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A Comparative Study of Water Chemistry Analyses from Canada, Norway, and the United States: Analytical Methods Raw Data

A COMPARATIVE STUDY OF WATER CHEMISTRY ANALYSES FROM CANADA, NORWAY, AND THE UNITED STATES: ANALYTICAL METHODS AND RAW DATA

by

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ABSTRACT

During the National Surface Water Survey Eastern Lake Survey - Phase I, 110 identical aliquots (split samples) from 97 lakes in North Carolina were routed to one analytical laboratory in Norway and one in the United States. In addition, 105 split samples from 92 lakes in New York state were routed to two laboratories in Canada and to a second laboratory in the United States. This report documents the analytical methods used by each of the five laboratories and presents the data from the analyses conducted by the Norwegian and Canadian laboratories. Results from the U.S. laboratories are published elsewhere. Statistical analyses and interpretation of the data are encouraged for subsequent investigation.

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SECTION 1

INTRODUCTION

There are no standard international methodologies for analysis of water samples (Sullivan et al., 1986). Observed differences in water chemistry analyses from different laboratories may be attributed to acidification processes, differences in methodologies, or both. The objective of this study was to compare the analytical methods used during the National Surface Water Survey (NSWS) Eastern Lake Survey - Phase I (ELS-I) (Linthurst et al., 1986) with those used in Canadian and Norwegian laboratories. Samples from two regions were used in the study. Identical aliquots (split samples) from lakes in New York state were analyzed by two Canadian laboratories and by a U.S. Environmental Protection Agency (EPA) contract laboratory, and split samples from lakes in North Carolina were analyzed by a Norwegian laboratory and by a second EPA contract laboratory. The two Canadian laboratories analyzed for different parameters. This report lists the methods used by the five laboratories and documents the data from the analyses performed by the Canadian and Norwegian laboratories. The corresponding data from the EPA contract laboratories appear as part of the complete ELS-I data set published in Kanciruk et al. (1986). Statistical analyses and interpretation of the data are encouraged for subsequent investigation.

SECTION 2

CONCLUSIONS AND RECOMMENDATIONS

The purpose of this report is to present the data from the Norwegian and Canadian laboratories, not to test hypotheses. Stapanian et al. (in prep.) tested whether the results for each analyte in the two sets of split samples were equal and comparable. In this experiment, methods for certain analytes differed between two laboratories that analyzed samples from the same lakes (Stapanian et al., in prep.; Hillman et al., 1986). However, the effects of method and laboratory are totally confounded in the statistical sense (Stapanian et al., in prep.). Extreme caution should be used when interpreting inter-laboratory statistical comparisons from this study.

Differences between analytical methods should be assessed so that more rigorous interpretations of data from acidic deposition studies in other countries can be made. Such assessments should be made with identical aliquots of known concentrations, within the same laboratory. When the bias and accuracy of each method are determined, standard international methods for analysis of each analyte can be established.

SECTION 3

METHODS

COLLECTION OF SAMPLES

All ELS-I samples were collected, preserved, and prepared as aliquots by using standard techniques (Hillman et al., 1986). For the study described here, 110 identical aliquots (split samples) from 97 lakes in the Southern Blue Ridge Mountains of North Carolina (ELS-I batches 704 through 709) were routed by air charter to the Norwegian Institute for Water Research (P.O. Box 333, Oslo 3, Norway) and to Global Geochemical Corporation (6919 Eton Avenue, Canoga Park, California 91303). Of the 97 lakes, 9 were sampled twice, and 2 were sampled three times in accordance with the ELS-I quality assurance plan (Drouse et al., 1986). In addition, 105 split samples from 92 lakes in the Adirondack region of New York (ELS-I batches 209 through 214) were routed by air charter to three laboratories: the National Water Quality Laboratory of the Canada Centre for Inland Waters, P.O. Box 5050, Burlington, Ontario L7R 4A6; Environmental Monitoring Services, Inc. (EMSI), 2421 W. Hillcrest Dr., Thousand Oaks, California 91320; and the Water Quality Section of the Ontario Ministry of the Environment, P.O. Box 213, Rexdale, Ontario M9W 5L1. Four of these lakes were sampled twice, three lakes were sampled three times, and one lake was sampled four times in accordance with the ELS-I quality assurance plan. As discussed below, the samples were analyzed for different parameters at the two Canadian laboratories.

A rigorous quality assurance program (Drouse et al., 1986) was implemented to minimize the variance introduced during sample collection, transportation, and preservation. The results of the quality assurance program can be found in Best et al. (1986).

LABORATORY ANALYTICAL METHODS

The Canada Centre for Inland Waters analyzed for 13 parameters, and the Ontario Ministry of the Environment analyzed for 5 parameters. The parameters assigned to each laboratory, the analytical methods used, and the reference for each method are given in Table 1. The Norwegian Institute for Water Research analyzed for 11 parameters (see Table 2). Global and EMSI analyzed for all ELS-I parameters (see Kanciruk et al., 1986); 18 of these parameters (Table 3) correspond to parameters for which the Canadian and Norwegian laboratories analyzed. For all analyses, the U.S. laboratories used the methods described in Hillman et al. (1986).

TABLE 1. ANALYTICAL METHODS USED BY THE CANADIAN LABORATORIES

Laboratory	Parameter (Units)	Method	Reference
Canada Centre for Inland Waters[a]	pH (pH units)	pH meter	Environment Canada (1979)
	Cl^- (mg/L)	Ion chromatography	"
	Nitrogen as NO_3 (mg/L)	Ion chromatography	"
	Ca (mg/L)	Atomic absorption spectroscopy (flame)	"
	Conductance (µS/cm)	Conductivity meter	"
	SiO_2 (mg/L)	Automated colorimetry	"
	Dissolved Organic Carbon (mg/L)	Carbon analyzer	"
	Dissolved Inorganic Carbon (mg/L)	Carbon analyzer	"
	Na (mg/L)	Flame photometry	"
	K (mg/L)	Flame photometry	"
	Mg (mg/L)	Atomic absorption spectroscopy (flame)	"
	Acid-neutralizing capacity as $CaCO_3$ (mg/L)[b]	Gran analysis	"
	SO_4^{2-}	Ion chromatography	"

(continued)

Footnotes on next page.

