MERRIMACK RIVER

TEMPERATURE AND DISSOLVED OXYGEN STUDIES

1972

by

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Manchester, New Hampshire

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I. INTRODUCTION

Temperature and dissolved oxygen surveys were conducted from June to September at the Bow Generating Plant before and after operation of the spray module cooling units. Primary emphasis was placed upon stations N-10, Zero-West, and S-4 at which dissolved oxygen and/or temperature profiles were measured at 1-foot depth intervals at five equidistant points across the river.

Data collected at weekly intervals during the Merrimack River Ecological Monitoring Program were compiled to supplement survey data. Temperature and surface dissolved oxygen data were collected near mid-river at all stations, with the exception of Station Zero-West, which was sampled at the confluence of the discharge canal and river. Temperature readings were taken at depth intervals of 1-foot at each sample station.

From July to September only Unit II was operational at the Bow Generating Station. Additional data was collected during September because both Units I and II were in operation and temperature and dissolved oxygen values should be more indicative of "normal" operating conditions. A temperature survey was conducted on October 19, 1972 during a performance test of the spray modules.

A list of dates and times of relative-humidity measurements and sampling of Station S-4 are included in Appendix 1.

II. MONTHLY TEMPERATURE AND DISSOLVED OXYGEN SURVEYS

A. JUNE

1. June 24, 1972

a. Conditions

(1). Units I and II in operation, before the sprays were being utilized.

(2). Flows: 6-hour averages 2,719 cfs (1200)
2,837 cfs (1800)

(3). Meterological: Windspeed, Mean = 12.2 mph[1]

Relative Humidity, Mean = 82.8%[1]

b. Water Temperature

(1). Highest Temperatures Noted:

Station:	N-10	O-W	S-4
Temperature (°F)	65.5	82.6	78.1
Δt's	----	17.1	12.6

(2). Thermal Configuration at Station S-4

(a). Vertical distribution of temperatures

	West				East
Data Points:	I	II	III	IV	V
Surface to Bottom Temp. Range (°F):	66.4-78.1	66.4-78.1	65.5-78.1	66.4-72.7	66.4-70.0
Mean Temp. (°F):	70.3	69.4	69.6	68.7	67.1
% of profile ≥ 5° F:	33%	33%	30%	36%	8%

5° F differences were observed from surface to 3 ft., but averaged 2.3 ft.

[1]Concord, New Hampshire Weather Bureau

(b). Horizontal distribution of temperatures

Depth (ft.)	Temperature Range (°F) across river	Mean Temperature (°F)	Mean Δt (°F)
Surface	70.0-78.1	75.4	9.9
1	69.1-78.1	75.0	9.5
2	67.3-78.1	73.9	8.4
3	67.3-76.3	72.7	7.2
4	66.4-67.3	66.9	1.4
5	66.4-67.3	66.6	---
6	-----	66.4	---
7	-----	66.4	---
8	-----	66.4	---
9	-----	66.4	---
10	-----	66.4	---
11	65.5-66.4	66.2 (N=4)	---
12	-----	66.4 (N=1)	---

The mean temperature, computed from all recorded temperatures at Station S-4, was 69.1°F and the mean Δt, 3.6°F.

(c). Isothermal cross-section:

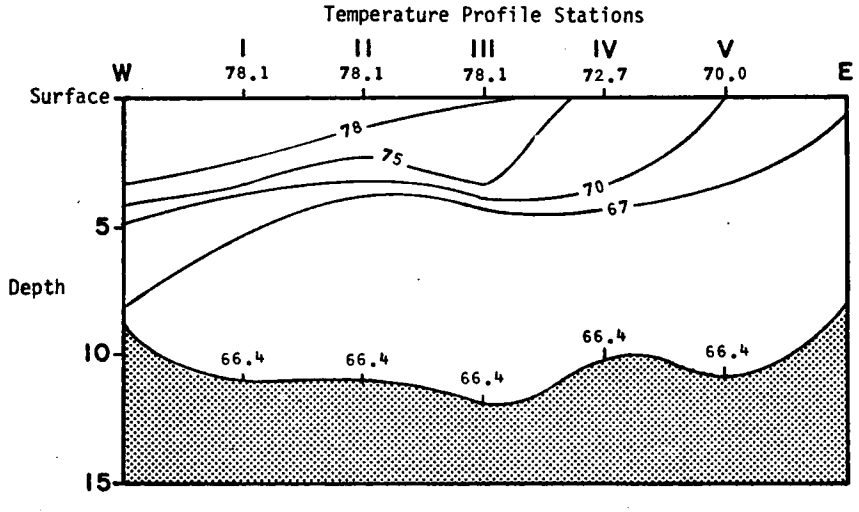

Figure 1. Isothermal cross-section of Station S-4 taken on 24 June 1972.

c. Dissolved Oxygen

(1). Station N-10:

(a). Vertical distribution of dissolved oxygen

	West				East
Data points:	I	II	III	IV	V
Surface to Bottom D.O. Range (ppm):	9.3-9.4	9.3-9.4	9.3-9.4	9.3-9.5	9.2-9.4
Mean Conc. (ppm):	9.3	9.3	9.4	9.4	9.3

(b). Horizontal distribution of dissolved oxygen

Depth (Ft.)	D.O. Range (PPM) Across River	Mean Concentration (PPM)	Mean Percent Saturation
Surface	9.3 - 9.4	9.3	98
1	9.3 - 9.4	9.4	99
2	9.3 - 9.4	9.4	99
3	9.3 - 9.4	9.3	97
4	9.3 - 9.5	9.4	99
5	9.3 - 9.4	9.4 (N=4)	99
6	9.3 - 9.4	9.3 (N=3)	97
7	-----	9.4 (N=3)	99
8	-----	9.4 (N=2)	99

(2). Discharge Canal

Dissolved Oxygen (ppm)	Percentage Oxygen Saturation
7.8	104%

(3). Zero-West

Dissolved Oxygen (ppm)		Percentage Oxygen Saturation	
Mean	Range	Mean	Range
8.5	8.4 - 8.6	97	93 - 105

b. Discharge Canal

Dissolved oxygen and temperature were monitored in the discharge canal at a point just below the last bank of spray modules beginning with activation of the units at 11:25 a.m. on June 30, 1972. Data presented below are for a time span of sufficient duration to allow a complete passage of water from a point just above the first bank of four modules through the entire 56-Module System.

