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CHEMICAL IMPACT OF SNOW DUMPING PRACTICES

Philip J. O'Brien, et al

Arthur D. Little, Incorporated

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16. ABSTRACT

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Unusually low snowfall during the winters of 1972-73 and 1973-74 together with a nationwide gasoline shortage (which limited or curtailed snow dumping operations) resulted in insufficient data. The following conclusions are, therefore, based on limited observations and tests:

1. Little effect of snow dumping was observed in the downstream concentration of any species examined.
2. Increased chemical concentrations observed during the late summer low-flow period were as great as any effect related to salt use examined in this study.
3. The maximum possible increase in concentration of chloride was calculated to be no more than 0.04 mg/l in the waterbody of lowest dilution volume (Horn Pond). This concentration is less than the precision of the assay technique used.

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14

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FOREWORD

Man and his environment must be protected from the adverse effects of pesticides, radiation, noise and other forms of pollution, and the unwise management of solid waste. Efforts to protect the environment require a focus that recognizes the interplay between the components of our physical environment -- air, water, and land. The National Environmental Research Centers provide this multi-disciplinary focus through programs engaged in

- studies on the effects of environmental contaminants on man and the biosphere, and
- a search for ways to prevent contamination and to recycle valuable resources.

The study described here was undertaken to determine the pollutional magnitude of continued practices of removing and dumping quantities of snow from streets and highways into nearby water bodies or onto water supply watersheds.

A.W. Breidenbach, Ph.D.
Director
National Environmental
Research Center, Cincinnati

ABSTRACT

This report contains the results of a study conducted for the U.S. Environmental Protection Agency to evaluate the chemical effects of dumping of snow collected from the municipal streets into watercourses or waterbodies in three selected areas: a large river (Mohawk at Schenectady, N.Y.), a smaller river (Concord at Lowell, Mass.), and a small pond (Horn in Woburn, Mass.).

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This report was submitted in partial fulfillment of Program Element 1PB034, Contract No. 68-03-0154 by Arthur D. Little, Inc., under the sponsorship of the Environmental Protection Agency. Work was completed in June 1974.

CONTENTS

	Page
Review Notice	ii
Foreword	iii
Abstract	iv
List of Figures	vi
List of Tables	vii
Acknowledgements	viii
CONCLUSIONS	1
SUMMARY AND RECOMMENDATIONS	2
SAMPLING PROGRAM	5
Site Selection	5
CHEMICAL ANALYSES	10
Species Analyzed	10
Samples Base/Methods	12
DATA ANALYSIS	14
REFERENCES	27
APPENDIX A - CHEMICAL ANALYSIS DATA SHEETS	28

FIGURES

No.		Page
1	Location of Representative Snow Dumping Sites	6
2	Sampling Locations - Mohawk River, Schenectady, New York	7
3	Sampling Locations - Concord River, Lowell, Massachusetts	8
4	Sampling Locations - Horn Pond, Woburn, Massachusetts	9
5	Chloride Concentration Levels	16
6	Nitrate Concentration Levels	17
7	Phosphate Concentration Levels	18
8	Chromium Concentration Levels	19
9	Lead Concentration Levels	20
10	Iron Concentration Levels	21
11	Total Solids Concentrations	22
12	Total Dissolved Solids Concentration Levels	23
13	Comparison of Woburn Chloride, Nitrate and Lead Lead Values	24
14	Comparison of Lowell Chloride, Nitrate and Lead Values	25
15	Comparison of Schenectady Chloride, Nitrate and Lead Values	26

TABLES

No.		Page
1	Chemical Species, Analytical Method and Detection Limit	11
2	Sampling Frequency	13
A-1	Summary of Sampling Analysis - Chloride, Cyanide	29
A-2	Summary of Sampling Analysis - Nitrate Nitrogen, Total Phosphorous	30
A-3	Summary of Sampling Analysis - Ammonia Nitrogen, Total Kjeldahl Nitrogen	31
A-4	Summary of Sampling Analysis - Chromium, Cr^{+6}	32
A-5	Summary of Sampling Analysis - Copper, Lead	33
A-6	Summary of Sampling Analysis - Iron, Zinc	34
A-7	Summary of Sampling Analysis - Sodium, Calcium	35
A-8	Summary of Sampling Analysis - Mercury, Nitrite Nitrogen	36
A-9	Summary of Sampling Analysis - Total Solids. Dissolved Solids	37
A-10	Summary of Sampling Analysis - Oil and Grease, COD	38
A-11	Summary of Sampling Analysis - Loss on Ignition	39

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Anthony Samsel and Richard Pride of Arthur D. Little, Inc., were responsible for gathering samples, and Celeste Babineau, Jane Morris, and Lawrence Damokosh analyzed them.

CONCLUSIONS

The following conclusions have been reached as a result of a snow sampling and analysis program conducted in New York and Massachusetts during the two winter seasons 1972-73 and 1973-74. The conclusions specifically and exclusively refer to the chemical effects of the dumping of snow collected from municipal streets into watercourses and waterbodies.

- Little effect of snow dumping is observed in the downstream concentration of any of the chemical species analyzed.

- Increased chemical concentrations observed during the late summer low-flow periods are as great as any effect related to salt use as examined in this study.

These conclusions are based on limited observations and tests due to unusual low snowfall during the study period, together with a nationwide gasoline shortage (which limited or curtailed snow dumping operations in the study areas).

SUMMARY AND RECOMMENDATIONS

SUMMARY

The United States annually applies approximately 9 million tons of salt or other deicing chemicals to its highways to improve winter driving conditions. In some locations, these deicing salts have had an adverse effect on roadside vegetation and on surface water and groundwater supplies. Salt enters these systems by one or a combination of three possible pathways:

1. Salt dissolves in the melting snow and runs off directly;

2. Traffic splashes the salt or salt solution onto the roadside environment where it percolates into the soil entering the water table or is deposited on the roadside vegetation;

3. Salt-laden ice and snow is picked up and hauled away for disposal in waterbodies or on land.

Many highway departments dispose of snow in nearby waterbodies (lakes, ponds, rivers, and streams). This practice is most common in urban areas with large snowfalls where the area available for storage of collected snow is limited. Along with the deicing agent, primarily sodium chloride, other substances that become mixed with the snow are suspended solids, organics, phosphates, lead, oil, trash, soot, and soil. All of these substances may have an adverse impact on the ecology of the receiving waterbody.

The effect of snow dumping upon the receiving waterbody is dependent upon a number of variables:

- size of the waterbody (amount of diluting water receiving runoff or snow disposal),
- rate of water flow,
- amount of snow disposed,
- nature of disposal site (ice or open water),
- amount of deicing substance,
- presence of other substances,
- amount of deicing agent from runoff, and
- other sources of pollution.

A study in the State of Washington by Sylvester and Dewalle states that dumping of large quantities of snow and ice containing deicing chemicals and other roadside contaminants into bodies of water may concentrate the adverse effects of highway runoff at the dumping site. Impacts associated with highway runoff and storm sewer inflow and the presence of deicing salts in particular include: a salty taste of water caused by salt; small amounts of toxic cyanides and chromates, which harm aquatic biota and are cause for rejection of public water supply use; and phosphates, which may stimulate undesirable growth of aquatic plants. The Washington State Highway Department does not presently dispose of snow in waterbodies.[1]

Desmaris[2] studied snow disposal in Ottawa, Canada, including the impacts of snow disposal by dumping either on ice or in fast-flowing open water. These two methods of snow disposal have subsequently been abandoned upon recommendations of the Ministry of the Environment of Ontario. In the Ottawa area, snow disposal on ice was in shallow water with a low-velocity flow rate. Chloride from road salt in this snow was not found to be a major concern because it steadily leached out of the dumped snow during the winter and the remaining chloride was greatly diluted when the ice breakup occurred during spring runoff. The principal problem associated with snow disposal on ice is the blanketing effect of the sediment, which is mixed with the snow, on riverbed vegetation. During spring thaw the ice melts and the sediment sinks to the bottom leading to increased concentration of lead in river bottom sediments.

For example, at one point on the Rideau River when snow was dumped on ice, the concentration of lead in sediment was found to be 1,344 mg/kg. The Rideau River has a mean lead concentration in the bottom sediment of 42 mg/kg. In 1972, the lead concentration in the former snow disposal site was 183 mg/kg, a reduction indicating that physical scour was taking place.

In order to determine the impact of the direct disposal of snow into rivers, a controlled experiment was performed on March 3, 1973. About 520 tons of snow per hour were dumped into the Ottawa River from two sites in the City of Ottawa. The samples contained an average of from 2,410 mg/kg to 3,965 mg/kg of salt in the snow. The chloride value upstream in the Ottawa River was 4.2 mg/l. The surface water at the monitoring site downstream yielded a measured chloride content of 3.7 mg/l, with 3 mg/l measured at 5-, 10-, and 15-foot depths. Monitoring at a site somewhat further downstream for three days (March 3-5) revealed a chloride content of 4.0, 5.0, and 3.0 mg/l, respectively. These data suggest that dumping snow at the test rate of 520 tons per hour had little or no effect on the chloride readings in the Ottawa River, even with snow containing as much salt as 3,965 mg/kg.

The purpose of this study was to examine the impact of direct dumping of salt-contaminated snow into watercourses and waterbodies in the process of municipal snow removal. Specifically, we:

- Identified the areas and specific locations where the snow was being disposed of,

- Determined quantitatively the chemical characteristics of the snow being disposed of in three selected locations, and

- Monitored the depository before and after dumping to determine time-related chemical concentrations during the period from December, 1972 to February, 1974, a period that had unusually low snowfall for the study area and that was affected by a nationwide gasoline shortage which limited or curtailed snow-dumping operations.

RECOMMENDATIONS

Areas that require snow disposal operations must have prearranged plans for dump sites. Material mass balances should be estimated, and every effort should be made to minimize the effect of discharge of waste materials from snow disposal areas into the aquatic environment.

SAMPLING PROGRAM

SITE SELECTION

The three sites selected for sampling and analysis (Figure 1) are located at and near:

Mohawk River - Schenectady, New York;
Concord River - Lowell, Massachusetts; and
Horn Pond - Woburn, Massachusetts.

These sites were selected because they represent a range of conditions; a large river, a relatively slowly flowing river, and a small pond. In addition, the sites were accessible during the winter and within 200 miles of Cambridge, Massachusetts, so that constraints could be met for sample retention time (such as for cyanide, which had to be analyzed within 24 hours of sample collection).

Mohawk River - Schenectady, New York

The City of Schenectady is on the banks of the Mohawk River west of that river's confluence with the Hudson. Contractors haul and dump snow from the downtown shopping area into the Mohawk River (Figure 2). Within the last two years, the New York State Water Resources Commission has reclassified the stretch of the river including the dump area from "B" to "A". The best usage of Class "B" waters is for bathing and any other usages except as a source of water supply for drinking, culinary, or food processing purposes. The best usage of Class "A" waters is as a source of water supply for drinking, culinary, or food processing purposes and any other usage. Downstream from the dump site, the Town of Niskayuna has a groundwater, induced infiltration well-field water supply. As a result, the quality of the river water is of fundamental importance to the quality of the water produced by Niskayuna wells.

Concord River - Lowell, Massachusetts

The Lowell Department of Public Works collects snow and dumps it directly into the Concord River just upstream of that river's confluence with the Merrimack River (Figure 3). Lowell utilizes 25 city trucks, as well as 28 vehicles from private contractors during snow removal operations.

Horn Pond - Woburn, Massachusetts

The Town of Woburn, Massachusetts, is located about 10 miles northwest of Boston in the Mystic River Watershed. Snow cleared from downtown Woburn streets was dumped directly into Horn Pond (Figure 4) when the study was initiated but the practice was subsequently discontinued. From the pond the water flows southeastward via Horn Pond Brook to the Aberjona River and thence into the Mystic Lakes. Chloride levels in the Mystic Lakes have increased significantly in recent years. Samples taken in Horn Pond by Massachusetts Department of Public Health officials show an increase in chlorides from 97 mg/l to 180 mg/l in the period 1970-71.

