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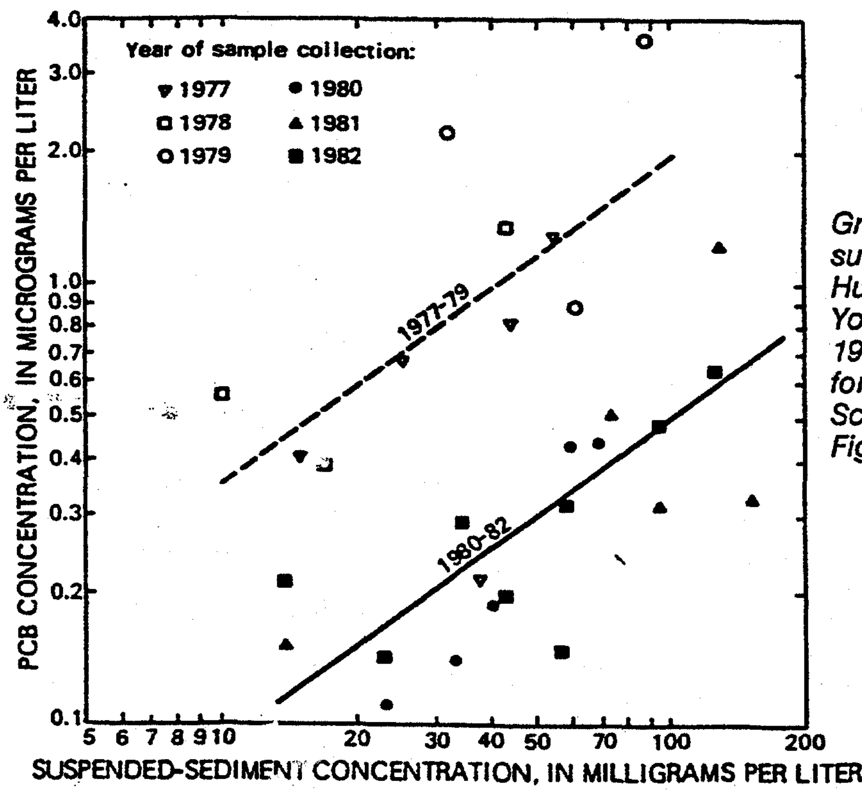

Graph of PCBs and concentration of suspended sediment in upper Hudson River at Schuylerville, New York, Water Years 1977 through 1982. Lines are best-fit regressions for years indicated. (USGU data; Schroeder and Barnes, 1983b, Figure 8, p. 18.)

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EDITOR
Peter J.R. Buttner
RD2 Box 92B
Hawes Road
Altamont, New York 12009
(518) 861-6821

MANAGING EDITOR
Sheila Kopaska-Merkel
Northeastern Science Foundation
PO Box 746
Troy, New York 12181-0746
(518) 273-3247

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Northeastern Environmental Science is a technical journal devoted to publishing research on environmental problems in northeastern North America, and to promoting discussion on the solutions to these problems. The journal provides a forum for researchers and policy-makers to share their knowledge and information with the public and with other scientists, scholars, and decision-makers.

The journal welcomes original papers concerning natural resources and environmental health and welfare. Because the scope is broad, individual journal issues may concentrate on single topics so as to provide depth as well as breadth. Besides technical and policy papers, the journal publishes interviews, comments, book reviews, and announcements.

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SYNOPSIS OF THIS ISSUE

The bulk of this issue is a thorough review of the PCB pollution problem in the Hudson River, written by John E. Sanders, Chair of the Hudson River PCB Settlement Advisory Committee (which advises the Commissioner of the New York State Department of Environmental Conservation). The Committee was established in 1976 as a part of the settlement agreement between New York State and GE concerning GE's pollution of the Hudson River with PCBs. Professor Sanders was elected Vice Chair of the Committee at its second meeting, and shortly thereafter became Chair of the Committee, a post he has ably discharged ever since.

In its capacity as a scientific advisory body to the Commissioner of NYS DEC, the Advisory Committee has played a pivotal role in efforts to deal with the catastrophic pollution of the Hudson by PCBs. Professor Sanders and the PCB committee have been intimately involved with every stage of the PCB problem since October of 1976. In many instances the Committee has played an absolutely essential role in dealing with the PCB-pollution problem. For example, several committee members, including Professor Sanders, discovered almost at the last minute a potentially disastrous error in the building materials for the New Moreau containment facility, which was intended as a secure site for the storage of highly-toxic sediment contaminated with PCBs.

Professor Sanders brings to the explication of the PCB-pollution problem a clarity of insight and breadth of understanding which could not be equaled by anyone else. This is particularly important for two reasons.

First, the PCB-pollution of the Hudson River is an ongoing problem *for which no politically and scientifically workable solution yet exists*. For the foreseeable future, the polluted waters of the Hudson river, containing PCBs in fish having concentrations far above the FDA's safe level of 2 ppm, will be a threat to the health and life of more than 10 million people. Further, the PCB-laden sediments of the so-called "hot spots" represent a ticking time bomb, waiting only for the next major flood to release tremendous quantities of the highly toxic PCBs into the already polluted water.

Second, the intensive scrutiny lavished on the Hudson River PCB-problem by Professor Sanders in this report makes it an extremely valuable case study for water pollution in general. Professor Sanders' report spells out with unequaled clarity and in great detail the processes controlling movement of PCBs through the river, how these processes may be studied, and the often-frustrating political maneuvers which have encumbered attempts to study and to solve the PCB-pollution problem.

Until recently, issues of **Northeastern Environmental Science** have contained few or no book reviews, despite the voluminous literature published each year in the field of Environmental Science. **Northeastern Environmental Science** has never before had a Book Review Editor, but we are inaugurating such a position (beginning with this volume) in the hope that more reviews of important new books will be published in future issues of this Journal. Our new Book Review Editor is Dr. David C. Kopaska-Merkel, of the Northeastern Science Foundation.

Reviews of all recent books pertaining to the field of Environmental Science are solicited. Prospective reviewers should write or call the Book Review Editor with titles intended for review. He will keep a list of reviews pending, for the purpose of preventing duplication. However, in some cases we may publish in the same issue contrasting reviews of the same book. Reviews will be edited for typographical and grammatical errors, but otherwise will normally be untouched. Reviews containing serious problems will be returned to their authors for possible revision.

Reviews should be submitted in one of three forms: (1) IBM format ASCII diskettes (5 1/4" double or high density or 3 1/2" double density); (2) IBM format Wordstar 5.5 (or earlier) diskettes; (3) paper copies in a simple type style suitable for scanning. Faint dot-matrix or proportionally spaced fonts are equally unsuitable. Ideally, both a diskette and a paper copy would be submitted.

From time to time Dr. Kopaska-Merkel will solicit reviews of particular books. Anyone who wishes to be contacted for this purpose should write him in care of the Journal, and should list the subdisciplines for which she or he would like to be considered.

All reviews and correspondence should be sent to Dr. Kopaska-Merkel in care of the Journal at the PO Box.

We are very grateful for the time and efforts of the following reviewers: David C. Kopaska-Merkel, Gerald M. Friedman, Peter J. R. Buttner, and others who wished to remain anonymous.

Sheila Kopaska-Merkel
Managing Editor

PCB-POLLUTION PROBLEM IN THE UPPER HUDSON RIVER:
FROM ENVIRONMENTAL DISASTER TO "ENVIRONMENTAL GRIDLOCK"

John E. Sanders

CONTENTS

THE PCB-POLLUTION PROBLEM IN THE UPPER HUDSON RIVER: FROM ENVIRONMENTAL DISASTER TO "ENVIRONMENTAL GRIDLOCK"

John E. Sanders
Professor of Geology
Barnard College
Columbia University
New York, NY 10027-6598

Chairman
Hudson River PCB Settlement Advisory Committee
to The Commissioner,
New York State Department of Environmental Conservation
50 Wolf Road
Albany, New York 12233-0001

ABSTRACT

The PCB pollution of the upper Hudson River has been traced to two discharge pipes from capacitor-manufacturing plants of the General Electric Company (GE) at Hudson Falls and Fort Edward, located about 40 miles north of Troy, New York. From about 1950 to 1973, most of the PCBs released into the river were soaked up in woody debris that had accumulated along the shores of the pool backed up behind the old Fort Edward Dam. This woody debris, named the remnant deposits (characterized as being "a remnant of an industrial era gone by," the Adirondack lumbering industry), was not recognized until the water level dropped by about 5 meters in 1973, after the Fort Edward Dam had been removed as part of a plan to replace it with a new dam. The environmental documents prepared as part of Niagara-Mohawk Power Corporation's request to the Federal Power Commission (FPC) to remove the dam in view of its age and evident structural weakness did not mention PCBs, the remnant deposits, nor the possibility that in view of the 5-meter or so drop in local base level to be caused by removal of that dam, post-dam-removal floods might erode the former pool-margin sediments and transport them farther downriver. Indeed, the prevention of sudden, unpredictable downriver transport of sediments, known to be contaminated with toxic heavy metals (such as lead, mercury, cadmium, chromium, copper, and zinc), during a flood-caused dam burst was one of the most-prominent arguments cited in favor of removing the dam under controlled conditions. Erosion of the remnant deposits and their accumulation near Fort Edward began in October 1973, almost immediately after the dam had been removed. The culmination of the first downriver surge of this debris came in mid-April 1974, during the crest of a large flood. As a result, nearly I million cubic yards of PCB-contaminated sediments were eroded from north of the former Fort Edward Dam, and most of it was deposited at or near Fort Edward.

In August 1974, biologists from Region II of the U. S. Environmental Protection Agency (US EPA) carried out a field investigation upstream of, at, and downstream of the GE discharge pipes. They collected samples of water, fish, snails, and riverbank sediments, which were analyzed in the EPA laboratory at Edison, New Jersey, using a computerized gas chromatograph/mass spectrometer. Their report, released before the end of 1974, included analyses of three samples from the remnant deposits. PCB values in the sediments ranged from 540 to 6700 parts per million. Despite this report, the staff of the New York State Department of Conservation (NYS DEC) did not discuss PCB contamination in their supervision of the 1975 and 1976 dredging by the New York State Department of Transportation (NYS DOT) of the clogged river channel at Fort Edward nor in measures taken to control further erosion of the remnant deposits. In the absence of any publicity about potential PCB toxicity of the sediments to be dredged, residents of Fort Edward not only did not object to the proposal to dredge the river, they positively welcomed it as a sure means of restoring the former volume of water flow that they were accustomed to expect as a means of transporting away the raw sewage they were discharging and of unclogging one of their sewer outfalls. Part of the debris dredged in the clean-up operation was placed on Rogers Island; the rest was trucked to Moreau, Saratoga County, opposite Fort Edward, on the west side of the Hudson River.

In September 1975, goaded by articles about PCB-contaminated fish from the Hudson Estuary written by Robert Boyle (published in Sports Illustrated Magazine of October 1970 and in September 1975, and in Audubon in 1975), the Commissioner of DEC, Ogden Reid, commenced an administrative proceeding against GE, alleging violations of New York State Environmental Conservation Law (ECL) sections 11-0503, 17-0501, and 17-0511, and seeking cessation of PCB discharges, penalties for past discharges, and rehabilitation of the upper river. Reid appointed as Hearing Officer, Professor Abraham Sofaer, of the Columbia University Law School. Party status was granted to the New York State Department of Commerce, the Natural Resources Defense Council, the Hudson River Fishermen's Association, the Hudson River Sloop Restoration, the Federated Conservationists of Westchester County, and the Associated Industries of New York, Inc. After 11 days of evidentiary hearings, during which DEC staff did not mention the inundation of Fort Edward by the eroded remnant deposits, and an adjournment, on 09 February 1976, Hearing Officer Sofaer dismissed the alleged violation of ECL 11-0503, but sustained those of 17-0501 and 17-0511. During the following 6 months, Hearing Officer Sofaer served as mediator and the principal parties reached a settlement agreement that also satisfied the intervenors. In the agreement,

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NYS DEC was awarded its objective number 1 (cessation of GE's PCB discharges), dropped its objective number 2 (penalties), and settled with respect to objective number 3 (rehabilitation of the upper river). The settlement agreement established the Hudson River PCB Settlement Advisory Committee to advise the Commissioner of DEC on all matters related to the studies and/or rehabilitation of the upper Hudson River and expenditures from the Settlement Fund (consisting of $3 million in cash paid by GE to the State of New York and $3 million in cash or "in kind" to come from the State of New York). A compelling argument made by Professor Sofaer in urging Commissioner Peter Berle (whom Governor Carey had appointed in April 1976 to replace Reid) to accept the settlement agreement was that New York State lacked any legal basis for forcing GE either to carry out a comprehensive study of the PCB pollution or to rehabilitate the upper river. Given the Settlement Fund, the DEC would be able at least to begin the comprehensive study of the PCB situation without delay.

The agreement also stipulated that New York State would "sign off" with GE over PCB pollution of the Hudson River and, if after reviewing the results of the comprehensive study, the Advisory Committee recommended in favor of rehabilitation, would use its "best efforts" to find funds from "sources other than GE" to help pay for the recommended rehabilitation. Because on 31 January 1975, US EPA had granted GE a permit to discharge 30 pounds of PCBs per day into the Hudson River, the settlement agreement specifically declared that no amount of the $3 million settlement fund was to be considered as a fine or a penalty and that GE had not committed any breach of duty. Because the federal government had contributed to the necessity for rehabilitation, Hearing Officer Sofaer hoped that "the federal government will also assume a share of the clean-up responsibility."

While negotiations were in progress, a second flood in mid-April 1976 transported another 250,000 cubic yards of remnant deposits to the Fort Edward area. As had the 1974 reports, the initial report to DEC in 1976 ignored the PCB contamination and likewise recommended placing dredge spoil on Rogers Island.

The Hudson River PCB Settlement Advisory Committee held its first meeting on 26 October 1976. At this meeting, DEC staff presented their view that dredging the contaminated sediments was the only proved means of rehabilitating the river. Although many members were in principle opposed to dredging as a means of river rehabilitation, all agreed that in March 1977, after study of the situation in the Hudson River and of dredging methods, they would be sufficiently informed to render a "yes" or "no" recommendation about dredging. Midway through this 6-month study period, the Advisory Committee members found out that no matter what they might recommend, it was already too late to begin river rehabilitation by dredging in the 1977 season. The Committee also learned about the New York State constitutional amendment mandating the continued operation of the barge-canal system; that in performing this mandate, NYS DOT had been dredging the upper river intermittently for many years and thus since 1950, had regularly been taking out PCB-contaminated sediments; and that NYS DOT had already set in motion the necessary advanced planning for carrying out a channel-maintenance dredging operation near Fort Edward during the 1977 season to clean up the second surge of the remnant deposits. The Committee voted to abandon the previous schedule, to monitor the 1977 dredging, to allocate money from the Settlement Fund to build a state-of-the-art encapsulation facility at Moreau to contain the highly contaminated debris to be dredged, and to withhold any recommendation about dredging until after it had in effect carried out a small-scale "dress rehearsal" of the proposed remedial dredging, and was satisfied from first-hand data that dredging would be more beneficial than harmful to the river.

Subsequently, the Committee became aware of the significance of the remnant deposits in the PCB-pollution situation, and reoriented the thinking of DEC staff and the personnel from Malcolm Pirnie, Inc., who had been serving as DEC's prime contractor on many aspects of the remnant deposits and in preparing environmental- and permit-application documents in connection with channel-maintenance dredging projects. As a result of Committee recommendations, a haul road was built down the east valley wall of the Hudson valley at Fort Edward, the new Moreau encapsulation site was redesigned to contain PCB-contaminated dredge spoils, and the debris, dredged from Fort Edward and from Area 3A of the remnant deposits, was placed in this site. In addition, quarried rock blocks were brought to the river's edge to construct a sturdy riprap to prevent erosion of the remaining remnant deposits of Area 3.

In June 1978, after learning from the results of DEC's monitoring of the 1977 dredging projects that stirred-up sediments are not detectable at stations 2 miles downriver from the dredge during low flows, and after inspection of the closed new Moreau encapsulation site, the Advisory Committee unanimously recommended that DEC pursue upriver rehabilitation by dredging and that the sediments removed be securely encapsulated at a site in southern Fort Edward designated as Site 10 (out of a list of 42 sites screened for their physical characteristics). From 1978 onward, DEC has been fully engaged in attempts to secure federal financial assistance for the proposed clean-up project and to acquire the necessary state permits to encapsulate PCB-contaminated dredge spoils at sites in Fort Edward. Included herein is a detailed account of these attempts, which so far have yielded a situation that can be characterized as "environmental gridlock."

Although both DEC and US EPA have rejected the no-action alternative as a permanent solution to the PCB-contamination problem in the upper Hudson River, they have both presided over what is a *de-facto no-action* situation that has come about against a background of shifting environmental legislation and generally declining amounts of water discharge. Continued monitoring has shown that the PCB values in the water and fish of the Hudson River have declined from their peak values of 1977. Although many believe that this decline signals that the "river is cleaning itself" and should be left alone, I contend that the decreases have resulted from two DEC actions (requiring GE to cease PCB discharges and belatedly including PCB-control measures in the second cleanup of Fort Edward and in building erosion-resistant structures along the shores of Area 3 of the remnant deposits) and from the declining water discharge. Monitoring has demonstrated that PCBs are continuing to be transported into the Hudson estuary from the upper river. Most of the PCB load is acquired north of the Thompson Island Dam from contact of the water with PCB-contaminated sediments. Since 1982, the PCB values in fish have fluctuated with discharge; in 1983, these values increased in step with greater water discharge. According to some investigators, the Hudson River's discharge varies cyclically and one important cycle is 20 years. If this is correct, then the high-flow decade of the 1970s, which was followed by a generally low-flow decade of the 1980s, forms the basis for the prediction that the 1990s will be a high-flow decade. If so, then all the delay over rehabilitating the upper river, which Hearing Officer Sofaer and others have tried so hard to prevent, will mean that if rehabilitation by dredging takes place in the 1990s, it will be done against a backdrop of higher-than-normal flows. The opportunity to rehabilitate the river during the low-flow decade of the 1980s has been squandered.

The future of the PCB problem in the upper Hudson River seems likely to be settled by the outcome of a class-action lawsuit that the commercial fishermen (including the Easthampton Baymen's Association) have filed against GE in Riverhead, Long Island. In January 1989, a New York Appeals Court voted 5-0 in favor of the ruling that the fishermen were entitled not only to payments for lost income, but to "injunctive relief" (which implies that GE must clean up the River).

INTRODUCTION

This paper analyzes the history of the PCB-pollution problem in the upper Hudson River and sets forth the activities of the New York State Department of Environmental Conservation (DEC) and of the Hudson River PCB Settlement Advisory Committee, which was established by the terms of the Settlement Agreement between DEC and the General Electric Company (GE), signed on 08 September 1976. Although various summary reports have been written about PCBs in the environment, none deals with the wide range of subjects included here.

Readers interested in general information should consult Ayer (1976) and Beeton (1979) for a nationwide view. In addition, in the Beeton paper, not widely known, is a neglected cost-benefit analysis which concludes that dredging the most highly contaminated of the PCB-polluted sediments in the upper Hudson River (the so-called hot spots, where total PCB concentrations exceed 50 parts per million, abbreviated ppm, on a dry-weight basis), is a cost-effective control strategy for the United States Environmental Protection Agency (US EPA) to adopt.

From time to time since 1976, various papers have been written that presented the essential details of the PCB-pollution problem in the Hudson River and of DEC's proposed plans to rehabilitate the upper river by dredging the hot spots and securely encapsulating the dredged sediments in a site close to, but out of the river. Some of these have included: Hetling and Horn (1977); Hetling, Horn, and Tofflemire (1978); Hetling, Tofflemire, Horn, Thomas, and Mt. Pleasant (1979); Horn, Hetling, and Tofflemire (1979); Carcich and Tofflemire (1982); Limburg (1984, 1985); M. P. Brown, Werner, Sloan, and K. W. Simpson (1985); and numerous environmental documents prepared by Malcolm Pirnie, Inc.; and the NUS Corporation. In addition, particular aspects of the problem have been discussed by the Hudson River Foundation for Science and Environmental Research, Inc. (1984) and by Borelli (1985).

The results of the 1984 resurvey of the hot spots in the Thompson Island pool are summarized in DEC reports to US EPA by M. P. Brown and Werner (1984, 1985), and by M. P. Brown, Werner, Carusone, and Klein (1988). The 1984 resurvey and the extensive body of analytical data (of both PCBs and density of sediments) formed the basis for a recomputation of the mass of PCBs (a function of volume, bulk density, and PCB concentration). The result indicates a value for PCBs in the hot spots in bottom sediments of the Thompson Island pool that is just under 40 percent of previous estimates (51,000 vs. 134,000 pounds). The chief bases for such a drastic change were more PCB analyses and measured values of bulk density that were less than the values used by those who made the 1977 computations. M. B. Brown *et al.* also used Richard Bopp's year-by-year values of PCBs for 1977-1983 in cores from New York Harbor and C. R. Barnes' value of 10,000 kg of PCBs transported from upriver into the estuary (1977-1983) to revise the computation of PCBs transported to the lower river. Table 1 shows the old and new budget of PCBs in the 5 major compartments of the Hudson River system (dredged from upper river, the remnant deposits, in Thompson Island Pool, elsewhere in the upper river, and transported to lower river).

Table 1. Calculated quantities of PCBs in the Hudson River/Estuary system. (M. P. Brown, Werner, Carusone, and Klein, 1988.)

Compartments	Year 1977	1985	Source(s)
	Mass of PCbs (thousands of pounds)		
In sediments dredged from upper river	160	160	Horn *et al.* (1979)
Remnant deposits	139	64	Tofflemire and Quinn (1979)
Sediments of Thompson Island Pool:			
Hot spots	105	32.9	(M. P. Brown *et al.*, 1985)
Other sediments	28.2	18.2	
Subtotal	133.2	51.1	
Upriver sediments (all other areas)	213	100	(M. P. Brown, based on proportional change in results from Thompson Island Pool.)
Transported to estuary		130	M. P. Brown *et al.* (1985)
In bottom sediments	170		Bopp, 1979 ms.
Carried to ocean	285		
Totals (rounded)	1100	505	

Limburg, Moran, and McDowell (1985) have published an extensive bibliography of reports about the Hudson River, including the PCB problem.

Notably absent from any of these documents is any hint that private citizens were agitating for public officials to act to end pollution and that government officials were ignoring these efforts. None of the above-mentioned documents contains an overview of the whole problem, from its beginning to the political aspects of DEC's attempts to mitigate it. Moreover, the Hudson River PCB Settlement Advisory Committee, which has been dealing with all phases of the PCB-pollution problem since late October 1976, has been scarcely mentioned.

I begin with citizen attempts to curb pollution. Thereafter, my order of presentation is: PCBs: description and regulatory framework; geographic-, geologic-, and hydrologic setting of the upper Hudson River (including a section discussing possible cyclicity in the variations of water discharge); the discovery of PCB pollution in the upper Hudson River and its relationships to discharges from the GE capacitor-manufacturing plants; the DEC-GE Settlement Agreement and the establishment of the Hudson River PCB Settlement Advisory Committee (including sections on Committee activities); the "great experiment" in spreading PCBs throughout the system (occasioned by floods that eroded the remnant deposits, exposed following removal of the Fort Edward Dam in 1973); upper river rehabilitation by dredging; DEC's proposed dredging of PCB hot spots, DEC's efforts to find funds from "sources other than GE" to help pay for starting the final phase of upriver rehabilitation; DEC's so-far futile attempts to obtain permits to encapsulate PCB-contaminated dredge spoil in Fort Edward; institutional/management considerations (including a section on the contrasts between US EPA's Superfund recommendation for remediating PCB contamination in the upper Hudson River and in New Bedford Harbor, Massachusetts); remedial actions taken and monitoring of them; and the current status of the PCB-pollution situation.

My own particular research interests have centered on sediments and the relationships between water flows and cohesionless sediments, and on the new vistas opening up by recognition of the significance of the cyclic orbit of the Sun around the center of mass of the solar system. I have compiled two extensive tables that appear in Appendix B: a chronology of events (Table B-1) and average daily flows on a monthly basis of the Hudson River at Green Island October 1929 through September 1988 and including the Julian days of the mid-month dates and of dates of lunar perigee-syzygy alignments (Table B-2).

CITIZEN ATTEMPTS TO CURB POLLUTION: THE HUDSON RIVER FISHERMEN'S ASSOCIATION

The first serious attempt by New York State to address the pollution problems of the Hudson River came in 1965, when New York voters approved a $1 billion bond issue to clean up the waters of the state. Plans for this proposed clean up were drawn up by the New York State Water Resources Commission and approved by the Federal Water Pollution Control Administration. The initial project was to establish standards and to apply them to the Hudson River (and other waterways).

More-direct approaches were taken by a group of concerned individuals, who in 1966 formed the Hudson River Fishermen's Association (HRFA) and began to prod government officials to enforce the existing anti-pollution laws. Two particular acts, the New York Harbor Dumping Act of 1888 and the Federal Refuse Act of 1899, prohibited pollution of waterways and provided that convicted violators would be fined and that half the fine of a convicted polluter would be given to the person who reported the violation. These acts were being ignored by public officials who should have been enforcing them all along. In attempts to stimulate government officials to do their duties, Robert Boyle and Arthur Glowka, of the HRFA, began a series of numerous visits to the responsible government agencies (U. S. Army Corps of Engineers, chiefly). After being generally ignored in these efforts, the HRFA set out to inform the public about their bounty possibilities under these two acts. Arthur Glowka designed, and the HRFA distributed, 10,000 "Bag-a-polluter" prepaid postcards. These cards were addressed to the HRFA. All any citizen had to do to report a polluter was to fill in the blanks with locations and times of pipes that were discharging pollutants into the Hudson River and its tributaries and drop the card in the mail. The HRFA acted vigorously on information received (Boyle, 1969, p. 102). This tactic was so effective that in passing the Clean Water Act, Congress repealed these earlier acts which encouraged citizens to report polluters by specifying they were entitled to half the fines levied on convicted polluters. The CWA abolished the Federal Water Pollution Control Administration and established the U. S. Environmental Protection Agency (US EPA), which was charged with operating a program of issuing licenses, presumably to control discharges into US waterways. This program of licenses was the National Pollution Discharge Elimination System (NPDES).

Under this CWA program, US EPA would grant the NPDES permits but the states would be responsible for enforcing the provisions of these permits (SPDES permits). In New York State, the 1972 legislature voted to change the State's departments to make the organization of environmental matters parallel to that adopted by the federal government. Accordingly, New York State established the New York State Department of Environmental Conservation (hereafter abbreviated DEC; also known as ENCON).

PCBs: DESCRIPTION AND REGULATORY FRAMEWORK

PCBs: Congeners and Aroclors

PCB is an abbreviation for polychlorobiphenyl (=polychlorinated biphenyl), a group of synthetic-organic compounds first synthesized in the laboratory in 1929. PCBs are manufactured by adding chlorine to various positions on the biphenyl double-ring structure. The number of chlorine atoms added and the positions they occupy form the basis for recognizing the many PCB congeners (Mieure, Hicks, Kaley, and Saeger, 1976).

In general, PCBs are only slightly soluble in water but are readily dissolved by organic solvents and oils. Also they possess a strong affinity for organic materials, such as wood debris, paper-pulp sludge, sawdust, and leaf litter. They also tend to become attached to clay minerals and thus to travel with fine sediments.

The U. S. Geological Survey (USGS) has established a nationwide network for monitoring both the quantity and the quality of water in US rivers. The procedures adopted by the Geological Survey Water Resources Branch have become widely accepted. In the USGS laboratory, PCBs may be extracted from the total sample, or only after filtration. In that case, the samples are passed through a 0.45-micron silver-oxide filter. What passes the filter is defined operationally as being the "dissolved load," whereas what remains on the filter is the "suspended load." As is explained in a following section, at times of low flow, the PCB content of all Hudson River samples is in the dissolved load. By contrast, at times of high flow, the PCBs are found in the suspended load and thus are attached to sediment particles.

Aroclor is the trademark name for PCBs manufactured by the Monsanto Industrial Chemicals Company (Forrestal, 1977). Monsanto devised a 4-digit code for designating its Aroclors. The first two digits of the code are either 12 or 10. In the 12-- series, the last two digits indicate the percent of chlorine (e. g., Aroclor 1242 contains 42 percent chlorine.) The last two digits in the 10-- series do not convey the percentage of chlorine. For example, Aroclor 1016 contains about 42 percent chlorine. It differs from Aroclor 1242 in containing fewer high-Cl congeners (the kind considered to display the greatest toxicity).

Laboratory procedures for identifying PCBs have progressed dramatically since 1978, the year when DEC wanted hundreds of samples analyzed within a short period of time. The requirements of the comprehensive study program of the Hudson River (Hetling and Horn, 1977; Hetling, Horn, and Tofflemire, 1978) tied up virtually all the existing analytical glassware within the commercial laboratories equipped with gas chromatographs capable of analyzing for PCBs. The analytical results were determined by measuring areas beneath the peaks on the chromatograms and by comparing the sample chromatogram with chromatograms of various Aroclor standards, to yield values for several Aroclors and total PCBs. Whereas such results satisfied DEC's requirements for computing total quantities of PCBs and for identifying areas of highest PCB concentrations, these results did not enable the PCBs to be used as environmental tracers. The full scientific value of PCB analyses began to be realized only in the mid-1980s, after capillary-column techniques had been applied and the chromatograms analyzed in terms of individual congeners (Stalling, Huckins, Petty, J. L. Johnson, and H. O. Sanders, 1979; Bush, Murphy, Connor, Snow, and Barnard, 1985). Congener-specific analyses on Hudson River samples have been carried out by Bopp and Simpson, by John Brown, and by Brian Bush, and their associates. The results of these new analyses are included here.

Public awareness of PCBs as a possible toxic compound began in 1968 with the "Yusho incident" in Japan (Urabi, Koda, and Asahi, 1979). Reports on the ill effects on the more than 1,000 people who had eaten rice cooked in Kanemi Rice Oil that had been inadvertently contaminated with PCBs (including also polychlorinated dibenzofurans, or PCDFs, which are more toxic even than are PCBs) were widely circulated in the public press. In 1970, the U. S. Congress passed the first of several regulatory acts governing PCBs. These are discussed in a following section. In September 1970, the Monsanto Industrial Chemicals Company, the sole manufacturer of PCBs in the United States, restricted its sales to those producers using PCBs in closed systems (Ahmed, 1976b, p. 412). Appendix Table B-1 presents a chronology of events connected with PCBs and the Hudson River situation.

Federal Regulatory Framework

In late 1972, the U. S. Congress passed the Federal Water Pollution Control Act of 1972 (popularly referred to as the "Clean-Water Act" or CWA). An amendment passed on 18 October 1972 took away the bounty-hunting aspect of the 1888 New York Harbor Act and the 1899 Federal Refuse Act. The CWA (or FWPCA) became PL 92-500. In this Act, Congress established the U. S. Environmental Protection Agency (US EPA; it replaced the former Federal Water Pollution Control Administration, or FWPCA) and assigned to it the responsibility for regulating the discharges of industrial wastes into waterways via a program of permits. This program was known as the National Pollution Discharge Elimination System (NPDES).

On 18 December 1972, GE applied to the US EPA for a NPDES permit to discharge 30 to 47.6 pounds per day of PCBs into the upper Hudson River. Table 2 shows the information GE submitted to US EPA with its permit application.

Table 2. GE discharges as submitted by GE to US EPA (Nadeau and Davis, 1974)

No.	Outfall loc.	Av. daily conc. (mg/liter) oil/grease	Av. daily conc. (mg/liter) PCB	Av. daily load (pounds) oil/grease	Av. daily load (pounds) PCB	Max. load (pounds) O/G	Max. load (pounds) PCB
002	Hudson Falls	13.77	0.5	239.8	10.0	250.9	17.5
003	Hudson Falls	02.1	—	4.9	—	5.23	—
004	Fort Edward	08.9	5.0	33.27	20.0	44.3	30.0

On 31 January 1975, EPA granted GE a permit to discharge 30 pounds per day of PCBs into the upper Hudson River (from both plants). EPA turned over the task of monitoring this permit program to DEC; this system became known as a State Pollution Discharge Elimination System (SPDES) permit.

Some of the other federal laws that relate to the PCB-pollution problem in the upper Hudson River are listed below. A more-complete list is contained in McCreary (1988, Table 6, p. 37-41).

The National Environmental Policy Act (NEPA; PL 91-190) requires that the environmental effects of proposed federal actions be considered in advance. Among other things, NEPA obliges the U. S. Army, Corps of Engineers (COE) to prepare a draft environmental-impact statement (DEIS) where a proposed dredging operation, for example, would create a significant environmental act. The DEIS is then reviewed by other federal agencies.

The Water Quality Act of 1970 (PL 91-224); sec. 21 (b) was cited as basis for the decisions about removing the Fort Edward Dam.

The Rivers and Harbors Act of 1970 (PL 91-611) established the Dredged Materials Research Program (DMRP) at the Waterways Experiment Station (WES), Vicksburg, Mississippi, of the U. S. Army, Corps of Engineers (COE).

Toxic Substances Control Act (TOSCA), passed by the 94th Congress, 2nd session, in 1976. Among other things, this act banned PCBs in the United States. It was signed into law (PL 94-469) on 11 October 1976.

Resources Conservation and Recovery Act of 1976 (RECRA) was passed by the 94th Congress, 2nd session on 30 September. It was signed into law (PL 94-580) on 21 October 1976.

US EPA published its rules for handling PCBs under TOSCA on 24 May 1977.

Federal Water Pollution Control Act of 1972 Section 404 (b) (1), Navigable waters, discharge of dredged or fill material, instructed EPA and the COE to formulate guidelines. The interim final guidelines, published in the Federal Register of 05 September 1975, "require that regulatory measures be based on information from scientific investigations about the natural environment and human health and welfare." (Davis, 1980, p. 289-290).

The Clean Water Act Amendment (PL 96-483), signed on 21 October 1980, included a new section, sec. 116, which authorized under certain conditions, the State of New York to transfer $20 million from its federal share of the Hudson River PCB-Demonstration-Reclamation project (dredging the PCB hot spots and securely encapsulating and/or disposing of the PCBs in the contaminated sediments).

The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), known generally as "Superfund," was passed by the 96th Congress, 2nd session, on 03 December 1982. This bill was signed into law (PL 96-510) on 11 December 1982. (In what must have been one of the first actions related to this law, on 28 December 1982, the Administrator of US EPA, Anne Gorsuch, determined that funds from Superfund were "available" for dealing with the PCB pollution of the upper Hudson River.)

The Superfund Amendments and Reauthorization Act of 1986 (SARA) was passed by Congress in October 1986, and signed into law (PL 99-499) on 27 October 1986. The provisions of this act obliged US EPA to reexamine the public-health determinations it had made under Superfund I and established a program entitled Superfund Innovative Technology Evaluation (SITE). Under SITE, funds were made available for field demonstrations of techniques for detoxifying toxic wastes as an alternative to simply covering the site or burying the wastes.

The Water Quality Act of 1987 became PL 100-4 after Congress passed it overwhelmingly and also overwhelmingly overrode a presidential veto early in February 1987.

Relevant State Regulatory Framework

New York State Conservation Law

The New York State Environmental Conservation Law (ECL), Article 3 deals with generalized powers of the Department. Section. 11-0503 is a prohibition on polluting streams with anything injurious to fish life.

Article 17, Title 5 of the ECL includes various prohibitions. Sec. 17-501 is a general prohibition against pollution in excess of certain standards contained in Sec. 17-0301. Sec. 17-0511 places restrictions on discharge of sewage, industrial wastes, or other wastes. Sec. 17-0701 provides for the SPDES permits.

The federal law (PL 92-500) allows the states to certify that they can enforce its provisions. Accordingly, New York State Laws of 1970 established the Department of Environmental Conservation (Chapter 140). In October 1975, US EPA formally approved New York's arrangements.

The Industrial Hazardous Waste Management Act of 1978

This act, which became Title 11 of Article 27 of the Environmental Conservation Law, took effect on 15 July 1978. The provisions of this act were incorporated into Title 6 of the Official Compilation of Codes, Rules and Regulations of the State of New York ("6 NYCRR"). The rules and regulations promulgated pursuant to this Act were incorporated into Part 360 (Solid Waste Management Facilities), Part 361 (Siting of Industrial Hazardous Waste Facilities), Parts 370-373 (Hazardous Waste), Part 608 (Use and Protection of Waters), Part 617 (State Environmental Quality Review), Part 621 (Uniform Procedures), Part 624 (Hearing Procedures), and Part 750 (SPDES regulations).

A specific provision of the law directed the Commissioner of DEC to promulgate rules and criteria for guiding Siting Boards and to have these rules and criteria in final form by 15 July 1979, one year after the passage of the act.

Included under this act are: Certificate and permit requirements and application procedures; the need for a hearing; the Department's actions after a Siting Board's decision; Certificate of Public Necessity and Environmental Safety; SPDES permit conditions; and facility-siting criteria.

NY State's Agricultural Districts Law

The NY State Agricultural and Markets Act 25 AA was intended to offer extra protection and tax advantages to owners of real estate in agricultural areas. A proposal to establish an Agricultural District starts with a petition by owners. If the county government concurs, it sends the petition to the Commissioner of Agriculture and Markets, who certifies it. One of the points in the certification procedure is consistency of the proposed district with the environmental laws of the state.

Once an Agricultural District has been established, it affects the eminent-domain powers of state agencies as far as condemnation proceedings are concerned. If a proposed action involves the taking of property by eminent domain, then the sponsoring agency must specifically address the impacts on agriculture of the proposed action.

(In 1987, Washington County residents opposed to DEC's application for a permit to encapsulate PCB-contaminated sediments at Site G in northern Fort Edward alleged that DEC had not abided by the provisions of this law. They claimed that DEC's alleged violations constituted a basis for stopping the hearings and for dismissing the application. Judge Louis ruled that this citation of the Agricultural Districts law was not sufficient grounds for terminating the permit-application proceedings.)

GEOGRAPHIC-, GEOLOGIC-, AND HYDROLOGIC SETTING OF UPPER HUDSON RIVER

Any modern discussion of specific places derives from base maps and from grid-coordinate schemes for specifying locations. Appendix A summarizes local base maps and grid coordinates. I proceed on the basis that the reader is familiar with the contents of Appendix A.

Geographic- and Geologic Setting

I begin with a brief look at the whole river (Figure 1). After that, I take a brief tour from the headwaters past the reach where the high levels of PCB contamination have been reported. Following that is a discussion of the general setting of the natural channel of the upper river, including the characteristics of its transverse profile.

Overview of the Hudson River system

The Hudson River is divided into upper river and lower river at the point of entrance of the Mohawk River, south of Waterford (1014N-675E; Figure 2). The lower river and Hudson Estuary are nearly synonymous. The upstream limit of the Hudson Estuary is at the Green Island Dam, Troy, which is the head of tidewater. The Green Island Dam is only about two miles south of the confluence of the Mohawk and Hudson rivers.

The contributions from the Mohawk greatly increase the size of the combined river. Based on data collected during the 1976 water year (01 October 1975 - 30 September 1976), the first period during which the USGS supplemented its daily records of water discharge by making daily determinations of suspended sediment, the water discharged from the Mohawk was about equal to that from the upper Hudson and the suspended sediment was about twice that of the Hudson (USGS, 1977). In effect, then, the additions from the Mohawk doubled the flow of water and tripled the quantity of suspended sediment carried into the estuary over the Federal Dam at Green Island opposite Troy compared with that at Waterford (Table 3).

Table 3. Upper Hudson and Mohawk comparisons.

