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Effects of Beaver (*Castor canadensis*) Activity On Stream Water Quality Under Conditions of Prolonged Snow and Ice-Cover (Winter 1991-1992)

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Effects of Beaver (*Castor canadensis*) Activity On Stream Water Quality Under Conditions of Prolonged Snow and Ice-Cover (Winter 1991-1992)[1]

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ABSTRACT

The main objective of this study was to determine the effects of beaver activity on water quality under conditions of winter ice-cover. A secondary objective was to contrast the water quality parameters from beaver ponds of different ages.

From November 30, 1991 until April 25, 1992 weekly water samples were collected under snow and ice-cover from two beaver ponds and their proximal streams in Catamaran Brook, a tributary of the Little Southwest Miramichi of Central New Brunswick. These samples were analyzed for specific conductance, turbidity, apparent colour, dissolved oxygen, dissolved nitrate and dissolved sulphate. It was hypothesized that stream "contamination" is likely to occur downstream from beaver ponds by diffusive transport of water quality parameters, and that the effects would be detected under ice-cover, as the "shield" resulting from ice-cover would exclude changes to water quality from environmental fall out. It was also hypothesized that older mature ponds, compared with newly created ponds, would induce greater changes to water quality of the proximal stream, as the water quality would be poorer in the older ponds. Also as more sediments accumulate in older ponds, the potential for water quality changes becomes greater (Johnston and Naiman, 1990, 1985). Therefore, both an old abandoned pond and a new active pond were chosen for study.

Results indicated that, under snow and ice-cover, there was no appreciable difference in the water quality within, or between, sampling sites. However, oxygen percent saturations and specific conductance for the older pond differed from the other study sites; respectively, oxygen saturation was 0.5 mg/l lower, and specific conductance were 10 units lower, on average. Several trends were observed at all sampling sites; oxygen percent saturation was highest prior to ice-cover and a positive trend occurred during the winter. Specific conductance, dissolved nitrate and sulphate initially tended to increase under ice-cover, but began to decline by mid-winter. Turbidity and apparent color tended to decrease under ice-cover.

The effects of beaver activity on stream water quality in or near beaver ponds, of different maturity, were found to be negligible under ice-cover at Catamaran Brook.

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RESUME

Le but principal de cette présente étude est de déterminer l'effet des barrages de castors sur la qualité de l'eau durant la couverture de glace en hiver. L'étude à également comme but secondaire, de comparer la qualité de l'eau des barrages de castors de différents âges.

Du 30 novembre 1991 jusqu'au 25 avril 1992, des échantillons d'eau ont été recueillis hebdomadairement à partir de deux sites sur le ruisseau Catamaran ayant un barrage de castors, ainsi qu'à partir de cours d'eau à proximité de ce ruisseau. Ces sites sont situés près du ruisseau Catamaran, un affluent de la rivière Little Southwest Miramichi au centre du Nouveau-Brunswick. Les échantillons d'eau ont été analysés pour la conductivité, la turbidité, la couleur apparente, l'oxygène dissous, l'azote-nitrate et les sulfates dissous. L'hypothèse à vérifier est qu'une contamination par diffusion des paramètres de qualité de l'eau a lieu dans les cours d'eau en aval des barrages de castors et que les changements peuvent être détectés sous la couverture de glace. En effet, la couverture de glace empêcherait les changements de la qualité de l'eau causés par la précipitation durant la période en étude. L'autre hypothèse à vérifier est que les barrages de castors plus âgés subissent des changements de qualité d'eau plus importants dans leurs cours d'eau en aval comparativement aux jeunes barrages. Ceci, étant donné que plus de sédiments sont déposés dans les barrages plus âgés et implique une probabilité d'un changement de qualité d'eau plus grand (Johnston et Naiman 1990, 1985). Alors, l'étude porte sur un barrage de castor âgé et abandonné et sur un jeune barrage actif.

Les résultats démontrent qu'il n'y a aucun changement dans la qualité de l'eau en conditions de couverture de glace et entre les barrages en étude. Par contre, le niveau de saturation de l'oxygène dissous et la conductivité du barrage âgé étaient plus faible de 0.5 mg/l pour l'oxygéne dissous et de 10 unités de conductivité inférieurs en moyenne. Quelques tendances ont été observées pour tous les sites: un pourcentage supérieur en oxygéne dissous avant la couverture de glace, une tendance positive pour la conductivité, une augmentation initiale des concentrations de nitrates et les sulfates dissous sous la couverture de glace, suivi d'une diminution à partir du mi-hiver. La turbidité et la couleur apparente étaient en diminution en conditions du couverture de glace.

Les effets sur la qualité de l'eau du ruisseau Catamaran, dans les barrages de castors et en aval de ceux-ci, étaient négligeables dans les conditions du couverture de glace et également pour des barrages de castors de différents âges.

INTRODUCTION:

Beaver, *Castor canadensis*, ponds are temporary structures that undergo constant change as in all types of habitats. As a beaver pond matures, debris and sediments accumulate in the pond basin where bacterial decomposition of these deposits occurs. During the bacterial decomposition process a series of redox reactions changes the sedimentary compounds into other elemental forms which are then released into the surrounding environment (water, land and air). Because beaver ponds are not totally isolated from their proximal streams, some stream "contamination" is likely to be carried downstream by diffusive transport. Therefore, by comparing the water quality of beaver ponds to that of the proximal stream, any impacts on quality should be detected downstream from beaver ponds. Testing the effects of a beaver pond on water quality would be best carried out under conditions of winter snow and ice-cover. The "shield" produced by snow and ice-cover should isolate water quality changes induced by sedimentary decomposition from those induced by environmental fall out, and the like (Wetzel, 1983).

To test this hypothesis, two beaver ponds and their proximal streams were monitored for changes in water quality. Specifically, the following water quality parameters were assessed under conditions of winter snow and ice-cover: dissolved oxygen content, specific conductance, turbidity, apparent colour, dissolved nitrate and sulphate. The ponds chosen for study were located within the catchment of Catamaran Brook (46°52.7'N, 66°06.0'W) a tributary of the Little Southwest Miramichi River of central New Brunswick (Cunjak et al., 1990).

A secondary objective of this study was to contrast the water quality from beaver ponds of different ages. Older, mature ponds, compared with newly created ponds, have less water storage capabilities and more sediment accumulation (Johnston and Naiman, 1990). Therefore, it was hypothesized that sedimentary decomposition processes and alterations to water quality should be greater in older ponds, and should induce greater water quality changes to its proximal stream than in newly created ponds.

STUDY AREA:

The study area was Catamaran Brook and included sites at: (1) an active beaver dam (approximately 2 months old at the onset of study) along the main stream of Catamaran Brook, approximately 7 km above the river mouth; (2) an old abandoned beaver dam (> 5 years old) on the main tributary (Tributary One) of Catamaran Brook; and (3) the confluence of the tributary and mainstream (Figure 1).

ACTIVE BEAVER POND:

The active beaver pond was located on the main stem of Catamaran Brook, 225 m upstream from the confluence (Tributary One), (Figure 1) and contained a dam that obstructed the entire width of the brook.

Several small islands, within the pond, were separated by a series of water channels, and supported a network of densely arranged alders, shrubs and grasses. A thick mixed canopy of coniferous forest plant species (furs, spruce and cedars) stood close to the water bank.

During a September 1992 survey, total water surface area of the pond was calculated at 580 m^2, with a minimum flooding potential of 1100 m^2, as predicted by the flood plain. Maximum water depth was 1.3 m with an average depth of 1 m. Differences in elevation between the water surface below and above the dam averaged 85 cm. Total length of the dam was 87 m. Two beaver lodges were located in the pond: a small bank lodge 12 m upstream from the dam, and a larger bank lodge 60 m upstream from the dam closer to the head of the pond (Figure 2a).

Generally, in the deeper water near the dam, water flowed over a largely sandy substrate mixed with an abundance of plant litter and debris (wood, leaves and needles). Further upstream (80 m) where water depths became shallower (≤0.50 m), water movement was faster, and flowed over coarse gravel, pebbles, small to large rubble and boulders. Water level and substrate composition below the dam was similar to the upstream reaches of this study location.

Four sampling sites were chosen in the active pond: 6 m below the dam in the outflow stream (N-1); 2 m above the dam within the pond (N-2); 65 m above the dam near the head of the pond (N-3); and, further upstream (135 m, above the dam) presumably removed from the pond's influence, at the sight of the first major riffle. Refer to Appendix A for substrate scores calculated for each of the sampling sites and Figure 2a for sampling site dimensions.

ABANDONED POND:

The abandoned beaver pond was located 165 m upstream from the confluence of Tributary One and the mainstem of Catamaran Brook (Figure 1) and contained a much smaller dam than the active pond. This dam did not obstruct the entire width of the brook. Several small grassy islands, separated by intermittent spillways, directed water in and around the pond. This was the first of several beaver impoundments along the length of the tributary.

This pond was not as densely covered by riparian vegetation as the active pond. Aside from the alders, there was a tall stand of white cedars to one side and spruce and fir on the other.

Total water surface area of this pond was 300 m^2 with a minimum flooding potential of 650 m^2. Maximum water depth was 74 cm, with an average depth of 0.5 m. Differences between the water surface upstream and downstream of the dam averaged 37 cm. Total length of the dam was 23 m. Remnants of an old bank lodge were located 37 m upstream from the dam near the head of the pond (Figure 2b).

Generally, pond sediments were composed of fine silt , sand, and gravel. Above the pond's inflow, substrate was composed of gravel, pebbles, rubble and boulders. Water depths were greatest at the inflow, measuring 74 cm during the September 1992 survey and gradually becoming shallower (40cm) as one approach the dam.

Three sampling sites were chosen: 7 m below the dam (O-1); 4 m above the dam (O-2); and, 36 m upstream from the dam at the pond's inflow (O-3). An active beaver dam was located 25 m upstream from O-3, therefore no upstream riffle was chosen as a forth sampling site. Refer to Appendix A for substrate scores calculated for each of the sampling sites and Figure 2b for sampling site dimensions.

JUNCTION SITES:

The third sampling location was at the convergence of Catamaran Brook and Tributary One (Figure 1). Three sampling sites were chosen: 7 m above the junction on Catamaran Brook (C-J), with a stream width of 3.5 m, stream depth of 15 cm and substrate composition of course gravel, pebbles and rubble; 7 m above the junction on the Tributary One (T-J), with a stream width of 2 m, stream depth of 43 cm and a substrate composition of boulder, gravel, and sand; and 20 m below the junction on Catamaran Brook (J-J), with a stream width of 6 m, stream depth of 15 cm and substrate composition similar to C-J. Refer to Appendix A for substrate scores for these sites.

For the remainder of this report sampling sites will be referenced as follows:

C-J	CATAMARAN BROOK ABOVE JUNCTION
T-J	TRIBUTARY ONE ABOVE JUNCTION
J-J	CATAMARAN BROOK BELOW JUNCTION
N-1	NEW ACTIVE POND BELOW DAM
N-2	NEW ACTIVE POND ABOVE DAM
N-3	NEW ACTIVE POND AT POND INFLOW
N-4	NEW ACTIVE POND UPSTREAM RIFFLE
O-1	OLD ABANDONED POND BELOW DAM
O-2	OLD ABANDONED POND ABOVE DAM
O-3	OLD ABANDONED POND AT POND INFLOW

Sampling occurred every Saturday from November 30, 1991 (just prior to freeze-up) until April 27, 1992, when all ice-cover on the stream/pond had disappeared. This corresponds to 22 sampling dates. Refer to Table 1.

MATERIALS and METHODS:

In total, 21 of 22 possible weekly samples were collected and analyzed. (Note: the tenth week of sampling was omitted due to a storm event, February 4, 1992).

Initially an ice chisel and manual ice auger were used to drill holes in the ice to obtain water samples. As the ice became progressively thicker, a chain saw had to be used. Samples were collected by working in an upstream direction to ensure that they were undisturbed. Once through the ice, water samples were collected; water temperature, water depth and snow and ice thickness was recorded.

At least two water samples were collected from each sample site. The first water sample was taken ≤30 cm above the substrate for measuring dissolved oxygen content (the method for collection and analysis of dissolved oxygen can be found in Appendix B). At sample sites where water depths were >80 cm (N-2 and O-3) two D.O. (dissolved oxygen) samples were obtained, the first approximately 30 cm above the substrate and the second approximately 20 cm below the water surface. This was to investigate possible differences in D.O. with water depth.

The second water sample was taken from mid-depth in a clean 250 ml white plastic bottle that was rinsed three times at the site prior to the actual collection. This sample was used to analyze the following parameters: turbidity, apparent colour, specific conductance, dissolved nitrate and dissolved sulphate (for methods for analysis see Appendix B, Naquadat 1991).

Final measurements and parameters were tabulated and arranged under the following headings: date of sampling, sample site, weather, air temperature, snow-cover, ice-cover, water depth, water temperature, dissolved oxygen content, specific conductance, apparent colour, turbidity, dissolved nitrate, and sulphate (Table 1).

Since oxygen content is inversely proportional to water temperature, a calculation determined the percent oxygen saturation (i.e. a value of 13 mg/l D.O. and a value of

14 mg/l D.O. can both be at 100% saturation because of the temperature dependance). Each value for D.O. (mg/l) and water temperature (°C) was compared with the value of D.O. at 100% saturation at that particular temperature to obtain percent saturation.

Example: at 0.5°C we obtain a value for D.O. of 13.00 mg/l on a particular sample date. We then find that water at 0.5°C is 100% saturated at D.O. 14.10 mg/l, now we calculate the percent saturation of our sample.

% oxygen saturation = 13.00(mg/l)/14.10(mg/l) * 100%= 92.20 %

Percent oxygen saturation values were computed and tabulated in Table 1.

Table 2 shows the calculated means and standard deviations computed for each of the above mentioned parameters, by sample site.

Slopes were calculated for percent oxygen saturations by site (Table 3) to determine the direction of the trend over time.

Percent oxygen saturation values from Table 1 were plotted over time by sample site and date (Figure 3). In addition, a graph contrasted average percent of oxygen saturation values among the three study areas (Figure 4).

Each parameter: Specific Conductance, Turbidity, Apparent colour, Dissolved Nitrate and Dissolved Sulphate from Table 1 were plotted as parameter versus time, by sampling site (Figures 5-9).

RESULTS AND DISCUSSION:

During the period of study only one sampling site remained free of snow or ice-cover (J-J). This site was located immediately downstream from the confluence of Tributary One in Catamaran Brook. Rapid water-flow rates caused by the confluence probably contributed to this observation. All other sampling sites experienced periods of complete snow and ice-cover (Table 1). A maximum ice thickness of 87 cm (±2.5 cm) was recorded at site N-3 on March 21, 1992. Observations recorded for N-3 showed a mean ice thickness of 50 cm (±28 cm), appreciably thicker than all the other sites (Table 2). Snow cover was highest on February 29, 1992 (Table 1), with the extreme accumulation recorded at 86 cm for C-J.

Water temperature was relatively consistent for each sampling site, varying by only 0.1°C among sites on any particular sample date. However, on the last date of sampling (April 27, 1992), once both streams were free of ice-cover, Catamaran Brook had water temperatures 0.6°C greater than the Tributary One (Table 1). Slower ice melt in the many beaver ponds along the tributary, combined with slower flow rates and a smaller more shaded stream channel may explain the temperature difference.

Lowest oxygen saturation values were recorded for the old abandoned pond (Table 1). However, anoxic conditions were never a factor during study. When considering "dissolved oxygen requirements as recommended by Davis, (1975)," at water temperatures between 0° and 5°C, warm-water biota require a minimum of 47% oxygen saturation, cold-water biota require 57% oxygen saturation, and salmonids primarily require a minimum of 57% oxygen saturation. The lowest percent oxygen saturation recorded during our observation was 79% (Table 1), far greater than the minimal requirements of the aquatic biota in Catamaran Brook.