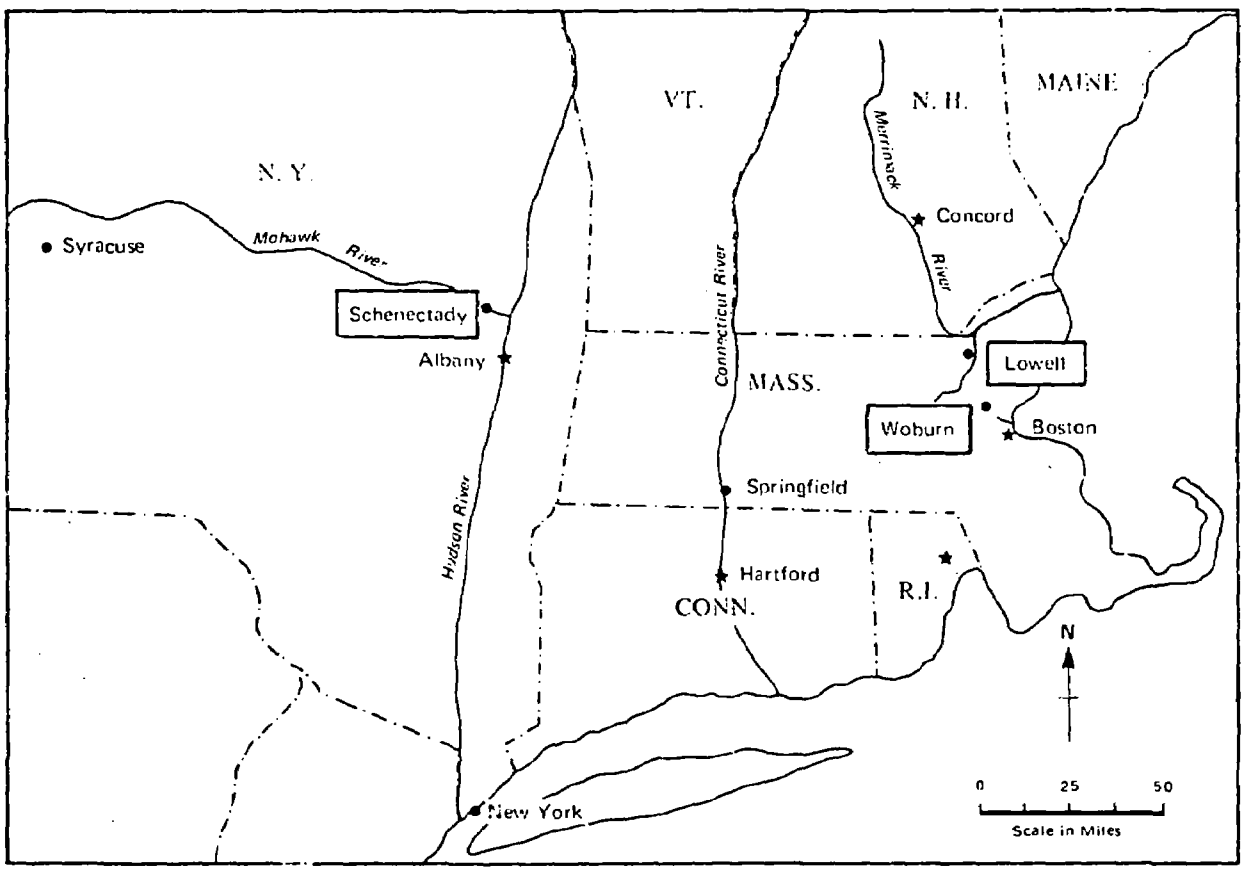


FIGURE 1 LOCATION OF REPRESENTATIVE SNOW DUMPING SITES

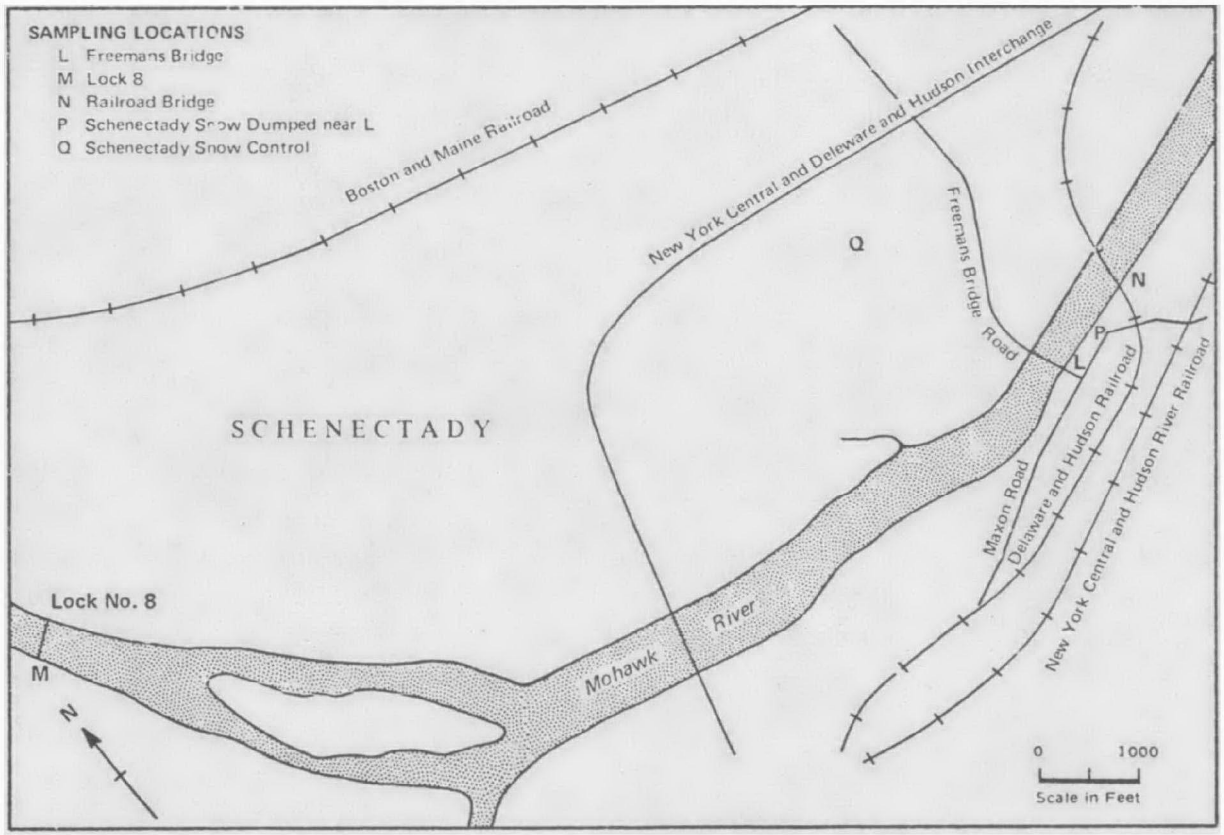


FIGURE 2 SAMPLING LOCATIONS – MOHAWK RIVER, SCHENECTADY, NEW YORK

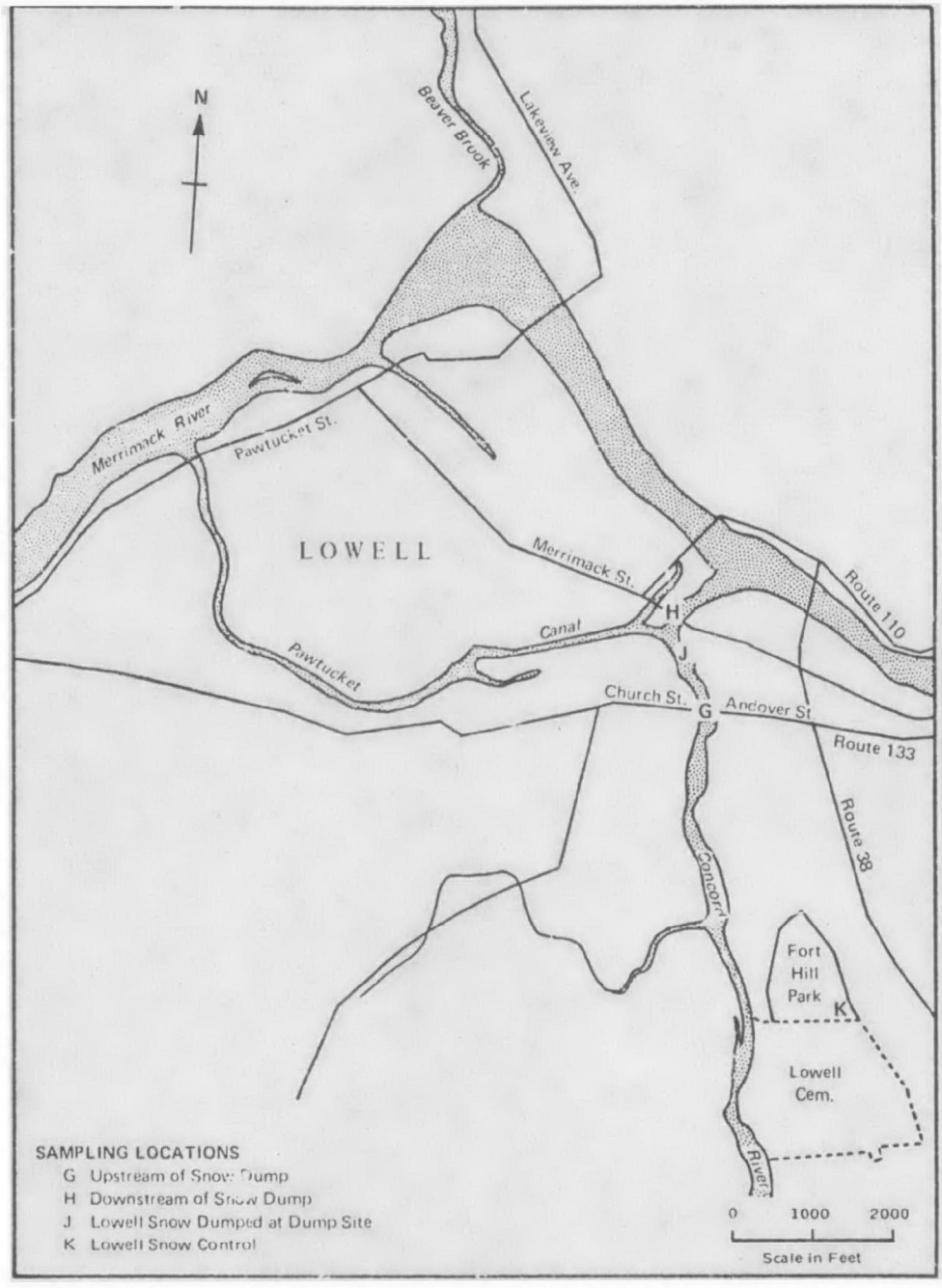


FIGURE 3 SAMPLING LOCATIONS – CONCORD RIVER, LOWELL, MASSACHUSETTS

Supporting analyses were made by Massachusetts Department of Public Works personnel.

A recent study[3] indicated that chloride levels at or near study sites A and D (Figure 4) exceeded 200 mg/l (Cl^-). The authors concluded that the source of the chloride was not related to snow dumping practices since five samples taken during October and November 1973 from a small stream entering the Pond contained an average chloride content of more than 225 mg/l.