TABLE 1. (Continued)

Laboratory	Parameter (Units)	Method	Reference
Ontario Ministry of the Environment[c]	Total P (mg/L)	Automated colorimetry	Ontario Ministry of the Environment (1983)
	Total F (mg/L)	Ion-selective electrode	"
	Total Al (mg/L)	Atomic absorption spectroscopy (furnace)	"
	Fe (mg/L)	Inductively coupled plasma emission spectroscopy	"
	Mn (mg/L)	Inductively coupled plasma emission spectroscopy	"

[a]Water Quality National Laboratory, Analytical Services, Canada Centre for Inland Waters, Burlington, Ontario, L7R 4A6

[b]Although acid-neutralizing capacity was measured in mg/L $CaCO_3$, data were converted to µeq/L for this report.

[c]Laboratory Services Branch, Water Quality Section, Rexdale, Ontario M9W 5L1

TABLE 2. ANALYTICAL METHODS USED BY THE NORWEGIAN INSTITUTE FOR WATER RESEARCH[a]

Parameter (Units)	Method	Reference
pH (pH units)	Orion APC-1 pH meter with Radiometer GK 2401 C electrode	Manufacturer's specifications
Ca, Mg, Na, K (mg/L)	Perkin Elmer 560 flame atomic absorption spectrophotometer	U.S. EPA (1983). Methods 215.1, 242.1, 273.1, 258.1
Conductance (μS/cm)	Phillips digital conductivity meter PW 9509	Manufacturer's specifications
NO_3^- (mg/L)	Copperized Cd-wire reduction method on Technicon Auto-Analyzer II	U.S. EPA (1983). Method 353.2
Cl^- (mg/L)	Automated thiocyanate method	U.S. EPA (1983). Method 325.2
Extractable Al (mg/L)	Pyrocatechol violet method	Henriksen and Bergmann-Paulsen (1975) Røgeberg and Henriksen (1985)
SO_4^{2-} (mg/L)	Thorin method AC	Henriksen and Bergmann-Paulsen (1974)
Acid-neutralizing capacity (μeq/L)	Fixed endpoint	Henriksen (1982)

[a]P.O. Box 333, Oslo 3, Norway

TABLE 3. ANALYTICAL METHODS USED BY THE U.S. LABORATORIES[a]

Parameter Units	Methods	Reference
Acid neutralizing capacity (μeq/L)	Gran analysis	Hillman et al. (1985)
pH (pH units)	pH meter	"
Conductance (μS/cm)	conductivity meter	"
Dissolved inorganic carbon (mg/L)	Carbon analyzer	"
Dissolved organic carbon (mg/L)	Carbon analyzer	"
Ca (mg/L)	Atomic absorption spectroscopy (flame)	"
Fe (mg/L)	Atomic absorption spectroscopy (flame)	"
Na (mg/L)	Atomic absorption spectroscopy (flame)	"
Mg (mg/L)	Atomic absorption spectroscopy (flame)	"
Mn (mg/L)	Atomic absorption spectroscopy (flame)	"
K (mg/L)	Atomic absorption spectroscopy (flame)	"
NO_3^- (mg/L)	Ion chromatography	"
SO_4^{2-} (mg/L)	Ion chromatography	"
Cl^- (mg/L)	Ion chromatography	"
SiO_2 (mg/L)	Automated colorimetry	"
Total F (mg/L)	Ion-selective electrode	"
Total Al (mg/L)	Atomic absorption spectroscopy (furnace)	"
Extractable Al (mg/L)	Atomic absorption spectroscopy (furnace)	"

[a]Environmental Monitoring Services, Inc., 2421 W. Hillcrest Dr., Thousand Oaks, California 91320
Global Geochemical Corporation, 6919 Eton Ave., Canoga Park, California 91303

SECTION 4

RESULTS AND DISCUSSION

The results from the Canadian and Norwegian laboratories are presented in Tables 4 and 5. Results from the EPA contract laboratories are published elsewhere (Kanciruk et al., 1986). Lake identification numbers can be used to identify corresponding samples in the data sets. Statistical analyses of the data are presented and discussed in Stapanian et al. (in prep.).

TABLE 4. DATA FROM THE CANADIAN LABORATORIES[a]

Lake ID[b]	pH (pH units)	Acid-Neutralizing Capacity (μeq/L)[c]	Total Al	Conductance (μS/cm)	Cl^-	Ca	Mg	Na	K
1A1-003	4.79	-23.978	0.290	25.40	0.26	1.17	0.19	0.39	0.24
1A1-004	4.71	-29.973	0.180	23.10	0.25	0.90	0.20	0.30	0.28
1A1-009	4.57	-37.966	0.530	29.30	0.30	1.12	0.26	0.42	0.06
1A1-012	5.86	4.396	0.030	18.20	0.28	1.74	0.31	0.35	0.18
1A1-014	6.30	31.372	0.036	19.80	0.27	2.01	0.37	0.48	0.14
1A1-016	4.63	-27.975	0.360	26.00	0.26	0.90	0.16	0.33	0.24
1A1-016	5.57	-2.198	0.000	1.30	0.01	0.02	0.01	0.01	0.01
1A1-038	6.56	94.914	0.036	25.80	0.37	2.37	1.00	0.42	0.16
1A1-042	6.21	43.561	0.051	21.80	0.27	1.95	0.42	0.69	0.32
1A1-043	6.16	52.952	0.043	26.60	0.45	2.66	0.54	0.85	0.39
1A1-046	6.32	41.962	0.092	25.30	0.33	2.62	0.48	0.76	0.43
1A1-049	4.66	-33.969	0.260	26.40	0.25	1.01	0.20	0.35	0.26
1A1-050	5.73	-1.399	0.057	21.00	0.27	1.76	0.35	0.60	0.32
1A1-051	6.20	27.375	0.039	24.40	0.30	2.29	0.45	0.76	0.43
1A1-055	6.39	28.175	0.051	22.40	0.33	2.04	0.36	0.70	0.37
1A1-057	4.85	-25.977	0.320	22.80	0.24	1.30	0.25	0.39	0.32
1A1-061	4.49	-43.960	0.540	32.10	0.34	1.04	0.21	0.40	0.15
1A1-077	5.68	1.199	0.160	21.70	0.33	2.05	0.36	0.48	0.15
1A1-079	5.39	-3.397	0.190	20.80	0.35	1.54	0.36	0.45	0.19
1A1-080	5.61	-0.799	0.110	18.80	0.28	1.43	0.34	0.50	0.24
1A1-084	4.77	-16.985	0.420	24.90	1.32	1.09	0.23	0.34	0.18
1A1-094	4.96	-21.980	0.350	24.90	0.43	1.15	0.21	0.51	0.24
1A1-095	4.85	-16.785	0.300	22.90	0.32	1.16	0.22	0.47	0.26
1A1-097	4.74	-21.980	0.210	24.50	0.26	1.10	0.20	0.38	0.29
1A1-099	5.98	22.979	0.034	20.00	0.29	2.07	0.40	0.41	0.19
1A1-101	6.18	35.168	0.020	22.80	0.28	2.56	0.33	0.51	0.24
1A2-001	6.48	128.284	0.051	29.20	0.42	3.05	0.77	1.08	0.31
1A2-002	5.48	-5.195	0.072	20.00	0.23	1.68	0.30	0.52	0.05
1A2-004	4.69	-25.977	0.330	24.00	0.21	0.90	0.17	0.35	0.07

