

The Niagara River Toxics Management Plan: An Approach to Measure and Communicate Progress

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INTRODUCTION

The contamination of the Niagara River by toxic substances and the impact of the river on Lake Ontario have been well documented (NRTC 1984; Allan *et al* 1983; Thomas *et al* 1988). To manage toxic substances in the river, Environment Canada, the U.S. Environmental Protection Agency Region II, the Ontario Ministry of the Environment and the New York State Department of Environmental Conservation signed a "Declaration of Intent" in February 1987. The objective of this Declaration is to achieve significant reductions of toxic contaminants in the Niagara River with a sub-objective of reducing the inputs of specific toxic "chemicals of concern" from point and non-point sources by 50% by 1996. Eighteen priority toxics have been identified for the Niagara River, ten of which, because they are deemed to have significant sources along the river, have been designated for 50% reduction (Table 1). The Niagara River Toxics Management Plan (NRTMP) is the program designed to achieve these objectives. An integral component of this plan is the upstream/downstream monitoring program established by Environment Canada (EC). Data from this program, along with those from point and non-point source programs were to be used in a mass-balance framework to determine if the 50% reduction goal had been achieved by 1996. Williams *et al* (1992) were the first to raise concerns that this approach would not be successful due to the incompatibility of data

among these programs. These concerns were subsequently confirmed in a report released as part of the NRTMP (NRTMP 1993). As a result, the Niagara River Coordinating Committee has recommended examining alternative ways to demonstrate progress.

The Ontario Ministry of Environment and Energy (MOEE) conducts a biomonitoring program on the Niagara River. Parts of this program have been operative since the mid-70s. Despite the fact that the program continues to produce valuable information relevant to the goals of the NRTMP, it is not currently a component of the NRTMP.

This paper presents our thoughts on how EC's upstream/downstream program and the MOEE's biomonitoring program can be used effectively as an approach to measure and communicate progress in meeting the goal of the Niagara River Declaration of Intent. It also provides some thoughts on a new, or perhaps revised, approach that could be considered in the NRTMP. In our opinion, this new approach would be more useful for determining the success of remedial actions in cleaning up the Niagara River.

THE UTILITY OF THE UPSTREAM/ DOWNSTREAM PROGRAM

Introduction

The upstream/downstream program measures the

inputs of both dissolved and suspended sediment-associated toxic chemicals to the Niagara River from Lake Erie and the loadings of these chemicals, from the river, to Lake Ontario. Weekly water and suspended sediment samples are collected at two permanent sampling stations located at the head (Fort Erie = FE) and mouth (Niagara-on-the-Lake = NOTL) of the Niagara River. The stations were chosen to be representative of water entering the river from the eastern basin of Lake Erie (Ad hoc Group on Physical Limnology and Hydraulics 1989) and the outflow from the Niagara River to Lake Ontario (Green 1988). Both stations are sampled continuously over a 24-hour period. Sampling times are offset by fifteen to eighteen hours to account for the travel time of water in the river.

The suspended sediment phase is analyzed for organochlorine pesticides (OCs), PCBs, chlorobenzenes (CBs), polynuclear aromatic hydrocarbons (PAHs), phthalates, phenols, 2,3,7,8-TCDD, trace metals, particulate organic carbon (POC) and particulate organic nitrogen (PON). The dissolved phase is analyzed for the same parameters excluding trace metals. Trace metals and phenols are also measured on whole water samples.

Details of sampling equipment and procedures are available elsewhere (NRSP 1988; NRDIG 1994). Analytical procedures are documented in Environment Canada (1979) and the Niagara River Analytical Protocol (NRAP 1987).

The suspended sediments are collected from a volume of about 8640 L of water. The data are considered to be a good estimate of the load in the Niagara River perhaps underestimated by an amount equivalent to the particulate recovery efficiency of the Westfalia centrifuge which is about 90-95% (Allan 1986).

Results and Discussion

Within the NRTMP framework, analysis of the upstream/downstream data is aimed at determining trends in loads at FE and NOTL and in the 'differential load' between these two stations. The differential load is obtained by subtracting the load

calculated for FE from that calculated for NOTL. The difference is taken as representative of additional loads entering from sources along the river. The calculation of loads and the determination of trends in loads presents several difficulties. For example, the concentrations for many of the chemicals are at, or below, method detection limits. This requires the application of specialized statistical analyses, such as the maximum likelihood estimate (MLE) method (El-Shaarawi 1989) to determine means, confidence intervals for means, and whether there is a significant difference between FE and NOTL loads.

Our approach here is much simpler. We have chosen to plot the concentration data over time, and to use all the data as reported by the laboratory, including data which were quantitated, but below the method detection limit (MDL). We have performed no statistical analyses on the data, and, therefore, imply no statistical inference in terms of trends. This is the reason why we have consciously chosen to use the word 'change' rather than 'trend'.

There is a quote from a well-known statistical text written about ten years ago by Chambers, Cleveland, Kleiner and Tukey, four reputed statisticians, which goes as follows: "There is no single statistical tool as powerful as a well chosen graph" (Chambers *et al* 1983). Or put more popularly "A picture is worth a thousand words". In short, our approach has been to let the data speak for themselves. The data we have used are those collected from April 1986 to the end of December 1993.

1. Measurement of Changes Over Time

The upstream/downstream program can measure changes in chemical concentrations over time in water and suspended sediments at NOTL and FE.

(i) Changes due to reductions in Niagara River Sources

Some of the changes in chemical concentrations observed at NOTL are due to reduction in loads from sources along the Niagara River. Figures 1

and 2 illustrate this using the concentrations of hexachlorobutadiene (HCB) and octachlorostyrene (OCS) on suspended sediments. OCS is one of the eighteen priority toxics. Neither of these chemicals are detected at FE, so we can be fairly certain that any changes in concentrations are due to changes in loads of these chemicals from Niagara River sources. Figure 1 shows the suspended sediment data for HCB at NOTL. The seasonality in the data is evident, with higher concentrations in summer and lower concentrations in winter probably due to sediment dilution. Storm-related sediment resuspension, shoreline erosion and ice scouring are all known to occur in Lake Erie during the winter (Kuntz and Warry 1983; Mudroch and Williams 1989). These contribute to increased suspended sediment concentrations in the river. Superimposed on this pattern are high concentration "spikes". These are due to inputs of HCB from sources along the river and the magnitude of the spikes suggests that the inputs are large. cursory analysis of the suspended sediment data indicates that these spikes are not correlated with changes in the particulate organic carbon content of the suspended sediments (i.e., possible changes in plankton biomass and the effects of bioconcentration/bioaccumulation) and do not correlate with rain events. Figure 1 also shows that the magnitude of these spikes has decreased over time and that, clearly, there is a difference *post-1990*. The explanation would seem to be better control of sources as evidenced by the reduction in the number of spikes, and a reduction in loads as evidenced by the change in the magnitude of the concentrations.

Figure 2 shows the suspended sediment data for OCS at NOTL. Measurement of OCS began in 1989. The results also show a decreasing pattern similar to that for HCB. The explanation for the observed decrease, therefore, is probably the same (i.e., better control of sources and reduced inputs). It can be noted that by 1993, OCS was detected in only a few samples.

Hexachlorobenzene (HCB), one of the ten chemicals designated for 50% reduction, is also a chemical which is detected at both FE and NOTL. We note that many of the concentrations reported

by the laboratory for FE, although quantified, are below the method detection limit (MDL) of 3.5 ng/g. Figure 3(a) shows the suspended sediment data for HCB at NOTL and Figure 3(b) shows the corresponding data for FE. The first point to note in these Figures is the difference in the magnitude of the concentrations between FE and NOTL. Concentrations of HCB at NOTL are from five to fifty fold (considering the peaks) higher than those observed at FE. This indicates that there are large inputs of HCB from sources along the river.

The concentrations of HCB at FE (Figure 3b) have changed very little over time, with the majority of the data being below 2 ng/g. There is some seasonality in the data, but it is sporadic and not as well defined as at NOTL. There are occasional spikes in the data. These may be due to bioconcentration/bioaccumulation of HCB by plankton, or, perhaps, to different types of sediment from Lake Erie entering the river (eg., nearshore sediments versus basin muds). Concentrations of organic chemicals in basin muds are usually higher than those in nearshore sediments. In general, the range of concentrations observed at FE agree reasonably well with those reported by Oliver and Bourbonniere (1985) for eastern basin Lake Erie bottom sediments [mean 2.7 ng/g; range 1.4 - 5.2 ng/g]. Indeed, it seems reasonable to suggest that the concentrations of HCB observed on FE suspended sediments are probably the result of resuspended bottom sediments making up the bulk of the suspended sediments being sampled at the FE station.

The pattern of HCB concentrations at FE can be contrasted to that observed at NOTL (Figure 3a). Clearly, the patterns at the two stations are very different. The change in HCB concentrations at NOTL, which is evident *post-1990*, is indicative of better control of sources and reduction of HCB inputs. The two high peaks in 1993 are inconsistent with the general decrease which is evident since early 1990. These may be due to an isolated episodic event at a point or non-point source (see Section 2). We shall have to wait for 1994 data to see if this is, indeed, the case.

(ii) Changes due to reduction in Lake Erie Inputs

The changes observed in the concentrations of some chemicals at NOTL are the direct result of changes that occur in Lake Erie inputs of these chemicals to the river. To illustrate this, we have chosen to look at the water (i.e., dissolved) concentrations of dieldrin. Dieldrin is also one of the eighteen priority toxics in the Niagara River. Figure 4(a) shows the water concentrations of dieldrin at NOTL while Figure 4(b) shows the corresponding data for FE. Comparison of these Figures indicates that the concentrations at both stations are very similar. Concentrations of dieldrin at FE appear to be decreasing. This decrease is also seen at NOTL. The inference is that dieldrin inputs to the Niagara River from Lake Erie are directly responsible for what is observed at NOTL. It is probable, therefore, that the effect of any additional inputs of dieldrin from Niagara River sources would be lost as noise in terms of the Lake Erie input. This raises the question of why dieldrin is listed as one of the eighteen priority toxics. Although further analysis of the data is required, we feel that a similar question could be raised with respect to DDT and its metabolites and, perhaps, chlordane. The differential load for the DDT metabolite, p,p'-DDE, has consistently been reported as negative (i.e., loads at FE higher than those at NOTL). Preliminary data from a recent study, which compares FE samples with those collected at the Buffalo Water Intake, suggest that the FE station is being influenced by an upstream source of DDT (Environment Canada, unpublished data). This has been previously suggested by Litten (1994). This means that the FE results might, therefore, be biased high compared to what would be considered as more representative concentrations of DDT and its metabolites entering the river from the eastern basin of Lake Erie.

2. Measurement of Continuing Episodic Chemical Inputs

The upstream/downstream program can measure sporadic changes in chemical concentrations in the

Niagara River which, we suspect, are related to episodic chemical loading events such as plant process upsets, spills and major leaks from hazardous waste sites. To illustrate this, we have chosen to look at mirex. Mirex only occurs at NOTL so, again, we can be fairly certain that any changes in concentration are due to changes in inputs from sources along the river. Mirex is also one of the chemicals designated for 50% reduction by 1996. It should be noted that the production of mirex by Hooker Chemical, now Occidental Chemical (OCC), ceased in 1976.

Figure 5 shows the suspended sediment data for mirex at NOTL. The pattern of the data is much different from that observed for the chemicals discussed above. In contrast to the time-distributions for the chemicals HCB, OCS and HCB, which are fairly continuous, the pattern for mirex is intermittent. Mirex inputs seem to have decreased between 1986 and 1989 as evidenced by the decreasing magnitude of the spike concentrations, and the decreased frequency of detection of mirex throughout the year. With the exception of 1991, however, the frequency of detection of mirex since 1989 has remained fairly constant. Clearly, something unusual happened in 1991 to cause the major peaks in that year. This can be corroborated by the data for hexachlorocyclopentadiene presented in Figure 6. Hexachlorocyclopentadiene has been detected only a few times since 1986. When it has been detected, it has been at very low concentrations. However, as Figure 6 shows, on July 18, 1991, hexachlorocyclopentadiene was detected in the Niagara River at a concentration exceeding 100 ng/g. This is the same date that the highest peak for mirex occurred in 1991.