(1). Temperature and Dissolved Oxygen Values -- Spray Module Activation:

Time	Temperature (°F)	Dissolved Oxygen (mg/l)	Percent Saturation
1100	88.7	8.0	108
1130	88.7	7.8	106
1200	87.8	7.6	102
1230	86.9	7.4	98
1300	86.0	7.4	97
1330	85.1	7.4	96
1400	84.2	7.4	95

As is shown by the data, water temperature dropped 4.5°F and percent saturation of dissolved oxygen, 13%. Heated water enters the discharge canal super-saturated with oxygen. The water which is sprayed upwards by the spray modules ~~looses~~ some of this oxygen to the air ~~by~~ turbulent diffusion which results in the noted reduction of percent saturation levels.

3. Merrimack River weekly monitoring data - June 1972

a. Monthly Temperature

Range and Mean Monthly Δt at Station S-4

Range (°F)	Mean (°F)
5.0 - 11.5	7.8

b. Dissolved Oxygen

Station:		N-10	O-W	S-4
PPM	mean	9.4	8.2	8.8
	range	8.8-10.1	8.0-8.4	8.7-9.0
Percent Saturation	mean	98.8	101.8	101.0
	range	95-108	99-105	96-106

c. Comments

During June, prior to the operation of the spray module cooling system, both weekly sampling and the June 24 survey showed peak temperature Δt's at Station S-4 to be consistently 5°F or greater. Data gathered during the June 24, 1972 survey showed a mean Δt computed from all temperatures recorded at Station S-4 to be 3.6°F. Flows for the month ranged from 2,367 to 10,012 cfs with a mean of 4,688 cfs.

Dissolved oxygen saturation levels in the discharge canal and at Stations Zero West and S-4 were generally higher than at Station N-10. As was shown by the horizontal distribution of dissolved oxygen computed from the June 24 sampling, super-saturation at Station S-4 occurred in the upper thermally affected area of the water column as a result of the layering of the super-saturated discharge water over the cooler, near-ambient

waters. Mean percentage saturation values computed from weekly sampling at Zero West and S-4 were also generally higher than at Station N-10 and were greater than 100%. Mean dissolved oxygen concentrations at these two stations were however, reduced over those at Station N-10, due to temperature differences.

B. JULY

1. July 7, 1972

a. Conditions

(1). Unit II in operation.

(2). Spray Modules — Out: 0; Re-Set: 2

(3). Flows: 6-hour averages — 3,084 cfs (1200); 3,166 cfs (1800)

(4). Meterological: Windspeed, Mean = 7.4 mph[1]

Relative Humidity, Mean = 54.3%[1]

b. Water Temperature

(1). Highest Temperatures Noted:

Station:	N-10	O-W	S-4
	7038 (1545)		
Temperature (°F)	69.1	79.9	74.5
Δt's	----	10.8	5.4

(2). Thermal Configuration at Station S-4

(a). Vertical distribution of temperatures

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[1] Concord, New Hampshire Weather Bureau

	West				East
Data Points:	I	II	III	IV	V
Surface to bottom Temp. Range (°F):	68.2-70.9	68.2-73.6	68.2-74.5	68.2.-74.5	68.2-70.9
Mean Temp. (°F):	69.1	69.4	69.1	69.3	69.1
% of profile ≥ 5° F Δt:	0	0	8%	8%	0

Depth Range: Δt of ≥ 5° F was confined to the surface layer of water.

(b). Horizontal distribution of temperatures

Depth (ft.)	Temperature Range (°F) Across River	Mean Temperature (°F)	Mean Δt (°F)
Surface	70.9-74.5	72.9	3.8
1	69.1-71.8	70.5	1.4
2	69.1-70.9	70.0	0.9
3	-----	69.1	0.0
4	68.2-69.1	68.9	---
5	68.2-69.1	68.7	---
6	68.2-69.1	68.4	---
7	68.2-69.1	68.4	---
8	68.2-69.1	68.4	---
9	68.2-69.1	68.4 (N=4)	---
10	68.2-69.1	68.4 (N=4)	---
11	68.2-69.1	68.2 (N=4)	---
12	-----	68.2 (N=1)	---

The mean temperature, computed from all recorded temperatures at Station S-4, was 69.3°F and the mean Δt, 0.2°F.

(c). Isothermal cross-section: An isothermal cross-section of Station S-4 is presented In Figure 2.

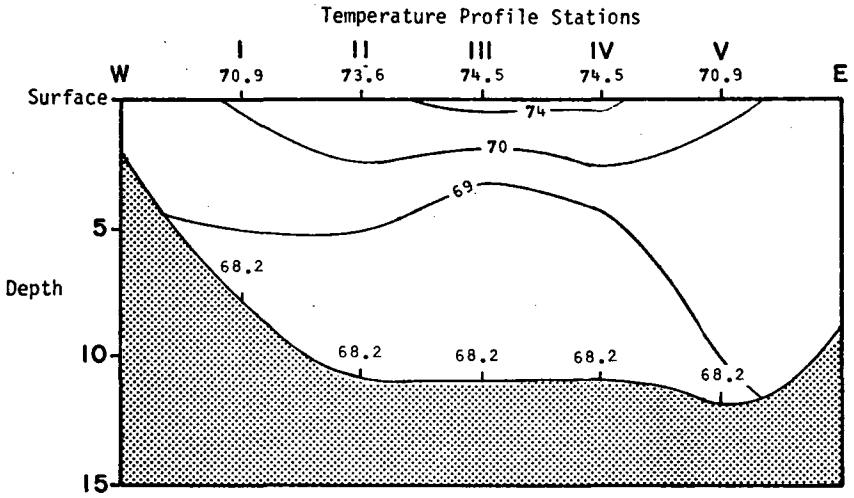

Figure 2. Isothermal cross-section of Station S-4 taken on 7 July 1972.

c. Dissolved Oxygen

(1). Station N-10:

(a). Vertical distribution of dissolved oxygen

	West				East
Data Points:	I	II	III	IV	V
Surface to bottom D.O. Range (ppm):	8.2-8.7	8.7-9.1	8.8-9.2	8.8-9.4	8.7-9.1
Mean Conc. (ppm):	8.6	8.9	9.1	9.2	9.0