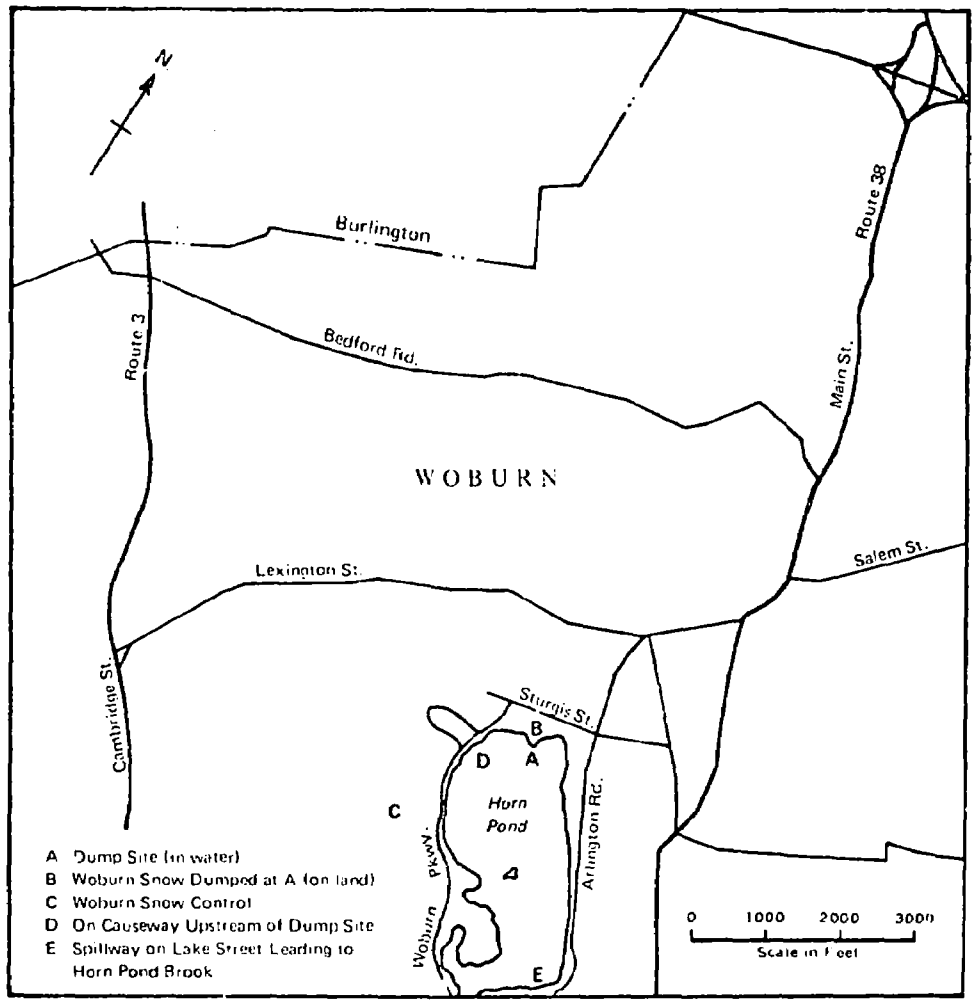


FIGURE 4 SAMPLING LOCATIONS – HORN POND, WOBURN, MASSACHUSETTS

CHEMICAL ANALYSES

SPECIES ANALYZED

A large number of chemical species or groups was selected for regular analysis on the basis of several criteria. Species such as chloride, chromium, and cyanide were measured as representatives of the direct impact of snow-dumping practices. Species such as lead, iron and oil and grease were selected to show the indirect effect of dumping caused by cars. Still other species such as mercury were analyzed in order to study the secondary effects of dumping on water quality - e.g., the possible chloride release of mercury from sediments. Other species and categories such as chemical oxygen demand (COD), phosphate, and nitrate were measured as normal indicators of water quality. The total list of species analyzed is given in Table 1, along with the analytical method used and the normal detection limits.

Analysis for mercury was performed by a flameless atomic-absorption method slightly modified to utilize the oxidizing potential of bromine. Nitrate nitrogen and ammonia nitrogen analyses were performed by use of ion-specific electrodes manufactured by Orion Research Corporation of Cambridge, Massachusetts. Analysis for cyanide was initially done by the method as described in the EPA Methods book, but was later modified to incorporate improvements suggested by EPA as indicated in ASTM Method D 2037-72. Analysis for oil and grease was done by means of the Freon 113 modification given in EPA AQC Newsletter #15, October, 1972 which allows cold extraction with the above solvent. Samples for optical emission spectroscopy were prepared by evaporation in the presence of Specpure lithium nitrate (Johnson Matthey Chemicals, London).

Table 1. CHEMICAL SPECIES, ANALYTICAL METHOD, AND DETECTION LIMIT

Species	Method	Detection Limit
Cl^-	Mercuric nitrate titration[a]	0.5 mg/l
CN^-	Colorimetric[b]	0.01 mg/l
NO_3^-/N	Ion specific electrode	0.1 mg/l
NH_3/N	Ion specific electrode	0.5 mg/l
TKN	Colorimetric[b]	0.05 mg/l
NO_2^-/N	Colorimetric[b]	2 μg/l
Total P	Colorimetric[b]	0.01 mg/l
COD	xs Cr_2O_7 titration[b]	10 mg/l
Solids -- Total Dissolved, Volatile	Gravimetric[b]	1 mg/l
Oil and Grease	Gravimetric[c]	0.5 mg/l
Na, Ca, Fe, Pb, Cr, Cu, Zn	Optical emission spectrometry	2-5 μg/element
Hg	Flameless atomic absorption	2 μg/l
Cr^{+6}	Colorimetric[a]	5 μg/l

(a) Standard Methods for the Examination of Water & Wastewater, 13th Edition.

(b) Methods for Chemical Analysis of Water & Wastes, 1971, EPA.

(c) Same as given in (a) with the Freon 113 modification (EPA AQC Newsletter #15, October 1972).

SAMPLE BASE/METHODS

Samples were collected from each site to be as representive as possible of

- The water at the dumping location,
- An upstream reference water sample,
- A water sample downstream from the dump site,
- The dumped snow, and
- A reference control snow sample from a nearby area.

The sampling frequency was either biweekly or monthly as shown in Table 2 and as shown specifically by date and location in Appendix A.

Collection of samples was carried out under a variety of field conditions and required only one piece of special equipment, a Van Dorn water sampler. The Van Dorn Sampler is a PVC cylinder with stoppers on each end connected internally by a piece of surgical tubing. These stoppers are hooked open, and the sampler is lowered on a nylon rope until it is 1 or 2 ft under the surface of the water. A triggering mechanism is then released (which unhooks the stoppers), the elastic surgical tube snaps the stoppers closed, and the sampler is hauled out. Then the cocks are opened and approximately 6 liters is poured into plastic bottles, coded, and recorded. This sampling method was used in Schenectady at the Freeman Street bridge (Figure 2, Location L), the railroad bridge (Figure 2, Location N) and at Lock 8 (Figure 2, Location M). It was also used in Lowell at the upstream and downstream sample locations (Figure 3, Locations G and H, respectively).

At Horn Pond samples were taken from the water's edge. The sample bottle was submerged by hand with the cap screwed on loosely. Once the bottle had been submerged, the cap was removed and the bottle filled. After removal from the water the bottle was coded.

At the snow control sites, the sampler walked into a field of virgin snow approximately thirty feet from the road, brushed the top layer of snow aside, and filled a barrel containing a plastic liner. The container was then coded and returned to the laboratory.

At the actual dump sites, the dump trucks would stop long enough for the sampler to remove from the load one or two shovelsful of snow, which were placed in a plastic-lined barrel. The procedure was repeated for three or four trucks which approximately filled the bag. The bag was then coded and returned to the laboratory.

All samples were returned to the ADL Laboratory on the day they were taken and stored at 40°F. All analyses were performed in the laboratory.

Table 2. SAMPLING FREQUENCY

Species	Samples to be Analyzed	Frequency[a]
Na, Ca, Fe, Pb, Cr, Cu, Zn, Hg	downstream water and snow	monthly
Cl^-, NO_3^-, PO_4^{-3}	all samples	biweekly or monthly
Solids: total, dissolved	all samples	biweekly or monthly
NH_3, TKN	all samples	biweekly or monthly
Oil and Grease	snow and downstream samples	biweekly or monthly
COD	all samples	biweekly or monthly
CN^-	all samples	biweekly or monthly
Hg	sediments	several samples
Cr^{+6}	all samples	monthly

(a) depending on season

DATA ANALYSIS

All of the analytical results obtained on the various samples are grouped according to the species analyzed and are tabulated in the Appendix. In order to facilitate analysis, some of the results have been presented graphically in Figures 5-15 at the end of this section. These figures present upstream (solid line) and downstream (dash line) results for chloride, nitrate, phosphate, total chromium, lead, iron, total solids and total dissolved solids. The arrows along the calendar axis of the graph indicate the dates on which snow was dumped at the site and snow samples were collected. As the figures indicate, there was limited or no dumping (Woburn after February 1973) at the sites due to the unusually low snowfall and to a reduction in snow loading and hauling occasioned by the fuel shortage during the 1973-74 winter season. Most agencies used their fuel allocation for plowing operations. Therefore, interpretation of these data must be made with this in mind.

Under the minimal conditions observed, snow dumping had little direct impact on the downstream concentration of any species (compare dashed and solid lines). Little effect was noticeable particularly at Horn Pond where the effect should have been most readily observed since flow conditions in the Pond are the lowest of the three sites that were studied.

The data for chloride (Figure 5) suggests a general impact of salting on chloride levels, but this must be the result of indirect runoff effects since both upstream and downstream levels are the same. It is interesting to note that the summer concentration due to low flow and reduced dilution volume is as great as that during the winter when salt is being used. Other interesting changes are observed, such as the nitrate peak during May and June (Figure 6), but once again, this change appears not to be attributable to the practice of snow removal and dumping since levels upstream and downstream are the same.

Of the variations observed in phosphate levels (Figure 7), none seem to be associated with the periods of heavy salt usage. The total chromium levels (Figure 8) do appear to be higher during the winter. Similar trends were not observed for lead (Figure 9) and iron (Figure 10).

The relatively toxic cyanide species, which could be released from the anti-caking agents in the salt, is only observed in the dump snow samples--none could be detected in any of the water samples.

The concentrations of total solids (Figure 11) and total dissolved solids (Figure 12) both varied similarly to the variation observed for chloride. These levels would indicate that the concentrations are attributable to normal flow variation in the three sampling areas.

In Figures 13-15, the levels of chloride, nitrate, and lead are compared as measures of three different water quality contributors for the downstream values at each of three sites. There is no apparent correlation between these different measures of water quality and the chloride levels either as a measure of total salting practice or as a measure of snow dumping.

The results of this study are in agreement with those of the Ottawa study[2] previously discussed. For all of the species analyzed, there was no significant difference between upstream and downstream concentration levels that could be attributable to dumping of snow. These results are not at all surprising when one considers the large dilution volume into which a relatively small amount of snow is dumped at any one time.

As a worst case example, calculations were made of the impact of dumping into Horn Pond in Woburn from a single storm. It was assumed that the snow is only diluted by the holding volume of pond. The pond has an area of about 5×10^5 square meters and an average depth of 6 meters for a volume 3×10^6 cu meters. During the February 1, 1973 storm, the measured average chloride concentration was 680 mg/l in the snow dumped into the pond. About 100 truck loads of snow were dumped, each with an average load of 1800 kg (2 tons), resulting in about 120 kg of chloride dumped with the snow. (Normal seasonal snowfall would result in significant increases in total amounts dumped.) If this chloride was thoroughly mixed with the total volume in the Pond, it would result in a concentration of only 0.04 mg/l, or less than the precision (0.5 mg/l) of the assay technique for chloride. The direct impact of such dumping in the high flow river sites would have been even less.