Mirex is, what is known as, a hexachlorocyclopentadiene dimer (i.e., it was produced by combining two hexachlorocyclopentadiene molecules). Therefore, the occurrence of mirex and hexachlorocyclopentadiene together is not unexpected. The fact that the production of mirex ceased in 1976 suggests that we are probably looking at input from a waste site. Since OCC was the only company on the Niagara River which pro-

duced mirex, the waste site is likely associated with OCC. Mirex and hexachlorocyclopentadiene or hexachlorocyclopentadiene derivatives have been identified at two OCC sites (NRTC 1984) -- S-Area and Hyde Park. Finally, something would have to be happening at one of these sites to cause the episodic event which caused the simultaneous occurrence of the major peaks for these two chemicals. From EPA reports, we know that considerable remedial work was going on at the Hyde Park site at this time. Thus, a reasonable conclusion would be that the Hyde Park waste site is the source for this event. Unfortunately, the caged mussels deployed at Bloody Run Creek on two occasions in 1991, which would have provided additional information, disappeared on both occasions. Therefore, this conclusion is only speculative, at this time, pending further follow-up.

3. Limitations in Demonstrating Reductions for the Current 18 Priority Toxics

Having looked at some of the things that the upstream/downstream program can do in terms of reporting on the progress toward achieving the goals of the Niagara River Declaration of Intent, we thought we should also state what it will not be able to do. For this, we have focused, specifically, on the list of eighteen priority toxics (Table 1). The limitations with respect to these are listed below:

- Even with detection limits at the pg/g ($=10^{-12}$ g/g) level, dioxin has never been detected in either water or suspended sediment in this program; therefore, it will be impossible to report anything with respect to load reductions.
- Tetrachloroethylene (TCE) and PCB either are not detected, or are higher, at FE (i.e., they exhibit losses between FE and NOTL); therefore, no statement on load reductions will be possible. Most of the volatile chemicals, such as TCE, disappear from the river between FE and NOTL probably due to volatilization. Analysis for volatiles, therefore, was discontinued in 1993.

- Suspended sediment concentrations of DDT and metabolites and dieldrin are usually higher at FE than NOTL (i.e., they exhibit losses between FE and NOTL); therefore, no statement on load reductions will be possible.
- Benzo(b)- and benzo(k)fluoranthene cannot be distinguished from each other analytically; therefore, it will not be possible to report on them separately in terms of meeting the 50% reduction goal.
- Chrysene cannot be distinguished analytically from triphenylene; we are not certain at this time, whether this actually represents a problem in Niagara River samples (i.e., can triphenylene be expected to occur in the Niagara River); until this is resolved, however, it raises a question as to what the chrysene data really represent.
- Mercury is detected only sporadically since its concentration in the river is close to, or below, the detection limit; the loads, therefore, might only be due to analytical noise.
- Analysis of octachlorostyrene only began in 1989; therefore, there are no 1986 baseline data (which is the benchmark date for determining the 50% reductions); despite this, the data appear to show reductions in loads.
- Toxaphene has not been measured in this program due to lack of an appropriate analytical methodology.

This means that of the ten chemicals designated for 50% reduction by 1996, results from the upstream/downstream program cannot be used to report on reductions for five (benzo(b)-, benzo(k)fluoranthene, dioxin, mercury and tetrachloroethylene). With respect to the eight additional chemicals, there are no data for toxaphene, the data for chrysene may be questionable in terms of what it actually represents, and there may be problems with interpretation of the data for DDT and metabolites, dieldrin and chlordane. The upstream/downstream program, therefore, will be useful to report on, perhaps, only eight of the eighteen priority toxics.

THE UTILITY OF THE BIOMONITORING PROGRAM

Introduction

Contaminants are often present in water at concentrations below available, routine analytical method detection limits. However, these same contaminants, once taken up by aquatic organisms, may attain tissue levels which are readily measurable by routine analytical means. As a result, biological organisms can be useful surrogates for water analyses. Biomonitoring studies can indicate the presence of contaminants, their sources and the availability of the contaminant to the organism. Therefore, in the Niagara River, the biomonitoring program and the upstream/downstream program are both important, and complementary to each other. For example, as noted above, dioxin has never been detected in the river by the upstream/downstream program. The biomonitoring program, however, has confirmed its presence and has identified sources. Furthermore, the upstream/downstream program is rather like a black-box; it tells you what comes in from Lake Erie, what goes out into Lake Ontario, and whether there is a difference in these. It cannot, however, tell you what source along the river is responsible for this difference. The biomonitoring program can help do this, as illustrated by the results presented below.

MOEE has used several types of biomonitors in the Niagara River including (1) introduced caged mussels and leeches, (2) indigenous spottail shiners, (3) sportfish, and (4) *Cladophora* (a type of filamentous green algae). We have chosen to present examples of mussel and spottail shiner data.

Mussels (*Elliptio complanata*) can rapidly accumulate (within 2 to 4 days) detectable levels of organochlorine contaminants, such as PCBs (Kauss *et al* 1981). In the Niagara River, mussels are introduced in cages, which permits individuals with a similar physical, chemical and biological background to be exposed for a pre-selected period in a selected area. The exposure period in the river is three weeks. Sampling stations are

located on both the Canadian and American sides at several tributary mouths and adjacent to known municipal and industrial outfalls and hazardous waste sites. The program is designed to measure contamination from shore-based sources rather than ambient conditions. Details of sampling and analytical methods are available elsewhere (Richman 1992).

Young-of-the-year spottail shiners (*Notropis hudsonius*), due to their low mobility, are good indicators of contaminant sources and they offer a high degree of sample comparability because of similar fish age and lipid content. Fish collection sites are located on both sides of the Niagara River. The selection of sites is aimed at identifying inputs of contaminants from localized pollution sources and providing information on the transboundary migration of contaminants. Details of sampling and analytical methods are available elsewhere (Suns *et al* 1993).

In general, the data from both programs are consistent with each other despite differences in the life habits, exposure periods, physiology, lipid content and positions in the food web of the organisms. According to MOEE, the mussel data cannot be used for trend analysis; the spottail shiner data can.

Results and Discussion

Figure 7 shows the results for mussels placed at various sites in the Niagara for a three-week period in 1993. The difference in the presence of contaminants between the Canadian and American sides of the river is obvious. In our opinion, this Figure illustrates, very clearly, the cause for contamination of the Niagara River. Many of the contaminants have been consistently detected at these sites since 1987.

The significance of some of the sites in Figure 7 is as follows:

- Bloody Run Creek runs adjacent to Occidental Hyde Park and was historically severely contaminated by leachate from the landfill. This mussel site in the river, at the base of Bloody Run Creek, is influenced by

input from the creek and contaminated sediments.

- The Gill Creek site is influenced by the input from Gill Creek which traverses the Olin Corporation and DuPont Chemical waste sites.

- Occidental Sewer 003 is an outfall from the Occidental Chemical Corporation Main Plant (Buffalo Avenue, Niagara Falls). The sewer runs underground through the OCC main plant site and adjacent to S-Area before discharging to the river. The mussel site is adjacent to this discharge. Several other outfalls adjacent to OCC property are also monitored.

- The Pettit Flume, which is a mile-long concrete box culvert that acts as a municipal storm sewer and drains the Occidental Durez plant as well as urban run-off from North Tonawanda, is monitored by two mussel sites within the contaminated cove and one upstream and one downstream site outside the cove.

1. Source Identification and Comparison of Relative Contributions

The biomonitoring program can be used to compare, spatially, the relative contributions of contaminants to the river from individual point and non-point sources.

Figures 8-10 show the 1993 mussel data for HCB, PCB and 2,3,7,8-TCDD (dioxin), respectively. They show that PCB, HCB and dioxin are not detected at any of the Canadian sites. In contrast, on the U.S. side, these compounds are identified at all sites, with the concentrations varying at each site for each chemical. Thus, for HCB, the relative concentrations, beginning with the highest are Bloody Run Creek, Pettit Flume and 102nd Street hazardous waste site. Similarly for PCB, the order is the Occidental sewer 003 and the 102nd Street sites. Finally, for dioxin, Bloody Run Creek has, by far, the highest concentration.

Contaminants detected in mussels at these sites are consistent with the presence of these compounds in the waste sites or effluents from the in-

dustries.

Figures 11-13 show the spottail shiner data from 1986-1993 for OCS, mirex and dioxin, respectively. The significance of some of these sites is as follows:

- Wheatfield is downstream of the Gratwick-Riverside Park waste site and is influenced by the inputs from Niagara County Refuse Disposal site.

- The 102nd Street site, located in the river at the 102nd Street waste site, is affected by runoff from five different waste sites, including the Love Canal.

- The Cayuga Creek site, located at the confluence of the Little River and Cayuga Creek, is directly affected by Love Canal.

- The Search and Rescue site is immediately downstream of Gill Creek.

- The Queenston and Lewiston sites are located downstream of the Canadian and U.S. power plant discharges, respectively.

- Peggy's Eddy, N.Y. is located immediately downstream of the S.C.A. discharge.

OCS occurs in spottails at a number of U.S. sites. The highest concentrations observed over this period were at the Search and Rescue station just downstream of Gill Creek. The highest concentrations of mirex occurred in the lower Niagara River; however, sources of this chemical have also been identified at the 102nd Street and Cayuga Creek sites. Dioxin has been detected at only the Cayuga Creek site.

The Queenston site on the Canadian side of the river, perhaps, deserves some explanation as to why chemicals (mirex, OCS) normally associated with U.S. sources occur at this site. We suspect that this may be due to inputs via the Robert Moses power plant discharge (or, perhaps, Hyde Park leachate), being well mixed in the turbulence caused by the discharges from the Robert Moses and Sir Adam Beck plants and crossing to the Canadian side of the river. The Power Authority of the State of New York (PASNY) conduits, which collect water from the river upstream of the Falls and deliver it directly to the Robert Moses power

plant, probably collect the inputs from sources upstream of the Falls and discharge them in the lower river. High concentrations of mirex, HCB and PCB have also been found in the bottom sediments at this location (Kauss 1983), which seems to corroborate our suspicion.

2. Assess Success of Remediation Activities

The biomonitoring program can assess the success of remediation activities at existing waste sites. Once the sites have been remediated, the organisms can indicate if the sites are still leaching contaminants to the Niagara River. We have chosen to illustrate this by looking at the mussel data for PCB collected since 1986 at Gill Creek (Figure 14). Two points of explanation about the Figure are warranted here. First, mussel collections on the river occur only every two years. Second, the data do not represent trends. They show, simply, the concentrations resulting from the three-week exposure period of the mussels in the river for that particular year. Notwithstanding this latter point, the concentrations of PCB measured in 1993 were the lowest recorded for the Gill Creek site over the period of record. The mean value was below the Canada/U.S. Great Lakes Water Quality Agreement guideline of 100 ng/g in fish tissue, for the protection of animals and fish eating-birds. Although this guideline is not directly applicable in this case, it does provide an indication of the significance of the mean concentration found at Gill Creek.

Gill Creek sediments were known to be highly contaminated with PCB. Clean-up of the creek began in June 1992 and was completed in December 1992. Remediation resulted in the removal of 7,680 yds³ of sediment. The measurements in 1993 may be a reflection of the impact of this clean-up. We have no explanation, at this time, for the exceedingly high concentrations measured in 1991.

3. Long-Term Trend Analysis

The spottail shiner program, in particular, can be used for long-term trend analysis of contaminants

at various site specific locations in the Niagara River. We have chosen to illustrate this with the data for PCB and mirex collected at NOTL since 1975. Figure 15 shows the spottail shiner data for PCB. In general, the data show that there has been a substantial decrease in PCB concentrations compared to those observed in the mid-70s. The nature of the changes since the mid-80s, however, is not as clear. Figure 16 shows the data for mirex. The data show the same sporadic occurrence of mirex in spottails as in suspended sediments. The sources of mirex identified by the spottail shiner data have been consistent with the data from caged mussels. While there appears to have been some decrease since the 70s, the changes since the mid-80s are more difficult to interpret due to fluctuations in the data.

A PROPOSED NEW APPROACH

1. The major source of loads to the Niagara river for some of the eighteen priority toxics is Lake Erie. We have illustrated this using the water concentrations of dieldrin and have suggested that a similar situation may apply for DDT and its metabolites and chlordane. We suggested that for these chemicals, any additional loads to the Niagara River from sources along the river would probably be lost in the noise of the data. More importantly, reductions in the loads of these chemicals from Niagara River sources probably would have negligible impact on improving conditions in the river, or in Lake Ontario. This is not to suggest that controlling any additional loads is not important. However, it does raise the question of why these chemicals are on the list of priority toxics. More generally, we have some problems with how the eighteen came to be designated as priority toxics in the first place. In our opinion, it would be more meaningful to focus more closely on those chemicals that we know are being contributed specifically and significantly by Niagara River sources. This has been previously recommended by Williams *et al* (1992) who suggested an initial short list might be composed of those chemicals which only show up at NOTL (mirex, HCB, OCS and several chlorobenzenes). Fig-

ure 17 shows the total chlorobenzenes loading data for the period 86/87 to 92/93 for both NOTL and FE. The Figure demonstrates, clearly, that there are very large additional loads of chlorobenzenes being added from sources along the river. The advantages of this approach are that (1) it deals very directly with chemicals from sources which must be along the river, and (2) successes in dealing with the sources of these chemicals will also reduce inputs of other chemicals at these same sources.