(b). Horizontal distribution of dissolved oxygen

Depth (ft.)	D.O. Range (PPM) Across River	Mean Concentration (PPM)	Mean Percent Saturation
Surface	8.2 - 9.3	8.8	96
1	8.3 - 9.3	9.0	98
2	8.7 - 9.3	9.1	99
3	8.7 - 9.4	9.1	99
4	8.6 - 9.4	9.0	98
5	8.8 - 9.3	9.0	98
6	8.7 - 9.3	9.0	98
7	8.9 - 9.2	9.1 (N=3)	99
8	9.0 - 9.2	9.1 (N=3)	99
9	-----	8.8 (N=2)	96
10	8.8 - 8.9	8.9 (N=2)	98
11	-----	8.8 (N=1)	96
12	-----	8.7 (N=1)	95

(2). Discharge Canal

Dissolved Oxygen (ppm)		Percentage Oxygen Saturation	
Mean	Range	Mean	Range
7.7	7.5-7.9	96	93-98

(3). Zero-West

Dissolved Oxygen (ppm)		Percentage Oxygen Saturation	
Mean	Range	Mean	Range
7.2	6.8-7.6	84	76-93

(4). Station S-4

(a). Vertical distribution of Dissolved Oxygen

	West				East
Data Points:	I	II	III	IV	V
Surface to bottom D.O. Range (ppm):	8.4-9.0	8.2-8.9	8.4-9.1	7.8-9.1	8.2-8.8
Mean Conc. (ppm):	8.8	8.6	8.8	8.9	8.7

(b). Horizontal distribution of dissolved-oxygen

Depth (ft.)	D.O. Range (PPM) Across River	Mean Concentration (PPM)	Mean Percent Saturation
Surface	7.8 - 8.4	8.2	93
1	8.2 - 9.0	8.6	95
2	8.5 - 8.9	8.6	95
3	8.6 - 9.1	8.8	96
4	8.6 - 9.1	8.8	97
5	8.6 - 9.1	8.9	97
6	8.6 - 9.1	8.9	96
7	8.5 - 9.1	8.8	96
8	8.4 - 9.1	8.8	96
9	8.7 - 9.1	8.9 (N=4)	97
10	8.6 - 9.1	8.8 (N=4)	96
11	8.7 - 9.1	8.9 (N=4)	97
12	-----	8.8 (N=1)	96

2. July 26, 1972

a. Conditions

(1). Unit II in operation

(2). Spray Modules . Out: 1
Re-Set: 14

(3). Flows: 6-hour averages 4,385 cfs (1200)
4,437 cfs (1800)

(4). Meteorological: Windspeed, Mean = 13.4 mph[1]

Relative Humidity, Mean = 54.4 %[4]

b. Water Temperature

(1). Highest Temperatures Noted:

Station:	N-5[2]	O-W	S-4
			80.57
Temperature (°F)	73.6[3]	79.9	78.1
Δt's	----	6.3	3.9

[1]Concord, New Hampshire Weather Bureau.

[2]Sampled in lieu of Station N-10 due to time and weather limitations -- temperatures at the two stations would have been comparable if not identical.

[3]Ambient temperature increased 0.6°F by the time Station S-4 measurements were completed.

[4] calculated from data obtained at 2-hour intervals during the survey

(2). Thermal Configuration at Station S-4

(a). Vertical distribution of temperatures

	West				East
Data Points:	I	II	III	IV	V
Surface to bottom Temp. Range (°F):	74.5-74.8	74.5-75.4	74.1-77.2	74.3-78.1	74.5-75.4
Mean Temp. (°F):	74.8	74.7	74.8	74.8	74.7
% of profile ≥ 5° F Δt:	0	0	0	0	0

Depth Range : N/A

(b). Horizontal distribution of temperatures

Depth (ft.)	Temperature Range (°F)	Mean Temperature (°F)	Mean Δt (°F)
Surface	74.8 - 78.1	76.1	1.9
1	74.8 - 75.4	75.0	0.8
2	74.8 - 75.4	74.8	0.6
3	74.5 - 74.8	74.7	0.5
4	74.5 - 74.8	74.7	0.5
5	74.5 - 74.8	74.7	---
6	74.5 - 74.7	74.5	---
7	74.1 - 74.7	74.5	---
8	74.1 - 74.7	74.5	---
9	74.1 - 74.5	74.5 (N=4)	---
10	74.1 - 74.5	74.5 (N=4)	---
11	74.1 - 74.5	74.5 (N=3)	---
12	74.1 - 74.5	74.5 (N=3)	---
13	74.1 - 74.5	74.5 (N=2)	---
14	-----	74.5 (N=1)	---

The mean temperature computed from all recorded temperatures at Station S-4, was 74.7°F and the mean Δt, 0.5°F.

(c). Isothermal cross-section: An isothermal cross-section of Station S-4 is presented in Figure 3.

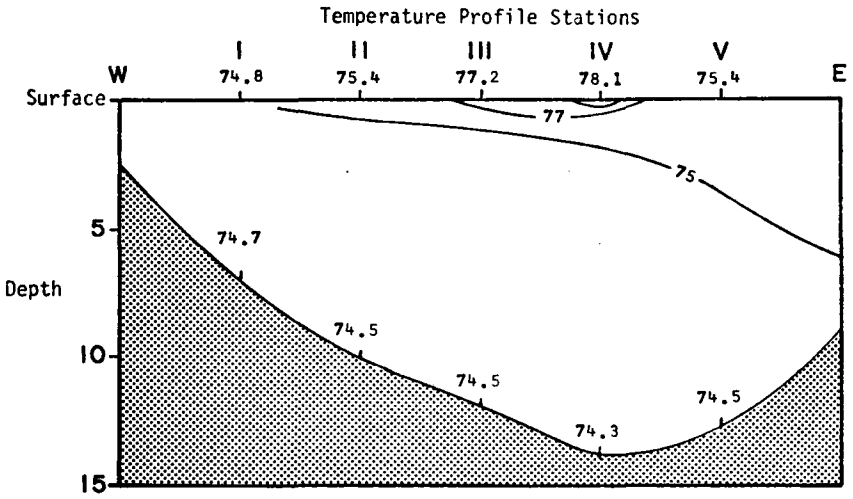

Figure 3. Isothermal cross-section of Station S-4 taken on 26 July 1972.