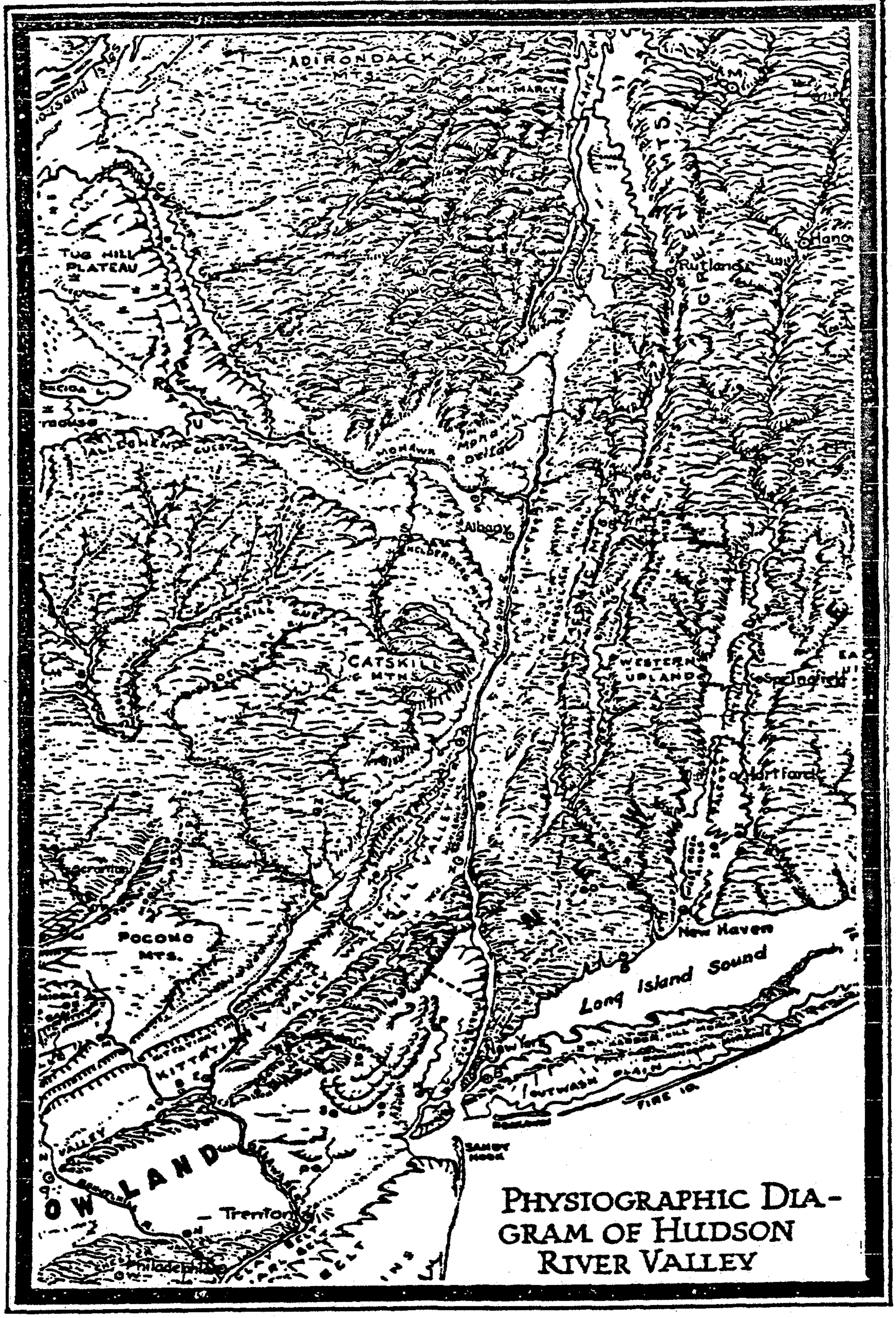
	Drainage area		Suspended sediment (Water year 1976)			
			Total		Sediment yield	
	(sq. km.)	(sq. mi.)	(Tonnes)	(tons)	(Tonnes/ sq. km.)	(Tons/ sq. mi.)
U. Hudson	11,966	4,620	354,282	390,523	29.6	84.5
Mohawk	08,951	3,456	746,165	822,492	83.4	238
Combined	20,917	8,076	1,100,447	1,213,015	52.6	150

Because no significant sources of PCBs have been reported from the Mohawk (Bopp, H. J. Simpson, Olsen, and Kostyk, 1981, Table IV, p. 213), its effect is to dilute the load of PCBs coming from north of Waterford.

Source to downstream of PCB-polluted reach

The source of the Hudson River is usually stated as being in

Figure 1. Physiographic diagramof upper Hudson River-Mohawk River drainage basins and adjacent regions.



PHYSIOGRAPHIC DIAGRAM OF HUDSON RIVER VALLEY

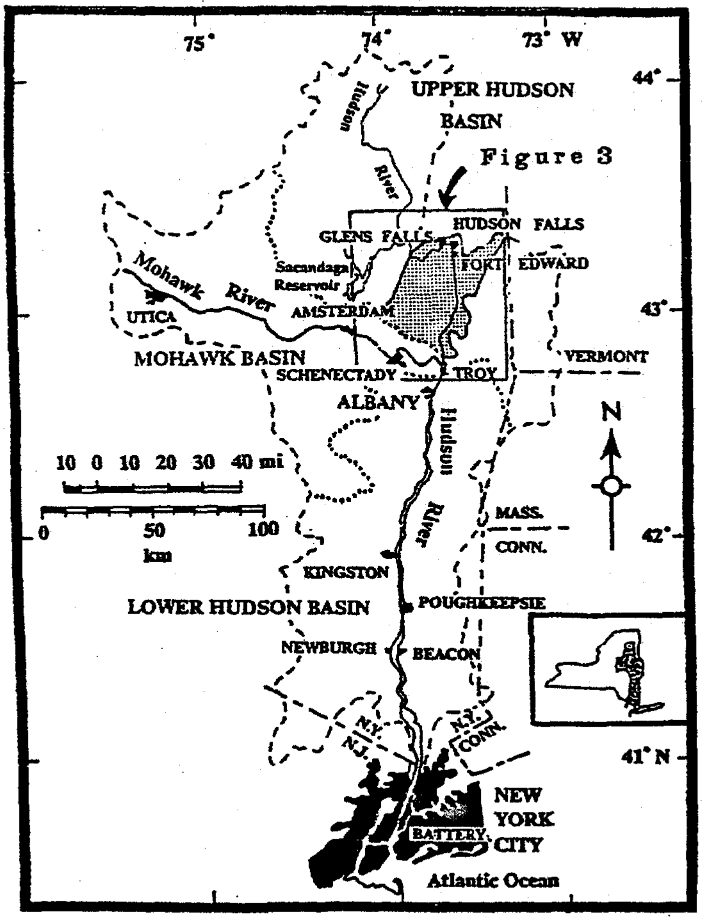


Figure 2. Index map of Hudson River basin (boundary shown by dashed line; dotted line delineates the three sub-basins). Inset at lower right shows location of Hudson River basin (stippled) within New York State. Rectangle in upper right center shows location of Figure 2; stippled area marks subbasin between Glens Falls and Troy. (Redrafted from NYS DEC map in Hetling, Horn, and Tofflemire, 1978, Fig. 1, p. 2.)

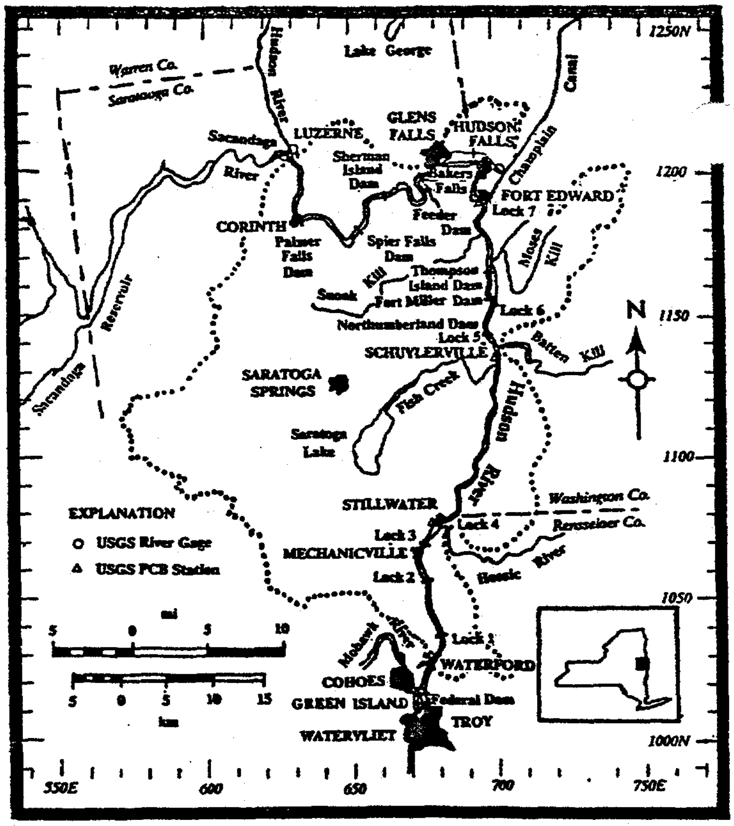


Figure 3. Location map of part of upper Hudson River between Luzerne and Troy. (Location within New York State shown by black rectangle on inset map.) Dotted line marks limit of subbasin drainage area [Redrafted from NYS DEC map in Hetling, Horn, and Tofflemire, 1978, Fig. 2, p. 3, with approximate locations of New York State 10,000-foot grid lines (east zone) added by J. E. Sanders.]

Lake Tear-of-the-Clouds on the slopes of Mount Marcy, Essex County. The overflow of Lake Tear is Feldspar Brook, which joins the Opalescent River. About 10 miles from Lake Tear, the Opalescent River joins what is marked as the Hudson River, a stream coming from Sanford and Henderson lakes (1490N-572E), Santanoni 15-minute quadrangle (Boyle, 1969, p. 69-71).

From its Adirondack headwaters, the Hudson River flows generally south and southeast to Hadley, Saratoga County (Lake Luzerne quadrangle), below which it is augmented by the Sacandaga River, with its outflow from the large Sacandaga Reservoir (on Harrisburg 15-minute quadrangle and Edinburg 7.5-minute quadrangle). This reach of the upper Hudson River lies within the rugged terrain of the Adirondacks physiographic province (See Figure 1).

At Corinth, the river turns east-northeast and enters the Appalachian Great Valley Province. From Hudson Falls southward, the Hudson generally follows the trend of the Appalachian Great Valley. From Kingston to Newburgh, however, the course of the river is almost due north-south, whereas the trend of the Great Valley swings gradually around toward the southwest. As a result, the river transects the Great Valley at a low-oblique angle (Sanders, 1974). The Hudson leaves the Great Valley at Storm King (south of the Newburgh-Beacon bridge on I-84), where it enters the Hudson Highlands. At the Highlands, I leave this regional description of the Hudson River to return to the features of the local setting of its PCB-polluted reach.

At Hudson Falls (Figure 3), the river turns south and flows over Bakers Falls into a narrow, steep-sided gorge formed by the upstream retreat of these falls. Just south of Bakers Falls, the river flows past two General Electric capacitor-manufacturing plants. The plant at Hudson Falls (1201.0N-697.5E; Hudson Falls quadrangle) began using PCBs in 1947; that at Fort Edward (1198N-698E; Hudson Falls quadrangle), in 1952.

South of Fort Edward, the Hudson River leaves this bedrock gorge and flows through Pleistocene and Holocene sediments including silts and clays deposited in Glacial Lake Albany, which formed during the meltdown phase as the latest continental glacier retreated from New York State (Lafleur, 1979).

Upper Hudson River: general setting of natural channel

The reach of the upper Hudson River where PCB-contaminated sediments attain their highest concentrations extends between the cities of Hudson Falls and Troy, particularly from about 1 mile north of Fort Edward to the Thompson Island Dam, which is about 5 miles south of Fort Edward (Figure 4).

Transverse profile of Upper Hudson valley.– Three surveys have been conducted of the morphology of the natural channel of the upper Hudson River. The first survey, completed by DEC personnel in 1976, consisted of selected transects along which the

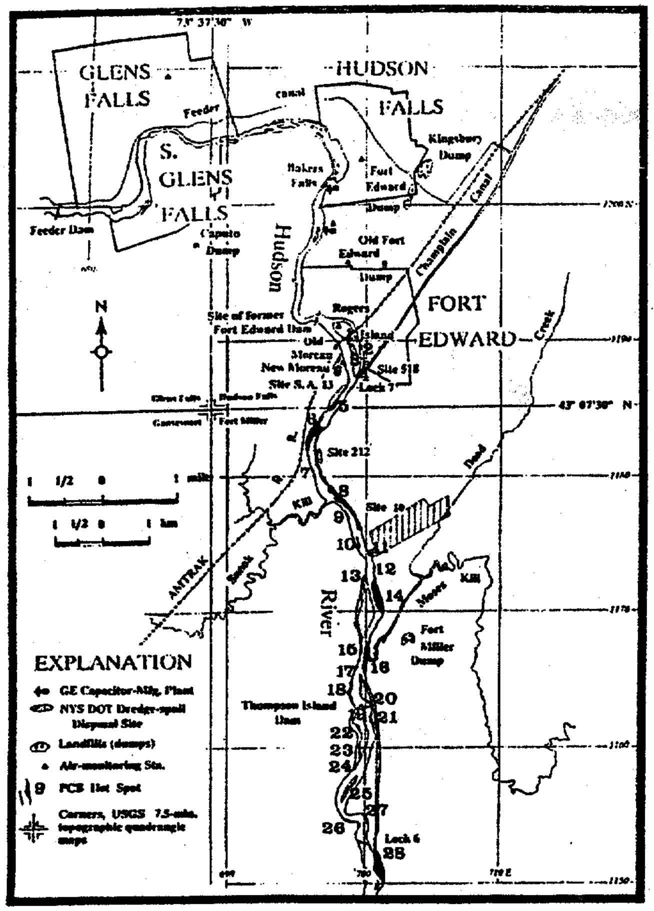


Figure 4. Map of Glens Falls-Fort Edward area showing locations of points of interest in connection with the PCB-pollution situation and the PCB hot spots from Rogers Island to the vicinity of Lock 6 (Redrafted from NYS DEC map in Hetling, Horn, and Tofflemire, 1978, Fig. 13, p. 35; and from MPI map, Pl. 2 in US EPA, 1981a, and with NYS 10,000-foot grid lines and USGS quadrangle map borders added.)

shape of the channel was recorded on a recording echo sounder (hereafter, DEC transects). The second survey, done by Normandeau Associates in 1977 (hereafter referred to as the Normandeau transects), consisted of echo-sounder transects at approximately one-mile spacings in the upper River. On these transects, locations were determined using the new base map and electronic navigation equipment. The third, carried out by Raytheon in the Thompson Island pool, combined closely spaced recording echo-sounder transects, the new base map, and the use of electronic navigation equipment (hereafter, Raytheon transects). The Raytheon survey led to the preparation of a detailed bathymetric map of the Thompson Island pool.

A typical profile section across the upper Hudson River shows marginal flats underlain by silty/clayey sediments in thicknesses up to 3 meters and a wide channel floor underlain by a thin (usually 1 meter or less) carpet of coarse sand/gravel resting on deformed Ordovician bedrock (Figure 5). This distribution of sediment has complicated the taking of sediment cores during the surveys carried out for the purpose of determining the locations and depths of PCB-contaminated sediments. The marginal fines can be cored easily simply by pushing or pounding a plastic tube into them. The coarse channel-floor lag can be cored only by means of more-elaborate techniques discussed in a following section.

An additional factor related to the upper river is the series of

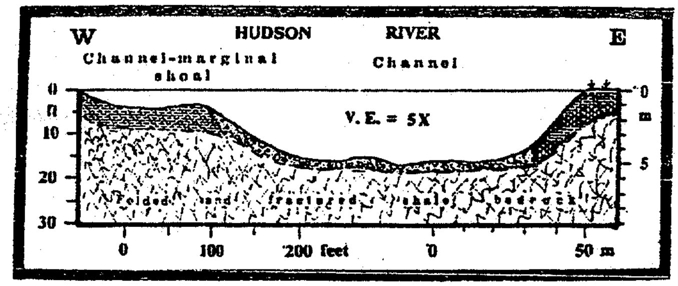


Figure 5. Schematic profile-section across upper Hudson River showing typical channel depth and width and adjoining channel-margin flats. Based on numerous echogram transects in files of NYS DEC, U. S. Geological Survey, and Normandeau Associates, Inc., and results of coring by Normandeau Associates in 1977 and by NYS DEC personnel in 1978. (Redrawn from J. E. Sanders, 1982, Figure 7, p. 10.)

dams associated with the Hudson-Champlain barge canal. For the most part, this canal follows the river's natural channel. In a few places, however, the canal has been cut through the bedrock beside the river.

Dams On Upper Hudson River; Hudson-Champlain Division of New York State Barge Canal

Between Hudson Falls and the Hudson Estuary opposite Troy, are seven dams that have been built to obtain water power (to be used directly to operate factories or to generate hydroelectric power) and/or to control the flow for navigation (Figure 6). Most of these dams are associated with locks on the Hudson-Champlain Barge Canal. An eighth dam site is situated at Fort Edward (1191.9 N-696.5 E, Hudson Falls quadrangle), but the dam that formerly existed there was removed in 1973. Because of its location, only a short distance downriver from the two wastewater-discharge pipes at the GE capacitor-manufacturing plants at Hudson Falls and Fort Edward, this former Fort Edward dam has been a significant factor in nearly every aspect of the problem of PCB pollution of the Hudson River. Accordingly, in a following section, I summarize the history of the Fort Edward Dam and the effects of its removal in 1973.

The Hudson-Champlain division of the New York State barge canal makes use of the upper Hudson River between the Federal dam at Green Island and a point just south of the village of Fort Edward, where the canal has been cut through the landscape in a northeast direction, away from the river, which swings to the west and then continues to the north. Seven dams and 7 locks enable small boats and barges (43.5 by 300 feet with a maximum draft of 12 feet) to navigate between the Hudson Estuary and Lake Champlain. As is explained in following sections, the New York State Constitution commits the State to maintaining the canals. Over the years, the navigation channel has tended to accumulate sediment. Thus, keeping the channel open for navigation has required repeated dredging. Incidentally, such channel-maintenance dredging operations have removed much PCB-contaminated sediment from the river.

Hydrologic Relationships: Water Discharge

USGS measurement network

A network of gaging stations for monitoring the upper Hudson River is maintained by the Water Resources Division of the USGS (locations shown on Figure 3). Results from this monitoring disclose the variations in discharge (shown by plotting the annual average daily discharge of the upper Hudson River) and the relationship between the discharge and rainfall (indicated by plotting the records from Albany and from New York City (Figure 7).

The 100-year flood flow of the Hudson River at Fort Edward is 50,000 cubic feet per second. This value is about 110,000 at Waterford, and 220,000, at Green Island (Darmer, 1987, Fig. 5a,

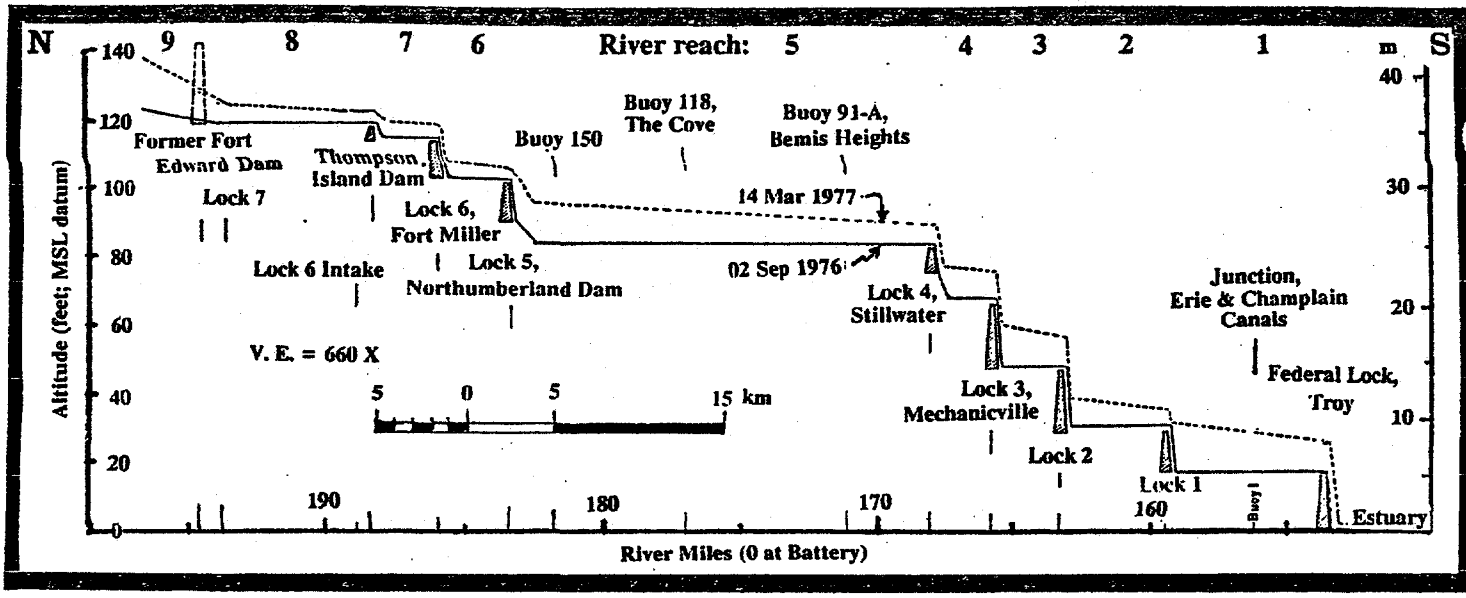


Figure 6. Profile of upper Hudson River showing dams built for navigation. (NYS DEC.)

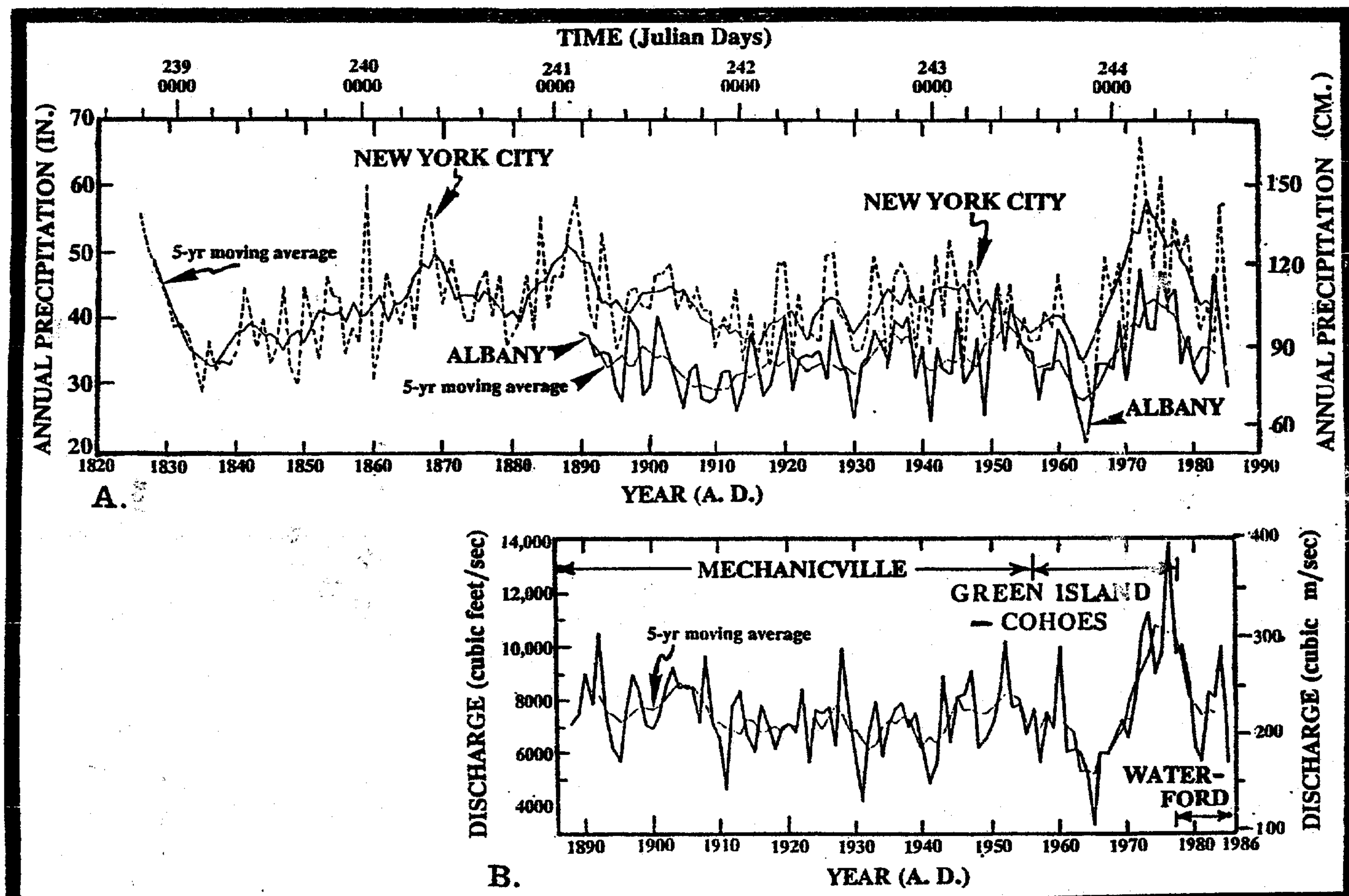


Figure 7. Rainfall at Albany and New York City compared with discharge of upper Hudson River.
A. Rainfall at New York City (1826-1985; dashed curve), at Albany (1890-1985; thicker solid line), and 5-year moving average (thinner solid line), based on U. S. Weather Bureau records. (Modified from K. I. Darmer, 1987ms, Fig. 3, p. 8, by changing size.)
B. Water discharge of upper Hudson River (expressed as mean daily discharge computed on an annual basis at Mechanicville, 1888 to 1956; and at Waterford, 1957 to 1985, based on records by U. S. Geological Survey. (Modified from K. I. Darmer, 1987ms, Fig. 4, p. 20 by changing size to match rainfall curves.)

p. 38). A complete list of maximum known discharge and stage for 326 localities within the Hudson River basin has been compiled by Robideau, Burke, and Lumia (1984).

Empirical studies of the relationship between water discharge and PCB transport into the Hudson estuary have shown that what might be termed the "high-water mode" starts when the daily discharge at Waterford exceeds 600 cubic meters per second (or about 21,200 cubic feet per second; Appendix Table B-2).

The flow of the combined Hudson-Mohawk rivers at Green Island is recorded daily by the USGS. Appendix Table B-2 shows the average daily flows computed for each month from October 1929 through September 1988.

Is discharge of the Hudson River cyclic?

Mathematical analyses of discharge records.– Two attempts to analyze mathematically the time history of the discharge of the Hudson River have been made. Two different sets of discharge records were used; both analyses suggested the presence of cyclic components.

Starting with a table showing average monthly flows at Green Island from October 1947 through September 1975, Texas Instruments International Ecological Services (TI) applied harmonic analysis and multiple regressions. TI found that the discharge data could be reconstructed using 5 major cyclic components: 105, 21, 10.5, 4.2, and 1.9 years. TI wrote:

> "All except the last cycle have periods which are multiples of the value 2.1; this suggests an outside controlling influence. There is some similarity to recurring cycles of solar activity, but the relationship remains to be defined" (TI, 1976, p. IV-12).

In analyzing the so-called "no-action" option as part of the management alternatives explored by DEC for dealing with the problem of PCB-contaminated sediments in the upper Hudson River, Lawler, Matusky, and Skelly Engineers (LMS) followed the TI cyclic approach (LMS, 1978, 1979; Apicella, 1984). The LMS forecasts of future river discharge (the critical variable in trying to predict future PCB transport into the estuary) were made by analyzing the average daily flows computed on a monthly basis at Spier Falls (1178N-653E, Corinth quadrangle) for the period 1930-1977 (computed by the Hudson River-Black River Regulating District). These values were then related to the flow of the combined Hudson-Mohawk rivers at Green Island, as recorded daily by the USGS.

Neither of these research groups found the longer list of monthly flows at Green Island that had been compiled by the New York City Bureau of Water Supply (1929 through 1945; continued thereafter by data from the USGS, such data being added by me after 1976 to complete Appendix Table B-2).

Ken Darmer, retired hydrologist formerly with the USGS, and the compiler of Figure 7, remarked on the graph as follows:

> "Extreme periods of precipitation, either high or low, are of concern because of their effect upon the environment. The extreme drought of the 1960's, followed by a series of wet years in the 1970's, imply that precipitation may follow some cyclic pattern rather than being entirely random" (Darmer, 1987 ms., p. 6).

Reaction to claims of cyclic discharge.– Although DEC accepted the LMS report advocating cyclicity as a basis for projecting future discharge, this acceptance has not been universal. For example, a contrasting, stochastic viewpoint was expressed about the LMS use of a 20-year flow cycle for projecting future discharge by the EPA's contractor, the NUS Corporation, who reviewed the LMS work as part of a study of the upper Hudson in preparing a Superfund Remedial Action Master Plan (RAMP). In response to my written comment in support of the LMS use of a 20-yr. flow cycle and the NUS RAMP's lack of recognition of the possibility of cyclic variations in the flow of the upper Hudson River, the NUS staff wrote the following official EPA response:

> "The 20-year flow cycle was apparently incorporated into the model (refers to LMS model) as a convenient time period for projecting model results. The 20-year flow pattern was identified on the basis of statistical evidence, and its validity must be considered in relation to the limitations of the statistical analysis. For example, based on the analysis of only 48 years of data, the LMS model indicates a tendency for high flows to occur at 20-year intervals. However, since (sic) runoff events are associated with a component of random variation, high flows can occur at any time. More importantly, the inherent inadequacies of the model (e. g., overestimation of PCB transport during high flows) largely overstate the importance of the 20-year flow cycle" (NUS Corporation, April 1984, Response to comments, Vol. II, Hudson River PCBs Site; NUS Project Number 0723.01, revised by EPA, September 1984, p. ES-5).

Fundamentally contrasting concepts: stochastic vs. cyclic.– Darmer's comment about cyclicity and the NUS/EPA mention of random variation go straight to the heart of a longtime, continuing, and not-yet-resolved scientific debate about the fundamental nature of the Earth's environmental variables and the nature of the mathematical relationships that should be used to characterize them most accurately.

The subject of whether such atmospheric variables as pressure, rainfall, and temperature are stochastic or cyclic is one guaranteed to start a heated argument among scientists of these contrasting schools of thought. (Compare the remarks of Lorenz, 1968; Hasselmann, 1976; Komintz and Pisias, 1979; or Pittock, 1979, on the stochastic side, with those of King, 1973; Currie, 1987; or Fairbridge and Sanders, 1987, in support of the cyclic concept.) Those advocating the stochastic point of view generally proceed on the proposition that the Sun's output of energy is constant (members of their school coined the term "solar constant"). Based on their ideas about nuclear reactions that give rise to the Sun's radiation, many prominent physicists in the 1960s were firmly convinced in favor of this supposed constancy. So entrenched was the solar-constancy viewpoint that in the 1960s, when the U. S. National Aeronautic and Space Administration (NASA) was soliciting suggestions for scientific instruments to be placed on the surface of the Moon by the U. S. astronauts, the final list did not include an instrument to measure solar radiation uninfluenced by the Earth's atmosphere. Evidently this priceless opportunity to record solar radiation was not deemed to be a significant scientific experiment. [Times change. Such measurement is now deemed important, and is being carried out from the Solar-Maximum Mission satellite (Solar Max). The results show that the Sun's output is not constant but varies by as much as 0.1 percent, with important consequences for the Earth's weather. In my judgment, the failure to deploy an appropriate instrument on the Moon for measuring solar radiation ranks at the top of the twentieth-century's list of scientific blunders.]

The standard response of a stochastic partisan to one who tries to suggest cycles is that in the absence of a demonstrated mechanism to connect putative cyclic function and a cyclic cause, cyclicity must be denied. Many partisans of the stochastic school disdain attempts to work from the opposite end, namely by interrogating time-series evidence to look for evidence of cyclicity (Pittock, 1978, 1979, 1983).

Some generally accepted natural cycles.– The partisans of the stochastic viewpoint will grudgingly concede that some important natural cycles, such as day vs. night, the seasons, and the astronomic (lunar-solar) tides, for example, do exist and that these cycles demonstrably influence certain processes on the

Table 4. Some short-period lunar-solar cycles
(Compiled from Pettersson, 1912, 1914b, 1930).

Cycle	Period
Earth's rotation/ Moon's orbit	
Twice daily	11 hours, 50 minutes
Daily	23 hours, 50 minutes.
Monthly (cycle of lunar phases)	29.531 days (synodic period).
Seasonal (coincidence of syzygy phases with lunar- and solar declination)	Quarterly (syzygy and maximum north lunar declination in June, the month of the summer solstice, hence maximum north declination of the Sun in the Northern Hemisphere; syzygy and Moon above the Earth's Equator in March and September, the months of the solar equinox; and syzygy and maximum south lunar declination in December, the month of the winter solstice, hence maximum south declination of the Sun in the Northern Hemisphere)
Perigee/syzygy cycle (the time required for lunar perigee at one syzygy phase to return to this same phase again after coinciding with the other syzygy phase).	14 months
Lunar node-apse cycle (the time required for the apse and node, explained below, which move in opposite senses, to coincide).	2.998 years
Lunar apse cycle (the time required for a complete progression of the lunar apse, i. e., the long axis of its orbit, within the plane of the Moon's orbit).	8.849 yr.
Lunar nodal cycle (the time required for the Moon's node, that is, the line formed by the intersection of the Moon's orbital plane and the plane of the Earth's orbit, to rotate 360 degrees).	18.6134 yr.

Earth. A clear and undoubted connection has been established between the cyclic variations of sea level and the variation in the gravitational tide-generating forces. The periods of the various lunar-solar cycles have been determined. A few of the short-term cycles include those shown in Table 4.

These periods and others are the bases for the harmonic analyses used to compile the annual predictions of times and heights of high- and low water in coastal localities (Schureman, 1958).

As an example of working on the problem of cyclicity from the "opposite end," consider the compilation of the relationship between severe coastal storms and the lunar perigee-syzygy cycle (Fergus Wood, 1978, 1985).

Various planetary influences on rainfall have been suggested in the past (for example, M. O. Johnson, 1946).

Recent results based on spectral analyses of various time series of weather-bureau records of precipitation and of atmospheric pressure have shown the importance of the 18.6-year cycle (the period of the lunar-nodal cycle; Currie, 1987).

Two contrasting viewpoints have been expressed about such mathematical demonstrations between a time series and one or more cyclic periods. According to one viewpoint: "Harmonic analysis, of course, is not adequate to prove the reality of cycles. It simply serves to measure possible periodic features of data, and it has the unique advantage that it always reproduces the original data" (Marvin, 1923, p. 666). According to an opposite viewpoint, the demonstration of a coincidence between the frequency peaks shown by spectral analysis of a time series of a geologic proxy record of climate, for example, and the periods of cyclic perturbations of the Earth's orbit constitutes proof of extra-terrestrial control (Imbrie and Imbrie, 1980). Many modern workers accept the validity of a coincidence between spectral-frequency peaks of certain cyclic variations in the Earth's orbital parameters and climate cycles even in the absence of an accepted hypothesis for how an extra-terrestrial forcing function may control a climatic variable on the Earth (or in the presence of an erroneous hypothesis about such a connection).

Some investigators who have found a 20-yr. period in their data have reported it as such. For example, Mock and Hibler (1976) reported finding a 20-yr. period in the observed temperatures in eastern North America. Hibler and Johnsen (1979) found a 20-yr. period in Greenland ice cores. By contrast, others who have found such a period in analyzing time series have not recognized it as an independent entity, but rather have considered it to be some kind of average between 22 +/- yr. Hale cycle of suns[illegible] polarities and the 18.6-yr. lunar nodal cycle or have treated it "beat" frequency between these two (Roberts, 1979; Guiot, 19[illegible]). In his spectral analyses of Hudson Valley temperature records, Thaler (1987) found several peaks, at 28 yr., ca. 10 yr., 6 yr., 3.6 yr., and ca. 2 yr. Of these, the statistical confidence level of greater than 95 percent was attained only by the peak at 9.8-yr., which is approximately half of the period of the Saturn/Jupiter lap cycle.

Orbit of the Sun: a long-ignored basis for solar cyclic variation.-- Recent emphasis on the importance of the Sun's orbit around the center of mass of the solar system (Jose, 1965; R. M. Wood and K. D. Wood, 196[illegible]; Pimm and Bjorn, 1969; Blizard, 1969, 1987; Landscheidt, 1976, 1981, 1983, 1984, 1987; Mörth and Schlamminger, 1979; Fairbridge and Sanders, 1987) and the connection between the Sun's orbit and positions of the planets (Fairbridge and Sanders, 1987) have established an entirely new and hitherto ignored physical reality. Yet to be demonstrated is a complete chain of causality between Sun's motion and Sun's output, and between Sun's output and environmental variation on Earth. Nevertheless, even in the absence of such a chain, the existence of the Sun's orbit and its dependence on planetary motions demonstrates some new solar-system cycles that merit further study. For example, because its orbit is in response to the forces exerted on it by the orbiting planets, the Sun's orbit is both cyclic and predictable. I emphasize the point about predictability because this contrasts with the lack of predictability (and thus lack of acceptance by many) of variations of environmental factors and a widely known example of a solar cycle, that of numbers of sunspots. The Sun's orbit and related variations in solar activity must now be considered as a heretofore neglected but significant physical reality.

The Sun's chief orbital response is to the changing positic[illegible] of Jupiter and Saturn. The orbital periods of these two planets are such that Jupiter gains about 90 degrees on Saturn in just under 5 years. Thus, if Jupiter and Saturn and the Sun start out in a line with Jupiter and Saturn on the same side of the Sun, then in about 10 years, these three line up again, but now with Jupiter and Saturn on opposite sides of the Sun (Figure 8). After about 20 years from the starting alignment, Jupiter gains a "lap" on Saturn and all three again fall along a line but with Jupiter and Saturn on the same side, as at the start (but now about 120 degrees away from the original line). The period of this Saturn-Jupiter lap cycle is just about 20 years (19.8). For further discussion of the solar cycles, see Fairbridge and Sanders (1987).

Predictions based on the concept of cyclic discharge.-- In their projections, LMS presumed that the flows during the 20-year period of 1957 to 1976 would be repeated during the forecast period of 1977 to 1996. Figure 9 shows the LMS forecast of mean daily flows for the calendar years based on a projected repetition of a 20-year cycle (heights of lined bars). The +symbols indicate the computed mean daily flows calculated from 365 daily observations from 1978 through 1985 as given in the USGS's annual reports. Only in 1979 and 1982 do the observed flows come close to matching the predicted flows. However, the observed flows do display a cyclic aspect. (See also Figure 7.)

If the cyclic interpretation proves to be correct, then it will provide a significant basis for understanding and predicting fundamental ecologic conditions in the Hudson River. A key task remaining to be done is mathematical analysis of the time history of flow variation.

I argue that if the flow of the Hudson River is cyclic, then it must be by a complex function of several cycles that are interacting with relative proportions of each not yet known. Cycles whose effects seem to be present include those having periods of: 14 months (a coincidence with the period of the lunar perigee-syzygy cycle, as emphasized by Fergus Wood, 1978, 1985), 18.6 years (a coincidence with period of the lunar-nodal cycle, a time period emphasized by Currie, 1987), and about 20 years (a coincidence with the 19.8-year period of the Saturn-Jupiter lap cycle, as explained by Fairbridge and Sanders, 1987).

The whole subject of possible extra-terrestrial cyclic influences on the Earth's environmental processes is very controversial. Although acceptance of the Milankovitch factors and related terrestrial climatic cycles having periods from about 20,000 to 100,000 years seems to be growing (Zeuner, 1959; Broecker, 1966, 1968; Broecker, Thurber, Ku, Matthews, and Mesolella, 1968; Hays, Imbrie, and Shackleton, 1976; Imbrie and Imbrie, 1980; Berger, Imbrie, Hays, Kukla, and Saltzman, 1984), nearly all efforts relate climate changes to cycles having periods from a few

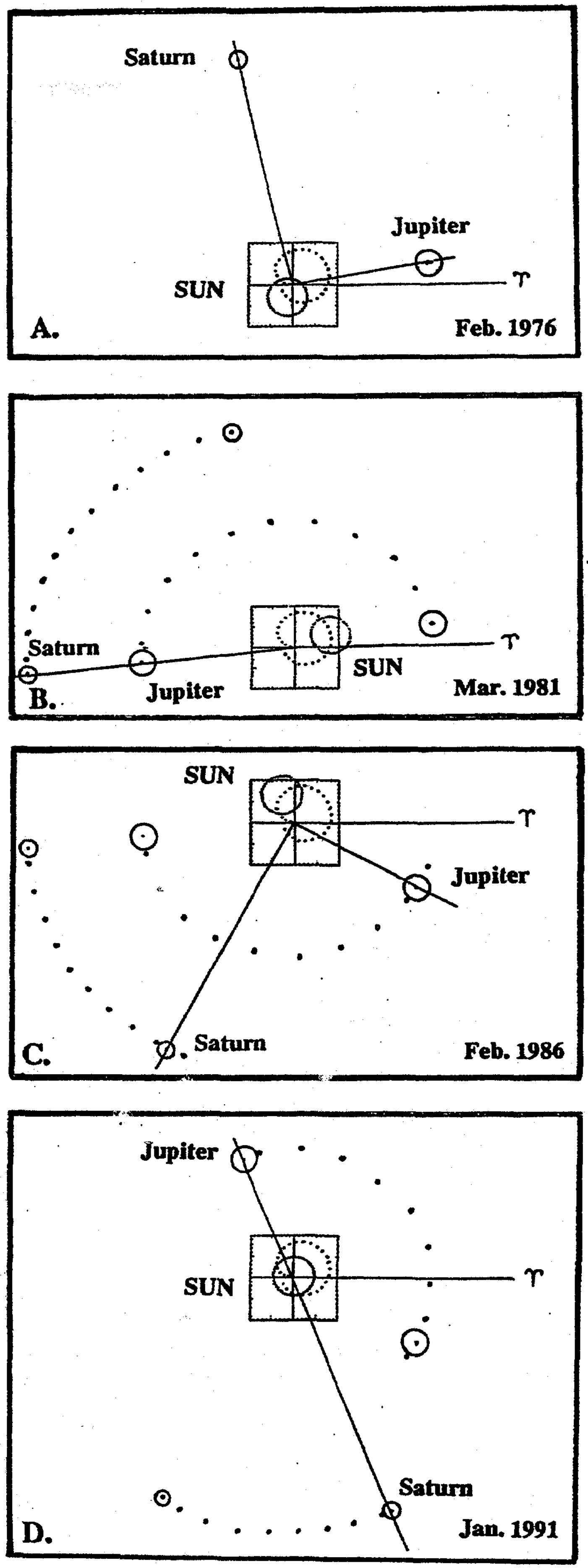


Figure 8. Relationships of Jupiter, Saturn, and the Sun during the current solar orbit shown by schematic "maps" of positions in the X-Y plane (Earth's equatorial plane extended outward in all directions). Intersection of axes that bisect the small reference squares (each measuring about 3 million km on a side) marks center of mass of solar system. Positions of centers of Sun, Jupiter, and Saturn iterated at intervals of 200 Julian days (dots); data from NASA JPL computerized ephemeris, computations from JPL tapes made at NASA's Goddard Institute of Space Studies, New York, N. Y., hand plotted. The direction of the positive X axis is the equinox of 1950.0

A. In February 1976, Jupiter and Saturn were situated about 90 degrees apart. The center of mass is within the Sun, but the center of the Sun is far enough away from the center of mass so that the center of mass lies close beneath the Sun's surface.