(continued)

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TABLE 4. (Continued)

Lake ID[b]	SO_4^{2-}	NO_3-N[d]	Total P	DIC[e]	DOC[f]	SiO_2	Fe	Mn	Total
1A1-003	6.42	0.00	0.000	0.4	1.3	0.83	0.056	0.031	0.0513
1A1-004	5.30	0.12	0.000	0.4	0.9	0.40	0.041	0.052	0.0389
1A1-009	6.18	0.01	0.010	0.4	3.2	1.88	0.092	0.035	0.0377
1A1-012	4.56	0.01	0.000	0.3	2.1	1.19	0.051	0.023	0.0376
1A1-014	4.47	0.03	0.000	0.4	1.8	2.40	0.027	0.007	0.0339
1A1-016	5.59	0.24	0.000	0.4	1.9	1.50	0.046	0.044	0.0550
1A1-016	0.00	0.00	0.000	0.4	0.1	0.02	0.012	0.001	0.0000
1A1-038	4.86	0.00	0.000	1.8	3.1	0.62	0.220	0.007	0.0829
1A1-042	4.52	0.00	0.013	1.3	4.4	0.98	0.240	0.025	0.0706
1A1-043	5.82	0.00	0.007	1.2	4.6	3.71	0.220	0.050	0.0850
1A1-046	5.29	0.00	0.000	1.1	4.5	3.51	0.370	0.063	0.1290
1A1-049	6.20	0.00	0.000	0.4	0.8	0.32	0.033	0.035	0.0558
1A1-050	6.22	0.00	0.000	0.5	2.1	2.00	0.042	0.018	0.0609
1A1-051	6.39	0.00	0.000	1.0	3.5	1.50	0.057	0.015	0.1060
1A1-055	5.75	0.00	0.000	1.0	3.4	3.60	0.140	0.043	0.0803
1A1-057	5.65	0.00	0.000	0.6	4.5	1.38	0.130	0.048	0.0867
1A1-061	6.46	0.01	0.005	0.3	4.8	4.13	0.160	0.040	0.0335
1A1-077	5.39	0.01	0.000	0.3	3.8	2.62	0.094	0.019	0.0389
1A1-079	5.45	0.04	0.000	0.3	2.8	2.97	0.150	0.061	0.0457
1A1-080	4.82	0.07	0.000	0.1	1.7	2.89	0.034	0.042	0.0510
1A1-084	6.29	0.10	0.000	0.3	1.6	1.67	0.027	0.041	0.0350
1A1-094	5.89	0.00	0.000	0.5	3.2	3.11	0.190	0.046	0.0560
1A1-095	6.23	0.00	0.000	0.4	2.3	0.88	0.038	0.028	0.1070
1A1-097	6.25	0.00	0.000	0.5	1.0	0.25	0.017	0.050	0.0565
1A1-099	4.26	0.02	0.007	0.4	2.7	1.82	0.094	0.021	0.0411
1A1-101	5.50	0.00	0.000	1.1	2.6	1.74	0.130	0.044	0.1270
1A2-001	3.50	0.00	0.024	2.9	5.5	2.86	0.200	0.031	0.0524
1A2-002	5.50	0.01	0.000	0.3	1.4	1.08	0.025	0.036	0.0452
1A2-004	5.56	0.05	0.006	0.3	1.6	0.81	0.041	0.020	0.0253

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TABLE 4. (Continued)

Lake ID[b]	pH (pH units)	Acid-Neutralizing Capacity (μeq/L)[c]	Total Al	Conductance (μS/cm)	Cl^-	Ca	Mg	Na	K
1A2-011	6.80	120.092	0.022	36.80	0.49	3.86	1.09	0.60	0.22
1A2-011	6.38	118.693	0.026	36.60	0.49	3.78	1.08	0.60	0.22
1A2-016	6.37	107.104	0.004	40.40	3.06	3.26	0.67	2.55	0.53
1A2-018	4.74	-25.977	0.170	23.40	0.30	1.22	0.26	0.45	0.32
1A2-021	4.73	-31.971	0.310	23.30	0.36	1.11	0.24	0.51	0.25
1A2-022	6.62	213.807	0.012	32.10	0.21	4.71	0.45	0.12	0.33
1A2-023	4.97	13.588	0.250	23.10	0.53	1.38	0.31	0.61	0.30
1A2-031	5.24	-19.183	0.090	18.50	0.27	1.16	0.27	0.55	0.13
1A2-036	6.48	172.245	0.041	34.10	0.42	4.49	0.54	0.79	0.34
1A2-037	6.22	150.265	0.068	32.20	0.48	3.44	0.82	0.88	0.34
1A2-038	6.36	117.494	0.037	26.00	0.30	3.11	0.52	0.84	0.09
1A2-039	6.30	133.080	0.017	37.00	2.49	3.41	0.96	1.76	0.28
1A2-040	6.96	233.789	0.041	50.70	2.82	5.37	1.08	2.01	0.39
1A2-041	5.99	22.180	0.120	22.50	0.45	2.10	0.43	0.75	0.16
1A2-042	5.51	-7.793	0.160	21.10	0.36	1.58	0.40	0.68	0.20
1A2-044	5.91	-3.197	0.180	21.60	0.51	1.55	0.38	0.69	0.23
1A2-045	5.96	57.948	0.017	18.00	0.39	1.49	0.30	0.60	0.14
1A2-046	6.27	7.793	0.029	21.40	0.42	1.81	0.50	0.45	0.17
1A2-048	5.77	-23.978	0.000	1.30	0.00	0.04	0.00	0.00	0.00
1A2-048	5.02	-9.591	0.084	19.30	0.63	1.18	0.33	0.45	0.29
1A2-052	5.31	-3.60	0.250	22.50	0.95	1.52	0.41	0.78	0.25
1A2-053	6.12	46.96	0.068	25.40	0.44	2.51	0.55	0.65	0.22
1A2-054	4.92	-17.38	0.210	19.90	0.26	1.09	0.26	0.37	0.20
1A2-056	5.74	14.39	0.030	12.35	0.28	1.06	0.24	0.36	0.28
1A2-058	6.84	384.65	0.007	61.20	0.80	7.02	2.13	0.75	0.32
1A2-058	5.70	-3.00	0.000	1.43	0.02	0.05	0.01	0.00	0.02
1A2-058	6.64	382.06	0.004	61.30	0.83	7.02	2.13	0.74	0.33
1A2-063	5.97	22.38	0.062	23.60	0.20	2.50	0.47	0.52	0.14
1A2-065	5.95	19.58	0.100	61.20	0.31	2.12	0.45	0.75	0.35