Percent oxygen saturation values showed a slight increase over the sampling period, with slopes between 0.05 to 0.36, and intercepts between 84.90 to 92.39, (Table 3).

Differences in percent oxygen saturation values below the beaver dam, above the dam and at the pond's inflow were negligible, as were top and bottom oxygen profiles monitored at N-2 and O-3 (Figure 3).

Average percent oxygen saturation values (Note: D.O.'s were pooled at each area because of negligible differences on any date), pooled for all three study sites, were greatest in the new active pond along Catamaran Brook proper, and lowest in the old abandoned pond in Tributary One (Figure 4).

Percent oxygen saturation values at the Junction study site, further downstream from both ponds, were intermediate in value to those from the other study sites. These results suggest that the old abandoned pond and the new active ponds and their combined influences alter water quality downstream for some distance (in this case >0.25 km).

Specific conductance (Figure 5) showed steady increases in concentration during the winter punctuated by marked declines in early January (week 7) and late March (week 19). These declines occurred after heavy rain events (January 11 and March 28, 1992) that caused the discharge to increase and concentrations to decrease because of an ion dilution effect.

There were no detectable differences in conductance within sample locations. However, the old abandoned pond was observed to be 10 conductance units lower than the new pond on most sampling dates. Lower flow rates in the older pond may have contributed to less mixing of ions at the sediment-water interface, perhaps resulting in the lower conductance values.

Turbidity was primarily unaffected by the presence of snow and ice-cover (Figure 6). However, a decline was observed for the older pond. An interesting observation noted on the 18th week of sampling (March 28, 1992) was that turbidity units increased greatly for all sampling sites. This flux in turbidity may have resulted from land surface runoff, as it was raining heavily on this date. An increase of 0.203 m^3/s in stream water discharge was recorded by Environment Canada (unpublished data) at Catamaran Brook on this date.

Apparent colour (Figure 7) decreased as snow and ice-cover increased (see Table 1). Colour units were observed to be greatest during ice-free and/or snow-free periods. Since apparent colour is a measure of suspended matter, it follows that increases would result from increased discharge produced by rain or runoff, especially during ice-free periods. Few differences were seen for apparent colour within or among the three study locations.

Dissolved nitrate (Figure 8) and dissolved sulphate (Figure 9) initially increased during winter. Nitrate showed a marked decline following the March 28 rain event (week 18) and thereafter continued to decline as snow/ice-cover disappeared. For dissolved sulphate, the decline in concentrations began at approximately week 16 (March 14), and continued the end of sampling, similar to the trend for specific conductance (Figure 5).

Both dissolved nitrate and sulphate originate from the oxidation of sediments and biological waste, and from industrial fall out (McNeeley, et al., 1979). Our results suggest that natural processes, i.e. oxidation of the sediments and organic biological waste (especially beaver feces), led to the initial increases in these parameters under ice-cover. As in the early months of winter, the water-sediment interface would be rich in those material available for oxidation. However, as the winter months progressed and these material diminished, so did the concentration of nutrients (nitrate and sulphate). Interestingly, on the 18th week of sampling (March 28, 1992), it rained heavily and the nitrate concentration increased, possibly resulting from mixing of the water-sediment interface, which stirred up traces of the materials needed for nitrate production.

The trend observed for Specific Conductance, Apparent Colour, Turbidity, Dissolved Nitrate and Dissolved Sulphate in this study, were compared to results from water quality analyses of two regular sampling sites on Catamaran Brook, and one site in the Little Southwest Miramichi River (where Catamaran empties). Similar trends for all of the above parameters were observed over the 1991-1992 winter period for all of the sampling sites. There were marginal differences in water quality values for the Little Southwest Miramichi River, having lower conductance levels and a greater amount of turbidity (Cunjak et al., 1993) however, the overall trends were the same.

In summary, no appreciable changes to water quality were detected under ice-cover, and changes to stream water quality resulting from beaver pond "contamination" were marginal. The greatest effects to water quality, under ice-cover, occurred during winter thaws, brought about by precipitation in the form of rain. However, rain effects were also marginal.

CONCLUSION:

It was hypothesized that stream "contamination" was likely to occur downstream from beaver dam/ponds by diffusive transport of water quality parameters, and that these effects would be more readily detectable under conditions of prolonged snow and ice-cover. It was also hypothesized that older mature ponds, compared with newly-created ponds would induce greater water quality changes to the proximal stream.

It was found that, under conditions of prolonged snow and ice-cover, there was no appreciable difference in the water quality of within, or between, sample sites. However, oxygen percent saturation values, and specific conductance values for the old pond differed from those of the other study sites; oxygen saturations were 0.5 mg/l lower, and specific conductance were 10 units lower on average. Overall trends were apparent for all sampling sites however, these trends were marginal. Oxygen percent saturation values were highest prior to ice-cover, specific conductance, dissolve nitrate and sulphate tended to increase in the early months of winter, and then began to decline in the late winter months. Turbidity and apparent color tended to decrease under ice-cover.

It can be concluded that the effects on stream water quality within Catamaran Brook in or near beaver ponds (of different ages) were negligible.

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bitterly cold winter days we shared together. -Sincerely thanks to all.

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Table 1. Chemical and Physical Water Quality Parameters measured in Catamaran Brook, N.B., in or near Beaver Ponds under ice–cover (1991–1992), by sampling date and study site.

WEEK	DATE DD-MM-YY	SAMPLE SITE:	WEATHER	AIR TEMP (°C)	SNOW COVER (cm)	ICE COVER: (cm)	WATER DEPTH (cm)	WATER TEMP: (°C) TOP	WATER TEMP: (°C) BOT	DISS OXYGEN: (mg/l) TOP	DISS OXYGEN: (mg/l) BOT	PERCENT DISS. OXYGEN: (%) TOP	PERCENT DISS. OXYGEN: (%) BOT	SPECIFIC CONDCTNC: (USIE/cm)	APPARENT COLOUR: (rel.unit)	TURBIDITY: (JTU)	NITROGEN DISSOLVED (mg/l)	SULPHATE DISSOLVED: (mg/l)
1	30-11-91	N-1a	OVERCAST	-12	0.0	0.0	25.0	0.5	—	14.93	—	103.57	—	49.20	20.00	0.60	0.03	4.00
2	07-12-91	N-1b	FLURRIES	-24	1.0	12.5	11.0	0.3	—	13.68	—	94.35	—	54.40	20.00	1.10	0.07	3.50
3	14-12-91	N-1c	OVERCAST	2	0.0	7.5	12.5	0.3	—	12.99	—	89.62	—	48.00	20.00	0.88	0.14	4.70
4	21-12-91	N-1d	SNOW-FALL	-9	17.5	10.0	10.0	0.3	—	12.85	—	88.64	—	62.30	10.00	0.73	0.09	3.80
5	28-12-91	N-1e	OVERCAST	-5	12.5	12.5	10.0	0.1	—	13.09	—	89.78	—	66.00	15.00	0.23	0.05	4.50
6	04-01-92	N-1f	SUN/CLEAR	0	11.0	12.0	10.0	0.1	—	13.14	—	90.10	—	71.00	15.00	0.34	0.06	5.10
7	11-01-92	N-1g	SUN/CLEAR	-13	3.0	19.0	13.0	0.1	—	13.60	—	93.28	—	54.20	15.00	0.32	0.14	4.20
8	18-01-92	N-1h	FLURRIES	-14	0.0	30.0	20.0	0.1	—	13.50	—	92.59	—	57.00	15.00	0.30	0.13	4.80
9	25-01-92	N-1i	SUN/CLEAR	-24	0.0	3.0	30.0	0.1	—	13.00	—	89.16	—	54.00	25.00	0.45	0.14	4.90
10	01-02-92	N-1j	HEAVYSNOW															
11	08-02-92	N-1k	SNOW-FALL	-14	25.0	12.0	35.0	0.1	—	13.70	—	93.96	—	68.50	5.00	0.34	0.15	4.40
12	15-02-92	N-1l	CLOUDYPER	-7	0.0	0.0	22.0	0.1	—	13.90	—	95.33	—	73.00	5.00	0.42	0.14	4.90
13	22-02-92	N-1m	SUN/CLEAR	-14	1.0	3.0	20.0	0.3	—	14.10	—	97.24	—	76.00	5.00	0.37	0.13	4.90
14	29-02-92	N-1n	SUN/CLOUD	-12	20.0	4.0	15.0	0.2	—	13.65	—	93.88	—	77.00	5.00	0.30	0.14	4.80
15	07-03-92	N-1o	FLURRIES	-4	0.0	1.0	13.0	0.2	—	14.05	—	96.63	—	79.00	5.00	0.29	0.13	5.20
16	14-03-92	N-1p	SUN/CLEAR	-16	0.0	2.0	20.0	0.2	—	13.85	—	95.25	—	60.00	10.00	0.37	0.14	4.60
17	21-03-92	N-1q	SUN/CLEAR	-6	0.0	5.0	12.0	0.1	—	14.10	—	96.70	—	71.00	5.00	0.49	0.14	4.60
18	28-03-92	N-1r	RAIN	3	0.0	0.0	20.0	0.1	—	13.50	—	92.59	—	66.00	20.00	3.20	0.20	5.10
19	04-04-92	N-1s	OVERCAST	3	0.0	0.0	45.0	0.2	—	13.00	—	89.41	—	41.00	15.00	0.70	0.09	3.40
20	11-04-92	N-1t	SUN/CLOUD	-3	0.0	0.0	33.0	0.3	—	14.20	—	97.93	—	45.00	15.00	0.57	0.11	3.00
21	18-04-92	N-1u	SUN/CLEAR	7	0.0	0.0	26.0	0.9	—	13.90	—	97.50	—	39.00	15.00	0.75	0.06	2.90
22	25-04-92	N-1v	FLURRIES	-1	0.0	0.0	48.0	1.2	—	13.95	—	98.67	—	52.00	10.00	0.47	0.07	3.40
1	30-11-91	N-2a	OVERCAST	-12	0.0	2.0	110.0	0.5	0.5	13.47	13.63	93.40	94.55	48.60	25.00	0.71	0.04	4.00
2	07-12-91	N-2b	FLURRIES	-24	10.0	8.0	110.0	0.3	0.3	12.75	12.84	87.93	88.55	54.30	15.00	1.00	0.08	3.60
3	14-12-91	N-2c	OVERCAST	2	0.0	15.0	92.0	0.3	0.3	13.09	13.28	90.28	91.59	51.40	15.00	0.71	0.16	4.30
4	21-12-91	N-2d	SNOW-FALL	-9	15.0	25.0	85.0	0.3	0.3	12.80	12.76	88.31	87.98	61.30	10.00	0.77	0.10	4.20
5	28-12-91	N-2e	OVERCAST	-6	15.0	32.5	90.0	0.0	0.1	13.28	13.33	90.83	91.41	67.00	15.00	0.22	0.05	4.60
6	04-01-92	N-2f	SUN/CLEAR	-4	15.0	25.0	85.0	0.1	0.1	13.33	13.42	91.41	92.06	71.00	15.00	0.36	0.06	4.90
7	11-01-92	N-2g	SUN/CLEAR	-13	3.0	48.0	82.0	0.1	0.1	13.40	13.35	91.90	91.56	54.20	15.00	0.39	0.14	4.60
8	18-01-92	N-2h	FLURRIES	-14	0.0	56.0	86.0	0.1	0.1	13.45	13.35	92.25	91.56	59.00	15.00	0.34	0.11	4.50
9	25-01-92	N-2i	SUN/CLEAR	-24	0.0	70.0	117.0	0.1	0.1	13.70	13.35	93.96	91.56	62.00	15.00	0.52	0.14	5.00
10	01-02-92	N-2j	HEAVYSNOW															
11	08-02-92	N-2k	SNOW-FALL	-14	34.0	77.0	80.0	0.1	0.1	13.70	13.75	93.96	94.30	68.70	5.00	0.34	0.13	4.60
12	15-02-92	N-2l	CLOUDYPER	-7	40.0	77.0	80.0	0.1	0.1	13.95	14.00	95.68	96.02	73.00	5.00	0.37	0.14	5.00
13	22-02-92	N-2m	SUN/CLEAR	-14	73.0	79.0	86.0	0.2	0.2	14.10	14.10	96.97	96.97	76.00	5.00	0.33	0.14	4.80
14	29-02-92	N-2n	SUN/CLOUD	-12	82.0	77.0	85.0	0.1	0.1	13.70	13.65	93.96	93.62	78.00	5.00	0.35	0.15	4.80
15	07-03-92	N-2o	FLURRIES	-4	64.0	77.0	83.0	0.2	0.3	14.05	14.20	96.63	97.93	79.00	2.00	0.31	0.14	4.80
16	14-03-92	N-2p	SUN/CLEAR	-16	55.0	70.0	85.0	0.2	0.2	13.70	13.35	94.22	91.82	60.00	10.00	0.37	0.14	4.60
17	21-03-92	N-2q	SUN/CLEAR	-6	48.0	77.0	85.0	0.1	0.1	14.15	13.65	97.05	93.62	71.00	15.00	0.37	0.15	4.60
18	28-03-92	N-2r	RAIN	3	33.0	55.0	94.0	0.2	0.2	13.30	13.45	91.47	92.50	61.00	15.00	5.10	0.20	5.10
19	04-04-92	N-2s	OVERCAST	3	0.0	48.0	129.0	0.4	0.3	13.00	12.95	89.91	89.31	42.00	15.00	0.45	0.10	3.30
20	11-04-92	N-2t	SUN/CLOUD	-3	0.0	28.0	96.0	0.4	0.4	14.10	14.05	97.52	97.17	45.00	15.00	0.54	0.11	3.00
21	18-04-92	N-2u	SUN/CLEAR	7	0.0	0.0	95.0	0.9	0.9	14.15	13.95	99.25	97.85	39.00	20.00	0.77	0.05	2.80
22	25-04-92	N-2v	FLURRIES	-1	0.0	0.0	97.0	1.2	1.2	13.60	13.70	96.19	96.90	52.00	10.00	0.44	0.07	3.40

(CONTINUED)

Table 1. Chemical and Physical Water Quality Parameters measured in Catamaran Brook, N.B., in or near Beaver Ponds under ice-cover (1991-1992), by sampling date and study site.