B. In March 1981, Jupiter and Saturn were aligned. The Sun has moved far enough away from the center of mass on the opposite side from the Jupiter-Saturn alignment so that the center of mass lies completely outside the body of the Sun.

C. In February 1986, Jupiter and Saturn are 90 degrees apart and the Sun occupies an opposing position. Notice that the center of mass still lies completely outside the body of the Sun.

D. In January 1991, Jupiter and Saturn will be aligned, but on opposite sides of the Sun, which is now very close to the center of mass of the solar system. (Redrawn from J. E. Sanders, 1981, Figure 1.5, p. 23.)

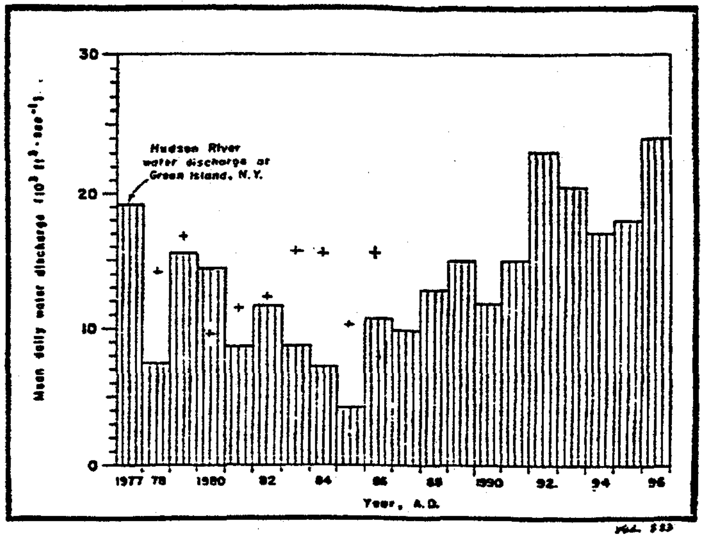


Figure 9. Projected mean daily water discharge of Hudson River at Green Island, New York (rectangles with parallel lines), 1977 through 1996, as prepared by Lawler, Matusky, and Skelly Engineers (1978) for NYS DEC, based on the supposition that the 20-year cycle of discharge variations from 1957 through 1976 detected by analysis of the monthly means in the flow at Spier Falls, 1930-1977 would be repeated in the time period 1977 through 1996. Plus signs indicate computed average daily-discharge values computed for a year (calendar-year basis) of values recorded at Green Island gaging station by U. S. Geological Survey. (LMS, 1978; with annual daily average discharges values 1978-1986 added by J. E. Sanders, 1988.)

years to a few hundred years and based on positions of planets in their orbits tend to be passed off as "astrology." Recognition that the configurations of the planets in their orbits exert the fundamental control on the Sun's orbit, however, places this whole subject on an entirely new and different footing. Still to be determined are what, if any, connections exist between the Sun's demonstrated orbit and its radiation regime and how any such solar variations can affect the Earth's weather/climate patterns (Landscheidt, 1987; Fairbridge and Sanders, 1987).

DISCOVERY OF PCB POLLUTION IN UPPER HUDSON RIVER: RELATIONSHIP TO DISCHARGES FROM GE CAPACITOR-MANUFACTURING PLANTS; NYS DEC ACTION TO END GE'S PCB DISCHARGES

The early history of the discovery of high PCB levels in Hudson River fish is obscured by NYS DEC's initial policy of ignoring the evidence. According to Sofaer (1976b), "High concentrations were found in Hudson River fish as early as 1972." This remark ignores the evidence published by Robert Boyle in October 1970. In 1974, much of the PCB contamination was traced to the GE discharge pipes (Nadeau and Davis, 1974). After Boyle had published two additional articles, NYS DEC banned all fishing in the upper Hudson River and closed the commercial striped-bass fishery in the Hudson Estuary and commenced an administrative proceeding against GE to stop the PCB discharges.

Robert Boyle's Discovery Of PCBs In Hudson River Fish And NYS DEC's Stonewalling

Author Robert Boyle first learned of widespread contaminants in fish at the annual meeting of the American Littoral Society held at Hunter College in 1968-69. Wayne Toddy, a biologist from the Michigan Division of Natural Resources, presented a paper showing high contents of DDT in Coho salmon, a species which had been successfully introduced into the Great Lakes to counter the lampreys and alewives that had entered via the St. Lawrence Seaway and had devastated the previous fish population. Biologist John Clark, U. S. Fisheries Laboratory, Sandy Hook, suggested to Boyle that a good project would be to sample coastal game fish for chemical pollutants.

Boyle persuaded the editors of Sports Illustrated Magazine to fund the proposed sampling-and-analysis program. Specimens were collected from off the California coast, Gulf coast, and east coast. Included were striped bass netted by Boyle in May 1970 during their spawning run in the Hudson River near Montrose. The analyses were carried out by the Wisconsin Alumni Research Foundation (WARF) Laboratory in Madison, Wisconsin, under the supervision of Dr. Francis Coon. The fish specimens were handled as specified by Dr. Coon; they were shipped to the laboratory in dry ice without ever being wrapped in plastic.

The original program of laboratory analyses included chiefly pesticides, such as DDT and DDE. While the project was in midstream, Boyle read an article by Robert Risebrough and others (Risebrough, Reiche, Peakall, Herman, and Kirven, 1969) on the widespread occurrence in the biosphere of PCBs. Boyle then telephoned Dr. Coon in Madison to ask that PCBs be included in the analytical program. This was done, with surprising results. High values were found in most of the fish. The highest values were in the Hudson River striped bass (4.5 to 5 ppm in the fish flesh; 11 to 12 ppm in the eggs).

The results appeared in an article published by Sports Illustrated Magazine in October 1970 (Boyle, 1970). Thinking that what he had found would be of importance to the State of New York, and that state officials might not have read his article, Boyle sent a letter about his results to Carl Parker, Chief of the Bureau of Fisheries in the New York Conservation Department. [This letter elicited what Boyle described as a "derisive" reply. But, without publicizing their activities, NYS DEC began to test fish. They did not announce their results until August 1975, after Boyle had written two more articles (Boyle, 1975a, b).]

The significant point about the striped bass collected by Boyle from the Hudson River in 1970 is that they showed elevated levels of PCBs even before the Fort Edward Dam had been removed in 1973 and thus prior to the great downriver surges of PCB-contaminated sediments in 1974 and 1976.

US EPA Region II's Samples

In August 1974, a team from the scientific staff of US EPA Region II investigated the upper Hudson River at a GE discharge pipe, and both downstream and upstream from it. They collected samples of the water, of the riverbank sediments, of a few kinds of fish, and of snails. Laboratory analysis at the US EPA facility in Edison, New Jersey, was by computerized gas chromatograph/mass spectrometer (GC/MS). They found elevated levels of PCBs at the GE-discharge stream and at two stations up to a half mile downriver from the GE plants. (The DEC copy of this report is marked CONFIDENTIAL.)

Their results are summarized in Table 5.

At Station 3, they reported that the bank sediments represent a "remnant of an industrial era gone by. The bank sediments consist of gravel, cinders, lumber slabs and bark from logging activities, forty years ceased...." They mentioned the removal of the Fort Edward Dam and the change from a tranquil pool to: "a rushing, roaring river that has cut new channels through the bottom deposits, exposing once buried (sic) trees, logs, several model T's, baby carriages and boulders (Figure 13 and 14). Needless to say, the biomass and community structure is (sic) rather sparse and deprived" (Nadeau and Davis, 1974).

In assessing their laboratory results, they began by comparing the chromatograms from their samples with those from PCB standards. The obtained a sample of Aroclor 1016 from GE and from Research Triangle Park. They also compared the mass spectra. They remarked (p. 9):

Table 5. US EPA Region II stations and sample results, upper Hudson River Survey (Nadeau and Davis, 1974).

Sta.	Location
0	In impounding area 0.5 mi N. of Baker Falls
1	At outfall of GE plant, where effluent enters HR
2	E bank of HR, 0.25 mi S of Sta. 1
3	E bank of HR, 0.25 mi S of Sta. 2
4	W bank of HR, 0.25 mi S of Sta. 3

Control Area:

Region II Lab. No.	Sample	PCB (micrograms/gram, wet) 1254	1248	Total PCB
46031	4 yellow perch	4.0	13.0	17.0
46031	131 shiner minnows	2.0	5.0	7.0
46031	snails (composite)	0.3	1.6	1.9

Below GE discharge:

Lab. No.	Sample	PCB as 1242 (microgram/gram)
46035	1 rock bass	350
46036	42 shiner minnows	78
46033	snails (composite)	45
46036	snails (composite)	27

Station	PCB as Aroclor 1016 Water (micrograms per liter = ppb)	Sediments (micrograms per gram = ppm)
0	< 1.0	6.9
1	2800	6700
2	2.2	540
3	(3.0); (3.1) dupl.	2980
4	< 1.0	6.6

"A confusing issue is that Aroclor 1016, although definitely analyzed in water and sediments by computerized GC/MS, was not clearly discerned in the biological tissues. The problem is particularly bothersome for interpreting the meaning of the contamination levels relative to section 504 (FWPCA)."

They raised the possibility that other sources of PCB exist. In their analysis of this subject, they noted that PCB contaminates sediments at Station 0; they inferred that such PCB might have come from the paper companies upriver.

With respect to the 350 ppm of PCB found in a rock bass, they wrote that this constitutes a "new record for PCB contamination of fresh water (sic) fish." It is higher than the values that Nisbet and Sarofin (1972) found in any US industrial river (Nadeau and Davis, 1974, p. 14).

In conclusion, Nadeau and Davis (1974 p. 15) wrote: "Other sources of Aroclor 1016 are present upstream from the General Electric Outfalls." Therefore, "The General Electric facility at Ft. Edward is a contributory source of PCB's to this waterway, and not a sole source."

NYS DEC's samples

Although, as mentioned, NYS DEC's initial response to Robert Boyle's letter about PCB contamination in fish was a "derisive" letter, a point was reached when NYS DEC could no longer suppress nor ignore the public-health aspects of PCB pollution from the two General Electric Company (GE) capacitor-manufacturing plants at Hudson Falls and Fort Edward. After these two plants had been identified as the point sources of the PCB pollution, NYS DEC attempted to assess the extent of the contamination. NYS DEC monitored fish and started to collect core samples of sediments from a network of stations and to analyze the cored sediments for their PCB contents.

On 08 September 1975, Commissioner Ogden Reid announced that PCB concentrations in a bass caught near the GE plants were 350 parts per million (the rock bass reported by Nadeau and Davis, 1974). The averages (parts per million) of several catches on 26 August 1975 at Waterford were: smallmouth bass, 41.5 and 53.5; white suckers, 28.2 and 48.9; and walleyed pike, 32.4.

Table 6 shows PCB values in fish caught during 1975-77 in various parts of the Hudson River.

Table 6. PCB values in edible flesh of fish caught in various parts of the Hudson River/Estuary system during 1975-77. (Horn, Hetling, and Toffiemire, 1978, Table 8, p. 23 and Table 9, p. 24; data from Ron Sloan, DEC).

Location	Species	Average length (mm)	Number of fish	Total PCB (ppm) Average	Range Low	Range High
1975-76 data, resident species:						
Upstream of Hudson Falls:	Smallmouth bass		26	Trace		
	Yellow Perch		15	Trace		
Fort Edward to Federal Dam (Troy)	Smallmouth bass		11	72.6	41.5	122.9
	Yellow Perch		10	134.6	79.3	299.3
	White Sucker		37	68.2	28.2	131.4
	Largemouth bass		37	61.7	12.5	164.4
Federal Dam to Battery	Yellow Perch		05	5.28	-	
	Largemouth bass		10	10.05	1.73	23.74
	White Perch		23	10.08	5.28	19.88
1977 (April & May) data, migrant species, Hudson Estuary:				PCB (as Aroclor 1254) (ppm) Average		
Poughkeepsie	American shad	513	39	1.14		
	Striped bass	516	28	15.6		
Peekskill Bay	Striped bass	518	61	12.2		
Tappan Zee Bridge	American shad	498	30	0.55		
	Striped bass	552	38	9.3		

GE Discharges

The GE discharges were from plant clean-up water. From the early 1950s to 1973, most of the PCBs came "from the practice of washing Aroclor 1242 (or 1016) from the outside of flood-filled small AC capacitors with water and detergent and then discharging the washings without treatment" (J. F. Brown, Jr.; Wagner; Bedard; Brennan; Carnahan; May; and Toffelmire, 1984, p. 168). The discharged washings with their PCBs went into the Hudson River. As soon as the newly established US EPA organized its NPDES program, GE applied for and received a discharge permit.

Historical records (1957-1975)

GE obtained its PCBs from Monsanto. Information about purchases comes from GE's plant records, made public in the 1976 administrative proceeding set in motion by NYS DEC (further details in a following section); from the article by J. F. Brown, Jr., and others, just cited; and from an analysis of Monsanto's records (Limburg, 1985). According to J. F. Brown, Jr., and others (1984, p. 168), Aroclor 1254 was used exclusively at the Fort Edward plant (small capacitors) from 1946-1950, and at Hudson Falls (large capacitors) in 1952-1953. In the early 1950s, Aroclor 1242 was introduced into both plants. It formed 25 percent of the 1953-55 usage at Hudson Falls and 20 percent of the 1950-1955 usage at Fort Edward. From 1955 into the early 1960s, the proportion of 1242 was increased to 95 percent of the usage at both plants. From 1964 to 1971, Aroclor 1254 was used for DC capacitors only and its proportion dropped to 1 percent of the combined total. From 1971 to 1977, all purchases were of Aroclor 1016, a variety having about the same properties as 1242, but containing fewer of the higher-chlorinated congeners and thus less toxic (Drinker, Warren and Bennett, 1937, p. 284-285).

Between 1957 and 1975, GE purchased PCBs in quantities ranging between 2000 and 4,500 metric tons (tonnes; 4,400,000 to 9,900,00 pounds) per year (Limburg, 1985, p. 122). Total purchases have been estimated at 60,500 tonnes (133,100,000 pounds). The amount that went into the river in the plant clean-up water was an unknown small fraction of that very large total. According to a plant manager's estimate during the 1976 proceeding, the losses were less than one percent (one percent would be 605 tonnes, or 1,331,000 pounds).

GE NPDES permit from US EPA under CWA

On 18 December 1972, GE filed an application for a permit from the US EPA requesting authorization for the discharge into the Hudson River of PCBs in amounts ranging from 30 to 47.6 pounds per day. The data submitted with the application are shown in Table 2.

In the fullness of time (on 31 January 1975, to be exact), the US EPA granted a PCB-discharge permit to GE, authorizing the discharge into the Hudson River of 30 pounds of PCBs per day.

NYS DEC Finally Takes Action

The mid-1970's must have been awkward times for NYS DEC. From many parts of the world, reports about the widespread distribution of PCBs were appearing with increasing frequency. (Risebrough, Reiche, Peakall, Herman, and Kirven, 1969; Zitko and Choi, 1971; Nisbet and Sarofin, 1972a, b; Ahmed, 1976a; Risebrough, 1976). When the fish in the Hudson River were found to be polluted with PCBs well in excess of the tolerance limit of 5 parts per million that had been set by the U. S. Food and Drug Administration (US Commissioner of Food and Drugs, 1972, 1973) DEC must have felt caught in the middle. They were supposed to administer the SPDES permit (granted via US EPA under the NPDES) that in effect sanctioned the GE discharges of 30 pounds of PCBs per day. Yet at the same time, the US FDA tolerance limits meant that NYS DEC had to respond to the public-health situation by banning the PCB-polluted fish. After two more articles had been published by Robert Boyle (1975a, b), Commissioner Ogden Reid took action. He issued a fishing ban and moved against GE to force an end to the PCB discharges.

DEC ban on Hudson River fishing

In September 1975, Commissioner Reid closed the entire upper Hudson River freshwater fishery and the commercial fishery for striped bass in the Hudson Estuary. As shown in Table 6, the fish between Fort Edward and Troy contained several tens to several hundreds of parts per million of total PCBs. The FDA action limit on PCBs in edible fish flesh at the time had been set at 5 ppm. The PCB levels in most samples of striped bass from the estuary fell in the range of 10 to 15 ppm.

NYS DEC administrative proceeding against GE

Background.-- On 08 September 1975, NYS DEC announced the start of an "administrative proceeding" against GE alleging violations of NY State Environmental Conservation Law (ECL) sections 11-0503, 17-0501, and 17-0511, with three goals:

1. Cessation of PCB discharges,
2. Penalties, and
3. Rehabilitation of the upper Hudson River.

Commissioner Reid appointed Abraham Sofaer, of the Columbia University Law School, to be the Hearing Officer to preside over the proceedings. The preliminary hearings started on 05 October 1975. Several groups, including the New York State Department of Commerce, the Natural Resources Defense Council, the Hudson River Fishermen's Association, the Hudson River Sloop Restoration, and the Federated Conservationists of Westchester County sought to intervene as parties. The issue of intervention was briefed and argued. On 19 November 1975, Sofaer issued a decision and opinion admitting all applicants as parties under certain conditions and limitations.

Phase I: merits of the alleged violations.-- The first phase of the hearings was devoted to the merits of the alleged violations. After extensive discovery, 11 days of evidentiary hearings commenced. Much of the evidence of upriver pollution was based on NYS DEC reconnaissance-type surveys of the river and river-bottom sediments (details in another section). During the proceeding, GE attorneys engaged Olko Engineering to provide them with a private, broad-brush opinion on estimates of how much it would cost to determine extent of pollution and to clean up the polluted reach of the upper river. (By having this estimate be a matter between Olko and its attorneys, GE did not need to disclose the existence of this estimate to NYS DEC as part of the "discovery" process whereby contending parties are free to peruse each other's document files and are obligated to hand over new materials as they arrive. Had the estimate been made directly to GE, the law required that the existence of the estimate be divulged to NYS DEC.)

After an adjournment, on 09 February 1976, Hearing Officer Sofaer issued an interim opinion. He dismissed GE's alleged violations of 11-0503, but sustained those of 17-0501 and 17-0511.

Phase II: remediation.-- The second phase involved further discovery and additional hearings. A petition for intervention was filed by the Associated Industries of New York, Inc., and granted. NYS DEC claimed that GE should be required to clean up the PCBs that it had discharged into the Hudson River.

The 1976 Hudson River PCB-Settlement Agreement.-- After several months of negotiations, in which the Hearing Officer functioned as mediator, the principal parties worked out an agreement that was fully reviewed and accepted by the intervenors.

In a long memorandum dated 07 September 1976 and addressed to NYS DEC Commissioner Peter A. A. Berle, Hearing Officer Sofaer recommended that NYS DEC accept the proposed settlement in which NYS would be awarded its objective number 1 (cessation of PCB discharges); would drop objective number 2 (penalties); and would settle with respect to objective number 3 (rehabilitation). Sofaer explained the background that led to the Settlement Agreement and cited numerous arguments in favor of its acceptance.

Sofaer commented about the proposal that the NYS DEC relinquish its demand that GE "be required to clean up the PCBs it has discharged into the Hudson" "in exchange for GE's $3 million participation in a clean-up project and its $1 million research commitment described in Exhibit 1 of the Agreement." Sofaer reminded the Commissioner that

> "The Department has never claimed that it has adequately demonstrated that a clean-up (sic) would be practicable or environmentally proper. It claims in its briefs only that GE be required to undertake or pay for a comprehensive study to determine whether a clean-up (sic) should be undertaken and how it can be accomplished, if at all. Testimony at the hearing by Department witnesses makes clear the possibility that the study may show that reclamation is environmentally undesirable or technologically impracticable."

DEC witnesses had estimated that the study would cost $0.75 million; and full dredging from Hudson Falls to Troy, $12 to 20 million. (The Olko Engineering private estimate to GE's attorneys was $8 or 9 million for the study and perhaps $250 million for full dredging.) Given the settlement, $6 million is available for reclamation, and such money is available immediately "to study and take action to correct the condition of the river."

Sofaer also cautioned Berle that the

> "assumption that GE could and would be required to restore the Hudson"..."cannot safely be made. New York law contains no explicit authority for ordering reclamation, except in special circumstances not applicable in the present case."
>
> "An effort to impose the full costs of reclamation on GE, in other words, might ultimately result in a ruling that no such cost may be imposed."
>
> "A final and impelling consideration in weighing the proposed settlement is time."

If NYS DEC were to order GE to carry out a comprehensive study,

> "One could expect, therefore, that an order requiring a study would result in a full series of appeals before it became final and enforceable. Under New York law, this could potentially mean three stages of review, easily consuming two years.
>
> "At that point the study would commence, and would take about one year, according to Department witnesses. The study results would undoubtedly be a separate matter for controversy. A hearing might be required on what action is proper in light of the study, and a separate appeal process might result on whether a decision to require reclamation is lawful and reasonable."
>
> "Delay is especially important to avoid in this case because of the persistent and accumulative nature of PCBs and their movement in the Hudson. They are being continually absorbed by creatures of all types and sizes, and passed up the food chain to fish. The evidence also shows that they are now passing over the Troy Dam into the lower Hudson, and may cause extensive damage, possibly avoidable if reclamation is promptly undertaken."

The proposed agreement would enable NYS DEC to undertake the study immediately.

"High concentrations were found in Hudson River fish as early as 1972. In 1973, the federal Food and Drug Administration established a 5 ppm limitation in the edible parts of fish."

"But none of the agencies with jurisdiction over the matter took any action with respect to GE. The federal Environmental Protection Agency claimed to lack statutory authority to act, in fact, because it could not establish a danger to the public health. See 33 U. S. C. par. 1364 (1976). The FDA's standard did not regulate discharges, and contained no enforcement mechanism..."

"Our legal system lacks devices for requiring agencies to participate in rectifying their own failures."

"Hopefully, the federal government will also assume a share of the clean-up responsibility, just as its actions contributed to making reclamation necessary."

"The settlement brings no sure solution to a serious and difficult ecological problem. But it does assure that a comprehensive study will occur, and that several millions of dollars will be spent to remove PCBs and improve the Hudson, if those measures are necessary and practicable..."

Commissioner Berle agreed and the Agreement was signed on 08 September 1976. The details of the Agreement follow in the next section.

NYS DEC - GE SETTLEMENT AGREEMENT: HUDSON RIVER PCB SETTLEMENT ADVISORY COMMITTEE ESTABLISHED

The major provisions of the Settlement Agreement are as follows:

I - GE agrees to cease PCB discharges by 1 July 1977.

II - GE agrees to construct wastewater-treatment facilities at its Fort Edward and Hudson Falls plants.

III - GE agrees to undertake $1 million worth of in-house research "to be approved prior to being undertaken by the Commissioner after his consultation with the advisory committee" in amounts of: $400,000 on "the environmental compatibility of its substitute non-PCB dielectric capacitor fluids"; $400,000 on "research and pilot plant (sic) studies" on "physical, chemical and biological means for the removal and treatment of PCBs"; and $200,000 on research related to "the effect on the environment of not more than three (3) substances which may be hazardous to the environment" to be named later by Commissioner of DEC after consultation with the Advisory Committee. (By mutual agreement upon recommendation of the Advisory Committee, this $200,000 was used to pay for PCB monitoring in Hudson River fish. The Advisory Committee had earlier rejected a request from GE to use this $200,000 for research on the effects of bacteria on PCBs.)

IV - Both parties agree to concept of "joint culpability"; NY State agrees that GE violated no laws.

V - A Settlement Fund was established with a value of $6 million ($3 million cash from GE to the State of New York; $3 million "in cash or in kind" to be matched by the State of New York) to carry out studies and/or rehabilitation with respect to PCB-contaminated sediments in the upper Hudson River.

VI - The Hudson River PCB Settlement Advisory Committee was established at the insistence of the environmentalist intervenors who had been granted Party Status to the Proceeding. The charge to this Committee was to advise the Commissioner of DEC on all matters related to the studies and/or rehabilitation of the upper Hudson River and expenditures from the Settlement Fund (further details in the following section).

VII - The agreement does not constitute any "finding of any issue of fact or law, or evidence or admissions by any party with respect to any issue in this proceeding, or be construed as, or operate as, an admission that General Electric has violated any law or regulation or otherwise committed a breach of duty at any time, and shall not constitute, in this proceeding or any other proceeding or litigation or otherwise, any evidence or implication of any such violation or breach of duty. No amount of the settlement contribution by General Electric constitutes a fine or penalty."

VIII - NY State "signed off" with GE as far as further action over PCB pollution of the Hudson River is concerned.

Origin and Charge of Advisory Committee

The Hudson River PCB Settlement Advisory Committee was established under par. 3(c) of the Settlement Agreement of 08 September 1976:

"The Commissioner of Environmental Conservation (Commissioner) will establish an advisory committee consisting of independent experts, governmental, and private interests which will, at regular meetings, review and make public recommendations to the Commissioner concerning the scope, content, programs and results of the programs, studies and expenditures for which provision is made in paragraph 3(b). In addition, the Department will furnish the advisory committee with any interim report(s) and final report(s) of the research described in Exhibit 1. The advisory committee will continue to function throughout the comprehensive program concerning PCBs and related environmental concerns."

In the event that the funds set aside by the settlement proved to be inadequate for implementing remedial action to assure protection of public health and resources, NYS DEC was charged with using its best efforts to "obtain additional funds, from sources other than General Electric" and to report periodically "to the Advisory Committee concerning its progress in implementing the plan of action."

Finally, under par. C. of Exhibit 1, "General Electric will conduct research, itself or by contract, as specified by the Commissioner of the effect on the environment of not more than three (3) substances which may be hazardous to the environment and which are to be selected by the Commissioner after his consultation with the advisory committee."

Organizational Meeting

The first meeting of the Advisory Committee took place on 26 October 1976, with the following membership:

Dr. David Axelrod (NYS DOH)
Prof. Raul Cardenas (civil engineer, Polytechnic Institute of NY)
Richard Dewling (US EPA, Region II, Edison, NJ)

Arthur Glowka (Hudson River Fishermen's Association)
Dr. William J. Nicholson (biomedical researcher, Mt. Sinai, New York City)
Professor Dominick J. Pirone (biologist, College of Mt. St. Vincent, (Manhattan College)
Prof. John E. Sanders (geologist, Barnard College, Columbia University, New York City)
Prof. Dwight Sangrey (civil engineer, Cornell University, Ithaca, NY)
Joseph Stellato (for Dugan, NY DOT)
Dr. Gilman D. Veith (chemist, U. S. EPA, Duluth, MN)
Charles Walker (biologist, US Fish & Wildlife Service)

Absent:
Robert Engler (US Army, Corps of Engineers)
David Sive (attorney, New York City)

The Committee elected Paul Cardenas to be Chairman, and Dominick Pirone, Recording Secretary. At the second meeting, on 19 November 1976, John E. Sanders was elected to be Vice Chairman.

At the first meeting, I raised the possibility that sediments in the Hudson Estuary had already been polluted by PCBs from upriver sources. Dewling suggested that the US EPA Edison Laboratory might be able to perform a screening survey if requested to do so by the Commissioner of NYS DEC. Accordingly, a subcommittee consisting of Cardenas, Sanders, and Sangrey agreed to remain after the meeting adjourned to draft a letter to US EPA for Commissioner Berle's signature. (This was done and the requested screening survey took place in December 1976; see following section: DEC's PROPOSED DREDGING OF PCB HOT SPOTS, Mapping of PCB-contaminated sediments.)

Initial Frenzy Of Activities

After their studies of the problem in connection with the Administrative Proceeding against GE, and in September 1976, after the Settlement Agreement had been signed and before the first meeting of the Advisory Committee, the DEC staff had carried out a series of sediment-coring and cross-river profiling operations in the upper Hudson River. They had concluded that dredging the contaminated sediments was the only feasible method for rehabilitating the river. They had commissioned Malcolm Pirnie, Inc. (MPI) to make preliminary estimates of volumes of contaminated sediments to be dredged and costs. But before any dredging contracts could be let, however, much more information about the distribution of PCBs would be required. Therefore, mapping of the PCBs by collecting and analyzing a large number of sediment cores would be necessary. By the end of October 1976, they had already prepared and distributed Requests for Proposals (RFPs) on mapping, coring, and laboratory treatment of cores, including analyses for PCBs. They had received back proposals from various potential contractors and were prepared to move ahead to implement these. The Advisory Committee insisted on evaluating the proposals received, as is explained in a following paragraph.

Because their position about dredging had proved to be controversial, the DEC staff inquired if the Advisory Committee thought it would be able to reach a verdict of "go" or "no go" on the proposed remedial dredging by March 1977 (6 months after organizational meeting). The NYS DEC staff's stated purpose in making this request was that should the Advisory Committee adopt a favorable recommendation, then DEC would be able to begin remedial dredging in the summer of 1977. The Committee agreed that they could meet the March 1977 deadline; to do so meant that many projects that might otherwise have been done in series would have to be carried out in parallel.

The first six meetings of the Committee included rancorous episodes over selection of contractors and attempts to persuade DEC staff to modify their ideas about how the study should be undertaken (for example, about how the cores to be collected should be handled and processed). After several requests by Committee members that the subject of potential liability to individual members be addressed, Phil Gitlen, of NYS DEC's legal staff, attended a meeting and reminded the members that their charge was to "advise the Commissioner." This salient point had been lost track of and once it had been brought to the Committee's attention, nearly all the friction between NYS DEC and the Committee ceased. Instead of trying to persuade the staff to do this or that, the Committee simply composed a recommendation to the Commissioner. When the message came to the staff via the Commissioner's office, they complied promptly.

Some of the projects the Committee undertook in its early months included: assisting the DEC staff in designing the proposed study elements and in preparing requests for proposals (RFPs) on these elements to be distributed to prospective contractors; assisting the DEC staff in evaluating proposals submitted; studying various dredging equipment; preparing a written statement of Committee procedures (published in NYS DEC July 1977 report: Hudson River PCB Study Description and Detailed Work Plan); trying to formulate a research agenda about the Hudson River for the Commissioner of DEC; and assisting DEC staff in preparing monitoring plans.

The Committee floundered over two recurring items on its agenda: (1) that it name for the Commissioner the three toxic substances called for in the Settlement Agreement that GE would study; and (2) that it compile a research agenda for the Hudson River. After much effort, the Committee submitted its conclusions, but these departed from what DEC had asked.

To focus the discussion, two subcommittees were created. On 26 January 1977, the toxic-substances subcommittee was appointed. It consisted of Charles Walker, Chair, and included Gil Veith and William Nicolson. On 30 March 1977, in my meeting with him as new chairman of the Advisory Committee, Commissioner Berle emphasized that as part of his effort to seek federal assistance for river rehabilitation, he needed a written research agenda for the Hudson River. On 30 March 1977, a subcommittee to prepare a long-range research plan was appointed with Sangrey as Chair and Sanders, Dewling, and Walker as members.

The first goal of the toxic-substances subcommittee was to try to keep any recommendation consistent with a list of toxic substances that was in preparation within Walker's agency, the US Fish and Wildlife Service. On 20 June 1977, Walker reported that the subcommittee would review the status of Federal studies and report in July. On 27 July 1977, Commissioner Berle prodded the Committee to give him the list so that GE could start work. Commissioner Berle hoped that GE's proposed research could be made the basis for attracting other funding to study the water-quality needs of New York State. Walker responded that his subcommittee had been active and was trying not to duplicate the national effort and also to take advantage of the DEC survey of New York industrial effluents.

On 22 August 1977, Walker reviewed the national effort to identify high-priority toxic substances. He listed 3 categories: (1) halogenated hydrocarbons; (2) petroleum hydrocarbons; and (3) heavy metals (especially lead, mercury, cadmium, chromium, copper, and zinc, as found associated with PCBs in the contaminated sediments of the upper Hudson River). On 27 September 1977, Walker and Mason reported on the results of their visit to Gil Veith about the 3 toxic substances. They presented their list of the three to be named. On it were: (1) dichlorobenzene; (2) alpha-benzopyrene; and (3) cadmium.

The full Committee prepared a recommendation to Commissioner Berle that also discussed the kinds of research for GE to do. Included were adequate analytical techniques, compilation of mass balance, biologic significance, and interactive relationships with other contaminants. The Committee also recommended that GE pursue such questions as: How much is present? What is it doing to the biota? It recommended that sampling be concentrated near places where the contaminant is known to be present, as at Foundry Cove, where high levels of cadmium had been discovered (H. J. Simpson, Bower, Williams, and Li, 1978).

On 19 January 1978, the DEC staff reported that the Commissioner had accepted the Committee's report on the Three Toxic Substances. However, no action would be taken until DEC had received the expected first printout of the Industrial Chemical Inventory. The DEC staff added that some of the work recommended, such as sampling, was considered inappropriate; instead, they felt GE should concentrate on environmental- and health effects.

By 06 March 1978, the DEC staff had reviewed the results from the Industrial Chemical Survey and presented to the Committee a plan that GE be asked to concentrate on petroleum hydrocarbons. After the Committee approved this request, the DEC would ask GE to present a plan of study and submit it for approval. When Commissioner Berle joined the meeting, he was asked if GE could be asked to study the effects of their new capacitor fluids, the Dielektrols, rather than petroleum hydrocarbons. No resolution was reached on this question.

The plan GE submitted was to carry out research on the aerobic-bacterial degradation of PCBs. The Committee rejected this proposal, and the matter remained pending for several years. Finally, the Committee recommended to the Commissioner, and both he and GE agreed, that the GE money set aside for research on the 3 toxic substances would be used to pay for analyses of PCBs in fish as part of the ongoing monitoring of the river.

On 27 April, the Committee recommended to the Commissioner that William Dovel, fisheries expert of the Boyce Thompson Institute, be engaged as a consultant to help draft an overall research plan for the Hudson River fisheries. Included were two specific charges: (1) that Dovel work with the group carrying out mathematical modeling of PCBs and fish in the estuary (Hydroscience) to find out if they were missing anything, and if so, to help them fill in the gaps; and (2) that he be asked to design an overall research plan for how to gather the data to quantify the Hudson River fisheries.

On 24 May 1977, Sangrey led the discussion based on a list of 6 questions he distributed. He emphasized the need to focus on management-oriented research directed toward the river as a fishery, as a water resource, and as a recreational resource. At the following meeting (23 June 1977), further discussion centered on the importance of knowing the effects of PCBs and possibly other toxic substances on fish, wildlife, and people.

The list of Committee queries is:

1. What species of fish are edible in view of toxics?
2. Are waterfowl and other wildlife as impacted as the fish?
3. What is the incidence of neoplasms in fish?
4. What informal groups have been trying to develop a research agenda for the Hudson River?
5. Do cooling towers increase PCB transfer from water to atmosphere?
6. Is Sloane-Kettering studying human-health effects of PCBs for GE?
7. What is the biomass of the various trophic levels in the river?
8. Do airborne PCBs add to river contamination?
9. Do experimental data on adsorption-desorption kinetics apply to the river?
10. Should a symposium be planned for Fall?

On 27 July 1977, Commissioner Berle requested that the Committee write up and submit a list of these questions. The Committee also listened to a presentation from R. Henshaw, from the Hudson River Research Council. He emphasized the following five aspects:

1. That researchers take an ecosystem view of the river.
2. That research needs be identified and prioritized.
3. That research be coordinated.
4. That existing data be consolidated.
5. That funding for needed research be secured.

In order to focus on immediate possibilities with the remaining Settlement Fund, at the meeting on 29 November 1977, Pirone suggested that the remaining money from the Settlement Fund be split into four roughly equal categories:

1. Remedial action and/or further studies on technology for remedial action.
2. Research on physical topics (such as volatilization, sedimentation, and PCB transport, to name three).
3. Research on biological topics with ecologic emphasis (phytoplankton, zooplankton, fish, biodegradation).
4. Public health.

To this list was added the work already in progress that should be given further support: at Poughkeepsie and Waterford water-treatment plants, on the biology of lower trophic levels, and on computer modeling of alternatives for river rehabilitation.

Eventually, the Committee decided that the broad research plan for the River that the Commissioner had in mind was something it could not do. Instead, it recommended that the four categories listed above guide the research effort for the immediate future; it recommended that a special task force be convened to deal with the broad research plan.

Changes in Initial Membership

The current committee includes four members who were present as members at the organizational meeting: Glowka, Pirone, Sanders, and Stellato; and Hetling (who was DEC Project Manager). Changes made over time resulted from reassignments within organizations represented on the Committee, various personal reasons, or desires by the Committee to enlarge its scope by adding new members.

The first change was made in December 1976, when John Zammit replaced Robert Engler as the Corps of Engineers representative. In January 1977, Veith released a letter to the press related to Committee business in violation of the agreement that only the Chairman would talk to the press. Veith was asked to resign. His letter of resignation was read to the meeting on : April 1977. He was replaced by Clifford Rice (who joined the Committee on 06 March 1978 and is still a member). At its first meeting, the Committee expressed the need for having a hydrologist. On 27 April 1977, Ken Darmer, a retired hydrologist from the U. S. Geological Survey, became a member.

At its first meeting, the Committee requested that GE be asked to send a representative to Committee meetings. As its principal representative, GE designated Paul Griffen, and as alternate, Charles McFarland. Griffen was promoted to another job that did not permit him to continue attending Committee meetings. McFarland replaced him and has continued attending Committee meetings. Since his retirement from GE, he has served GE in the capacity as a part-time consultant.

When Dr. David Axelrod became New York State Commissioner of Health, he appointed Dr. Leo Hetling, former NYS DEC project manager, as a Deputy Commissioner in the New York State Department of Health (NYS DOH) and also NYS DOH representative to the Advisory Committee.

Cardenas resigned from the Chairmanship on 25 February 1977, but remained on the Committee as a member for another year, when he resigned for personal reasons. Dewling left the Committee as US EPA Region II's representative and was replaced by Bob Mason, and Mason, by Pat Harvey. (In January 1989, Harvey took over the division dealing with the Construction Grants Program of CWA, the division that would supervise the cleanup of the Hudson River using sec. 116 funds. Thus, his continued membership on the Committee was deemed to be inappropriate. He has been succeeded by M. Chang, the current member). Nicholson lost interest and Sangrey left because he accepted other jobs that left no time for the Committee's demands. Walker was replaced by Michael J. Stoll. This agency decided to discontinue its membership on the Committee when the Committee's role changed after it had recommended the dredging option. Zammit has been replaced by other representatives from the U. S. Army Corps of Engineers; these have included Dennis Suszkowski, Philip McGrade, and the current member, Joseph Seebode, Jr. As mentioned, Darmer joined the Committee early in 1977 and thus qualifies as being an almost-original member. Other additions to the Committee are mentioned in following sections.

.dvisory Committee's Prejudices Against Dredging Reversed By Facts Obtained From Monitoring Of Channel-Maintenance Dredging

The Committee's first formal recommendation to the NYS DEC Commissioner addressed channel-maintenance dredging. When the Committee learned of the NYS constitutional mandate for keeping the canal system, the Committee realized that the requirements for keeping the navigation channels open would have to be met. Accordingly, the Committee sent a recommendation to Commissioner Berle that channel-maintenance dredging should be specifically excluded from any Committee-recommended ban on dredging, should the Committee vote to recommend that dredging not be used for rehabilitating the upper river.

The Advisory Committee requested from NYS DEC staff and/or NYS DOT a compilation of previous NYS DOT channel-maintenance dredging. In January 1977, a summary table was distributed. Using this table, I calculated that NYS DOT had already in fact been taking out large quantities of sediment, and from their locations near Fort Edward, it was reasonable to infer that large quantities of PCB-contaminated sediment had already been dredged from the upper Hudson River (Table 7). The Advisory Committee pointed out that the way to determine how much PCB-contaminated sediment had been removed was to make borings at the out-of-river dredge-spoil sites where the sediments had been dumped and to analyze a representative collection of samples. [This Committee connection between former NYS DOT dredging operations, along with information being received from the general public about the locations of PCB dump sites having nothing to do with the contaminated river sediments, led to the Weston study and report and eventually, to remediation of many of the old landfill sites containing PCBs. The ...te of New York later filed a separate legal action against GE ...r seven of these sites. The matter was settled out of court (the so-called "seven-sites agreement") and GE took over the task of their remediation at a cost of about $30 million. These remediation projects were completed in 1988.] In January 1977, the Advisory Committee learned from casual conversations with Richard F. Thomas, engineer for MPI, who had been MPI's chief for the upper Hudson River, that no matter what decision the Committee might reach about dredging, it was already too late for actual remedial dredging to begin in the 1977 work season. This statement was based on the necessity for having a year or so lead time in order to prepare plans and specifications and to secure competitive bids for any dredging operation. However, he added, NYS DOT had "in the works" a channel-maintenance project at the Fort Edward terminal and that the preliminary work had already been done so that this operation could be carried out during the 1977 work season. At this point, the Committee voted to abandon the previous schedule and to defer any decision about dredging as a rehabilitation option and to concentrate on the upcoming 1977 channel-maintenance dredging operation. The Committee recommended that the river be extensively monitored during the 1977 dredging and assisted in the design of a state-of-the-art encapsulation site, the "new Moreau" facility, to receive the highly contaminated dredge spoils. The Committee recommended expenditures from the Settlement Fund so that money would be available to pay for whatever "extra" features the new Moreau facility might require in order to contain the PCB-polluted sediments safely--over and above whatever NYS DOT had already planned. The Committee's position was that it would fall back and re-group. It would take this opportunity to observe first hand a river-dredging operation and to demonstrate that PCB-contaminated sediments could be securely encapsulated in an out-of-the-river facility. Then, with this background in hand, the Committee felt it would be in a secure position for reaching a decision about rehabilitation by dredging. The chance to monitor a dredging operation first, however, meant that the Committee's decision on the dredging proposal would be delayed and could not be expected before Spring 1978 at the earliest, a year later than hoped by NYS DEC.