(continued)

Footnotes at end of table.

TABLE 4. (Continued)

Lake ID[b]	SO_4^{2-}	NO_3-N[d]	Total P	DIC[e]	DOC[f]	SiO_2	Fe	Mn	Total
1A2-011	7.09	0.00	0.000	2.0	4.5	0.72	0.030	0.007	0.1600
1A2-011	7.08	0.00	0.006	1.9	4.5	0.74	0.035	0.008	0.1600
1A2-016	5.54	0.00	0.000	2.1	2.2	0.24	0.042	0.007	0.0624
1A2-018	5.88	0.00	0.000	0.7	4.6	2.08	0.110	0.020	0.0954
1A2-021	4.97	0.00	0.000	0.4	4.3	2.88	0.330	0.036	0.0642
1A2-022	2.58	0.00	0.014	3.5	4.6	0.29	0.190	0.017	0.0251
1A2-023	5.64	0.00	0.010	0.9	5.0	1.24	0.340	0.032	0.1640
1A2-031	5.23	0.04	0.000	0.4	0.8	2.08	0.073	0.029	0.0286
1A2-036	4.19	0.00	0.008	2.3	5.7	3.91	0.093	0.010	0.1030
1A2-037	3.89	0.00	0.010	2.3	4.5	5.38	0.390	0.029	0.0445
1A2-038	3.37	0.00	0.008	1.8	5.3	1.82	0.077	0.008	0.0240
1A2-039	4.35	0.00	0.008	2.0	4.8	1.15	0.120	0.004	0.0521
1A2-040	6.17	0.00	0.005	3.1	3.7	6.06	0.280	0.015	0.0384
1A2-041	5.30	0.01	0.015	0.9	6.3	3.91	0.090	0.021	0.0590
1A2-042	5.71	0.00	0.005	0.5	4.0	3.88	0.091	0.028	0.0421
1A2-044	5.68	0.01	0.005	0.8	4.9	4.01	0.220	0.032	0.0415
1A2-045	5.49	0.01	0.006	0.4	1.7	1.78	0.058	0.036	0.0407
1A2-046	6.57	0.01	0.000	0.4	1.5	1.76	0.076	0.017	0.0360
1A2-048	0.26	0.05	0.000	0.4	0.1	0.02	0.001	0.001	0.0000
1A2-048	4.44	0.00	0.012	0.5	4.4	1.28	0.170	0.031	0.0441
1A2-052	5.78	0.02	0.008	0.5	4.10	2.18	0.210	0.035	0.0431
1A2-053	4.60	0.06	0.000	0.8	2.80	3.68	0.095	0.023	0.0426
1A2-054	5.02	0.01	0.000	0.5	3.80	1.17	0.110	0.028	0.0272
1A2-056	2.23	0.00	0.009	0.8	4.70	0.18	0.310	0.020	0.0474
1A2-058	7.51	0.00	0.000	4.8	3.70	0.81	0.230	0.015	0.0410
1A2-058	0.00	0.00	0.000	0.4	0.10	0.02	0.009	0.001	0.0000
1A2-058	7.48	0.00	0.000	4.8	3.70	0.49	0.022	0.016	0.0400
1A2-063	5.45	0.00	0.009	1.2	5.30	0.57	0.160	0.014	0.1280
1A2-065	5.63	0.00	0.000	0.9	3.70	3.18	0.370	0.022	0.0970

(continued)

Footnotes at end of table.

TABLE 4. (Continued)