WEEK	DATE DD-MM-YY	SAMPLE SITE:	WEATHER	AIR TEMP. (°C)	SNOW COVER: (cm)	ICE COVER: (cm)	WATER DEPTH: (cm)	WATER TEMP: (°C)		DISS. OXYGEN: (mg/l)		PERCENT DISS. OXYGEN: (%)		SPECIFIC CONDCTNC: (USIE/cm)	APPARENT COLOUR: (rel.unit)	TURBIDITY (JTU)	NITROGEN DISSOLVED: (mg/l)	SULPHATE DISSOLVED: (mg/l)
								TOP	BOT	TOP	BOT	TOP	BOT					
1	30-11-91	N-3a	OVERCAST	-11	0.0	2.0	86.0	0.5	0.5	13.83	13.75	95.92	95.36	46.90	20.00	0.74	0.04	4.00
2	07-12-91	N-3b	FLURRIES	-24	0.0	12.5	60.0	0.3	—	14.33	—	98.83	—	54.80	15.00	0.90	0.10	3.50
3	14-12-91	N-3c	OVERCAST	1	0.0	17.5	45.0	0.3	—	12.71	—	87.65	—	48.00	20.00	0.85	0.12	4.20
4	21-12-91	N-3d	SNOW-FALL	-9	17.5	21.0	45.0	0.3	—	13.55	—	93.45	—	61.80	10.00	0.77	0.09	4.30
5	28-12-91	N-3e	OVERCAST	-7	15.0	33.0	41.0	0.1	—	13.14	—	90.10	—	67.00	15.00	0.23	0.05	4.50
6	04-01-92	N-3f	SUN/CLEAR	-4	13.0	33.0	42.0	0.1	—	13.57	—	93.04	—	71.00	15.00	0.29	0.06	4.90
7	11-01-92	N-3g	SUN/CLEAR	-13	1.0	40.0	45.0	0.1	—	13.35	—	91.56	—	56.00	15.00	0.52	0.15	4.50
8	18-01-92	N-3h	FLURRIES	-14	0.0	54.0	48.0	0.1	—	13.50	—	92.59	—	63.00	15.00	3.60	0.13	5.20
9	25-01-92	N-3i	SUN/CLEAR	-22	0.0	53.0	76.0	0.1	—	13.45	—	92.25	—	57.00	10.00	0.47	0.12	4.60
10	01-02-92	N-3j	HEAVYSNOW										—					
11	08-02-92	N-3k	SNOW-FALL	-14	26.0	77.0	27.0	0.1	—	13.70	—	93.96	—	69.50	5.00	1.25	0.13	4.60
12	15-02-92	N-3l	CLOUDYPER	-7	32.0	77.0	25.0	0.1	—	14.00	—	96.02	—	74.00	5.00	0.54	0.14	4.70
13	22-02-92	N-3m	SUN/CLEAR	-14	66.0	77.0	31.0	0.2	—	14.05	—	96.63	—	76.00	5.00	0.65	0.14	4.70
14	29-02-92	N-3n	SUN/CLOUD	-12	75.0	77.0	30.0	0.2	—	13.65	—	93.88	—	78.00	5.00	0.60	0.16	5.00
15	07-03-92	N-3o	FLURRIES	-4	63.0	77.0	30.0	0.2	—	14.30	—	98.35	—	80.00	30.00	5.50	0.18	5.00
16	14-03-92	N-3p	SUN/CLEAR	-16	42.0	70.0	33.0	0.1	—	13.90	—	95.33	—	64.00	10.00	1.50	0.15	4.40
17	21-03-92	N-3q	SUN/CLEAR	-6	38.0	87.0	30.0	0.1	—	14.10	—	96.70	—	74.00	15.00	8.50	0.14	4.10
18	28-03-92	N-3r	RAIN	3	30.0	85.0	51.0	0.1	—	13.60	—	93.28	—	19.00	10.00	9.00	0.16	2.50
19	04-04-92	N-3s	OVERCAST	3	23.0	62.0	75.0	0.3	—	13.10	—	90.35	—	42.00	20.00	0.52	0.10	3.40
20	11-04-92	N-3t	SUN/CLOUD	-3	12.0	60.0	54.0	0.4	—	14.30	—	98.90	—	47.00	15.00	1.90	0.11	3.00
21	18-04-92	N-3u	SUN/CLEAR	7	10.0	32.0	45.0	1.0	—	13.90	—	97.78	—	39.00	15.00	0.82	0.05	2.90
22	25-04-92	N-3v	FLURRIES	-1	0.0	0.0	62.0	1.2	—	13.75	—	97.25	—	51.00	10.00	0.46	0.06	3.40
1	30-11-91	N-4a	OVERCAST	-10	0.0	0.0	15.0	0.5	—	13.20	—	91.55	—	45.40	25.00	0.59	0.04	4.00
2	07-12-91	N-4b	FLURRIES	-25	0.0	0.0	15.0	0.3	—	14.33	—	98.83	—	50.40	15.00	0.90	0.10	3.50
3	14-12-91	N-4c	OVERCAST	0	0.0	0.0	30.0	0.3	—	12.61	—	87.00	—	49.00	15.00	0.80	0.14	3.90
4	21-12-91	N-4d	SNOW-FALL	-10	0.0	0.0	15.0	0.3	—	12.95	—	89.29	—	61.90	15.00	0.70	0.09	4.40
5	28-12-91	N-4e	OVERCAST	-6	10.0	5.0	15.0	0.1	—	13.33	—	91.41	—	67.00	15.00	0.25	0.05	4.50
6	04-01-92	N-4f	SUN/CLEAR	-4	5.0	11.0	18.0	0.1	—	13.38	—	91.74	—	71.00	15.00	0.28	0.06	5.00
7	11-01-92	N-4g	SUN/CLEAR	-13	0.0	0.0	33.0	0.1	—	13.50	—	92.59	—	55.00	15.00	0.25	0.14	4.60
8	18-01-92	N-4h	FLURRIES	-14	0.0	17.0	21.0	0.1	—	13.65	—	93.62	—	59.00	10.00	0.28	0.10	4.80
9	25-01-92	N-4i	SUN/CLEAR	-24	0.0	32.0	50.0	0.1	—	13.55	—	92.93	—	54.00	15.00	0.40	0.12	4.80
10	01-02-92	N-4j	HEAVYSNOW															
11	08-02-92	N-4k	SNOW-FALL	-14	40.0	51.0	20.0	0.1	—	13.80	—	94.65	—	68.40	5.00	0.29	0.16	4.50
12	15-02-92	N-4l	CLOUDYPER	-7	36.0	45.0	18.0	0.1	—	14.20	—	97.39	—	74.00	8.00	0.32	0.16	4.60
13	22-02-92	N-4m	SUN/CLEAR	-14	70.0	44.0	12.0	0.3	—	14.10	—	97.24	—	75.00	5.00	0.28	0.15	5.10
14	29-02-92	N-4n	SUN/CLOUD	-12	80.0	44.0	10.0	0.2	—	13.70	—	94.22	—	77.00	5.00	0.33	0.15	5.10
15	07-03-92	N-4o	FLURRIES	-4	64.0	47.0	17.0	0.2	—	14.25	—	98.01	—	80.00	5.00	0.27	0.13	5.40
16	14-03-92	N-4p	SUN/CLEAR	-16	48.0	43.0	12.0	0.1	—	13.95	—	95.68	—	60.00	10.00	0.34	0.15	4.40
17	21-03-92	N-4q	SUN/CLEAR	-6	49.0	50.0	17.0	0.3	—	14.20	—	97.93	—	72.00	5.00	0.32	0.15	4.10
18	28-03-92	N-4r	RAIN	3	39.0	39.0	40.0	0.3	—	13.25	—	91.38	—	66.00	15.00	2.20	0.18	4.20
19	04-04-92	N-4s	OVERCAST	3	0.0	13.0	79.0	0.3	—	13.00	—	89.66	—	42.00	15.00	0.56	0.10	3.40
20	11-04-92	N-4t	SUN/CLOUD	-3	0.0	0.0	37.0	0.3	—	14.10	—	97.24	—	45.00	15.00	0.59	0.11	3.00
21	18-04-92	N-4u	SUN/CLEAR	7	0.0	0.0	30.0	1.0	—	13.95	—	98.13	—	39.00	15.00	0.57	0.04	3.00
22	25-04-92	N-4v	FLURRIES	-1	0.0	0.0	46.0	1.2	—	13.75	—	97.25	—	52.00	10.00	0.49	0.06	3.50

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Table 1. Chemical and Physical Water Quality Parameters measured in Catamaran Brook, N.B., in or near Beaver Ponds under ice-cover (1991-1992), by sampling date and study site.

WEEK	DATE DD-MM-YY	SAMPLE SITE:	WEATHER	AIR TEMP (°C)	SNOW COVER: (cm)	ICE COVER: (cm)	WATER DEPTH: (cm)	WATER TEMP: (°C)		DISS. OXYGEN: (mg/l)		PERCENT DISS. OXYGEN: (%)		SPECIFIC CONDCTNC (USIE/cm)	APPARENT COLOUR: (rel.unit)	TURBIDITY: (JTU)	NITROGEN DISSOLVED: (mg/l)	SULPHATE DISSOLVED (mg/l)
								TOP	BOT	TOP	BOT	TOP	BOT					
1	30-11-91	O-1a	OVERCAST	-7	0.0	0.0	45.0	0.5	——	13.67	——	94.79	——	40.60	30.00	0.66	0.04	3.90
2	07-12-91	O-1b	FLURRIES	-19	0.0	2.0	45.0	0.2	——	12.13	——	83.43	——	50.40	20.00	1.00	0.07	3.40
3	14-12-91	O-1c	OVERCAST	-4	0.0	0.0	47.5	0.3	——	12.38	——	85.35	——	42.60	20.00	0.87	0.12	3.80
4	21-12-91	O-1d	SNOW-FALL	-11	12.5	5.0	40.0	0.3	——	12.19	——	84.04	——	53.40	20.00	0.95	0.08	4.20
5	28-12-91	O-1e	OVERCAST	-12	13.0	6.0	35.0	0.2	——	12.47	——	85.77	——	57.00	20.00	0.39	0.05	4.80
6	04-01-92	O-1f	SUN/CLEAR	-13	9.0	2.0	38.0	0.1	——	12.61	——	86.51	——	63.00	15.00	0.53	0.06	4.90
7	11-01-92	O-1g	SUN/CLEAR	-15	0.0	0.0	50.0	0.1	——	13.05	——	89.50	——	43.20	25.00	0.37	0.13	4.60
8	18-01-92	O-1h	FLURRIES	-14	0.0	12.0	42.0	0.1	——	13.00	——	89.16	——	50.00	20.00	0.46	0.10	4.60
9	25-01-92	O-1i	SUN/CLEAR	-17	0.0	36.0	92.0	0.1	——	12.80	——	87.79	——	43.00	20.00	0.72	0.11	4.30
10	01-02-92	O-1j	HEAVYSNOW										——					
11	08-02-92	O-1k	SNOW-FALL	-14	35.0	21.0	36.0	0.1	——	13.40	——	91.90	——	65.00	5.00	0.44	0.17	4.70
12	15-02-92	O-1l	CLOUDYPER	-10	34.0	27.0	35.0	0.1	——	13.50	——	92.59	——	67.00	10.00	0.35	0.11	5.00
13	22-02-92	O-1m	OVERCAST	-11	61.0	40.0	32.0	0.2	——	13.55	——	93.19	——	68.00	5.00	0.33	0.12	5.30
14	29-02-92	O-1n	SUN/CLOUD	-13	76.0	35.0	32.0	0.2	——	13.10	——	90.10	——	69.00	10.00	0.37	0.14	5.20
15	07-03-92	O-1o	FLURRIES	-3	52.0	29.0	32.0	0.2	——	13.55	——	93.19	——	71.00	5.00	0.46	0.12	5.00
16	14-03-92	O-1p	SUN/CLEAR	-16	49.0	37.0	41.0	0.2	——	13.35	——	91.82	——	55.00	15.00	0.57	0.14	4.50
17	21-03-92	O-1q	SUN/CLEAR	-6	38.0	40.0	40.0	0.1	——	13.50	——	92.59	——	64.00	10.00	0.60	0.14	4.50
18	28-03-92	O-1r	RAIN	3	34.0	30.0	58.0	0.3	——	12.75	——	87.93	——	57.00	20.00	2.00	0.19	4.10
19	04-04-92	O-1s	OVERCAST	3	0.0	40.0	81.0	0.4	——	12.40	——	85.76	——	38.00	20.00	0.59	0.09	3.60
20	11-04-92	O-1t	SUN/CLOUD	-3	0.0	14.0	75.0	0.4	——	13.25	——	91.64	——	40.00	20.00	0.61	0.10	3.00
21	18-04-92	O-1u	SUN/CLEAR	7	0.0	0.0	60.0	0.6	——	13.35	——	92.85	——	36.00	20.00	0.72	0.04	2.80
22	25-04-92	O-1v	FLURRIES	-1	0.0	0.0	62.0	0.7	——	13.15	——	91.72	——	47.00	10.00	0.73	0.06	3.40
1	30-11-91	O-2a	OVERCAST	-10	0.0	2.0	70.0	0.5	0.5	13.40	13.80	92.94	95.71	39.40	35.00	0.75	0.04	4.00
2	07-12-91	O-2b	FLURRIES	-19	4.0	6.0	65.0	0.2	0.2	11.79	12.74	81.09	87.62	50.50	20.00	1.20	0.07	3.60
3	14-12-91	O-2c	OVERCAST	-4	0.0	15.0	47.5	0.3	——	11.42	——	78.79	——	42.80	20.00	0.89	0.09	4.10
4	21-12-91	O-2d	SNOW-FALL	-11	19.0	14.5	47.5	0.3	——	12.09	——	83.38	——	52.80	20.00	1.10	0.08	4.70
5	28-12-91	O-2e	OVERCAST	-11	15.0	25.0	42.5	0.2	——	12.38	——	85.12	——	57.00	20.00	0.43	0.05	4.80
6	04-01-92	O-2f	SUN/CLEAR	-13	15.0	22.0	33.0	0.1	——	12.57	——	86.19	——	62.00	20.00	0.63	0.05	4.90
7	11-01-92	O-2g	SUN/CLEAR	-14	4.0	15.0	22.0	0.1	——	12.70	——	87.10	——	43.10	25.00	0.58	0.12	4.50
8	18-01-92	O-2h	OVERCAST	-14	0.0	49.0	42.0	0.1	——	12.85	——	88.13	——	50.00	20.00	0.45	0.10	4.90
9	25-01-92	O-2i	SUN/CLEAR	-16	0.0	39.0	75.0	0.1	——	12.75	——	87.45	——	43.00	25.00	0.71	0.12	4.40
10	01-02-92	O-2j	HEAVYSNOW															
11	08-02-92	O-2k	SNOW-FALL	-14	33.0	70.0	43.0	0.1	——	13.30	——	91.22	——	65.00	5.00	0.36	0.17	4.70
12	15-02-92	O-2l	CLOUDYPER	-10	30.0	67.0	12.0	0.1	——	13.50	——	92.59	——	67.00	10.00	0.39	0.12	5.00
13	22-02-92	O-2m	OVERCAST	-11	63.0	60.0	23.0	0.2	——	13.60	——	93.54	——	68.00	5.00	0.37	0.13	5.20
14	29-02-92	O-2n	SUN/CLOUD	-13	72.0	62.0	34.0	0.2	——	13.15	——	90.44	——	69.00	10.00	0.43	0.13	5.00
15	07-03-92	O-2o	FLURRIES	-3	61.0	62.0	34.0	0.3	——	13.50	——	93.11	——	5.00	71.00	0.42	0.14	5.30
16	14-03-92	O-2p	SUN/CLEAR	-16	49.0	57.0	39.0	0.2	——	13.25	——	91.13	——	55.00	15.00	0.52	0.15	4.60
17	21-03-92	O-2q	SUN/CLEAR	-6	43.0	53.0	33.0	0.1	——	13.55	——	92.93	——	64.00	10.00	0.62	0.14	4.70
18	28-03-92	O-2r	RAIN	3	32.0	53.0	56.0	0.3	——	12.85	——	88.62	——	56.00	20.00	1.60	0.19	4.10
19	04-04-92	O-2s	OVERCAST	3	0.0	45.0	83.0	0.5	——	12.35	——	85.65	——	38.00	20.00	1.00	0.09	3.70
20	11-04-92	O-2t	SUN/CLOUD	-3	0.0	32.0	68.0	0.4	——	12.30	——	85.07	——	40.00	20.00	0.57	0.10	3.20
21	18-04-92	O-2u	SUN/CLEAR	7	0.0	0.0	57.0	0.6	——	13.25	——	92.15	——	36.00	20.00	0.70	0.04	2.80
22	25-04-92	O-2v	FLURRIES	-1	0.0	0.0	57.0	0.7	——	13.15	——	91.72	——	45.00	10.00	0.64	0.06	3.40

(CONTINUED)

Table 1. Chemical and Physical Water Quality Parameters measured in Catamaran Brook, N.B., in or near Beaver Ponds under ice-cover (1991-1992), by sampling date and study site.