2. Some interesting studies have been done to identify specific organic compounds migrating from specific waste sites on the American side of the Niagara River. Jaffe, Hites and co-workers have been able to identify, what we call, "marker" or "tracer" chemicals which are unique for specific sites. These marker chemicals can also be used for distinguishing inputs between sites. For example, using a group of compounds which apparently come from Love Canal, they were able to distinguish between inputs from Love Canal and the 102nd Street waste sites (Jaffe and Hites 1984). Likewise a group of fluorinated aromatic compounds were linked specifically with inputs from the Hyde Park waste site (Elder *et al* 1981; Jaffe and Hites 1986). These fluorinated compounds could be traced right into the sediments in Lake Ontario. We feel strongly that serious consideration should be given to including the use of marker chemicals as part of the NRTMP. The advantages of such an approach are (1) being able to chemically tag the inputs from a specific site, and (b) being able to comment effectively on the success of remedial actions at those sites. Perhaps, incorporating this approach into the NRTMP might even circumvent the need for determining reliable loads from these sites, which we feel, because of the uncertainties involved, is close to an impossible task.

3. To determine reliable estimates of loads from sources, improvements will be required in the point and non-point source components of the NRTMP. These include improved detection limits and improved frequency of monitoring.

4. The overall goal of the Niagara River Declaration of Intent is to achieve significant reduc-

tions of toxic contaminants in the Niagara River. In keeping with this goal, we feel that the NRTMP should not restrict its focus to just 18 priority toxics, but report on all toxics for which useful information is available.

5. Finally, this paper has demonstrated the importance and complementarity of the upstream/downstream program and the biomonitoring program. We feel that biomonitoring should become a component of the NRTMP. Furthermore, we feel that all other useful, available information, whether a current component of the NRTMP or not, should be used to help assess the effectiveness of remedial actions being taken in the Niagara River.

REFERENCES

- Ad hoc Group on Physical Limnology and Hydraulics. 1989. The Flow and Circulation Characteristics in Eastern Lake Erie and Upper Niagara River Area. Report to the River Monitoring Group of the NRTMP.
- Allan, R.J. 1986. The Role of Particulate Matter in the Fate of Contaminants in Aquatic Ecosystems. Scientific Series No 142. Inland Waters Directorate, Environment Canada.
- Allan, R.J., A. Mudroch and A. Sudar. 1983. An introduction to the Niagara River/Lake Ontario pollution problem. *J. Great Lakes Res.* 9:111-117.
- Chambers, J.M., W.S. Cleveland, B. Kleiner and P.A. Tukey. 1983. *Graphical Methods for Data Analysis*, Duxbury, Boston.
- Elder, V., B.L. Proctor and R.A. Hites. 1981. Organic compounds found near dump sites in Niagara Falls, New York. *Env. Sci. Technol.* 15:1237-1243.
- El-Shaarawi, A.H. 1989. Inference about the mean from censored water quality data. *Wat. Resour. Res.* 25(4):685-690.
- Environment Canada. 1979. *Analytical Methods Manual*. Water Quality Branch, Inland Waters Directorate, Ottawa, Ontario.
- Green, D. 1988. Determination of Contaminant Concentrations Across the Niagara River Using

- Automatic *in situ* Water Samples. DSS Contract No. 02SE-KW405-7-9195. Final Report, April 1988. Seastar Instruments Ltd., Dartmouth, Nova Scotia.
- Jaffe, R. and R. Hites. 1984. Environmental impact of two, adjacent, hazardous waste disposal sites in the Niagara River watershed. *J. Great Lakes Res.* 10(4):440-448.
- Jaffe, R. and R. Hites. 1986. Fate of hazardous waste derived organic compounds in Lake Ontario. *Env. Sci. Technol.* 20(3):267-274.
- Kauss, P.B., M. Griffiths and A. Melkic. 1981. Use of freshwater clams in monitoring trace contaminant source areas. *Proc. Technol. Transfer Conf. No. 2*, pp.371-378. November 24, 1991, Toronto, Ontario.
- Kauss, P.B. 1983. Studies of trace contaminants, nutrients, and bacteria levels in the Niagara River. *J. Great Lakes Res.* 9(2): 249-273.
- Kuntz, K.W. and N.D. Warry. 1983. Chlorinated organic contaminants in water and suspended sediments of the lower Niagara River. *J. Great Lakes Res.* 9(2): 241-248.
- Litten, S. 1994. Niagara River Cross Channel Homogeneity and Analysis of Upstream/Downstream Monitoring Data. New York State Department of Environmental Conservation, Albany, New York, 79p.
- Mudroch, A. and D.J. Williams. 1989. Suspended sediments and the distribution of bottom sediments in the Niagara River. *J. Great Lakes Res.* 15(3): 427-436.
- NRAP. 1987. Niagara River Analytical Protocol. Joint Report of Environment Canada, United States Protection Agency, New York State Department of Environmental Conservation and Ontario Ministry of the Environment.
- NRDIG. 1994. Joint Evaluation of the Upstream/Downstream Niagara River Monitoring Data 1991-1992. Niagara River Data Interpretation Group. Environment Canada, Ontario Ministry of the Environment, New York State Department of Environmental Conservation and the U.S. Environmental Protection Agency.
- NRSP. 1994. Niagara River Sampling Protocol. Joint Report of Environment Canada, United States Protection Agency, New York State Department of Environmental Conservation and Ontario Ministry of the Environment.
- NRTC. 1984. Report of the Niagara River Toxics Committee. Joint Report of Environment Canada, Ontario Ministry of the Environment, N.Y. State Department of Environmental Conservation and the U.S. Environmental Protection Agency.
- NRTMP. 1993. Progress Report on Reduction of Priority Toxics in the Niagara River. Niagara River *ad hoc* Workgroup Report, January 15, 1993.
- Oliver, B.G. and R.A. Bourbonniere. 1985. Chlorinated contaminants in surficial sediments of Lakes Huron, St. Clair and Erie: implications concerning sources along the St. Clair and Detroit River. *J. Great Lakes Res.* 11(3):366-372.
- Richman, L. 1992. The Niagara River Biomonitoring and Leech Study. Great Lake Section, Water Resources Branch, Ontario Ministry of the Environment.
- Suns, K., G.G. Hitchin and D. Toner. 1993. Spatial and temporal trends of organochlorine contaminants in spottail shiners in selected sites from the Great Lakes (1975-1990). *J. Great Lakes Res.* 19(4):703-714.
- Thomas, R.L., J.E. Gannon, J.H. Hartig, D.J. Williams and D.M. Whittle. 1988. Contaminants in Lake Ontario -- a case study. In N.W. Schmidtke [ed.] *Toxic Contamination in Large Lakes. Vol. III. Sources, Fate and Controls of Toxic Contaminants.* (pp.327-387). Lewis Publishers, Chelsea, Michigan.
- Williams, D.J., K.W. Kuntz and A.H. El-Shaarawi. 1992. The Niagara River, Lake Ontario and the Niagara River Toxics Management Plan (NRTMP), Environment Canada Report.

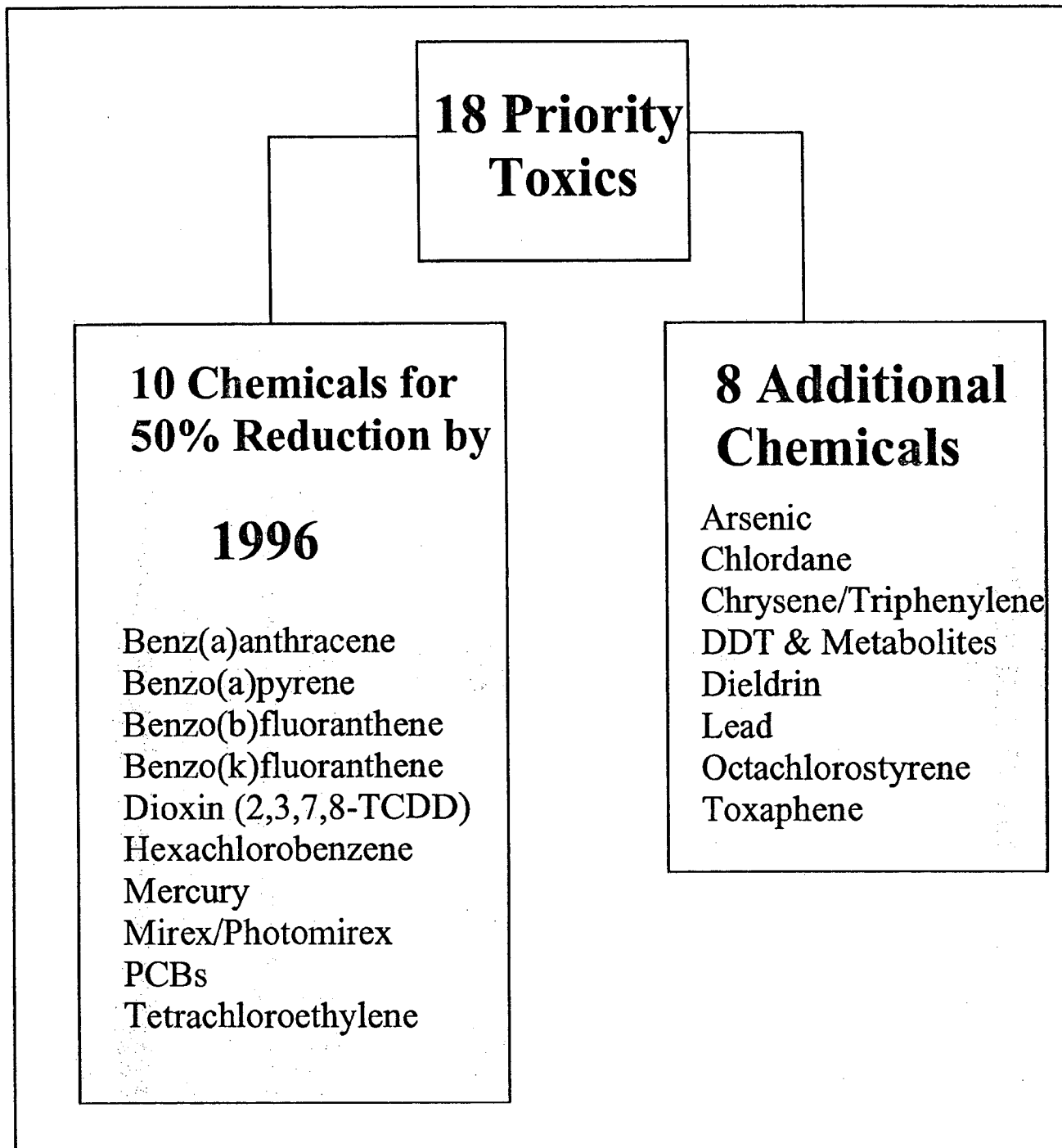


Table 1. Eighteen Priority Toxics for the NRTMP.