Table 7. Quantities of sediment dredged by the New York State Department of Transportation in maintaining navigation channels in the upper Hudson River, 1950-1976. (Source: NYS DOT.)

River reach	Quantity dredged (cubic yards) Removed from river	Relocated within river
North of Thompson Island Dam	1,336,662	186,190
Ft. Miller Dam to Northumberland Dam	0	110,171
Northumberland Dam to Waterford Dam	234,503	285,141
Waterford Dam to Green Island Dam	128,884	68,649
Subtotals	1,700,049	650,151
Proportion (percent)	72.3	27.7
TOTAL	2,350,200	

Subcommittees

The Advisory Committee has established two standing Committees: (a) an Executive Committee (composed of the Chairman, Vice Chairman, and Secretary), and (b) a Science Subcommittee (composed initially of Sanders, Sangrey, Mason, Darmer, Hetling, Pirone, and Rice). In addition, from time to time, as mentioned, various subcommittees have been appointed as needed for specific assignments. In addition to the two subcommittees mentioned in a previous section, others are noted below.

At the first meeting, a coring subcommittee, consisting of Cardenas, Sanders, and Sangrey, remained after the meeting to confer with DEC staff about procedures for handling the cores of river-bottom sediments. This subcommittee discussed the need to collect the cores in plastic liners and then to split the cores into two longitudinal halves. One half would be used for analyses and the other, stored as an archive. The subcommittee drew the attention of DEC staff to the procedures followed at the Lamont-Doherty Geological Observatory of Columbia University in handling and storing their large collection of cores of deep-sea sediments. (The Subcommittee never filed a written report, nor was a written recommendation sent to the Commissioner. As a result, DEC staff handled the cores their way. They cut the plastic liners into various shorter segments and sent the entire core cylinder out for PCB analyses. No core archive was established from the 1977-78 cores collected and analyzed.) Subsequently, a written recommendation about handling of cores was submitted to the Commissioner in time to be the basis for treating the cores collected in 1984 from the resurvey of the hot spots in the Thompson Island Pool. The archive halves of these cores were sent to the Lamont-Doherty Geological Observatory of Columbia University.

In connection with the proposed 1977 dredging at Fort Edward, two subcommittees were appointed. The first, on 30 March 1977, to review the Environmental Assessment Statement (EAS) prepared by MPI, consisted of Sanders, Glowka, Axelrod, and Walker. The second, appointed on 27 July 1977, was to review the MPI revised report on the removal of the Fort Edward Dam. This subcommittee, composed of Darmer, Sanders, Stellato, and Walker, focused its attention on the remnant deposits (Figure 10) and thus became known as the remnant-deposits subcommittee.

This group (minus Walker) carried out a crucial site visit on 14 November 1977. It prepared a written report, and presented its impressions orally to the full Committee at its 15th meeting on 29 November 1977. At this meeting, the new MPI report on the conditions associated with the removal of the Fort Edward Dam was distributed. It included 6 alternatives. After the remnant-deposits subcommittee had submitted its report, MPI added a 7th alternative, complete removal of the remnant deposits.

Russell Mt. Pleasant, of DEC staff, indicated DEC preferred alternative 6, removal of some material and riprapping other areas. He pointed out that if the balance in the Ft. Edward clean-up fund were supplemented by $200,000 from the GE Settlement Fund, it would be possible to add a clay liner to the new Moreau disposal site to prevent migration of PCBs from the contaminated debris.

The Committee voted to recommend that DEC proceed to implement the MPI alternative 6, but recommended to the Commissioner that he give the highest priority to doing whatever could be managed in the way of preventing further erosion of the remnant deposits and of carrying out further sampling with a view toward removal of those most highly contaminated. Included were amendments proposed by me that the EAS be prepared to include additional samples for PCB analysis, that a haul road be built as soon as possible down the east valley wall, and that work be started on identifying a suitable disposal site that could contain all the remnant deposits still left along the river's edge.

On 31 March 1978, MPI presented its new draft of the EAS that incorporated the Committee recommendations. After making new borings and digging new test pits in the winter, MPI had found extremely high concentrations in an area of about 10 acres in Area 3; it became area 3A (Figure 11). PCB levels were about 950 ppm in the top foot and less than 3 ppm at deeper levels. MPI estimated that 20,000 cubic yards of debris there contained 30,000 pounds of PCBs.

In the summer of 1978, 14,000 cubic yards from Area 3A, where PCB levels were in the 10,000-ppm range and no plants were growing, were trucked to the new Moreau encapsulation site. (In 1979, after the highly contaminated surficial layer of debris had been removed, plants began to grow.) In addition, the east shore of the river along Area 3 was armored with a solid riprap of stone, brought in via the haul road that the Committee had recommended be built for access to Areas 3 and 3A (for removal of contaminated sediments as well as the hauling in of stone from a nearby quarry).

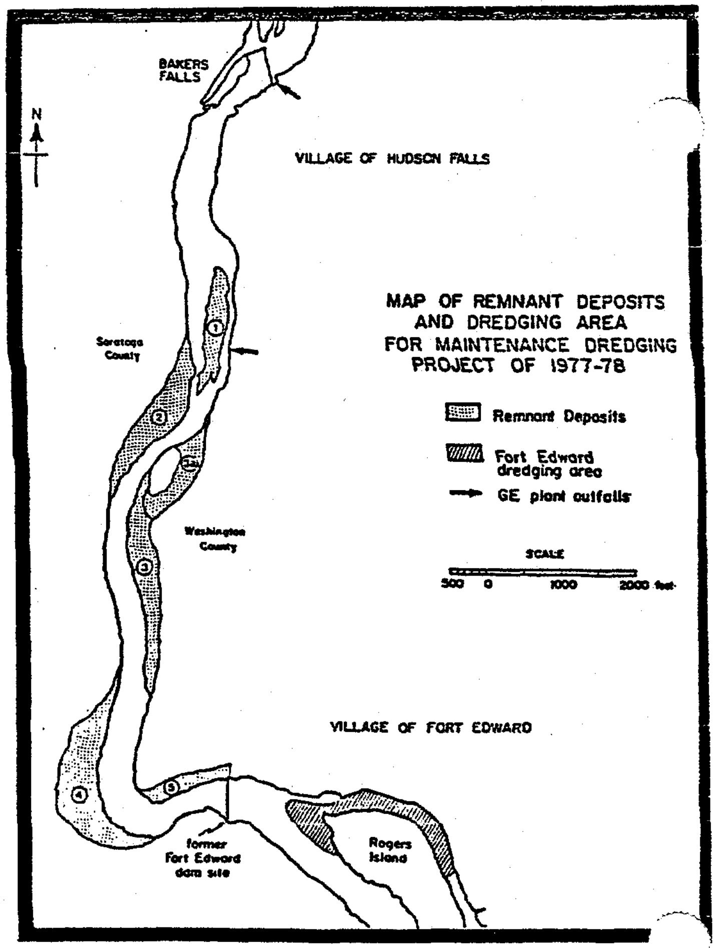


Figure 11. Map of area of former pool backed up behind the Fort Edward Dam. Numbers inside circles within stippled areas indicate areas of remnant deposits as designated and so used in reports by MPI and NYS DEC. (NYS DEC map from Hetling, Horn, and Tofflemire, 1978, Fig. 20, p. 68.)

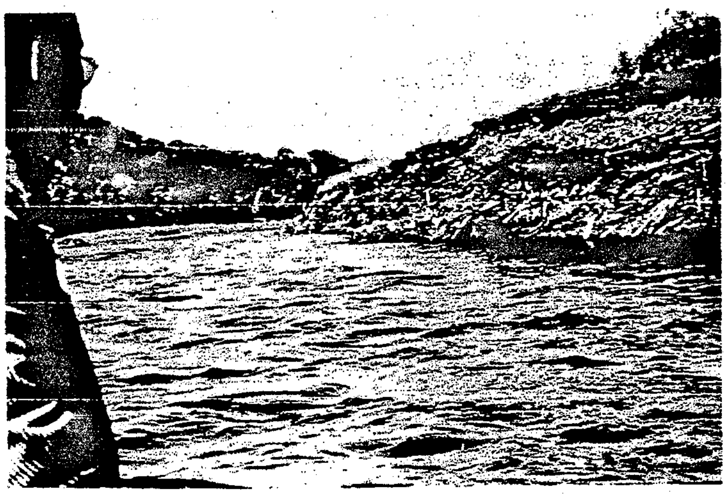


Figure 10. View upstream in Hudson River north of former Fort Edward dam in October 1973, soon after the dam had been removed. Steep banks expose remnant deposits, composed largely of debris from Adirondack lumber mills. In the river just to the right of the man's (Russell Mt. Pleasant, of NYS DEC) profile are two rock-filled log cribs formerly used in logging operations. The steep banks are about 5 m high, the amount the water level dropped after the dam had been removed. (NYS DEC photo.)

Other subcommittees were appointed to plan a public-information meeting (26 January 1977, including Commissioner Berle, Nicholson, Pirone, and Hetling); to prepare the specifications for the recommended photo documentation (27 July 1977, including Sanders, Glowka, and Pirone); to evaluate vibrocoring if cores longer than those collected by Normandeau were needed (Cardenas); to work with DEC and COE to develop a monitoring plan for the proposed dredging of the Albany Turning Basin and at Germantown (on 26 October 1977, composed of Stellato, Darmer, Axelrod, and Pirone); to work with DEC to modify the RFP for the study of the municipal water supplies at Waterford and Poughkeepsie and to help select the contractor (on 29 November 1977, including Axelrod and Nicholson); to review proposals received for biological work (on 19 January 1988, Pirone and Walker); and to meet with GE on their plan of study for three toxic substances (on 06 March 1978, Walker).

Field Trips

Field trips turned out to be some of the most-valuable Committee activities. At the December 1976 meeting, NYS DEC arranged for members to participate in a helicopter overflight of the upper Hudson River. Trips on land have been made to various landfill sites that were heavily contaminated with PCBs, to NYS DOT dredge-spoil sites, to the remnant deposits, and to candidate encapsulation sites. Thanks to the hospitality of the NYS DOT via the DOT representative to the Committee (initially Mr. Joseph Stellato and currently, Mr. John Germano) the Committee has been able to make annual trips via tugboat to inspect various parts of the upper River and the NYS Canal system first hand.

Two particularly significant field trips, which resulted in important changes in the NYS DEC program include that taken to the remnant deposits in September 1977 by a subcommittee composed of Sanders, Ken Darmer, and Joseph Stellato, as already discussed; and a full-committee trip to the new Moreau encapsulation site during its early phase of construction, on 23 August 1977. This new Moreau excursion was one of the few rainy-day trips, but because of all the water at the site, the Committee discovered that the plastic fabric which had been delivered as a permeable filter cloth for the drainage system was in fact not permeable. Fortunately, this situation was discovered and reported to the contractor in time for the correct filter cloth to be exchanged and installed.

Joint Planning With NYS DEC For Contractors' Symposia

The Committee worked with DEC in organizing two symposia at which DEC contractors presented their results, in January 1978, and on 11 and 12 June 1979 (entitled PCBs in the Hudson River, 2 1/2 years of research). A DEC-published report incorporated the highlights of the January 1978 symposium (Hetling, Horn, and Tofflemire, 1978). No comparable summary resulted from the 1979 meeting.

The Committee also deserves credit for raising the level of excellence of the work done by some of DEC's regular contractors, whose representatives regularly attended Committee meetings and heard the wide-ranging Committee discussions and presentations to it. On occasion, a report contains an acknowledgement of the Committee's contribution (for example, MPI, 1978c).

Photographic Documentation Of PCB-related Activities

The Committee recommended and NYS DEC staff and contractors carried out a complete photographic documentation of all aspects of the field work and other activities related to the PCB problem in the upper Hudson River. As a result, an extensive file of 35-mm color slides, black-and-white photos, and movies is now available.

Changing Role Of Committee

After he had received the Committee's unanimous positive recommendation about proceeding with rehabilitation by dredging, Commissioner Peter Berle began to consider where to seek funds to pay for the project. Before he would apply for any federal assistance, he wanted to be certain that the public and particularly, the various environmental groups, supported the proposed rehabilitation. Accordingly, he requested that the Committee expand its role to include meeting with the public and especially with environmental groups to explain why the Committee had reached its position and to seek their support for efforts to find federal funds to carry out the proposed dredging-and-encapsulation project.

In this capacity, the Committee has conducted many meetings at various locations in the Hudson Valley (Piermont, Poughkeepsie, New Paltz, Fort Edward, and Hudson Falls). The first such meeting, held in Hudson Falls High School on 26 July 1978, drew a crowd of 240 persons. Many questions were raised, which I list under five categories: (1) Direct health effects (What is the safe level of consumption of PCBs? Are individual wells along the river contaminated? Will wells near the proposed spoil site be contaminated?); (2) Safety to agriculture (Washington County contains 23 agricultural districts and the value of dairy products produced annually is $40 million; Are PCBs volatilizing from the hot spots now and contaminating adjacent land and vegetation? To what extent do cows pick up PCBs from eating plants contaminated with PCBs? What assurances can be given that farmland adjacent to the proposed encapsulation site will not be contaminated with PCBs?); (3) Construction design and management (many doubts were expressed that the cover design would be able to withstand the area's deep winter frost of 4 to 6 feet with surplus of water during spring thaw and desiccation in summer or that DEC could prevent woodchucks from burrowing into the closed site and thus exposing the contaminated dredge spoil; What happens if a worst-case failure occurs? Where will the PCBs go? How will dust during construction be prevented from contaminating hay and forage crops? During the filling of the proposed containment site, how frequently with the contaminated sediments be covered to prevent volatilization and leaching during construction?); (4) Remarks about the general sloppiness of the 1978 DEC operation (Why was the MPI recommendation to post signs at Area 3A of the remnant deposits to inhibit children from playing there not carried out? What assurances are there that the clay borrow pit used for material lining the new Moreau facility will be cleaned up and restored and not left as an eyesore and a place in which mosquitoes can breed? Why is the new Moreau site being used to contain such PCB-contaminated debris when the MPI EIS states that the natural conditions of the site are inadequate?); and (5) General (What will happen if nothing is done? The audience lustily applauded my response that the PCBs would continue to be eroded and washed down the river.) At the end of the meeting, Mr. R. McGuire (of the local Conservation Advisory Commission) and Congressman Gerald H. B. Solomon called for a one-year moratorium on any construction work until further study can answer the questions raised.

After hearing all these questions and comments, the Committee recommended that its membership be enlarged by two new appointments, one from the general citizenry in the Glens Falls-Fort Edward area and the other from among the dairy farmers. Commissioner Berle agreed and thus were added to the membership Mr. George Muse, a retired teacher of physics and resident of Glens Falls, and Mr. George Allen, a dairy farmer from Washington County.

Committee Cooperation With Hudson River Foundation's Mediation Efforts Between Residents of Washington County and DEC

As part of the Committee's outreach on behalf of its recommendation in favor of dredging, Chairman Sanders held a meeting on December 1983 with Ross Sandler, Executive Director of the newly created Hudson River Foundation for Science and Environmental Research, Inc. (HRF). Also present were Jon Cooper, Science Officer of HRF; and A. Karim Ahmed and Sarah Chasis, of the Natural Resources Defense Council (NRDC). After Sanders had summarized the current situation with respect to NYS DEC's proposal and all the opposition that had arisen in connection with it, Sandler decided that the HRF should take an active role as ombudsman between NYS DEC and the residents of Washington County, who were raising legitimate concerns that NYS DEC seemed incapable of dispelling. Accordingly, a decision was made to organize a one-day workshop in New York City on issues related to PCB dredging in the Hudson River. The date of 19 January 1984 was chosen so as to coordinate with the Advisory Committee's scheduled meeting in New York City on 20 January 1984. All interested persons were invited and HRF agreed to pay for the travel and subsistence expenses of a delegation from Washington County CEASE, Inc. (CEASE is an acronym for Citizen Environmentalists Against Sludge Encapsulation.) The only parties that did not attend were representatives of US EPA and the NUS Corp., US EPA's contractor for the Superfund RAMP, who declined on advice of counsel in view of the then-unsettled lawsuit over the Gorsuch determination about CWA Sec. 116 funds (explained in a following section).

Subsequently, a second meeting was held in Saratoga on 08 March 1984, to seek a basis for negotiation between residents of Washington County and NYS DEC over PCB-related issues. On the day of this meeting, the public announcement was made that the Appellate Division of the New York State Supreme Court had affirmed Justice Thomas Mercure's decision sustaining CEASE's grounds for appealing the verdict to grant permits for the use of a site in Fort Edward to contain PCB-contaminated dredge spoil. Although this meeting to attempt negotiations was well attended, a follow-up meeting drew no one from Washington County. After the court had supported their petition to void the Certificate and permits granted by the Siting Board, CEASE evidently felt they had nothing further to negotiate.

Committee Interest In Methods For Destroying PCBs And/or Stripping PCBs From Contaminated Sediments

The Committee maintains a continuing interest in learning first-hand about proposals for PCB destruction and/or for stripping PCBs from contaminated sediments. In this connection, Committee members have made many site visits and have sent a continuing stream of recommendations to the DEC Commissioner about such matters. Some of these have recommended that Settlement Funds be expended for collecting and sending samples for demonstrations, for supporting bacteriological research on Hudson River sediments, and the like. The Committee was instrumental in working out a close cooperation between NYS DEC and US EPA's Cincinnati research facility, via Charles Rogers. This led to US EPA's contract with the Research Triangle Institute for evaluating various processes specifically as they might be applicable to treatment of PCB-contaminated Hudson River sediments (Carpenter, 1987).

The Carpenter 1987 report found three methods other than incineration that could be used to treat the PCB-contaminated sediments once these sediments had been dredged out of the river. These are: (1) Basic Extraction Sludge Treatment (B. E. S. T.) process of the Resources Conservation Co., Bellevue, Washington; (2) ozone-ultraviolet exposure in an ultrasonic bath developed by Ozonic Technology, of Closter, New Jersey; and (3) microbial scheme of Bio-Clean, Inc., of Burnsville, Minnesota. Two other processes for removing PCBs from contaminated sediments from the upper Hudson River have or are being investigated by NYS DEC and the Advisory Committee that were not considered in the Carpenter 1987 report. These are: PCB stripping by a rising current of heated air, developed by American Toxics Disposal, Incorporated (ATDI) of Waukegan, Illinois; and the steam-gasification process developed by Wright Malta, Inc., of Ballston Spa, New York. Brief summaries of some of these methods follow.

The B. E. S. T. process separates wastes into dry-solid-, oil-, and water fractions, with the PCBs from contaminated sediments extracted with the oil fraction and the heavy metals locked up in the dry-solid fraction. The process is based upon the reverse immiscibility of triethylamine (TEA) to oil-water mixtures as a function of temperature. Below about 70 degrees F, TEA is not miscible with oil/water. Accordingly, solids can be centrifuged out of a mixture of oil, water, and TEA. The centrifuge separates out solids and TEA and the TEA can be recovered, leaving dry solids. Above 70 degrees, TEA is miscible with oil/water; the oil- and water fractions are separated by gravity. The B. E. S. T. process recovers PCBs and other organic compounds in the oil fraction after the treatment of contaminated sediments; the separation does not destroy them. Such destruction is an additional step that must be applied. But, because PCBs are extracted from the sediments and concentrated in the oil fraction, the final destruction would involve far smaller quantities than the large amounts of contaminated sediment that would be dredged out of the river.

In 1987, the Resources Conservation Corporation carried out preliminary laboratory experiments on two samples of PCB-contaminated materials from the upper Hudson valley. These were: (1) A composite sample of river sediments from Hot Spots 2 and 20 in the Thompson Island Pool, containing 22 ppm of PCBs; and (2) a sample from the remnant deposits in Area 5 containing large amounts of wood debris, with PCB content of 960 ppm. The B. E. S. T. process reduced the PCB content of the river sample from 22 to less than 2 ppm; and of the remnant deposits, from 960 to 40 ppm. The large quantity of wood debris as in the remnant-deposit sample and also in many of the hot spots in the Thompson Island pool, evidently represents a special problem for the B. E. S. T. process.

The estimated cost for using the B. E. S. T. process for extracting PCBs from Hudson River contaminated sediments and for rendering the heavy metals non-leachable in the dry-solids fraction is $133.30 per cubic meter for the first 380,000 cubic meters and $73.31 per cubic meter for additional sediments (Table 15, p. 48 in Carpenter, 1987). To this would have to be added the cost of destruction of the PCBs removed from the sediments. The B. E. S. T. process is the only one that has been actually used to clean up a CERCLA site (PCB-contaminated General Refining oil-recycling plant near Savannah, Georgia; job ended on 6 March 1987.)

Ozonic Technology of Closter, New Jersey, has succeeded in cleaning up transformer cases and destroying PCBs using a combination of ultrasonic vibrations and ozone-ultraviolet treatment. The Carpenter (1987) report (Table 17, p. 58) gives cost estimates of $24.19 per cubic meter for a residence time of 9 minutes and $41.02, for a residence time of 18 minutes. NYS DEC has been cooperating with Ozonic Technology in providing samples of contaminated Hudson River sediments for experiments. As of June 1989, no experimental results have been reported. In a laboratory demonstration in a standard ultrasonic bath at the Closter facility, however, ultrasonic energy rapidly broke down a piece of wood dropped into the water.

Several microbial proposals are being investigated by GE, by the NYS Health Department, and by other companies, including Bio-Clean, Inc., of Burnsville, Minnesota, whose process was evaluated in the Carpenter report. According to Carpenter (1987, Table 21, p. 73), the estimated cost per cubic meter of the Bio-Clean process for treating PCB-contaminated sediments dredged out of the upper Hudson River would be $155.94 per cubic meter.

The ATDI PCB-stripping process works in a large vertical cylindrical apparatus in which the sediments are introduced into a rising current of heated air and at the same time ground and subjected to continuous-flow centrifugation. The hot air strips the PCBs from the sediments and conveys them to a collection chamber filled with activated charcoal, where they are recovered and removed for incineration elsewhere. (The action inside the ATDI PCB-stripping machine can be compared to what goes on inside a Pop-air popcorn popper.)

In a set of preliminary experiments carried out in Waukegan, Illinois during June 1984, the concentration of PCBs from the hot-spot sediments from the Thompson Island pool was reduced to a level of less than 2 ppm.

These experiments were carried out under the supervision of US EPA Region V, and as part of the experimental protocol specified by US EPA, PCBs removed from the sediments had to be accurately accounted for. Evidently, ATDI experienced difficulty in accounting to US EPA for the whereabouts in their apparatus of the PCBs that had been stripped from the contaminated sediments.

In 1988, the apparatus has been modified so that it can be transported to a site on a low-loader trailer truck. ATDI has applied to US EPA for a license to operate as a mobile PCB-stripping unit in all 50 states.

The latest candidate process soon to be tested with Hudson River sediments is a steam-gasification process in a reducing environment in the presence of sodium carbonate, a catalyst, that is being prepared by the Wright-Malta Corp., of Ballston Spa, New York, in partnership with Zurn Industries. In earlier versions of the Wright-Malta process, organic compounds, including

PCBs, were introduced into a reducing environment at a temperature of seven hundred degrees C. Under such conditions, organic compounds break down into various gaseous components that are subjected to a high-temperature burn in a turbine, where any remaining PCBs are destroyed and the energy from the combustion of the gases is used to generate electricity. Left-over heat is recycled to warm the reaction chamber. The alkaline environment in the reaction chamber renders the heavy metals in the char fraction nonleachable. Wright-Malta has succeeded in destroying PCBs on a bench scale, but has not yet completed successful engineering-scale tests. If this process passes its forthcoming round of engineering tests, then its advocates plan to build a plant that would generate electricity from feedstock consisting of wood chips, paper waste, remnant deposits, and other PCB-contaminated sediments to be dredged from the hot-spot areas in the Thompson Island pool.

The Advisory Committee has recommended to the Commissioner of NYS DEC that $35 thousand from the GE Settlement Fund be made available in 1988 for engineering tests by Wright-Malta on PCB-contaminated sediments from the upper Hudson River.

Committee's Function As Ongoing US EPA's Citizen's Advisory Committee

After the 1981 US EPA Environmental Impact Statement and evaluation of the proposed hot-spot dredging with secure upland encapsulation, which included a Citizen's Advisory Committee appointed by US EPA Region II, the Committee recommended that the Commissioner inquire of US EPA if a suitably enlarged Advisory Committee could serve as an ongoing CAC to US EPA Region II. Upon receipt of a positive response from US EPA, the Commissioner appointed three new members to fulfill this expanded role: one (Karen Scelzi) from upriver, one (Cara Lee) from the mid-Hudson region, and a third (Linda O'Leary) from the New York metropolitan region.

Executive Committee's Appearance Before Governor's Task Force On Hazardous Wastes

The Governor's Task Force on Hazardous Wastes was established in 1982 to review the problem of hazardous wastes. They held a series of hearings at which the Executive Committee (Sanders, Glowka, and Pirone) testified about the experiences of the 1981-82 request from the first and at that time, the only Siting Board which had been convened under the Industrial Hazardous Waste Management Act of 1978 for permission to use Site 10 in Fort Edward as an encapsulation facility for PCB-contaminated sediments to be dredged out of the hot spots in the Thompson Island pool. The Executive Committee summarized their reactions to the 1981-82 Siting Board hearings and tried to present the problems that had arisen with the residents of Fort Edward and that the State seemed to be able to handle only in adversarial ways, if at all. Glowka summarized his research into the ways in which the Japanese Government compensates citizens in connection with such facilities. I presented some options by which the State might compensate affected residents (decreased assessments or other tax reductions and purchase of "hazardous-waste easements" from individuals; State grants to affected towns) and pointed out how the Canal provisions of the New York State Constitution could serve as a model for establishing some kind of permanent State commitment, particularly of funds, to maintain any kind of long-term encapsulation facility that might be built.

Committee's Relationship to Hudson River Siting Boards I and II

The Committee's interaction with these two Siting Boards differed significantly. Several members of the Advisory Committee testified before Hudson River Siting Board I as expert witnesses on behalf of the DEC application. By contrast, the Committee was totally excluded from participation in Hudson River Siting Board II. At the suggestion of DEC staff, the Advisory Committee filed for Party Status in connection with the preliminary procedures for the hearings. However, the committee voted to persist with its application for Party Status only if such status did not interfere with its primary charge to serve in an advisory role to the Commissioner of DEC. When this vote was taken, the news of Thomas Jorling's appointment as new Commissioner of DEC had just broken. Accordingly, the Chairman was instructed to contact Commissioner-designate Jorling (then a Professor at Williams College) to discuss the proposed application and seek his guidance on the matter. After he had consulted with DEC's legal staff, Professor Jorling informed me that if the Committee were to be granted Party Status, then the only way the Committee could communicate with the Commissioner would be through the Administrative Law Judge. With this clear indication that potential Party Status definitely conflicted with the Committee's primary charge as advisory to the Commissioner, the Committee withdrew its application for Party Status. Subsequently, on the basis of *ex-parte* considerations based on DEC's internal organization, the Committee found that it was cut off from the Commissioner. As a result, insofar as the Committee is aware, its experience and expertise were not made available either to Hudson River Siting Board II or to the Commissioner of DEC.

Miscellaneous Activities Of Chairman

On behalf of the Committee I have attended public hearings held by US EPA, the US Corps of Engineers, and by NYS DEC, and have submitted written comments on various documents connected with these hearings. I have met with congressional delegations, New York legislators, and the Governor's staff; addressed the Dutchess County legislature; attended meetings of the Save-Our-Port coalition; granted interviews to reporters; appeared (with Vice Chairman Glowka) on a phone-in talk show broadcast by the Glens Falls radio station; and was the featured guest on the weekly half-hour television program originating from Channel 62, Kingston entitled: "On the River." I have prepared written depositions in connection with legal actions, and appeared as an expert witness before Hudson River Siting Board I in 1981.

THE "GREAT EXPERIMENT" IN SPREADING PCBs THROUGHOUT THE HUDSON RIVER-HUDSON ESTUARY SYSTEM: REMOVAL OF THE FORT EDWARD DAM AND THE UNCOVERING OF THE REMNANT DEPOSITS

The removal of the Fort Edward Dam in 1973 was undertaken in full ignorance of the high levels of PCB contamination in the unique debris that had accumulated along the shores of the pool of water backed up behind the dam (See Figure 10.). What happened as a result is most aptly described in the words of my colleague, Professor H. James Simpson: it amounted to a "great experiment" in sediment distribution--one that all responsible authorities would surely have rejected outright had any scientist proposed that it be done for the purpose of understanding how the Hudson River and Hudson Estuary work. The saga of the removal of the Fort Edward Dam should rank high up on the list of human folly into which governments wander with the best of intentions. I review this continuing story under the headings of: background and preliminary considerations, removal operation, and some consequences. In a following section entitled UPPER RIVER REHABILITATION BY DREDGING, I summarize the remedial actions taken.

Background And Preliminary Considerations

The Fort Edward Dam was completed in September 1822 to divert water from the upper Hudson River into the Champlain Canal (now referred to as the Old Champlain Canal) via a short feeder canal. In 1843, this feeder was abandoned; it was replaced by one at Glens Falls that connected to the new Champlain Canal. Two years later, the dam was sold to local interests who used its water power. In 1898, the Fort Edward Dam was enlarged and made into a rock-filled timber-crib dam that was 586 feet long and 19 feet high. The enlarged dam

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backed up a water pool that was about 2.5 miles long and 400 to 800 feet wide (MPI, 1975).

The Niagara-Mohawk Power Corporation purchased the Fort Edward Dam in 1953 for the purpose of building a hydroelectric-generating facility using the backed-up water. In order to operate such a generating facility, it is necessary to have a license from the Federal Power Commission (FPC). Niagara-Mohawk was granted such a license in 1968.

The topic of the removal of the Fort Edward Dam began with concerns over public safety and stretched tortuously through the decision-making apparatus of two unrelated governmental agencies. One of these agencies, NYS DEC, was in effect *operating as if its staff had been blindfolded; information about* PCB pollution, of vital consequence to its responsibilities, was being withheld by orders from on high. The effects on the Hudson River of various actions and events connected with the removal of the Fort Edward Dam proved to have been a major environmental calamity, whose consequences have not ended yet. PCB-tagged sediments were spread throughout the entire river system south of Fort Edward, including the estuary and extending into the New York Bight.

According to the FPC Final Environmental Statement of May 1973:

> "A stone dike was constructed in 1969 to protect a section at the south end of the dam which had experienced significant settlement and deterioration due to floods and the age of the structure, coupled with flood damage. FPC engineers have inspected the development and report that the dam is in a deteriorating condition. Thus removal prior to the next seasonal flood flow is recommended to avert the danger of dam failure with resultant damage to downstream areas" (MPI, 1975, p. B-1).

This 1969 stone dike, or cofferdam, did not function too well. In the floods of 1970, it had been breached in two places. Niagara-Mohawk began to formulate plans for a new dam. The company hired Dames and Moore to conduct a foundation study for a proposed replacement gravity dam. Dames and Moore carried out 18 core borings close to the existing dam. Some of these borings showed that the bottom of the pool next to the dam was covered by soft organic silt and paper waste ranging in thickness from 2 to 14 feet.

In December 1970, Clarkeson, Clough & Associates carried out a study to determine the extent of sediments near the dam (to a distance of 300 feet upriver). They found two kinds of fine-grained sediments: (a) brown, fibrous sludge (similar to that found in the Dames and Moore borings), and (b) black sandy silt. They found very little organic silt and discovered that the quantity of the brown, fibrous sludge varied from day to day according to the changes in water level and speed of the flow. Eight samples were subjected to analysis for heavy metals; elevated levels of lead, cadmium, arsenic, mercury, copper, and zinc were found (MPI, 1975, 1978a; Table 8).

After they had reached a decision that the interests of public safety required the Fort Edward dam to be removed, Niagara-Mohawk applied to the FPC, who held jurisdiction over the disposition of the Fort Edward Dam, seeking a license to remove the dam. In contemplating the possible environmental consequences of the dam's removal, however, FPC did not act alone, but consulted with NYS DEC and the U. S. Army Corps of Engineers, New York District Office. NYS DEC joined in the evaluation, but the Corps of Engineers did not. The Corps advertised for comments in Public Note No. 7057, but held that public interest would be protected by the FPC and thus took no further action other than sending to FPC any public comments (MPI, 1975, p. B-3).

Table 8. Heavy-metal content of selected upriver sediments (Malcolm Pirnie, Inc., 1975, 1978a)

Sample	Metal					
	Pb	Cd	Cu	Hg	As	
Fort Edward Dam (brown fibrous sludge and black silt)	234 to 3630 (8)	14 to 138 (8)	27 to 159 (8)	0.28 to 1.28 (4)	3.2 to 22 (8)	74 tc 2950
Remnant deposits	(ug/g)	(ug/g)				
Area 3A	<3 to 5600	6 to 110				
Area 4	20 to *460*	<4 to *12*				
Area 5	40 to 1100	<4 to 93				

(Pb = Lead, Cd = Cadmium, Cu = Copper, Hg = Mercury, As = Arsenic, Zn = Zinc)

A major point at issue was possible adverse impacts on downriver water quality from transport of sediment that had been deposited in the pool behind the dam. The chief points of concern were heavy-metal content (as determined from measurements on the sludge found next to the dam) and particulate matter. Indeed, one of the strongest arguments made in favor of removing the dam, as opposed to taking no action, was precisely the threat of the:

> "...problems of further deterioration of the dam with the eventuality of its washing out during a flood flow and causing unpredictable damage to navigation and private property downstream of the project. In addition, the sludge load, and deposits of industrial wastes (from upstream mills) in the forebay would be washed downstream possibly causing a significant environmental impact on water quality and the river ecology. If such depositions (sic) were to wash out during spawning migration of anadromous fish in the Hudson River below Troy Dam, located approximately 40 miles downstream of the Fort Edward Development, damage to the shad and striped bass (sic) fisheries could occur" (FPC Final Environmental Statement, May 1973, in MPI, 1975, p. B-5).

According to the FPC environmental-impact statement, the proposed dam removal: "will expose about 100 acres of flooded land comprised of strips of firm alluvium averaging about 100 feet in width along either bank of the river." Nothing was indicated about the composition of this "firm alluvium."

After conferring with NYS DEC, the FPC concluded that there is "no practical method of reclaiming the denuded area, and that the area should be allowed to recover naturally." The sludge behind the dam was identified as constituting a possible hazard should it be allowed to wash downriver. In order to forestall this possibility, the sludge behind the dam was to be removed before the dam could be demolished. The FPC staff expressed its position on these matters as follows:

> "The Licensee should take all appropriate erosion control (sic) and preventive measures and if necessary should revegetate all exposed soil surfaces."

At no time in these discussions did anyone consult the Stat Geological Survey of New York, on whose staff was an Envirc mental Geologist. Nearly any geologist could have foreseen the serious consequences that would arise when the upper river would be rejuvenated by dropping its former level by up to 5 meters.

Acting under Sec. 21(b) of the Water Quality Act of 1970 (P. L. 91-224), personnel from the NYS DEC granted a DEC Water-Quality Certificate dated 24 March 1973. According to NYS DEC:

> "There is reasonable assurance that removal of the existing timber crib (sic) dam and adjoining facilities will not contravene the adopted water quality (sic) standards of the State, if work is performed in accordance with the procedures outlined above."

The subject of PCB contamination, then still suppressed within NYS DEC, was not mentioned.

Niagara-Mohawk even secured written assent to their request for removing the dam from the Towns of Moreau (west bank) and Fort Edward and from the Village of Fort Edward (east bank; MPI, 1975, p. B-2).

Given the NYS DEC approval, on 14 June 1973, the Federal Power Commission (FPC) issued an "Order Approving Proposed Amendment of License" to the Niagara-Mohawk Power Company approving the requested removal of Fort Edward dam.

Removal operation

Niagara-Mohawk wasted no time in carrying out the demolition of the Fort Edward dam. They began the dam-removal project in July 1973 and completed it by October 1973. Little did Niagara-Mohawk (or anyone else, for that matter) realize that removal of the dam would set the stage for several mighty surges downriver of debris highly contaminated with PCBs. What happened was that the worst-case scenario projected in FPC's environmental statement cited above, i. e., washout of the dam during a flood and resultant damage downriver, took place anyhow. The result amounted to an extraordinary experiment in the distribution of sediment throughout the upper river and the Hudson estuary.

The immediate consequences of the dam's removal were to expose the "firm alluvium along the banks" (Figure 12), now designated as the remnant deposits, which consist mostly of wood debris that have soaked up high concentrations of PCBs (See Figure 10.).

Some consequences

The "great experiment" in spreading PCB-contaminated sediments began in the fall of 1973, but its consequences were at first noticeable only by NYS DOT's attention to its navigation channel. On 04 October 1973, NYS DOT carried out soundings of the channel because debris eroded from the area of the former Fort Edward Pool were threatening to block the channel. The high-water flows that were to be so important to the "experiment," began in December, 1973. At that time, the only stream-discharge gages on the upper Hudson River were located at Hadley, well upstream from Fort Edward, and at Green Island, well downstream from Fort Edward. (Thus, the discharge at Fort Edward cannot be determined directly, but can be approximated by adding the quantity of water released from the Sacandaga Reservoir to that measured at the Hadley gage.)

The mean discharge at Hadley is about 5,000 cubic feet per second, and that of Green Island, about 15,000 cubic feet per second. The releases from Sacandaga Reservoir aim to keep a minimum of 3,000 cubic feet per second in the river. During floods, reservoir releases may stop (if the reservoir is not full to overflowing). I illustrate the times of high water by listing the days when the flow at Hadley exceeded 10,000 cubic feet per second, and that at Green Island, 30,000 cubic feet per second.

From December 1973 through July 1974, the discharge at Green Island fell in the range of 30,000 to 40,000 cubic feet per second on 25 days; of 40,000 to 50,000, on 8 days; Of 50,000 to 60,000, on 7 days; and in excess of 60,000, on 3 days. During this period, the peak flow of 69,300 cubic feet per second came on 29 December 1973. In the spring of 1974, a sustained period of high flows began on 05 April. A flood peak of 52,000 cubic feet per second was registered on 06 April, and a second peak of 55,700, on 16 April. Two other flood crests exceeded the 50,000 level: on 24 May (50,600), and on 04 July (51,400). The effects of the mid-April flood wreaked havoc that caught everyone's attention. An estimated 850,000 cubic yards of debris were eroded from the river banks north of the former Fort Edward dam and transported downriver. The Fort Edward terminal was clogged with an estimated 790,000 cubic yards of this debris (Figure 13) that blocked the navigation channel for a distance downstream for about three-quarters of a mile. In addition, the Town of Fort Edward's two water lines that crossed at the dam were exposed and several sanitary sewer outfalls and the water-supply intake at the Scott Paper Company were blocked. The debris that had accumulated at the north end of Rogers Island reduced the flow into the east channel to such an extent that the raw sewage that the population of Fort Edward had been discharging directly into the Hudson River was not being flushed away downstream as the residents had grown accustomed to expect. Instead, Fort Edward was in danger of being engulfed in its own excrement. The 94 rock-filled timber cribs, formerly used for logging classification, became fully exposed (MPI, 1975, p. S-1).

Figure 12. View upstream from former Fort Edward dam showing cribs used for timber classification and remnant deposits along the water's edge. (NYS DEC photo.)

Figure 13. View upstream (to west) off north end of Rogers Island, Fort Edward, showing upstream edge of mass of debris that washed down from the remnant deposits north of the former Fort Edward Dam and clogged the Fort Edward terminal (marked by parallel diagonal lines at bottom of Figure 11). (NYS DEC photo taken in April 1974.)

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As for dealing with the problem, the citizens of Fort Edward clamored for immediate action. They saw nothing but virtuous results to be gained from dredging the river as soon as possible. (This contrasts sharply with their positions in the 1980s, when they argued that no possible good would be associated with dredging the river.)

In what I regard as one of the classic environmental understatements of all time, MPI wrote:

> "Apparently the conditions which existed during the Spring of 1974 following the removal of the dam were not anticipated by the State or Federal Agencies involved or by the Niagara-Mohawk Power Corporation" (MPI, 1975, p. I-2).

