Report COO-3568-13

MASTER

CONTRACT E(11-1)-3568

GENERAL SUMMARY OF PROGRESS
1975 - 1976

PLUTONIUM AND AMERICIUM CONCENTRATION ALONG FRESH WATER FOOD CHAINS OF THE GREAT LAKES, U. S. A.

Principal Investigator: Vaughan T. Bowen
Woods Hole Oceanographic Institution
Woods Hole, Massachusetts 02543

Introduction

Our purpose in this program is to understand and evaluate the freshwater biogeochemistry of long-lived transuranic nuclides introduced into large lakes; it is hoped that the final product will be both the ability to predict the distributions of transuranics that would result following any of several kinds of releases to the lake studied, and also an understanding of how far our information may be extrapolated to other lakes. Lake Ontario was chosen for study, originally because of assumptions about its simplicity and tractability that have proved over optimistic. It appears, however, to have been a very fortunate choice, partly because of its morphometric similarity to Lake Michigan, which is under intensive study by Argonne National Laboratory, partly because its relationship to Lake Erie (which we are also beginning to study) through the Niagara River is proving suggestive of a number of generalizations, and partly because its receipt of nuclides leaking from the Nuclear Fuels Services operation at Springville, New York, is enabling us to look at curium in an environment context, as well as, we now believe, a two-source Pu 238 experiment. As noted last year, we also believe that because of its terminal position in the Great Lakes Chain, Lake Ontario provides the most sensitive test of any models of transuranic nuclide transport through the lakes.

Bibliographic Summary

1. Only one report under this contract is, finally, now in press; ~~it is included as an Appendix to this Report.~~

Report COO-3568-12: Livingston, H. D. and V. T. Bowen. Contrasts between the marine and freshwater biological interactions of plutonium and americium. Presented at the International Symposium "Interaction between Water and Living Matter", Odessa, USSR, October 1975. Our latest information is that the symposium papers will be published first in Russia, in Russian translation, and subsequently in Europe or U. S. A. in the original languages if Professor G. G. Polikarpov, the Editor, can complete the arrangements.

The Abstract that led to this report was included, as Report COO-3568-7, with last year's Progress Report.

2. Also enclosed is the final form, considerably revised, of the following, which was enclosed, in second draft, with last year's Report:

Report COO-3568-6: Farmer, J. G., V. T. Bowen and V. E. Noshkin. Long-lived artificial radionuclides in Lake Ontario I. Supply from fallout, and concentrations in lake water, of plutonium, americium, strontium 90 and cesium 137. This has been submitted to Limnology and Oceanography.

3. Other reports are still in preparation:

Farmer, J. G., V. T. Bowen and V. E. Noshkin. Long-lived artifical radionuclides in Lake Ontario 2. Plutonium, americium, strontium 90 and cesium 137 in sediment cores.

Volchok, H. L. Final report of sampling and analysis of environmental materials from around Mound Laboratory.

Farmer, J. G. Pb-210 dating of Lake Ontario sediments.

Farmer, J. G. Distributions of Pb-210 and stable lead in Lake Ontario sediments.

Farmer, J. G. Distribution of trace elements in Lake Ontario sediments.

Farmer, J. G., V. T. Bowen and V. E. Noshkin. Pb-210 dating and fallout radionuclide profiles in Lake Ontario sediments.

Collecting Program

In 1975-1976 two cruises were undertaken to collect samples for this program:

A. In July, on the R.V. C. A. DAMBACH, of the New York State University College at Buffalo, sampling was done as shown in Figure 1, in Lake Erie and in Lake Ontario. As shown, operations were successful except that at Station 2 no corable bottom could be found. The "muddy bottom water", indicated at Station 3, was an attempt to follow up on our accidental finding (see 1974-75 Progress Report) of high Pu, and high ^{238}Pu to $^{239,240}Pu$ ratio, in the fine sediment stirredup by banging the water sampler on the bottom.

B. In October-November, on the first cruise of R.V. OCEANUS, of Woods Hole Oceanographic Institution, sampling was done as shown in Figures 2, 3, 4, 5 and 6, in Lake Erie, Lake Ontario, and the St. Lawrence River-Gulf of St. Lawrence. As discussed in the 1975-76 Proposal it was possible to do this work at very low cost because the vessel was coming down the lakes and the St. Lawrence Seaway, anyway, on the way to Woods Hole from Sturgeon Bay, Wisconsin, where she was built. This cruise was also very successful, in spite of interruption to go into drydock near Quebec for correction of a design defect.

The dredges, and the extra cores, that were collected were sieved to remove benthic biota, both for taxonomic and biomass study, and for transuranic nuclide analysis.

In addition, through the good offices of Mr. G. C. LeTendre, of the Cape Vincent Fisheries Station, New York State Department of Environmental Conservation, we obtained a considerable number of fish samples. These are listed in Table 1a. Finally, and also listed in Table 1a, we have obtained, after many vicissitudes, two muskrat samples (less the hide); these were collected through the good offices of Mr. William Pearce.

Mrs. C. M. Lawson, of our group, on a trip to pick up fish from Mr. LeTendre, collected a set of algae, and one eel grass sample, as listed in Table 1b. These are intended as supplement and follow up to the series of algae collected in 1973-74. The "site" identifications by letter refer to the location map included in the 1973-74 Progress Report.

ANALYTICAL PROGRAM

There has been no substantial change in any of our radiochemical methods; those for the transuranics have recently been described in Report COO-3563-27: Livingston, H. D., D. R. Mann and V. T. Bowen, 1975. Analytical procedures for transuranic elements in seawater and marine sediments. Pages 124-138 in Analytical Methods in Oceanography, Advances in Chemistry Series, No. 147 (ACS, Washington).

Recently there was published an intercomparison of our methods for transuranium nuclides versus those of the National Bureau of Standards, of the ERDA Health and Safety Laboratory, and of the ERDA Health Services Laboratory (Mr. C. W. Sill): Noyce, J. R. et al, 1976. "Development of a National Bureau of Standards environmental radioactivity standard: river sediment." Annals of the Institute of Electrical and Electronics Engineers 75 CH 1004-1 19-5 pages 1-9. The WHOI data for Pu 239 + 240, Am 241 and Pu 238 agree well with those of other laboratories or with the certified value; our value for Cm 244 does not agree with that reported by HSL, but we are still confident in our data.

A good deal of data generated under this project were recently published, without specific authorship, in the text of the International Atomic Energy Agency Technical Report No. 169, "Reference Methods for Marine Radioactivity Studies II. Iodine, Ruthenium, Silver, Zirconium and the Transuranics Elements". IAEA, Vienna. Our data deal especially with the inclusion of surface sediment (as shown by high Cs 137 values) in the nose-cone material of our 21-cm diameter corer (ibid, p. 8), and with the leaching of Pu 239,240 from fresh water sediments with either HNO_2 or HNO_5-HCl (ibid, p. 16).

Several relatively minor changes in radiochemical procedures have proved unexpected by effective in increasing both the mean yield of plutonium and the uniformity of yield; we intend to report this, in a brief note, shortly. Also we have found that a change in the method of measuring the final recovery of Y-90, for counting, in strontium 90 radiochemistry, makes an important improvement by using iron (rather than yttrium or a lanthanide) as carrier for the Y-90, and by measuring not the iron recovered on the counting planchet, but the iron remaining in the other phases, we get a more sensitive and accurate estimate of the Y-90 losses in this final step. There has been one unfortunate byproduct of this latter advance: it has led to a reassessment of the efficiency factors of all of our beta counters, so that for about 10 months we have been unable to report any final Sr 90 values. This bottleneck has finally been broken, but has left us with an enormous backlog of calculation and recalculation, that is an effective bottleneck itself.

DATA

New data are at hand for several cores, and for the 1975 plankton samples. In Tables 2-4 are shown the analytical profiles for cores 74-1, 74-4, and 74-6; in Tables 5-8 are shown those for cores 75-1, 75-5, 75-8 and 75-11.

Also, in Table 9, are shown the analyses so far completed on four 1975 plankton samples.