c. Dissolved Oxygen

(1). Station N-5

(a). Vertical distribution of dissolved-oxygen

	West				East
Data Points:	I	II	III	IV	V
Surface to bottom D.O. Range (ppm):	7.6-7.8	7.8-8.2	8.1-8.2	8.0-8.2	7.6-8.2
Mean Conc. (ppm):	7.7	8.0	8.2	8.1	7.9

(b). Horizontal distribution of dissolved-oxygen

Depth (ft.)	D.O. Range (PPM) Across River	Mean Concentration (PPM)	Mean Percent Saturation
Surface	7.8 - 8.2	8.1	94
1	7.8 - 8.2	8.0	93
2	7.8 - 8.2	8.0	93
3	7.7 - 8.1	8.0	93
4	7.6 - 8.1	7.9	92
5	7.6 - 8.1	7.9 (N=4)	92
6	7.7 - 7.8	7.8 (N=2)	91

(2). Discharge Canal

Dissolved Oxygen (ppm)	Percentage Oxygen Saturation
7.0	88%

(3). Zero-West[1]

Dissolved Oxygen (ppm)		Percentage Oxygen Saturation	
Mean	Range	Mean	Range
7.1	6.9-7.3	85	83-87

(4). Station S-4

(a). Vertical distribution of dissolved-oxygen

	West			East	
Data Points:	I	II	III	IV	V
Surface to bottom D.O. Range (ppm):	6.5-7.2	7.1-7.5	7.5-8.0	7.9-8.2	7.9-8.2
Mean Conc. (ppm):	6.9	7.3	7.8	8.1	7.9

[1] Monitoring of dissolved oxygen during the survey indicated no unusual concentration fluctuation resulting from operation of the spray modules.

(b). Horizontal distribution of dissolved-oxygen

Depth (ft.)	D.O. Range (PPM) Across River	Mean Concentration (PPM)	Mean Percent Saturation
Surface	7.0 - 8.2	7.7	90
1	6.8 - 8.0	7.6	89
2	6.8 - 8.2	7.7	91
3	6.7 - 8.2	7.6	89
4	6.8 - 8.2	7.6	89
5	6.5 - 8.2	7.5	88
6	6.8 - 8.2	7.5	87
7	6.7 - 8.2	7.5	88
8	7.3 - 8.2	7.8 (N=4)	91
9	7.1 - 8.1	7.8 (N=4)	91
10	7.1 - 8.0	7.8 (N=4)	91
11	-----	8.0 (N=3)	93
12	8.0 - 8.1	8.0 (N=3)	93
13	8.0 - 8.1	8.1 (N=2)	94
14	-----	8.1 (N=1)	95

3. Merrimack River weekly monitoring data - July 1972

a. Monthly Temperature

Range and Mean Monthly Δt at Station S-4

Range (°F)	Mean (°F)
2.0 - 6.0	4.1 6.59

b. Dissolved Oxygen

Station:		N-10	O-W	S-4
PPM	Mean	8.8	8.1	7.8
	Range	8.1-9.7	7.3-8.7	7.3-8.4
Percent Saturation	Mean	101.2%	100.2%	94.6%
	Range	96-114%	91-105%	89-100%

c. Comments

During July, the first month of spray module operation, maximum Δt's of 5.4°F and 3.9°F were noted at S-4 on July 7 and 26, respectively. Mean cross-sectional Δt's computed from all temperatures recorded at Station S-4 on July 7 were 0.2°F, and 0.5°F on July 26. Flows during the month ranged from 2,034 cfs to 4,367 cfs with a mean of 3,536 cfs.

Data collected during the two July surveys and weekly sampling indicated the percent saturation of dissolved oxygen at Stations Zero West and S-4 was reduced from pre-spray module levels, with the phenomenon of super-saturation being absent in the first few feet of the water column. Dissolved oxygen concentration as determined from weekly sampling, showed differences between stations to be approximately the same as in June.

C. AUGUST[1]

1. August 3, 1972

a. Conditions

(1). Unit II in operation

(2). Spray Modules: Out: 7
Re-Set: 2

(3) Flows: 6-hour averages 2,542 cfs (1200)
2,441 cfs (1800)

(4). Meteorological: Windspeed, Mean = 8.6 mph[2]

Relative Humidity, Mean = 68.1%[3]

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[1]Malfunction in temperature compensating unit prevented the gathering of viable dissolved oxygen data during the August 3, 1972 survey at the profile stations. However, a continual monitoring unit, located at S-4, indicated no unusual fluctuation in concentrations.

[2]Concord, New Hampshire Weather Bureau

[3] calculated from data gathered at 2-hour intervals during the survey.

b. Water Temperature

(1). Highest Temperatures Noted:

Station:	N-5[1]	O-W	S-4
Temperature (°F)	72.7	78.1	75.9
Δt's	----	5.4	3.2

(2). Thermal Configuration at Station S-4

(a). Vertical distribution of temperatures

	West				East
Data Points:	I	II	III	IV	V
Surface to bottom Temp. Range (°F):	74.5-75.4	73.6-75.4	72.7-75.9	72.7-74.7	72.7-73.4
Mean Temp. (°F):	74.8	74.5	73.6	73.0	72.9
% of profile ≥ 5° F Δt:	0	0	0	0	0

Depth Range: Δt of ≥ 5° F not present

(b). Horizontal distribution of temperatures

Depth (ft.)	Temperature Range (°F)	Mean Temperature (°F)	Mean Δt (°F)
Surface	73.6 - 75.9	75.0	2.3
1	73.6 - 74.8	74.5	1.8
2	72.7 - 74.8	73.8	1.1
3	72.7 - 74.8	73.6	0.9
4	72.7 - 74.5	73.4	0.7
5	72.7 - 74.5	73.4	---
6	72.7 - 74.5	73.4	---
7	72.7 - 73.6	73.0 (N=4)	---
8	-----	72.7 (N=3)	---
9	-----	72.7 (N=3)	---
10	-----	72.7 (N=2)	---
11	-----	72.7 (N=2)	---

The mean temperature computed from all recorded temperatures at Station S-4, was 73.6°F and the mean Δt, 0.9°F.

[1] Sampled in lieu of N-10 due to time and weather limitations -- temperatures between the stations would have been comparable, if not identical.

(c). Isothermal cross-section: An isothermal cross-section of Station S-4 is presented in Figure 4.