Lake ID[b]	pH (pH units)	Acid-Neutralizing Capacity (μeq/L)[c]	Total Al	Conductance (μS/cm)	Cl^-	Ca	Mg	Na	K
1A2-068	5.20	-10.59	0.150	19.90	0.31	1.37	0.31	0.39	0.15
1A2-070	4.81	-18.38	0.220	22.00	0.33	1.15	0.23	0.37	0.16
1A2-071	6.24	49.56	0.080	25.40	0.30	2.63	0.56	0.80	0.37
1A2-072	5.10	-15.59	0.230	24.90	0.27	1.27	0.26	0.58	0.25
1A2-073	4.94	-19.98	0.160	19.90	0.25	1.14	0.26	0.38	0.12
1A2-074	4.93	-31.97	0.200	22.10	0.24	1.17	0.21	0.35	0.10
1A2-078	5.09	-13.39	0.140	22.00	0.26	1.33	0.32	0.58	0.13
1A2-093	5.21	-11.39	0.230	23.70	0.37	1.62	0.34	0.56	0.25
1A3-018	6.61	270.16	0.025	37.40	0.00	5.33	0.89	1.29	0.14
1A3-020	6.61	330.50	0.004	58.90	2.49	6.95	1.09	0.78	0.29
1A3-022	6.47	193.03	0.000	41.10	0.57	5.16	0.83	0.58	0.41
1A3-025	6.90	570.09	0.230	82.70	1.09	10.47	2.18	1.32	0.42
1A3-027	7.17	78.73	0.025	30.50	0.48	3.12	0.72	0.80	0.18
1A3-028	5.19	-8.99	0.016	12.20	0.25	0.91	0.16	0.08	0.21
1A3-028	5.24	-7.59	0.017	12.20	0.25	0.93	0.15	0.08	0.21
1A3-029	6.71	39.76	0.004	26.40	0.45	2.72	0.51	0.85	0.30
1A3-031	6.77	620.04	0.016	97.40	2.99	12.50	1.96	2.57	0.42
1A3-051	8.27	1469.48	0.008	155.00	2.56	20.90	5.40	1.49	0.67
1A3-067	5.63	-4.20	0.000	1.30	0.00	0.19	0.02	0.00	0.00
1A3-067	6.82	590.67	0.003	86.50	3.26	11.80	1.17	1.98	0.88
1A3-067	6.47	594.66	0.004	86.80	3.22	12.00	1.22	1.96	0.88
1A3-067	4.95	-18.18	0.260	20.50	0.35	1.19	0.26	0.47	0.10
1A3-069	5.18	-169.85	0.140	21.20	0.33	1.34	0.30	0.47	0.16
1C1-056	6.25	150.86	0.027	34.10	0.53	3.82	1.07	0.60	0.29
1C1-059	7.46	1068.64	0.000	146.90	7.09	12.70	6.00	5.24	0.53
1C1-059	6.91	1064.44	0.000	147.50	7.62	13.50	5.90	5.26	0.53
1C1-059	5.56	-1.60	0.000	1.40	0.02	0.14	0.03	0.00	0.01
1C1-061	7.79	602.66	0.016	89.40	1.53	12.10	1.15	2.06	0.84
1C1-062	6.96	659.41	0.006	82.00	0.83	13.20	1.26	0.93	0.31
1C1-063	6.92	1949.24	0.066	250.00	3.99	35.30	3.40	7.45	1.45

(continued)

Footnotes at end of table.

TABLE 4. (Continued)

Lake ID[b]	SO_4^{2-}	NO_3-N[d]	Total P	DIC[e]	DOC[f]	SiO_2	Fe	Mn	Total
1A2-068	5.33	0.03	0.004	0.5	2.60	0.96	0.048	0.033	0.0354
1A2-070	5.68	0.06	0.000	0.1	1.40	0.64	0.031	0.036	0.0337
1A2-071	4.47	0.00	0.010	1.4	8.00	3.93	0.460	0.050	0.1320
1A2-072	4.92	0.00	0.005	0.6	4.90	1.02	0.320	0.039	0.1170
1A2-073	5.09	0.01	0.008	0.4	3.20	0.73	0.140	0.027	0.0326
1A2-074	5.94	0.01	0.004	0.4	1.00	0.36	0.017	0.033	0.0348
1A2-078	6.85	0.01	0.000	0.3	0.80	0.72	0.009	0.050	0.0477
1A2-093	6.63	0.00	0.007	0.9	3.80	1.26	0.110	0.051	0.0926
1A3-018	2.72	0.00	0.016	3.5	8.10	6.63	0.150	0.007	0.0552
1A3-020	6.16	0.00	0.006	4.3	2.80	3.27	0.094	0.035	0.0709
1A3-022	6.64	0.00	0.000	2.8	3.36	0.92	0.100	0.026	0.0499
1A3-025	8.86	0.00	0.000	6.9	2.70	3.48	0.100	0.053	0.0536
1A3-027	6.94	0.00	0.012	1.1	3.10	0.75	0.069	0.005	0.0816
1A3-028	2.95	0.00	0.008	0.5	2.60	0.24	0.065	0.031	0.0156
1A3-028	2.89	0.00	0.006	0.4	2.50	0.23	0.059	0.028	0.0154
1A3-029	6.19	0.00	0.000	1.0	2.80	1.69	0.047	0.001	0.0811
1A3-031	10.81	0.00	0.005	7.6	2.50	1.01	0.022	0.010	0.0444
1A3-051	3.33	0.00	0.000	17.6	2.60	0.57	0.030	0.023	0.0455
1A3-067	0.07	0.00	0.007	0.1	0.10	0.04	0.001	0.001	0.0000
1A3-067	4.97	0.01	0.019	7.7	4.20	1.94	0.230	0.025	0.0415
1A3-067	4.94	0.00	0.012	7.7	4.20	1.91	0.230	0.025	0.0405
1A3-067	5.39	0.00	0.012	0.4	3.20	1.65	0.150	0.031	0.0319
1A3-069	6.24	0.06	0.000	0.3	0.80	2.71	0.006	0.082	0.0326
1C1-056	5.16	0.00	0.022	2.5	5.90	0.18	0.098	0.032	0.0341
1C1-059	3.30	0.00	0.011	12.4	3.30	0.45	0.013	0.022	0.0239
1C1-059	3.45	0.00	0.007	12.5	3.30	0.43	0.017	0.030	0.0248
1C1-059	0.04	0.00	0.000	6.9	1.80	0.02	0.001	0.001	0.0000
1C1-061	2.89	0.00	0.005	7.3	2.40	1.53	0.013	0.003	0.0590
1C1-062	4.43	0.00	0.008	8.4	5.00	0.79	0.051	0.006	0.0298
1C1-063	5.33	0.00	0.028	25.6	3.30	7.34	0.170	0.150	0.0422

(continued)

Footnotes at end of table.

TABLE 4. (Continued)

Lake ID[b]	pH (pH units)	Acid-Neutralizing Capacity (μeq/L)[c]	Total Al	Conductance (μS/cm)	Cl^-	Ca	Mg	Na	K
1C1-081	7.86	1485.66	0.006	176.00	0.28	28.20	1.09	3.47	0.98
1C1-091	5.78	16.19	0.053	18.90	0.29	1.73	0.46	0.42	0.14
1C1-105	6.48	146.67	0.073	37.40	0.40	4.62	0.58	0.50	0.33
1C1-108	6.46	52.55	0.024	23.70	0.25	3.02	0.38	0.25	0.14
1C1-114	6.10	63.94	0.100	20.30	0.25	1.88	0.87	0.20	0.12
1C2-071	6.57	81.33	0.052	27.80	0.34	3.31	0.44	0.81	0.26
1C2-071	6.70	66.14	0.048	27.90	0.35	3.30	0.46	0.82	0.26
1C2-071	5.84	-4.00	0.000	1.38	0.00	0.17	0.01	0.00	0.00
1C3-011	7.84	823.46	0.033	115.00	1.76	14.30	2.50	3.16	0.85
1C3-012	6.95	558.30	0.099	72.20	1.19	9.66	1.66	1.08	0.36
1C3-013	7.39	589.07	0.000	89.4	1.24	11.46	2.24	1.08	0.35
1C3-014	8.19	1331.40	0.000	152.2	2.81	22.60	3.30	2.63	0.67
1C3-017	8.12	1998.20	0.007	229.0	3.02	29.30	6.20	4.52	2.30
1C3-021	6.73	720.55	0.022	85.7	0.39	14.80	1.07	0.58	0.26
1C3-059	6.54	1073.83	0.017	124.4	1.84	13.70	5.20	1.53	0.50
1C3-065	7.33	817.46	0.005	103.0	0.39	16.20	2.20	0.63	0.26
1C3-072	7.81	568.29	0.000	98.0	3.96	10.98	1.89	3.94	0.46