DISCUSSION

Because so many of our data are in various stages of preparation for publication, we wish here to address only a few points -f special interest:

A. The supply of radionuclides from Lake Erie:

Of the cores tabulated in this report, 74-1, and 75-5, we believe should have shown the effects of the Lake Erie supply of nuclides to Lake Ontario; core 75-1, from Lake Erie, must represent at least a part of the raw-material for this supply. These cores should all be considered in comparison with Lake Ontario cores 72-4, 72-5, 73-1, 73-5, and 73-6, data from which were reported in our last two Progress Reports.

We have recently reported (Livingston and Bowen, Report COO-3563-47, 1976) data that indicate that in shallow water marine sediments fallout plutonium slowly solubilizes and moves upward, within the sediment column, while Cs 137 probably does not move except as a result of mechanical reworking of the sediments. Partly to explore this possiblity in the case of fresh water sediments, and partly in the expectation that a Cs 137 to Pu 239+240 ratio different from that in fallout would characterize any pulse of radionuclides leaking from the Nuclear Fuels Services plant at Springville, N. Y., we calculated the Cs 137 to Pu 239+240 ratio versus depth in core for each of the nine cores listed above. These values are shown in Table 10. For each core the depth of the maximum in fallout Cs 137 concentration, such as might indicate the 1963-1964 peak in delivery rate, is shown by an asterisk. We were surprised that the result of this exercise suggests so strongly an upward movement of Cs 137 in these cores, and one that was so slow as to be perceptible in the time span 1972 to 1975. But the evidence is quite strong:

1) Both the 1972 cores show the maximum ratio at depth (5-6 cm) in the core, although in both the concentration maxima are at the surface, in the 0-1 cm slice.

2) By 1973 the three cores each shows its maximum ratio near the surface (between 0 and 3 cm), although the concentration maxima are at surface in two of the cores (73-1 and 73-5), but at considerable depth (10-11 cm) in 73-6.

3) The four 1974-1975 cores show maximum ratios at or near the surface in each case.

4) Whereas core 73-6, the only 1972-1973 core showing a clear subsurface maximum in fallout Cs 137, shows its Pu 239+240 maximum at this same depth, the 1974-1975 Ontario cores with subsurface maxima in Cs 137 show the Pu 239+240 maximum deeper than that in Cs 137. As far as the data go, the 1975 Lake Erie core and the 1973 Lake Ontario core agree in having both Cs 137 and Pu 239+240 maxima at the same depth.

We do not believe there have been any major changes in the ratio Cs 137 to Pu 239+240 in fallout, although there is disagreement what the ratio actually has been. Thomas and Perkins reported 0.008 as the mean ratio Pu 239+240 to Cs 137 from 1902 to 1972 in ground level air at Richland, Washington, whereas Harley reported 0.012 as the value preferred at HASL; these convert, respectively to 125 or 83 at the ratio Cs 137 to Pu 239+240. Inspection of Table 10 suggests that, even though the disagreement is still without resolution, all the cores show a broad deficiency in Cs 137, whichever ratio is chosen to represent the source. This deficiency could, of course, be explained by a less efficient mechanism for transfer of Cs 127 than of Pu to the lake sediments. Taken in conjunction with the year-by-year tendency of the maximum ratio to move higher in the cores, and with the upward displacement, in some later cores, of the Cs 137 maximum vs the Pu maximum, the Cs 127 deficiency suggests one more piece of evidence that, after deposition in fresh water sediments, Cs 137 migrates up to the sediment surface and finally leaves the sediment. It is tempting to relate thisrremobilization to an expected increase in the ionic strength of the sediment interstitial water resulting from diagenetic processes at depth. But whatever the explanation, it appears clear from these data that we cannot hope, from systematic fluctuations in sediment ratios of Cs 137 to Pu 239+240 to infer anything useful about changes in sources of supply of these nuclides to the lakes.

It would be not unreasonable to expect that any Nuclear Fuels Services leakage would exhibit different transuranic ratios, either Pu 238 to Pu 239+240 or Am 241 to Pu 239+240. In fact, we suggested this in last year's Progress Report in connection with our finding of Curium 244 in the upper parts of core 73-6.

With respect to Pu isotope ratios, the new data agree with this idea, or are easily explained away:

a) Core 74-1 must, relatively recently, have had all its upper layers scoured away; its 238 to 239+240 ratio is characteristic of pre-SNAP 9A fallout.

b) Core 74-4, apparently from an area of lower rate of sediment accumulation than was core 73-6, still shows evidence of elevated 238 to 239+240 ratios beginning just above the 1963-1964 fallout maximum and extending to the surface. Allowing for compression of all the detail in core 74-4, it looks amazingly like core 73-6 in respect to 238 to 239+240 ratio.

c) Core 75-5, allowing both for difference in sedimentation rate and an incomplete pattern of analyses, also exhibits most of these details; the top of this core, however, shows definite reduction of 238 to 239+240 ratio. This could, of course, be explained by both the higher sedimentation rate than that of 74-4, and the two years more accumulation than in 73-6.

d) Core 75-1, from Lake Erie, also exhibits higher 238 to 239+240 ratios beginning well above the fallout peak. There is no evidence that the ratio has begun to diminish, but this could indicate simply that this core has a low sedimentation rate, quite like that of 74-4.

With respect to Am 241 to Pu ratios, the argument goes less swimmingly, possibly because there are fewer data. As we noted last year, in the sections of core 73-6 that contained Cm 244, we were struck that the ratio Am 241 to Pu 239+240 was lower than in most sediments: 0.15 to 0.17 rather than the 0.20 we expected. In core 75-1 from Lake Erie, the Am 241 to Pu 239+240 ratios, and the Pu 238 to 239+240 ratios, from sections so far analyzed, are as follows:

0 - 1cm	Am241 to Pu	0.21	Pu238 to 239	0.08
2 - 3cm		0.22		0.08
4 - 5cm		0.22		0.03
6 - 7cm		0.30		0.03

The change in the Pu isotope ratio, then, appeared between 3 and 4cm down the core, while that in Am to Pu ratio appeared between 5 and 6cm down. Evidently the two -arameters were not, as we had suggested, causally connected. None of Pu's core so far has shown any Cm244 at all, so it is quite possible that it was not from an area contaminated by the Nuclear Fuels Services leakage. In that case by juggling the SNAP 9A debris (as source of excess Pu238) and the differences between Am and Pu behavior in fresh water (described, for biota, in report COO-3568-10), the profiles observed are explainable.

Fragmentary as they still are, these data confirm us in the opinion that sedimentation and sediment redistribution in eastern Lake Erie and western Lake Ontario can be understood only with the aid of careful measurement of all possible transuranium nuclides.

B. Sedimentation in the deep part of the easternmost basin, Lake Ontario:

We have now cored several times in the deepest part of Lake Ontario; cores 71-5, 73-13A, 73-13B, 74-9, and 75-10 represent this area. Although some of these cores remain unanalyzed, enough data have accumulated to reveal a quite puzzling picture. It had been our expectation that sedimentation in this deep hole would have proceeded undisturbed, yielding a uniform accumulation of layers that would be readily interpretable in temporal terms -- as, in fact, are cores 73-6 and 75-5 from the Niagara River Fan. The data now at hand, summarized in Table 11 show the situation was quite otherwise:

1. Core 71-5, in 215m of water, revealed a Cs 137 peak at 4-5 cm depth, and a curve of great irregularity below that, with sizable secondary peaks at 14-15 and 18-20 cm, and lesser ones scattered at random in between. The $Pu^{239,240}$ curve was similar, but with a good deal of difference in detail; this was even more true of the Sr 90 curve. And the Pu 238:239, 240 ratio distribution was quite uninterpretable.
2. Core 73-13A, in 250m of water, was quite a short one and only the top has been analyzed. Even so, the Cs 137 curve starts out peculiarly, the increase in concentration at 3-4 cm being much greater than seems reasonable. The Pu 239,240 concentration at the surface is one of the highest that we have seen in the lake.
3. Core 73-13B, in 245m of water, was quite different from both the others: the top of the core was the richest in fallout of any of the layers, with 9800 and 307 dpm per kg for Cs 137 and Pu 239,240 respectively. These concentrations diminish quite steadily with depth in the core, Cs 137 showing one good secondary maximum at 8-9 cm, and another of questionable significance at 20-22 cm; Pu 239,240 shows a few more inflections than does Cs 137, but nothing that appears notably interpretable.