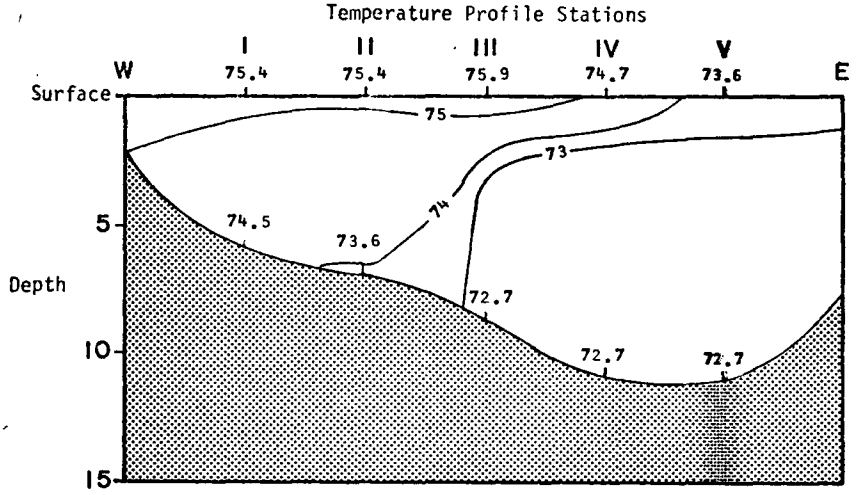

Figure 4. Isothermal cross-section of Station S-4 taken on 3 August 1972.

2. Merrimack River weekly monitoring data - August 1972

Units I and II were not in operation during two of the four weekly samplings in August. Data from the remaining two weeks are presented below:

a. Monthly Temperature

Range and Mean Monthly Δt at Station S-4

Range (°F)	Mean (°F)
6.0 - 8.5	7.3

618

b. Dissolved Oxygen

Station:		N-10	O-W	S-4
PPM	Mean	8.1	7.7	8.0
	Range	7.6-8.5	7.5-7.8	7.6-8.3
Percent Saturation	Mean	90.5%	98.0%	96.5%
	Range	84-97%	94-102%	90-103%

c. Comments

In August, during weekly samplings Δt's at Station S-4 were above 5°F. The August 3, 1972 survey indicated a maximum Δt of 3.2°F, with a cross-sectional Δt of 0.9°F. Flows during the month ranged from 932 cfs to 4,155 cfs with a mean of 1,826 cfs. Oxygen saturation of surface waters at Stations Zero West and S-4 were generally greater than at Station N-10. The disparity of dissolved-oxygen concentration between ambient and thermally affected stations, as shown from weekly sampling, was significantly reduced from those of the previous survey. This is probably the result of (1) increased oxygen demand in ambient waters and (2) increased capacity for dissolved oxygen in the cooled and aerated water due to passage through the spray modules.

D. SEPTEMBER

1. September 18, 1972

a. Conditions

(1). Units I and II in operation

(2). Spray Modules: Out: 11
Re-Set: 3

(3). Flows: 6-hour averages: 1,455 cfs (1200)
1,676 cfs (1800)

(4). Meteorological: Windspeed, Mean - 10.1 mph[1]

Relative Humidity, Mean = 60%

b. Water Temperature

(1). Highest Temperatures Noted:

Station:	N-10	O-W	S-4
Temperature (°F)	68.1[2]	84.5	80.5
Δt's	----	16.4	12.4

(2). Thermal Configuration at Station S-4

(a). Vertical distribution of temperatures

	West				East
Data Points:	I	II	III	IV	V
Surface to Bottom Temp. Range (°F):	68.5-79.8	68.0-80.5	68.0-80.2	68.0-78.5	68.5-77.0
Mean Temp. (°F):	74.3	71.9	71.6	70.7	71.1
% of profile ≥ 5° F Δt:	44%	31%	27%	14%	27%

Depth range: 5° F differences were observed from the surface to 3 ft. but averaged 2.3 ft.

(b). Horizontal distribution of temperature

Depth (ft.)	Temperature Range (°F)	Mean Temperature (°F)	Mean Δt (°F)
Surface	77.0 - 80.5	79.2	11.1
1	76.0 - 80.0	77.9	9.8
2	73.0 - 79.8	76.5	8.4
3	71.5 - 79.5	74.8	6.7
4	69.9 - 73.0	71.0	2.9
5	69.0 - 70.0	69.6	---
6	68.5 - 69.5	68.9	---
7	68.2 - 69.2	68.8	---
8	68.0 - 69.0	68.5	---
9	68.0 - 69.0	68.5 (N=4)	---
10	68.0 - 68.5	68.3 (N=4)	---
11	68.0 - 68.2	68.1 (N=2)	---
12	68.0 - 68.2	68.1 (N=2)	---
13	-----	68.0 (N=1)	---

The mean temperature, computed from all recorded temperatures at Station S-4, was 71.8°F and the mean Δt, 3.7°F.

(c). Isothermal cross-section: An isothermal cross-section of Station S-4 is presented in Figure 5.

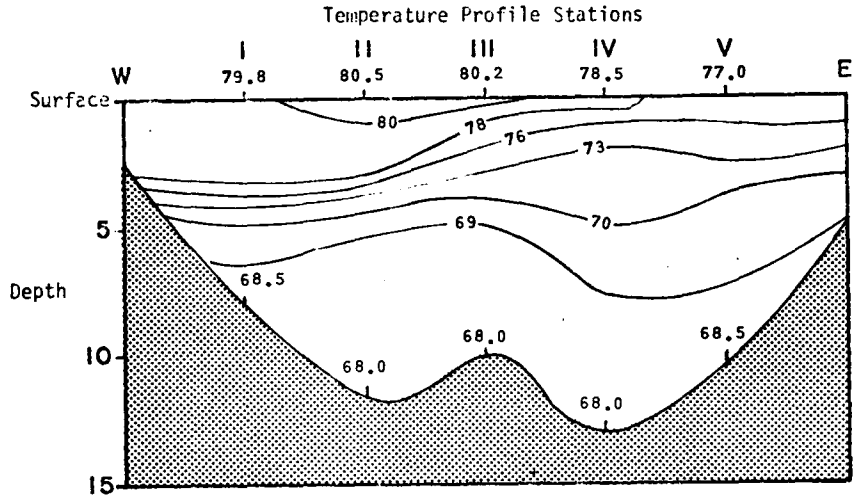

Figure 5. Isothermal cross-section of Station S-4 taken on 18 September 1972.