The political/bureaucratic scramble began immediately. On 26 April 1974, the FPC issued an "Order Providing for Hearing and Prescribing Procedures" for hearings that began on 29 May in Glens Falls and continued intermittently in Washington, D. C., and/or Albany, until 08 January 1975, when they were adjourned *sine die*. These hearings were intended to show that the conditions set forth in their license for removal had been complied with (MPI, 1975, p. I-2 and I-3).

In April 1974, the Attorney General of the State of New York filed a suit for damages against Niagara-Mohawk Power Corporation alleging violation of the permit that had been issued by NYS DEC and other violations. (In the early 1980s, the parties settled for much less than the $5 million spent by NYS DEC and NYS DOT to restore Fort Edward.)

On 02 May 1974, in its supplemental budget, the New York State Legislature voted $5 million for the emergency cleanup of Fort Edward terminal and repair of the broken water main.

Studies to assess the situation were carried out under the direction of Richard F. Thomas, of MPI. Detailed maps were made to estimate the quantities that had been eroded and to guide the cleanup operations. The remnant deposits were designated as areas 1 through 5 (See Figure 11).

The Fort Edward water main was repaired by 840 feet of new pipe. The channel leading to Fort Edward terminal was dredged. Other steps that were taken to deal with the deluge of debris are discussed in a following section (REMEDIAL ACTION TAKEN).

During the spring floods of 1976, flows even higher than those of 1974 came down the Hudson River, and again eroded the remnant deposits. The records at Hadley show the differences. In 1974, the maximum flow at Hadley was attained on 15 April (16,300 cubic feet per second). Values in excess of 10,000 were recorded for 5 consecutive days. In 1976, this 1974 maximum was exceeded twice during a 14-day period that started on 27 March and ended on 09 April. The peak flow in March reached 17,300. On 02 April, the maximum of 31,200 was recorded. A second period of flows exceeding the level of 10,000 cubic feet per second began on 17 April, peaked at 12,900 on the 19th, and returned to a value of <10,000 on the 21st.

Although MPI documents and NYS DEC staff refer to these two flood events as being the "100-year flood," the discharge records indicate otherwise. As mentioned on a previous page, the U. S. Geological Survey rates the 100-year flood at Fort Edward as 50,000 cubic feet per second, and at Green Island, as 220,000 cubic feet per second. The maximum flows at Fort Edward in 1974 and in 1976 cannot be determined directly, but the flows at Green Island can. The 1976 maximum at Fort Edward is estimated to have been 41,600 cubic feet per second (33,450 at Hadley plus 8120 from the Sacandaga Reservoir (MPI, 1977b, p. 4-1). The 1974 maximum at Green Island was 69,300, and the 1976 maximum, 99,900 (02 April 1976).

The quantity of debris deposited in the Fort Edward terminal in 1976 was less than in 1974 (200,000 cubic yards vs. 790,000 cubic yards. This contrast of higher flows and less debris eroded can be explained by the fact that the 1974 floods washed away about two-thirds of estimated volume of all the remnant deposits (MPI, 1975). Accordingly, in 1976, there was less to erode. To some extent, the 1975 remedial measures in areas 4 and 5 prevented further erosion. But, in areas 2 and 3, the remedial measures were ineffective.

UPPER RIVER REHABILITATION BY DREDGING

What I regard as the least-understood aspect of the PCB situation in the upper Hudson River is the extent to which the upper river has been relieved of PCB-polluted sediments by necessary channel-maintenance dredging. A certain amount of the dredging has been necessitated by the natural supply of sediment to the parts of the river used by the canal system. As is evident from the discussion of the "great experiment," however, much debris that had to be dredged washed downriver when floods eroded the remnant deposits in 1974 and 1976, after the Fort Edward Dam had been removed. I organize the discussion of previous dredging into three major categories: NYS DOT channel-Maintenance Dredging (1931-1974), Fort Edward Cleanup I (1974-1975), and Fort Edward Cleanup II (1977-1978).

NYS DOT Channel-Maintenance Dredging (1931-1974)

As part of their constitutional mandate to maintain the canal system, NYS DOT has kept channels open by dredging. As shown in Table 7, the area north of the Thompson Island Dam has required about 60 percent of the dredging between 1950 and 1976. In the following discussion of the DOT channel-maintenance dredging in the upper Hudson River, I make two categories: (1) Fort Edward and Lock 7, and (2) everywhere else.

Dredging near Fort Edward and Lock 7 (1931-1974)

Because Fort Edward is situated at the foot of a series of rapids, where the valley widens at the south end of the steep gorge (Baker Falls retreat track), it is located where the upper Hudson River naturally tends to deposit sediments. Just dow[n]stream of the rapids, the river divides around Rogers Island ([See] Figure 11).

The former Fort Edward terminal is situated on the east side of Rogers Island, on the west side of the east channel, 0.7 mi. upstream from Lock 7, the point where the Champlain Barge Canal leaves the upper Hudson River.

From 1931 to 1974, DOT dredged 234,620 cubic yards from the channels near Fort Edward, for an average of about 5,400 cubic yards per year (Table 9).

Table 9. NYS DOT Channel-Maintenance Dredging Near Fort Edward, 1931-1974 (MPI, 1975, 1977b).

Year	Quantity dredged (cubic yards)
1931	15,360
1934	4,700
1936	8,400
1948	35,000
1951	3,760
1955	12,324
1957-65	10,390
1963	144,686
Subtotal	234,620

In the vicinity of Fort Edward, NYS DOT has used four dredged-material disposal sites (Figure 4): Rogers Island, Special Area 13, Moreau ("old" Moreau prior to 1977; new Moreau in 1978), and Site 518.

Dredging between Lock 7 and Troy

As shown in Table 7, NYS DOT channel-maintenance dredging in the upper river is presented in four reaches. Of these, the two south of Northumberland Dam (Lock 5) include the three major tributaries of the upper Hudson: the Batten Kill, which enters about a mile south of Lock 5; the Hoosic, which enters just south of Lock 4, Stillwater; and the Mohawk, which enters just south of Waterford. The reach from Northumberland Dam to Waterford Dam, therefore, includes the stretch affected by tributaries from the east; and that from Waterford Dam to Green Island Dam, by the largest tributary, from the west.

In the time period shown, DOT crews dredged 519,644 cubic yards of sediment between Northumberland and Waterford dams, and 197,533 from the reach between the Waterford and Green Island dams, for a total of 717,177 cubic yards for both reaches.

Fort Edward cleanup I (Apr. 1974-Nov. 1975)

The first clean up of Fort Edward became necessary to deal with the great surge of sediments from north of the former Fort Edward Dam. After this dam had been removed and the spring floods of 1974 had severely eroded the remnant deposits, the Village of Fort Edward was a disaster area.

Table 10 shows the quantities removed and costs in the first clean up of Fort Edward in 1974 and 1975.

Because the dredged material's high concentrations of PCBs had not been acknowledged at the time, the debris was disposed of according to long-followed practices. Some of was spread on Rogers Island and the rest was placed in the state-owned Moreau disposal site ("Old Moreau" on Figure 4).

Fort Edward cleanup II (1976 and 1977)

The second cleanup of Fort Edward was carried out to get rid of the downriver surge of debris that accompanied the large flood of mid-April 1976. I divide my discussion of this second cleanup into two parts: (1) the initial MPI plan, and (2) the revised plan that was presented after the Advisory Committee recommended that the initial version be modified.

Initial plan presented to NYS DEC by MPI.-- The initial report on the second cleanup of Fort Edward was a draft EAS presented to DEC in April 1987 on the proposed maintenance-dredging project in the East Channel of the Hudson at Fort Edward. A subcommittee to review this draft of the Pirnie EAS consisting of Axelrod, Glowka, Sanders, and Walker was appointed on 30 March 1977 and instructed to report to the full Committee on 27 April 1977.

Axelrod presented the subcommittee's report. He noted that since the EAS had been prepared, more debris had arrived, thus doubling the amount to be removed. He noted that the main discussion emphasized navigation, not the health threat from the PCB-contaminated debris. All members of the subcommittee had objected to the proposal to dispose of the dredge spoil on Rogers Island, as previously.

Revisions recommended by Advisory Committee.-- At its 8th meeting, held on 27 April 1977, the Advisory Committee recommended to Commissioner Berle that the MPI EAS be accepted with the understanding that a supplement be prepared to deal with the newly arrived debris; that dredging be expanded to include parts of the West Channel; that Moreau is the only acceptable dredge-spoils site; that the best-available technology be used to achieve maximum containment of PCBs in the newly dredged material; and that additional studies be carried to monitor any leaching from existing dredge spoils already placed in the Moreau site.

The contaminated debris dredged from the navigation channels during 1977-78 (Table 11) was trucked to the special containment site named new Moreau (See Figure 4). As can be seen from adding the totals in Tables 10 and 11, the final quantity dredged from navigation channels near Fort Edward during the two clean-up operations was 855,000 cubic yards at a cost of something more than $2,960,000 (a figure that does not include DOT labor costs for Buoy 212, engineering, and other costs). The measures taken with the remnant deposits in 1975-1978 are discussed in a following section entitled: REMEDIAL ACTIONS TAKEN, NYS DEC Actions With Respect To Remnant Deposits (1975-1978).

Table 10. Quantities of sediment dredged from Fort Edward in the clean-up operations following the spring floods of March and April 1974.

Dates	Location of project	Quantities dredged (cu. yd.)	NYS DOT Contract No.	Cost
1974 Apr.-Dec.	Main channel S of Lock 7	175,000		
	Lock 7 - AMTRAK RR bridge	85,000		$604,000 (labor only)
Jul. 1974-Jul. 1975	N. tip of Rogers Is. - AMTRAK RR bridge	250,000	74-05	$834,000 (contract only)
May-Nov. 1975	West channel, Rogers Is.	130,000	75-06	$497,000 (contract only)
Totals		640,000		$1,935,000 (plus engineering & other costs)

Table 11. Quantities of sediment dredged from channels near Fort Edward in second cleanup of Fort Edward (1977-1978).

Dates	Location of project	Quantities dredged (cu. yd.)	Cost
1977	Channel near Buoy 212	35,000	
1977	Channel to Fort Edward terminal	180,000	$1,025,000
	Total	215,000	

Relationship of Previous Dredging to Proposed Hot-Spot Dredging Project

The principal purpose in presenting the details about the previous dredging in the upper Hudson River is to emphasize the point that the proposed hot-spot dredging plan is the outgrowth of considerable experience in dredging the navigation channels. In particular, the second cleanup of Fort Edward in 1977-78 was used by the Advisory Committee as a basis for recommending to the Commissioner of DEC that the DEC staff's proposal to carry out rehabilitation of the upper river by dredging was not only an environmentally safe course to follow (proved by the monitoring results) but indeed was the only method available for dealing with the contaminated sediments. The Advisory Committee made its recommendation in favor of dredging in 1978. Nothing that has come to its attention in the ensuing 11 years has caused it to waver in this position. Indeed, the Committee feels that its position is entirely consistent with Section 404 (b) (1) of the Federal Water Pollution Control Act of 1977, with respect to dredged material. The interim final guidelines of 05 September 1975 require that "regulatory measures be based on information from scientific investigations about the natural environment and health and welfare."

NYS DEC's PROPOSED DREDGING OF PCB HOT SPOTS

As indicated previously, the DEC staff have argued from 1976 onward that the upper river could be rehabilitated by dredging the PCB-contaminated sediments. Accordingly, they have urged that investigations be made to map the PCB-contaminated sediments as a basis for calculating volumes of sediments to be dredged and their contents of PCBs. I continue my account of the DEC efforts to carry out this controversial proposal by summarizing the data devoted to mapping.

Mapping of PCB-Contaminated Sediments

Methods of coring

During the two major coring campaigns that have been carried out to assess the extent of PCB pollution in the sediments in the upper Hudson River, two methods have been used. These are (1) the pounded-in-plastic-tube method, and (2) vibro-drilling.

As mentioned, most of the cores of the fine sediments in the channel-marginal fine sediments have been collected simply by pounding a plastic pipe (liner) into them (Normandeau Associates, 1977-78). By contrast, the coarse sediments underlying the channel floors have required a vibro-drilling rig in order to penetrate to the desired depth. Vibro-drilling was used extensively during the 1984 season in which the Thompson Island Pool was resurveyed (Normandeau Associates, 1985). Once the tube of the vibro-corer had been driven into the sediment, the problem of keeping the coarse sediment from washing out of the core tube had to be faced. This problem of coarse-sediment washout arises in two phases of a coring operation. The first phase is when the tube is pulled out of the bottom. The second phase is when the tube is lifted out of the water en route back to the drilling platform. For best results, the coring tube must be equipped with special devices to counteract the tendency for the core to wash out. One aid is a special check valve using an O-ring seal within the plastic liner that is taped to the top of the plastic liner that fits inside the steel coring tube. A second aid is some kind of core retainer at the bottom of the plastic liner/steel coring tube.

Analyses of cores

The purpose of collecting the cores was to determine the concentrations and depths of PCBs within the river-bed sediment. Before I take up the results of the PCB determinations, I review briefly two related topics, heavy-metal pollution and cesium-137 from atmospheric nuclear-weapons tests. Both heavy metals and cesium-137 have been used as geochemical tracers to indicate important relationships with respect to the distribution of PCBs.

Heavy-metal pollution.-- In addition to their contents of PCBs, the sediments in the upper Hudson River contain elevated levels of Pb, Hg, Zn, Cu, Cr, Cd, and Ni (Matusik, 1978 ms.; MPI, 1975, 1978a; Tofflemire and Quinn, 1978; Tofflemire, 1984; M. P. Brown, Werner, Carusone, and Klein, 1988). It seems probable that these heavy metals came from the Marathon Battery plant and/or the Hercules Chemical (now CIBA-Geigy) chemical plant or elsewhere in the Hudson Falls-Glens Falls area (Tofflemire and Quinn, 1978; Tofflemire, 1984). In general, large lead discharges from the Hercules plant coincided in time with the PCB discharges from the GE plants. As a result, sediments containing elevated levels of PCBs tend to be high in lead, also. The details of the lead pollution of the upper Hudson River are not known and have not been carefully investigated.

Measurements of heavy-metal content have been made in samples collected near the former Fort Edward Dam, in the remnant deposits, and in selected cores from the Thompson Island(See Table 8.).

Cesium-137 fallout from nuclear explosions in the atmosphere.-- The cesium-137 fallout from nuclear weapons tests carried out in the atmosphere during the 1950's has been used to indicate ages of sediment layers in core samples. A large network of cores in which cesium-137 has been used in this way has been established in the Hudson River by investigators from Lamont-Doherty Geological Observatory of Columbia University (H. J. Simpson and co-workers, including Curt Olsen and Richard Bopp). The relationship between such cesium-137 in cores and PCB con[illegible] is discussed in a following section.

Cores from upper Hudson River

NYS DEC (September 1976).-- In September 1976, NYS DEC staff surveyed 23 cross-river transects between Fort Edward (River Mile 194.2) and Waterford (River Mile 157.0). They determined channel configuration with a recording echo sounder and collected 23 cores (typically about 1 foot long) and 54 dredge samples. They split the cores into 64 samples for PCB analyses. (Another 70 cross-river transects had been recorded in a 1967 survey carried out by NYS DEC staff in August and September. In 1976, the results of this earlier survey were not fully accepted and no sediment samples had been collected.) Altogether in the period 1974-1977, the NYS DEC sampling effort amounted to 200 grabs and cores.

US EPA Region II (1976).-- At the second meeting of the PCB Settlement Advisory Committee, in November 1976, I communicated the information that cores of bottom sediment from the Hudson Estuary collected by a research group headed by Prof. H. J. Simpson of Lamont-Doherty Geological Observatory showed high levels of PCB pollution. I had received this information orally from Curt Olsen, a Columbia Ph. D. candidate, with whom I had been conferring about the sedimentological aspects of the chronological information that had been developed by measuring the fallout of cesium-137. The high PCB levels had been found by Richard Bopp, another Columbia Ph. D. candidate working in Simpson's research group. Evidence that the estuary might already have been polluted by PCBs had been mentior[illegible] in the memorandum to Commissioner Berle written by Profess[illegible] Sofaer in September 1976. Nevertheless, this idea that the estuary had already been polluted by PCBs from upriver was not accepted by NYS DEC staff, who held the opinion that the upriver dams had thus far contained the PCB-polluted sediments. They believed that if the upriver pollution problem could be solved promptly, the estuary could be spared the otherwise-inevitable invasion of PCBs.

In order to settle this dispute, Dr. Richard Dewling, US EPA Region II's representative on the Advisory Committee, arranged for a set of 29 short cores (to 30 cm in length and 3.5 cm in diameter) to be collected with a Phleger corer as a reconnaissance from localities between Troy and New York Harbor (Figure 14). The cores were collected in mid-December 1976 from a helicopter equipped with pontoons for setting down on the water and an electrically powered winch for lowering and raising the corer through an opening in the floor of the helicopter. The stations were chosen to coincide with NYS DEC's macroinvertebrate study sites; areas that the U. S. Army, Corps of Engineers planned to dredge; or sites thought to be places where sediment was accumulating.

After the helicopter had settled down on the water at a station, the corer would be lowered to a level just below the water surface, and then allowed to drop freely to the bottom. Two levels from the cores were subsampled for PCB analyses: top, 0 to 7.6 cm; and bottom, 18-25 cm (measured down from the core tops). The analyses were performed in US EPA's laboratory at Edison, New Jersey, and the results were reported as Aroclor 1016 expressed as mg per kg on a dry-weight basis. The highest value found was 58.3 (in the Albany Turning Basin). At Piermont, the values were 56.4 in the top sample, and 0.35, in the bottor[illegible] In Foundry Cove and the NW corner of Peeksill Bay, the top-cc[illegible] values were 11 and the bottom, low or not detectable. As a resu[illegible] of this screening survey, NYS DEC staff had to admit that the dreaded event had already taken place: PCBs had already

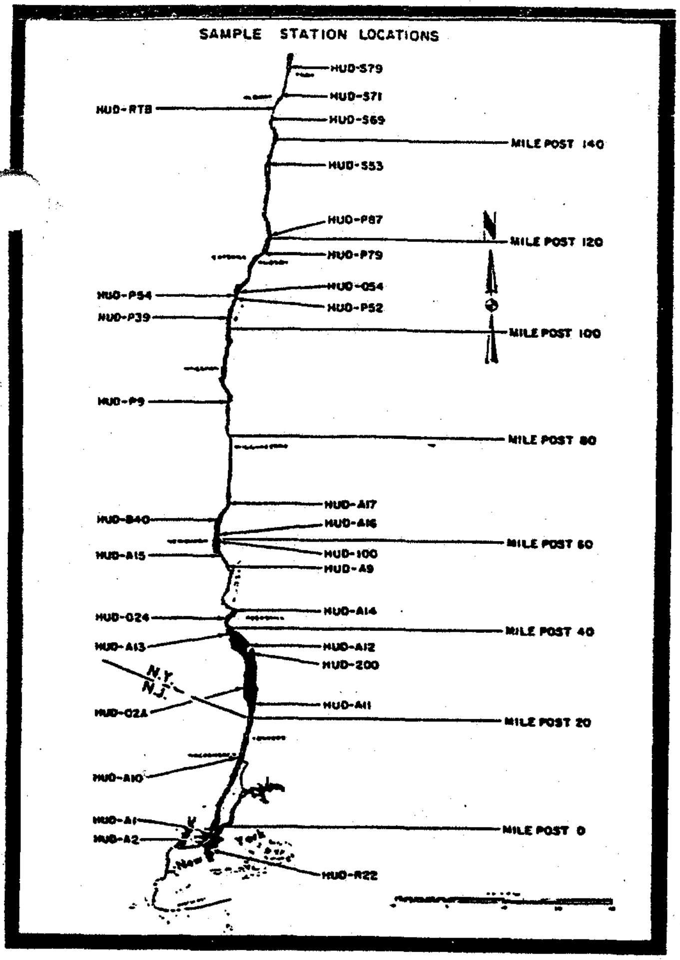

Figure 14. Map of lower Hudson River, showing locations of cores collected in December 1976 during US EPA Region II's screening survey using a small Phleger corer from a pontoon-equipped helicopter. During US EPA Region II's 1981 survey, attempts were made to re-core these same stations. ("Same stations" refers to limits achieved using "eye-ball" navigation methods; US EPA, 1977, Fig. 1, following p. 9.)

polluted the sediments of the Hudson Estuary. This conclusion was later fully substantiated by Richard Bopp's results.

Normandeau Associates (I; 1977-1978).-- Using funds from the GE Settlement, NYS DEC contracted with Normandeau Associates, Inc., of Bedford, New Hampshire, for detailed mapping and sediment collecting in the upper river. Normandeau collected 312 short cores from channel-margin flats in the upper Hudson River, and 600 grab samples on 40 transects at approximately one-mile intervals between Fort Edward and Waterford. The 672 analyses for total PCB by O'Brien & Gere formed the basis for the NYS DEC map of 40 hot spots (See Figure 4) and computations of sediment volumes and quantities of PCBs in the sediments. The PCB content of the Thompson Island pool was calculated to be 61 tonnes. Figure 15 summarizes the aggregate distribution of PCBs with depth in the core samples collected in the Normandeau I operation.

Box-coring tests (1979).-- In order to obtain a clearer understanding of the nature of the channel-floor coarse sediments that had proved so difficult for Normandeau to core, Steve Selwyn and I used a box corer that he had designed and built at Lamont-Doherty Geological Observatory of Columbia University to collect 4 samples from the Thompson Island pool between Normandeau transects 7-4 and 7-6, at Hot Spot No. 5 (Figure 16). Dr. James Tofflemire, of NYS DEC, participated in this operation by arranging for NYS DOT assistance, by selecting the coring sites, by determining positions with an optical range finder, and by taking care of the details involved in having PCB analyses made. The box corer that we used measured 0.5 x 0.5 x 1.5 meters. In our initial attempts, we lowered the rig on a wire rope from a crane aboard a NYS DOT work barge. The box was rigged so that it would fall freely to the bottom from just beneath the water surface after a trigger weight attached to the end of a release-lever arm had touched bottom, thus allowing the release lever to swing upward and open the release clamp.

After the box had penetrated into the sediment, the upward pull on the wire rope would activate the jaws, which would be drawn shut and thus prevent the sediment from escaping out the bottom. In their open position, these jaws fit closely along the outside of the box.

The box had been constructed so that the vertical plate on one side could be unbolted. Therefore, after a box had been retrieved from a drop, we would lay it on the side opposite the removable plate, unbolt and remove the plate, and thus reveal a view of the sediment on a plane that was perpendicular to the water/sediment interface (Figure 17).

In the first 3 drops, the opened box was found to contain only about 30 cm or so of coarse sediment. We concluded that the coarse channel-floor sediments must have been thicker than 30 cm but were not being penetrated by the box because of their great resistance. The driving weight on top of the box was only 1000 pounds and we supposed that more weight was needed. These results left us somewhat discouraged. However, the crew told us that NYS DOT was preparing to use the crane and barge to set sheet piling nearshore at their disposal site Special Area 13, only a short distance away. They seemed interested in learning more about what the box corer might be able to do, so they were amenable to our suggestion that we adapt the box to their pile driver. Accordingly, they gave us free access to their metal scrap yard and the services of a welder. In a few hours, we built an adapter so that the box corer could be attached to the pile driver and thus pounded into the bottom sediments by repeated blows. We did not witness the pile-driver box-coring operation; it was carried out by NYS DOT work crews at site BC-11 just downstream from the sheet piling (See Figure 16.). They reported to us that they drove the box corer in to a point of refusal, which was reached after the box had penetrated nearly its entire length into the sediment.

The NYS DOT crew did not open the box. Instead, they brought it ashore and left it for us to examine. When we opened it, we found 42 inches of sediment within the rectangular part and another 6 inches in the closing jaws. We sketched the relationships visible on the vertical face of the contents of the box and collected samples for PCB analysis. Then, after several attempts, we finally made a successful relief peel using the techniques described in Burger, Klein, and Sanders (1969). Figure 18 shows a photograph of the relief peel alongside a sketch of the lettered subdivisions that we selected for PCB analyses. The numbers are total PCBs expressed as parts per million on a dry-weight basis.

The NYS DOT personnel were so pleased with the box corer-pile driver combination that they requested we leave it with them for another attempt at a later time. After we had made the peel and emptied the sediment collected at station BC11, they took it back aboard the barge and tried it again. On this second trial (at a location not indicated on Figure 16), they encountered refusal almost immediately. Nevertheless, they persisted with the pounding just to make certain. As a result, they bent the box corer and it had no sediment inside when they retrieved it. From this, I conclude that the small amount of sediment which we collected at stations BC1, BC2, and BC3 probably represented the full thickness of what was only a thin veneer of coarse debris overlying bedrock beneath the main channel of the river. Presumably, then, despite our disappointment with the results of the free-fall technique, we had collected all there was to collect. If so, then our 1000-pound dropping weight was really adequate

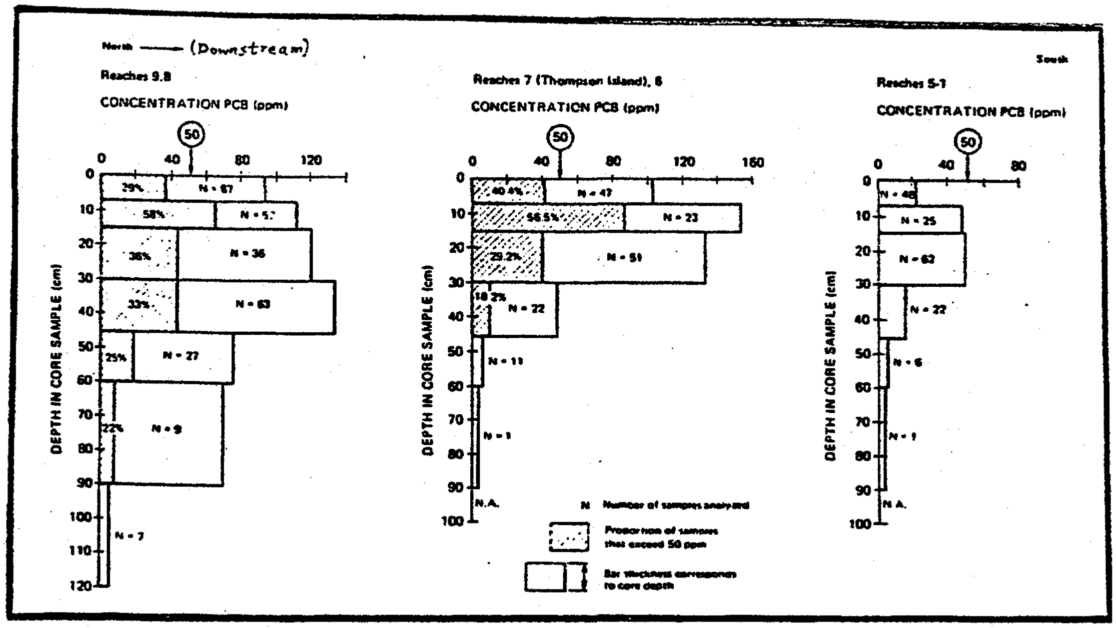

Figure 15. Graphic representation of 672 PCB analyses by O'Brien and Gere Engineers, Inc., of sediment samples selected from 312 short cores collected in 1977 for NYS DEC from channel-margin flats along the upper Hudson River, grouped according to three reaches: (1) Reaches 9 and 8 (at left), north of Thompson Island Dam; (2) reaches 7 and 6, between Thompson Island Dam and the dam for Lock 5; and (3) reaches 5 to 1, between dam for Lock 5 and the Federal Dam at Troy. Using the chronology developed by Richard Bopp, of Lamont-Doherty Geological Observatory, Columbia University, based on the vertical distribution in cores of fallout cesium-137, one can infer that the high PCB values above the 90-cm level in reaches 8 and 9, and above the 45-cm level in the other reaches, mark the flow of April 1974, when debris from the then-newly exposed remnant deposits was able to surge downriver because the Fort Edward Dam had been removed (in 1973). (Data from NYS DEC, Hetling, Horn, and Tofflemire, 1978, Fig. 6, p. 14, drawn in this form and first published in A. M. Beeton, Chm., 1979, Fig. 1.1, p. 34, but with incorrect source cited therein; also appeared as Fig. 8, p. 10, in Sanders, 1982.)

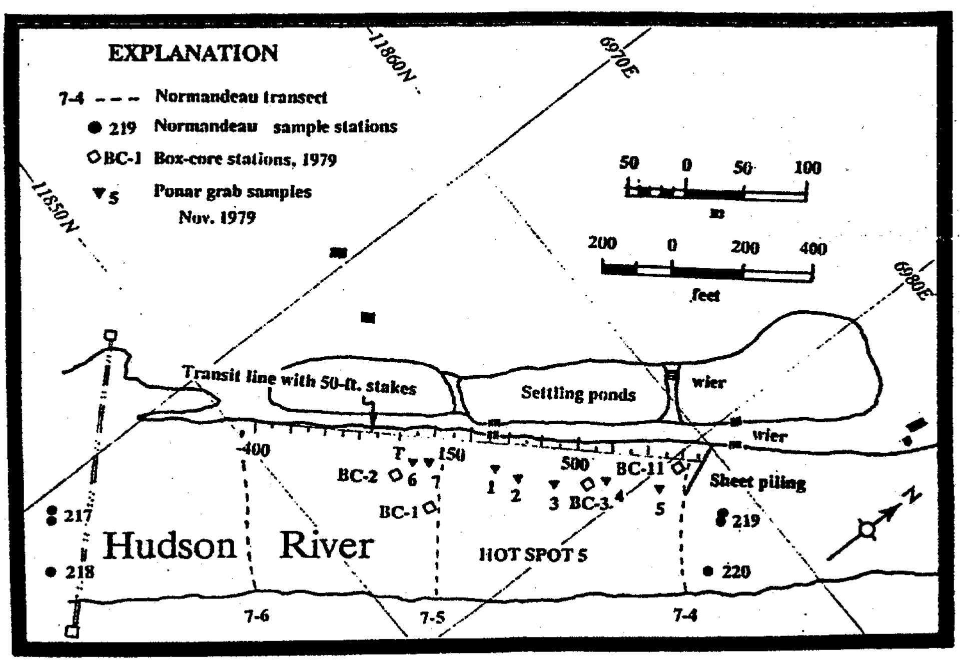

Figure 16. Location map of northern part of Thompson Island pool in upper Hudson River near hot spot No. 5, showing Normandeau transects (dashed lines) and sampling stations (circles), NYS DEC ponar grab samples (triangles), and box cores (open squares) collected in August (BC1, BC2, and BC3) and September (BC11). Areas marked lagoons are part of Special Area 13 of NYS DOT dredge-spoil sites. (NYS DEC map prepared by Dr. J. Tofflemire, slightly modified by J. E. Sanders for use here.)

Figure 17. View into Selwyn box corer in upright position after sample had been collected and side plate removed. Gates in closed position kept sample from dropping out the bottom. Length of trowel at lower left is 25 cm. Aboard a NYS DOT work [illegible]e, upper Hudson River, August 1979. (Photo by J. E. [illegible]ders.)

after all. But, our doubting mood did give rise to a positive outcome. We were motivated to build the adapter for use with the pile driver, and this effort was rewarded by the collecting of BC11. Had we *not* been discouraged yet determined to find a way to get a boxful of sediment, BC11 would not have been collected.

The large relief peel from station BC11 gives a dramatic indication of the kinds of debris that washed into the northern end of the Thompson Island pool as a result of the two post-dam-removal floods (1974 and 1976). Several noteworthy features stand out that are clearly visible in the photograph of this relief peel (Figure 18, B). First of all, the general inclination of the layers to the right, indicated on the sketch of the vertical face of the freshly collected sediment, is confirmed but shown to be steeper and to involve more units that initially sketched. Secondly, two units of laminated fine sand are present; each overlies a much-coarser layer along a sharp contact and grades upward into the overlying coarser layer. The upper of these laminated fine-sand units is clearly visible in the middle of the photograph along the left side. The thickness of this unit decreases toward the right and the curvature of the laminae is convex up. The lower unit of laminated fine sand is not well shown on the photograph; it begins just above the triangular black spot in the lower center (a shadow from a protruding part of the peel surface). Thirdly, the basal contact of the horizontal capping layer at the top (unit A'), is very irregular and includes parts of two small channels cut into the top of the underlying unit having steep dips. I infer that these complexly dipping units capped by the channeled unit at the top prove that what one sees on this peel of BC-[illegible] are the true relationships within the sediment and are not artifacts of the coring operation. I think these steep dips, indeed some are vertical, are real; I totally reject the idea that these dips were acquired by flow of sediment within the box somehow resulting from the fact that it was used by non-geologists.

I interpret the steeply dipping units as oversteepened cross strata that resulted from flow across a shallow area into a deeper area. I infer that the sediment being swept across the shoal avalanched into the deeper water but that the dip was steepened well beyond its normal angle of repose because of flow up the slope that was associated with a separation eddy (Friedman and Sanders, 1978, p. 111-112).

The distribution of PCB concentrations in BC-11 (shown by the numbers in units A', A, C, and E of Figure 18, A) is typical of that found in the many cores collected in the Hudson River. The highest PCB concentrations are not at the sediment/water interface, but up to a few tens of centimeters below it. And, the layers containing elevated levels of PCBs overlie sediments in which PCB concentrations are much lower. Using the PCB results and the two coarsening-upward cycles of the sediments displayed on the relief peel, I infer that BC-11 displays sediments deposited before, during, and after the two large floods of 1974 and 1976. According to this interpretation, the coarse bottom part of BC-11 with the low concentration of PCBs is older than 1974. The lower couplet of laminated fine sand grading upward into coarser debris is assigned to the 1974 flood. The upper couplet, forming nearly half the thickness and featuring very steep dips and convex-up curvature, to the 1976 flood. The capping layer is inferred to represent the results of reworking by smaller floods since the spring of 1976. If my interpretation is correct, then BC-11 has captured, as it were, and has "frozen in time" the key events in the spreading of PCBs throughout the Hudson River.

EPA Region II (1981).-- As part of their evaluation of the validity of the NYS DEC reports on distribution of the hot spots in the Thompson Island pool, US EPA Region II collected a suite of cores and carried out new PCB analyses (B. J. Johnson, 1981).

NUS Corp. (summer 1983).-- As part of their assignment in preparing the Superfund I RAMP, NUS Corp. re-examined the "hot spots" that NYS DEC had mapped in the Thompson Island pool on basis of the Normandeau I cores (1977-78). NUS found that no hot spots had disappeared, but that the mapped values needed revision. Accordingly, NUS recommended to US EPA that all the hot spots in the Thompson Island pool be remapped. US EPA accepted this recommendation and directed NYS DEC to perform a further detailed re-coring and re-mapping of the Thompson Island pool.

Normandeau Associates (II; 1984): resurvey of hot spots in Thompson Island pool.-- A detailed re-survey of "hot spots" in the Thompson Island pool was mandated by US EPA as part of its requirements in connection with NYS DEC's application for the balance of the Sec. 116 funds. In this resurvey, 400 sediment cores and 600 grab samples were collected and analyzed (1984; Normandeau Associates II). After all the PCB analyses had been submitted to NYS DEC, the results were summarized using NYS DEC's newly organized computer programs. The concentrations of PCBs were integrated at depth intervals of 0.5, 1.0, and 1.5 meters. Approximately 95 percent (21.9 tonnes) of PCBs were found to be in the top 0.5 m, and 99.91 percent (23 tonnes), in the top 1 m. The total value of 23.3 tonnes for the PCBs in the sediments in the Thompson Island pool (15 tonnes in the hot spots) is significantly smaller than the 61 tonnes calculated in 1978 (M. P. Brown and Werner, 1985). The results from the resurvey of the Thompson Island Pool served as a basis for recalculating all previous estimates of the PCB budget in the Hudson River (See Table 1).

Others.-- Many cores have been collected in the upper river by John Brown of GE (J. F. Brown, Bedard, Brennan, Carnahan, Feng, and Wagner, 1987; J. F. Brown, Wagner, Bedard, Brennan, Carnahan, Mayh, and Tofflemire, 1984) and by Richard Bopp and his associates, of Lamont-Doherty Geological Observatory of Columbia University (Bopp, H. J. Simpson, Deck, and Kostyk,

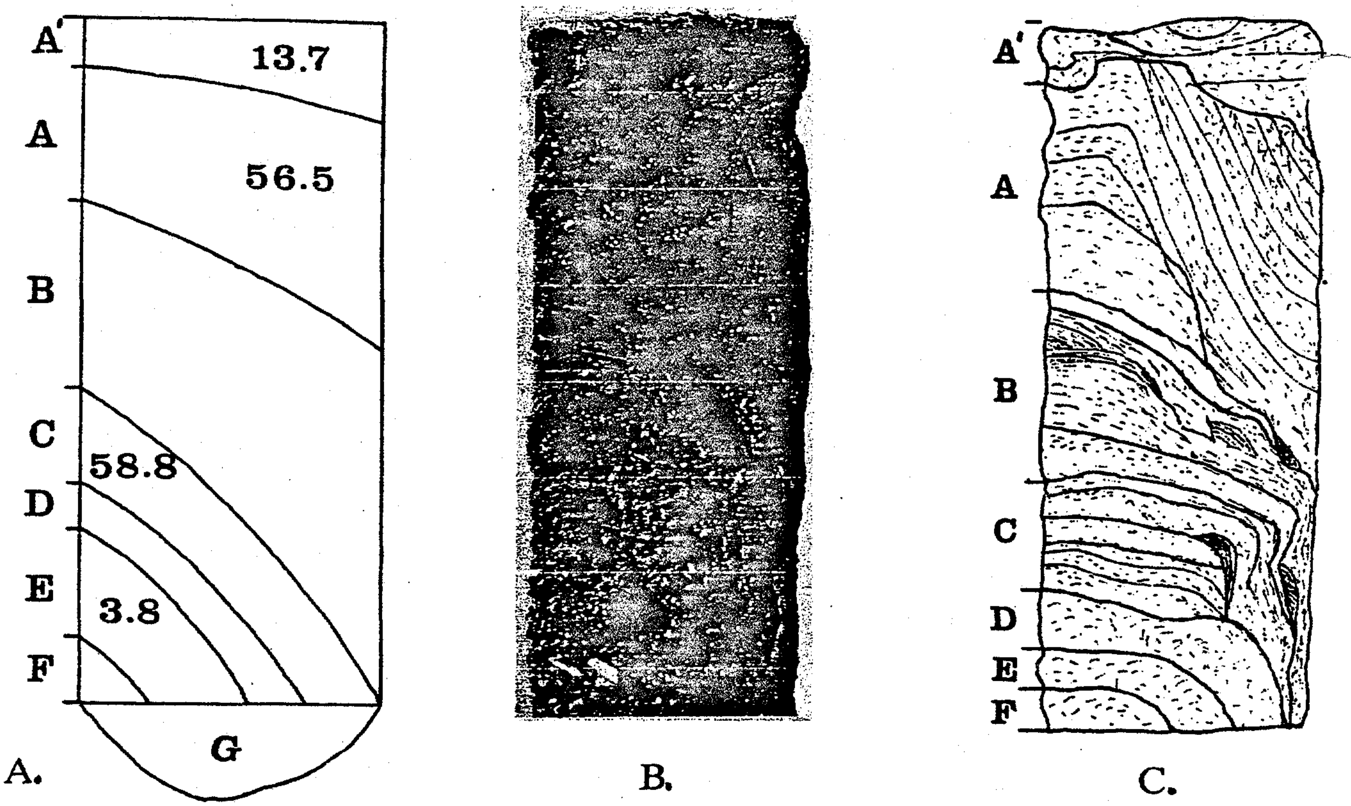

Figure 18. View and sketches of box core B11 (location on Figure 16).
A. Sketch made at the time the box corer was first opened and samples were collected for PCB analyses. Numbers are total PCBs in ppm.
B. View of relief peel. (Photo by J. E. Sanders.)
C. Sketch of relief peel, which was made from a face deep inside the box, possibly 30 cm away from the face sketched in A. The relief peel displays more subunits than were visible on the face seen when the box was first opened. The lettered units on the two sketches match only approximately and do not correspond with the cyclic flood-deposited couplets mentioned in text.

1984; Bopp, H.J. Simpson, Olsen, and Kostyk, 1982; H. J. Simpson, Bopp, Deck, Warren, and Kostyk, 1984; Bopp and Simpson, 1988ms). Both have analyzed for individual PCB congeners, instead of for comparison with a given standard or total PCBs. They have found evidence that the lower-chlorinated congeners are being enriched relative to the higher-chlorinated congeners. According to the experimental evidence later presented to Hudson River Siting Board II by Dr. James Tiedje, these changes have resulted from the effects of anaerobic bacteria (Quensen, Tiedje, and Boyd, 1988). The congeners being formed by bacterial action are unlike those thought to have been washed into the river from the GE plants and are unlike those being transported downriver (sampled by Bopp and Simpson) and are unlike those found by Bopp and Simpson in the lower river. These findings supply further proof that the hot spots are not being eroded and are not contributing to the downriver migration of PCBs as sampled by the U. S. Geological Survey.