WEEK	DATE DD-MM-YY	SAMPLE SITE	WEATHER	AIR TEMP (°C)	SNOW COVER (cm)	ICE COVER (cm)	WATER DEPTH (cm)	WATER TEMP (°C)		DISS. OXYGEN (mg/l)		PERCENT DISS. OXYGEN (%)		SPECIFIC CONDCTNC (USIE/cm)	APPARENT COLOUR (rel.unit)	TURBIDITY (JTU)	NITROGEN DISSOLVED (mg/l)	SULPHATE DISSOLVED (mg/l)
								TOP	BOT	TOP	BOT	TOP	BOT					
1	30-11-91	O-3a	OVERCAST	-12	0.0	2.0	96.0	0.5	0.5	13.63	14.03	94.55	97.33	41.20	30.00	1.10	0.03	4.00
2	07-12-91	O-3b	FLURRIES	-19	4.0	13.0	94.0	0.3	0.3	11.42	14.75	78.76	101.73	50.90	20.00	1.10	0.07	3.60
3	14-12-91	O-3c	OVERCAST	-4	0.0	13.0	94.0	0.3	0.3	12.00	12.19	82.73	84.04	42.80	25.00	0.79	0.11	4.10
4	21-12-91	O-3d	SNOW-FALL	-11	18.0	20.0	85.0	0.3	0.3	12.19	12.09	84.04	83.38	52.60	20.00	0.86	0.09	4.30
5	28-12-91	O-3e	OVERCAST	-11	16.0	23.0	85.0	0.2	0.1	12.28	12.23	84.46	83.90	56.00	20.00	0.43	0.05	4.80
6	04-01-92	O-3f	SUN/CLEAR	-13	14.0	25.0	83.0	0.1	0.1	12.57	12.66	86.19	86.84	63.00	20.00	0.53	0.07	4.90
7	11-01-92	O-3g	SUN/CLEAR	-14	4.0	30.0	89.0	0.1	0.1	12.60	12.50	86.42	85.73	44.00	25.00	0.41	0.13	4.60
8	18-01-92	O-3h	OVERCAST	-14	0.0	38.0	90.0	0.1	0.1	12.80	12.80	87.79	87.79	49.00	20.00	0.40	0.12	4.80
9	25-01-92	O-3i	SUN/CLEAR	-15	0.0	70.0	145.0	0.1	0.1	12.90	12.95	88.47	88.82	44.00	15.00	0.65	0.13	4.40
10	01-02-92	O-3j	HEAVYSNOW															
11	08-02-92	O-3k	SNOW-FALL	-14	38.0	67.0	100.0	0.1	0.1	13.30	13.35	91.22	91.56	65.00	5.00	0.45	0.13	5.00
12	15-02-92	O-3l	CLOUDYPER	-10	38.0	67.0	71.0	0.1	0.1	13.50	13.45	92.59	92.25	63.00	10.00	0.28	0.12	5.20
13	22-02-92	O-3m	OVERCAST	-11	66.0	58.0	88.0	0.2	0.2	13.50	13.60	92.85	93.54	68.00	5.00	0.51	0.13	5.30
14	29-02-92	O-3n	SUN/CLOUD	-13	78.0	57.0	77.0	0.2	0.2	13.25	13.10	91.13	90.10	69.00	10.00	0.36	0.13	5.30
15	07-03-92	O-3o	FLURRIES	-3	61.0	70.0	78.0	0.3	0.3	13.60	13.55	93.80	93.45	71.00	5.00	0.39	0.15	4.70
16	14-03-92	O-3p	SUN/CLEAR	-16	51.0	60.0	88.0	0.3	0.3	13.25	—	91.38	—	55.00	10.00	0.54	0.15	4.60
17	21-03-92	O-3q	SUN/CLEAR	-6	40.0	60.0	81.0	0.2	0.2	13.45	13.55	92.50	93.19	64.00	10.00	0.66	0.14	4.80
18	28-03-92	O-3r	RAIN	3	40.0	56.0	109.0	0.3	0.3	12.75	12.75	87.93	87.93	58.00	15.00	1.60	0.19	4.10
19	04-04-92	O-3s	OVERCAST	3	0.0	50.0	140.0	0.5	0.5	12.50	12.30	86.69	85.31	38.00	20.00	0.50	0.09	3.40
20	11-04-92	O-3t	SUN/CLOUD	-3	0.0	36.0	124.0	0.5	0.4	13.25	13.25	91.90	91.64	41.00	20.00	0.60	0.09	3.00
21	18-04-92	O-3u	SUN/CLEAR	7	0.0	0.0	114.0	0.8	0.8	13.35	13.25	93.38	92.68	36.00	20.00	0.62	0.04	3.00
22	25-04-92	O-3v	FLURRIES	-1	0.0	0.0	111.0	0.8	0.8	13.05	13.15	91.28	91.98	46.00	10.00	0.67	0.07	3.30
1	30-11-91	C-Ja	OVERCAST	-4	0.0	0.0	18.0	0.5	—	14.10	—	97.79	—	46.60	30.00	1.80	0.04	4.00
2	07-12-91	C-Jb	FLURRIES	-25	0.0	0.0	17.5	0.3	—	12.26	—	84.55	—	56.60	15.00	1.00	0.08	3.60
3	14-12-91	C-Jc	OVERCAST	0	0.0	0.0	17.5	0.3	—	12.95	—	89.29	—	48.80	15.00	0.85	0.10	3.90
4	21-12-91	C-Jd	SNOW-FALL	-11	10.0	9.0	17.0	0.3	—	12.76	—	87.98	—	60.80	10.00	0.78	0.07	4.20
5	28-12-91	C-Je	OVERCAST	-7	10.0	4.0	12.5	0.1	—	13.14	—	90.10	—	63.00	10.00	0.39	0.05	4.60
6	04-01-92	C-Jf	SUN/CLEAR	-13	7.0	10.0	17.0	0.1	—	13.23	—	90.76	—	71.00	10.00	0.42	0.06	4.80
7	11-01-92	C-Jg	SUN/CLEAR	-15	0.0	0.0	24.0	0.1	—	13.55	—	92.93	—	54.20	15.00	0.36	0.16	4.50
8	18-01-92	C-Jh	FLURRIES	-14	0.0	28.0	25.0	0.1	—	13.50	—	92.59	—	57.00	15.00	0.32	0.08	4.90
9	25-01-92	C-Ji	SUN/CLEAR	-22	0.0	33.0	41.0	0.1	—	13.25	—	90.87	—	54.00	10.00	0.42	0.12	4.40
10	01-02-92	C-Jj	HEAVYSNOW															
11	08-02-92	C-Jk	SNOW-FALL	-14	40.0	64.0	9.0	0.1	—	13.35	—	91.56	—	68.00	5.00	0.50	0.14	4.40
12	15-02-92	C-Jl	CLOUDYPER	-7	40.0	52.0	10.0	0.1	—	13.60	—	93.28	—	73.00	5.00	0.33	0.15	4.70
13	22-02-92	C-Jm	OVERCAST	-11	70.0	50.0	10.0	0.2	—	13.95	—	95.94	—	75.00	5.00	0.32	0.14	4.80
14	29-02-92	C-Jn	SUN/CLOUD	-13	86.0	52.0	10.0	0.2	—	13.55	—	93.19	—	77.00	5.00	0.37	0.15	4.80
15	07-03-92	C-Jo	FLURRIES	-3	65.0	50.0	11.0	0.2	—	13.95	—	95.94	—	78.00	5.00	0.30	0.16	4.90
16	14-03-92	C-Jp	SUN/CLEAR	-16	52.0	57.0	13.0	0.2	—	13.80	—	94.91	—	61.00	5.00	0.35	0.15	4.40
17	21-03-92	C-Jq	SUN/CLEAR	-6	38.0	62.0	10.0	0.1	—	13.95	—	95.68	—	71.00	5.00	0.33	0.15	4.30
18	28-03-92	C-Jr	RAIN	3	37.0	55.0	29.0	0.1	—	13.30	—	91.22	—	66.50	20.00	4.40	0.20	3.80
19	04-04-92	C-Js	OVERCAST	3	21.0	49.0	56.0	0.4	—	13.00	—	89.91	—	41.00	20.00	0.53	0.09	3.30
20	11-04-92	C-Jt	SUN/CLOUD	-3	17.0	19.0	38.0	0.3	—	13.95	—	96.21	—	44.00	20.00	0.74	0.11	3.00
21	18-04-92	C-Ju	SUN/CLEAR	7	6.0	18.0	37.0	1.0	—	13.80	—	97.07	—	39.00	15.00	0.86	0.07	2.70
22	25-04-92	C-Jv	FLURRIES	-1	0.0	0.0	42.0	1.3	—	13.90	—	98.58	—	51.00	10.00	0.57	0.06	3.10

(CONTINUED)

Table 1. Chemical and Physical Water Quality Parameters measured in Catamaran Brook, N.B., in or near Beaver Ponds under ice-cover (1991-1992), by sampling date and study site.

WEEK	DATE DD-MM-YY	SAMPLE SITE:	WEATHER	AIR TEMP (°C)	SNOW COVER: (cm)	ICE COVER: (cm)	WATER DEPTH: (cm)	WATER TEMP: (°C)		DISS. OXYGEN: (mg/l)		PERCENT DISS. OXYGEN: (%)		SPECIFIC CONDCTNC: (USIE/cm)	APPARENT COLOUR: (relune)	TURBIDITY: (JTU)	NITROGEN DISSOLVED: (mg/l)	SULPHATE DISSOLVED: (mg/l)
								TOP	BOT	TOP	BOT	TOP	BOT					
2	07-12-91	J-Jb	FLURRIES	-25	0.0	0.0	30.0	0.3	—	13.16	—	90.76	—	56.70	15.00	0.95	0.07	3.40
3	14-12-91	J-Jc	OVERCAST	0	0.0	0.0	30.0	0.3	—	12.71	—	87.65	—	47.40	20.00	0.71	0.08	3.90
4	21-12-91	J-Jd	SNOW-FALL	-11	0.0	0.0	22.5	0.3	—	12.76	—	87.98	—	62.30	10.00	0.90	0.09	4.30
5	28-12-91	J-Je	OVERCAST	-7	0.0	0.0	22.5	0.1	—	12.80	—	87.82	—	64.00	15.00	0.36	0.05	4.50
6	04-01-92	J-Jf	SUN/CLEAR	-8	0.0	0.0	20.0	0.1	—	13.19	—	90.43	—	71.00	15.00	0.39	0.06	4.80
7	11-01-92	J-Jg	SUN/CLEAR	-13	0.0	0.0	33.0	0.1	—	13.20	—	90.53	—	47.00	20.00	0.40	0.12	4.90
8	18-01-92	J-Jh	FLURRIES	-14	0.0	0.0	15.0	0.1	—	13.30	—	91.22	—	53.00	20.00	0.35	0.08	4.90
9	25-01-92	J-Ji	SUN/CLEAR	-22	0.0	0.0	50.0	0.1	—	12.90	—	88.47	—	45.00	20.00	0.54	0.12	4.50
10	01-02-92	J-Jj	HEAVYSNOW															
11	08-02-92	J-Jk	SNOW-FALL	-14	0.0	0.0	26.0	0.1	—	13.25	—	90.87	—	64.00	5.00	0.56	0.12	4.70
12	15-02-92	J-Jl	CLOUDYPER	-7	0.0	0.0	20.0	0.1	—	13.40	—	91.90	—	69.00	10.00	0.51	0.12	5.20
13	22-02-92	J-Jm	OVERCAST	-11	0.0	0.0	22.0	0.3	—	13.69	—	93.80	—	73.00	5.00	0.46	0.15	5.00
14	29-02-92	J-Jn	SUN/CLOUD	-13	0.0	0.0	18.0	0.2	—	13.69	—	93.54	—	77.00	5.00	0.34	0.15	5.00
15	07-03-92	J-Jo	FLURRIES	-3	0.0	0.0	17.0	0.3	—	13.90	—	95.87	—	78.00	5.00	0.36	0.17	4.90
16	14-03-92	J-Jp	SUN/CLEAR	-16	0.0	0.0	26.0	0.1	—	13.40	—	91.90	—	58.00	10.00	0.51	0.14	4.60
17	21-03-92	J-Jq	SUN/CLEAR	-6	0.0	0.0	15.0	0.2	—	13.90	—	95.60	—	71.00	5.00	0.40	0.12	4.30
18	28-03-92	J-Jr	RAIN	3	0.0	0.0	26.0	0.2	—	13.15	—	90.44	—	65.00	25.00	5.20	0.20	3.90
19	04-04-92	J-Js	OVERCAST	3	0.0	0.0	38.0	0.3	—	12.60	—	86.90	—	40.00	20.00	0.56	0.07	3.60
20	11-04-92	J-Jt	SUN/CLOUD	-3	0.0	0.0	32.0	0.3	—	13.35	—	92.07	—	41.00	20.00	0.54	0.10	3.20
21	18-04-92	J-Ju	SUN/CLEAR	7	0.0	0.0	20.0	0.9	—	13.50	—	94.69	—	38.00	20.00	0.74	0.07	2.70
22	25-04-92	J-Jv	FLURRIES	-1	0.0	0.0	33.0	1.1	—	13.35	—	94.16	—	48.00	15.00	0.68	0.05	3.20
2	07-12-91	T-Jb	FLURRIES	-23	4.0	15.0	46.0	0.2	—	13.53	—	93.05	—	52.40	40.00	7.40	0.07	3.40
3	14-12-91	T-Jc	OVERCAST	-3	0.0	3.0	33.0	0.3	—	12.22	—	84.30	—	43.60	20.00	0.85	0.06	4.00
4	21-12-91	T-Jd	SNOW-FALL	-11	10.0	1.0	30.0	0.3	—	12.28	—	84.70	—	56.20	15.00	0.89	0.08	4.30
5	28-12-91	T-Je	OVERCAST	-8	8.0	5.0	28.0	0.2	—	12.66	—	87.08	—	63.00	15.00	0.30	0.05	4.50
6	04-01-92	T-Jf	SUN/CLEAR	-13	10.0	10.0	26.0	0.1	—	13.04	—	89.45	—	69.00	15.00	0.36	0.05	4.70
7	11-01-92	T-Jg	SUN/CLEAR	-13	0.0	0.0	17.0	0.1	—	12.95	—	88.82	—	47.40	20.00	0.38	0.12	4.90
8	18-01-92	T-Jh	OVERCAST	-14	0.0	24.0	32.0	0.1	—	13.10	—	89.85	—	52.00	25.00	0.38	0.08	4.80
9	25-01-92	T-Ji	SUN/CLEAR	-21	0.0	37.0	70.0	0.1	—	13.05	—	89.50	—	42.00	20.00	0.58	0.12	4.40
10	01-02-92	T-Jj	HEAVYSNOW															
11	08-02-92	T-Jk	SNOW-FALL	-14	44.0	35.0	16.0	0.1	—	13.20	—	90.53	—	63.50	5.00	0.61	0.14	4.70
12	15-02-92	T-Jl	CLOUDYPER	-10	37.0	42.0	23.0	0.1	—	13.20	—	90.53	—	67.00	10.00	0.41	0.12	5.00
13	22-02-92	T-Jm	OVERCAST	-11	70.0	50.0	23.0	0.2	—	13.55	—	93.19	—	69.00	5.00	0.44	0.13	5.60
14	29-02-92	T-Jn	SUN/CLOUD	-13	66.0	40.0	20.0	0.2	—	13.10	—	90.10	—	70.00	10.00	0.33	0.15	5.00
15	07-03-92	T-Jo	FLURRIES	-3	57.0	40.0	20.0	0.3	—	13.55	—	93.45	—	72.00	5.00	0.42	0.16	4.70
16	14-03-92	T-Jp	SUN/CLEAR	-16	45.0	38.0	24.0	0.1	—	13.60	—	93.28	—	56.00	10.00	0.51	0.14	4.60
17	21-03-92	T-Jq	SUN/CLEAR	-6	46.0	42.0	23.0	0.1	—	14.00	—	96.02	—	65.00	10.00	0.50	0.13	4.60
18	28-03-92	T-Jr	RAIN	3	42.0	34.0	33.0	0.1	—	12.60	—	86.42	—	57.00	20.00	1.69	0.20	3.90
19	04-04-92	T-Js	OVERCAST	3	30.0	24.0	43.0	0.3	—	12.30	—	84.83	—	39.00	20.00	0.64	0.09	3.70
20	11-04-92	T-Jt	SUN/CLOUD	-3	13.0	23.0	36.0	0.3	—	13.20	—	91.04	—	41.00	20.00	0.66	0.10	3.20
21	18-04-92	T-Ju	SUN/CLEAR	7	0.0	20.0	47.0	0.4	—	13.30	—	91.98	—	38.00	20.00	0.56	0.07	2.70
22	25-04-92	T-Jv	FLURRIES	-1	0.0	0.0	42.0	0.9	—	13.25	—	92.94	—	47.00	10.00	0.76	0.05	3.40

Table 2. Averages calculated by sample site for Water Quality Parameters measured under ice-cover in or near Beaver Ponds in Catamaran Brook, N.B., during the Winter of 1991-1992.