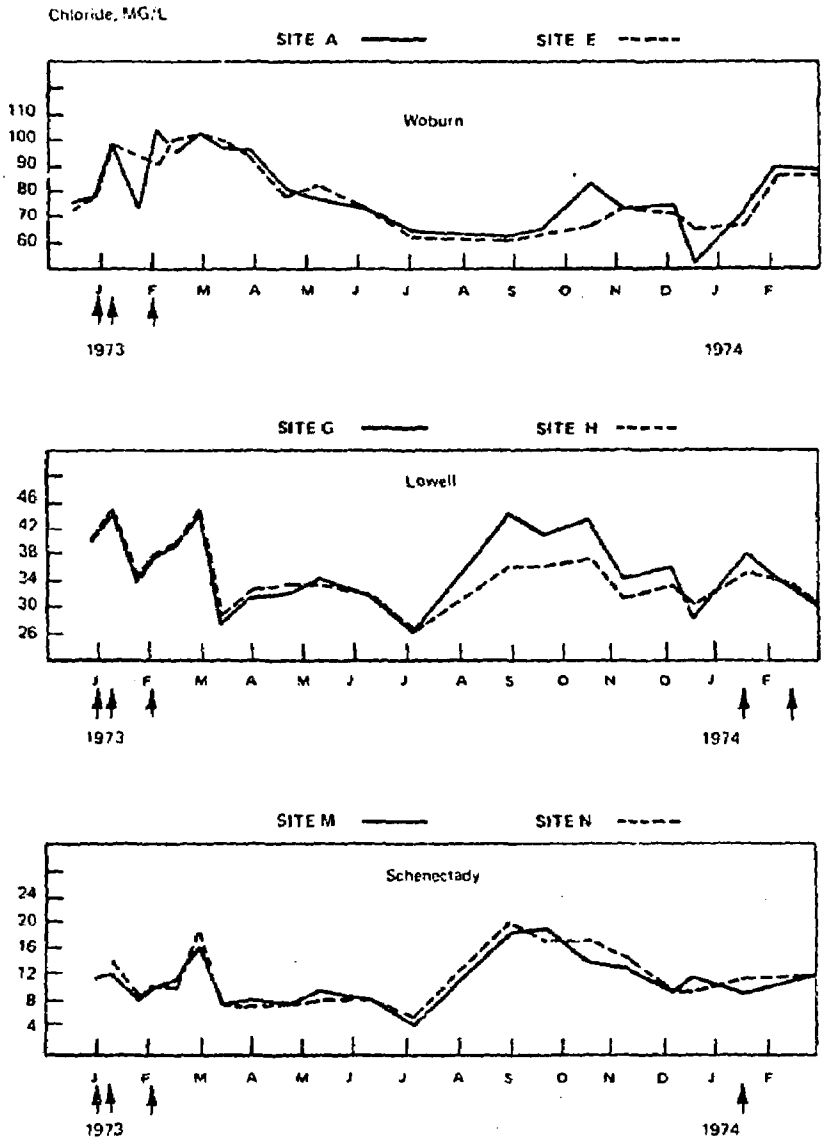
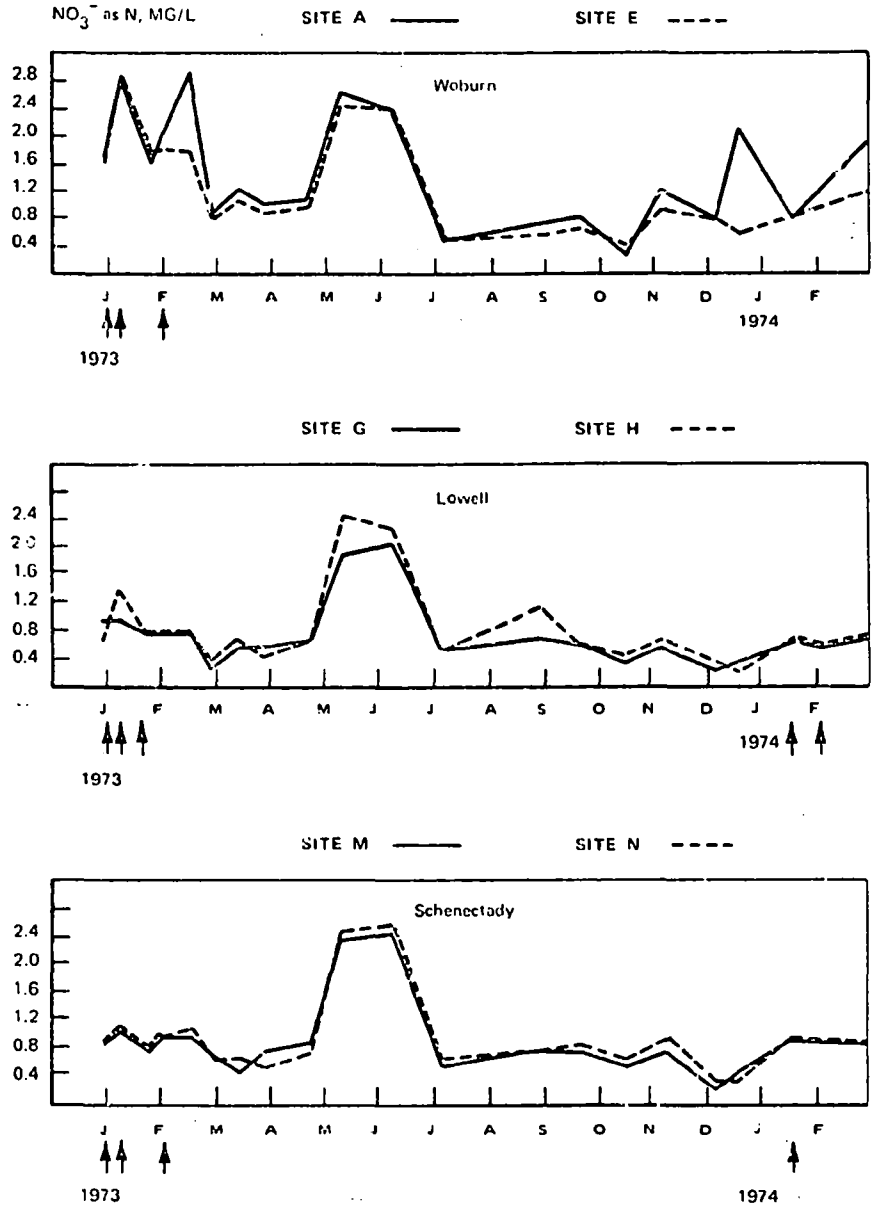
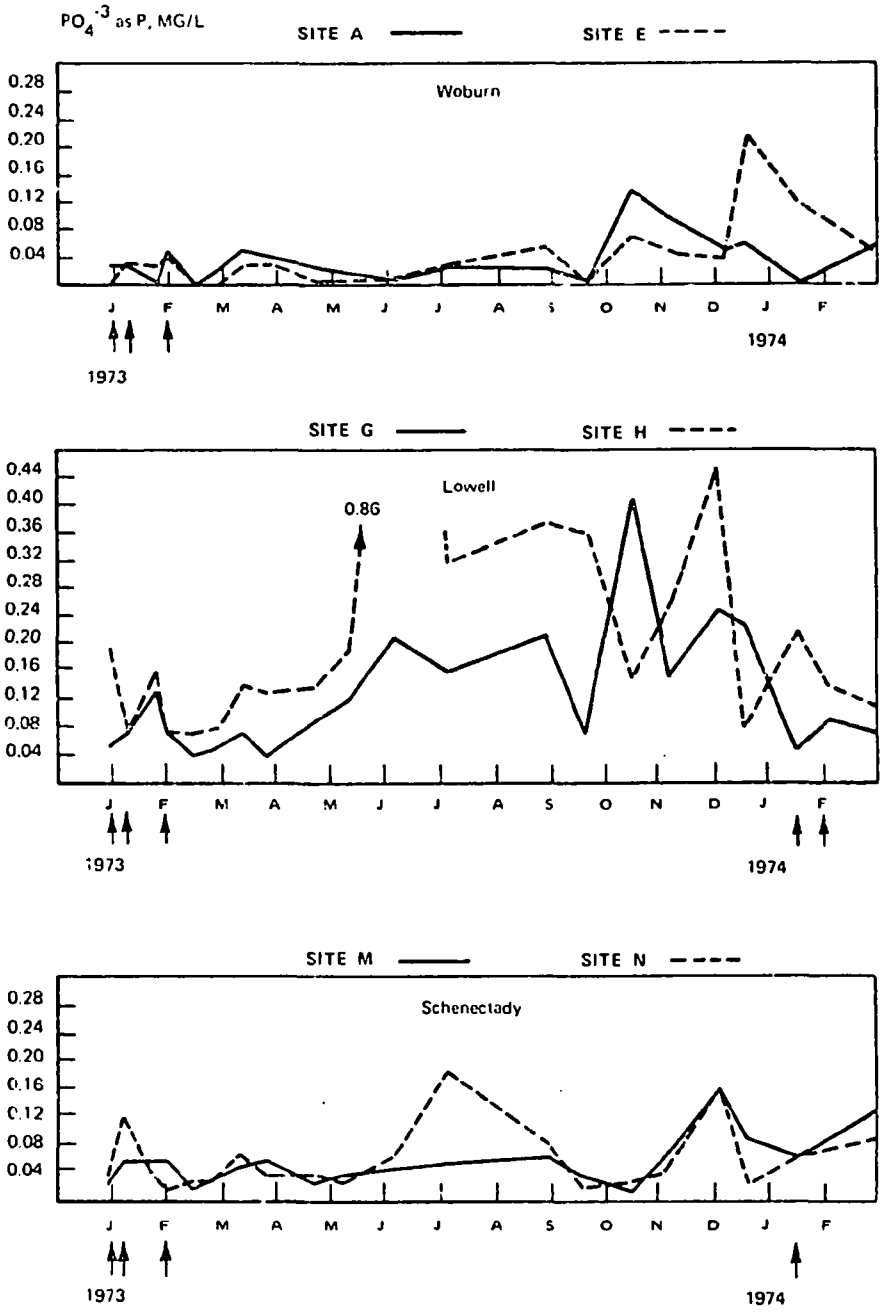


FIGURE 5 CHLORIDE CONCENTRATION LEVELS



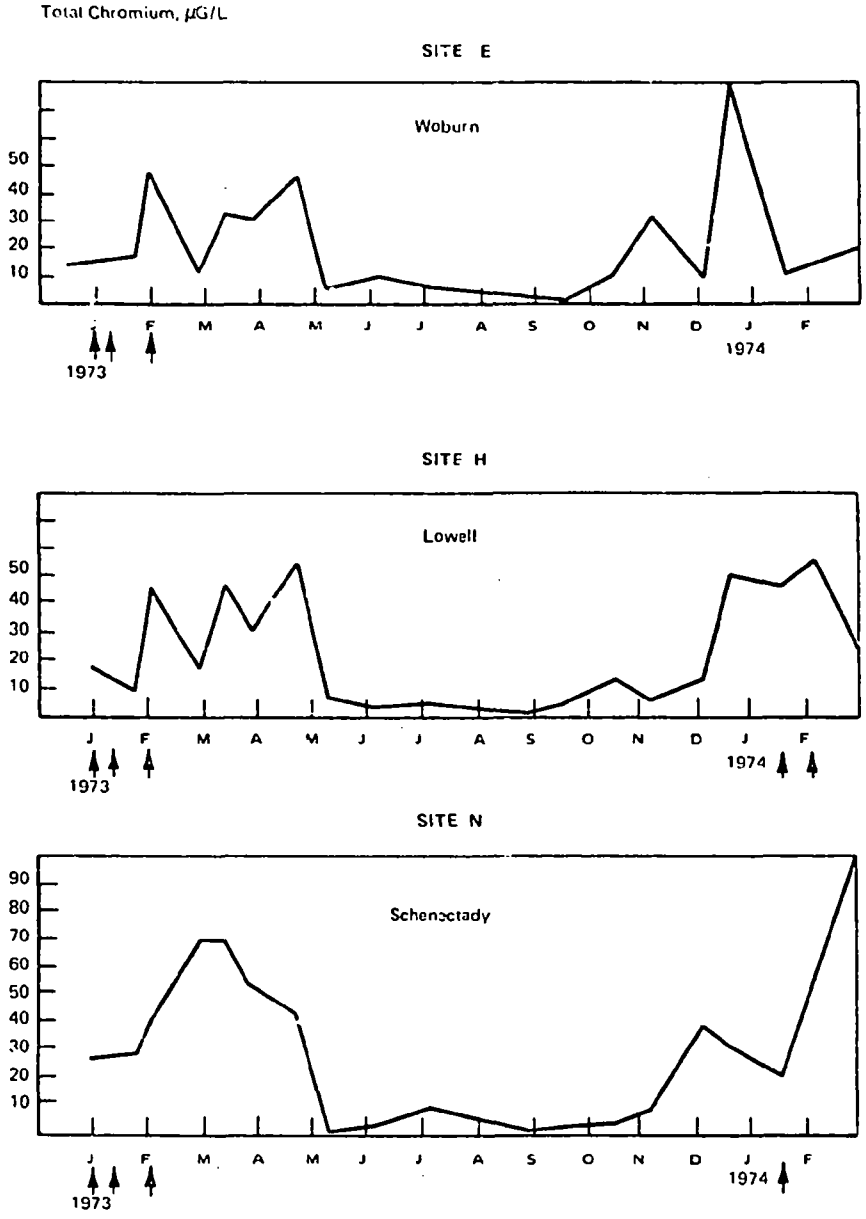
Arrows are snow dump dates.