NYS DEC's EFFORTS TO FIND FUNDS FROM "SOURCES OTHER THAN GE" FOR BEGINNING THE FINAL PHASE OF UPRIVER REHABILITATION

After NYS DEC Commissioner Peter Berle had received the recommendation from the Advisory Committee to pursue the dredging option for the PCB Hot Spots, the remaining Remnant deposits, and the old NYS DOT dredge-spoil sites, he set in motion attempts to obtain federal funds to help pay for the project. The cost estimate was $40 million, of which he sought $30 million of federal matching funds. The only assistance offered by US EPA in response to several applications by NYS DEC under the Clean Water Act (PL 92-500), was the possibility of a grant of $100,000 for research under Sec. 105 (Grants for research and development). Sec 115 (In-place toxic pollutants in navigable waterways), the section clearly dealing with the kind of problem represented by the Hudson River PCB pollution, contained a meager authorization of $15 million, but Congress had never actually appropriated any funds and in the absence of a concerted lobbying effort by EPA and others, seemed unlikely to do so. NYS DEC focused on Sec 205, grants for construction of sewage-treatment works. Under this section, US EPA had already allotted federal funds to New York State. Under this grants program, individual states are to assign a priority ranking to proposed projects. NYS DEC placed the PCB hot-spot dredging proposal at the top of its priority list of how to spend Sec. 205 funds. and requested that $30 million of the federal dollars be reassigned to pay for the federal share of the proposed hot-spot dredging. US EPA rejected this idea. Nevertheless, New York State managed to have an amendment added to the 1980 bill extending the life of the CWA. Congress adopted a Sec. 116, Hudson River PCB Reclamation Demonstration project, authorizing the US EPA Administrator to shift $20 million of New York's Sec. 205 funds to pay a federal share (75 percent) of the hot-spot dredging. This legislation included a time limit of September 1983 and specified that the US EPA Administrator had to make a final determination about the funds, those specified in the new Sec. 116 not to be used "if Superfund became available." The following paragraphs summarize these actions in detail.

NYS DEC–US EPA Interactions

The interactions between NYS DEC and the US EPA have spanned a wide range of topics. Personnel from the US EPA were among the first to point out the high level of PCB contamination in fish, water, sediments, and snails from the upper Hudson River. In addition, staff from US EPA's Region II office have carried out two sampling operations in which cores of sediment were collected and analyzed. Despite their cooperation in many projects, these two organizations have been adversaries at times over the PCB-pollution problem in the Hudson River. The following paragraphs summarize some of the NYS DEC and US EPA relationships.

Early US EPA Region II results in identifying PCB problem in upper Hudson River

As was mentioned in a preceding section, Nadeau and Davis (1974, 1976) reported on PCB-contaminated fish, snails, water, and riverbank sediments from the upper Hudson River. Their samples pinpointed the two GE plants as sources of the PCB pollution. In addition, US EPA Region II carried out a screening-sample coring operation in the Hudson Estuary in 1977. In 1981, the same stations were re-sampled and in addition, cores were collected from selected upriver locations (B. J. Johnson, 1981).

NYS DEC–US EPA differences over interpreting CWA

After the first study effort using Settlement Funds had been completed, the monitoring results of an actual dredging operation had been compiled, and the new Moreau encapsulation site constructed, filled and closed, the Advisory Committee was satisfied that the facts disproved the popular evil images of dredging and of encapsulation ("landfilling"). NYS DEC's monitoring showed that sediment stirred up during the NYS DOT dredging was subject to the law of gravity. Accordingly, gravity pulled such sediment back to the bed of the river within a mile or so of the dredge. Such stirred-up sediment did not constitute a "nuclear-winter" type of cloud that spread downriver, a notion popularly associated with dredging in the minds of many environmentalists. Being thus convinced on this crucial aspect of dredging, and satisfied that the highly contaminated sediment encapsulated at new Moreau had been successfully isolated from the environment, the Committee unanimously recommended that dredging and secure encapsulation be undertaken as the only practical way to rehabilitate the upper Hudson River. Dredging offered the only viable means of taking these sediments out of the river bottom, and thus out of potential circulation downriver. As long as these contaminated sediments remained in the river, a substantial quantity of PCBs remained subject to scour during large floods. A large flood had displaced these sediments into the hot spots and another large flood could shift them farther downriver. The cost estimates for the various rehabilitation options ranged from $40 to $204 million. The estimate of $40 million included the costs for dredging all the hot spots north of Troy, for removing the remnant deposits, for relocating highly contaminated sediments previously dredged from the river and now situated in some of NYS DOT's upland dredge-spoil sites, and for isolating these materials by encapsulating them in a secure facility. (The proposed secure encapsulation site was a parcel in southern Fort Edward, known as Site 10 in NYS DEC documents). The estimate of $204 million was for doing the above and in addition, for dredging all PCB-contaminated sediments out of the upper river.

Upon receipt of this recommendation, NYS DEC Commissioner Peter Berle and his staff took up the matter of funding. They set out to comply with the Settlement Agreement, which indicated that NYS DEC would use its best efforts to "obtain additional funds, from sources other than General Electric." In his memorandum urging NYS DEC to accept the settlement agreement, Hearing Officer Sofaer had written:

"Hopefully, the federal government will also assume a share of the cleanup responsibility, just as its actions contributed to making reclamation necessary."

The NYS DEC staff concluded that the PCB-pollution problem in the upper Hudson River might qualify for federal assistance under provisions of the Clean Water Act (PL 92-500, 92nd Congress). Accordingly, NYS DEC submitted a proposal to US EPA seeking financial assistance. As justification, NYS DEC cited two sections under Title I--Research and Related Programs: Section 105 (Grants for research and development) and Section 115 (In-place toxic pollutants). As for funds, NYS DEC requested that $30.5 million of New York State's allotment under Title II--Grants for Construction of Treatment Works, Section 205, Allotment, be reassigned to pay for the proposed dredging and encapsulation. This proposal was submitted to US EPA Region II, who evaluated it and forwarded it to US EPA Washington headquarters.

On 08 January 1979, US EPA Washington prepared a response in which the headquarters staff concurred with Region II that the proposed cleanup of PCB-contaminated sediments from the Hudson River would be desirable. However, US EPA Washington determined that funds available under Section 105 were not sufficient to meet the request, that Congress had not actually appropriated any funds under Section 115, and that NYS DEC's proposed use of funds allotted to New York State under Title II, Section 205 (construction of sewage-treatment plants) for dredging the PCB-contaminated sediments from the upper Hudson River was not consistent with the intent of Congress when it passed the CWA.

New York State Prods Congress To Revise CWA: Sec 116 Added

In its reaction to US EPA's statement about the intent of Congress, NYS DEC decided to appeal to Congress itself for a statement of congressional intent on this matter. After various meetings with the New York State congressional delegation, a decision was made to draft a bill to amend the CWA in such a way as to authorize the Administrator of EPA to reallocate New York State's Title II funds so that some would be available to pay for the proposed hot-spot dredging project. One such meeting that I attended was held on 25 January 1979. Present were staff members from the Governor's Office, from Senator Moynihan's Office, and from the Commissioner's Office of NYS DEC. The first part of the agenda centered on the quest for federal funds to assist in renovating the upper Hudson River. The three funding options of the CWA were reviewed: Sec. 105 (judged to be the most likely funding vehicle); sec. 115 (most appropriate, but lacking funds), and sec. 201 (the US Office of Management and Budget had indicated its reluctance for any further proceeding by New York with this option). Other possibilities mentioned were the Toxic Substance Control Act (TOSCA) and Resource Conservation and Recovery Act (RECRA).

Other questions discussed at this meeting were: (1) the consequences of leaving large quantities of PCBs in the upper river even after completion of the proposed hot-spot dredging; (2) the ultimate disposal of the PCBs in the dredged material; (3) the projected time frame for return of the river to an acceptable level of PCB contamination; and (4) public support for the proposed hot-spot dredging project.

A key factor in discussions with the New York Congressional delegation was a letter to NYS DEC Commissioner Robert F. Flacke from Thomas Jorling, Assistant Administrator for Water and Waste Management of US EPA dated 28 February 1979 which presented US EPA's position on the subject of funding, but beyond that, endorsed the technical aspects of the proposed Hudson River reclamation project:

"I am writing to reaffirm the U. S. Environmental Protection Agency's conceptual support for the technical viability and need for the PCB reclamation project in the Hudson River proposed by your

11.2801

Department. I was briefed on the project by your staff last year and have spoken at length with Regional Administrator Chris Beck about this proposal to stop the alarming PCB migration (sic) problem in the Hudson River. We fully agree that the project is sound and probably cost-effective (sic).

"Unfortunately, as I mentioned to you in our meeting on February 8, EPA cannot promise Federal funding support for this project under Sec. 201 of the Clean Water Act since the project does not fall within the legal realm of projects funded pursuant to that section. While the Act authorizes the funding of projects under Sec. 115 of the Act (to be administered by the Army Corps of Engineers), sufficient funds have not been appropriated under that section to adequately (sic) fund the Hudson River project at this time. However, EPA stands ready to confirm that this is a sound reclamation project and represents a professional engineering solution."

In the Fall of 1979, EPA Region II rejected several applications for dredging in the Port of New York and New Jersey because they involved ocean dumping of sediments containing PCB's.

In response to these rejected applications for dredging in the commercial ship channels, a group named Save-Our-Port was formed. The Save-Our-Port coalition included representatives from the Port Authority of New York and New Jersey, the New York Towboat and Harbor Carriers Association, and others. The EPA Region II decisions had raised the whole subject of ocean dumping of PCB-contaminated sediments, which were found to be present in the fine sediments needing dredging from the ship channels. Because approximately 75 per cent of the PCBs that were coming into the harbor at the time had been shown to come from the two GE plants at Hudson Falls and Fort Edward (Bopp, 1979 ms.; Bopp, Simpson, and Olsen, 1978; Bopp, Simpson, Olsen, and Kostyk, 1981, 1982; Bopp, Simpson, Deck, and Kostyk, 1982), the Save-Our-Port coalition mounted a considerable lobbying effort on behalf of the proposed rehabilitation project in the upper Hudson River.

On 31 October 1979, NY Representatives Stratton and Fish introduced H. R. 5767 (96th Congress, 1st Session) to amend the Federal Water Pollution Control Act (CWA) by adding a new section, Par. 116, to Title I--Research and Related Programs. The proposed Par. 116 amendment authorized a demonstration project for the reclamation of the Hudson River. Money for the federal share (up to 75 per cent) of such a project would come from funds allotted to New York State under section 205(a). On 06 May (legislative day, 03 January) 1980, a companion bill, S. 2663, was introduced to the 96th Congress, 2nd Session, by Senators Moynihan and Javits, of New York and Williams, of New Jersey.

Richard Ottinger (Dem., NY, 20th), proposed to amend the original House bill by adding the following to par (a):

"The Administrator is authorized to enter into contracts and other agreements with the State of New York to carry out a project to demonstrate methods for the selective removal of polychlorinated biphenyls contaminating bottom sediments of the Hudson River; treating such sediments as required; disposing of such sediments as necessary in secure landfills or through the use of alternative technologies; and installing monitoring systems. Such demonstration project shall be for the purpose of ascertaining the improvement of the rate of recovery of a toxic contaminated (sic) national waterway."

Bill H. R. 5767 evidently died in committee. It was referred to the Committee on Public Works and Transportation, of which Rep. Gerald B. H. Solomon, an outspoken opponent of the proposed dredging project, was a member. The House version of the extension of the Clean Water Act was bill H. R. 6667, which included no mention of the Hudson River PCB Reclamation Demonstration Project. The Committee report on H. R. 6667 unanimous (House Reports, 96th Congress, 2nd session, No. 983, dated 15 May 1980).

Bill S. 2663 was referred to the Committee on Environment and Public Works, chaired by Senator Jennings Randolph. Senator Moynihan was a member of this committee. In dealing with several bills that had been submitted on the subject of the Clean Water Act, the Senate committee composed an original bill, S. 2725, as an extension of the Clean Water Act. Section 3 of the Senate committee's bill included authorization of the use of construction-grant money for the Hudson River PCB Reclamation Demonstration Project (Senate Report No. 96-744, dated 15 May 1980, p. 5-7).

US EPA's objections to the Senate's proposed revisions to the CWA were spelled out in a letter dated 20 June 1980 from the Administrator, Douglas Costle, to Senator Jennings Randolph, Chairman of the Senate Committee on Environment and Public Works:

"Section 3 of S. 2725 would authorize use of section 201 funds to dredge PCB's from the Hudson River unless funds become available for this project under section 115 or Superfund. H. R. 6667 has no comparable provision. We recognize the problem associated with the hot spots, as well as migration of PCB-contaminated dredge spoils in the New York Harbor. However, we cannot approve the use of municipal treatment works construction grant (sic) funds (section 201) for this purpose. Such an action would establish a precedent which, if followed nationally, could seriously deplete available allocations of 201 dollars in several States and jeopardize the integrity of the construction grants program."

On 25 June 1980, the Senate considered and passed S. 2725 by a vote of 93 to 0. Section 3 of S. 2725 was devoted to the Hudson River PCB reclamation-demonstration project. Included were a 3-year time limit on the authorization, a statement that money from the superfund bill under consideration should take preference over CWA funds, and a reduction of New York State's other CWA needs by the amount of the PCB project (Congressional Record, v. 126, p. 16724-16733; see also Senate Reports, 96th Congress, 2nd session, No. 96-744, Committee on Environment and Public Works, 15 May 1980, Clean Water Act Extensions).

As noted above, the corresponding House bill, H. R. 6667, lacking any mention of the Hudson River PCB project, was sent to the House with a unanimous recommendation by the House Committee on Public Works and Transportation. On the last evening of the legislative session, when the House finally took up S. 2725 that had been passed by the Senate, Representative Breaux (Louisiana) moved to amend the Senate bill by offering a substitute bill that had been agreed on in advance by the respective House and Senate committees. The substitute bill included the section pertaining to the Hudson River PCB Reclamation Demonstration Project, but with the language modified in light of the Ottinger amendment and including a Solomon amendment.

The substitute bill was passed by both houses of Congress on 01 October 1980 and became Public Law 96-483, Clean Water Act Amendment, on 21 October 1980.

In the final bill, the intent of Ottinger's amendment was written as follows:

"No pollutants removed pursuant to this paragraph shall be placed in any landfill unless the Administrator first determines that disposal of the pollutants in such landfill would provide a higher standard of protection of the public health, safety, and welfare than disposal of such pollutants by any other method including, but not limited to, incineration or a chemical destruction (sic) process."

Under par (b), Gerald Solomon (Rep., NY, 24th), the congressman in whose district the proposed project was located, added the following :

"The authority of this section shall be available until September 30, 1983. Funds allotted to the State of New York under section 205(a) shall be available under this subsection only to the extent that funds are not available, as determined by the Administrator, to the State of New York for the work authorized by this section under section 115 or 311 of this Act or a comprehensive hazardous substance response and clean up fund."

Finally, the bill concluded:

"Any funds used under the authority of this subsection shall be deducted from any estimate of the needs of the State of New York prepared under section 616(b) of this Act. The Administrator may not obligate or expend more than $20,000,000 to carry out this subsection."

Congressman Solomon later vowed to try to stop the project, by using "every ounce of influence I have with the (Reagan) administration" (quotation from Troy Times Record, Friday, 23 April 1982) to block the project at its final step, the signature of the Administrator of US EPA, Anne M. Gorsuch, which is required for approval of the final draft of the Federal Environmental Impact Statement (FEIS), and for allocating the balance of the $20 million authorized by the congressional amendment to the CWA.

US EPA Region II and CWA Sec 116 (I)

Despite their previous opposition, US EPA accepted the new congressional vote, but indicated that the rules for expenditure of funds by NYS DEC on the proposed dredging-encapsulation project would be those governing Title-II projects, not those related to Title-I projects. In other words, the rules would be determined by where the money was coming from, not from where the authorizing amendment had been added to the CWA.

As soon as the appropriate protocols had been developed, NYS DEC applied to US EPA for a Step-1 Grant under Sec. 116 to purchase equipment, to carry out design studies, and to do other preparatory work in connection with the Hudson River Reclamation-Demonstration Project. On 02 March 1981, EPA approved NYS DEC's Step-I grant proposal and provided $1,722,000 of the Federal authorization of $20 million to enable NYS DEC to commence the preparatory work.

Pursuant to the National Environmental Policy Act (NEPA), US EPA Region II began to prepare an Environmental Impact Statement for the proposed project. The Draft Environmental Impact Statement (DEIS) was published on 08 May 1981, and Legislative Hearings held on 23 June in the Washington County Courthouse, on 24 June at Dutchess County Community College, and on 25 June at the World Trade Center. Written comments from the public were due by 06 July. The Supplemental DEIS with EPA's written replies to the public comments was published on 08 August, with a deadline of 06 October set for comments on the Supplemental DEIS. The final EIS (FEIS) was published in October 1981.

As part of their effort in connection with the preparation of the EIS, US EPA Region II established a Citizen's Advisory Committee composed of 21 persons drawn from the three sections of the river: upriver (in the vicinity of the proposed project), midriver (near Poughkeepsie, which draws its drinking water from the Hudson River), and downriver (near the Port of New York and New Jersey).

The FEIS recommended a scaled-down version of the program of upriver rehabilitation recommended by the Advisory Committee to the Commissioner of DEC. The re-scoped version scaled down the amount of funds proposed for research, eliminated any actions with respect to the remnant deposits, and dropped the plan to relocate PCB-contaminated dredge spoils from certain NYS DOT sites to the proposed encapsulation facility at Site 10. The DEC plan for the re-scoped program was prepared without consultation with the Advisory Committee. The elimination of any action with respect to the Remnant Deposits amounted to a total repudiation by DEC of the recommendations about the remnant deposits that had been prepared and submitted by the Advisory Committee.

Also starting in 1981, NYS DEC commenced the processes involved in application for necessary permits to carry out the proposed dredging and to construct a facility for encapsulating hazardous waste at Site 10, in southern Fort Edward. (Further particulars related to the permit applications are found in a following section entitled NYS DEC's ATTEMPTS TO OBTAIN PERMITS TO ENCAPSULATE PCB-CONTAMINATED DREDGE SPOIL IN FORT EDWARD.)

US EPA determination re: CWA Sec 116: the Gorsuch R.O.D.

The final EIS prepared by EPA Region II contained a favorable recommendation for proceeding with the proposed reclamation-demonstration project. Accordingly, in November 1981, NYS DEC applied to US EPA for the remaining $18.2 million of federal funds to proceed with the project.

In a letter dated 11 December 1981 to New York Governor Hugh L. Carey, US EPA Administrator Anne M. Gorsuch indicated that US EPA was in final stages of the FEIS process, but that "the final decision on the funding of this project cannot be made until the New York State Hazardous Waste Siting Board completes its review of the State's proposal and renders a decision as to whether or not a Certificate of Environmental Safety and Public Necessity will be issued. Once that decision is made public, a final decision on the project will be made by EPA."

On 28 December 1981, US EPA Administrator Anne M. Gorsuch signed EPA Agency Order 2200.4 that mandated external peer review for all documents attributable to EPA and prepared by an EPA employee, consultant, contractor or grantee for distribution outside the Agency. NYS DEC first learned of this order in a letter to NYS DEC Commissioner Robert F. Flacke from US EPA Deputy Administrator John W. Hernandez, Jr., dated 24 June 1982, in reply to Commissioner Flacke's letter to Anne Gorsuch dated 01 June 1982 in which Commissioner Flacke, having learned about the peer review of the Hudson River project, had complained about this "additional" requirement. In his letter, Hernandez indicated that the technical experts had been chosen for their work "in biological and ground water (sic) research." The reviewers were: Dr. Martha Sager (Biology, American University); Dr. C. H. Ward (Groundwater, Rice University); Dr. Raymond Harbison (Toxicology, University of Arkansas for Medical Sciences); Dr. Richard Hill (Senior Science Advisor to Assistant Administrator, EPA); and Mr. David Davis (Division Director, Special Environmental Programs, EPA).

These reviewers made at least 19 comments, 4 of which (Nos. 14, 15, 16, and 17) asserted (without supporting documentation and in the face of data presented in the document reviewed) that dredging would reintroduce large quantities of PCB back into the water column. Two others (Nos. 11 and 19) questioned the need for any further "demonstration" projects. One (No. 12) asked: "How urgent is the need for the river and for the exposed population?" No. 7 asked for geologic study of the location and extent of sand "discontinuities" (within the clay-silt) at the proposed containment site. No. 2 stressed that the issue of compensation for economic loss to those living near the proposed containment site had not been adequately addressed in the FEIS. No. 9 found a deficiency in that: "The no-action alternative has not been fully explored to consider cost effectiveness. Potential damage claims may exceed the cost of the project." No. 4 was upset because the "primary method of PCB transport in the water column has not been identified (e.g., dissolved or adsorbed). Resolution of this would allow dredging in the hot spots which contribute the most PCB to the water column." No. 13 pointed out that because the U. S. Department of the Interior has classified the upper Hudson as a "recreational river," it is presumably recovering from PCB contamination the assumption follows that recovery will continue if the river is left undisturbed." The writer of No. 13 did not make the connection between remedial measures taken and less water flowing down the river and lower PCB values, but instead, accepted the popular belief that "the river is cleaning itself." (This point is discussed further in the section entitled: CURRENT STATUS OF THE PCB-POLLUTION SITUATION IN THE UPPER HUDSON RIVER.)

By October 1982, after a year's delay for the newly instituted "peer-review" procedure, US EPA indicated that its final EIS on the Hudson River project was finished. Accordingly, on 08 October 1982, NYS DEC submitted its grant application for the remaining funds.

On 31 October 1982, US EPA published its final EIS. In this document, the proposed Hudson River hot-spot dredging project was recommended in view of its net environmental benefit for both New York and New Jersey.

On 22 December 1982, 22 members of the Congressional delegations from New York and New Jersey (Congressman Gerald Solomon not included) sent a letter to Anne Gorsuch urging expeditious approval of the project funds. They wrote: "Failure by EPA to obligate these already appropriated funds could result in further delay, possibly jeopardizing funding support for the project and contributing to further accumulation of PCBs in the Port of New York-New Jersey."

Late on Thursday afternoon, 30 December 1982, US EPA Administrator Ann Gorsuch issued a Record of Decision on NYS DEC's application for the balance of the CWA Sec 116 (via Sec 201) funds ($18.2 million). Administrator Gorsuch declared that the balance of Sec 116 funds is "not available" for the proposed Hudson River Reclamation-Demonstration project; that all work on the Hudson River Reclamation-Demonstration Project using such funds be halted; that any unexpended funds from the Step-I grant be frozen; and that all equipment purchased thereunder be turned over to US EPA. Despite the fact that the upper Hudson River had not been placed on the Superfund National Priorities List (NPL), Administrator Gorsuch determined that funds for dealing with the Hudson River PCB-pollution problem from Superfund were "available". (The language of this part of the EPA Record of Decision conforms to the Solomon amendment to Section 116.)

US EPA And Superfund (I): NUS R.A.M.P.

In February 1983, US EPA formally notified GE that under the terms of CERCLA ("Superfund"), GE is designated as the "responsible party" with respect to the PCB contamination of the Hudson River.

Also, early in 1983, US EPA engaged the NUS Corp. of Pittsburgh, Pennsylvania to carry out the Remedial Action Assessment required under the Superfund legislation and to prepare a Remedial Action Master Plan (R.A.M.P., or RAMP). This entailed another complete review of all the documents that had been assembled into US EPA's EIS (which had, in turn, been "peer reviewed" and delayed for a year in 1982), plus another round of public hearings and preparation of responses to public comments. A new feature of the NUS document was the preparation of cost estimates for various PCB-destruction processes that had been proposed.

On 05 May 1983, US EPA met with GE representatives to discuss the Agency's intention of listing the Hudson River PCB site on the Superfund National Priorities List (NPL). On 08 September 1983, US EPA published a proposed update of th NPL that included the upper Hudson River.

On 26 July 1983, a Congressional delegation consisting of representatives and senators from New York and New Jersey met with William Ruckelshaus, then newly reappointed as Administrator of US EPA. As Chairman of the Hudson River PCB Settlement Advisory Committee, I had been invited to attend by representatives Ottinger and Fish. Over the objection of representative Solomon, I was allowed to remain in the meeting, whereas all congressional staff were excluded.

In September 1983, only a few days before 30 September 1983, the statutory deadline for authorization of Section 201 funds for Hudson River Reclamation-Demonstration Project under Sec. 116 of the CWA, the NUS Corp. issued its RAMP. The RAMP recommended that the remnant deposits be covered (estimated cost: $2.53 million), that the only public-health concerns were direct exposure via municipal drinking-water supplies in Waterford (to be evaluated at a cost of $120,000), and that no Superfund money should be devoted to the previously recommended hot-spot dredging-and-encapsulation project.

Lawsuit over Gorsuch R.O.D. re: CWA Sec 116

In order to try to "stop the clock" and thus to keep the about-to-expire Section 116 funds potentially available for the Hudson River Reclamation-Demonstration Project, and to try to find ways to convince EPA to revise the Gorsuch determination, the State of New York; Hudson River Sloop Clearwater, Inc.; Scenic Hudson, Inc.; Natural Resources Defense Council, Inc.; The Hudson River Fishermen's Association; John Mylod; and Hon. Richard Ottinger filed a lawsuit against US EPA.

In a letter dated 29 September 1983 to the members of Congress who had attended the meeting with him on 26 July 1983, Mr. Ruckelshaus indicated that the agency contractor's (NUS Corp.) report about the options under CERCLA ("Superfund") had concluded that the only cost-effective options were:

> "(1) the containment of exposed deposits of polychlorinated biphenyls (PCBs) at five contaminated areas along the shoreline of the Hudson River and (2) the evaluation of drinking water (sic) supplies at Waterford, New York to determine if PCB contamination poses any potential threat to the public. (Item 1 refers to the remnant deposits; the estimated cost of this shoreline project was cited here as being only $1.8 million.)

The Ruckelshaus letter continued:

> "The study also concluded that the dredging of bottom sediments, whose PCB concentration is greater than 50 parts per million, is not cost-effective (sic) because: (1) the lack of a defined threat to public health; and (2) the difficulty in showing that significant environmental and public health (sic) benefits would result."

> "Because it appears that CERCLA funds may not be available for the dredging project, I have decided to consider an application under section 116 for a PCB demonstration project."

He listed two points of particular concern to him:

(1) "the availability of a secure landfill site," and
(2) "better data defining the location of the significant bottom sediment (sic) areas."

In concluding his remarks about the CWA funding, Ruckelshaus stated:

"I am willing to consider a PCB dredging (sic) project for funding when these two matters are resolved."

Finally, he mentioned the consent order that had been signed 23 September 1983 in connection with the lawsuit. "This order uld give us the opportunity to insure that the intent of Con-ess is carried out."

On 10 May 1984, US EPA and parties to the lawsuit signed a settlement agreement and the lawsuits were dismissed. In this agreement, US EPA stated it would make a grant of ca. $18 million of Sec 116 funds to the State of New York for the dredging and disposal of PCBs in the Hudson River. In a new Step I, NYS DEC agreed to resurvey the hot spots in the Thompson Island pool, which had been recommended by EPA's contractor (NUS Corp.) in the Superfund RAMP, and to resume the search for and, having found, to carry out the required environmental studies of a suitable encapsulation site. A new deadline of 11 May 1988 was agreed to by which time NYS DEC estimated that it would be able to resurvey the hot spots in the Thompson Island Pool, identify new candidate encapsulation site(s), carry out environmental studies at the site(s), and acquire the necessary site permits.

What this settlement agreement did in effect, was to undo the Gorsuch "shell game" about the "availability" of funds from CWA Sec. 116 and Superfund. Administrator Gorsuch had denied the balance of the CWA funds, stating that Superfund was "available." But, then when the Superfund RAMP had been completed, the *recommendation was not to dredge the upper Hudson River.* Thus, for the dredging project, Superfund was "not available." That position reopened the situation with respect to funds from CWA Sec 116, which then became "available" once again.

(In view of delays in state permit proceedings, particularly with respect to the New York legislature's passage of an authorization for the State to override local zoning in connection with hazardous-waste facilities and Commissioner Jorling's ruling that this y applied to Siting Board II and thus that a comparison be de between Site G and Site 10, the 11 May 1988 deadline has een extended, subject to provisions whereby New York State guarantees the 1982 value of the federal funds, however these are finally spent.)

US EPA R.O.D. of 25 September 1984: CWA Sec 116 (II) and Superfund (I)

On 25 Sept. 1984, Lee M. Thomas, Assistant Administrator, Office of Solid Waste and Emergency Response, signed US EPA's Record of Decision, Remedial Alternative Selection with respect to Hudson River PCB Site; Glen (sic) Falls, New York. This document reviews some of the history of the PCB pollution and attempts to deal with it. Under the heading of Enforcement, it states:

> "On October 27, 1983, EPA issued a Notice Letter to G. E. as a responsible and liable party. This letter notified G. E. of EPA's intentions to conduct a predesign sampling program and implement the remedial alternatives unless the company agreed to do so itself.
>
> "G. E. responded to this letter by calling EPA's notice premature and unjustified. First, G. E. objected to the fact that EPA issued a notice letter for a site that is not on the NPL; and second, the company did not recognize a threat caused by the site to human health or the environment.
>
> "EPA has responded to G. E.'s letter by stating that remedial planning (sic) activities can be undertaken for a site on the proposed list. EPA may issue an order to the company for remedial design and clean-up. EPA also discovered that the Niagara Mohawk (sic) Power Corporation may also be a site owner and responsible party. A notice letter was issued on February 29, 1984, to Niagara Mohawk (sic), and an order will be issued if it is determined that the company is a responsible party..."

With respect to the river sediments, US EPA wrote:

> "Although *studies of the river system are continuing*, sufficient data to support a no-action alternative as the permanent recommended alternative are not available at this time."

US EPA found no methods for in-river destruction of PCBs and that in-river containment would cost about the same as dredging initially, but would incur large maintenance problems. They also rejected bank-to-bank dredging.

As for contaminated fish, US EPA held that NYS DEC restrictions ban the fish and that:

> "the average level of contamination of Hudson River fish has declined below the FDA limit of 5 ppm although highly contaminated individual fish are still found in both the Upper and Lower Hudson."

US EPA's final remark about fish is:

> "The enforcement of the fishing bans and the continued monitoring of the contamination should reduce the threat to consumers while the fish population continues its natural recovery during the *interim* evaluation period. It is projected that the natural assimilative capacity of the river will continue the downward trend in the levels of PCBs found in the river."

US EPA wrote that current information made it difficult to determine PCB release from the remnant deposits

> "pending an ultimate decision on whether and how the contaminated sediments will be addressed."

Because they preferred the least-expensive option, US EPA decided that:

> "in-place containment is the recommended remedial option for the remnant sites at this time. The appropriateness of further remedial action for these sites will be reexamined if EPA decides at a later date to take additional action with respect to sediments in the river."
>
> "The lack of sufficient data to establish the fate and transport of PCBs in the Hudson River prevents the Agency from making a final determination of no-action (sic)."

But, for various reasons, US EPA has recommended the no-action alternative at this time. However:

> "This decision may be reassessed in the future if, during the interim evaluation period, the reliability and applicability of in-situ or other treatment methods is demonstrated, or if techniques for dredging of contaminated sediment from an environment such as this one are further developed."

Finally, US EPA noted the problem between their interim decision about the remnant deposits and TSCA regulations:

> "Full consistency with these TSCA standards is not being achieved because in-place containment is intended as an interim remedy to address the direct contact and volatilization threat posed by the

sites. The remedy is not intended to eliminate the low levels of release of PCBs into the Hudson River."

US EPA Region II, NYS DEC, and CWA Sec 116 (II)

Since US EPA and NYS DEC and others signed their settlement agreement on 10 May 1984, US EPA Region II personnel have been very supportive of and cooperative with NYS DEC's efforts to carry out the proposed reclamation-demonstration project.

In 1984, NYS DEC received a second Step-1 grant to carry out the resurvey of the hot spots in the Thompson Island pool and to pay for the work associated with selection of a new proposed encapsulation site. After two extensions, another court-established deadline has passed without NYS DEC's being able to fulfill Ruckelshaus condition (1), mentioned previously. Whether a further extension will be agreed to is yet to be determined. (The US EPA regional administrator had agreed informally with Congressman Solomon that US EPA Region II would not be a party to extending the 11 May 1988 deadline, but that has, in fact, been done.) A brief summary of the permit proceeding is contained in the following section.

US EPA and Superfund (II)

As mentioned, the 99th Congress passed amendments to and an extension of CERCLA known as SARA. One of the changes in the new law is the program entitled Superfund Innovative Technology Evaluation (SITE), in which funds have been made available for field demonstrations of techniques for detoxifying toxic wastes as an alternative to simply encapsulating them. Nothing official has been put in place for bringing the upper Hudson River into the SITE program, but informal discussions toward that end between US EPA Region II and NYS DEC have begun.

Superfund II obliges EPA to reexamine its public-health determinations made for sites under Superfund I. As far as the upper Hudson River is concerned, the 1984 FDA change in its tolerance limit of PCBs in contaminated fish from 5 ppm to 2 ppm means that the lack-of-public-health-hazard position reached by US EPA in 1983 with respect to eating PCB-contaminated fish will have to be changed. (See under section entitled INSTITUTIONAL/MANAGEMENT CONSIDERATIONS the sub-section entitled Contrast Between US EPA's Superfund Recommendation For Remediating PCB Contamination in Upper Hudson River And In New Bedford Harbor, Massachusetts.)

NYS DEC's ATTEMPTS TO OBTAIN PERMITS TO ENCAPSULATE PCB-CONTAMINATED DREDGE SPOIL IN FORT EDWARD

From the time that the Advisory Committee recommended that NYS DEC proceed with the dredging option, it became clear that two requirements would be: (1) a suitable site, and (2) permits to construct a hazardous-waste facility. Moreover, in order to obtain these permits, stringent provisions of both state and federal laws would have to be met. The relevant state statutes were passed in 1978 (The Industrial Hazardous-Waste Management Act of 1978). A key provision is the appointment by the Governor on request from the NYS DEC Commissioner of a Siting Board to evaluate the application. The law directed the Commissioner of NYS DEC to promulgate rules and criteria for guiding Siting Boards and to have these in final form by 15 July 1979. NYS DEC began the proceedings for Siting Board I in September 1981, at a time when these required rules and criteria were only in draft form. Under this state law, two requests have come from NYS DEC over proposals to encapsulate PCB-contaminated dredge spoil from the hot-spot dredging project. I will discuss these under the headings of Hudson River Siting Board I and Hudson River Siting Board II.

Hudson River Siting Board I

Hudson River Siting Board I was convened late in 1981 to weigh NYS DEC's request for Site 10, close to the river in southern Fort Edward (See Figure 4). The Commissioner of NYS DEC appointed Administrative Law Judge Robert Drew as the Hearing Officer to preside over the joint hearings for the NYS DEC permits and the Certificate required under the Industrial Hazardous Waste Facility Siting requirements. As NYS DEC representative and Chairman, Commissioner Robert Flacke appointed Richard A. Persico, the chief legal counsel to NYS DEC.

The pre-hearing conference was held on 24 September 1981, at which time a group of local residents opposed to the proposed dredging project and named Washington County CEASE, Inc., filed for and was granted full-party status. (CEASE is an acronym for "Citizen Environmentalists Against Sludge Encapsulation.") The attorney for CEASE moved to halt the proceeding on the grounds that they would be premature because the required rules and criteria for guiding siting boards had not attained their mandated final status. This motion was denied and the evidentiary hearings began on 04 November 1981. They spanned a 22-day period and ended on 21 January 1982. No substantive evidence against the NYS DEC proposal was introduced, nor were any objections raised to the scientific aspects of the proposal.

On 22 April 1982, Hudson River Siting Board I voted affirmatively to recommend to the Commissioner of NYS DEC that the requested Certificate of Environmental Safety and Public Necessity and the DEC permits be granted. As part of their decision, the board listed 16 conditions that NYS DEC was obliged to meet in connection with the proposed project. Commissioner Flacke accepted the recommendation of Hudson River Siting Board I, and issued the Certificate and NYS DEC permits.

CEASE appealed this action, on 3 grounds:

1. The Siting Board had acted under draft guidelin[es] not under the required final criteria;
2. The decision illegally overrode local zoning laws;
3. Mr. Persico, Chairman of the Siting Board, had continued to serve as Chief Counsel to NYS DEC, and thus potentially advised both the applicant group within NYS DEC who sought the permit, and another group within NYS DEC that was responsible for granting permits. As such, CEASE claimed Mr. Persico was in a position of conflict of interest.

Supreme Court Justice Thomas Mercure sustained all three of CEASE's grounds for appeal and on 18 July 1983, voided the permits and the Certificate. NYS DEC appealed to the Appellate Division of the NYS Supreme Court, but on 08 March 1985, the Appellate Court sustained Justice Mercure. Thus ended the episode of Siting Board I.

Hudson River Siting Board II

In order to forestall all suspicions about conflict of interest with respect to another siting-board proceeding, NYS DEC has, on all matters related to PCBs in the upper river, reorganized itself into three distinct divisions. These are: (1) DEC Executive; (2) Project Sponsor Group (PSG); and (3) Regulatory Review Group (RRG). Pursuant to the State Administrative Procedure Act, section 307, covering communications with the decision maker, on all matters related to PCBs in the Hudson River, these groups must remain isolated from one another. They can communicate only through the Administrative Law Judge.

After it had fulfilled US EPA's requirement (2) of the Ruckleshaus letter of 29 September 1983 (about the resurvey of the hot spots in the Thompson Island pool), the NYS DEC PSG prepared and submitted a new application for the Certificate and NYS DEC permits. The proposed site requested is known as Site

G; it is located adjacent to an unremediated PCB dump site in northern Ford Edward (See Figure 4) on a tract lying within an Industrial Zone. The PSG submitted the application to the RRG for the required DEC permits. On 12 January 1987, Administrative Law Judge Robert Drew, of the DEC Regulatory Review Group, determined that the application was complete and issued Certificate of Completeness. At the same time, the notice of ..mpletion of the Draft Supplemental Environmental Impact Statement prepared jointly with US EPA Region II was issued, with a notice of joint Legislative Hearings to be held on 24 February 1987 in Poughkeepsie, and on 25 February 1987 in Fort Edward.

Administrative Law Judge Daniel E. Louis was designated to be the Hearing Officer for the proceeding with Hudson River Siting Board II over the request for building an encapsulation facility at Site G, adjacent to the Fort Edward landfill, and Irwin King, to be the Chairman. Judge Louis scheduled an Issues Conference on 26 February 1987. *In connection with this conference,* GE announced its intention of filing for party status in opposition to the NYS DEC proposal. Others requesting party status included: Washington County CEASE, the Town of Fort Edward, Sharon Ruggi, Eleanor Burch, the Kingsbury Chamber of Commerce, the New York Farm Bureau in opposition; and Scenic Hudson, The Hudson River Sloop Clearwater and the Hudson River Fishermen's Association in support. The Town of Waterford, which filed for Party Status in opposition, settled its differences with DEC over the potential impact of the proposed project and withdrew.

After the Hudson River Siting Board II had studied the points raised at the Issues Conference and the pre-filed written testimony, it concluded on 20 March 1987 that two issues had to be adjudicated before the formal testimony could be heard. These were: (1) the compatibility of the proposed project with local zoning regulations; and (2) whether there is any conflict between the project and New York State's Agricultural and Markets Law and any local laws related to the agricultural district.

The Adjudicatory Hearings began on 19 May 1987; approximately 30 sessions were held during the following months.

In July 1987, the Commissioner of Agriculture held a Legislative Hearing on the agricultural aspects of the proposed project and subsequently filed a "Report of Public Hearing" with the Administrative Law Judge. Judge Louis accepted this report and included it with the record of the Siting Board.

While the Hudson River Siting Board II hearings were in progress, the 1987 New York State Legislature adopted the recommendations of the Governor's Task Force on Hazardous Wastes and revised the State Environmental Conservation Law (ECL), which eliminated local zoning and land-use regulations from decisions related to the applications for constructing or for operating a hazardous-waste disposal facility.

On 19 November 1987, the new NYS DEC Commissioner, Thomas Jorling, ruled that this new State law must be applied in Hudson River Siting Board II's hearings over the NYS DEC PSG's permit request for Site G. Commissioner Jorling directed the PSG to review the merits of sites previously considered but rejected because of zoning conflicts. In effect, this meant including Site 10, for which Hudson River Siting Board I had granted a Certificate and the NYS DEC permits but which, on the basis of Site 10's incompatibility with local zoning, the PSG had excluded from the request to Hudson River Siting Board II.

On 24 November 1987, the PSG commented on alternative sites and argued that considering other sites would only delay the project.

On 05 January 1988, the New York Farm Bureau filed a motion to discontinue the hearing on the grounds that the new amendments to the State's Environmental Conservation Law (ECL) had set forth a hierarchy of practices in which land disposal ranked as the "least preferable" method.

On 22 January 1988, Judge Louis denied the Farm Bureau motion, citing that the ECL did not exclude land disposal where other methods were not available.

On 27 January 1988, Judge Louis ordered the PSG to prepare a study comparing Sites G and 10 and that Site 10 would be the only location to receive further consideration. He directed PSG to gather information for a State Environmental Quality Review Act (SEQRA) comparative study of Sites G and 10. After the Regulatory Review Group (RRG) had decided that the comparative study was complete, the hearings before Hudson River Siting Board II were reopened on 12 April 1988. Further testimony was introduced, not only about the relative merits of Sites G and 10, but also about new experimental evidence on anaerobic dechlorination of PCBs from the laboratory of Dr. James Tiedje, Michigan State University (introduced by GE).

