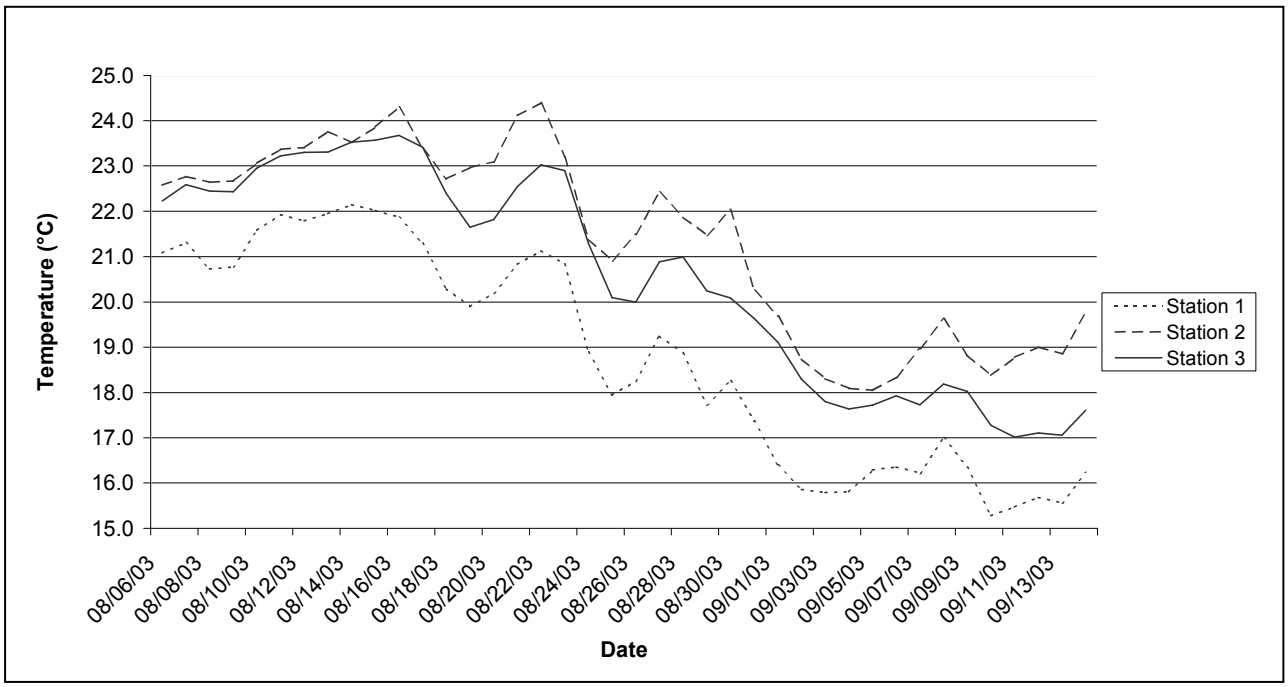

Figure 3. 40-day daily average temperatures from three stations on the Squannacook River.

Table 2 displays the maximum and minimum average daily water temperatures for each station over the 40-day period (6 August through 14 September 2003), over the 30-day period (6 August through 4 September 2003) and the number of days that exceedences of the 20°C standard occurred. Violations of the SWQS occurred over the 30-day period 57% to 87% of the time at the three stations, but only 43% to 65% of the time over the 40-day period. Daily temperatures peaked in the late afternoon or early evening hours.

Table 2. Maximum and minimum daily average temperatures at three stations on the Squannacook River.

	Station 1	Station 2	Station 3
Maximum Daily Average Temperature over 40 days	22.2°C	24.4°C	23.7°C
Minimum Daily Average Temperature over 40 days	15.3°C	18.0°C	17.0°C
Mean Monthly Temperature - 40 days	18.8°C	21.4°C	20.6°C
Maximum Daily Average Temperature over first 30 days (08/06/03 - 09/04/03)	22.2°C	24.4°C	23.7°C
Minimum Daily Average Temperature over first 30 days (08/06/03 - 09/04/03)	15.8°C	18.1°C	17.6°C
Mean Monthly Temperature - 30 days	19.7°C	22.2°C	21.6°C
Number of days (out of 40) with Daily Average Temperature >20°C	17 (43%)	26 (65%)	24 (60%)
Number of days (out of 30) with Daily Average Temperature >20°C	17 (57%)	26 (87%)	24 (80%)

Quality control in-situ precision measurements were performed on one occasion, 05 August 2003 (Table 3). Temperature differences (Stowaway sensors as compared to NIST-traceable) ranged from 0.04 - 0.26°C for the four units. These differences essentially meet the Data Quality Objectives (~ ±0.25°C to NIST-traceable unit).

Table 3. Quality Control in-situ precision measurements.

Station	Date/Time	Stowaway Sensor Temperature	NIST-Traceable Temperature	Range
Station 1	08/05/03 09:30	19.73°C	19.69°C	0.04
Station 2	08/05/03 10:00	20.84°C	21.10°C	0.26
Station 3	08/05/03 10:30	21.32°C	21.22°C	0.10
Station 3 (Duplicate)	08/05/03 10:30	21.36°C	21.22°C	0.14

RECOMMENDATIONS

1. Repeat the temperature study adding one or more stations downstream from the Hollingsworth & Vose company discharge, in order to:
   a. examine the temperature impact, if any, of the Hollingsworth & Vose NPDES discharge to the Squannacook River; and
   b. provide information for the SWQS branch with regard to the request by the Massachusetts Department of Fish and Game to change the designation of the portion of the Squannacook River downstream from the discharge from a warm water fishery to a cold water fishery.

2. Additional temperature studies should be started in early July and extended through the beginning of September to confirm that instream water temperatures are normally highest in July and August.

3. Examine the results of this study along with data from fish population surveys (Massachusetts Division of Fisheries and Wildlife) and dissolved oxygen data, if available, in order to evaluate the aquatic health of the cold water fishery.

REFERENCES

USGS. 2004. *Water Resources Data Massachusetts and Rhode Island Water Year 2003*. U.S. Geological Survey, Northborough, MA.

NOAA. 2005. *Unofficial Daily Climate Data* [Online]. National Oceanic and Atmospheric Adminstration. National Weather Service Forecast Office, Boston, MA. Accessed 24 March 2005 from http://www.erh.noaa.gov/box/dailystns.shtml.