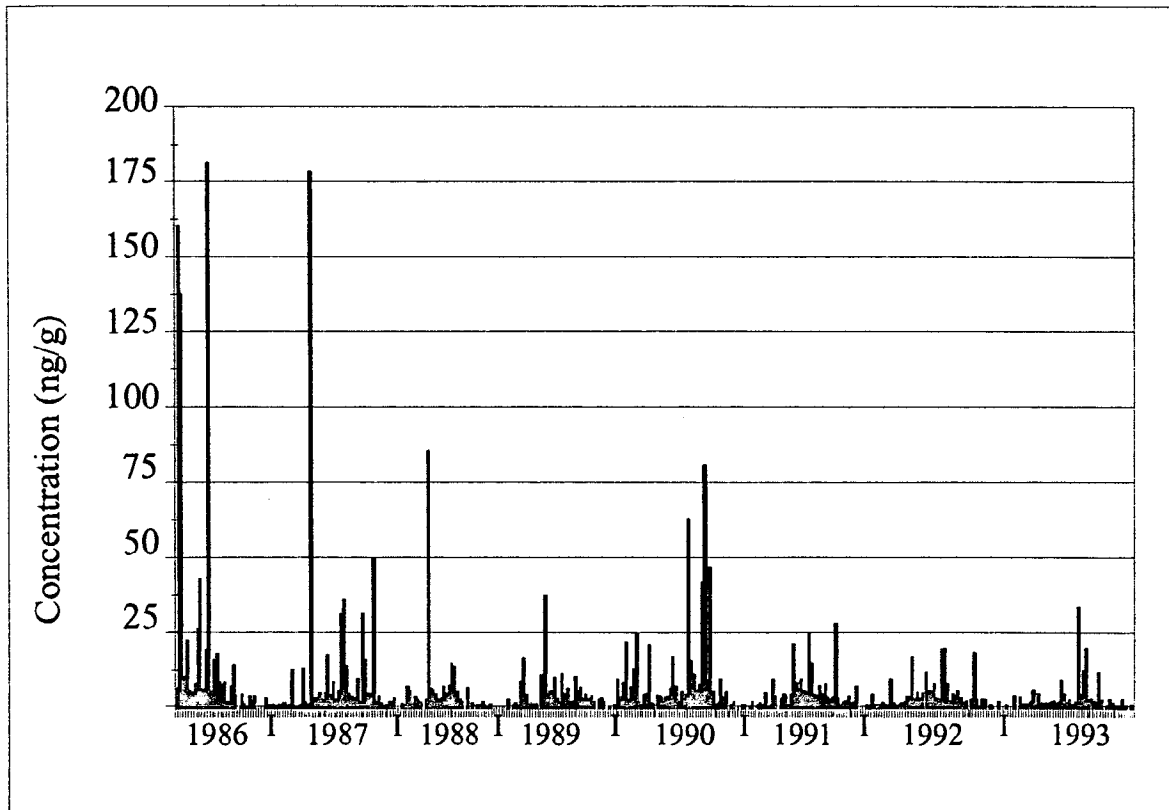


Figure 1. Concentration of Hexachlorobutadiene on Suspended Sediments at NOTL, 1986- 1993.

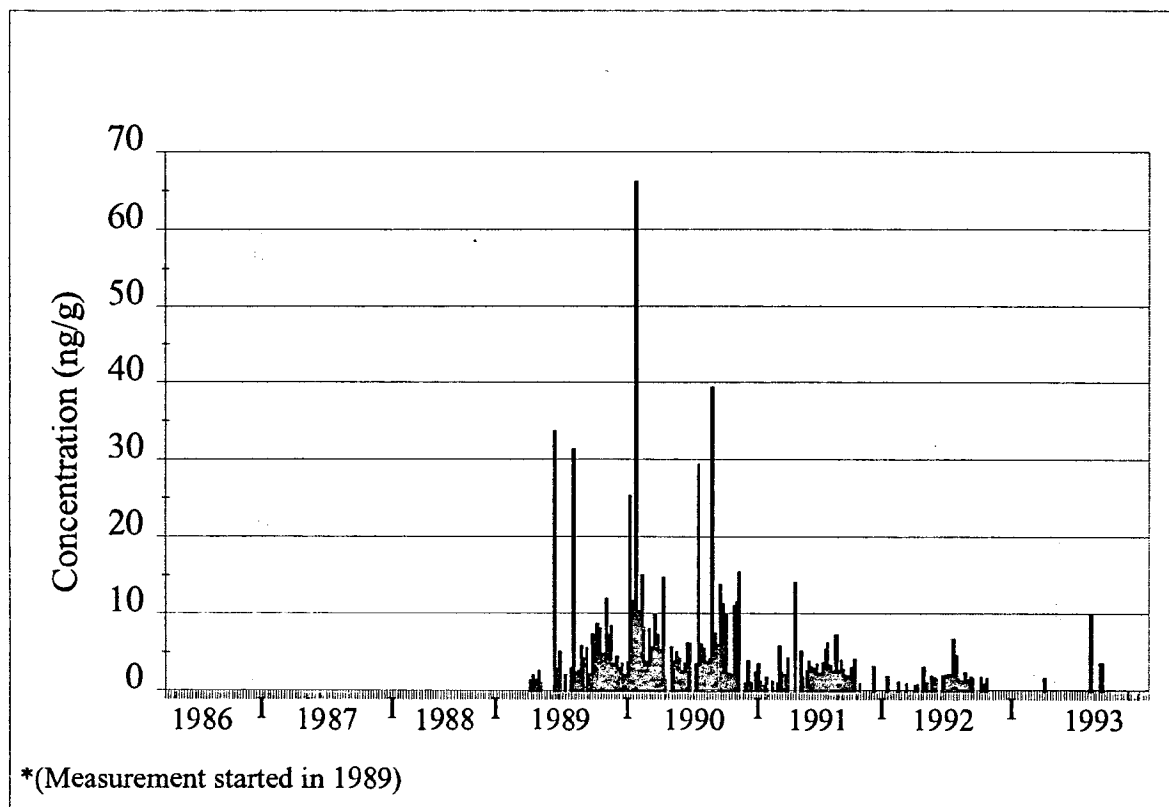


Figure 2. Concentration of Octachlorostyrene on Suspended Sediments at NOTL, 1986 -1993.

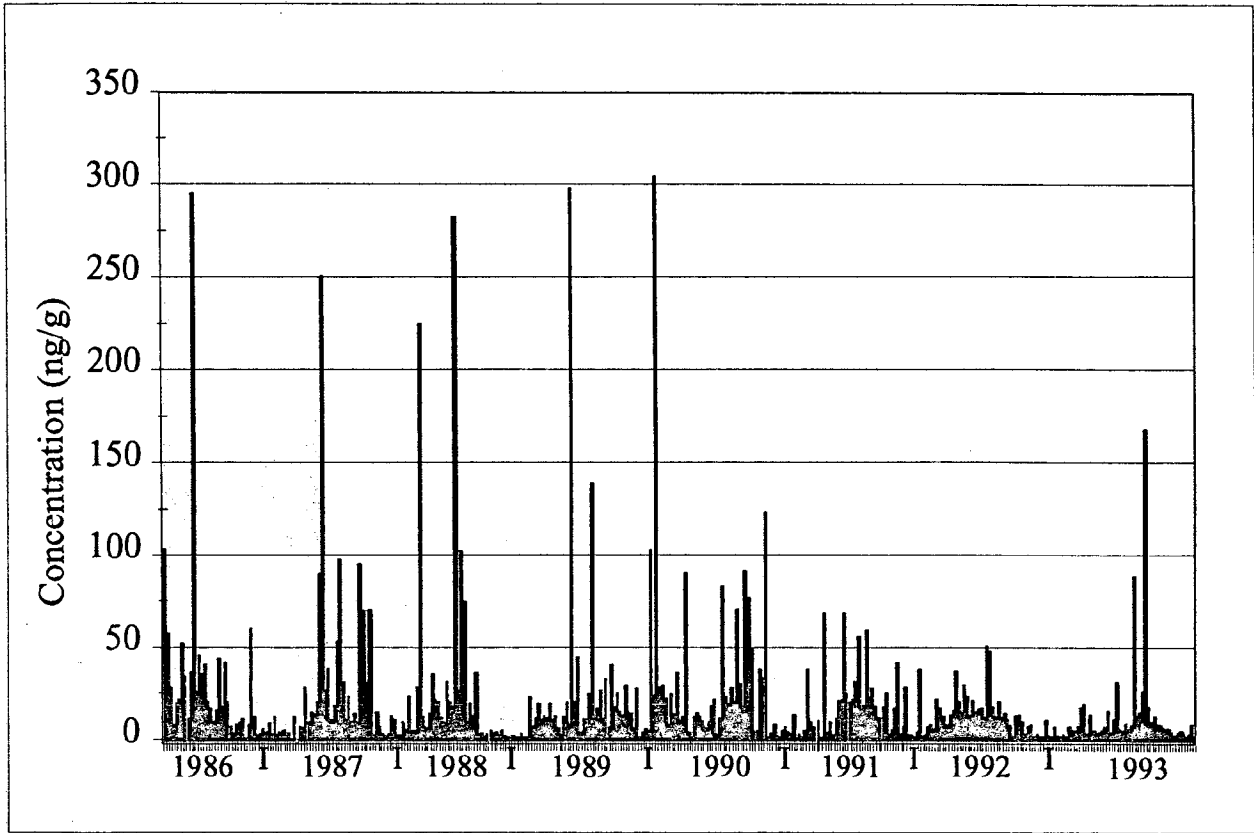


Figure 3a. Concentration of Hexachlorobenzene on Suspended Sediment at NOTL.

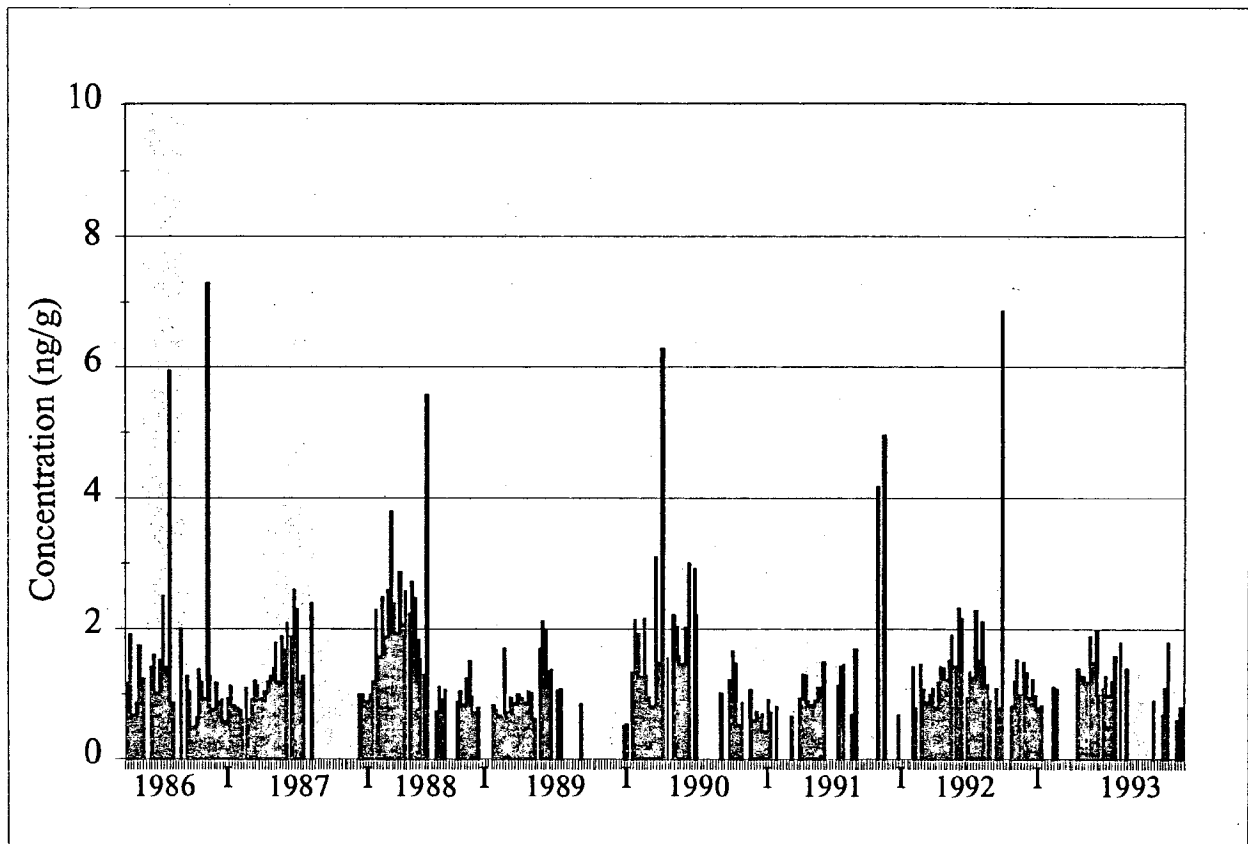


Figure 3b. Concentration of Hexachlorobenzene on Suspended Sediment at FE.