After this testimony had been presented, the hearings were closed and a schedule set for filing of final briefs, appeal procedures, and the decision. On 20 September 1988, Judge Louis issued his Recommended Decision (RD) in which he advocated an affirmative recommendation with respect to the Certificate and NYS DEC permits. The Record of Hudson River Siting Board II was closed on 10 November 1988.

On 09 January 1989, Hudson River Siting Board II voted in favor of the need for the proposed dredging project, but rejected the application for Site G. NYS DEC Commissioner Jorling accepted Hudson River Siting Board II's report and directed the PSG to reapply for Site 10, but to expand the scope of the application to the level recommended by the Advisory Committee in 1978 (all 40 hot spots, the remnant deposits, and the NYS DOT dredge-spoil sites). He also directed them to include in their future application permission for the use of processes to remove PCBs from contaminated sediments and/or to destroy the PCBs.

The Town of Fort Edward has engaged an attorney and filed a court challenge to Hudson River Siting Board II's decision. According to Fort Edward's petition, the decision lies outside the limits the law specifies for siting-board options. Stated in brief, the two legal options are: (1) to deny the application (a "No" verdict), or (2) to approve it with conditions (a "Yes, but" verdict). Hudson River Siting Board II's decision can be characterized as a "No, but" verdict. The objective of the petition is to force NYS DEC to start over with a totally new Hudson River Siting Board III when the application for the second request for Site 10 is ready. The petition is intended to prevent NYS DEC from reconvening Hudson River Siting Board II, as IIa, for example, to proceed on the grounds that the Certificate has been approved and that the only business to be dealt with concerns the merits of Site 10 and the SPDES permits.

INSTITUTIONAL/MANAGEMENT CONSIDERATIONS

New York State Constitutional Mandate re: Barge Canal

The New York State Constitution, Article 15, Canals, prohibits the State from ever disposing of the canal system. In effect, then, this amounts to a constitutional mandate to maintain the barge-canal system. This article obliges individual Legislatures to appropriate funds needed to keep the canal system operative, including maintenance dredging as required. In terms of the PCB-pollution problem, NYS DOT has in the past removed an estimated 160,000 pounds of PCBs in the sediments dredged to keep open the canal, and in the future, NYS DOT will have to dredge time and again to stay ahead of the accumulating sediment. In short, dredging has been and will continue to be a necessary activity in the upper river. Accordingly, it becomes imperative that the State acquire one or more sites and the appropriate permits for the upland deposition of dredge spoils which will continue to contain large concentrations of PCBs for the foreseeable future. The so-called "no-action" alternative, therefore, does not mean no dredging, ever. It means only that no dredging other than channel-maintenance dredging will take place.

Miscellaneous Political Considerations

No account of the history of the attempts to deal with the Hudson River PCB-pollution problem would be complete without at least some mention of several miscellaneous political considerations that have become closely intertwined with nearly all facets of the problem. These have included the changing governors and NYS DEC commissioners, the relationships between New York State and GE, the opposition to the proposed encapsulation sites by nearby residents, Congressman Gerald B. Solomon's opposition, ingrained differences between New York residents living upstate as contrasted with those living downstate, and structural problems in the organization of New York State government that preclude smooth accommodations between the State and residents living near a proposed environmental facility.

Changing Governors and NYS DEC Commissioners

The topic of PCB pollution of the upper Hudson River and the fishery was made public in 1970, two years before the creation of NYS DEC (from its former status of Department of Conservation). Governor Nelson Rockefeller announced the appointment of Henry Diamond as his first NYS DEC Commissioner on 24 April 1973. Diamond was sworn in on 26 June 1973 and served until 09 December 1973, when he resigned to become the head of a Rockefeller commission on "Critical Choices..." First Deputy Commissioner James L. Biggane was appointed to succeed Diamond; Biggane was sworn in as Commissioner on 28 December 1973. Both Diamond and Biggane suppressed all the information from the NYS DEC staff and elsewhere about PCB pollution.

Hugh Carey was elected Governor of New York in November 1974. He appointed as NYS DEC Commissioner Ogden Reid, who was sworn in on 08 January 1975. One of Reid's first major actions was to assemble the case showing that the PCB pollution of the upper Hudson River was coming from GE discharge pipes in Hudson Falls and Fort Edward. As noted in a previous section, Commissioner Reid began the Administrative Proceeding against GE in September 1975. By the end of 1975, Reid had fallen out of favor with Governor Carey, who fired him on 29 April 1976. On 30 April 1976, Carey named as acting NYS DEC Commissioner Peter A. A. Berle. On 26 May 1976, Berle was sworn in as NYS DEC Commissioner. Berle signed the Settlement Agreement with GE and appointed the members of the Hudson River Settlement Advisory Committee in October 1976. Commissioner Berle actively pursued the goal of rehabilitating the upper Hudson River; his staff commenced the negotiations with US EPA and the New York Congressional delegation over the revisions to the CWA. In 1978, however, Berle ran afoul of Governor Carey over the Air-Quality Permit for the controversial Westway project in Manhattan. On 23 December 1978, Governor Carey fired Berle and replaced him with Robert F. Flacke. This change was made soon after the Legislature had passed the Industrial Hazardous Waste (sic) Management Act of 1978. Commissioner Flacke was not able to comply with the provision of this act that required the NYS DEC Commissioner to promulgate by 15 July 1979 the final guidelines and siting criteria to be used by siting boards. Commissioner Flacke appointed the Chairman of Siting Board I and was also the Commissioner who granted the permits that the Supreme Court voided.

In November 1982, Mario Cuomo was elected Governor of New York. Governor Cuomo's first NYS DEC Commissioner was Henry G. Williams, who took office in January 1983. Commissioner Williams reorganized the NYS DEC in response to the court's verdict. In January 1987, Cuomo decided to replace Williams and announced his plans to appoint the incumbent, Thomas C. Jorling.

Relationships between New York State and GE

The terms of the initial settlement have been set forth in a previous section. New York State went to court against GE over the cleanup of seven sites where PCBs had been dumped ("seven-sites" agreement). Finally, GE has sought and been granted party status in opposition to NYS DEC's presentation before Hudson River Siting Board II.

Opposition of local residents

As a general statement, one can characterize most Washington County residents as being opposed to the notion that their county is to be the site where PCB-contaminated sediments dredged out of the Hudson River are to be encapsulated. I have heard nearly every conceivable argument about why the proposed reclamation project is not a good thing to do. Some advocate leaving the river alone (See following section on miscellaneous political considerations, ingrained differences: upstate vs. downstate.). Others have expressed various fears about what might happen to them if the project is carried out. These fears include the possibility that their wells might be contaminated with PCBs leaking out of the encapsulation site or that the PCBs volatilizing from the site during the filling stages may contaminate their crops or their cattle. Owners of adjacent properties fear loss of value from proximity to the encapsulation site. Many residents, whether they live near or far from the proposed encapsulation site, worry that the facility, once established, ostensibly to receive PCB-contaminated sediments dredged from the Hudson River, may later become a catchall site to which various unspecified toxic wastes from all over will be shipped. Still other arguments against the proposal are based on the notion that if the whole job is not to be done, then why do some fractional part of it. Some residents have expressed the idea that if the federal and state governments are going to spend $30 million in the Fort Edward area, then this money should go toward fixing roads, bridges, or other public facilities that need attention. In sum, what NYS DEC and the Hudson River PCB Settlement Advisory Committee see as a vital part of the solution to a complex environmental morass in the Hudson River is to the residents of Washington County a huge problem. They can see zero positive benefits to themselves arising from the proposed project and a seemingly endless list of negative factors.

Citizens actively opposed to the project have formed organization named Washington County CEASE, Inc. C groups who have sought party status in connection with the hearings of Siting Board II include the Washington County chapter of the New York Farm Bureau, the Town of Fort Edward, and the Kingsbury Chamber of Commerce.

The individual landowners in opposition have changed, depending on whether the proposed encapsulation site was Site 10 or Site G. Most of the individuals who actively opposed the proposal for using Site 10 have not bothered about the proceedings over Site G, and vice versa.

Congressman Solomon's opposition

A political consideration of the utmost importance in connection with the delay in carrying out the Hudson River PCB Reclamation-Demonstration Project has been the resolute and effective opposition on the part of the congressman from New York's 24th district. This district is not only much affected by the PCB-pollution problem but also is the one in which the two cost-effective dredge-spoil/encapsulation sites are located. More than any other single factor, the maneuvers of Representative Gerald B. H. Solomon have kept NYS DEC from carrying out the first step in the comprehensive rehabilitation of the upper Hudson River. In a previous section, I have summarized Congressman Solomon's role in reacting to the bills mandating that US EPA allow NYS DEC to use CWA funds for dredging the Hudson River, which were introduced by his colleagues in the New York congressional delegation. Here, I propose to deal with some of the arguments he has raised in public statements.

In a letter dated 05 March 1982 and addressed: "Dear Friend of the Agricultural Community," Congressman Solomon sounded the alarm that NYS DEC (ENCON) was proposing a dr[illegible] plan that "could jeopardize hundreds of farms in our area. ...[illegible] direct threat to dairy, fruit, and other agricultural concerns canno[t] be overstated."

After noting that the proposed project would cost $30 million and would dredge less than 25 percent of the PCBs in the river, Solomon wrote: "...but even worse, the dredging will stir thousands of pounds of PCBs back into the river right at a time when the level of PCBs found in the fish down stream is actually decreasing! This stirring will cause PCBs to evaporate into the air ...d could damage crops and livestock which feed on the crops ...eral miles away from the river. I believe we must unite to stop this dredging plan!" (Solomon's emphasis).

The facts about the stirring effects of dredging do not support the congressman's vision of dredging stirring "thousands of pounds of PCBs back into the river," but he was correct in stating that the PCB levels in fish were declining (See a following section on MONITORING OF REMEDIAL ACTIONS, subsection Time history of PCB levels in fish.). However, faithful to his vision of the "thousands of pounds of PCBs" going "back into the river" from dredging, he connected these presumed consequences with dredging requirements downriver:

"The Hudson River's deep water (sic) channels are in constant need of dredging and by raising the PCB level downstream a serious question arises as to where the dredged materials will be dumped and how the dumping will affect farmland all along the Hudson Valley."

Solomon also raised the specter of groundwater contamination "by the dredging or by a leak from the proposed PCB waste-site."

Finally, he noted that in his judgment, the dredging plan "fails to respond to the effects of the dredging procedure on the drinking water in localities along the Hudson which do not use special filtration systems."

In a statement sent to the Hudson River PCB Settlement Advisory Committee at its meeting in Fort Edward on 20 October 1986, Congressman Solomon stated his desire to see the "majestic Hudson River restored," but that he does not support the proposal to "restore this through the dredging of PCB-laden ...iment on the river bottom, and landfilling this sediment in Fort ...ward." He contended that this plan is counter to the trend away from landfilling and "ignores the various technological alternatives that do exist."

As a method for dealing with the river by means other than dredging, Solomon advocated a scheme entitled: "capping on the river bottom." In favor of this proposal, he cited the US EPA's Superfund decision to provide funds "to cap PCB hot spots on the river banks near Fort Edward (i. e., the remnant deposits--JES), and for initial work on the construction of activated carbon (sic) filtration systems to replace outdated water systems along the Hudson River." Continuing, he argued for capping other hot spots in place on the river bottom and for monitoring the places thus capped. [As authority for the merits of his capping proposal, Solomon cited Dr. Joseph O'Connor (a New York University biologist), who has worked with the U. S. Army, Corps of Engineers in capping dredge-material disposal sites in the New York Bight, and who "believes dredging will release large amounts of PCBs into the water column of the river."]

As a "promising new technological development," Solomon cited the bacteriological processes being developed by the University of Houston and Detox Industries, of Sugarland, Texas. According to Solomon, Detox Industries "has already received approval from the Environmental Protection Agency to degrade PCBs biologically. Approval came following a successful demonstration project during which PCB concentrations in contaminated soil were reduced from 2,000 parts per million to less than four parts per million." What Congressman Solomon left unsaid with respect to the Detox bacterial processes is that for them to be applied to the Hudson River case means dredging the sediments from the river bottom. And a proposal for such ...edging triggers provisions in federal law that require the construction of a secure containment site, even if that site is to be used only as a work space.

In conclusion, Solomon raised once again the question of: "Why landfill?" He wrote: "The point that needs to be made is that landfilling is the least desirable solution, and that any alternatives should and must be explored."

According to a report in the Watertown Times, 19 January 1988, Congressman Solomon sponsored a groundwater-research bill that the House passed, "that puts off the dredging until the Agriculture Department and Environmental Protection Agency can put together a report from existing information on the potential impact of the dredging on groundwater contamination."

Congressman Solomon has insisted that calendar deadlines be written into the legislation authorizing the Hudson River reclamation-demonstration project under CWA Section 116. He has also opposed any extension of the court-ordered deadlines that were part of the Settlement Agreement which ended the lawsuit between the various parties and the US EPA over the Gorsuch Record of Decision of 30 December 1982 (See previous section entitled: NYS DEC's EFFORTS TO FIND FUNDS FROM "SOURCES OTHER THAN GE" FOR BEGINNING THE FINAL PHASE OF UPRIVER REHABILITATION). Therefore, his call for another study must be interpreted as a delaying tactic. I think it illustrates the different ways in which "studies" are employed by politicians as contrasted with "academics." New York City's Water Resources Commissioner Maurice Feldman pointed out the important distinction to the participants in the symposium on Water Pollution in the New York Area, convened by the Mayor's Task Force on Oceanography, and held in New York City on 13 December 1969. According to Commissioner Feldman, in the academic world, making a study is a way of life and a natural way to proceed as a basis for doing nearly everything. By contrast, to a politician, he said, calling for a study to be made is a tried-and-true delaying tactic.

Ingrained differences: upstate vs. downstate

Nearly any state-wide issue in New York tends to divide the citizens according to where they live. The "two New York's" are "upstate" (predominantly rural) and "downstate" (mostly the New York City metropolitan area). The proposed rehabilitation project for the upper Hudson River is no exception. The so-called NIMBY ("Not In My Back Yard") syndrome is buttressed by the notion that if nothing at all is done, the river will eventually wash the PCBs away from their existing upstate locations and spread them downstate. The extent to which this notion is comfortably held by the residents of Washington County is aptly illustrated by an exchange between one of the audience and me at a public-information meeting called by the NYS DEC staff and the Advisory Committee on 26 July 1978 and held in the Hudson Falls High School. I chaired the meeting and took questions from the floor that I either directed to other Committee members or to NYS DEC staff or answered myself. In reply to the question: "What would happen if nothing was done?" I stated that the PCBs would continue to be washed downstream. My answer was greeted by enthusiastic applause.

The local-level issues would appear to resolve themselves into the upstate farmers vs. the downstate fishermen. So far, the farmers have not been inclined to cooperate in an enterprise whose most-obvious potential economic benefits would accrue to downstate fishermen and the most-obvious problems to the upstate farmers.

Structural problems in organization of New York State government

One of the basic difficulties that has surfaced again and again at meetings in Fort Edward or Hudson Falls where the Advisory Committee has invited public comments is that local residents simply do not trust state officials. Despite their best efforts, the staff of NYS DEC have failed to convince residents living near a proposed hazardous-waste site that what a given staff member may say will actually happen. When one strips away all the points raised that can be dealt with using well-established scientific- or engineering-principles, one is still left with local fears about economic sacrifices; lack of local control on what kinds of wastes may be placed in the site; and a belief that even the most-carefully constructed encapsulation site, for example, will not be maintained. In short, most residents are convinced that what NYS DEC really intends to do is carry out a "dump-and-run" operation.

An example of how the residents of Washington County feel about NYS DEC staff's pledges about what kinds of wastes would be encapsulated at Site 10 is their support for legislative action. On 31 March 1981, a bill restricting the uses of Site 10 was introduced jointly: into the State Senate by Senator Stafford, and into the Assembly by members Hague, Engel, and Hinchey. This bill stipulated that the industrial hazardous-waste facility in the town of Fort Edward be operated "solely for the purpose of disposal of polychlorinated biphenyl taken from the Hudson River bed between Lock 2 and the village of Fort Edward." This bill was signed on 21 July 1981 as Chapter 700 of NYS Laws of 1981.

In practice, many of the fears expressed by the residents can and should be dealt with by the Siting Board. Under existing law, New York State is not able to volunteer to make certain arrangements that the residents would find satisfactory. However, the Siting Board can issue them as conditions. For example, the permits could limit what kinds of wastes become encapsulated. The Board could set conditions about local representation on control boards. But what the Board evidently cannot do is commit future legislatures to financial obligations. As mentioned, the Executive Committee of the Advisory Committee recommended to the Governor's Task Force on Hazardous Wastes that New York establish a special organization, such as the Triborough Bridge and Tunnel Authority or the New York Thruway Authority, having financial resources based on bond issues so that it could have the funds available to meet appropriate needs as they arise.

Contrast Between US EPA's Superfund Recommendation For Remediating PCB Contamination In Upper Hudson River And In New Bedford Harbor, Massachusetts

A final institutional/management consideration (and one that I think could as well have been placed under "miscellaneous political considerations") is the contrast in the decisions which US EPA has reached in its Superfund recommendations for the PCB-contaminated sediments in the upper Hudson River and in New Bedford Harbor, Massachusetts. The Remedial Action Master Plans (RAMPs) for both sites were prepared by the same contractor, the NUS Corporation, of Pittsburgh, Pennsylvania. The RAMP for New Bedford was issued in August 1984, within one month after US EPA's official Record of Decision (R.O.D.) on the Hudson River PCB Superfund site and in the same month in which FDA's lowering of the action level for PCBs in fish from 5 ppm to 2 ppm took effect.

In New York State, where the Hudson River is demonstrably spreading PCBs from upriver contaminated sediments into the largest metropolitan area in the country, New York City and vicinity, the US EPA R.O.D. (25 Sept. 1984) concluded that the existence of fish whose edible flesh contains about 4 ppm of PCBs does not constitute a human-health hazard. Specifically, EPA's decision about the fish in the Hudson River is to rely on what I call "nature's remedy." I repeat here the critical phrase from the US EPA R.O.D.:

> "The enforcement of the fishing bans and the continued monitoring of the contamination should reduce the threat to consumers while the fish population continues its natural recovery during the interim evaluation period. It is projected that the natural assimilative capacity of the river will continue the downward trend in the levels of PCBs found in the river."

This assertion was made one month after the US FDA had lowered its action level for PCBs in fish from 5 ppm to 2 ppm. Therefore, EPA's R.O.D. that consumption of fish containing 4 ppm of PCBs is not a human-health hazard not only flaunted the FDA's action level but represented a gross insult to the people of New York City.

Reduced to its simplest terms, the EPA position, as stated in the Hudson River R.O.D., compares with the famous remark ascribed to Marie Antoinette when she heard of the lack of bread for the hungry mobs of Paris 200 years ago: "Let them eat cake." EPA's 1984 equivalent is: "Let them (the New Yorkers) eat PCBs." [And to that may also be added: "Let them drink PCBs," for in early 1989, during a drought emergency, New York City tapped into the Hudson at Chelsea to augment its water supply by pumping 100 million gallons per day into its Croton Reservoir.] In short, faced with a major river spreading PCBs into the nation's largest metropolitan area, EPA's R.O.D. under Superfund I concluded that no human-health hazard exists!

In total contrast is the EPA position with respect to New Bedford, Massachusetts, where PCB-contaminated sediments are concentrated at the head of a small estuary, where the entering Acushnet River brings in what must be considered a "trickle" of water compared with the flow of the Hudson. Moreover, the natural action of the tides in New Bedford is to deposit suspended sediment at the head of the estuary rather than spread the PCB-contaminated sediments away from their existing locations. In the vicinity of New Bedford Harbor, edible marine organisms (fish, lobsters, shellfish) have been found to contain PCBs in excess of the FDA action limit (officially 2 ppm at the time the NUS Corp. RAMP was published after August 1984, just one month before the US EPA R.O.D. on the Hudson River and in the same month in which the new FDA limit became effective). The official EPA position about the PCBs in New Bedford Harbor is that the continued presence of PCBs in edible fish and other marine organisms constitutes a human-health hazard that must be eliminated. Accordingly, US EPA is actively attempting to clean up the PCB-contaminated sediments from New Bedford Harbor, by dredging. Here, then, is EPA advocating dredging to eliminate a PCB threat to human health in one state (Massachusetts), where natural spreading of PCBs from contaminated sediments is minimal at most and the size of the potentially affected population is in the low hundreds of thousands. Yet, in another state (New York), Epa opposed dredging because it claimed that eating fish containing PCBs in excess of the FDA action limit does not constitute a human-health hazard! As a result, US EPA blatantly refused to recommend remedial action by dredging in the PCB-polluted upper Hudson River. They did this despite all the scientific data showing that the Hudson River is continuing to spread PCBs down a major waterway into the nation's largest metropolitan area where the size of the population potentially affected by eating PCB-contaminated fish numbers in the range of ten million. And to repeat, the reason given for their rejection of dredging was lack of a demonstrated human-health hazard. According to EPA, what's a human-health hazard in Massachusetts is _not_ a human-health hazard in New York.

From these facts in the two cases, one may draw various conclusions. I think that a large political component has been at work. In New York State, the local congressman is totally opposed to river rehabilitation by dredging (and encapsulation of PCB-contaminated dredge spoils in his district). In Massachusetts, the entire congressional delegation, led by the local congressman, advocates EPA remedial action, and continues to pressure EPA to "do something." I think it is appropriate to end this section by repeating Prof. Sofaer's remark in his September 1976 memorandum to NYS DEC Commissioner Peter Berle:

> "Our legal system lacks devices for requiring agencies to participate in rectifying their own failures."

REMEDIAL ACTIONS TAKEN

The remedial actions taken to deal with the PCB pollution of the upper Hudson River have focused on: (1) eliminating the original point sources from the GE plants, and (2) trying to cut back on the amounts of PCB-polluted sediments available to the river. The first was taken by GE and the second includes steps taken by York State agencies, NYS DOT and NYS DEC.

GE Actions

Pursuant to the 1976 Settlement Agreement, GE has taken three significant actions in connection with the PCB situation in the upper Hudson River: (1) On the agreed-to date of 01 July 1977, GE stopped discharging PCBs into Hudson River; (2) GE has constructed wastewater treatment facilities at it capacitor-manufacturing plants at Fort Edward and Hudson Falls as agreed; and (3) GE is now using alternative compounds (alkyl phthalates) in its capacitors.

New York State Actions

New York State's remedial actions have included: (1) actual removal of PCB-contaminated sediments from the river by dredging and (2) steps to curb erosion of the remnant deposits and to remove and encapsulate those having the highest concentrations of PCBs.

NYS DOT dredging

As discussed in a previous section, NYS DOT dredging operations have included routine channel maintenance at various locations between Lock 7 and Troy and two massive cleanup operations at Fort Edward after the Fort Edward Dam had been removed in 1973, and great quantities of remnant deposits eroded by flood stages of the Hudson River in 1974 and 1976, surged downriver. Nothing further needs to be added here other than the remark that dredging as a remedial action has been taking place for other purposes and will continue to be required as long as the canal system must be maintained. Readers should bear in mind that the Advisory Committee's support for DEC's proposed project to rehabilitate the upper Hudson River by dredging PCB-contaminated sediments is based on critical scrutiny of all phases of a large-scale dredging operation in 1977 by members who, as a matter of "environmental first principles," were initially biased against dredging.

NYS DEC's actions with respect to remnant deposits (1975-1978)

The initial program followed by NYS DEC to curb erosion of the remnant deposits in 1974-1975 was designed and carried out after the 1974 flood, before the 1976 flood, and independently of the PCB contents of these deposits. I discus these under the heading of Erosion-control measures (I). The follow-up program took place after the 1976 flood and after the Advisory Committee itself became aware of the connection between eroding remnant deposits and continuing PCB pollution of the river. I discuss the DEC follow-up program under the headings of Erosion-control measures II and Removal and encapsulation at new Moreau facility of highly contaminated debris from Area 3A.

Erosion-control measures (I).-- New York State's reaction to the effects of the March-April floods of 1974 was to clean up the debris that inundated Fort Edward and to carry out various projects for preventing further erosion of the remnant deposits. The clean-up efforts have been set forth in a previous section related to dredging. The erosion-control measures, discussed here, are explained with reference to the work areas defined in the MPI reports. I proceed on the supposition that the reader understands where these areas are located (shown on Figure 11).

Two methods of controlling erosion were applied: (1) grading a low-angle slope and planting a vegetative cover; and (2) building a rock riprap. Table 12 gives the details.

Erosion-control measures (II).-- The flood of April 1976 constituted a severe test of NYS DEC's erosion-control measures (I). Before I take up the second stage of erosion-control measures, I summarize the effects of this second flood on the first-stage erosion-control measures.

As a general statement, the amounts of sediment eroded by the second flood were inversely proportional to the amount of rock riprap emplaced after the first flood. The rock riprap of Areas 4 and 5 withstood the flood waters, but the slope grading and planting and partial rock treatment did not. The mid-river island, Area 1, where no erosion-control measures had been carried out, migrated downriver (450 ft. at its upstream end; 300 ft. at its downstream end) and lost an estimated 60,000 cubic yards of debris. The nonprotected "beach" of Area 2 retreated up to 200 feet over a length of 2,200 feet. The quantity of debris eroded was estimated to have been 100,000 cubic yards. The result was a steep slope as after the 1974 flood. Although the flood waters overtopped the partial rock riprap of Area 3, they did not undermine it, but they did erode debris from landward of it. Much debris was also eroded from the parts of Area 3's shore that had not been armored by rock. The scour losses from Area 3 were estimated at 60,000 cubic yards. The rock ripraps of Areas 4 and 5 were submerged by 1.5 to 2 feet of water, but nevertheless seem to have withstood the ravages of the flood water. The protected debris in these two areas was not eroded.

The plans for erosion-control measures II began with a document prepared by MPI that summarized the costs of several alternative programs, with the factor of PCB containment newly considered.

The Advisory Committee modified the MPI-DEC preferences by emphasizing the urgency of preventing further erosion of the remnant deposits. The Advisory Committee unanimously recommended that money from the GE Settlement Fund be used to build a haul road down the steep east valley wall. Such a road facilitated the exporting of highly contaminated debris and the importing of blocks of quarried rock for further bank protection. After the road had been built, stone from the local quarry was brought in to construct a complete rock riprap along the east shore of Hudson River at Area 3. This riprap has prevented further erosion from Area 3.

The inaccessible shorelines of Areas 1 and 2 were not treated during the second phase of erosion-control measures.

Removal and encapsulation at New Moreau facility of highly contaminated debris from Area 3A of remnant deposits.-- The most highly contaminated remnant deposits were found in Area 3A. (This area had been discovered by MPI's further sampling and PCB analyses made in the winter of 1977-78 after the recommendations about the remnant deposits made at the November 1977 meeting of the Advisory Committee had been presented to Commissioner Berle.) As part of the rehabilitation program recommended to NYS DEC, 14,000 cubic yards of debris were scraped off from the barren flats in Area 3A and trucked to the new Moreau encapsulation facility (location shown on Figure 4).

MONITORING OF REMEDIAL ACTIONS

Under this heading, I present the results of NYS DEC's monitoring of NYS DOT's channel-maintenance dredging of 1977-1978 and of the rejected but de-facto "no-action" alternative.

Monitoring Of NYS DOT's Channel-Maintenance Dredging, 1977-1978

During the second cleanup of the Fort Edward navigation channel during 1977-1978, NYS DEC carried out a monitoring program designed to record the ambient effects of dredging. The dredging took place in the East Channel, Rogers Island, at Fort Edward (Hudson Falls quadrangle). Monitoring stations were established upstream of the operation (at the site of the former Fort Edward Dam; 1192.0 N, 696.8 E), in the West Channel (at the

Table 12. Erosion-control measures taken by New York State in remnant deposits, 1974-1975 (MPI, 1977b).

Dates	Project description	Work Area	DOT Contract	Cost
Oct. 74-Jul. 75	Remove 94 timber cribs from former pool area	NA	74-07	
Apr.-Dec. 75 1975	Bank graded from steep to low slope by bulldozing debris landward along 2,400 linear feet of shore; the MPI-recommended planting of willow shoots was not done because the work was completed in December (not a propitious time for starting willow shoots). Difficulty of access precluded economic delivery of rocks for bank armoring with a riprap.	2	75-06	$30/lin. ft. excl. eng., overhead, & right of way.
Oct. 74-Jul. 75	Bank graded to a 2-to-1 slope for 3,100 feet subject to scour; rocks filling old timber cribs in the river were placed along 2,000 feet of the graded slope and seeds were planted in a strip 25 feet wide above the rock.	3	74-07	
Oct. 75-Jul. 75	Bank protected with rocks from the former timber cribs for 2,000 linear feet along shore and planted (the area was hospitable to good growth of the vegetation planted).	4	74-07	
Oct. 74-Jul. 75	Bank protected by hauling in quarried blocks to build a rock riprap, 3 ft. thick, 1,100 feet long and to the height of NYS DOT 25- to 50-yr flood flow. Project involved 4,700 cu. yd. and bedding and dumped rock from a local quarry.	5	74-07	$68/linear ft. (contract only)

(Contract 74-07, for $75,000, included the above plus building a new 16-inch water line across the Hudson River.)

SE end of the small island below the railroad bridge, 1189.9 N, 698.5 E), at various points in the East Channel (at stations that moved with the location of active dredging, and downstream: at Buoy 227, 1188.4 N, 699.6 E; and at the SW entrance to Lock 7, 1187.3N, 699.4 E), and in the main channel at Buoy 219 (about 0.5 mi. southwest of the south end of Rogers Island, 1186.6 N, 698.9 E).

Water samples were collected for measurements of suspended sediment, of PCBs, of heavy metals, of dissolved oxygen, of pH, and of temperature. In addition, field determinations of turbidity were made using a Helige Turbidimeter (Miner, 1977 ms.) This program was supplemented by additional samples collected by the USGS at Waterford. The sampling program did not examine nutrients, such as organic carbon, ammonia, nitrates, nitrites, or phosphate. The PCB measurements were made on the water-column composite samples. No attempt was made to distinguish between dissolved PCBs and PCBs attached to sediments. Furthermore, the PCB results were reported as individual Aroclors, of which only that reported as 1016 varied significantly. Typical results are shown in Figure 19.

The increase of PCB content in the water column varies with the suspended sediment. In light of what is known now about PCBs in the river, one would like to know, for example, how much and what kind of PCBs were dissolved in the water upstream of the dredging operation and how these reacted with the stirred-up sediments. Did any exchange of PCBs take place between the water and the sediment? The usual interpretation is that some PCBs from the stirred-up sediments would go into solution and thus increase the PCBs in the dissolved load. But, the results of the USGS program of measuring PCBs in river-water samples (Schroeder and Barnes, 1983; discussed further in the following section) and also those by Brian Bush suggest that the reactions may have been more complex than this. Indeed, one possibility is that the sediments stripped some or all of the dissolved PCBs out of the water.

A favorite question biologists ask about dredging has to do with "bioavailability." For example, the summary statement about the proposed hot-spot dredging project in the PCB management document for New York Bight and vicinity includes the following remark written with respect to NYS DEC's proposal to dredge the PCB hot spots in the Thompson Island Pool:

> "Remedial dredging could be expected to remove some proportion of PCBs, but uncertainty remains as to whether dredging will increase bioavailable PCBs" (McCreary, ed., 1988, p. 4).

I do not know how "bioavailable" PCBs differ from those dissolved in the water or attached to sediments. Presumably, the most-

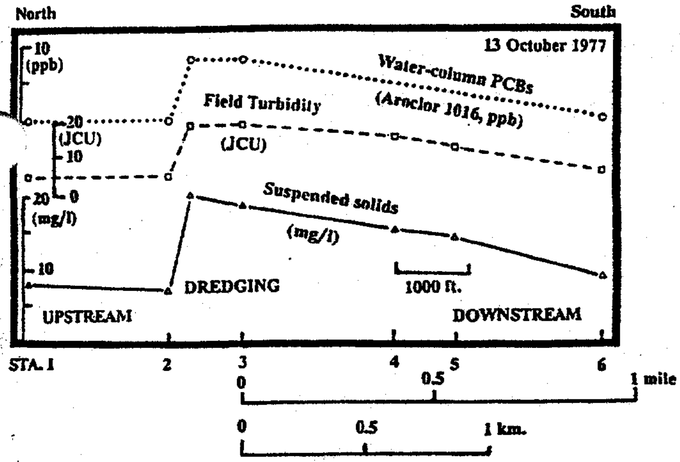

Figure 19. Typical results from NYS DEC monitoring of channel-maintenance dredging, Fort Edward East Channel, 13 October 1977. (Data from W. Miner, 1977 Ms., Table 1.)

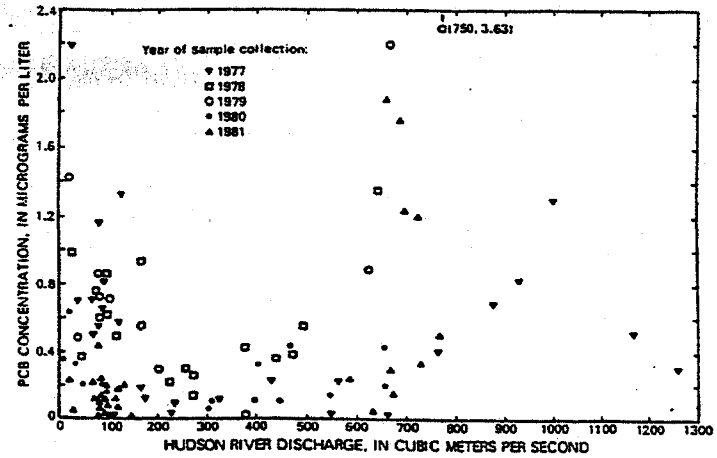

Figure 20. Graph of PCB concentration and water discharge, upper Hudson River at Schuylerville, New York, Water Years 1977 through 1982. U. S. Geological Survey data; Schroeder and Barnes, 1983b, Figure 4, p. 11.)

bioavailable substances include nutrients, which were not measured in 1977. By way of comparison, however, nutrients were measured in the monitoring of a 1981 dredging operation in the Wards Point Bend Channel off southern Staten Island, Raritan Bay (Tavolaro and Mansky, 1984). In this open-water operation, the dredge plume did not spread more than 470 meters from the dredge at the surface nor beyond 570 meters of the dredge at the bottom. The dredging increased the low nitrite concentration as well as the nitrate concentration temporarily, but ambient values reappeared within approximately one week after dredging had stopped. By contrast, during dredging, total phosphate and orthophosphate in the water near the dredge were reduced, presumably as a result of reacting with the sediment plume stirred up by the dredge.

Monitoring The Rejected But De-Facto "No-Action" Alternative

During the "decade of delay" that has intervened between the time when NYS DEC proposed the hot-spot dredging project and the writing of this paper, various components of a river-monitoring plan have been functioning. These have included the USGS network for determining river-water discharge, suspended sediment, and PCBs and other constituents in water; PCB determinations in fish; and PCB determinations in other organisms from a program of biological monitoring carried out by personnel from the New York Department of Health.

USGS monitoring of the upper Hudson River

Starting in the Water Year 1977 (defined as beginning on 01 October 1976 and ending on 30 September 1977), with additional support provided by the GE Settlement Fund, the U. S. Geological Survey intensified its monitoring activities of the upper Hudson River. They began collecting daily samples for determining suspended sediment in the upper Hudson River (and for a time, also in the Mohawk; but beginning in 1980, discontinued in the upper Hudson during the winter months), and intermittently collected samples for PCB measurements. The samples for PCB analyses were collected to represent the range of variations of water discharge. The number collected at an individual station in a given year has varied from as low as 6 to as high as 38.

At low flows, the PCBs are found in the fraction that passes through the 0.45-micron filter and thus are assigned to the "dissolved load." [However, it is possible that PCBs in the water that passed through the filter are attached to colloidal particles, which are small enough to pass through the filter (Schroeder and Barnes, 1983, p. 13)]. The concentrations of the low-flow PCBs tend to increase as water discharge decreases (Turk, 1980; Turk and Troutman, 1981b; Schroeder and Barnes, 1983b; Figure 20).

At high flows, the PCBs are found almost entirely in the fraction that remains on the 0.45-micron filter, and thus must be attached to the sediment (Schroeder and Barnes, 1983b, p. 10-11). In general, the greater the water discharge, the greater the suspended sediment, and thus, the higher the concentration of PCBs (Figure 21).

Because the initial supposition was that the concentration of PCBs would increase with water discharge (as on the right-hand side of Figure 20), this relationship of higher concentrations of PCBs at lower discharges was referred to as the "low-flow anomaly." The inverse relationship between water flow and concentrations of PCBs implies that PCBs are entering the water column at a constant rate (such as being dissolved out of or otherwise migrating out of PCB-contaminated bottom sediments, for example) so that as the amount of water decreases, the concentration of the PCBs increases (same amount of PCBs mixed with less water, thus a higher concentration).

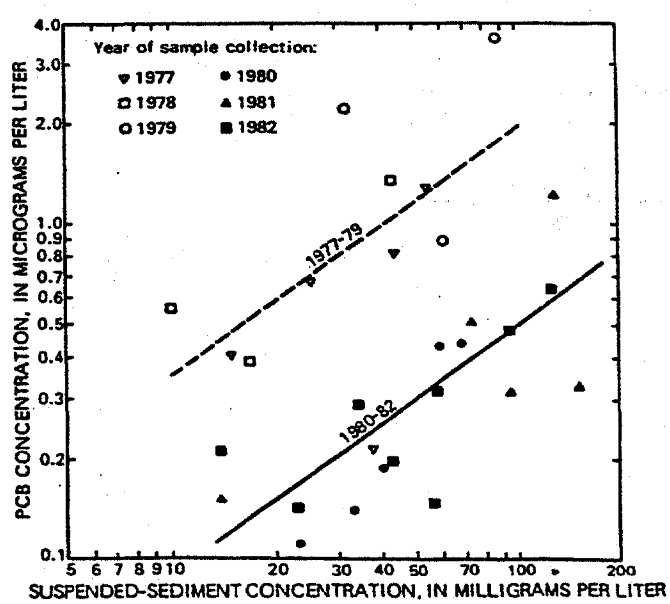

Figure 21. Graph of PCBs and concentration of suspended sediment in upper Hudson River at Schuylerville, New York, Water Years 1977 through 1982. Lines are best-fit regressions for years indicated. (USGS data; Schroeder and Barnes, 1983b, Figure 8, p. 18.)

The downriver changes in PCB concentrations indicate that the low-flow PCBs are also derived from the reach of the river between Rogers Island (Fort Edward) and Schuylerville (Figure 22). The low-flow PCBs move with the water.

Water discharge determines which mode is predominant. The upper discharge limit for PCBs in the dissolved state is about 600 cubic meters per second at Waterford (Figure 23; also set at about 21,200 cubic feet per second). (This boundary for upstream stations is at correspondingly lower flows: 490 cubic meters per second at Stillwater; 447, at Schuylerville; and 366, at Rogers Island).

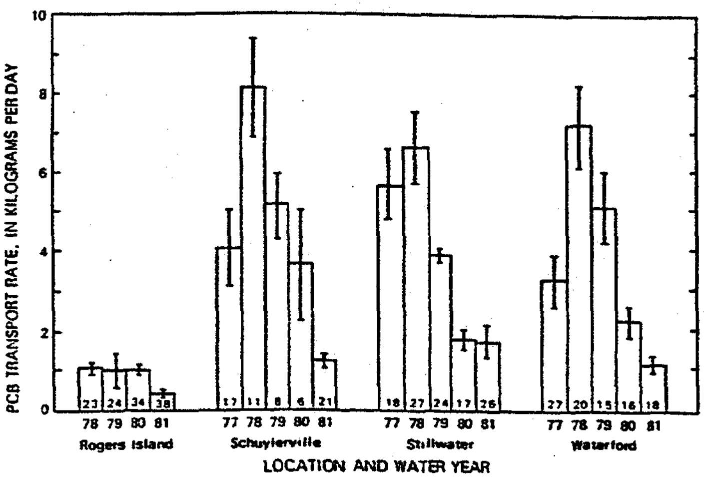

Figure 22. Bar graph showing transport rates of PCBs in upper Hudson River during nonscouring discharges, Water Years 1978 through 1981, calculated by multiplying PCB concentration by river discharge at station indicated. Standard-error bars at tops of rectangles; numbers of samples shown within and at bases of rectangles. (USGS data; Schroeder and Barnes, 1983b, Figure 7, p. 15.)