CALCULATIONS	SAMPLE SITE:	SNOW COVER: (cm)	ICE COVER: (cm)	WATER DEPTH: (cm)	WATER TEMP: (°C) TOP	WATER TEMP: (°C) BOT	DISS. OXYGEN: (mg/l) TOP	DISS. OXYGEN: (mg/l) BOT	SPECIFIC CONDCTNC (USIE/cm)	APPARENT COLOUR: (rel.unit)	TURBIDITY (JTU)	NITROGEN DISSOLVED: (mg/l)	SULPHATE DISSOLVED (mg/l)
MEAN	C-J	24	29	22	0.3	0.0	13.47	0.00	59.83	11.9	0.76	0.11	4.1
STD	C-J	26	24	13	0.3	0.0	0.46	0.00	11.75	6.6	0.88	0.04	0.7
MEAN	J-J	0	0	26	0.3	0.0	13.25	0.00	58.42	14.0	0.77	0.11	4.3
STD	J-J	0	0	8	0.3	0.0	0.36	0.00	12.50	6.4	1.03	0.04	0.7
MEAN	T-J	24	24	32	0.2	0.0	13.08	0.00	55.51	15.8	0.93	0.11	4.3
STD	T-J	24	16	13	0.2	0.0	0.46	0.00	11.10	8.1	1.51	0.04	0.7
MEAN	N-1	4	6	21	0.3	0.0	13.65	0.00	60.17	12.9	0.63	0.11	4.3
STD	N-1	8	8	11	0.3	0.0	0.50	0.00	11.81	6.1	0.61	0.04	0.7
MEAN	N-2	23	45	93	0.3	0.3	13.56	13.53	60.64	12.5	0.70	0.11	4.3
STD	N-2	27	29	13	0.3	0.3	0.42	0.39	11.55	5.5	1.00	0.04	0.7
MEAN	N-3	22	50	47	0.3	0.0	13.70	0.00	59.00	13.3	1.89	0.11	4.2
STD	N-3	23	28	17	0.3	0.0	0.41	0.00	14.97	6.0	2.53	0.04	0.7
MEAN	N-4	21	21	26	0.3	0.0	13.65	0.00	60.15	12.0	0.52	0.11	4.3
STD	N-4	27	21	16	0.3	0.0	0.47	0.00	12.10	5.1	0.42	0.04	0.7
MEAN	O-1	20	18	49	0.3	0.0	13.01	0.00	53.34	16.2	0.65	0.10	4.3
STD	O-1	24	16	17	0.2	0.0	0.48	0.00	11.11	6.7	0.36	0.04	0.7
MEAN	O-2	21	36	47	0.3	0.0	12.84	0.00	49.93	20.0	0.68	0.10	4.4
STD	O-2	24	24	18	0.2	0.0	0.60	0.00	14.49	13.4	0.31	0.04	0.7
MEAN	O-3	22	39	97	0.3	0.3	12.91	12.45	53.21	16.0	0.64	0.11	4.3
STD	O-3	25	24	20	0.2	0.2	0.58	2.86	10.78	7.0	0.30	0.04	0.7

Table #3. Calculated slopes, intercepts, regression and regression sqaures for Percent of Oxygen Saturation by Sample Sites.

STUDY LOCATIONS	I.D.	DESCRIPTION OF SITES	SLOPE	INTER-CEPT	r	r^2
CATAMARAN AND TRIBUTARY JUNCTION SITES	C-J	CATAMARAN JUNCTION	0.30	89.38	0.565	0.319
	T-J	TRIBUTARY JUNCTION	0.20	87.70	0.378	0.143
	J-J	JOINT JUNCTION	0.24	88.47	0.558	0.311
NEW ACTIVE POND SAMPLE SITES	N-1	BELOW DAM	0.17	92.14	0.291	0.085
	N-2(TOP)	ABOVE DAM	0.31	89.85	0.664	0.441
	N-2(BOT)	ABOVE POND	0.25	90.38	0.554	0.307
	N-3	POND ENTRANCE	0.18	92.34	0.395	0.156
	N-4	UPSTREAM RIFFLE	0.24	91.36	0.472	0.223
OLD ABANDONED POND SAMPLE SITES	O-1	BELOW DAM	0.24	86.89	0.457	0.209
	O-2	ABOVE DAM	0.31	84.90	0.486	0.236
	O-3(TOP)	POND ENTRANCE	0.36	84.91	0.565	0.32
	O-3(BOT)	POND ENTRANCE	0.05	89.55	0.077	0.006

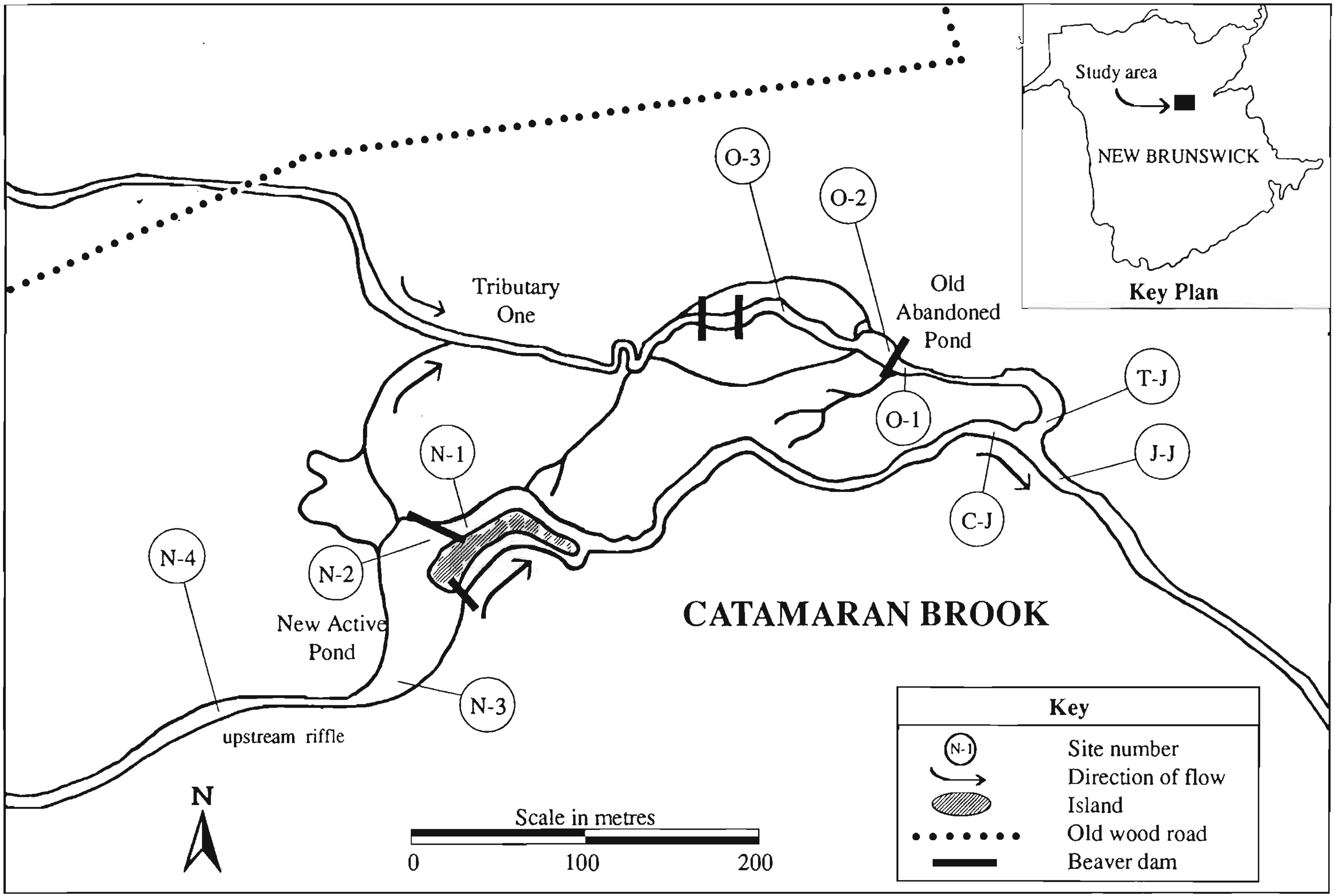

Figure 1. Map of Catamaran Brook beaver dam study area indicating water collection sites for water quality analysis of two beaver ponds.

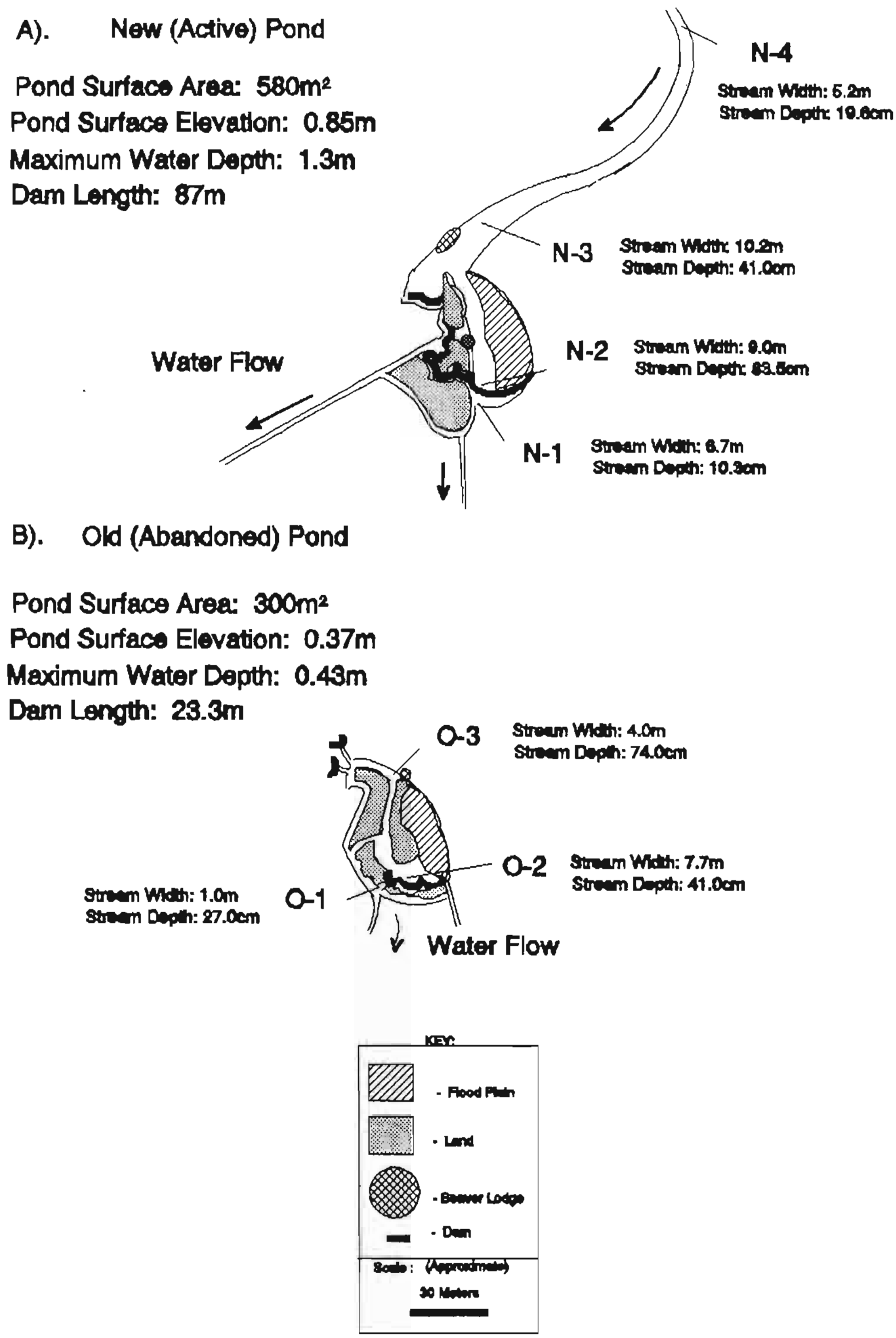

Figure 2. Site dimensions for two beaver ponds studies in the catchment of Catamaran Brook, N.B., for changes in water quality under ice-cover (winter 1991-1992).

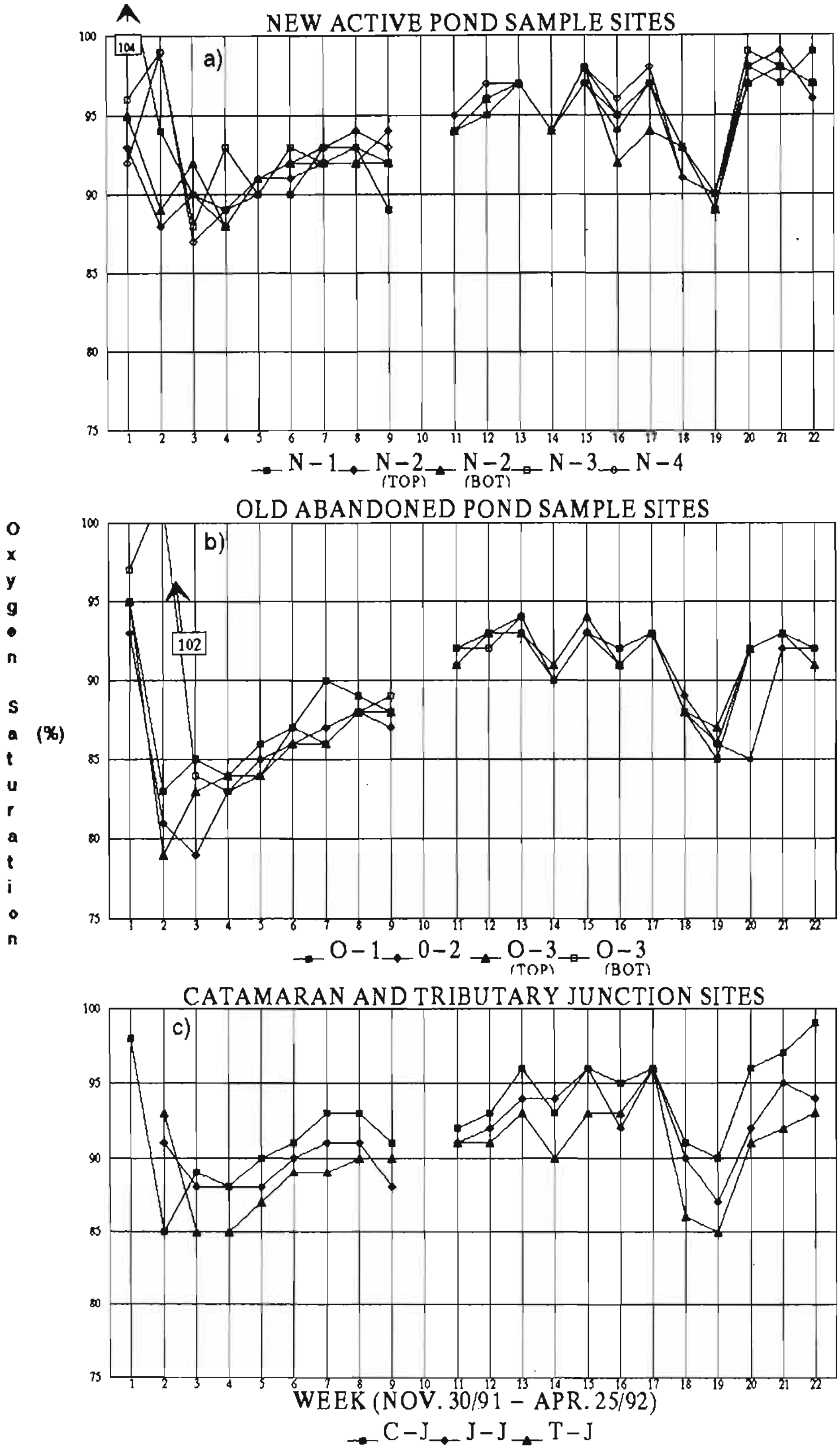

Figure 3: Percent of Oxygen Saturation measured at three study areas, in or near Beaver Ponds in Catamaran Brook, under ice-cover (winter 1991-1992).