FIGURE 6 NITRATE CONCENTRATION LEVELS



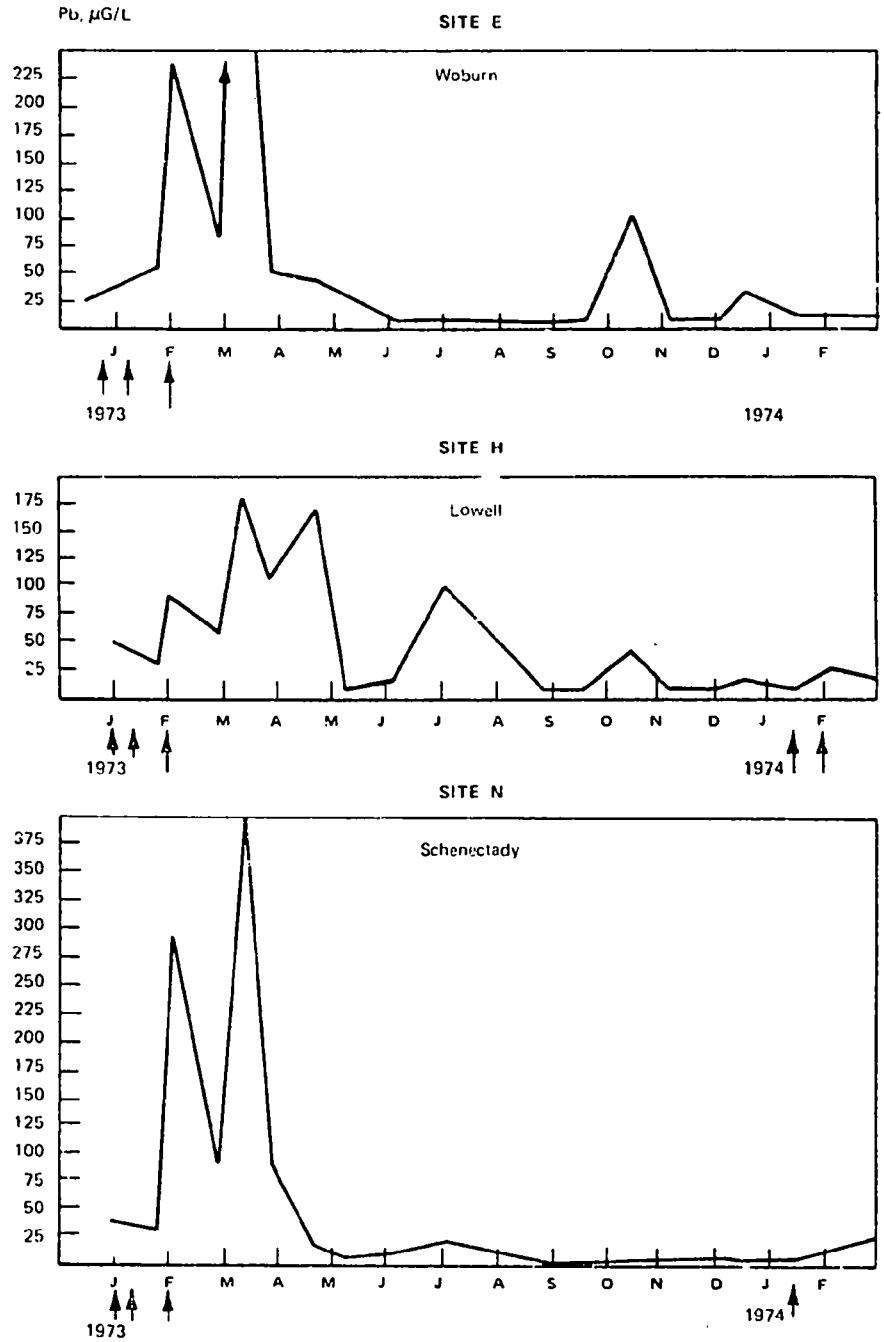
Arrows are snow dump dates.

FIGURE 7 PHOSPHATE CONCENTRATION LEVELS



Arrows are snow dump dates.

FIGURE 8 CHROMIUM CONCENTRATION LEVELS



Arrows are snow dump dates.

FIGURE 9 LEAD CONCENTRATION LEVELS

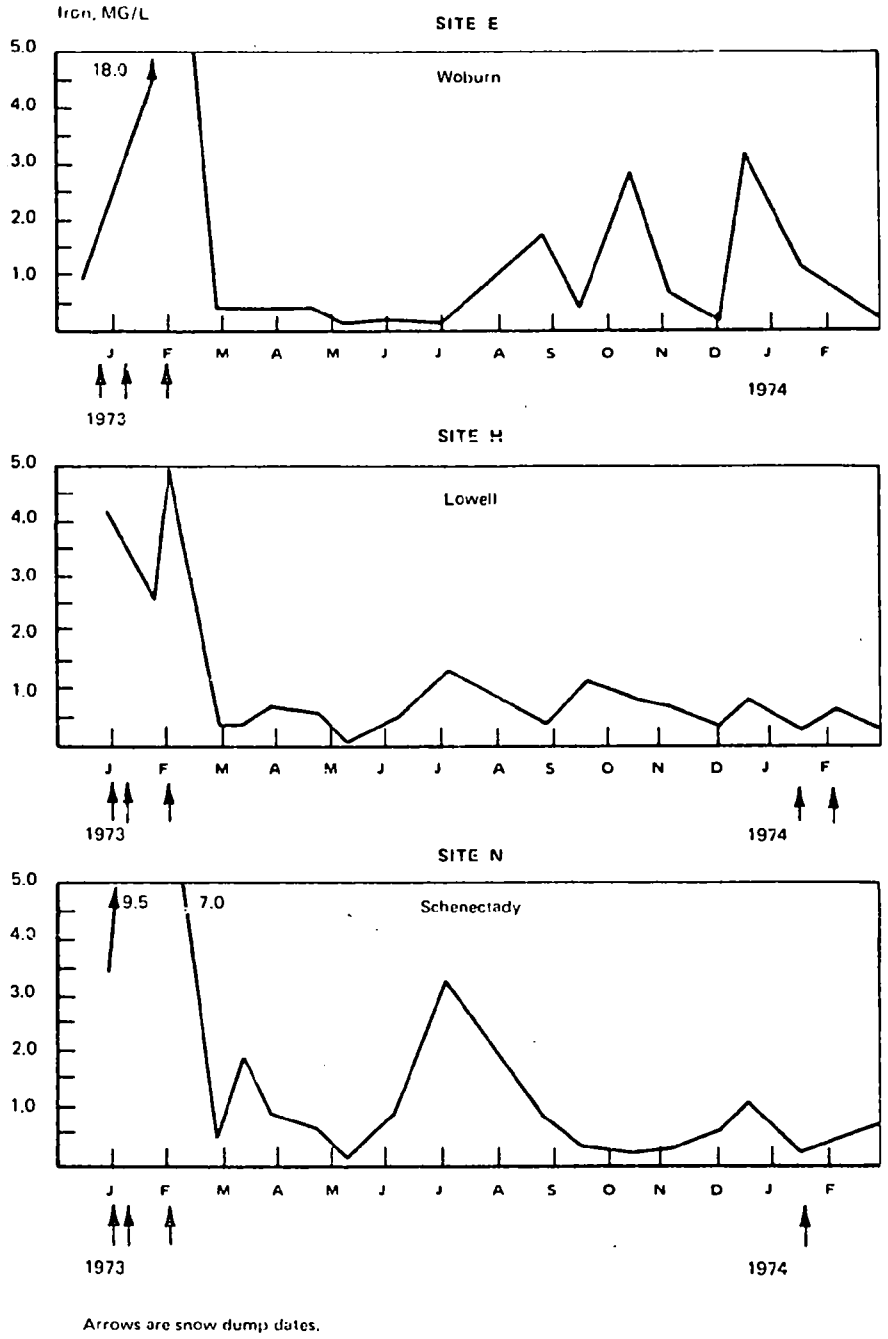


FIGURE 10 IRON CONCENTRATION LEVELS

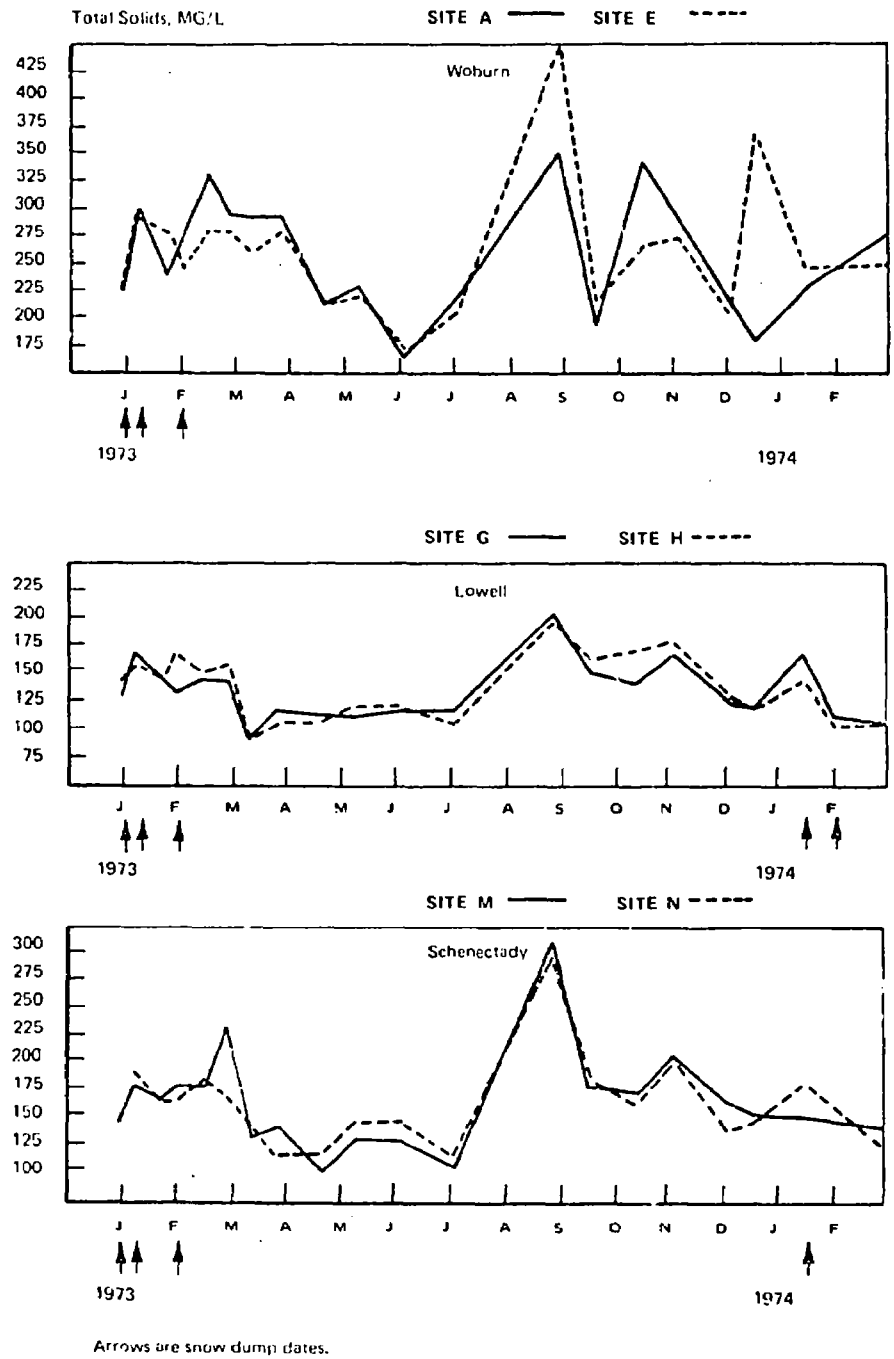
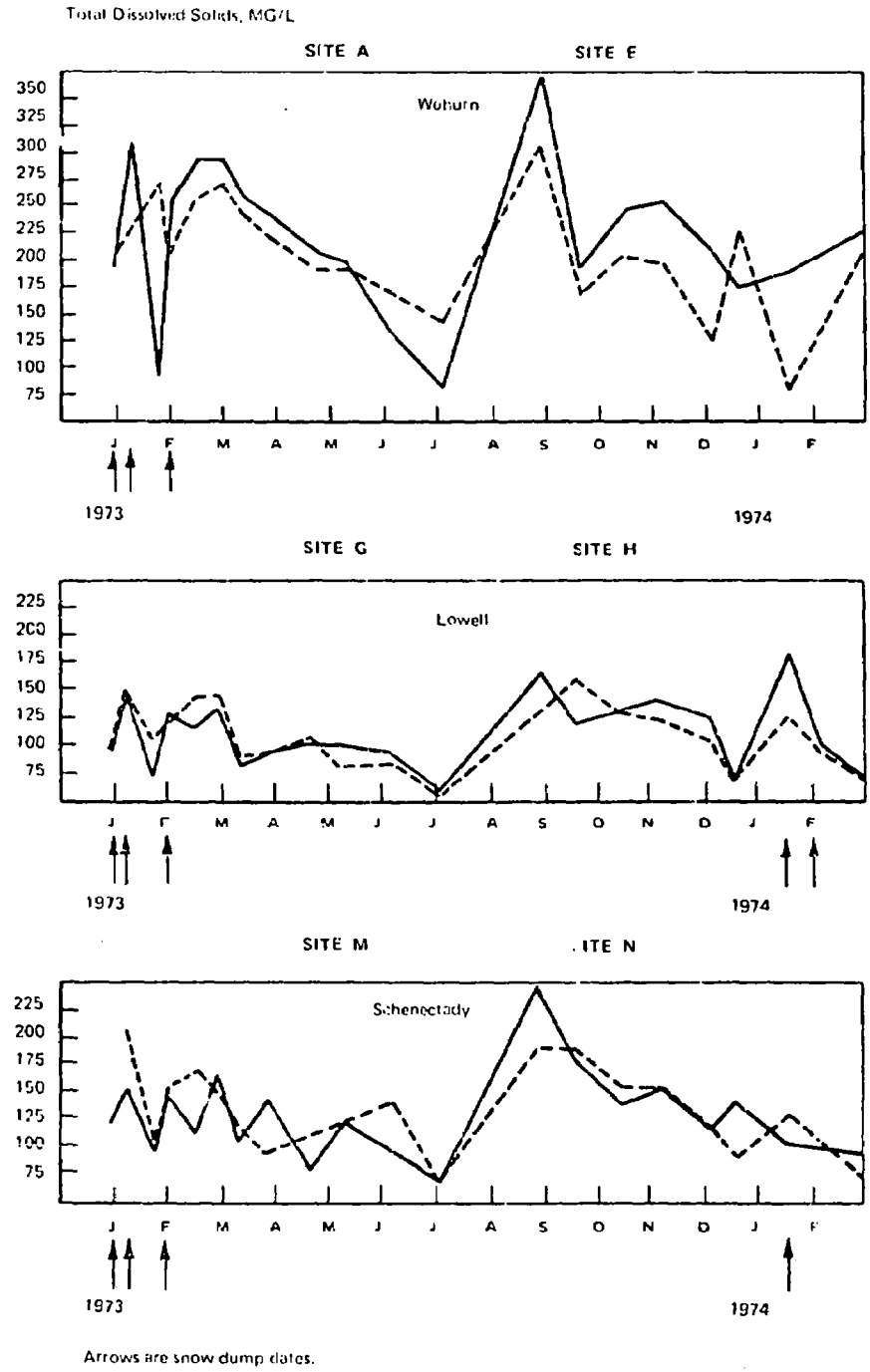