2. September 21, 1972

a. Conditions

(1). Units I and II in operation.

(2). Spray Modules: Out: 4
Re-Set: 4

(3). Flows: 6-hour averages 1,935 cfs (1200)
1,756 cfs (1800)

(4). Meteorological: Windspeed, Mean = 2 mph

Relative Humidity, Mean = 66.7%

b. Water Temperature

(1). Highest temperatures Noted:

Station:	N-10	O-W	S-4
	66.95 (0430)		77.36 1945
Temperature (°F)	64.8[1]	79.0	73.8
Δt's	----	14.2	9.0

[1] Mean temperature

(2). Thermal Configuration at Station S-4

(a). Vertical distribution of temperatures

	West				East
Data Points:	I	II	III	IV	V
Surface to bottom Temp. Range (°F):	65.6-73.8	65.3-72.4	65.3-71.0	65.3-67.2	65.4-67.0
Mean Temp. (°F):	69.4	67.8	66.8	65.8	65.9
% of profile $\geq$ 5° F Δt:	44%	27%	8%	0	0

Depth Range: 5° differences were observed from surface to 3 ft. but averaged 1.2 ft.

(b). Horizontal distribution of temperatures

Depth (ft.)	Temperature Range (°F) Across River	Mean Temperature (°F)	Mean Δt (°F)
Surface	67.0 - 73.8	70.3	5.5
1	66.6 - 73.5	69.7	4.9
2	66.0 - 73.3	69.1	4.3
3	65.9 - 71.4	67.9	3.1
4	65.8 - 68.8	66.8	2.0
5	65.7 - 66.4	66.0	---
6	66.0 - 65.6	65.8	---
7	65.4 - 65.7	65.6	---
8	65.3 - 65.6	65.4	---
9	65.3 - 65.4	65.4 (N=4)	---
10	65.3 - 65.4	65.3 (N=4)	---
11	65.3 - 65.3	65.3 (N=2)	---

The mean temperature, computed from all recorded temperatures at Station S-4, was 67.0° and the mean Δt, 2.2°F.

(c). Isothermal cross-section: An isothermal cross-section of Station S-4 is presented in Figure 6.

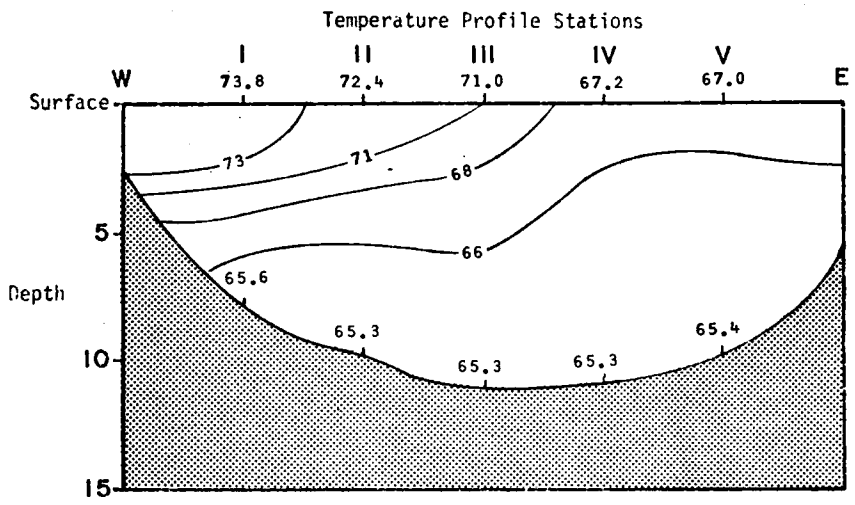

Figure 6. Isothermal cross-section of Station S-4 taken on 21 September 1972.

3. September 26, 1972

a. Conditions

(1). Units I and II in operation.

(2). Spray Modules: Out: 2
Re-Set: 7

(3). Flows: 6-hour averages 1,130 cfs (1200)
1,123 cfs (1800)

(4). Meteorological: Windspeed, Mean = 3.8 mph

Relative Humidity, Mean = 77.7%[2]

b. Water Temperature

(1). Highest Temperatures Noted:

Stations:	N-10[3]	O-W	S-4
Temperature (°F)	62.5[4]	79.0	77.4
Δt's:	----	16.5	13.9

3 Ambient temperature increased 1.0°F by the time S-4 measurements were completed.

4 Mean temperature.

(2). Thermal Configuration at Station S-4

(a). Vertical distribution of temperatures

	West				East
Data Points:	I	II	III	IV	V
Surface to bottom Temp. Range (°F):	63.3-76.8	63.9-77.4	62.6-75.9	63.1-74.5	63.9-76.3
Mean Temp. (°F):	71.2	68.9	68.7	65.8	66.6
% of profile ≥ 5° F Δt:	57%	38%	40%	30%	20%

Depth Range: 5° F differences were observed from surface to 3 ft. but averaged 2.4 ft.

(b). Horizontal distribution of temperatures

Depth (ft.)	Temperature Range (°F) Across River	Mean Temperature (°F)	Mean Δt (°F)
Surface	74.5 - 77.4	76.1	12.6
1	69.4 - 77.4	74.7	11.2
2	67.5 - 76.8	72.9	9.4
3	64.8 - 76.5	69.4	5.9
4	63.9 - 64.8	64.2	0.7
5	63.3 - 64.6	63.9	---
6	63.3 - 63.9	63.7	---
7	63.3 - 63.9	63.7 (N=4)	---
8	63.3 - 63.9	63.7 (N=3)	---
9	62.6 - 63.9	63.1 (N-3)	---

The mean temperature, computed from all recorded temperatures at Station S-4, was 68.0°F and the mean Δt, 4.5°F.

(c). Isothermal cross-section: An isothermal cross-section of Station S-4 is presented in Figure 7.