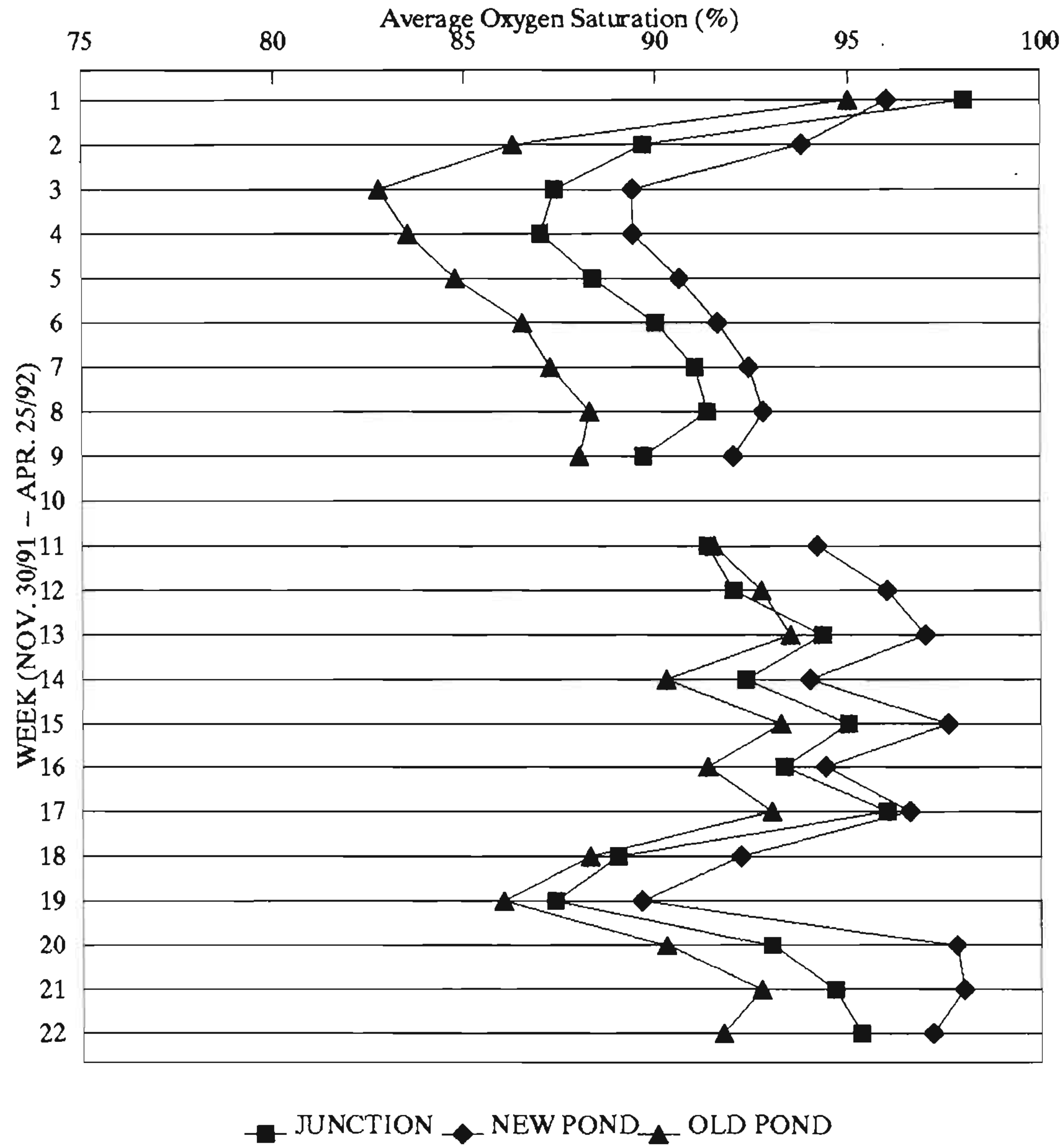

Figure 4. Study area comparison of mean pecent of Oxygen Saturation, in or near Beaver Ponds in Catamaran Brook, under ice-cover (Winter 1991-1992).

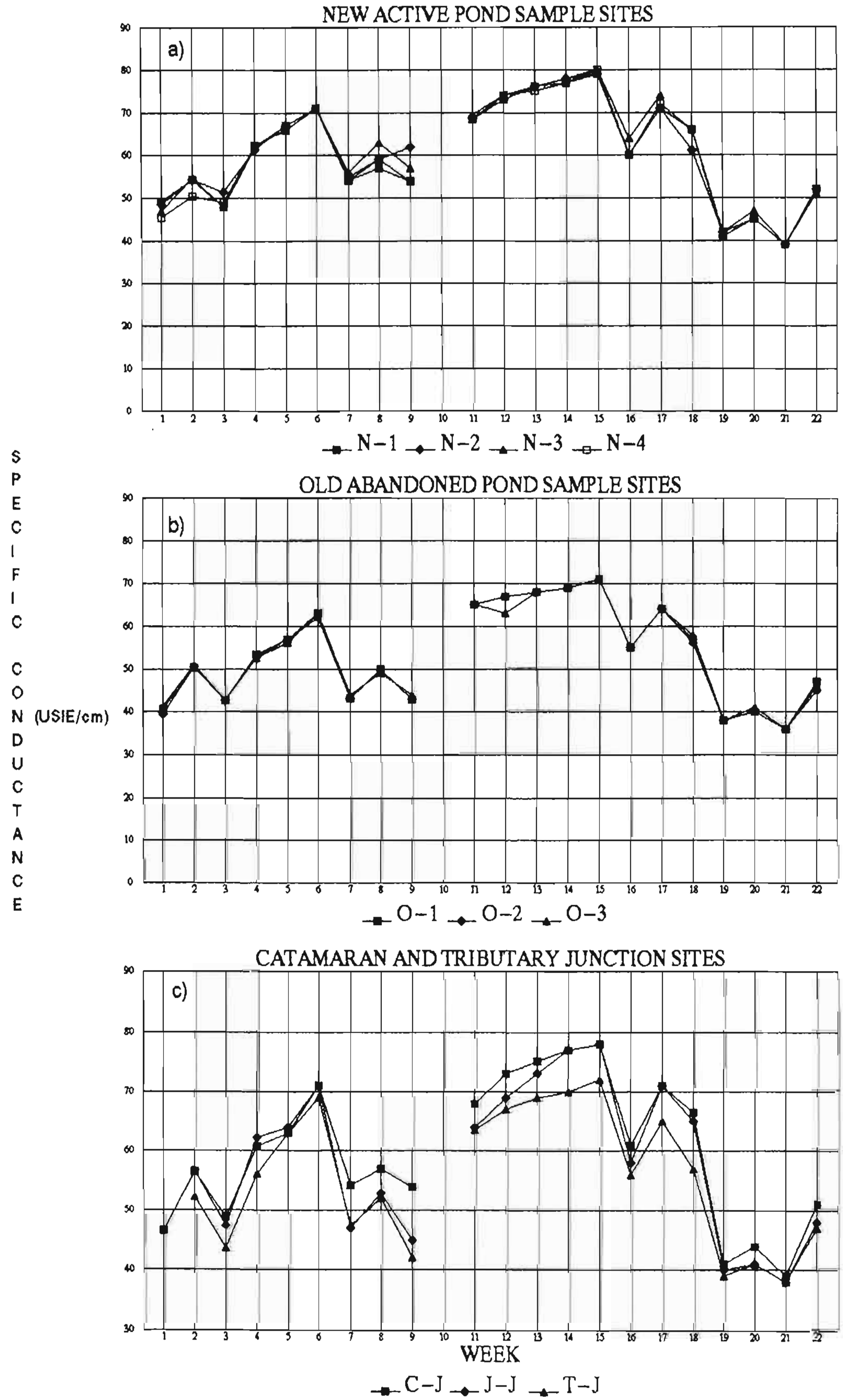

Figure 5. Specific Conductance measured at three study locations, in or near Beaver Ponds in Catamaran Brook, under ice-cover (winter 1991-1992).

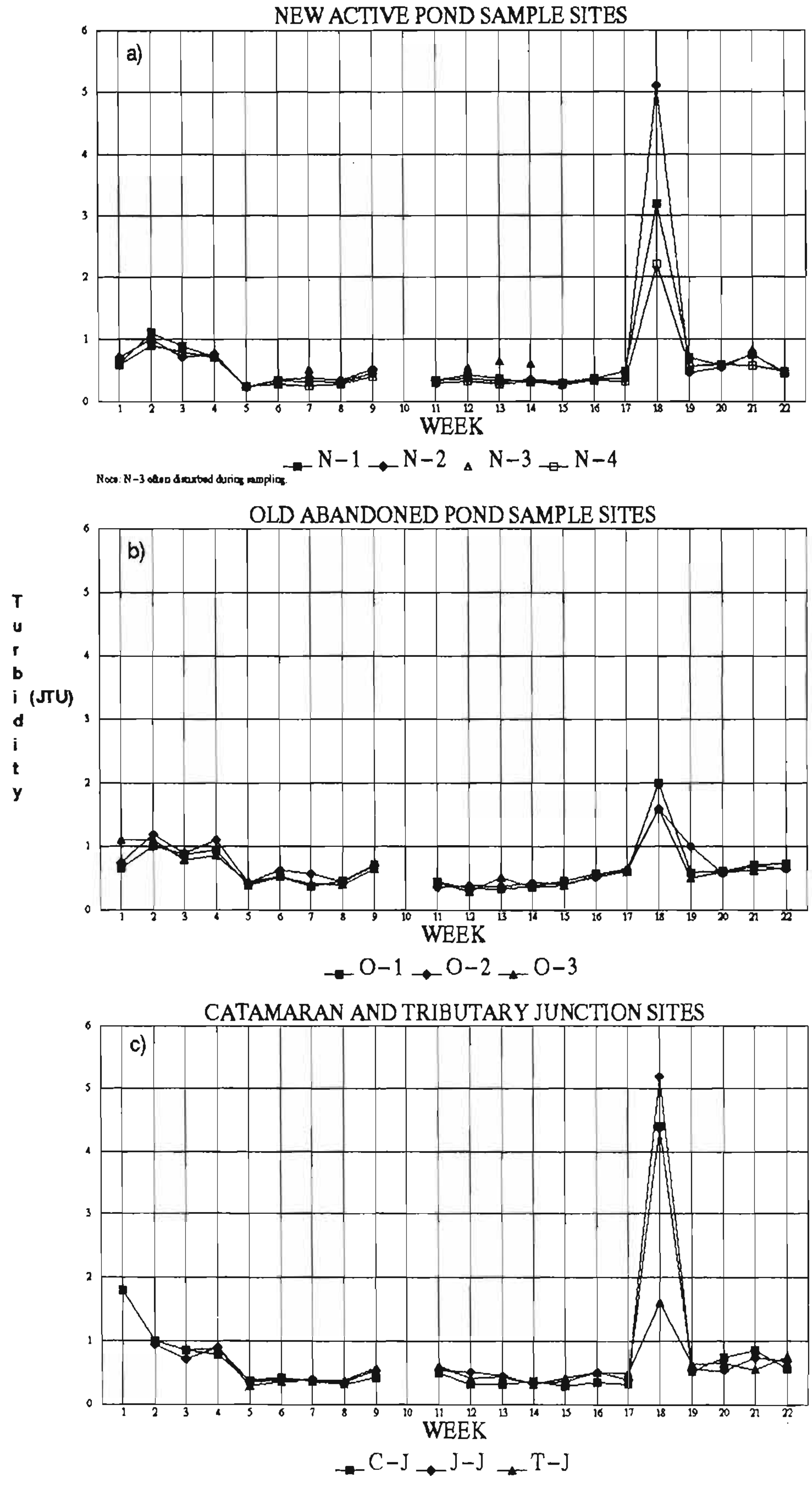

Figure 6. Turbidity measured, at three study locations in or near Beaver Ponds in Catamaran Brook, under ice-cover (winter 1991-1992).

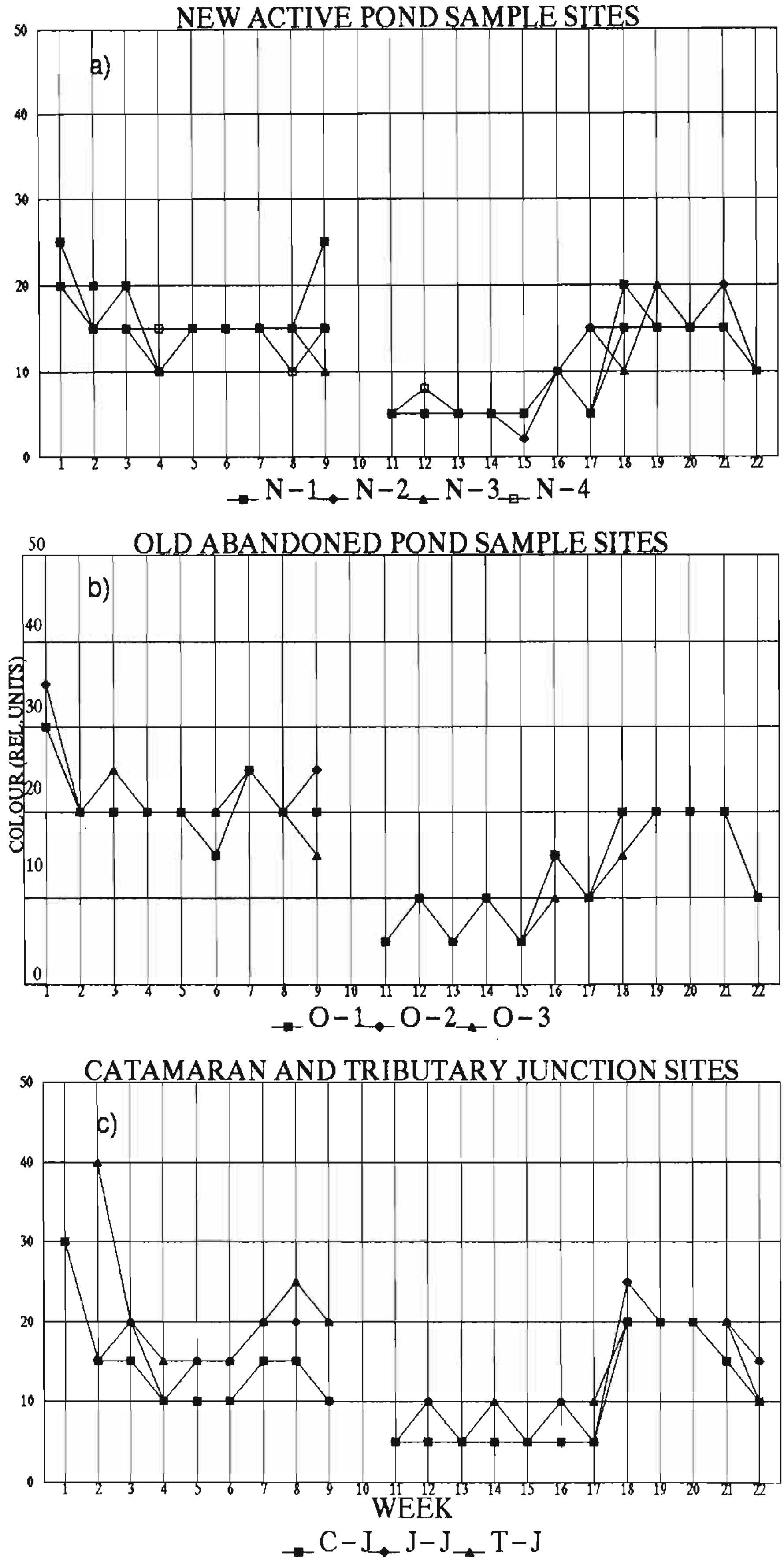

Figure 7. Apparent colour measured at three study locations, in Beaver Ponds in Catamaran Brook, under ice-cover (winter 1991-1992).