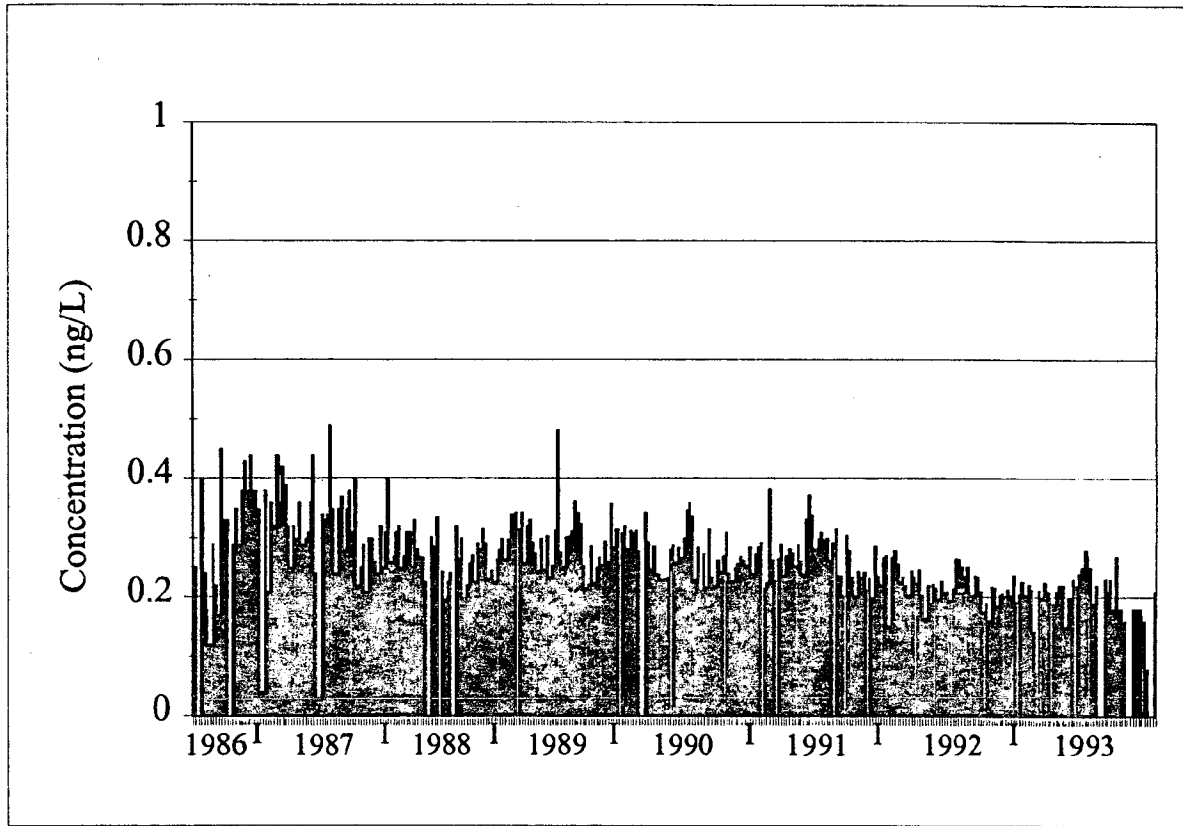


Figure 4a. Concentrations of Dieldrin in Water at NOTL, 1986 - 1993.

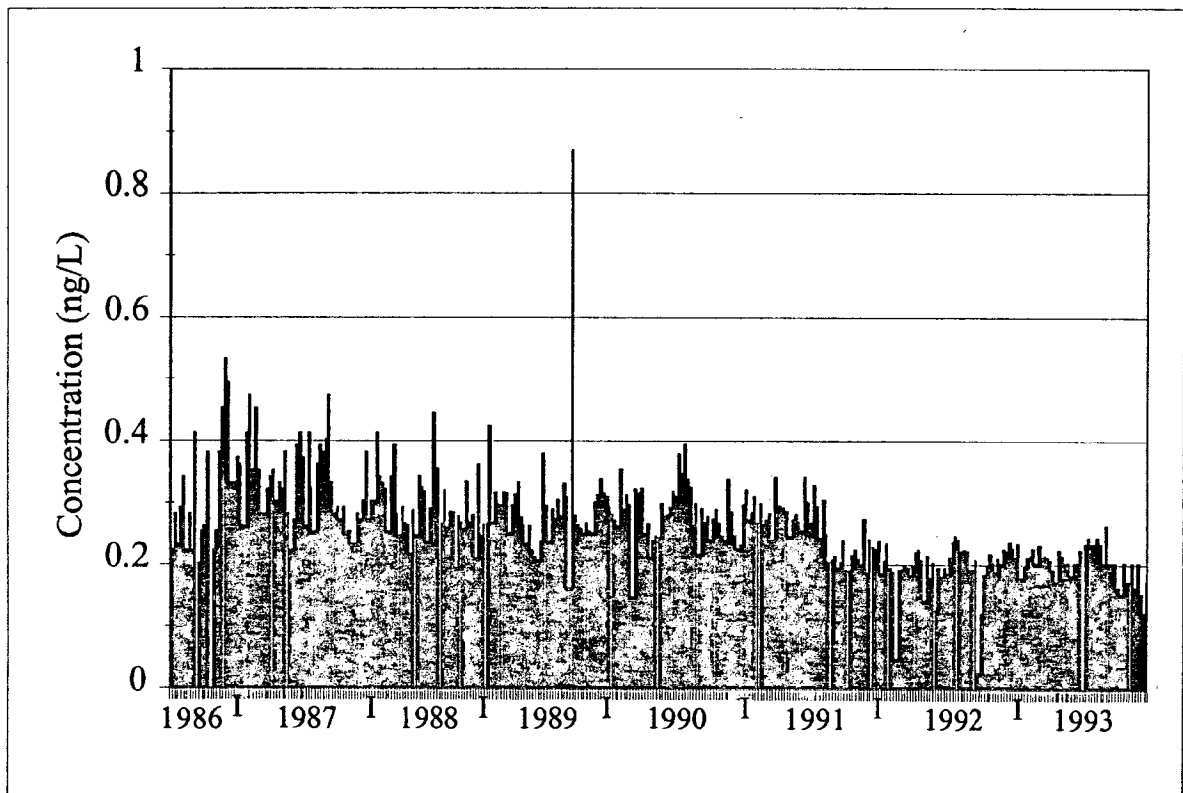


Figure 4b. Concentrations of Dieldrin in Water at FE, 1986 - 1993.

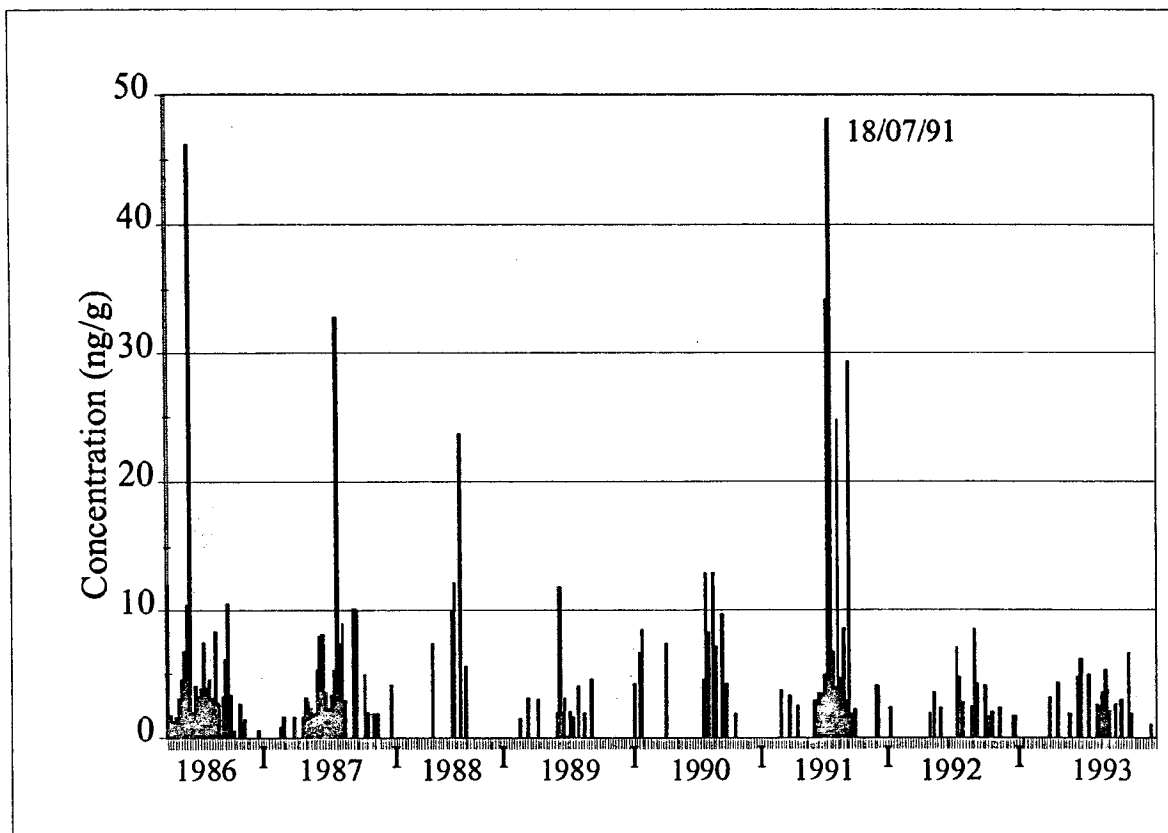


Figure 5. Concentration of Mirex on Suspended Sediment at NOTL, 1986 -1993.

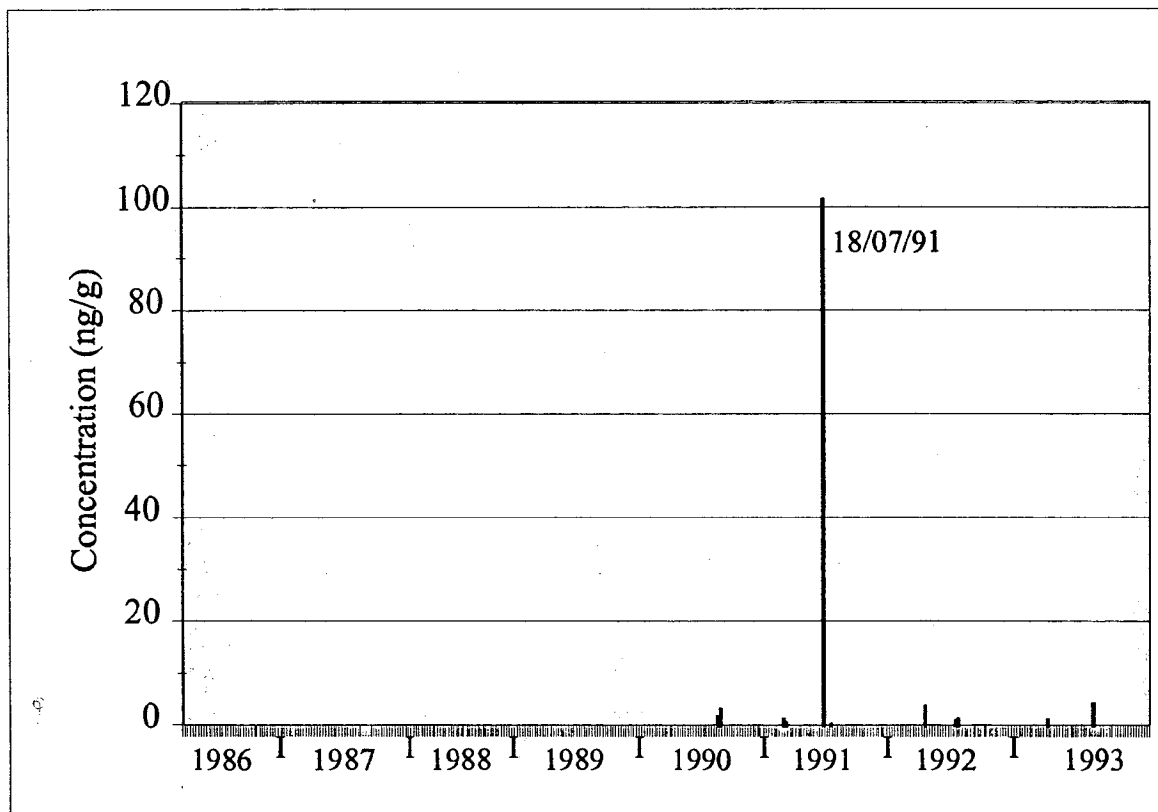


Figure 6. Concentration of Hexachlorocyclopentadiene on Suspended Sediment at NOTL, 1986 -1993.