4. Comparison of the Cs 137 to Pu 239,240 ratios from these cores, with those of Table 10, is also surprising: nowhere in any of these three cores do we see a ratio as high as 50, and the mean ratios are in the 30's; there is a tendency for more high ratios in core 71-5 than in the two 1973 cores. Evidently a much greater proportion of fallout Cs 137 is missing from sediments in this part of the lake than was missing from Lake Erie or from the Niagara River Fan, and it is difficult to avoid the impression that a good deal of this missing Cs 137 was just not deposited in the mud, rather than having diffused upward and out, as appears to have happened further west.

We do not believe than any of these cores can be interpreted as indicating normal, continuous, sediment deposition. A sedimentation rate so slow as to retain the "fallout peak" in the top layer would not allow any fallout penetration as deep as 20-22 cm, whereas a sedimentation rate that placed the 1957-58 fallout maximum at 18-20 cm, would have to place the 1963-64 maximum around 9 cm (not about 4-5 cm as suggested by core 71-5).

By good fortune and thanks to the skill of Dr. H. H. Hoskins, on cruise 1 of R.V. Oceanus, we obtained a very high resolution bathymetric profile, with considerable sub-bottom detail, as the vessel was approaching station #7 in the deep part of Lake Ontario's eastern basin. A section of this profile is shown as Figure 7. It appears to us that these subbottom and bottom contours clarify a good deal what must be the sediment pattern in this part of the lake. Evidently a considerable amount of faulting has occurred, on rather closely spaced centers, and with substantial amounts of sediment translocation, laterally, either at the same time or subsequently. In several places the contours resulting are such that subsequent sediment accumulations could confidently be expected to move down slope either by plastic flow or by periodic slumping.

Clearly, even with a detailed survey of this sort, pin-point accuracy in core placing would be needed to ensure a "normally sedimented" sam le, and without such a survey, hitting on such a place by luck would be unlikely indeed. It is, of course, also true that we have only the one profile, and so can only guess at the 3-dimensional patterns of relief.

We are no longer surprised at the data shown in Table 11, but are now very eager to obtain a more extensive survey, to see whether anywhere in this part of the lake there exists a "good" basin for coring.

C. Fallout nuclides in Gulf of St. Lawrence sediments:

Preliminary data are at hand from several of the cores taken on R.V. OCEANUS cruise 1, in the Gulf of St. Lawrence. This work was done as an extension of the Lake Ontario program because of both our increasing certainty that the lake has retained only about half of the Cs 137 or Pu 239,240 that it has received, and our curiosity to establish where the rest of these nuclides have gone. We also have begun to wonder about the nuclear materials introduced at various times and in various ways to the Ottawa River.

In Table 12 are set out the values so far determined for sections of cores Oceanus 11, 13, and 14. As is our custom, every other slice has been analyzed. In the lower half of the table are shown the ratios of Pu 238 or of Am 241, respectively, to Pu 239,240.

That these are "salt water cores" immediately strikes the eye from the Cs 137 to Pu 239,240 ratios: here these run 2.5 to 6 at most, in sharp distinction from the 80 or 125 expected in fallout, or the 30 to 120 that we observe in the Lake Erie or Lake Ontario cores. Salinities are high enough everywhere in the Gulf and the St. Lawrence estuary so that the action of stable Cs and of K, as hold-back carriers, has retained Cs 137 in solution, or displaced it from particle associations established upstream. Any Cs 137 lost from the Great Lakes will not be found in sediments of the Gulf.

Overall these three cores give an impression of considerable sediment translocation. Although two, #11 and #14, show modest subsurface concentration maxima in the curves of Cs 137 and of Pu 239,240, the concentrations indicated are too small, compared with those in the top of the sediment, to support interpretation of these maxima in terms of the history of fallout delivery. Furthermore, the Pu 238 to 239,240 ratios appear almost randomly distributed in core #14, and show the SNAP 9A effect too soon and too little in core #11. Also the Am 241 to Pu 239,240 ratios suggest an odd mixture of quite young with very old layers. At the same time, the variations of Cs 137 to Pu 239,240 ratio, and of Pu 238 or Am 241 to Pu 239,240 ratio, versus depth in cores do not suggest that there has been vertical redistribution of any of these nuclides after sediment deposition.

It would be possible to argue that the frequency of high ratios of Am 241 to Pu 239,240 suggests a second source of Am 241: either its release at Chalk River in significant amounts or its preferential remobilization from the lake or river sediments. There are still too few data for us to be categorical about this; certainly so far none of the Am fractions has shown evidence of Cm 244, which we would rather expect to accompany any Am from a reactor-complex release.

At this stage it is not possible, either, to argue that the inventories of Cs 137 or Pu 239,240 suggest any other than a fallout source for these nuclides. This could well be clarified by analysis of the remaining alternate sections, or of course by that of the other cores collected in this area. At the present we have a large number of unanswered questions.

D. Sediment cores near water-cooled electricity-producing reactors on Lake Ontario:

Core 75-8 was taken near the reactor at Putneyville, N. Y., as close as soft bottom could be found. Core 75-11 was taken in the same sort of proximity to the reactor at Nine Mile Point. It is evident that neither of these cores represents a sedimentation regime very suitable for revealing the accumulation of reactorreleased nuclides. A good deal of sediment scour is suggested, and the curves of Cs 137 to Pu 239,240 ratios suggest also diffusion out of the sediment of most of the Cs 137. The ratios Pu 238 to 239,240 in the core tops are normal, compared to the other shallow water Ontario cores. We hope there may be some interesting information in the careful measurements of Am 241 and of Cs 134 to Cs 137 ratio, that are still in progress. But it looks as if it will be profitable to make a really detailed survey around one of these reactors to ascertain where the affected sediments finally do accumulate.

TABLE 1

Biological Samples from Lake Ontario, 1975

Table 1a - Fish and Mammals:

Sample Identification	Collection Date-1975	Wet Weight-kg	Collection Location
Minnows	3-7/Oct.	?	Mouth of Oswego River
White Sucker	8/Oct.	~2	Henderson Harbor
Rainbow Smelt	10/Oct.	~2	Charity Shoal
Gizzard Shad	8/Aug.	~2	Henderson Harbor
White Perch	8/Aug.	~2	Henderson Harbor
White Perch	23/Sept.	~2	Lake Ontario
Yellow Perch	23/Sept.	~2	Lake Ontario
Rock Bass	23/Sept.	~2	Lake Ontario
Rock Bass	10/Sept.	~2	Chaumont Bay
Brown Trout	25/Apr.	0.74(1 fish)	Wilson, N.Y.
Lake Trout	10/Sept.	~2(2 fish)	Henderson Harbor
Lake Trout	10/Oct.	~2	Charity Shoal
Chinook Salmon	16/Oct.	~2	Salmon River
Coho Salmon	25/Aug.	~2(1 fish)	off Salmon River
Coho Salmon	28/Oct.	~2(whole fish)	Lake Ontario
Coho Salmon	30/Oct.	0.5(viscera only)	Lake Ontario
Coho Salmon	?	0.5(viscera only)	Lake Ontario
Muskrat	20/April	~2(whole,skinned)	Point Peninsula,Town of Lyme
Muskrat	21/April	~2(whole,skinned)	Point Peninsula,Town of Lyme

TABLE 1

Table 1b - Plant Material

Sample Identification	Collection Date-1975	Wet Weight-kg	Collection Location
Cladophora	3-7/Oct.	?	Site I(West of Power Plant)
Cladophora	3-7/Oct.	?	Site H(Sandy Point Corners)
Cladophora	3-7/Oct.	?	Site B (Wilson's Point)
Cladophora	3-7/Oct.	?	Site D (Burnham State Park)
Eel Grass	3-7/Oct.	?	Site D (Burnham State Park)