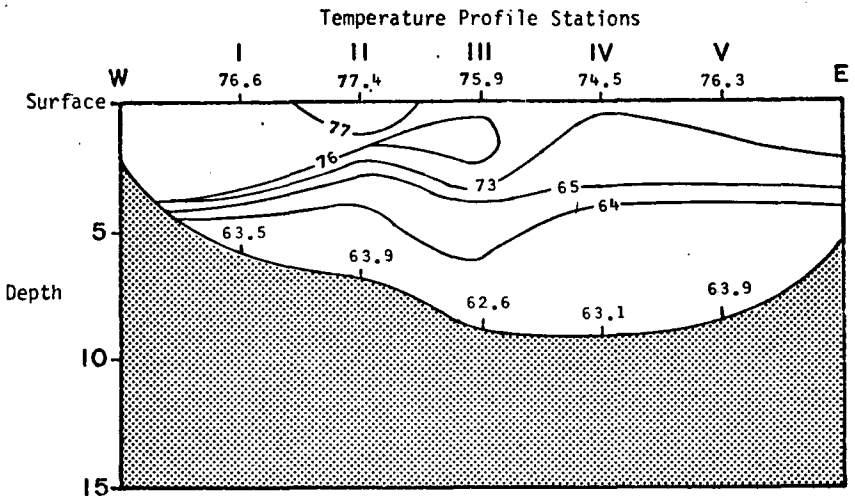

Figure 7. Isothermal cross-section of Station S-4 taken on 26 September 1972.

c. Dissolved Oxygen

(1). Station N-10:

(a). Vertical distribution of dissolved oxygen

	West				East
Data Points:	I	II	III	IV	V
Surface to Botton D.O. Range (ppm):	---	---	8.9-9.0	---	8.9.9.0
Mean Conc. (ppm):	9.1	9.1	9.0	8.9	9.0

(b). Horizontal distribution of dissolved oxygen

Depth (ft.)	D.O. Range (PPM) Across River	Mean Concentration (PPM)	Mean Percent Saturation
Surface	8.9 - 9.1	9.0	92
1	8.9 - 9.1	9.0	92
2	8.9 - 9.1	9.0	92
3	8.9 - 9.1	9.0	92
4	8.9 - 9.1	9.0	92
5	8.9 - 9.1	9.0	92
6	8.9 - 9.1	9.0 (N=4)	92
7	8.9 - 9.0	9.0 (N=2)	92
8	8.9 - 9.0	9.0 (N=2)	92
9	8.9 - 9.0	9.0 (N=2)	92
10	-----	9.0 (N-1)	92
11	-----	9.0 (N-1)	92

(2). Zero-West

Dissolved Oxygen (ppm)		Percentage Oxygen Saturation	
Mean	Range	Mean	Range
8.1	8.1-8.2	98	98-100

(3). Station S-4:[1]

(a). Vertical distribution of dissolved oxygen

	West			East	
Data Points:	I	II	III	IV	V
Surface to Bottom D.O. Range (ppm):	8.5-9.2	8.6-9.2	8.8-9.4	8.7-9.5	8.9-9.4
Mean Conc. (ppm):	8.8	9.0	9.1	9.3	9.2

(b). Horizontal distribution of dissolved oxygen

Depth (ft.)	D.O. Range (PPM) Across River	Mean Concentration (PPM)	Mean Percent Saturation
Surface	8.6 - 8.9	8.8	103
1	8.6 - 9.1	8.8	102
2	8.6 - 9.1	8.8	100
3	8.5 - 9.2	8.9	97
4	8.9 - 9.2	9.2	96
5	9.1 - 9.4	9.2	95
6	9.2 - 9.4	9.3	96
7	9.2 - 9.4	9.3 (N=4)	96
8	9.1 - 9.4	9.4 (N-3)	97
9	9.4 - 9.5	9.4 (N=3)	96

[1]Monitoring of dissolved oxygen during the survey indicated no unusual concentration fluctuations resulting from operation of the spray module.

4. Merrimack River weekly monitoring data - September 1972

a. September 5, 1972

(1). Conditions

(a). Units I and II in operation.

(b). Spray Modules: Out: 9
Re-Set: 6

(c). Flows: 1,638 cfs

(d). Meteorological: Windspeed, Mean = 9.7 mph[1]

Relative Humidity, Mean = 57%

(2). Water Temperature

(a). Highest Temperatures Noted:

Station:	N-10	O-W	S-4
Temperature (°F)	69.0	80.5	75.5
Δt's	----	11.5	6.5

(b). Thermal Configuration of S-4 Profile

Temperature Range (°F)	Mean Temperature (°F)	Percent of profile ≥ 5° F Δt
70.5 - 75.5	72.1	18

[1]Concord, New Hampshire Weather Bureau.

(3). Dissolved Oxygen

Station:	N-10	O-W	S-4
Dissolved Oxygen (ppm)	8.1	8.1	8.1
Percent Saturation	88%	100%	96%

b. September 14, 1972

(1). Conditions

(a). Spray Modules: Out: 18
Re-Set: 1

(b). Flows: 1,042 cfs

(c). Meteorological: Windspeed, Mean = 3.7 mph

Relative Humidity, Mean = 88%

(2). Water Temperature:

(a). Highest Temperatures Noted:

Station:	N-10	O-W	S-4
Temperatures (°F)	62.2[1]	81.0	79.5
Δt's	----	14.8	13.3

---

3 Mean temperature.

(b). Thermal configuration of S-4 Profile:

Temperature Range (°F)	Mean Temperature (°F)	Percent of Profile ≥ 5° F Δt
66.0 - 79.5	71.1	36

(3). Dissolved Oxygen

(a). Dissolved Oxygen

Station	N-10	O-W	S-4
Dissolved Oxygen (ppm)	8.0	8.0	8.5
Percent Saturation	86%	100%	104%

c. September 19, 1972

(1). Conditions

(a). Spray Modules: Out: 9
Re-Set: 4

(b). Flows: 1,289 cfs

(c). Meteorological: Windspeed, Mean = 2.3 mph[1]
Relative Humidity, Mean = 100%

(2). Water Temperature

(a). Highest temperatures Noted:

Station:	N-10	O-W	S-4
Temperature (°F)	67.6[2]	79.9	77.0
Δt's	----	12.3	9.4

[1]Concord, New Hampshire Weather Bureau.

[2]Mean temperature.