FIGURE 11 TOTAL SOLIDS CONCENTRATIONS



Arrows are snow dump dates.

FIGURE 12 TOTAL DISSOLVED SOLIDS CONCENTRATION LEVELS

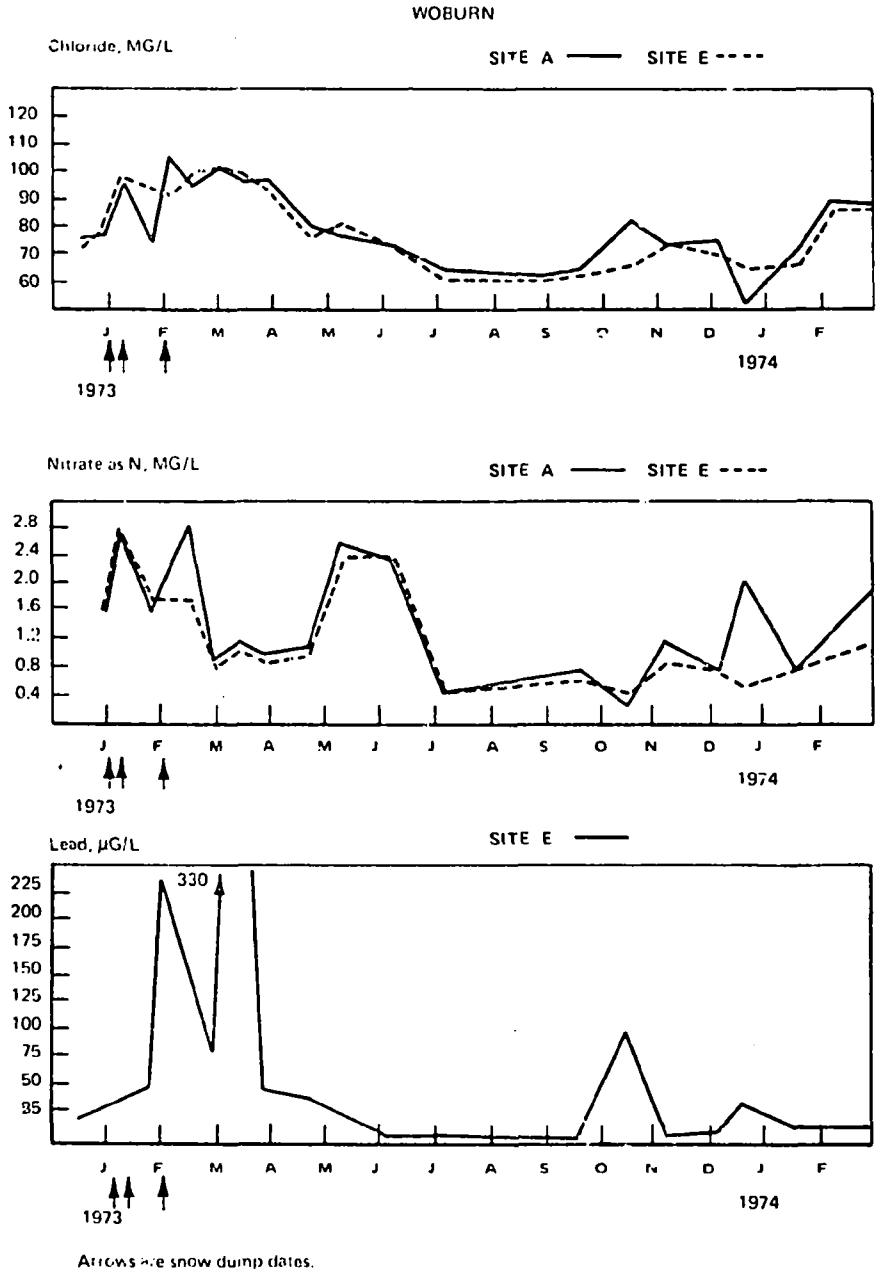


FIGURE 13 COMPARISON OF WOBURN CHLORIDE, NITRATE AND LEAD VALUES

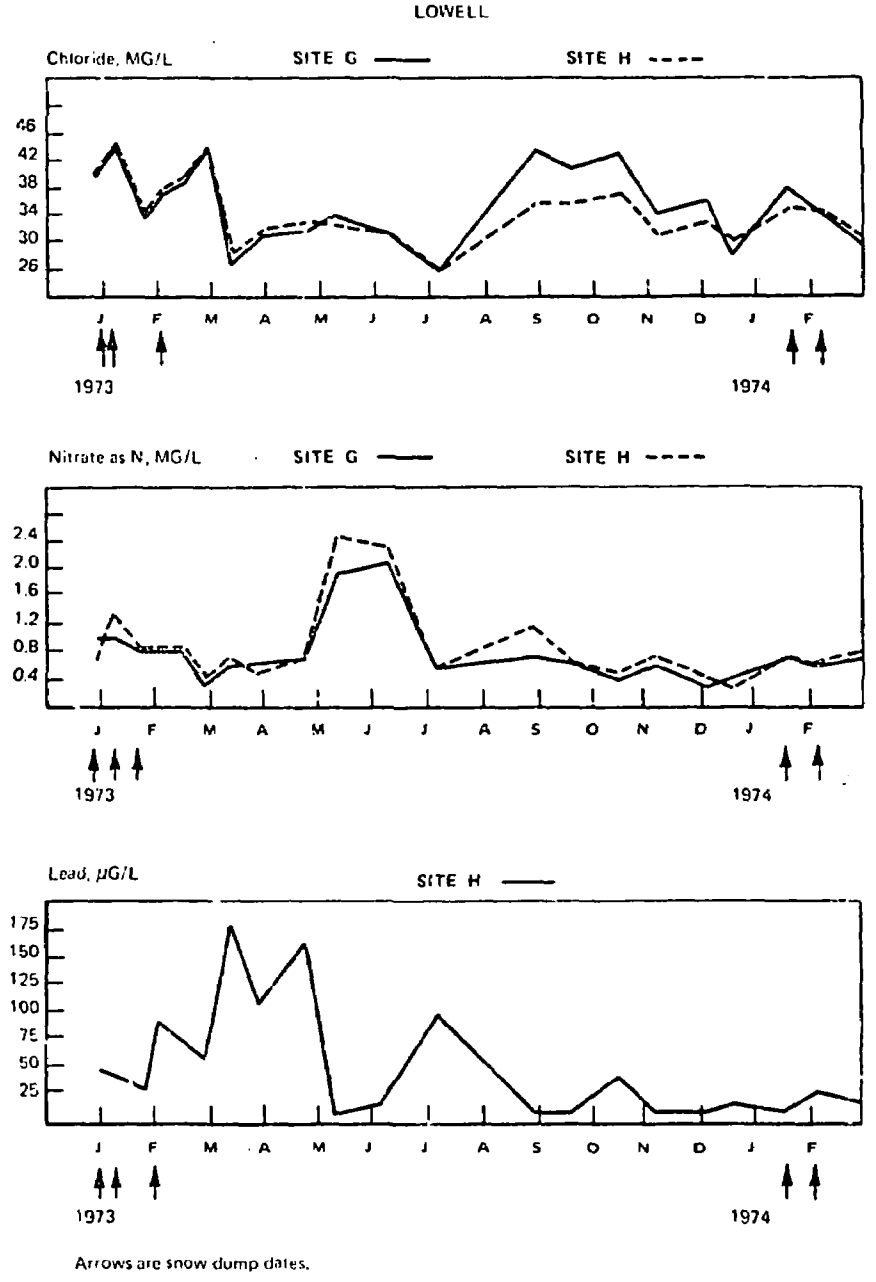


FIGURE 14 COMPARISON OF LOWELL CHLORIDE, NITRATE AND LEAD VALUES

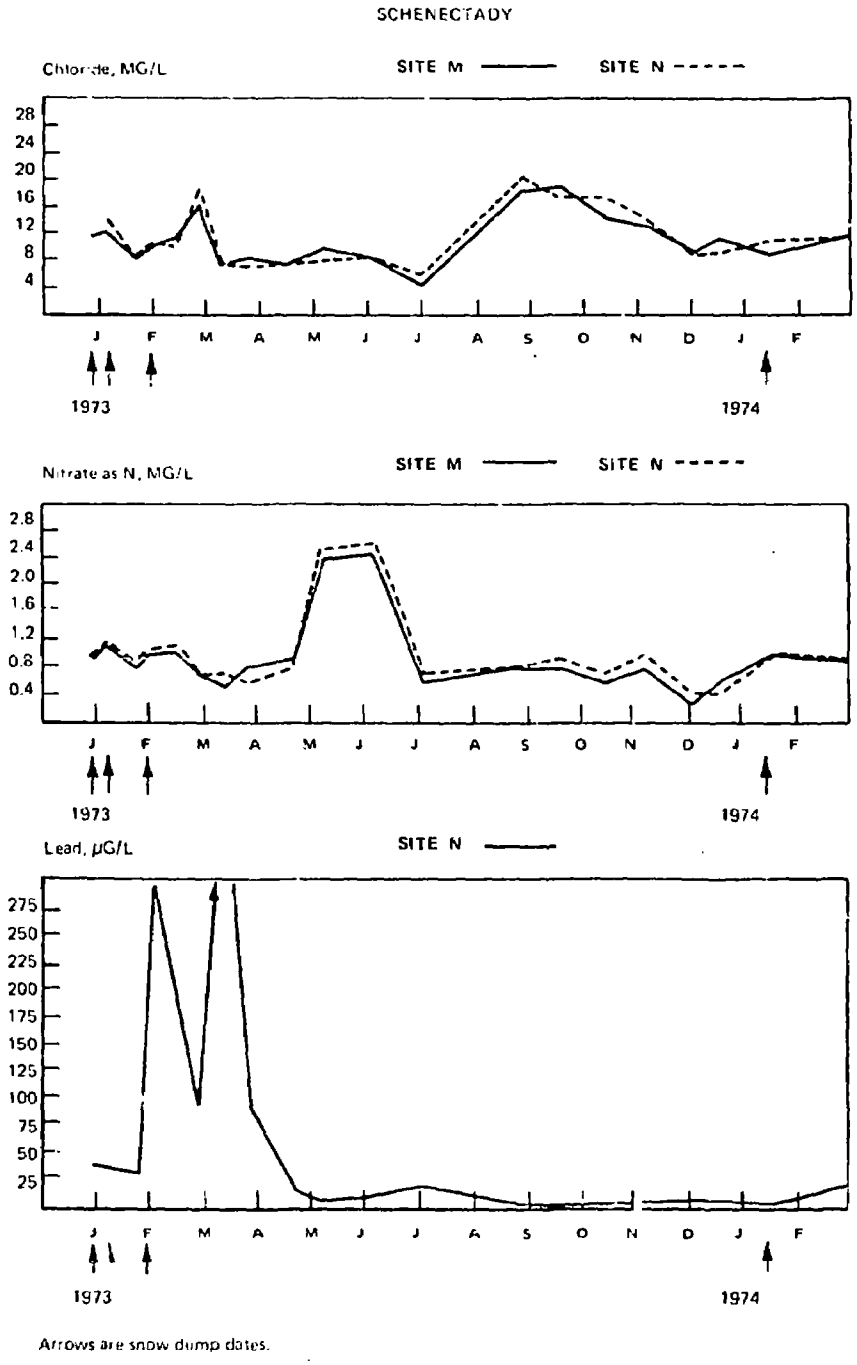


FIGURE 15 COMPARISON OF SCHENECTADY CHLORIDE, NITRATE AND LEAD VALUES

REFERENCES

1. Sylvester, R.O., Dewalle, F., Character and Significance of Highway Runoff Waters: A Preliminary Appraisal, Washington State Highway Commission, Department of Highways/Federal Highway Administration (NTIS/PB-220 083), 1972, 97 p.

2. Desmaris, J.N., Pollutional Aspects of Snow Disposal, Road and Transportation Association of Canada, First National Snow Conference, Ottawa, April 16-18, 1973, 32 p.

3. Habitat, Inc., Horn Pond Water Quality Survey, The Habitat School of Environment, Belmont, Ma. 02178, 1973.

APPENDIX A

CHEMICAL ANALYSIS DATA SHEETS

	Table
Chloride	A-1
Cyanide	A-1
Nitrate Nitrogen	A-2
Total Phosphorus	A-2
Ammonia Nitrogen	A-3
Total Kjeldahl Nitrogen	A-3
Chromium	A-4
Cr^{+6}	A-4
Copper	A-5
Lead	A-5
Iron	A-6
Zinc	A-6
Sodium	A-7
Calcium	A-7
Mercury	A-8
Nitrite nitrogen	A-8
Total Solids	A-9
Dissolved Solids	A-9
Oil and grease	A-10
COD	A-10
Loss on ignition	A-11

TABLE A–1 SUMMARY OF SAMPLING ANALYSES

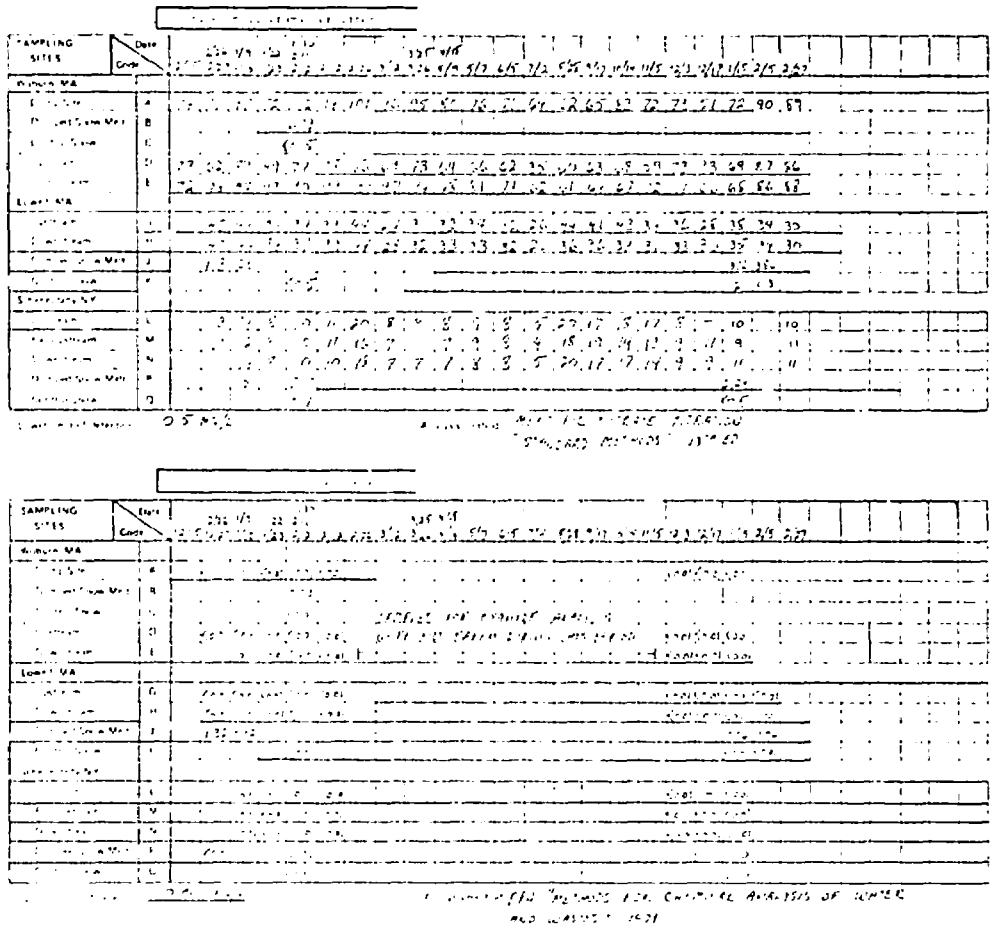


TABLE A–2 SUMMARY OF SAMPLING ANALYSES

SAMPLING SITES	Code	[illegible]
Woburn MA		
[illegible]	A	[illegible]
[illegible]	B	[illegible]
[illegible]	C	[illegible]
[illegible]	D	[illegible]
[illegible]	E	[illegible]
Lowell MA		
[illegible]	G	[illegible]
[illegible]	H	[illegible]
[illegible]	J	[illegible]
[illegible]	K	[illegible]