TABLE 2

LAKE ONTARIO SEDIMENT CORE - STATION 74-1

RADIONUCLIDES IN DPM/KG DRY SEDIMENT

Core Collection Date: 25 June 1974

Location: $43^{0}24'N$; $79^{0}25'W$

Water Depth: 105m

M#	Depth in Sediment (cm)	Wet/Dry Weight	^{137}Cs	^{239}Pu	^{241}Am	$^{238}Pu/^{239}Pu$
1608	0-1	3.36	630±8	11±1		0.038
	1-2					
1609	2-3	3.53	86±4	2.3±0.7		-
	3-4					
1610	4-5	3.66	35±3	0.08±0.08		-
	5-6					
1611	6-7	3.40	10±3	<0.07		-
	7-8					
1612	8-9	3.32	13±5	0.07±0.07		-
	9-11					
1613	11-13	3.59	-5±6	0.22±0.12		-
	13-15					
1614	16-17	3.56	-0.9±6	0.13±.09		-
	17-19					
1615	19-20	3.42	-5±6	0.06±.06		-
	20-21					
1616	21-22	3.36	-0.7±6	<0.06		-
	22-23					
1617	23-25	3.30	-8±7	0.01±0.07		-
	25-27					
	27-29					
	31-33					
	33-35					
	35-37					
	37-39					
	39-41					
	41-43					
	43-45					
	45-47					
	47-49					
	49-51					
	51-55					
	55-58					

TABLE 3

RADIOCHEMICAL ANALYSES OF LAKE ONTARIO SEDIMENT CORE -- STATION 74-4
RADIONUCLIDES IN DISINTEGRATIONS PER MINUTE PER KG DRY SEDIMENT

Core Collection Date: 6/26/74
Location: 43°20'N, 79°W
Water Depth: 53 m
Core Cross-Sectional Area: 285 cm^2

Depth in Sediment (cm)	Wet/Dry Weight	Dry Weight Section (Kg)	^{90}Sr	^{137}Cs	^{239}Pu	^{241}Am	$^{238}Pu/^{239}Pu$
0-1	2.78			8710±20	94.9±3.6		0.089
1-2	2.88			12600±130	135 ±7		0.102
2-3	2.83			16700±170	285 ±10		0.042
3-4	2.71			16000±160	301 ±10		0.035
4-5	2.68			11379±26	228 ±6		0.026
5-6	2.66			9209±25	207 ±6		0.033
6-7	2.56			6828±20	196 ±6		0.027
7-9	2.45			3540±35	106 ±4		0.016
9-11	2.34			1610±15	36.3±1.7		0.020
11-13	2.33			401±3	9.0±0.6		0.044
13-15	2.15			103±2	3.4±0.3		0.047
15-17	2.03			28±1	0.8± .2		--
17-19	1.82			60±2	0.4±0.1		--
19-21	1.71			2.4±1.1	0.1±0.7		--
21-23	1.63			3.2±1.1	0.07±0.4		
23-25	1.61			6±2	0.2±0.1		-
25-27	1.54			-2.3±1.3	0.04±.03		
27-29	1.51			0.4±1.2	0.04±.03		
29-31	1.46			-1.5±1.3	0.06±.04		
31-35	1.54				<0.06		

Sediment contained red worms down to ~15 cm

TABLE 4

LAKE ONTARIO SEDIMENT CORE - STATION 74-6

RADIONUCLIDES IN DPM/KG DRY SEDIMENT

Core Collection Date: 26 June 1974

Location: $43^{o}26'N; 78^{o}W$

Water Depth: 100m

M#	Depth in Sediment (cm)	Wet/Dry Weight	^{137}Cs	^{239}Pu	^{241}Am	$^{238}Pu/^{239}Pu$
1618	0-1 1-2	7.05	1425±21	31.1±3.0		0.045±.019
1619	2-3 3-4	3.39	38±10	7.4±1.2		--
1620	4-5 5-6	3.92	157±7	3.4±0.9		0.04 ±.05
1621	6-7 7-8	3.82	33±6	0.39±0.25		--
1622	8-9 9-10	3.53	16±4	0.87±0.18		--
1623	10-11 11-13	3.15	17±4	0.60±0.15		--
1624	13-15 15-17	3.39	0.3±4	0.04±0.04		--
1625	17-19 19-21	3.35	-3.6±4.4	0.01±0.02		--
1626	21-23 23-25	3.47	1.0±3.5	0.16±0.12		--
1627	25-27 27-29	3.01	1.8±1.1	<0.14		--
1628	29-31 31-33 33-37 37-41 41-45 45-49 49-53 53-57 57-61 61-65 65-69 69-71	3.05	7.3±2.1	<0.13		--

TABLE 5

LAKE ERIE SEDIMENT CORE - STATION 75-1

RADIONUCLIDES IN DPM/KG DRY SEDIMENT

Core Collection Date: 15 July 1975

Location: 42°38'N;79°11'W

Water Depth: 22m

M#	Depth in Sediment (cm)	Wet/Dry Weight	^{137}Cs	^{239}Pu	^{241}Am	$^{238}Pu/^{239}Pu$
1657	0-1 1-2	1.99	4360±20	54.3±4.6	11.4±0.7	0.08
1658	2-3 3-4	1.89	7046±17	111±5	24.5±1.2	0.08
1659	4-5 5-6	2.08	16160±42	329±24	71.2±3.1	0.03
1660	6-7 7-8	1.81	4147±16	108±10	32 ±1.4	0.03
1661	8-9 9-10	1.82	447±7	11.3±1.1		0.02
1662	10-11 11-12	1.68	86±4	1.6±0.5		--
1663	12-13 13-14	1.64	10±3	to be counted		
1664	14-17	1.45	2±3	to be counted		

TABLE 6

LAKE ONTARIO SEDIMENT CORE - STATION 75-5
RADIONUCLIDES IN DPM/KG DRY SEDIMENT

Core Collection Date: 17 July 1975
Location: 43°21'N;79°04'W
Water Depth: 59m

M#	Depth in Sediment (cm)	Wet/Dry Weight	^{137}Cs	^{239}Pu	^{241}Am	$^{238}Pu/^{239}Pu$
1629	0-2 2-3	2.22	5850±20	57.6±3.4		0.055
1630	3-4 4-5	2.20	6440±20	58.9±3.4		0.076
1631	5-6 6-7	2.16	7111±21	75.8±4.2		0.084
1632	7-8 8-9 9-10	2.40	7422±25	111.1±6.0		0.054
1633	10-12 12-14	2.17	5658±25	112.6±6.0		0.026
1634	14-16 16-18 18-20	2.10	2789±16	77.9±4.7		0.013
1635	20-24 24-28	2.02	19.73±5.80	0.84±0.26		--
1636	28-32 32-36 36-40 40-44	1.78	0.65±5.55	<0.07		--

TABLE 7

LAKE ONTARIO SEDIMENT CORE - STATION 75-8
RADIONUCLIDES IN DPM/KG DRY SEDIMENT

(~ 1-3/4 mi. offshore the nuclear power plant at Putneyville, N. Y.)