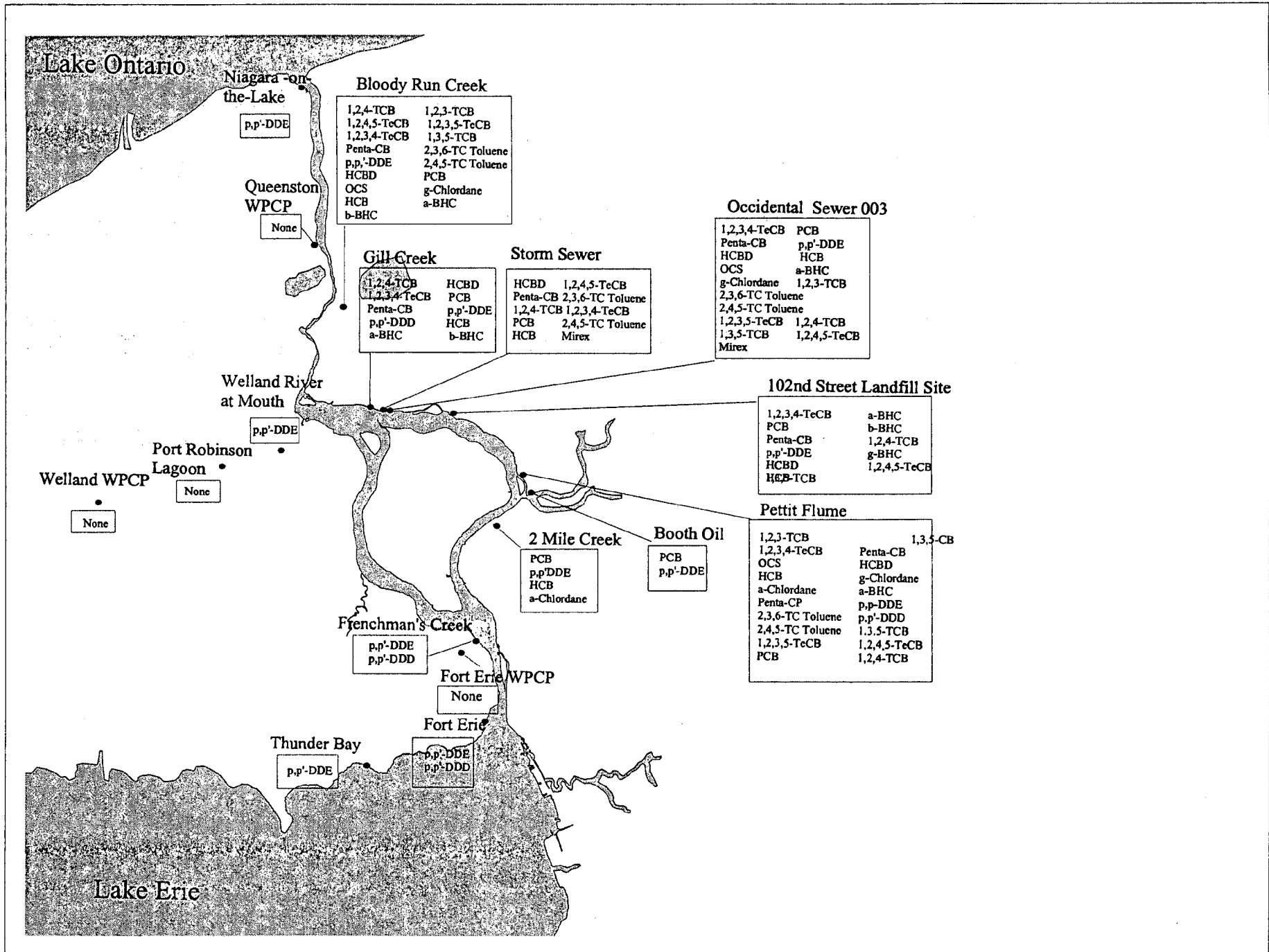


Figure 7. Contaminants detected in caged mussels introduced to the Niagara River for three weeks in 1993. Many of these contaminants have been consistently detected at these sites since 1987.

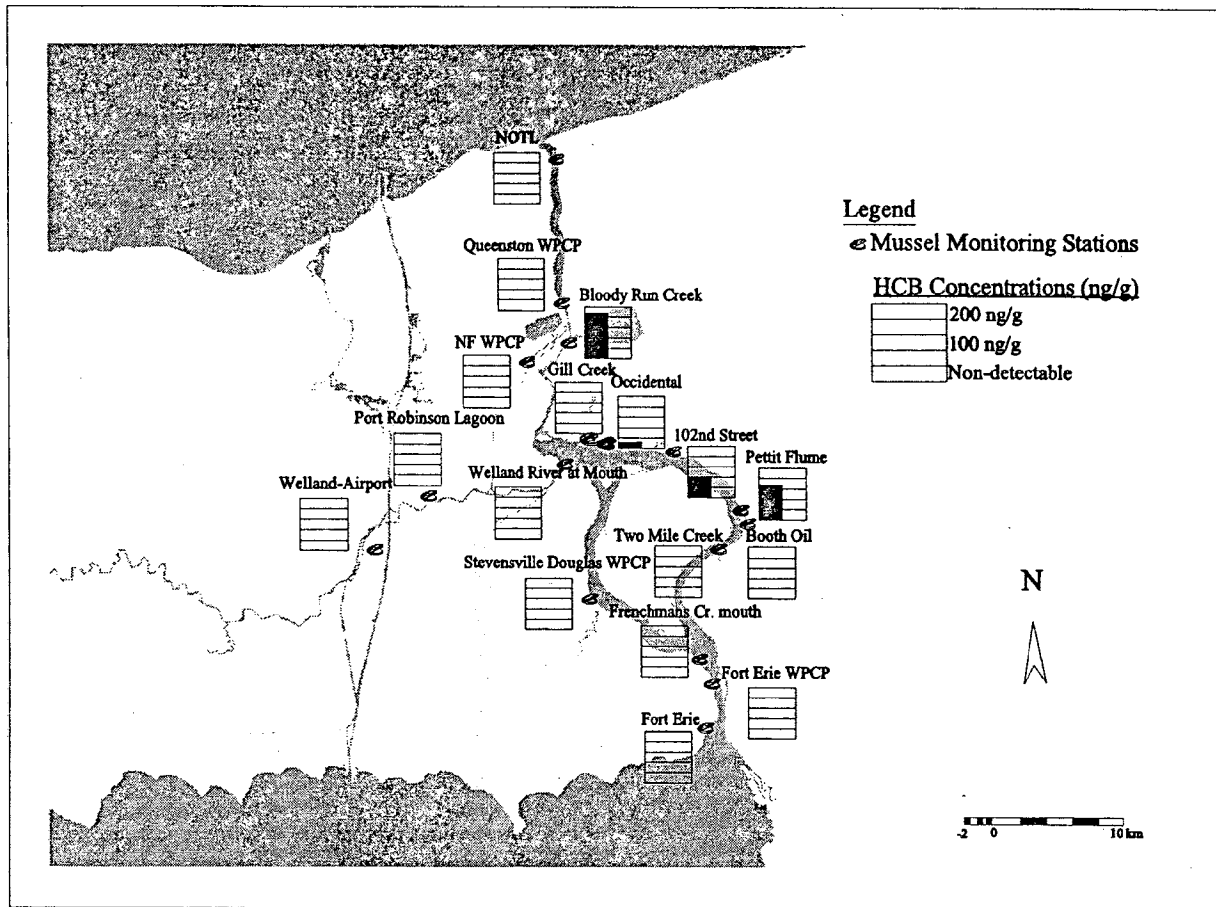


Figure 8. Hexachlorobenzene Concentrations in Mussels, 1993.

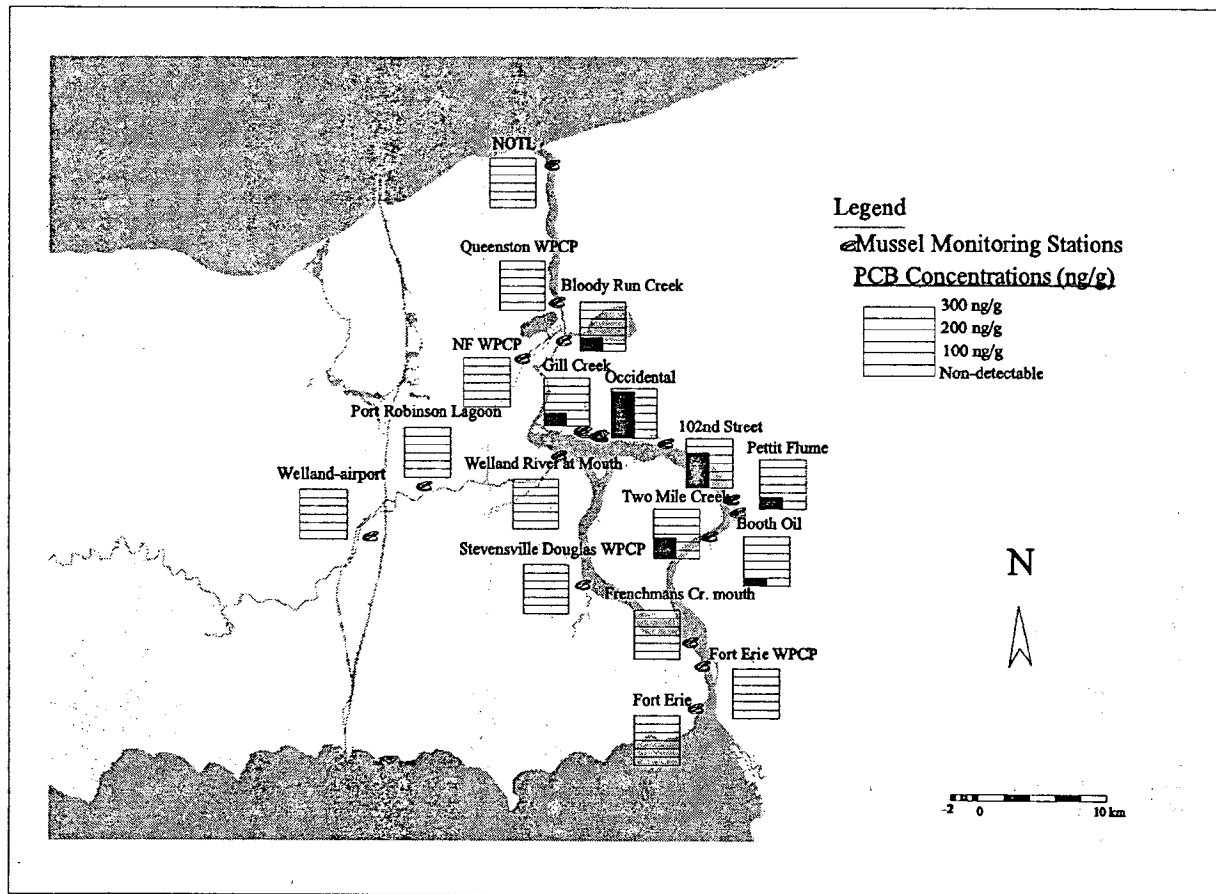


Figure 9. PCB Concentrations in Mussels, 1993.

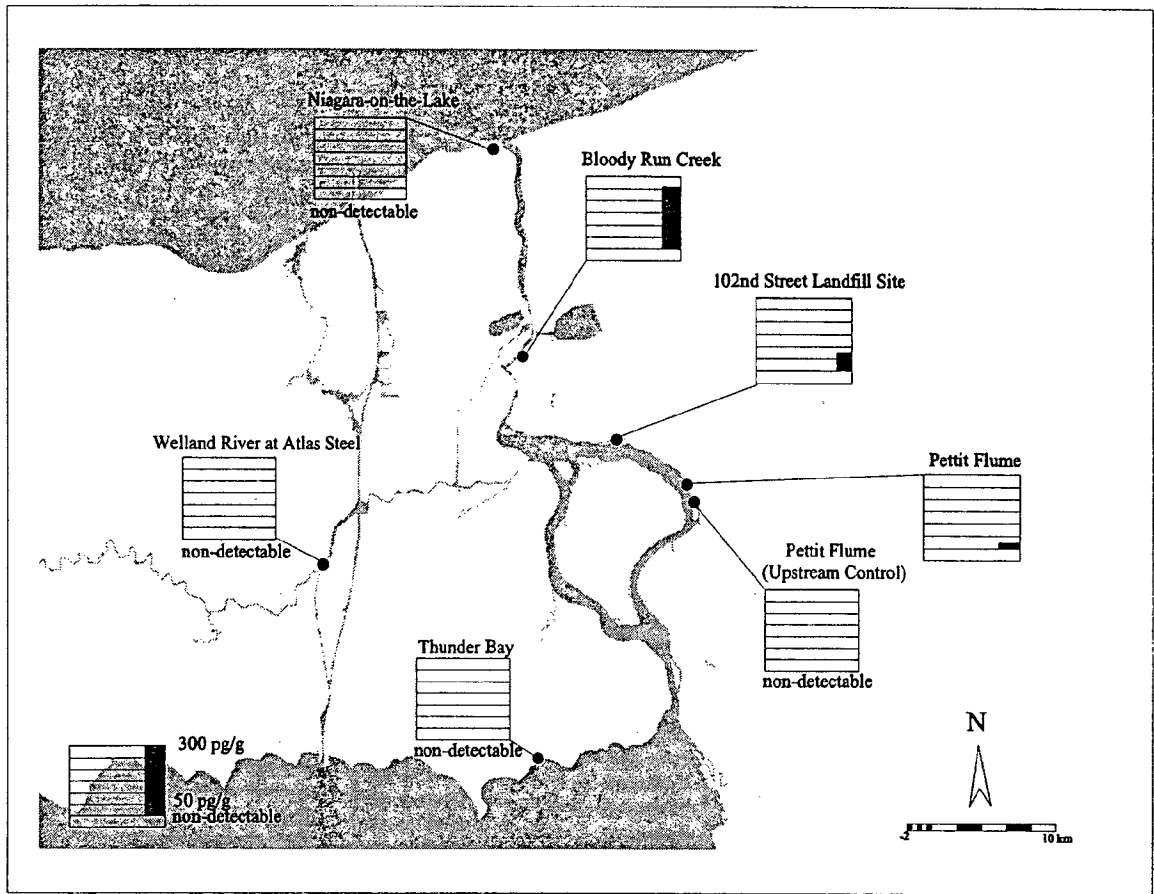


Figure 10. Concentrations of 2,3,7,8-TCDD in Mussels, 1993.