Schenectady NY		
[illegible]	L	[illegible]
[illegible]	M	[illegible]
[illegible]	N	[illegible]
[illegible]	P	[illegible]
[illegible]	Q	[illegible]

Lower limit of detection, 0.1 MG/L

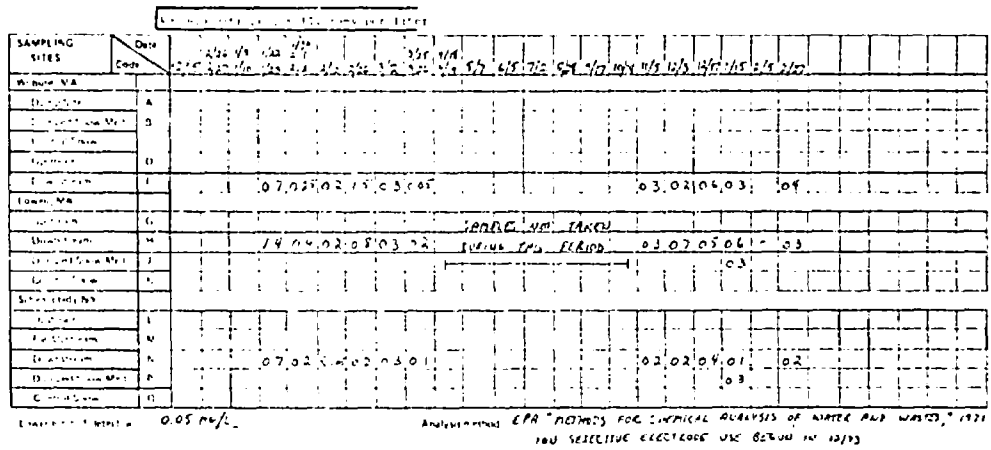
Analysis method ION SPECIFIC ELECTRODE

SAMPLING SITES	Code	[illegible]
Woburn MA		
[illegible]	A	[illegible]
[illegible]	B	[illegible]
[illegible]	C	[illegible]
[illegible]	D	[illegible]
[illegible]	E	[illegible]
Lowell MA		
[illegible]	G	[illegible]
[illegible]	H	[illegible]
[illegible]	J	[illegible]
[illegible]	K	[illegible]
Schenectady NY		
[illegible]	L	[illegible]
[illegible]	M	[illegible]
[illegible]	N	[illegible]
[illegible]	P	[illegible]
[illegible]	Q	[illegible]

Lower limit of detection, 0.01 MG/L

Analysis method "METHODS FOR CHEMICAL ANALYSIS OF WATER AND WASTES," 1971, EPA

TABLE A–3 SUMMARY OF SAMPLING ANALYSES



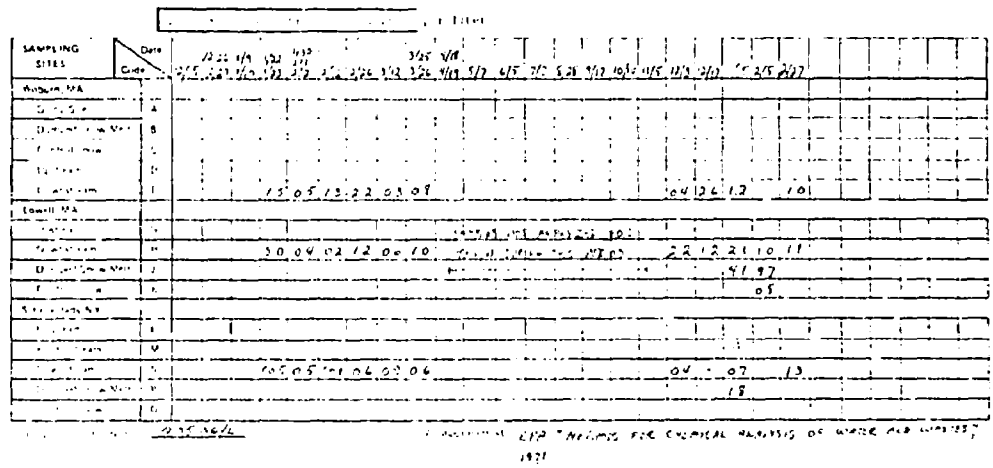


TABLE A–4 SUMMARY OF SAMPLING ANALYSES

SAMPLING SITES	Code	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Woburn MA																									
[illegible]	A																								
[illegible]	B																								
[illegible]	C																								
[illegible]	D	20			22																				
[illegible]	E	27		17	55		11	32	30	45	5	10	6	2	52	10	31	10	52	10		20			
Lowell MA																									
[illegible]	G	27																							
[illegible]	H	17		10	46		15	26	31	15	7	4	5		5	14	7	14	50	45	56	25			
[illegible]	I																								
[illegible]	J																								
Schenectady NY																									
[illegible]	L																								
[illegible]	M	26																							
[illegible]	N	27		29	21		70	70	59	44	2	4	10	2	2	4	10	40	33	22		100			
[illegible]	P																								
[illegible]	Q																								