Core Collection Date: 19 July 1975
Location: 43°19'N; 77°17'W
Water Depth: 38m

M#	Depth in Sediment (cm)	Wet/Dry Weight	^{137}Cs	^{239}Pu	^{241}Am	$^{238}Pu/^{239}Pu$
1637	0-2 2-3	1.29	3267±9	31.8±2.1		0.085
1638	3-4 4-5	1.32	1.8±1.8	4.6±0.5		--
1639	5-6 6-7 7-8	1.31	-5.4±2.4	0.11±0.10		--
1640	8-9 9-10	1.29	-3.6±2.2	<0.08		--
1641	10-12 12-14	1.33	-0.4±2.3	0.18±0.12		--
1642	14-16 16-18	1.30	0.1±0.2	0.04±0.05		--
1643	18-20 20-22	1.32	0.1±0.2	0.02±0.04		--
1644	22-26	1.42	2.05±1.57	0.11±0.04		--
1645	26-30	1.32	1.43±1.62	0.03±0.04		--

TABLE 8

LAKE ONTARIO SEDIMENT CORE - STATION 75-11

RADIONUCLIDES IN DPM/KG DRY SEDIMENT

(~ 1 mi. offshore from Niagara Mohawk Nuclear Power Station at Nine Mile Point)

Core Collection Date: 20 July 1975
Location: 43°33'N; 76°23'W
Water Depth: 40m

M#1	Depth in Sediment (cm)	Wet/Dry Weight	^{137}Cs	^{239}Pu	^{241}Am	$^{238}Pu/^{239}Pu$
1646	0-2 2-3	1.55	3985±16	52.2±3.0		0.06
1647	3-4 4-5	1.43	668±7	12.5±2.2		--
1648	5-6 6-7	1.48	34±4	0.71±0.21		--
1649	7-8 8-9	1.49	1.9±5.6	0.03±0.04		--
1650	9-10 10-12	1.52	1.2±3.1	0.41±0.16		--
1651	12-14 14-16	1.52	-2.0±3.3	<0.08		--
1652	16-18 18-20	1.52	2.1±3.2	<0.07		--
1653	20-22 22-26	1.45	3.9±2.9	0.14±.09		--
1654	26-30 30-34	1.49	1.1±2.9	<0.06		--
1655	34-38	1.43	1.6±2.9	.05		--
1656	38-41	1.38	9.5±1.4	0.14±0.09		--

TABLE 9

LAKE ONTARIO PLANKTON 1975

RADIONUCLIDES IN DPM/KG WET MATERIAL

M#	Station	Wet Wt. kg	Dry Wt. kg	^{137}Cs	^{239}Pu	^{241}Am	$^{238}Pu/^{239}Pu$
1668	75-3	0.1171	0.0005	18.8±1.5	<0.04		--
1669	75-7	0.2776	0.0082	1.0±0.7	being recounted		--
1670	75-8	0.1417	0.0032	5.2±1.2	0.12±0.04		--
1671	75-11	0.2686	0.0095	1.3±0.8	0.05±0.01		--

TABLE 10

Cs^{137} to $Pu^{239+240}$ Ratio in Sediment Cores of western Lake Ontario and Lake Erie

Depth in Core-Cm	LAKE ERIE 75-1	LAKE ONTARIO 72-4	72-5	73-1	73-5	73-6	74-1	74-4	75-5
0-1	80	29*	36*	45*	60*	84	57*	92	101
1-2	NA		39 46		(4.9)	96	NA	93	
2-3	63	34	60 71	56	46	100	37	59*	NA
3-4	NA	32	68	95	49	93	NA	53	109
4-5	49*	30	34	72	NA	95	-	50	NA
5-6	NA	110	75	43	50	86	NA	45	94
6-7	38	57	39	-	42	81	-	35	NA
7-8	NA	-	28	39	40	72	NA	33	67*
8-9	39	-	-	-	53	60	-		NA
9-10	NA	33	-	-	53	62	NA	44	NA
10-11	54	-	-	-	-	57*	-		51
11-12	NA	-	-	-	-	-	NA	45	
12-13	NA	-	-	-	-	57			NA
13-14	NA	-	-	-	-			30	NA
14-15	NA	-	-	-	-	61			36
15-16		-	-	-	-			35	
16-18		-	-	-	-	49			
17-18		-	-	-	-			150	NA
18-19		-	-	-	-	36	-		23
19-20		-	-						
20-22						36			
22-24						36			
24-26						38			
26-28						52			
28-30						51			
30-32						14			

* = Indicates depth of the highest Cs^{137} concentration.

NA = NOT YET ANALYZED.

\- = Cs^{137} or $Pu^{239+240}$ Concentration too low for significant ratio.

TABLE 11

Deep-water Cores from eastern Basin of Lake Ontario
Cs^{137*} and $Pu^{239,240*}$ Profiles

Depth in Sediment (cm)	Core 71-5 215m		Core 73-13A 250m		Core 73-13B 245m	
	Cs-137	Pu-239	Cs-137	Pu-239	Cs-137	Pu-239
0 - 1	1033±8	27.6±1.4	10,400±50	338±18	9796±31	307.3±12.7
1 - 2	945±7	40.9±3.7	6,240±30	186± 4	2061±14	59.6± 5.5
2 - 3			2,290±20	80± 2	1672±10	60.9± 4.8
3 - 4	1402±10	48.2±2.2	4,560±50	131± 3	1054±14	25.3± 5.1
4 - 5	2377±43	49.8±5.6			959± 9	33.8± 1.9
5 - 6	994± 9	37.8±2.3			769± 9	24.0± 1.5
6 - 7	490±30	28.2±2.3			380± 9	13.1± 1.4
7 - 8	640±20	20.4±1.9			238± 9	6.5± 0.8
8 - 9	268±10	9.0±1.2			612± 9	17.6± 1.6
9 - 10	139±5	4.6±0.6			245± 9	8.4± 0.8
10 - 12	211±8	7.5±2			96± 5	4.6± 0.6
12 - 14	442±8	11.5±1.5			35± 5	1.2± 0.3
14 - 16	967±10	10.9±5			8± 5	0.4± 0.1
16 - 18	lost	lost			4± 5	0.3± 0.2
18 - 20	1350±20	36.6±4			0± 4	0.1± 0.1
20 - 22	517±5	16.2±1.3			18± 4	0.2± 0.1
22 - 24	764±5	21.5±1.6			4± 5	<0.1
24 - 26	704±6	23 ±1.6			4± 4	0.3± 0.1
26 - 28	560±4	15 ±1.7			7± 5	<0.3
28 - 30	693±4	22 ±1.8			3± 5	0.2± 0.1
30 - 32	509±4	11 ±1.6			4± 3	0.9± 0.2
32 - 34					3± 5	0.1± 0.1
34 - 36	364±5	8.2±1.1			0± 4	0.2± 0.1
36 - 38					2± 4	<0.1
38 - 40					-1± 4	<0.1
40 - 42					-2± 5	0.4± 0.2
42 - 44					-1± 3	<0.1
44 - 46					2± 3	<0.1
46 - 48					3± 4	<0.1
48 - 50					4± 5	0.5± 0.1
50 - 54					-2± 4	0.1± 0.1
54 - 58					-4± 4	<0.1
58 - 62					3± 3	<0.1
62 - 66					-1± 4	0.4± 0.2
66 - 70					-1± 4	0.2± 0.1
70 - 74					1± 4	0.2± 0.1
74 - 78					0± 7	0.4± 0.2
78 - 82					16± 4	0.9± 0.3

* Concentrations in dpm per Kg dry sediment

TABLE 12

R. V. OCEANUS, cruise 1, cores from the St. Lawrence Estuary and Gulf.
Nuclide values in dpm per 100 kg dry sediment.

Depth in Core-cm	CORE 11		CORE 13		CORE 14	
	Cs137	Pu239,240*	Cs137	Pu239,240	Cs137	Pu239,240
0-1	388±7	143	366±4	80.4±6	499±6	143±9
2-3	189±4	54.6	175±4	31.4±1.9	524±6	97±8.5
4-5	232±4	68.9	66.4±3.7	10.9±1	352±5	61±3.3
6-7	123±3	48.5	43.1±3.9	9.7±0.9	158±3	36±3.1
8-9	99.5±3.4	33.2	8.9±3.9	6.1±1.3?	163±3	34±2
10-12	35.3±2.8	10.5	2±3	1 ±0.4	193±3	43±2.8
14-16	19±2	0.1	0±3	1.3±0.4	25±3	5±0.6 [3]
18-20	21±2	0.3 [1]	1±2	0.2±0.2		
22-24			1±3	<0.3 [2]		
	Pu238/239,240	Am241/Pu239,240	Pu238/239,240	Am241/Pu239,240	Pu238/239,240	Am241/Pu239
0-1	0.037		0.047	0.39	0.043	0.18
2-3	0.038		0.041	0.36	0.058	lost
4-5	0.051		0.046	0.40	0.026	0.44
6-7	0.015		-	0.33	0.023	0.40
8-9	0.022		-	?	?	0.27
10-12	0.03		-		0.034	0.28
14-16	-		-		-	0.56
18-20	-		-			
22-24			-			

Notes: * = Preliminary data only.
1 = Core length 22 cm; See Figure 4 for Position; Water depth 215m.
2 = Core length 47 cm; See Figure 5 for Position; Water depth 390m.
3 = Core length 20 cm; See Figure 5 for Position; Water depth 132m.