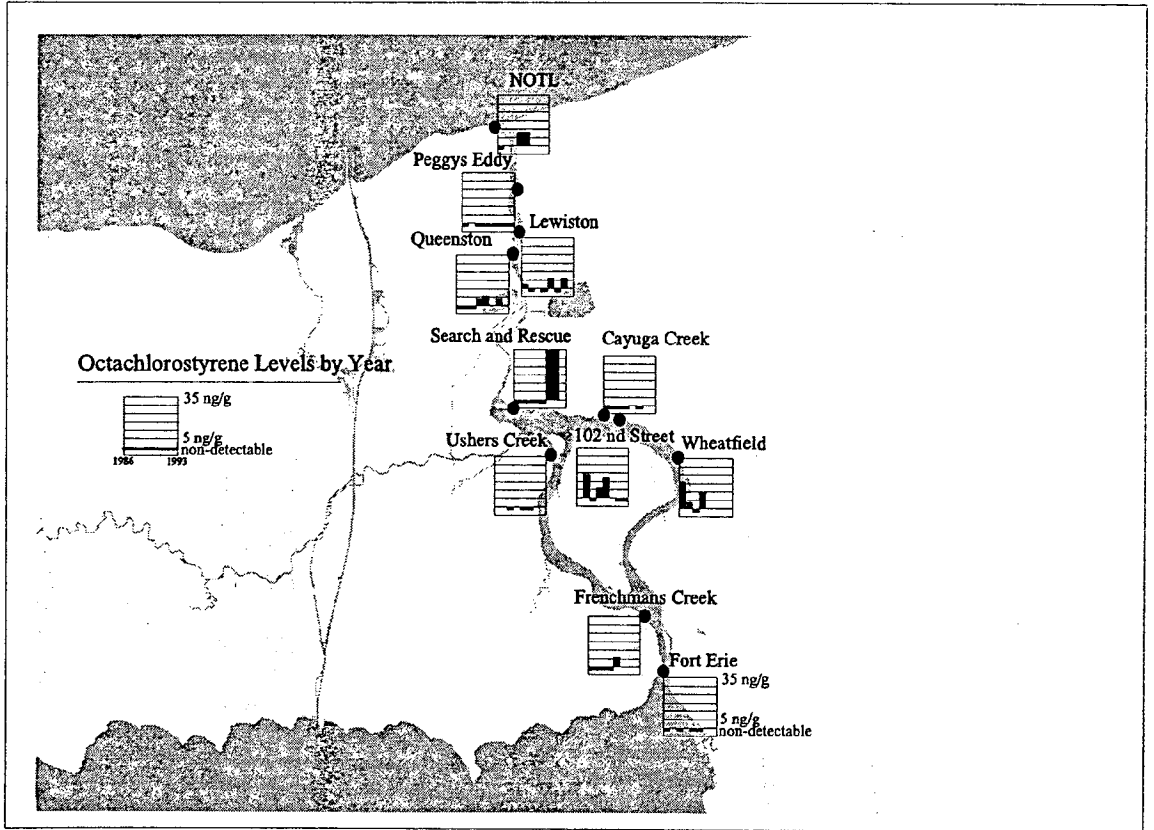


Figure 11. Octachlorostyrene Concentrations in Spottail Shiners, 1986 - 1993.