(b). Thermal configuration of S-4 Profile:

Temperature Range (°F)	Mean Temperature (°F)	Percent of Profile ≥ 5°F Δt
69.0 - 77.0	72.1	40

(3). Dissolved Oxygen

Station:	N-10	O-W	S-4
Dissolved Oxygen (ppm)	8.2	8.0	8.2
Percent Saturation	88%	98%	98%

d. September 27, 1972

(1). Conditions

(a). Spray Modules — Out: 2; Re-Set: 8

(b). Flows: 1,293 cfs

(c). Meteorological: Windspeed, Mean = 6 mph
Relative Humidity, Mean = 58.3%

(2). Water Temperature

(a). Highest Temperatures Noted:

Station:	N-10	O-W	S-4
Temperature (°F)	64.1[1]	78.9	76.1
Δt's	----	14.8	12.0

[1]Mean temperature.

(b). Thermal configuration of S-4 Profile:

Temperature Range (°F)	Mean Temperature (°F)	Percent of Profile ≥ 5°F Δt
64.0 - 76.1	69.6	18

(3). Dissolved Oxygen

Station:	N-10	O-W	S-4
Dissolved Oxygen (ppm)	9.2	8.4	8.7
Percent Saturation	96%	102%	102%

e. Comments

During September, Δt's at Station S-4 were consistently higher than 5°F. Cross-sectional Δt's ranged from 2.2°F to 4.5°F with a mean of 3.5°F. Flows for the month ranged from 661 cfs to 2,123 cfs with a mean of 1,146 cfs, which represent the lowest flows encountered for the year. Dissolved oxygen saturation levels were higher at Stations Zero-West and S-4 than at N-10, and as a result of this disparity, dissolved-oxygen concentrations at these two stations remained nearly equal to the ambient station throughout the month. Means computed from weekly sampling of dissolved oxygen at Stations N-10, Zero-West, and S-4 during September were 8.4, 8.1, and 8.4 ppm, respectively.

E. OCTOBER

1. October 19, 1972

a. Conditions

(1). Survey was conducted in conjunction with a Spray Module Performance Test.

(2). Units I and II in operation.

(3). Spray Modules: Out: 9
Re-Set: 0

(4) Flows: 6-hour averages 2,113 (1200)
1,638 (1800)

(5). Meteorological: Windspeed, Mean = 3 mph
Relative Humidity, Mean = 38%

b. Water Temperature

(1). Highest Temperatures Noted:

Station:	N-10	O-W	S-4
Temperature (°F)	48.4[1]	63.1	57.8
Δt's	----	14.7	9.4

[1]Mean temperature.

(2). Thermal configurature at Station S-4

(a). Vertical distribution of temperatures

	West				East
Data Points:	I	II	III	IV	V
Surface to bottom Temp. Range (°F):	51.6-55.1	50.4-57.2	49.4-57.8	49.1-56.8	49.3-53.9
Mean Temp. (°F):	53.1	53.0	51.5	51.0	50.9
% of profile ≥ 5° F Δt:	50%	41%	16%	20%	20%

Depth Range: 5°F differences were observed from surface to 4 ft. but averaged 2.4 ft.

(b). Horizontal distribution of temperatures

Depth (ft.)	Temperature Range (°F)	Mean Temperature (°F)	Mean Δt (°F)
Surface	53.9 - 57.8	56.2	7.8
1	53.6 - 56.9	55.8	7.4
2	52.2 - 55.8	53.9	5.5
3	50.8 - 54.1	52.4	4.0
4	49.8 - 53.6	51.7	3.3
5	49.6 - 52.8	51.1	---
6	49.5 - 52.3	50.8	---
7	49.3 - 51.8	50.3	---
8	49.3 - 51.7	50.2	---
9	49.1 - 51.6	50.1	---
10	49.1 - 50.7	49.8 (N=3)	---
11	49.1 - 50.4	49.8 (N=3)	---
12	-----	49.3 (N=1)	---
13	-----	49.3 (N=1)	---
14	-----	49.3 (N=1)	---

The mean temperature, computed from all recorded temperature at Station S-4, was 51°F and the mean Δt, 3.4°F.

9.30

(c). Isothermal cross-section: An isothermal cross-section of Station S-4 is presented in Figure 8.

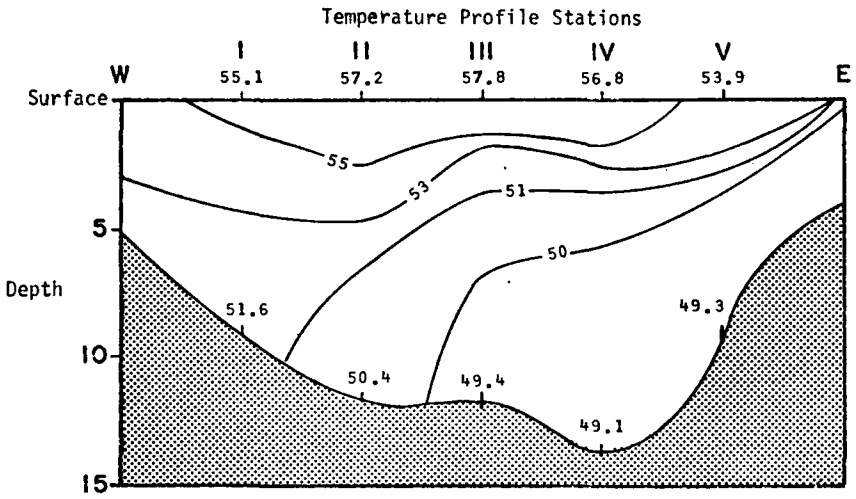

Figure 8. Isothermal cross-section of Station S-4 taken on 19 October 1972.

III. SUMMARY AND CONCLUSIONS

A. DISSOLVED OXYGEN

The spray module cooling system reduced concentration of dissolved oxygen in the discharge canal to levels below super-saturation. In terms of actual oxygen concentrations (ppm) the effect was slight, as cooling the discharge water increased its dissolved-oxygen capacity. During periods of low flows (August and September) reduction in saturation levels at the ambient stations was responsible for similar concentrations at Zero-West and S-4. Monitoring of dissolved oxygen at various times from July through September at both Zero-West and S-4 showed no unusual concentration fluctuations resulting from spray module operation.

B. TEMPERATURE

During low-flow periods, maximum temperature Δt's at Station S-4 were greater than $5^{\circ}F$. At no time during the study period did mean cross-sectional Δt's reach $5^{\circ}F$. On September 26, 1972, the date of the lowest flows recorded during the survey ($\simeq$1,1000 cfs), the cross-sectional Δt was $4.5^{\circ}F$.