Figure 1

C. A. DAMBACH cruise July 1975

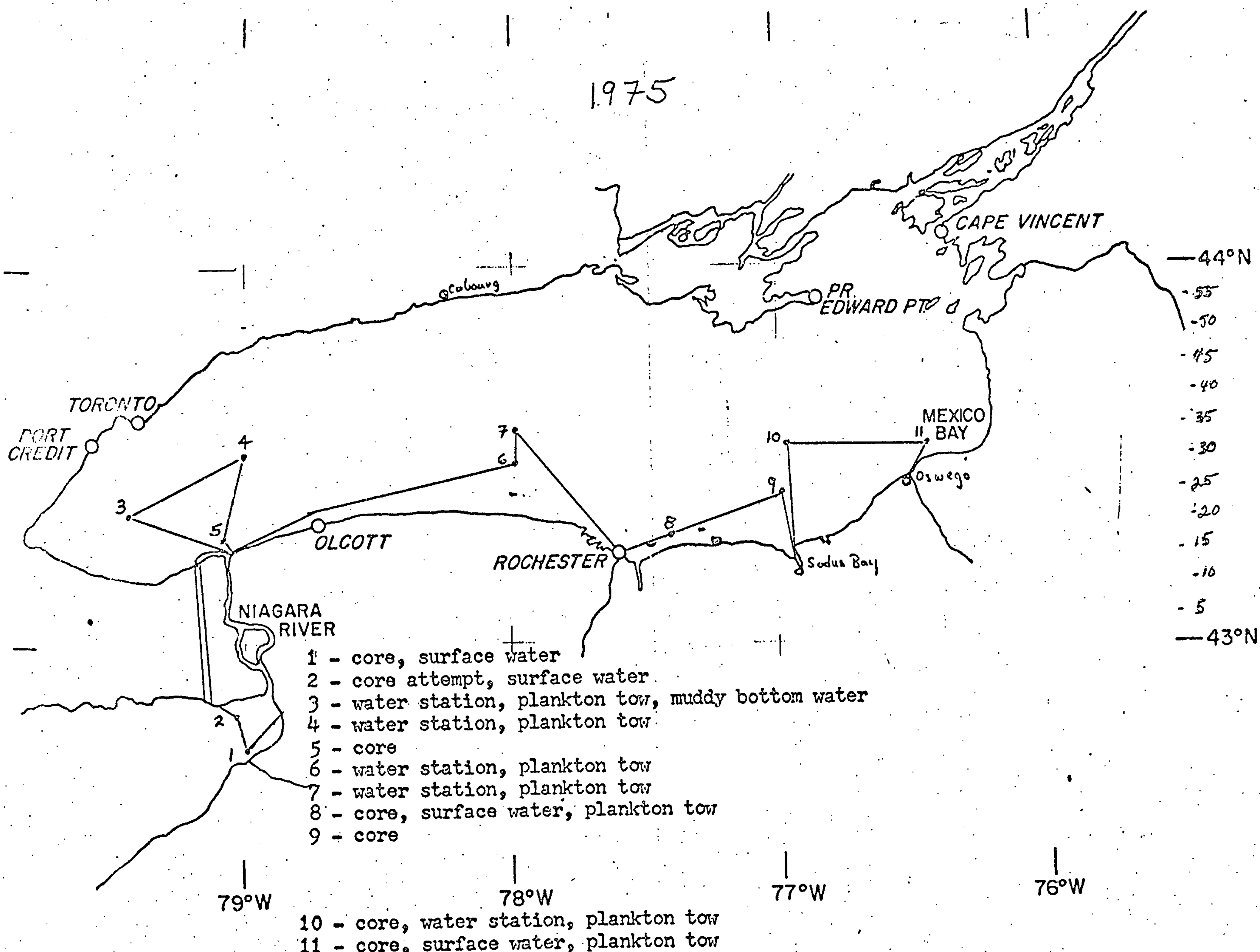
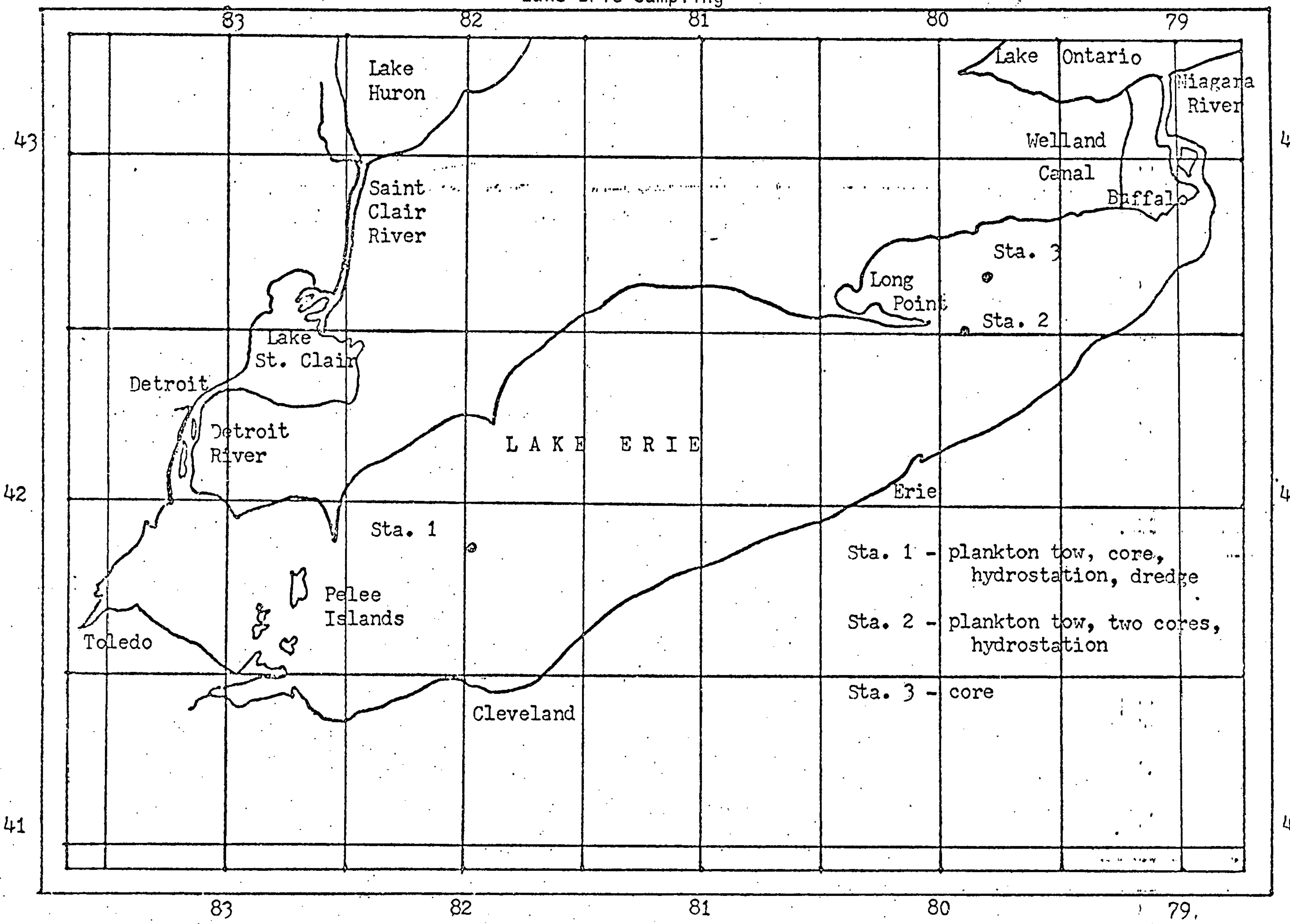