[illegible] 2-5 MICROGRAMS PER LITER — Analytical method: OPTICAL EMISSION SPECTROMETRY

SAMPLING SITES	Code	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Woburn MA																									
[illegible]	A					5	17							4	4	2	5	3	4	5		12			
[illegible]	B				4																				
[illegible]	C																								
[illegible]	D					4	7							4	6	2	5	4	20	5		16			
[illegible]	E				4	8	5							6	3	5	10	4	12	3		16			
Lowell MA																									
[illegible]	F					2	13	No Analysis Made						7	8	7	17	4	12	7	9	20			
[illegible]	H				3	14	4	[illegible]						10	13	12	27	9	5	14	16	20			
[illegible]	J																			74	56				
[illegible]	K																			2	2				
Schenectady NY																									
[illegible]	L					20	19							12	5	4	19	12	[illegible]	11		26			
[illegible]	M					17	16							7	4	4	5	17	32	12		25			
[illegible]	N				5	17	18							6	4	4	[illegible]	14	37	11		39			
[illegible]	P				3															101					
[illegible]	Q																			3					

[illegible] 5 MICROGRAMS PER LITER — Analytical method: "STANDARD METHODS," [illegible]

TABLE A–5 SUMMARY OF SAMPLING ANALYSES

| SAMPLING SITES | Code | Date | | |

TABLE A-6 SUMMARY OF SAMPLING ANALYSES

SAMPLING SITES	Code	[illegible]
Woburn MA		
[illegible]	A	
[illegible]	B	
[illegible]	C	
[illegible]	D	26
[illegible]	E	10 [illegible]
Lowell MA		
[illegible]	G	26
[illegible]	H	42 26 50 [illegible]
[illegible]	I	
[illegible]	K	
[illegible] NY		
[illegible]	L	
[illegible]	M	58
[illegible]	N	35 95 70 [illegible]
[illegible]	P	
[illegible]	Q	

[illegible] 2-5 μg [illegible] OPTICAL EMISSION SPECTROMETRY

SAMPLING SITES	Code	[illegible]
Woburn MA		
[illegible]	A	
[illegible]	B	
[illegible]	C	
[illegible]	D	<50 <50
[illegible]	E	<50 <50 <50 <50 <50 <50 <50 <50 <50 <50 <50 <50 <50 <50 <50 <50 <50 <50 <50 <50
Lowell MA		
[illegible]	G	<50
[illegible]	H	<50 <50 <50 <50 <50 <50 <50 <50 <50 <50 <50 <50 <50 <50 <50 <50 <50 <50 <50 <50
[illegible]	J	
[illegible]	K	
[illegible] NY		
[illegible]	L	
[illegible]	M	<50
[illegible]	N	<50 <50 <50 <50 <50 <50 <50 <50 <50 <50 <50 <50 <50 <50 <50 <50 <50 <50 <50 <50
[illegible]	P	
[illegible]	Q	

[illegible] 2 μg [illegible] OPTICAL EMISSION SPECTROMETRY

TABLE A–7 SUMMARY OF SAMPLING ANALYSES

SAMPLING SITES	Code	12/5	12/22	1/9	1/28	2/10	2/12	2/26	3/2	3/26	3/26	4/18	5/7	6/5	7/6	8/28	9/17	10/4	11/5	12/3	12/17	1/5	2/5	2/27
Woburn, MA																								
[illegible]	A																							
[illegible] Sewer Main	B																							
[illegible] Sewer	C																							
[illegible] Upstream	D	25				24																		
[illegible] Upstream	E	24			44	38		18	17	15	12	3	4	9	22	17	23	15	16	18	24		19	
Lowell, MA																								
[illegible] Upstream	G		14																					
[illegible] Upstream	H		25		16	17		10	10	10	9	8	6	9	18	15	18	12	10	11	15	12	14	
[illegible] Sewer Main	J																							
[illegible] Sewer	K																							
Schenectady, NY																								
[illegible] Upstream	L																							
[illegible] Upstream	M		5																					
[illegible] Upstream	N		5		4	11		8	3	2	2	3	2	5	10	5	9	10	8	4	7		4	
[illegible] Sewer Main	P																							
[illegible] Sewer	Q																							

[illegible] detection 2.5 micrograms per liter [illegible] OPTICAL EMISSION SPECTROMETRY

SAMPLING SITES	Code	12/5	12/22	1/9	1/28	2/10	2/12	2/26	3/2	3/26	3/26	4/18	5/7	6/5	7/6	8/28	9/17	10/4	11/5	12/3	12/17	1/5	2/5	2/27
Woburn, MA																								
[illegible]	A																							
[illegible] Sewer Main	B																							
[illegible] Sewer	C																							
[illegible] Upstream	D	45				16																		
[illegible] Upstream	E	44			36	12		37	35	25	21	29	13	20	10	11	10	8	9	12	9		10	
Lowell, MA																								
[illegible] Upstream	G		18																					
[illegible] Upstream	H		32		11	8		21	14	20	13	25	20	33	9	5	9	9	9	8	11	11	8	
[illegible] Sewer Main	J																							
[illegible] Sewer	K																							
Schenectady, NY																								
[illegible]	L																							
[illegible] Upstream	M		65																					
[illegible] Upstream	N		40		24	15		41	29	26	36	12	28	39	7	11	7	11	13	19	18		15	
[illegible] Sewer Main	P																							
[illegible] Sewer	Q																							

[illegible] 2.5 micrograms per liter [illegible] OPTICAL EMISSION SPECTROMETRY

TABLE A–8 SUMMARY OF SAMPLING ANALYSES

| SAMPLING SITES | Code | Date | | |

TABLE A–9 SUMMARY OF SAMPLING ANALYSES

SAMPLING SITES	Code	[illegible]
[illegible] MA		
[illegible]	A	[illegible]
[illegible]	B	[illegible]
[illegible]	C	[illegible]
[illegible]	D	[illegible]
[illegible]	E	[illegible]
Lynn MA		
[illegible]	G	[illegible]
[illegible]	H	[illegible]
[illegible]	I	[illegible]
[illegible]	J	[illegible]
[illegible] NY		
[illegible]	L	[illegible]
[illegible]	M	[illegible]
[illegible]	N	[illegible]
[illegible]	P	[illegible]
[illegible]	Q	[illegible]

[illegible] 1 mg/L [illegible] [illegible] METHODS FOR CHEMICAL ANALYSIS OF WATER AND WASTES, 1971

SAMPLING SITES	Code	[illegible]
Woburn MA		
[illegible]	A	[illegible]
[illegible]	B	[illegible]
[illegible]	C	[illegible]
[illegible]	D	[illegible]
[illegible]	E	[illegible]
Lynn MA		
[illegible]	G	[illegible]
[illegible]	H	[illegible]
[illegible]	J	[illegible]
[illegible]	K	[illegible]
[illegible] NY		
[illegible]	L	[illegible]
[illegible]	M	[illegible]
[illegible]	N	[illegible]
[illegible]	P	[illegible]
[illegible]	Q	[illegible]

[illegible] 1 mg/L [illegible] [illegible] METHODS FOR CHEMICAL ANALYSIS OF WATER AND WASTES, 1971

TABLE A–10 SUMMARY OF SAMPLING ANALYSES

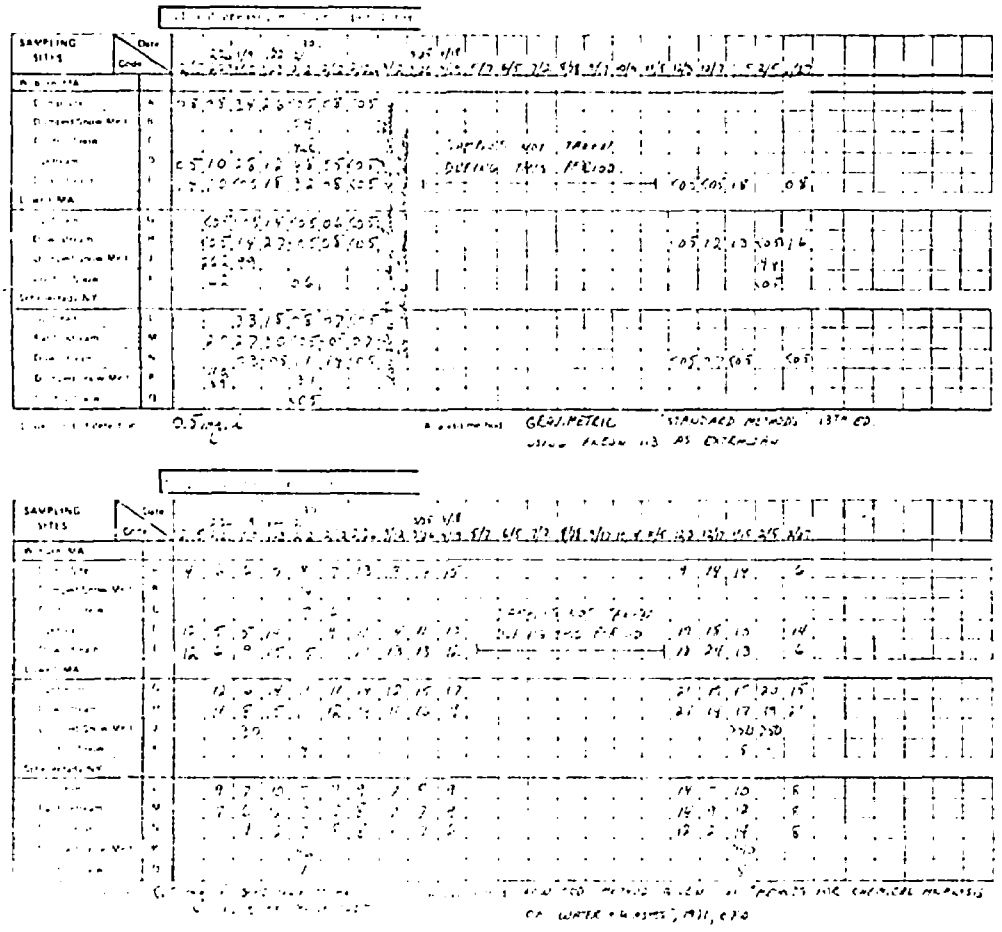


TABLE A-11 SUMMARY OF SAMPLING ANALYSES

SAMPLING SITES	Code	12/24	1/9	1/22	1/30	2/5	2/12	2/26	3/12	3/26	3/31	4/16	5/7	6/5	7/3	8/14	9/10	10/14	11/5	11/13	12/3	1/15	2/15	3/27
Wilmore MA																								
Downstream	A						26	52	92	30	9	35	27	30	85	90	110	53	87	42	23		65	
Downstream Well	B																							
Control Stream	C																							
Upstream	D																							
Upstream	E				97	58	21	43	43	26	16	18	26	9	59	67	50	52	70	60	48		96	
Lowell MA																								
Upstream	G						11	25	13	16	20	21	25	10	56	105	81	50	105	25	60	92	55	
Downstream	H				11		9	26	20	30	21	36	29		100	45	63	[illegible]	82	13	125	73	54	
Downstream Well	I																				165	90		
Control Stream	K																					65		
Schenectady NY																								
Upstream	L							34	20	19	51	23	9		110	64	53	79	48		42		53	
Downstream	M						5	30	16	67	11	33	25	20	104	83	90	51	97	34	116		85	
Downstream	N				55	16	19	25	15	16	13	29	22	13	105		92	100	91	20	101		56	
Downstream Well	P																				51			
Control Stream	Q																				20			

Lower limit of detection = 1 MG/L

Analysis method: EPA "METHODS FOR CHEMICAL ANALYSIS OF WATER AND WASTES", 1971