(continued)

Footnotes at end of table.

TABLE 4. (Continued)

Lake ID[b]	SO_4^{2-}	NO_3-N[d]	Total P	DIC[e]	DOC[f]	SiO_2	Fe	Mn	Total
1C1-081	0.53	0.00	0.006	12.6	3.00	3.69	0.029	0.010	0.0501
1C1-091	4.73	0.00	0.014	1.1	3.70	0.37	0.160	0.020	0.0288
1C1-105	6.99	0.04	0.005	2.4	2.22	2.59	0.490	0.085	0.0270
1C1-108	5.34	0.00	0.010	1.2	3.40	0.39	0.038	0.024	0.0244
1C1-114	3.72	0.00	0.009	1.2	4.40	0.86	0.190	0.020	0.0188
1C2-071	5.45	0.00	0.000	1.4	4.30	4.03	0.017	0.016	0.0417
1C2-071	5.46	0.00	0.006	1.4	4.20	3.97	0.016	0.015	0.0400
1C2-071	0.08	0.00	0.000	0.5	0.10	0.02	0.002	0.001	0.0000
1C3-011	3.28	0.00	0.018	10.2	4.00	0.40	0.160	0.026	0.0488
1C3-012	4.77	0.00	0.011	7.2	3.50	1.34	0.450	0.044	0.0365
1C3-013	10.31	0.00	0.000	7.2	2.2	1.48	0.030	0.069	0.0322
1C3-014	8.04	0.00	0.006	15.9	5.7	2.44	0.020	0.009	0.0466
1C3-017	2.28	0.00	0.066	24.9	5.8	5.95	0.500	0.260	0.0520
1C3-021	4.14	0.00	0.010	8.5	10.3	0.35	0.150	0.004	0.0298
1C3-059	6.30	0.00	0.018	13.0	3.7	1.24	0.270	0.190	0.0412
1C3-065	7.30	0.00	0.005	9.9	3.2	0.66	0.034	0.073	0.0287
1C3-072	6.62	0.00	0.000	0.1	0.3	1.37	0.027	0.082	0.0240

[a]Unless specified, units for each analyte are in mg/L. Analyses performed by each laboratory are listed in Table 1.
[b]Lake identification numbers (Lake IDs) correspond to those used in the Eastern Lake Survey - Phase I data set published in Kanciruk et al. (1986).
[c]Although acid-neutralizing capacity was measured in mg/L $CaCO_3$, data were converted to μeq/L for this report.
[d]Nitrogen as nitrate.
[e]Dissolved inorganic carbon.
[f]Dissolved organic carbon.

TABLE 5. DATA FROM THE NORWEGIAN INSTITUTE FOR WATER RESEARCH[a]

Lake ID[b]	pH (pH Units)	Acid-Neutralizing Capacity (μeq/L)	Extractable Al	Conductance (μS/cm)	Cl^-	Ca	Mg	Na	K	SO_4^{2-}	NO_3^-
3A3-066	6.85	133.3	0.00	22.4	0.3	1.72	0.51	1.31	0.72	1.7	0.00000
3A3-004	7.09	237.8	0.00	46.3	2.7	2.42	1.19	4.10	0.97	4.0	0.23028
3A3-056	7.14	313.2	0.00	70.5	6.7	3.04	1.11	8.00	1.36	4.5	0.59786
3A1-008	5.60	0.0	0.00	1.4	0.0	0.04	0.00	0.02	0.00	0.0	0.00000
3A3-006	6.67	62.9	0.00	15.9	0.1	1.05	0.34	0.87	0.44	1.6	0.22143
3A1-008	7.24	329.5	0.00	46.2	1.9	3.15	1.74	2.50	1.61	1.5	0.04428
3A2-001	7.26	358.0	0.00	48.8	1.0	4.10	1.85	1.87	0.91	2.5	0.09300
3A3-092	7.63	1229.4	0.00	177.0	7.2	17.00	6.70	5.90	2.12	1.0	0.97428
3A2-001	7.25	360.1	0.00	49.2	1.1	4.15	1.86	1.88	0.94	2.6	0.09743
3A2-001	5.63	0.0	0.00	1.3	0.0	0.03	0.00	0.00	0.00	0.0	0.00000
3A3-001	7.22	585.4	0.04	78.8	3.1	7.90	2.01	3.00	1.92	3.1	0.19486
3A3-087	7.47	783.9	0.00	110.0	3.5	9.60	4.20	4.10	1.54	6.8	1.61643
3A2-066	6.84	103.4	0.00	18.1	0.2	1.31	0.45	1.09	0.55	0.9	0.25243
3A1-006	7.14	258.2	0.00	40.2	1.6	2.81	1.09	2.40	1.33	1.9	0.27457
3A2-065	6.78	89.9	0.07	20.5	0.7	1.69	0.37	1.14	0.44	1.4	0.51371
3A3-102	6.95	213.2	0.02	29.4	0.3	3.10	0.42	1.60	0.59	1.0	0.03543
3A2-004	6.98	234.7	0.07	57.8	6.0	4.36	1.13	3.90	0.96	2.3	1.79357
3A2-045	6.80	98.2	0.09	16.7	0.4	1.00	0.40	1.13	0.63	0.8	0.18600
3A2-044	6.80	85.8	0.00	14.6	0.4	0.76	0.44	1.00	0.52	0.6	0.00000
3A2-044	5.66	0.0	0.00	2.0	0.0	0.02	0.00	0.02	0.02	0.0	0.00000
3A2-017	6.84	120.9	0.00	17.6	0.2	1.28	0.47	1.05	0.51	0.7	0.01771
3A2-018	6.76	120.9	0.00	17.7	0.2	1.20	0.45	0.98	0.52	0.7	0.06200
3A2-044	6.83	84.7	0.00	14.9	0.4	0.76	0.44	1.09	0.51	0.6	0.00000
3A2-047	7.05	326.5	0.00	45.2	1.6	3.88	0.96	2.80	1.12	1.9	0.06643
3A2-046	6.94	145.6	0.07	23.5	1.2	1.24	0.59	1.77	0.83	0.7	0.25243
3A3-014	7.05	217.3	0.00	27.7	0.6	1.84	0.92	1.80	0.92	0.6	0.00000
3A2-049	7.12	208.1	0.00	28.5	1.0	1.68	0.76	2.70	1.10	0.9	0.00000
3A2-048	7.18	322.4	0.01	39.1	0.8	2.94	0.84	3.20	1.08	0.4	0.00000