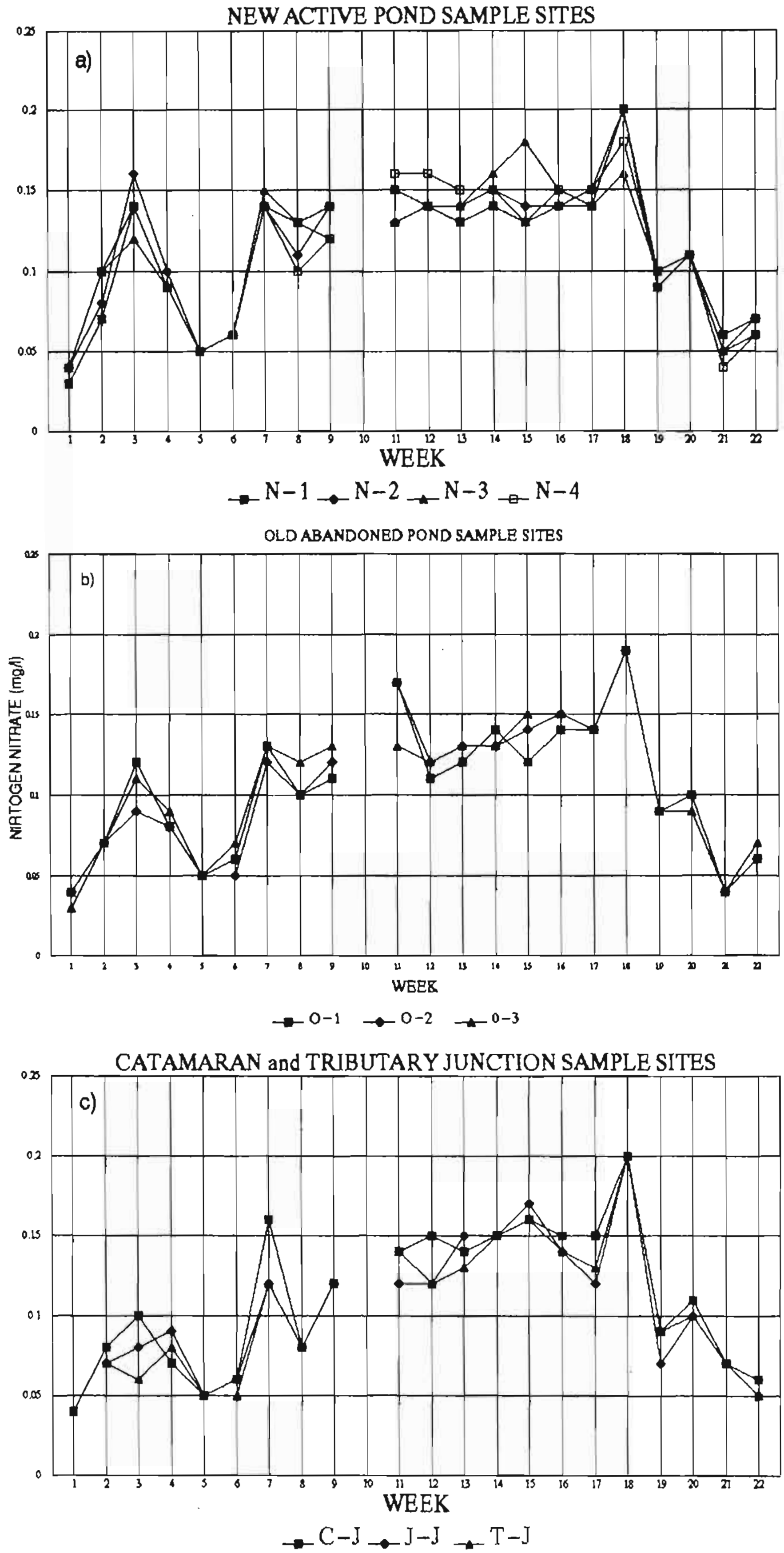

Figure 8. Dissolved Nitrogen-Nitrates measured at three study locations, in Beaver ponds in Catamaran Brook, under ice-cover (winter 1991-1992).

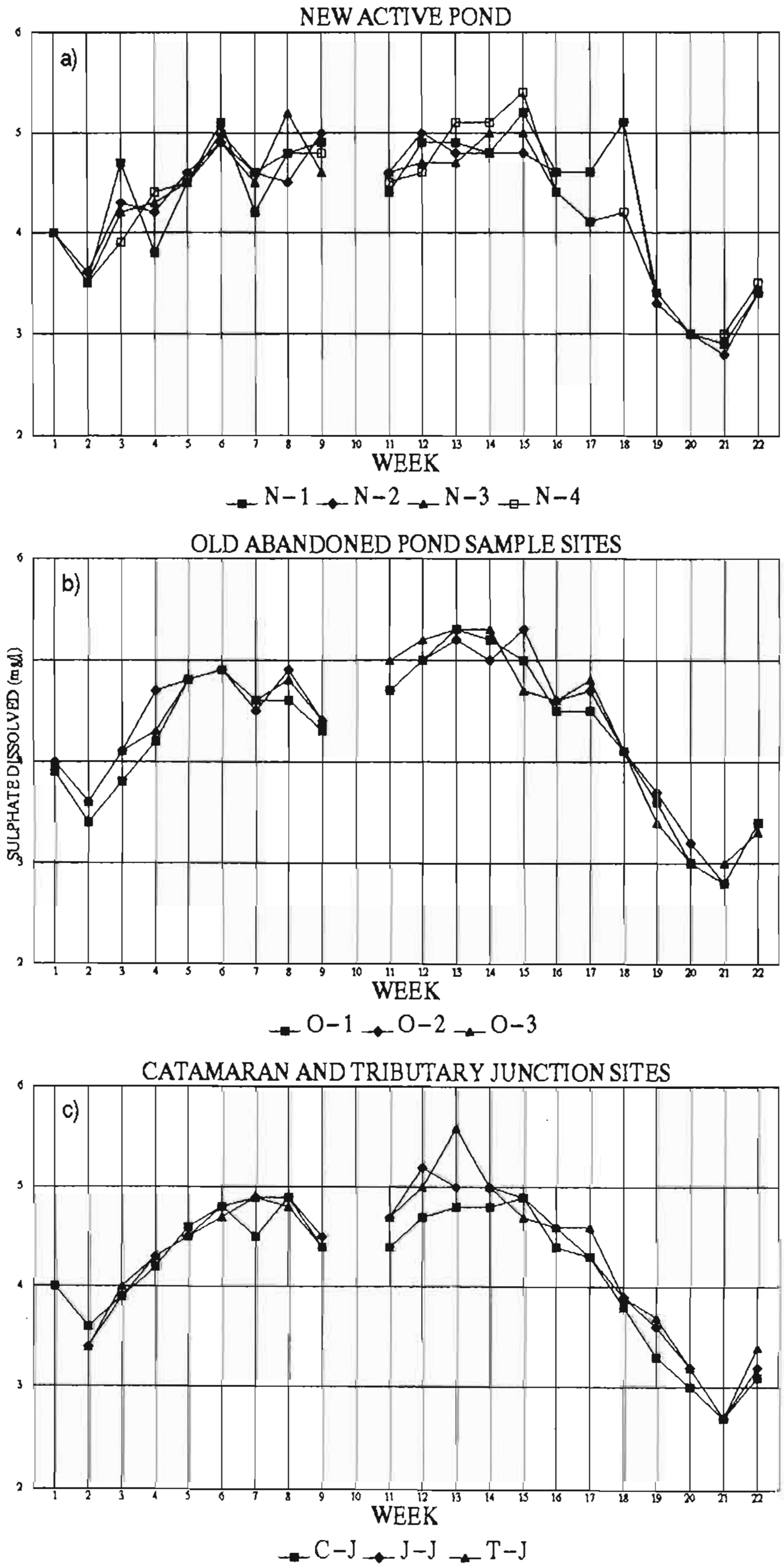

Figure 9. Dissolved Sulphates measured at three study locations, in Beaver Ponds in Catamaran Brook, under ice-cover (winter 1991-1992).

Appendix A:

Combination of the Modified Wentworth Classification for sub particle sizes, and Values for particle sizes/embeddedness us calculating substrate score (Cummings 1962).

Classification	Particle Size (mm)	Characteristic Particle Type and Size	Value
		Organic cover (>50%) of Bottom Surface	1
Sand	0.0625-0.125	<1-2mm	2
Gravel	2-32	2-5mm	3
		5-25mm	4
		25-50mm	5
Pebble	32-64	50-100mm	6
Rubble	64-256	100-250mm	7
Boulder	>256	>250mm	8
		Embeddedness:	
		Completely Embedded	1
		3/4 Embedded	2
		1/2 Embedded	3
		1/4 Embedded	4
		Unembedded	5

To calculate substrate scores one must determine the particle size that is most prominent in the area of concern, than the second most prominent and the third. Compare these three particle sizes with the 'Characteristic Particle Type or Size' from the chart above, and record the corresponding number from the 'Value' heading. You should now have three numbers or values ranging between 1-8. A forth value must be added which is the percentage of embeddednes the three particle types. This forth number should be between 1-5 as can be seen from the chart above.

EXAMPLE: Most prominent 25mm
2nd prominent 2mm
3rd prominent 5mm

Assume the particles were 3/4 embedded, and look at the embeddness value above that corresponds to our assomption. Our Substrate score should read 4;2;3;2.

From the example above we find from the substrate score that the substrate was composed of gravel and sand that was almost comple embedded.

The following is a list of substrate scores by sampling site for the two beaver pondSubstrate Score
under ice-cover (winter 1991-1992) in Catamaran Brook, N.B.

Site	Substrate Scores
N-1	5;4;6;4.
N-2	1;2;2;5.
N-3	4;7;5;3.
N-4	7;7;5;4.
O-1	5;6;5;2.
O-2	2;2;3;5.
O-3	1;2;3;2.
C-J	5;3;2;3.
T-J	8;2;3;3.
J-J	5;6;7;4.

Appendix B:

PROCEDURE: DISSOLVED OXYGEN

The procedure used for measuring the dissolved oxygen content was the Winkler Method. Each water sample was collected in a clear narrow-mouth glass stopper bottle. Methods for the collection of D.O. samples were applied in such a way as to not allow air to come in contact with the sample in order to avoid false readings. In most cases a metal sampler containing a D.O.B. (D.O. Bottle) was emerged under water and removed once all air bubbles diminished, indicating that the D.O.B. was filled and permitted to overflow three times (Figure A1). In shallow sample site, modifications had to be applied to the collection technique. First a one litre plastic bottle was fit with a cover containing a 12" plastic hose, with 6" extending into the bottle when closed. A hole was cut into the bottle to allow air to escape from the bottle as it was filling, once immersed into the water column. Once the bottle was filled to its capacity the plastic hose extending from the bottle was placed deep into the D.O. bottle and allowed to over fill approximately three times (Figure A2).

Once the D.O. bottle was filled, 2 ml of manganese sulphate solution was placed in the sample below the water surface, then immediately following 2 ml of alkali iodide solution was also injected into the sample. Then a ground-glass pointed stopper was carefully placed in the bottle so as not to allow any air to be trapped in the bottle. The sample was then inverted repeatedly to allow mixture of the solutions with the water sample. The sample was left to settle for approximately two minutes or until at least 100 ml of supernate was apparent. At this time the stopper was removed and 2 ml of concentrated sulfuric acid was administered in such a fashion as to allow the acid to flow down the neck of the bottle into the sample. The glass stopper was then replaced and the bottle was again inverted until colouration from the iodine became uniform throughout the sample. Once these procedures were completed each sample was sealed with a small sheet of paraffin, and then placed into an insulated box, to maintain sample temperature and protect the bottles from breaking, until they could be transported to the lab to be titrated with sodium thiosulphate iodide and starch solution.

All D.O. samples were taken to the lab and titration were performed as soon after collection as possible. D.O samples were transferred from 300 ml DOB into a 200 ml flask (Figure A3). After transfer the sample was titrated with 0.0250 N of sodium thiosulphate iodide from a 50 ml glass burett. Titration continued until a pale straw yellow colouration was obtained, then 2 ml of starch solution was added to the flask containing the D.O. sample. The addition of the starch solution turned the sample a deep blue colour, and titration continued until this blue coloration was no longer visible, indicating that the titration was completed. The volume of titration used to reach the end point was recorded, and dissolved oxygen content determined in mg/l, by the following calculation;

1ml 0.0250N sodium thiosulphate = 1mg/l of D.O.

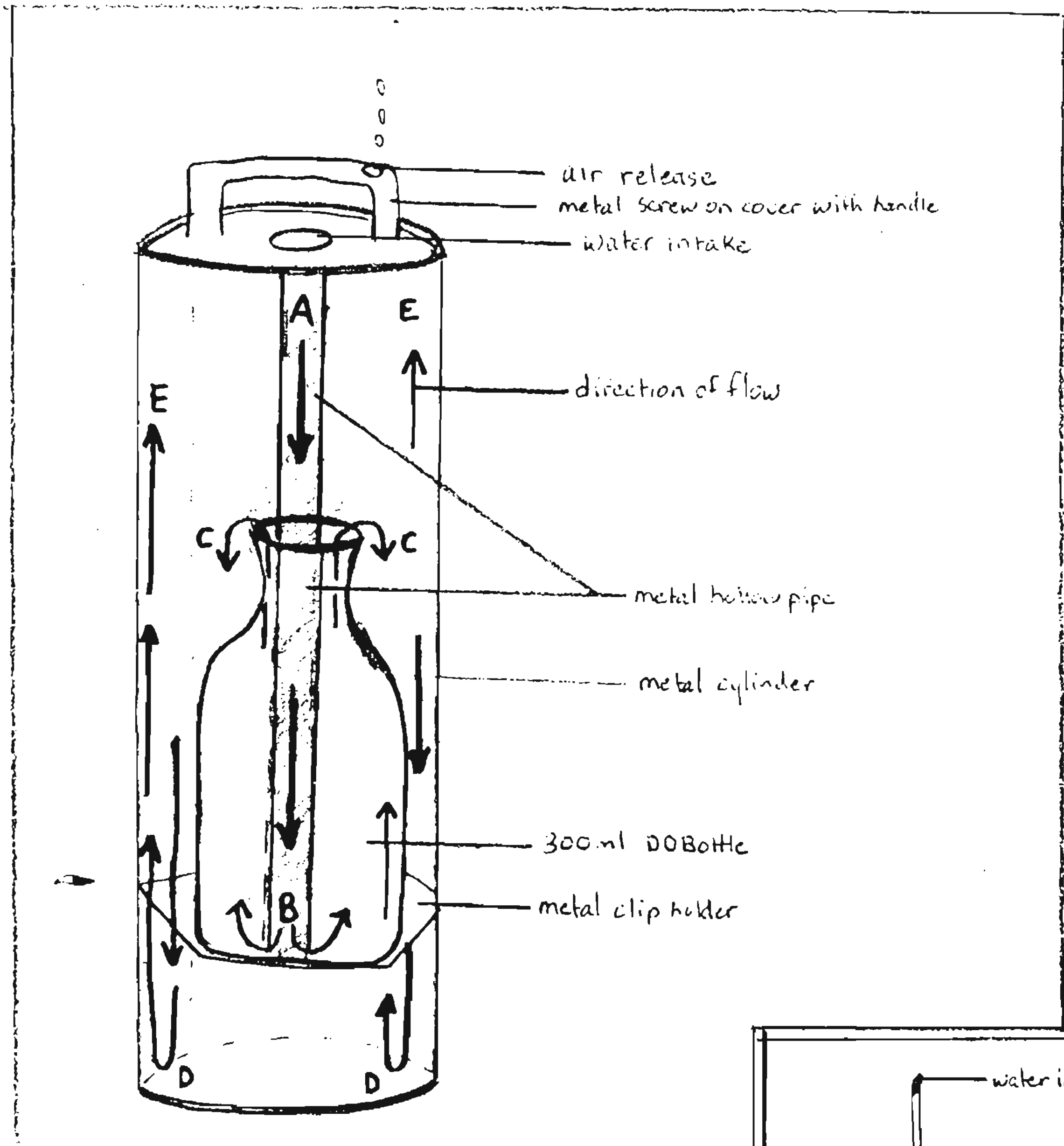

FIG.A1 : Metal D.O. Sampler Used to Obtain Water Samples Without Saturating with Air.