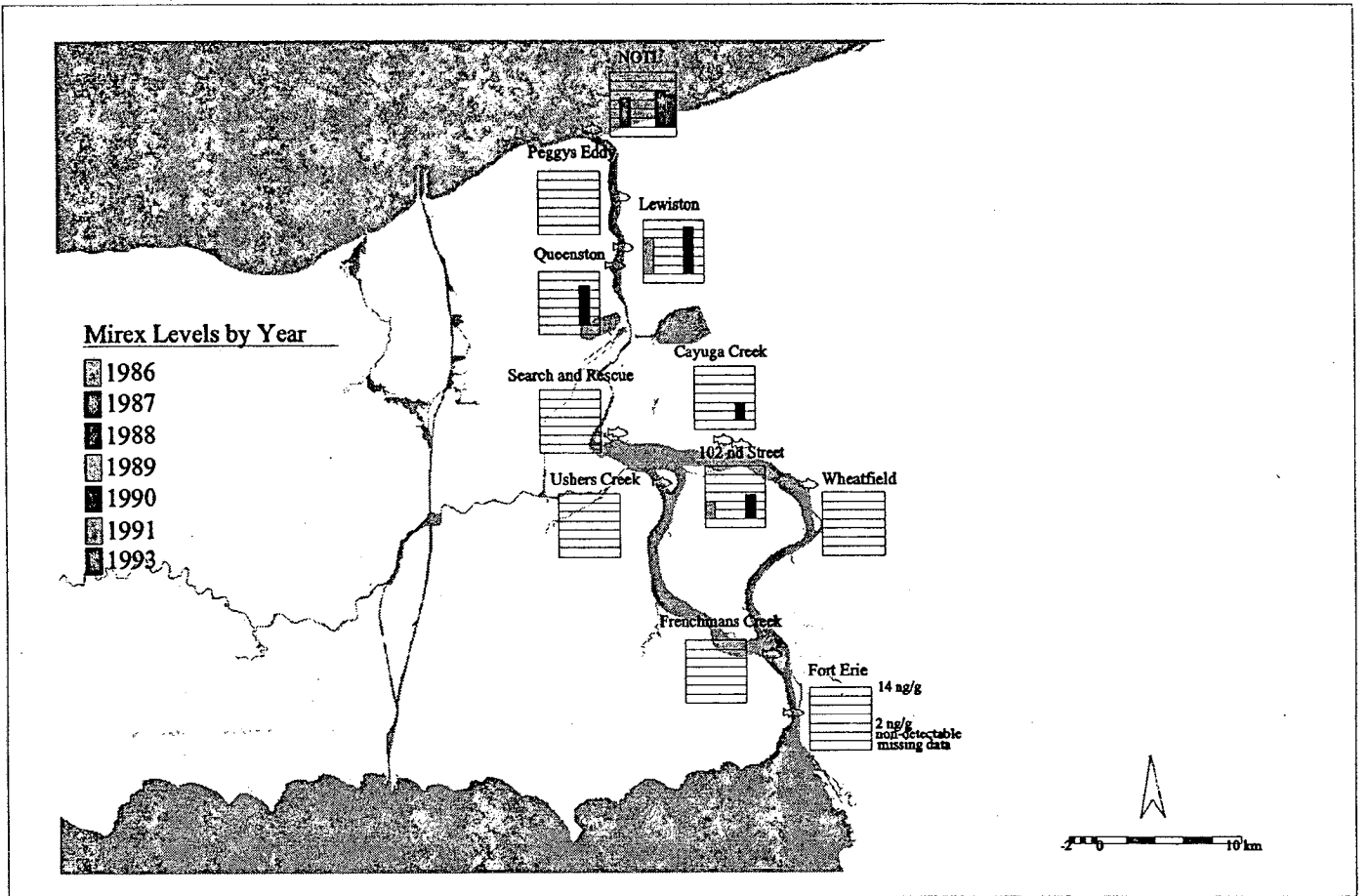


Figure 12. Levels of Mirex in Spottail Shiners 1986-1993

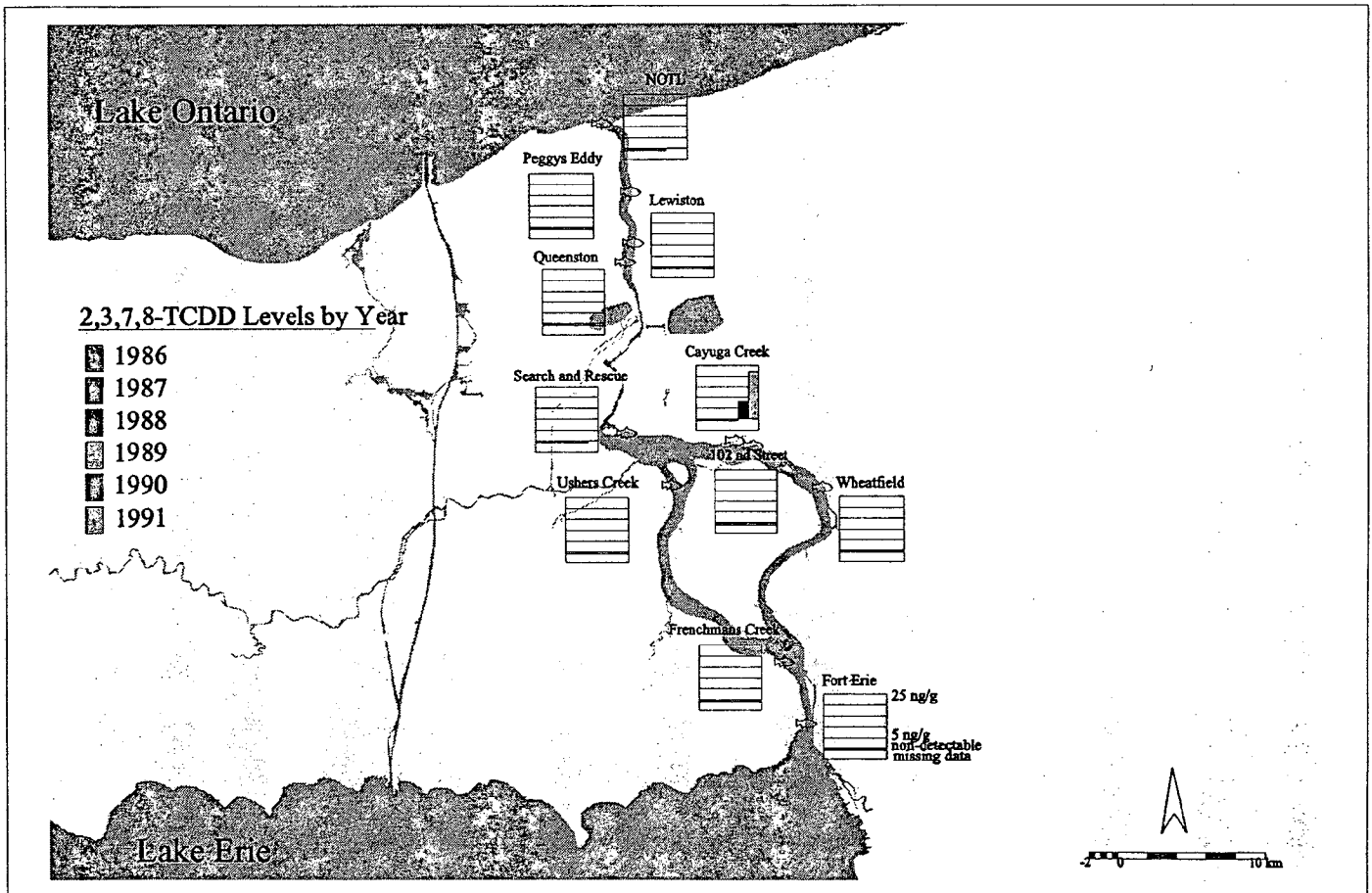


Figure 13. Levels of 2,3,7,8-TCDD in Spottail Shiners 1986-1991

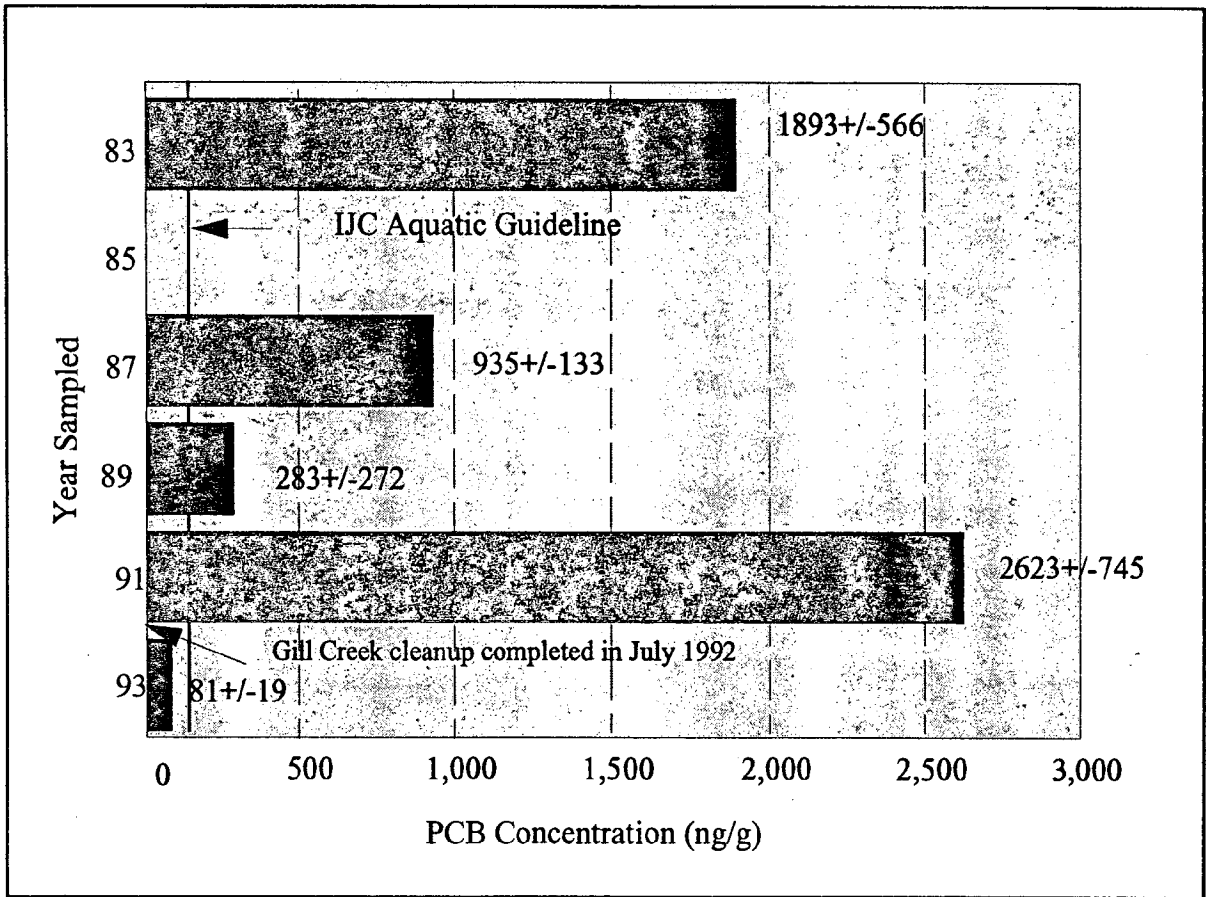


Figure 14. PCBs in Mussels at Gill Creek

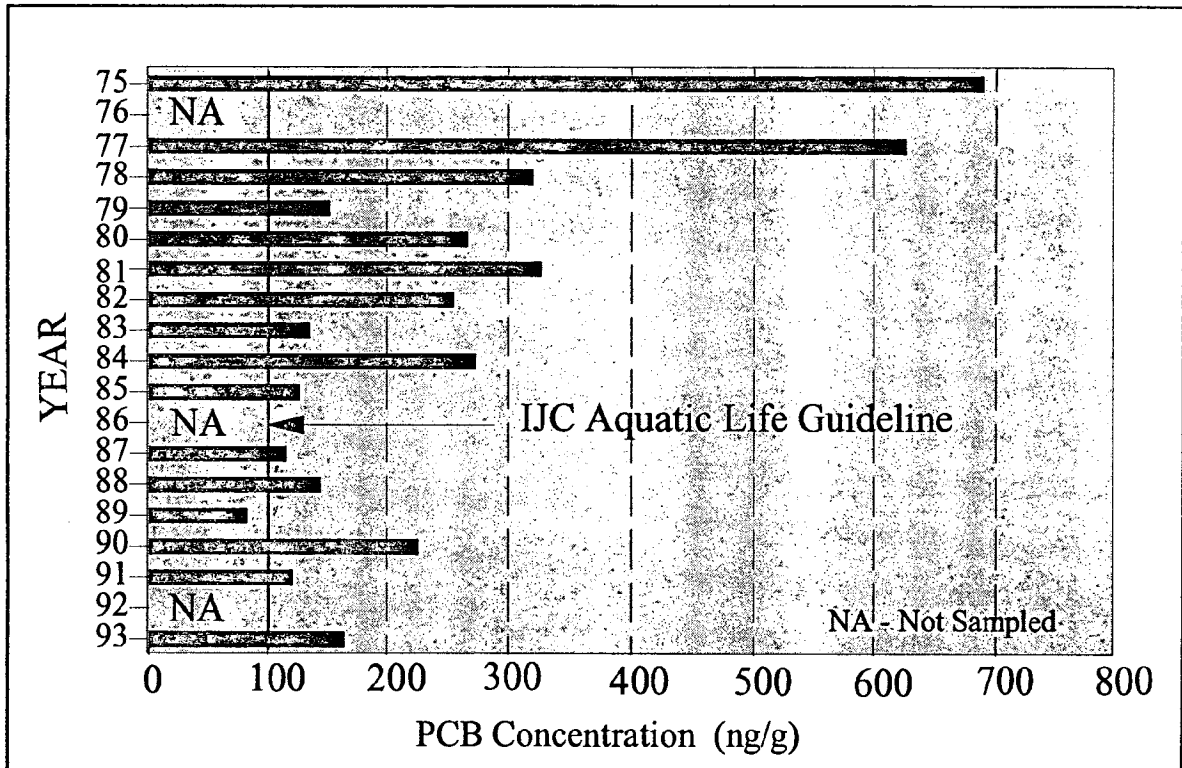


Figure 15. PCBs in Spottail Shiners at NOTL.

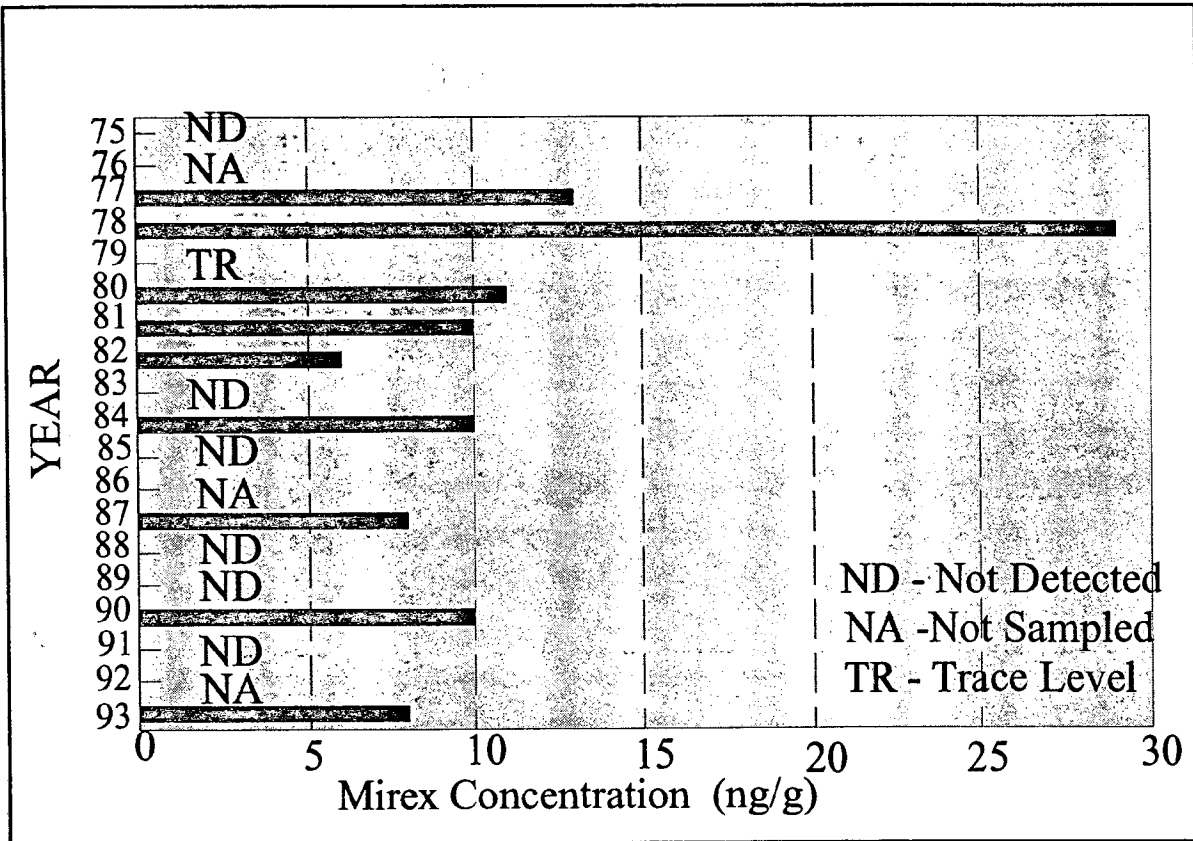


Figure 16. Mirex Levels in Spottail Shiners at NOTL.

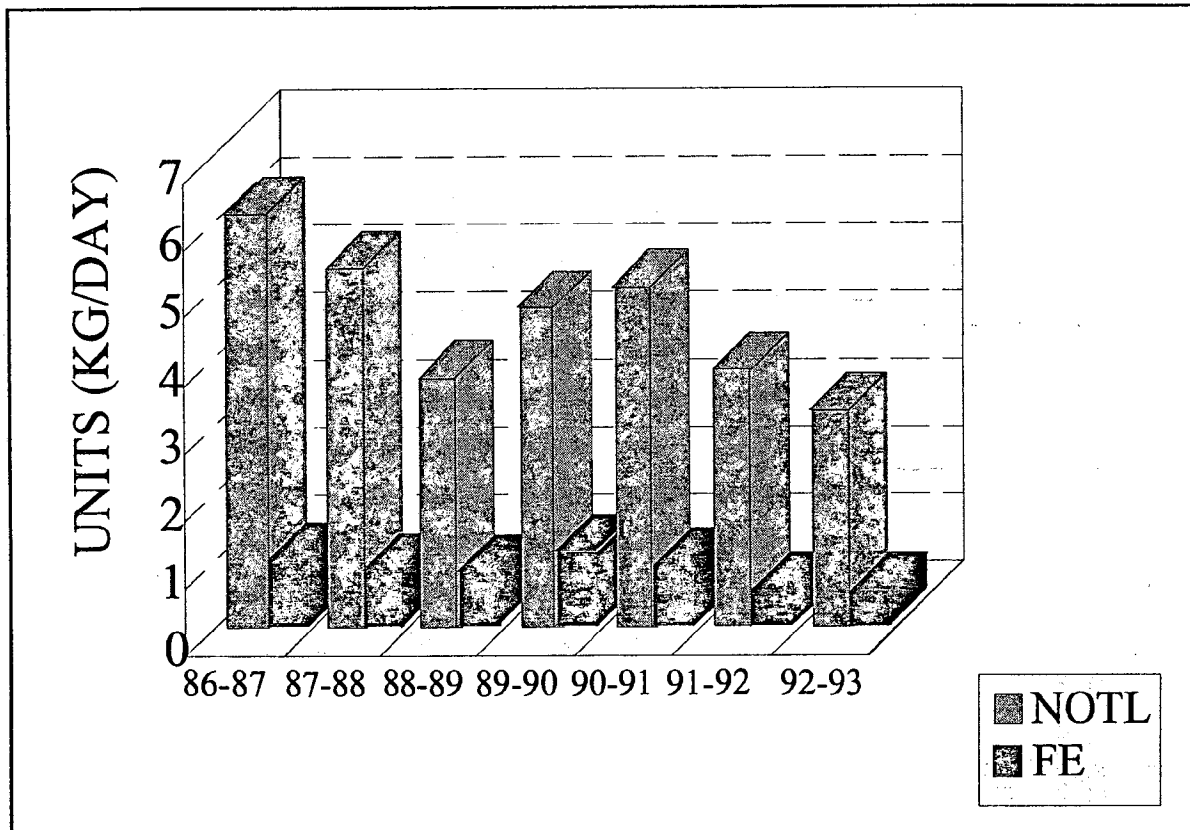


Figure 17. Total Chlorobenzenes loading data during 1986 - 1993 for both NOTL and FE.