Figure 2

R. V. OCEANUS, cruise 1, October-November 1975

Lake Erie Sampling



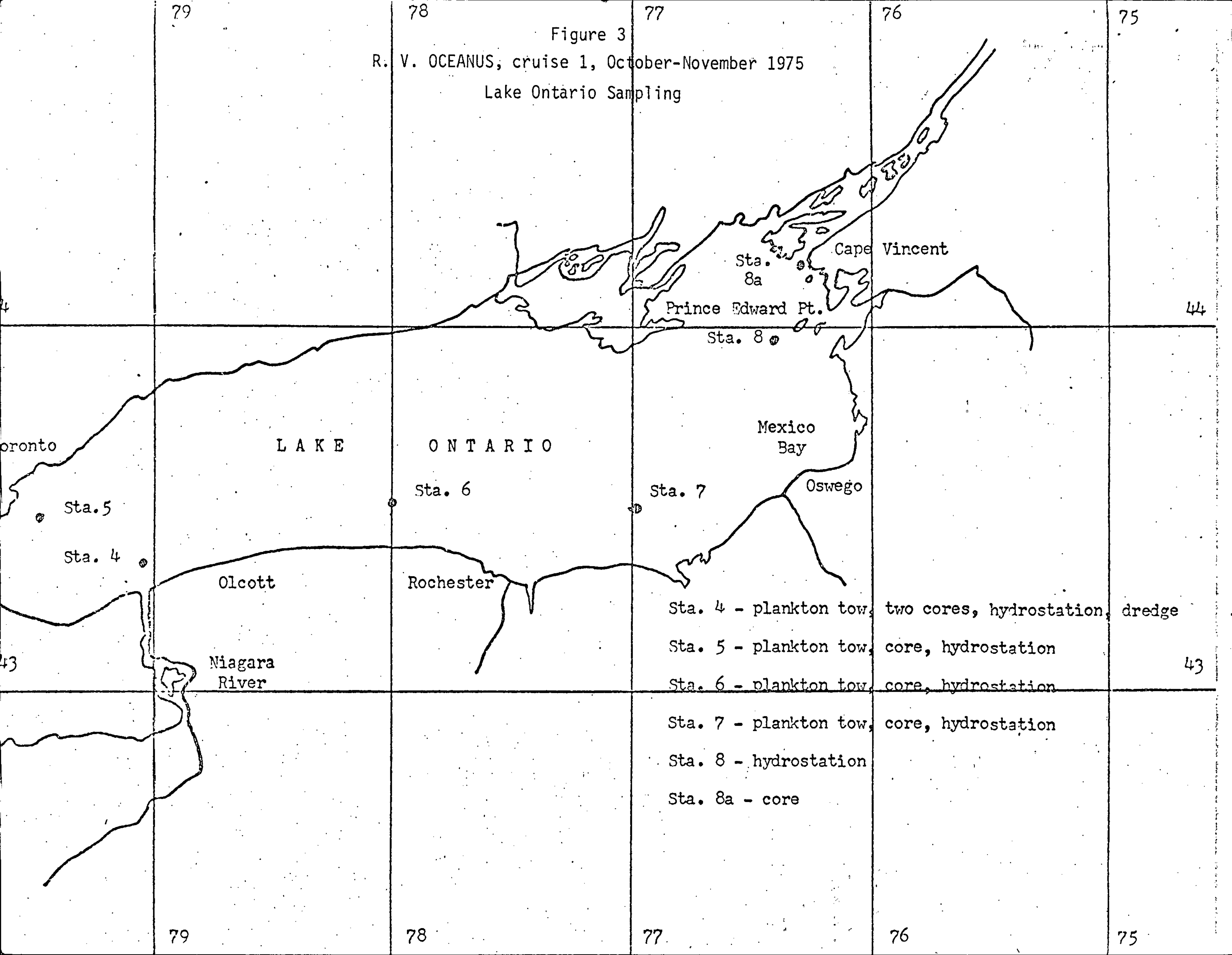


Figure 3

R. V. OCEANUS, cruise 1, October-November 1975

Lake Ontario Sampling

Sta. 4 - plankton tow, two cores, hydrostation, dredge

Sta. 5 - plankton tow, core, hydrostation

Sta. 6 - plankton tow, core, hydrostation

Sta. 7 - plankton tow, core, hydrostation

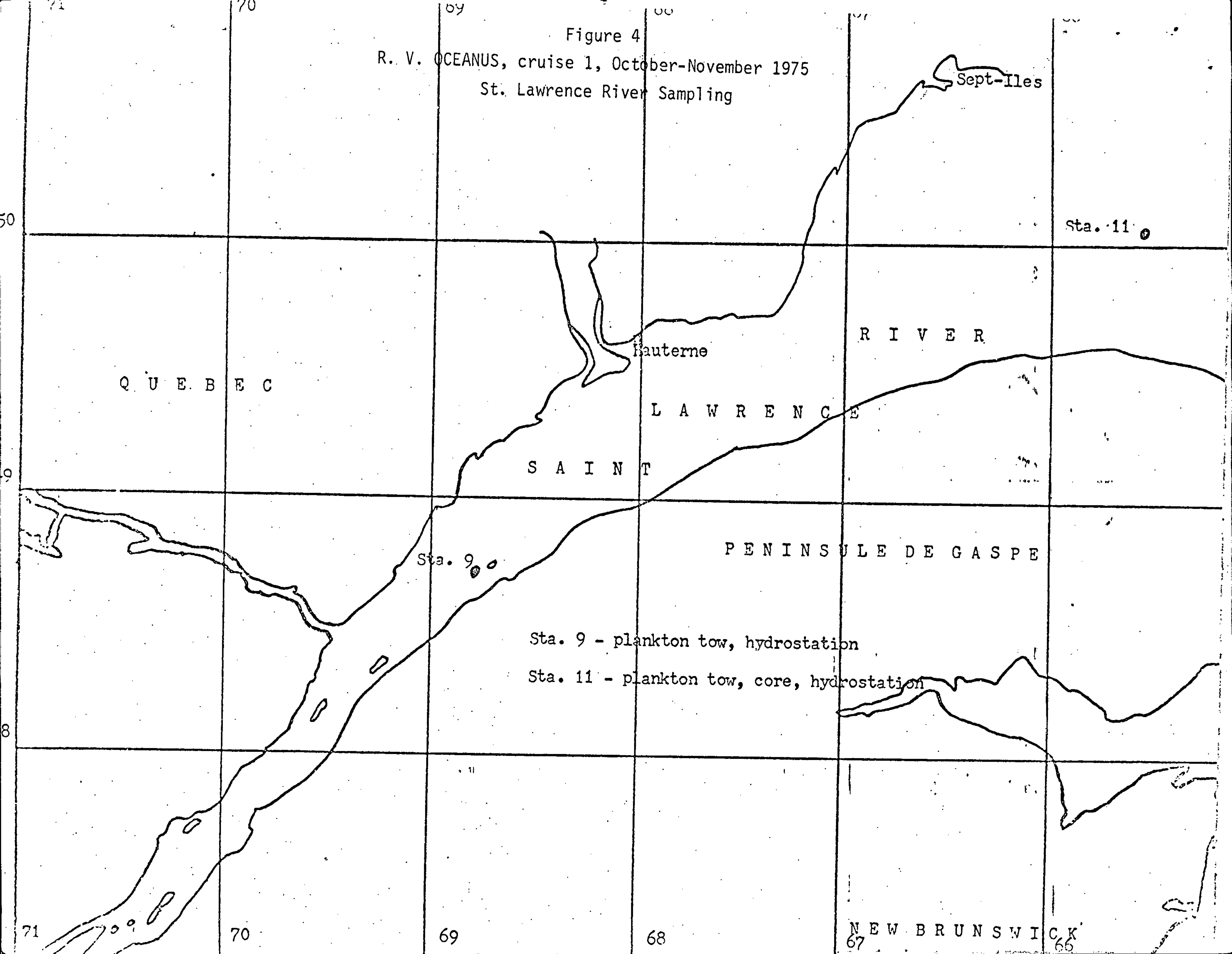
Sta. 8 - hydrostation

Sta. 8a - core

Figure 4

R. V. OCEANUS, cruise 1, October-November 1975