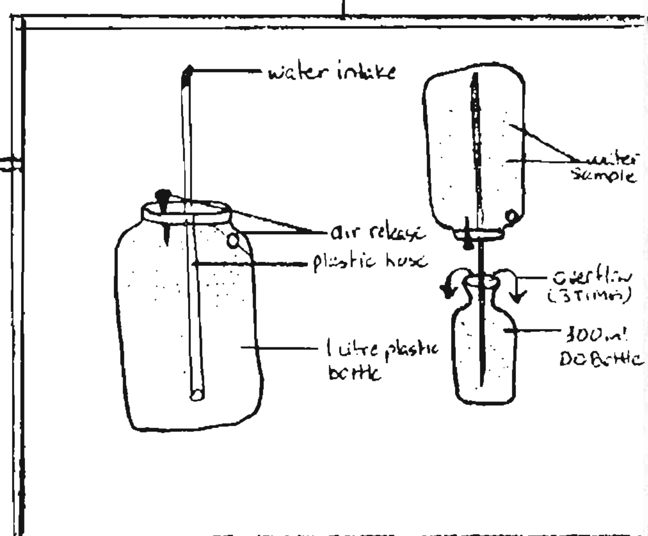

FIG.A2: Plastic D.O. Sampler Used in Place of Metal Sampler in shallow areas.

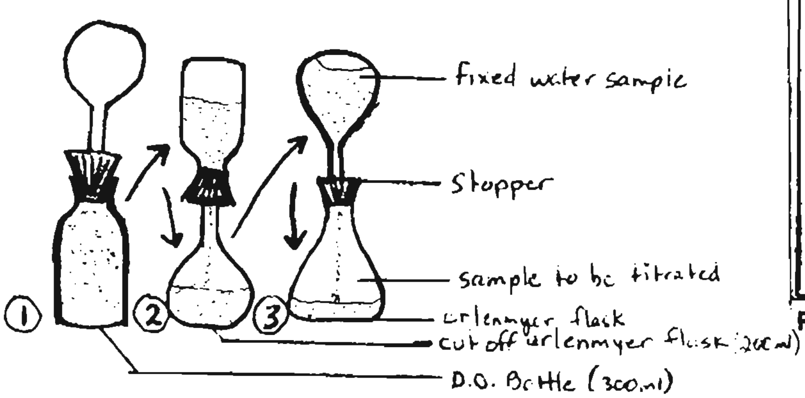

FIG.A3: Fixed D.O. Sample being Transfered without Air Saturation to prepare for Titration.

ATLANTIC REGION WQL

JANUARY 1991

NAQUADAT NO. 02041
02011

SPECIFIC CONDUCTANCE
AND APPARENT COLOR
(WHEATSTONE BRIDGE, CONDUCTANCE CELL)
(COLORIMETER)

---

1. SCOPE AND APPLICATION

1.1 Specific conductance and color are both determined simultaneously using a manual pumping system attached to a colorimeter and conductance cell. This method is applied to surface, ground and saline waters. The range for conductance is almost unlimited and is measured in usie/cm. The range for apparent color is 5 to 500 relative color units (ru).

2. PRINCIPLE AND THEORY

2.1 The conductivity of a solution is the ability of the solution to carry an electric current. Since electricity is carried in the solution by migration of the solute ions, the conductivity has some relationship to the total ionic concentration of the solution. The principle of the conductivity meter is that of an ohmmeter in which the resistance is measured in ohms and is written in terms of the reciprocal of the resistance and is written in microsiemens per centimeter (usie/cm), usually at 25 degrees celcius. The conductivity meter is therefore used to measure the resistance and through the use of a temperature probe it can correct for any temperature deviations from 25 deg. C. Values are then displayed in a digital window in usie/cm.

2.2 The color of a solution is the color caused by natural substances such as leaves, bark, roots, humus and peat materials that are in solution with the water. Apparent color includes the color due to these substances in solution and also that due to suspended matter. One relative unit of color is that produced by 1 mg/L of platinum in the form of chloroplatinate ions. A colorimeter basically takes a sample and determines its color using a spectrophotometer equipped with a wide-band filter (450 nm) and compares it against std. solutions of cloroplatinate and cobalt ions.

3. INTERFERENCES

3.1 Slight traces of turbidity can interfere causing high results in color.

4. SAMPLING PROCEDURE AND STORAGE

4.1 The plastic sample bottle should be tightly sealed after collection of the sample as biological changes occuring may affect the color. Samples should be analysed as soon as possible after collection.

5. SAMPLE PREPARATION

5.1 Samples should be permitted to reach laboratory temperature before measurements of specific conductance are taken.

5.2 Samples cannot be filtered because it may remove some of the color as well as the turbidity.

6. APPARATUS

6.1 Radiometer type CDM83 conductivity meter.

6.2 Conductivity cell, radiometer type CDC 114.

6.3 Technicon Auto-Analyser II colorimeter.

6.4. Socorex 511, 10 mL dispenser.

7. REAGENTS

7.1 YSI 3161 conductivity standard, 1000 usie/cm. Dilute as necessary.

7.2 Fisher Scientific SP120-1 platinum cobalt color standard. Dilute as necessary and use only when the conductivity cell is disconnected.

8. PROCEDURE

8.1 Turn on the conductivity meter and colorimeter and allow approx. 15 to 30 min. for warm-up.

8.2 See the CDM83 and Technicon manuals for specific instructions on calibrating the system.

8.3 Samples are pumped through the cells of the colorimeter and conductivity meter and the corresponding values are displayed in digital windows on a voltmeter and conductivity meter respectively.

9. CALCULATIONS

9.1 All calculations are done directly by the meters.

ATLANTIC REGION WQL

FEBRUARY 1990 TURBIDITY

NAQUADAT No. 02073 (Turbidimetric)

---

1. SCOPE AND APPLICATION

1.1 This method is applicable to the determination of turbidity in surface, ground and wastewaters over the range 0 to 1000 Jackson Turbidity Units (JTU). Samples having higher turbidities can be measured by appropriate dilution of an aliquot.

2. PRINCIPLE AND THEORY

2.1 In the Hach laboratory turbidimeter, a strong light beam is sent upward through a transparent tube containing the sample, and the suspended particles reflect the light. That light which is reflected at 90° to the axis is received by photocells and their electrical response is proportional to the amount received and hence to the sample turbidity. A calibration of the instrument is made using a standard suspension of Formazin - the reaction product of aqueous solutions of hydrazine sulphate and hexamethylenetetramine. Standardization of the instrument utilizes a polyacrylic plastic rod into which a special turbidity material has been cast.

3. INTERFERENCES

3.1 In water samples, air bubbles can give false, high readings, and the samples must be free from these prior to measurement. With very turbid or highly coloured samples, the meter may read less than the actual amount of turbidity present and hence it should be diluted quantitatively and re-measured using a filtered portion of the same sample for dilution to maintain equilibrium in the suspension. Floating grease and oil may require skimming off prior to measurement.

4. SAMPLING PROCEDURE AND STORAGE

4.1 Equilibrium conditions may change sufficiently to alter the suspension characteristics of a water sample with time. The measurement should thus be made as rapidly as possible after sample collection.

5. SAMPLE PREPARATION

5.1 Samples should be well shaken for turbidity measurement.

5.2 Since there is a progressive error on sample turbidities in excess of 40 JTU using the Hach turbidimeters, dilution is recommended for high-level samples.

5.3 See Section 3, Interferences, for precautions to be observed prior to measurement.

6. APPARATUS

6.1 Hach turbidimeter model 2100A, from Hach Chemical Company, Ames, Iowa.

6.1.1 The standard for turbidity is a polyacrylic plastic rod with a special turbidity material cast into it which is supplied with the instruments.

7. REAGENTS

7.1 Standard turbidity suspension kits from the Hach Chemical Company.

8. PROCEDURE

8.1 Turn instrument on and allow 30-s warm-up.

8.2 Insert the standard turbidity rod, and place the light shield over the cell holder.

8.3 Adjust the standardization control on the 0-100 JTU scale for a reading equal to that stamped on one end of the standardization rod. Do not leave the standard turbidity rod in the instrument for long periods while the instrument is turned on.

8.4 The instrument is now standardized. When the range 0-1000 or 0-100 JTU is to be used, the small cell and cell adapter must be used. When using the lower ranges, 0-10 JTU, 0-1 JTU and 0-0.2 JTU, the large cell must be used.

8.5 To determine turbidity of a water sample, fill the sample cell with a representative portion of sample to within 6 mm or 12 mm of the top. Adjust the range switch until a reading can be made.

8.6 If sample dilution is required, a filtered portion of the same sample should be used for dilution water to maintain equilibrium conditions.

8.7 The standardization rod should be checked periodically using standard turbidity suspension in order to ensure the reliability of the rod.

9. CALCULATIONS

9.1 The meter reads directly in JTU.

10. PRECISION AND ACCURACY

10.1 No data available.

11. BIBLIOGRAPHY

11.1 Analytical Methods Manual (1979), WQB, Environment Canada.

ATLANTIC REGION WQL

JANUARY 1991

CHLORIDE, NITRATE AND SULPHATE

NAQUADAT NOS. - See below

(ION CHROMATOGRAPHY)

---

1. SCOPE AND APPLICATION

1.1 This ion chromatographic method is applicable to the determination of chloride, nitrate and sulphate in fresh waters in the range of 0.5 mg/L to 20 mg/L for chloride and sulphate, and 0.05 mg/L to 2.0 mg/L for nitrate.

1.2 The detection limit is 0.5 mg/L for chloride, 0.05 mg/L for nitrate and 0.5 mg/L for sulphate respectively.

1.3 The NAQUADAT Numbers for this method are:

Chloride - 17209
Nitrate - 17305
Sulphate - 16309

2. PRINCIPLE AND THEORY

2.1 The sample containing chloride, nitrate and sulphate, is injected into a steady stream of sodium carbonate/sodium bicarbonate eluent flowing through an anion separator column. The ions of interest are separated according to their affinity for the ion exchange resin. Separated anions are then carried by the eluent through a "conductivity suppressor" and the microcell of a conductivity detector. Anions are identified by their retention times compared to known standards. The concentration of the anions is calculated by comparing the peak area of the sample to the peak area of a standard.

3. INTERFERENCES

3.1 With fresh waters possible interferences are high turbidity, sulphides and sulphites. Turbidity can be eliminated by filtration. Sulphides and sulphites, found in some waste waters, seem to quickly ruin the separator column, thus, these samples are best analyzed by alternate methods.

3.2 Seldom found in significant amounts in fresh waters, bromides may easily be mistaken for chlorides - the retention times for these anions are quite close.

4. SAMPLING PROCEDURE

4.1 The samples should be stored in polyethylene bottles at 4°C.

5. SAMPLE PREPARATION

5.1 The sample aliquot used for the analysis should either be free from particulate matter or should be filtered or allowed to settle prior to analysis.

6. APPARATUS

6.1 Dionex Ion Chromatograph 2010i System, fully automated and connected to SP 4270 Integrator.

6.2 Dionex HPIC-AS3 column.

6.3 Dionex Membrane Suppressor - anion type

6.4 Technicon Autoanalyzer Pump II for pumping sulphuric acid to the membrane suppressor and rinse water to the sampler.

7. REAGENTS

7.1 Stock Eluent Solution (0.300 M $NaHCO_3$, 0.240 M Na_2CO_3): weigh 25.20 g of sodium bicarbonate and 25.49 g of sodium carbonate and dissolve in 1L of DI water.

7.2 Eluent Working Solution (0.012 M $NaHCO_3$, 0.010 M Na_2CO_3): 40 mL of stock eluent solution is diluted to 1 L with DI carbon dioxide - free water (purged with nitrogen).

7.3 Sulfuric Acid solution (for the suppressor): 15% H_2SO_4 is added to 4 L of DI water until a solution of 700 $\pm$ 10 μS/cm is obtained.

7.4 Mixed Standard Stock Solution: 2000 mg/L chloride, 200 mg/L nitrate and 2000 mg/L sulphate is obtained by dissolving8.40 g of potassium chloride (KCl), 2.92 g of potassium nitrate (KNO_3) and 7.28 g of potassium sulphate (K_2SO_4) in 2 L of DI water.

7.5 Working Standard Solutions: from the Mixed Standard Stock Solution prepare the following concentrations using DI water (CO_2-free):

1) 0.5 mg/L Cl; 0.05 mg/L NO_3; 0.5 mg/L SO_4
2) 2.0 mg/L Cl; 0.20 mg/L NO_3; 2.0 mg/L SO_4
3) 5.0 mg/L Cl; 0.5 mg/L NO_3; 5.0 mg/L SO_4
4) 10.0 mg/L Cl; 1.0 mg/L NO_3; 10.0 mg/L SO_4
5) 20.0 mg/L Cl; 2.0 mg/L NO_3; 20.0 mg/L SO_4
6) 40.0 mg/L Cl; 4.0 mg/L NO_3; 40.0 mg/L SO_4

8. PROCEDURE

8.1 Set up the instrument according to the instructions in the operation manual.

8.2 Run the ion chromatographic system in the manual mode until acceptable performance is established (i.e. good baseline, good reproduceability of the lowest and highest standards, no drift in baseline).

8.3 Enter retention times for the three anions in the SP 4270 integrator.

8.4 Load the sampler with the standards, samples and blanks.

8.5 Switch to the automated mode and run the instrument according to instructions in the operation manuals.

8.6 At the end of the run, check, edit and report the concentrations.

9. CALCULATIONS

9.1 The integrator print-out will provide the calculated values for the parameters being analyzed.

10. PRECISION AND ACCURACY

10.1 The coefficient of variation for chloride at 1.0 mg/L and 15.0 mg/L was $\pm$ 4.8% and $\pm$ 3.1% respectively.

10.2 The coefficient of variation for nitrate at 0.1 mg/L and 2.0 mg/L was $\pm$ 3.2 and $\pm$ 2.4% respectively.

10.3 The coefficient of variation for sulphate at 1.0 mg/L and 15.0 mg/L was $\pm$ 3.7 and $\pm$ 3.3% respectively.

10.4 In FP 33-34, PP 73-74 Q.C. study (1989), for 14 participating laboratories the mean concentrations for a pair of chloride samples were 1.2309 mg/L and 16.250 mg/L. The recovery rates for this procedure were 97.5% and 98.5% respectively.

10.5 In the same study (10.4), the mean concentrations for a pair of sulfate samples were 3.1882 mg/L and 28.1929 mg/L. The recovery rates were 97.2% and 96.9% respectively.

11. BIBLIOGRAPHY

11.1 Dionex 2010i Methods and Operations Manuals.

11.2 SP 4270 Operations Manual.

11.3 Dionex specifications for the employed column.

12. QUALITY CONTROL

12.1 Q.C. samples are run immediately after both standardizing procedures and again before the end of the run.