(continued)

Footnotes at end of table.

TABLE 5. (Continued)

Lake ID[b]	pH (pH Units)	Acid-Neutralizing Capacity (μeq/L)	Extractable Al	Conductance (μS/cm)	Cl^-	Ca	Mg	Na	K	SO_4^{2-}	NO_3^-
3A2-015	7.04	209.1	0.03	32.8	0.6	3.02	0.88	1.34	0.75	2.0	0.26571
3A2-023	6.85	93.0	0.00	22.0	2.1	1.48	0.50	1.32	0.62	0.8	0.05757
3A2-019	6.91	174.3	0.00	30.7	0.6	2.51	0.79	1.34	0.97	2.2	0.67757
3A2-014	6.67	75.4	0.01	17.0	0.3	1.56	0.39	0.57	0.48	1.4	0.00000
3A2-022	6.80	172.3	0.00	26.8	0.6	2.06	0.63	1.42	0.85	1.2	0.00886
3A2-057	6.60	79.6	0.00	15.8	0.4	0.80	0.36	1.13	0.66	0.6	0.00443
3A2-058	7.10	294.9	0.00	41.1	1.1	3.43	1.08	2.09	1.27	1.5	0.09743
3A2-026	6.66	118.8	0.01	20.7	0.7	1.24	0.49	1.11	0.90	0.7	0.00886
3A2-028	6.57	66.0	0.03	13.6	0.4	0.57	0.35	0.98	0.66	0.3	0.16386
3A2-027	6.83	119.9	0.07	21.9	0.8	1.30	0.53	1.33	1.00	0.7	0.41628
3A2-029	7.14	278.6	0.07	37.9	1.1	2.41	0.94	3.10	1.25	1.2	0.00886
3A2-030	6.98	218.3	0.01	33.2	1.0	2.28	0.87	2.50	0.89	1.3	0.37200
3A3-009	6.90	235.7	0.01	32.7	0.7	2.09	0.86	2.40	0.86	1.3	0.00443
3A3-011	6.93	197.9	0.05	36.7	2.3	2.27	1.20	1.80	1.57	1.9	0.95214
3A3-065	6.97	255.1	0.03	40.0	2.2	2.49	1.07	2.40	1.70	2.0	0.42071
3A3-072	7.03	288.8	0.03	40.7	2.0	2.62	1.13	2.60	1.12	1.3	0.12400
3A3-011	5.59	0.0	0.00	1.3	0.0	0.03	0.00	0.01	0.00	0.0	0.00000
3A3-084	6.97	243.9	0.04	36.4	1.7	2.43	1.29	1.82	1.25	1.4	0.27457
3A3-070	6.89	178.4	0.02	35.6	2.9	1.94	0.96	2.40	1.64	1.8	0.13728
3A2-031	6.67	74.4	0.02	14.8	0.2	0.90	0.30	0.99	0.48	0.9	0.14171
3A2-033	6.42	35.7	0.06	11.8	0.2	0.66	0.26	0.80	0.40	1.4	0.09743
3A3-104	6.74	74.4	0.00	13.1	0.0	0.79	0.27	0.96	0.48	0.6	0.04428
3A3-104	6.72	75.4	0.00	13.1	0.0	0.79	0.27	0.95	0.48	0.8	0.04428
3A1-015	6.56	65.0	0.06	15.5	0.4	1.00	0.24	1.21	0.45	1.4	0.11957
3A1-014	6.79	117.8	0.13	34.8	4.0	1.91	0.45	3.20	1.24	1.4	0.20814
3A2-053	6.68	71.2	0.02	16.4	0.7	1.03	0.30	1.10	0.44	1.1	0.09300
3A2-038	6.58	57.7	0.12	21.1	1.6	1.32	0.37	1.46	0.55	1.9	0.62886
3A2-032	6.61	64.0	0.030	13.4	0.1	0.76	0.28	0.95	0.46	0.9	0.09743

(continued)

Footnotes at end of table.

TABLE 5. (Continued)