St. Lawrence River Sampling



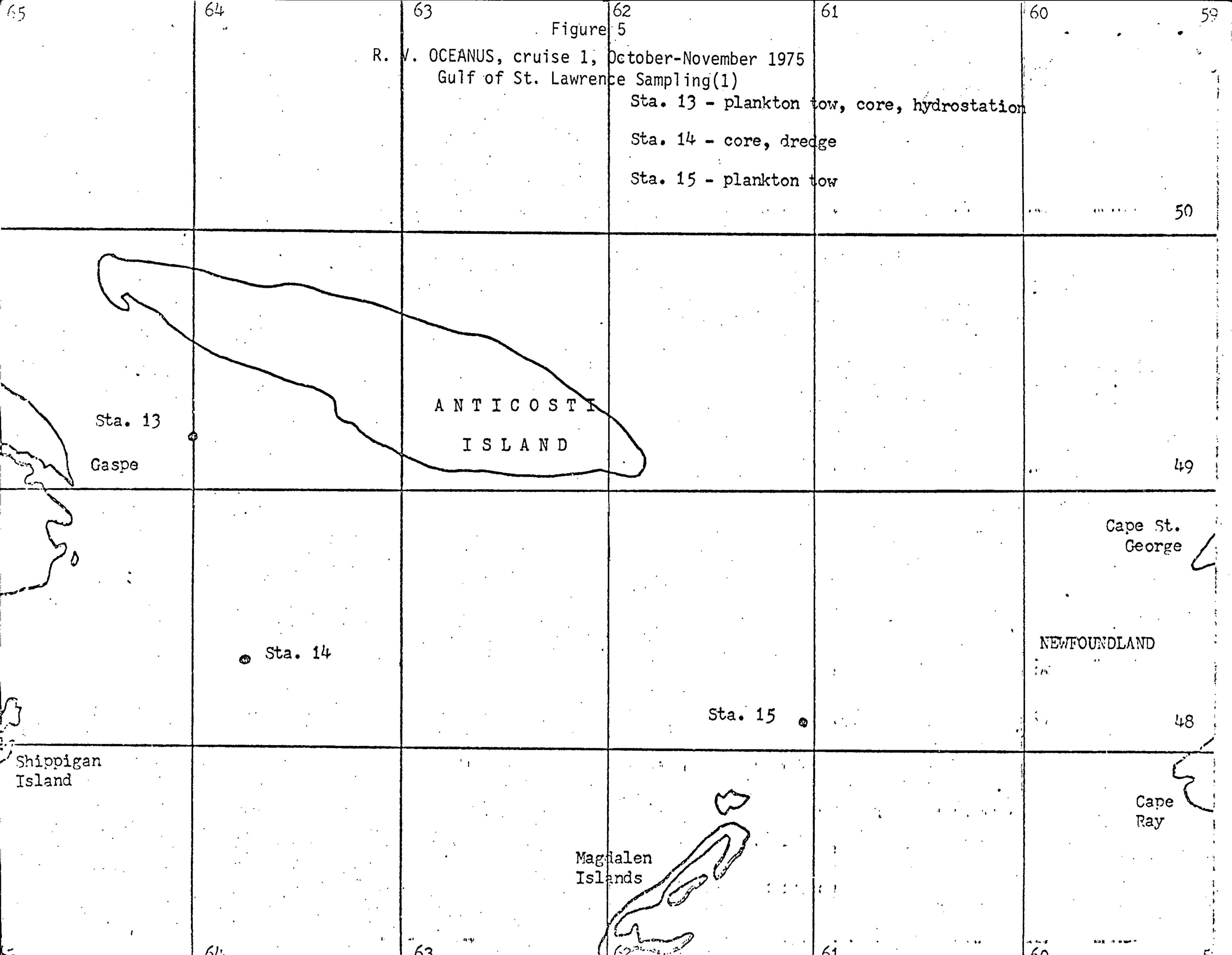


Figure 5

R. V. OCEANUS, cruise 1, October-November 1975

Gulf of St. Lawrence Sampling(1)

Sta. 13 - plankton tow, core, hydrostation

Sta. 14 - core, dredge

Sta. 15 - plankton tow

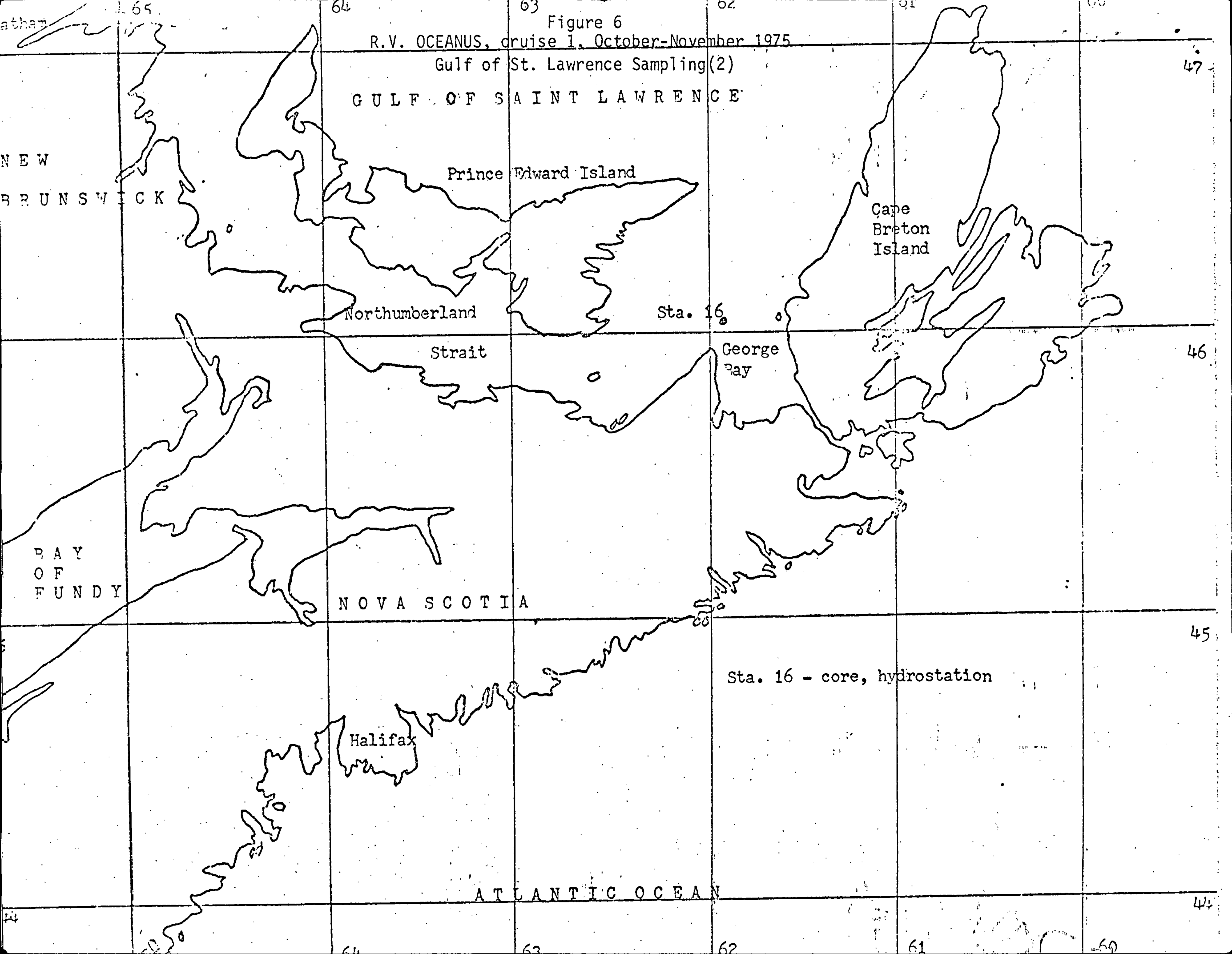


Figure 6
R.V. OCEANUS, cruise 1, October-November 1975
Gulf of St. Lawrence Sampling (2)

Figure 7

Short ping-length bathymetric profile of Lake Ontario; made on R.V. OCEANUS
Cruise 1, just west of Station 7

See Figure 3

Depth interval 10 fm, nominal