Lake ID[b]	pH (pH Units)	Acid-Neutralizing Capacity (μeq/L)	Extractable Al	Conductance (μS/cm)	Cl^-	Ca	Mg	Na	K	SO_4^{2-}	NO_3^-
3A2-061	6.46	53.5	0.080	27.9	3.0	1.96	0.63	1.26	0.97	3.0	0.06200
3A3-052	7.36	482.0	0.000	57.5	2.2	4.79	1.79	3.90	1.63	1.3	0.01771
3A3-057	7.30	365.1	0.000	57.0	3.5	4.24	1.45	3.70	1.75	2.9	0.07971
3A3-044	7.53	616.8	0.010	133.0	11.9	5.02	1.51	17.30	2.86	12.0	0.50486
3A3-046	5.67	0.0	0.000	1.4	0.0	0.02	0.00	0.02	0.02	0.0	0.00000
3A3-046	7.05	246.9	0.010	42.6	3.4	2.11	1.10	3.20	2.28	0.9	0.31886
3A3-061	7.10	229.6	0.000	40.0	2.9	2.33	1.14	2.80	1.77	1.7	0.18157
3A3-036	7.20	353.9	0.000	63.9	3.5	5.08	0.84	5.00	2.38	5.2	0.19486
3A3-078	7.25	345.8	0.000	89.6	7.0	6.70	1.36	5.90	3.06	11.0	0.59786
3A3-073	7.00	183.5	0.000	58.9	3.1	4.80	0.96	3.40	1.97	11.0	0.03543
3A3-035	7.13	291.8	0.000	51.1	3.8	3.27	1.02	3.60	2.09	2.1	0.12843
3A2-064	6.99	145.6	0.000	24.4	1.2	1.60	0.76	1.35	0.76	0.8	0.51371
3A3-017	7.27	474.9	0.010	63.2	2.8	4.68	1.74	3.60	2.60	1.2	0.97428
3A3-099	7.28	385.5	0.010	52.9	2.2	3.90	1.52	3.30	2.02	1.3	1.24000
3A3-095	6.98	173.3	0.000	31.5	1.7	1.94	0.81	1.90	1.29	2.2	0.18600
3A2-020	6.90	124.0	0.000	20.4	1.0	1.34	0.54	1.23	0.75	0.9	0.11957
3A2-021	7.07	188.7	0.000	27.7	1.1	2.42	0.62	1.52	0.88	1.3	0.04428
3A3-063	7.04	369.2	0.010	54.8	3.0	4.29	1.30	3.20	1.92	2.2	0.18600
3A3-068	7.35	417.0	0.110	69.9	2.8	5.90	1.95	3.00	2.62	6.5	0.63328
3A3-068	7.41	420.0	0.070	69.9	2.8	5.80	1.95	2.90	2.60	6.7	0.62886
3A3-026	6.67	176.4	0.011	43.1	4.4	2.21	0.70	3.46	2.31	3.4	0.00000
3A3-026	6.67	175.3	0.010	43.2	4.4	2.21	0.70	3.50	2.29	3.5	0.00000
3A3-086	6.89	216.3	0.000	33.2	3.0	1.56	0.61	3.82	0.77	0.7	0.03100
3A3-064	6.63	252.0	0.013	31.6	1.5	1.78	1.00	1.78	1.44	0.7	0.00000
3A3-021	6.73	234.7	0.000	45.7	3.9	2.12	0.70	4.01	2.46	1.7	1.81571
3A3-045	6.65	527.6	0.000	65.5	2.8	5.00	1.97	4.50	1.47	2.5	0.00000
3A3-053	6.98	177.4	0.000	28.2	1.4	1.70	0.68	2.21	0.89	2.1	0.08857
3A3-050	6.51	139.4	0.103	35.2	5.0	1.82	1.12	2.13	0.83	0.7	0.16386

(continued)

Footnotes at end of table.

TABLE 5. (Continued)

Lake ID[b]	pH (pH Units)	Acid-Neutralizing Capacity (μeq/L)	Extractable Al	Conductance (μS/cm)	Cl^-	Ca	Mg	Na	K	SO_4^{2-}	NO_3^-
3A3-038	6.86	680.6	0.017	82.8	3.6	6.04	2.09	5.57	2.60	0.8	0.18157
3A3-060	7.15	762.6	0.000	90.0	3.5	7.48	2.30	7.20	2.54	1.0	0.00000
3A3-053	5.79	1.6	0.000	1.1	0.0	0.02	0.00	0.00	0.00	0.0	0.00000
3A3-027	6.74	253.1	0.000	39.3	2.7	2.03	1.01	2.42	2.27	0.8	0.25243
3A3-022	6.63	185.6	0.000	30.8	2.1	1.54	0.69	2.13	1.68	1.3	0.17714
3A1-012	5.68	0.0	0.000	1.3	0.0	0.02	0.00	0.00	0.00	0.0	0.00000
3A2-036	6.76	202.0	0.000	29.1	1.1	2.12	0.78	1.58	0.68	1.1	0.34543
3A1-019	5.88	19.7	0.088	9.2	0.6	0.39	0.24	0.51	0.30	1.1	0.01328
3A2-039	6.91	119.9	0.000	18.9	0.8	1.19	0.42	1.28	0.56	1.3	0.07528
3A2-063	5.83	14.2	0.143	9.5	0.6	0.31	0.13	0.80	0.25	1.4	0.04871
3A1-012	6.53	65.0	0.014	12.2	0.6	0.84	0.25	0.65	0.32	0.9	0.03543
3A2-043	6.77	160.0	0.067	21.6	0.9	1.25	0.38	1.95	0.86	0.8	0.00000
3A2-042	6.96	149.7	0.000	22.8	0.9	1.31	0.61	1.88	0.62	1.3	0.00000
3A3-058	7.14	500.2	0.000	80.2	2.4	7.20	3.30	2.20	1.30	6.6	3.05571
3A3-058	7.22	496.2	0.000	80.3	2.5	7.10	3.20	2.30	1.29	6.9	3.03357
3A3-103	7.40	499.2	0.000	76.4	2.5	6.70	3.00	2.50	1.28	6.0	2.08143
3A2-003	6.78	94.1	0.000	23.1	2.6	1.14	0.59	1.58	0.52	0.6	0.13286
3A2-002	6.62	70.2	0.000	13.9	0.7	0.67	0.44	0.91	0.34	0.9	0.00443
3A3-082	7.02	250.0	0.040	43.7	2.4	2.74	0.94	3.60	1.52	2.4	1.24000
3A2-035	6.93	112.7	0.020	17.8	0.9	1.00	0.31	1.60	0.71	0.4	0.01771
3A3-074	7.49	907.3	0.010	232.0	27.0	5.50	1.44	39.00	3.90	15.0	9.74286
3A3-012	6.62	48.3	0.000	15.5	0.9	0.62	0.43	0.99	0.64	1.8	0.00000
3A2-008	7.19	227.5	0.000	29.5	0.6	3.23	0.72	1.13	0.59	1.4	0.14614
3A2-006	7.26	694.8	0.150	470.0	110.0	24.60	2.05	59.00	3.66	34.0	2.50214
3A1-010	6.39	22.9	0.100	15.3	0.6	0.90	0.36	0.67	0.60	2.0	0.69971
3A2-009	6.83	82.7	0.000	14.6	0.6	1.04	0.42	0.79	0.37	1.4	0.03100

[a]Unless specified, units for each analyte are in mg/L.
[b]Lake identification numbers (Lake IDs) correspond to those used in the Eastern Lake Survey - Phase I data set published in Kanciruk et al. (1986).

SECTION 5

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