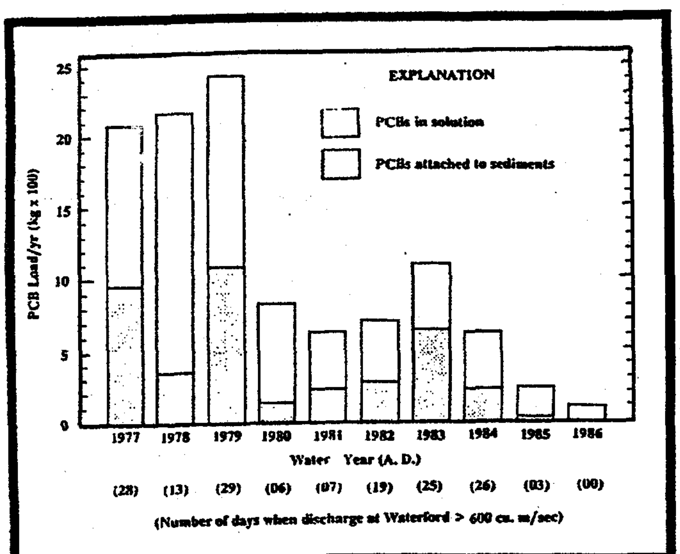

Figure 23. Computed annual transport of PCB in the Hudson River at Waterford, New York, for water years 1977 through 1986 (water year = 1 October of one year through 30 September of the following year) based on USGS data. Numbers in parentheses below the year labels are total number of days during that water year when the discharge at Waterford exceeded the estimated scour threshold of 600 cubic meters per second. (Redrawn from M. P. Brown, Werner, Carusone, and Klein, 1988, Fig. 1, p. 3, which was based on Barnes, 1987.)

The USGS results prompt one to ask about what becomes of the disssolved PCBs at high discharges (times when most of the PCBs are on the filter rather than in the water which passes through the filter)? Brian Bush (personal communication) proposed an answer: the sediments scavenge the PCBs c the water. As an example in support of this contention, he cites the measurements he made near the mouth of the Hoosic River (See Figure 3). Here, "clean" sediment from the Hoosic mixes with Hudson River water containing dissolved PCBs. In a sample collected a short distance downstream, he found PCBs on the sediment particles, but could not detect dissolved PCBs in the water. He thus inferred that the PCBs, which were dissolved in the water and displayed the typical water congener pattern, had left the water and become attached to the sediment particles. If Bush's example represents the results of a general principle, then it is very significant, especially because it appears to go against what one would expect to find. It forms the basis for Bush's position that the popular concept about "PCB-clean" sediments circulating in the heavily polluted reach of the upper Hudson River is a fallacy. According to Bush, any "PCB-clean" sediments coming down from upriver would become immediately "infected" as a result of coming into contact with PCBs, which had become dissolved in the water as it passed over the PCB-contaminated bottom sediments.

Since 1977, the average concentrations of PCBs found in the analyses of samples collected during both high flows and low flows have generally decreased. What has not decreased is the maximum concentration of total PCBs found on sediments being transported during the high-flow events (Schroeder and Barnes, 1983b, p. 16).

The important subject of the decreasing values of PCBs in the upper river with time is presented in detail in a following section entitled: CURRENT STATUS OF THE PCB-POLLUTION SITUATION IN THE UPPER HUDSON RIVER, subsection: Is Nature "Curing" The PCB-Contamination Problem?

The USGS results, supplemented by the work of Richard E (Lamont-Doherty Geological Obsesrvatory of Columbia University), and Brian Bush (New York State Department of Health), have established a substantial body of knowledge about the fate and transport of PCBs. Much more is known now than in 1982, when one of US EPA's peer reviewers objected to the proposed hot-spot dredging project because:

> "The primary method of PCB transport in the water column has not been identified (e.g., dissolved or adsorbed). Resolution of this would allow dredging in the hot spots which contribute the most PCB to the water column" (Comment No. 4).

We now know that:

(1) most of the PCBs are entering the river from north of the Thompson Island Dam;

(2) the dissolved PCBs come from PCB-contaminated riverbed sediments;

(3) a distinctive pattern of congeners results from selective dissolution;

(4) distinctive congener patterns are found in the sediments of some buried hot spots;

(5) "PCB-clean" sediments do not exist in the upper river south of the northern end of the remnant deposits;

(6) the quantity of PCBs exported to the estuary has been declining, but is still governed by variable water

discharge (which has been lower during the 1980s than it was during the 1970s);

(7) in most PCB hot spots, the highest values lie not at the sediment/water interface but at variable depths beneath this interface. [The origin of this relationship is not known with certainty, but because of (5), it cannot be ascribed to "covering by clean sediments brought down from upriver." Farther along, I make the case for an origin by small-flood reworking of the large-flood deposits of 1974 and 1976.]

(8) Most of the PCBs in the subsurface hot spots have been out of circulation since the PCB-contaminated sediments were emplaced in the mid-1970s. In other words, these subsurface PCBs are not contributing directly to the ongoing PCB transport from upper river to the estuary. [Accordingly, a fundamental decision needs to be faced about PCB objectives and tasks. If the objective is to reduce the immediate, ongoing transport of PCBs to the estuary, then one should dredge everything but the hot spots. If the goal is to prevent another catastrophic downriver surge of PCB-contaminated sediments at some time in the future (an event projected to accompany the next major flood), then one should dredge the hot spots. The first option is a short-range proposition; it deals with putting the finishing touches on the waning effects of the mid-1970s catastrophic PCB release. It does nothing to forestall the explosion of the PCB "time bomb." The second option is in the category of a long-range venture. It deals with the ticking PCB "time bomb" and aims to prevent another mighty downriver surge, which would set the reworking "clock" back to zero. The explosion of the PCB time bomb would constitute another great "experiment" in spreading PCBs throughout the system. Thus, it would bring about a near-repetition of the mid-1970s disaster. Similarly, another long period of PCB leaching and downriver transport would be required before its reworking clock would wind down to conditions approaching today's. These two objectives cannot both be met by any single partial dredging program. Only a full dredging of the upper river would fulfill them.]

Two floods in 1977 provided convincing evidence that the source of the PCB load was bottom scour in the reach north of Stillwater [closer inspection shows that it came from the reach between Schuylerville and the upper end of the Thompson Island Pool (Turk and Troutman, 1981a; Schroeder and Barnes, 1983b)] and that the PCB load going into the estuary is not a simple function of water discharge at Waterford, as was formerly supposed.

The flood of 14-15 March 1977 originated in the southern (lower) part of the drainage basin, whereas that of 24-28 April 1977, came from the northern (upper) part. During the March flood, much of the water entered the Hudson from the Hoosic River, which joins the Hudson just south of Stillwater (1067N-682E, Figure 3) and thus south of the reach most heavily contaminated with PCBs. The ratio of PCBs to suspended sediment at Waterford for the April flood was 7 times that of the March flood.

This proof that the PCBs transported into the estuary are coming from north of the Thompson Island Dam [conclusion (1)] and not from the pool behind the Green Island Dam raises a significant sedimentologic point that I address in the following section. Similarly, I defer comment on (4) and (7). I close out this part with remarks about (3) and (5).

The most-recent monitoring of the Hudson River is being carried out by Brian Bush, whose laboratory techniques enable him to achieve congener-specific results on water samples having very small amounts of PCBs in solution. An example of such a chromatogram is shown in Figure 24. As found also by Bopp, the pattern of congeners dissolved in the water differs greatly from the pattern of those attached to sediments. In addition, Bush has reported finding surprising results from the mixing of various clays and other sediments with Hudson River water containing dissolved PCBs. At the June 1989 meeting of the Advisory Committee, he showed chromatograms of analyses made of clay mixed with Hudson River water that displayed an assemblage of peaks from lower-chlorinated congeners that seemed to be identical to those found by J. F. Brown, Jr. in the lower layers of cores from selected PCB hot spots and found in the Michigan State experiments with anaerobic bacteria.

Time history of PCBs in Hudson River fish

A program of fish monitoring for PCBs has been carried out in the Hudson River since 1977. The results of the PCB analyses show that peak values were attained in 1977 and since then, have been generally less. When the PCB values in striped bass from the estuary approached the 5-ppm FDA action level in the early 1980s, DEC staff were preparing the background papers for a possible lifting of their ban on commercial fishing for striped bass. The results of the PCB analyses are shown in Figure 25. Notice that the geometric means of the fish analyzed since 1980 have hovered around 4 ppm (total PCBs), but that these means have fluctuated slightly with a small rise in 1983. DEC staff now consider that the values of PCBs in the Hudson estuary striped bass have reached equilibrium values based on the variations of PCBs as functions of river discharge.

PCBs in organisms other than fish

Although most of the early attention to PCBs in organisms was concentrated on fish, for the obvious reasons of the direct entry into humans who eat fish, many other parts of the biota proved to contain PCBs. The New York Health Department, started a program of biological monitoring of the river under the leadership of the late K. W. Simpson, and now operated by others, with the PCB analyses performed in Brian Bush's laboratory. In this program, arrays of plates are placed in the water to be colonized by various invertebrates. In addition, certain larvae are set out in the river and batches of them later recovered after varying expo-

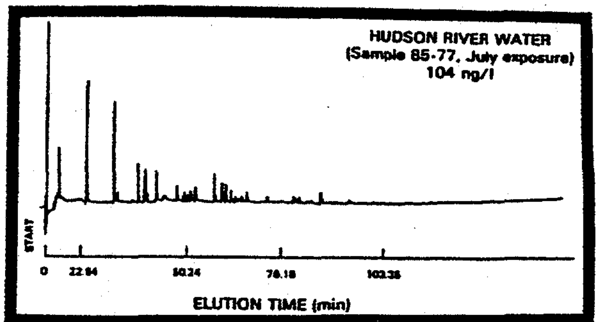

Figure 24. Capillary-column chromatogram (B. Bush).

HUDSON RIVER STRIPED BASS

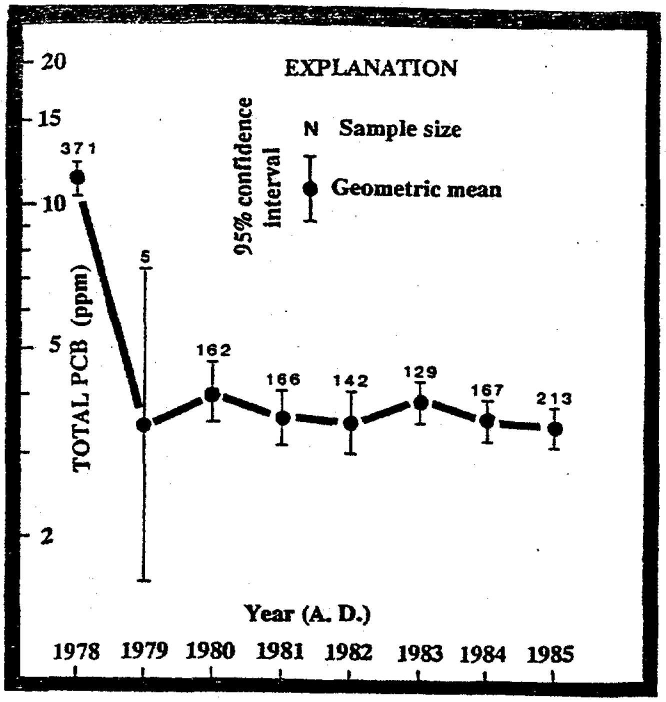

Figure 25. PCB values in striped bass caught in Hudson River 1977 through 1984. (NYS DEC, courtesy Ron Sloan.)

sure times and analyzed for PCBs. The 1978-1985 results are summarized in Figure 26.

The sharp peak in 1982 does not exactly match the lower peak found in the striped bass in 1983. The origin of this sharp rise in 1982 is not yet known.

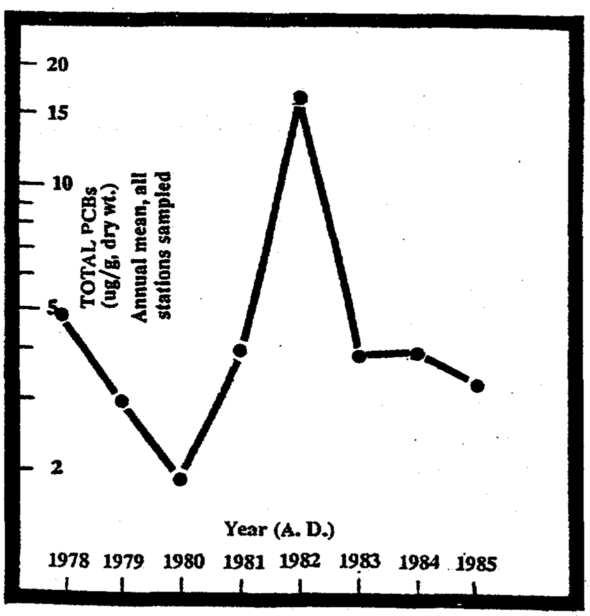

Figure 26. Results of biological monitoring of upper Hudson River based on PCB analyses of aquatic organisms that attached themselves to arrays of metal plates (=multiplates) suspended in the water, 1978 through 1985. (K. W. Simpson, Novak, and Reilly, 1986, Figure 10, p. 27.)

Plants

Plants from selected localities in the upper Hudson valley have been sampled and analyzed (Weston Environmental Consult 1978; Buckley, 1982, 1983, 1987) . Buckley's initial res appeared to support the conclusion that the PCBs found in plant samples come from the atmosphere. Table 13 shows some of the data.

In 1981, Buckley established a network of plant- and air-monitoring stations in the vicinity of Site 10. The objective was to determine in analyzing PCBs if plants could serve as a proxy for the time-integrated history of PCBs in the atmosphere and to establish base-line data for the conditions prior to the possible use of Site 10 as a PCB-encapsulation facility and also for determining the width of the zone surrounding such a facility within which PCBs from the atmosphere might so pollute hay crops that NY State would purchase the crop to prevent an economic loss to the farmer involved. Buckley laid out a program costing more money than DEC had available. Hence, it was discontinued.

Table 13. PCB concentrations in plants from selected localities in upper Hudson valley region (Hetling, Horn, and Tofflemire 1977, Table 16, p. 40).

Location and species	PCB concentration (Total PCBs; milligrams per gram, dry-weight basis)				
	Lower leaves (0 to 2m)	Upper leaves (ca 5m)	Lower twigs (0 to 2m)	Upper twigs (ca 5m)	Cores from trunk, 1 to 1.5m; bark discarded
Caputo dump:					
Pitch pine	317	81.2	87.1	17.7	1.2
White pine	215	—	120	—	1.16
Quaking aspen	89.6	28	—	—	—

SOME SEDIMENTOLOGIC ASPECTS OF PCB-CONTAMINATED RIVERBED DEPOSITS

In this section, I bring together some diverse sedimentologic aspects bearing on the PCB-contaminated sediments in the upper Hudson River. I begin with some general relationships and then examine the distribution of PCBs with depth in the riverbed sediments.

General Relationships

Under this heading, I include a brief discussion of the two chief parts of the system: (1) the channel and (2) the channel-marginal shoals/flats; the chief physical mechanisms of sediment transport; the sediment response to variable water discharge, focusing on the importance of scour during floods; and the base-level control of sediment behavior.

The channel and its marginal shoals/wetlands

A look back at Figure 5 will show the contrasting sedimentary associations: a thin carpet of coarse debris on the floor of the channel and a thicker deposit of finer sediments beneath the marginal shoals, some of which have built upward to the point where plants have colonized their top surfaces to form freshwater wetlands. I have previously mentioned how this sediment distribution complicated the program to collect core samples in the PCB mapping program.

Although a map has been prepared showing the distributio coarse- and fine sediment of the Thompson Island Pool (M. P. Brown, Warner, Carusone, and Klein, 1988, Figure 7a, b, p. 25-26), not much specific is known about the subsurface relationships between these two kinds of sediment. At the insistence of

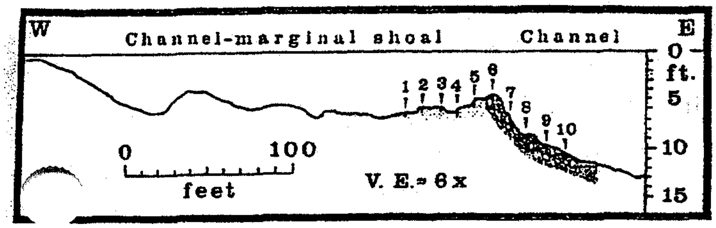

Figure 27. East-west profile of transition from channel to marginal shoal, west side of Thompson Island Pool, upper Hudson River at MP 192.7, in hot spot 6, showing locations of closely spaced (ca. 3-meter intervals) series of 10 short (10-25 cm) B-6 vibracores collected on 15 November 1984 by Normandeau Associates, in resurvey of hot spots 1-20. Depths of patterns for fine sand (at left) and gravel are schematic; maximum depth of cores is less than 1/3 the thickness of the pattern. These cores do not show the relationships between the two kinds of sediment. (Redrawn from Figure 9, p. 28 in M. P. Brown, Werner, Carusone, and Klein, 1988.)

Karim Ahmed (then of the Natural Resources Defense Council and now with Environ) and the Science Subcommittee of the Advisory Committee, some special attention was paid to this matter during the 1984 resurvey of the hot spots in the Thompson Island Pool. As a result, the transect at MP192.7 (in hot spot 6 on the outside of the bend in the river that brings it closest to the Amtrak R.R. line, 1182.5N 696.0E, Fort Miller quadrangle) was occupied on 15 November 1984. A line of 10 B-6 vibracores was collected at ca. 3-meter spacing along a transect 27 m long and centered on the shoulder between the channel to the east (depth about 4.5 meters) and a marginal shallow-water area (depth about 2 meters) to the west (M. P. Brown, Warner, Carusone, and Klein, 1988, Figure 9, p. 28; location on Figure 11b, p. 45). Gravel forms the bottom east of the shoulder and fine sand, the bottom to the west of the shoulder (Figure 27). The lengths of the cores range from 7 to 25 cm. Analyses of PCB and cesium-137 appear in the final report to US EPA cited above, but this report does not [illegible]ss subsurface textural relationships.

Physical sediment-transport mechanisms

Analyses of rivers worldwide have demonstrated that at least two, and possibly three physical sediment-transport mechanisms operate and all are connected to variations in water discharge. Because, as mentioned previously, one of the chief mechanisms of PCB transport in the Hudson River is via attachment to sediment particles, it will be helpful to review these sediment-transport mechanisms. (For further particulars, see summary in Friedman and Sanders, 1978, p. 97-101.). In a following section, I take up sediment responses to variable water discharge.

As a first approximation, sediment transport in response to the forces imposed by a stream of flowing water takes place at two sites: (a) along the base of the flow and (b) within the flow.

In many engineering publications, sediment moving along the base of a flow is referred to as the "contact" or "bed" load, and sediment moving within the flow (thus not in contact with the bed) is defined as the "suspended" load (Zimmie, 1984, p. 191). As thus defined, a particle in the bed load is easy to distinguish from a particle in the suspended load. If the particle is on the bed of the flow, it is in the bed load. If the particle is above the bed of the flow, it is in the suspended load. Closer analysis indicates that such use of the term "suspended" can lead to confusion (Sanders, 1963).

According to much geologic usage, a sediment particle traveling within the body of a fluid flow is said to be suspended in a fluid only when the fluid flow is turbulent and the upward components of flow within turbulent eddies exceed the settling speed of that particle in still water (Bagnold, 1968). Particles being trans-[illegible]d by the upward components of flow within turbulent eddies [illegible]asily identified. They can be visualized as being "prisoners" of the water; wherever the irregular motions within the turbulent flow take the water, there they will take suspended particles, also. Such particles travel with the water. Recognition of this relationship is implied in the concept of what some engineers refer to as the "wash load" (particles that are washed away with the water). A geologic term that has been proposed for such suspended particles is *uniform suspension*, defined as a suspension that is independent of its substrate and within which the quantity and particle sizes of the load are more or less uniform throughout (Passega, 1957).

As Bagnold has shown, many particles that are not being transported along the bed of a flow are also not being turbulently suspended, as just described. Such particles travel within the flow but are not prisoners within it. Such particles have been dispersed within the flow and tend to return to the bed of the flow, either from time to time and briefly during times of "fast" current, or for longer periods during times of "slow" flow. How to classify such particles is complicated and how to identify them in natural streams is even more complicated. Collectively, they belong to the *traction load*, but in practice, they have probably been assigned to the suspended load. For example, Passega (1957) proposed the term *graded suspension* for a turbulent suspension that is exchanging sediment with its substrate and within which the quantity and particle-size distribution of the sediment load decrease upward within the flow. Undoubtedly, much (but unfortunately how much is not known) of the sediment that Passega would claim within his graded suspension probably belongs within Bagnold's category of *dynamically dispersed sediment*. These sticky points of definition aside, what is important is that the finest sediments usually travel from their point of entry into a river to its mouth, perhaps nonstop. By contrast, the coarser sediments move in a stepwise fashion, making downriver excursions only during floods.

The foregoing discussion of mechanisms of sediment transport may help one understand why the computations of future PCB transport into the estuary, prepared by LMS and based on the COE HEC-6 riverbed scour model, have been so much higher than the values observed. The HEC-6 model is predicated on the concept that transport is stepwise downriver from pool to pool, in sequence (as in a Passega graded suspension). According to the LMS model, the PCBs that wash over the Green Island Dam at Troy should come from the pool backed up behind this dam. And these same PCBs would have reached the Green Island pool only after having traversed all the other pools between Fort Edward and Green Island. For whatever reason(s), the information from the U. S. Geological Survey indicates that on the upper Hudson River since 1980, a pass-through type of mechanism has been dominant. The PCB load transported into the estuary by the upper river is acquired not from coming into contact with the bed sediments in the Green Island Pool but rather by flowing over those lying north of the Thompson Island Dam. The PCB load becomes an input and an output for each pool just by flowing into it and out of it. But as far as the pools south of the Thompson Island Dam are concerned, the PCBs are now known to be "just passing through."

Sediment responses to variable water discharge

Problem of scour during floods.-- From observations at single points, it is known that during a flood, not only does the elevation of the water surface increase, but also the level of the sediment/water interface is lowered (Figure 28). This lowering of the level of the sediment/water interface is known as scour. For example, during the spring flood season of 1912, the elevation of the water surface of the Colorado River at Yuma, Arizona, shifted upward from about 113 feet to about 128 feet, a rise of 15 feet. Simultaneously, the maximum depth of the channel shifted its location from an elevation of about 105 feet to 80 feet, a lowering of 25 feet (See Figure 28). In the following paragraphs, I review some contrasting ideas about scour, and then discuss the importance to the PCB situation of understanding scour.

Two contrasting ideas have been expressed about the subject of scour of a stream bed consisting of cohesionless sediment.

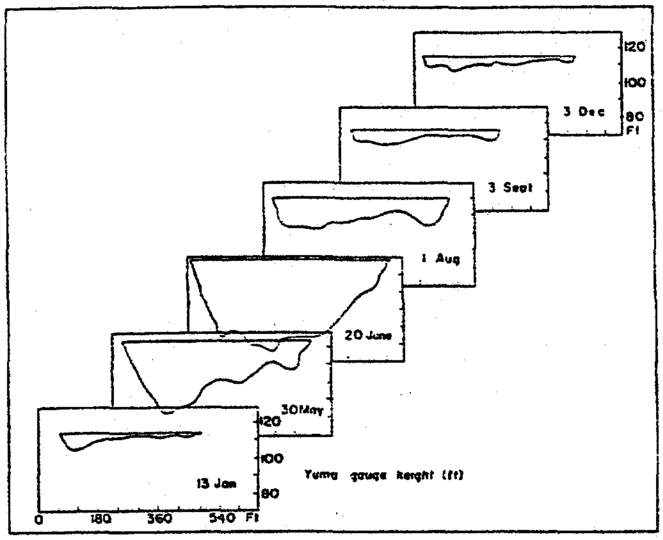

Figure 28. Profiles at right angles to the channel of the Colorado River at Yuma, Arizona, on various dates during the annual flood passage of snowmelt water from the high plateaus in the drainage basin. All panels drawn to the same scale, with vertical exaggeration of 5X. (G. M. Friedman and J. E. Sanders, 1978, Figure 8-42, p. 224, which was modified from E. W. Lane and W. M. Borland, 1953, Figure 4, p. 1076.)

According to one idea, bed scour during a flood is general. That is, the water mobilizes the bottom sediment throughout the reach(es) experiencing the bulge of flood water, and as the flood wanes, redeposits sediment on the bed again. This behavior is implied by the term *mean-bed scour*. According to this view, scour of the kind that has been observed at some individual stations, as in Figure 28, for example, takes place everywhere.

According to a second and contrasting idea, the behavior of the cohesionless bed sediment is determined by the migration of *bed forms*, which are "streamlined" relief features having rhythmic patterns. As shearing stresses between the water and the cohesionless sediment bed are increased, various bed forms appear and tend to migrate (Figure 29). The behavior of the cohesionless sediments with various flow characteristics have been made the basis of the concept of *flow regimes* (Simons and Richardson, 1961, 1962, 1966; Simons, Richardson, and Albertson, 1961). If the flow-regime concept is a valid generalization of how a water flow interacts with a cohesionless-sediment bed, then during a flood, migration of sediment in bed forms governs what happens and "scour" is best described as being local. Thus, at a given point, the lowering of the bed should be visualized as reflecting the change from a crest of a migrating bed form to its trough. Such lowering should be governed by the amplitudes of the bed forms. This second idea is embodied in the term *local scour* (Foley, 1978, p. 559).

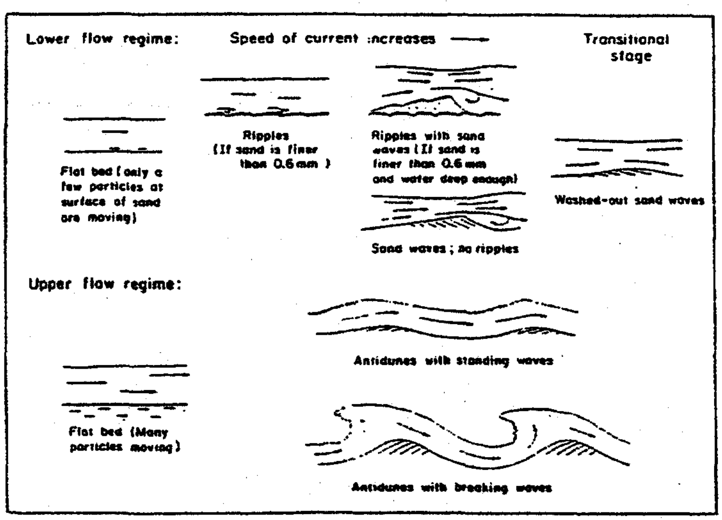

Figure 29. Schematic profiles of interaction between water flowing from left to right at speeds that increase from the lowest value in the sketch at the upper left to the highest value in the sketch at lower right to illustrate conditions at various flow regimes. (G. M. Friedman and J. E. Sanders, 1978, Figure 4-33, p. 114, which was based on D. R. Simons, E. V. Richardson, and C. F. Nordin, Jr., 1965; and J. C. Harms and R. K. Fahnestock, 1965.)

Scour and deposition during floods.– The flow-regime concept grew out of the contrasting sediment behavior at various water discharges. In the lower flow regime, the movement of the bed sediment and downcurrent migration of bedforms are intimately coupled. The particles forming the bed sediment move downstream individually; they are stripped from and moved up the gentler slope facing upstream to the crest of a bed form, are impelled past the crest, and then avalanche down the steeper downcurrent face. As a result of this erosion of the upcurrent side and accumulation on the downcurrent side, the entire bedform migrates downcurrent. Nearly all of the sediment moving along the bed partakes of this bodily migration of the bed forms.

In the upper flow regime, however, the movement of the bed sediment and the associated bedforms, if any, is decoupled. A thick carpet of sediment is in rapid transit downcurrent. Its top surface may be plane or it may be shaped into bed forms. These upper-flow-regime bed forms do not migrate downcurrent. Rather, they move upcurrent. Because of this "retrograde" motion, they have been named *antidunes*.

From the point of view of flood release of PCBs from bed sediments into the water flow, the most-important consideration may not be simply the amount of net lowering of the bed associated with migrating bed forms, but rather the thickness of rapidly moving sediment carpet within which the particles are in a condition known as *dynamic dilatation* (Bagnold, 1968).

Base-level control of sediment behavior

In order for any depositional surface to accrete sediments, two conditions must be satisfied. These are: (a) new sediment must be supplied; and (b) the surface must lie below the local *base level of aggradation*. The control of sediment accumulation by *base level* (water level) and by the base level of aggradation (conditions on the bottom) is a fundamental proposition familiar to all geologists. (For a summary and review, see Dunbar and Rodgers, 1957, p. 128-131.) The base-level concept is complex, but important insights into the conditions in the upriver pools can be derived by considering only its broadest outlines.

The most-important starting point in applying the base-level concept is that the local conditions of water depth and strength of currents interact to determine whether sediment brought to the area will be: (a) deposited and thus build up the bottom (level of the bottom below the local base level of aggradation), (b) kept in motion and thus transported elsewhere (level of the bottom equal to that of the local base level of aggradation), or (c) eroded (level of the bottom above that of the local base level of aggradation).

If a depositional surface lies beneath the local base level of aggradation, then available sediment tends to accumulate to build the surface up to the local base level of aggradation. Such conditions that enable sediment to accumulate (i. e., bottom lower than base level of aggradation) are met on parts of the deep-sea floor, in many lakes, and in parts of the Hudson Estuary, for example, but may not prevail in large areas within the pools behind the dams in the upper Hudson River.

In an area where the bottom lies at the position of the base level of aggradation, sediment is kept in motion and not deposited. Such an area is said to be undergoing *bypassing*. Examples are provided by all the pools south of the Thompson

Island Dam. As mentioned previously, USGS monitoring has demonstrated that the bulk of the PCB load which the upper river delivers to the estuary is acquired from the contaminated bed sediments north of the Thompson Island Dam. Accordingly, such PCB-contaminated sediment is passing through, that is bypassing, all the other pools. Once conditions for bypassing have been established in an area, no new sediment can be added until the relationship between the bottom and the base level of aggradation changes.

In the upper Hudson River, the tops of the dams regulate the heights of the water in each pool. The dams, therefore, exert powerful influences on local base level. (In one sense the top of a *dam is* the local base level; that is, it is a level above which sediments cannot accumulate.) Careful investigations of the base levels of aggradation in each of the pools have not been made. Nevertheless, from the ages of the dams, amounts of sediment that have been deposited in the pools, and the evidence of bypassing cited above, one can scarcely escape the inference that sediments have built up to local base level of aggradation and that conditions favoring bypassing have been established. *If that is true, then the only situation that will enable* new sediment to be added is a change of the base level of aggradation. Three categories of ways to change the base level of aggradation are: (a) to lower the bottom independently of the water level (by tectonic subsidence of a local part of the sea floor, for example; by compaction of the sediments; by scouring of a local depression; or by dredging), (b) to raise the water level (base level) independently of the bottom; and (c) by changing the relationships between both controlling levels (base level and the base level of aggradation) and currents, as happens during a flood.

In the upper Hudson River, the tectonic factor of (a) can be set aside, because tectonic subsidence would lower the dams as well as the bottom. However, the sediment surface doubtless can be lowered independently of the water surface by compaction of the sediment, by scouring during a flood, or by dredging. Factor (b) can be dismissed because as far as the pools behind the dams are concerned, water level could be raised independently of the bottom only by building each dam higher, and that has not been done systematically (at least not since 1974 when the great PCB-spreading "experiment" took place). Factor (c) is applicable, but in complex ways not altogether understood. It is well known that during a flood, both ends of the base-level transaction (the water level and the base level of aggradation) are subject to change, as was explained in a previous section. For example, during a flood, the bottom may be temporarily lowered by scour. If nothing else changed, one would expect that a lowered bottom would enable new sediment to accumulate. But, the hitch is that during a flood, the base level of aggradation is lowered more than the bottom, and the sediment above base level is eroded. As the flood crest passes, however, two changes are made: (1) the base level of aggradation is raised; and (2) parts or all of the bottom are also raised as the sediment stirred up by the flood is redeposited. These two changes may be equal. If so, then the restoration of the bottom up to the pre-flood base level of aggradation may be established within a matter of hours, or at most, a few days, and no room for receiving new sediments is created. Or, as noted, the flood may scour a depression in the bottom that is not immediately filled. In such a low area, the bottom may build up, layer by layer.

The relationships that prevailed at the Fort Edward Dam before and after its removal in 1973 provide striking evidence of the importance of base-level control on sediment behavior. In December 1970, before the dam was removed, Clarkeson, Clough & Associates carried out sediment surveys upstream of the dam. They found that the amounts of the brown fibrous sludge, matching the sludge Dames and Moore had found in their borings alongside the dam, varied from day to day, depending on the changes of water level and the speed of the current. In geologic terms, the base levels were changing. When the position of base level of aggradation was relatively high (as at minimum water levels and slowest currents), much brown sludge could accumulate. When the base level of aggradation was relatively lowered (as during higher water flows and swifter currents), the brown sludge was swept away. When the dam was removed, base level was "permanently" lowered by about 5 meters. The effect on the sediments was immediate and dramatic. In the words of Nadeau and Davis (1974), the former tranquil pool was replaced by "a rushing, roaring river that has cut new channels through the bottom deposits." In geologic terms, the base level had been lowered and the exposed remnant deposits suddenly were placed well above the base level of aggradation; hence, they were rapidly eroded.

The Albany turning basin (at M.P. 144) is a depression required for the maneuvering of oceangoing ships. Enough sediment comes downriver to require periodic dredging about every 10 years. Each time this basin is dredged, its bottom is lowered below that of the local base level of aggradation. Hence, sediments tend to fill it in on a layer-by-layer basis. This basin is an especially favorable locality for layer-by-layer sedimentation (Bopp, 1979ms; Bopp, H. J. Simpson, Olsen, and Kostyk, 1981; H. J. Simpson, Bopp, Deck, Warren, and Kostyk, 1984, p. 163-164; Simpson and Bopp, in press). Cores collected from it display the kind of sediment records that geochemists interested in using anthropogenic tracers would like to find everywhere, but do not find in many places in the upper Hudson River. This dearth of upriver localities that display anthropogenic tracers distributed as in many parts of the estuary is strong evidence against the view that in the upriver pools, layer-by-layer sedimentation is widespread. Another relevant point based on these studies of the sediments in the Albany turning basin is that the new sediment still contains PCBs. This finding raises the issue of the PCB composition of the sediments that I address in the next section.

Distribution Of PCBs With Depth In Riverbed Sediment

I divide the topic of distribution of PCBs with depth in riverbed sediment into three parts: (a) the total amounts of PCBs; (b) the patterns of PCB congeners; and (c) the implications of (a) and (b) on evaluating two contrasting models of sediment behavior, which I shall designate as "covering with new blankets" on the one hand, and "thrashing the same old carpet," on the other.

Total quantities

Under this heading I include two related topics: (1) the changes with depth as indicated by the laboratory results from individual cores of river-bottom sediment in which the PCB values were shown as various Aroclors and then a total PCB number found by addition, and (2) the summation by M. P. Brown *et al.* on the depth distribution of PCBs in the Thompson Island Pool, based on the 1984 resurvey.

The depth distribution of PCBs at a given locality, as shown by analyzed core samples is admirably exemplified by the data from BC-11 (See Figure 18.) and also by the graphic summary of the 1977 core collection (summarized in Figure 15). To rehearse the results, the pattern is from water/sediment interface downward: (a) surficial layer, as much as 20 cm thick, in which PCB values, although possibly elevated, are not as high as those below; (b) main zone of PCB contamination, with values in the upper river reaching into the hundreds of parts per million for total PCBs; and (c) underlying layers in which the concentrations of PCBs are about 5 ppm or less.

As mentioned previously, M. P. Brown and others (1988) performed a depth-integrated analysis of the 1984 cores from the resurvey of the Thompson Island Pool. They found that 95 *percent of the PCBs were distributed in the first 0.5 m of sediment* below the sediment/water interface. This first depth interval in their analysis includes the entire layer I have been designating as the surficial layer and much (in some cases, all) of the main zone of PCB contamination. Another 4.91 percent was distributed in the depth zone 0.5 to 1.0 m.

Patterns of PCB congeners

A new chapter in our understanding of the PCB situation at depth began when geochemists began to record chromatograms based on analyses made using the capillary packed-column electron-capture gas-chromatography technique. The first scientific papers based on congener-specific analyses appeared in 1984. They reported on studies made of sediments from cores collected in hot spots from the Thompson Island Pool and elsewhere (Simpson, Bopp, Deck, Warren, and Kostyk, 1984; J. F. Brown, Jr., Wagner, Bedard, Brennan, Carnahan, Mayh, and Tofflemire, 1984). The chromatograms showed patterns in which lower-chlorinated congeners predominated. Such peak patterns dominated by the lower-chlorinated congeners contrasted with chromatograms recorded using comparable analyses of the mixture of Aroclors used by GE in the capacitor-manufacturing plants in Hudson Falls and Fort Edward.

The interpretation placed on these patterns, and much emphasized by J. F. Brown, Jr. and his colleagues from the GE Research Laboratories in Schenectady, New York, was that the change from the input congeners to the observed congeners had resulted from the effects of anaerobic bacteria (J. F. Brown, Jr., Bedard, Brennan, Carnahan, Feng, and Wagner, 1987; Bush, Shane, Wahlen, and M. P. Brown, 1986).

Implications: covering with new blankets versus thrashing the same old carpet

The observed distribution of PCBs with depth is amenable to several interpretations. One concept is that the sediment which directly underlies the sediment/water interface is new, "clean" sediment which has been deposited on top of the more-contaminated sediments below. Use of the words "clean," "cover," or "capping," for example, conveys this interpretation. I shall refer to it as the "covering-with-new-blankets" viewpoint.

According to a second interpretation, the less-contaminated upper sediments do not represent "new" sediment, but rather the same, old PCB-contaminated sediments that are "stirred" (=dynamically dilated, in Bagnold's terminology) to various depths by each flood, according to the amount of water involved, location in the river, and duration of the flood. As a result of this "stirring," the contaminated bed sediments and the water column interact. Some PCBs may be released and enter the water in amounts that are determined by the various solubilities of the PCB congeners, as expressed in the partition coefficients determined experimentally using sediments from the upper river (Bopp, 1979 ms.; Bopp, H. J. Simpson, and Deck, 1975). Such selective dissolution results in a major fractionation of PCB congeners (Brian Bush, presentation to Advisory Committee, 22 June 1989). Other PCBs are mobilized out of the bed sediment attached to particles and travel with the river's suspended load (Schroeder and Barnes, 1983).

In this "bottom-stirring" model of river-bed behavior, a critical factor is the depth to which the dilatant effect extends during a flood. According to the bottom-stirring model, the observed PCB-distribution with depth in the riverbed sediments can be explained without adding significant quantities of "new" sediment. The decreased levels of PCB-contamination with time could be visualized as a river-bed-"cleaning" process of sorts, but one that definitely does not involve the passive covering of the hot spots with "new," clean sediment, as in the "covering-with-new-blankets" model. Rather, the "cleaning" action can be compared with shaking out the same carpet repeatedly. It is a result of the dilating, caused by the shearing of the flood waters, over more or less the same contaminated layer of sediment that overlies the hot spots. If this concept is correct, then as mentioned, the amount of PCBs removed during each flood should be some function of the pre-flood concentration of PCBs, depth to which the dilatant effect extends, and duration of the flood.

As has been mentioned many times previously, the first surge of PCBs came down the river in April 1974 during the first large flood after the Fort Edward Dam had been removed with no thought given to the PCB-contaminated sediments in 1973 when the Niagara-Mohawk Power Corporation requested permission to remove this dam. It is also known that a second, even-larger flood came almost exactly two years later, in April 1976. The second flood did not wash away the deposits left by the April 1974 flood, but it surely must have reworked them. No subsequent flood has equalled the 1976 event.

The large relief peel made from BC-11 from hot spot 5 (See Figure 18.) displays with striking clarity a sedimentary record that I think epitomizes the whole history of the PCB-contamination situation in the upper Hudson River. The top unit (A'), contains 13.7 ppm total PCB. I interpret as a result of many episodes of small-flood reworking of the underlying thick coarsening-upward couplet, ascribed to the 1976 flood. Below is a thinner coarsening-upward couplet inferred to have been deposited by the 1974 flood. The total PCBs in these two units, inferred to be products of the two large mid-1970s floods, is 56.5 for the coarse part of the upper couplet, and 58.8 for the coarse part of the lower couplet. At greater depth are other coarse layers, but the total PCB in a sample of one of them is only 3.8 ppm.

If my concept about the behavior of the surficial layer of the riverbed sediments is correct, then its implications about the deeper hot spots are clear. It implies to me that leaving the PCB hot spots where they are, as many have advocated, is like playing PCB "Russian roulette." Because these hot spots were emplaced by two floods, they can be reactivated again by a third, or a fourth, or a fifth, or whatever is the number of future floods sufficiently powerful to dilate not only the existing active surficial layer but to extend the zone of dilatancy into the underlying layer that has been inactive since 1976.

If that ever happens, then another large upriver PCB "cat" will be let out of its "bag." A huge "new" supply of PCB-contaminated sediments will then be "on the prowl." The PCB "clock" will be turned back to April 1976.

I think it would be irresponsible to let such an event happen, especially because: (a) the likelihood that it will happen has be[en] made unmistakeably clear and grows more probable with ea[ch] passing day as the decade of the 1990s comes upon us; (b) th[e] way to prevent it is well known (i. e., to dredge the upriver PCB hot spots); and (c) the "learning curve" of technical information which has been developed from more than a decade of studies devoted to the proposal extends well above the level needed to buttress responsible preventative action.

EVALUATION OF THREAT TO FOOD CHAIN AND HUMAN HEALTH

The main basis for evaluating activities with respect to Superfund sites is impact on human health. At least five threats of PCBs to human health have been evaluated. These are from: (1) contaminated sediments and -water into various organisms and up the aquatic food chain to fish and from contaminated fish to people who eat the fish; (2) drinking water (either ground water from wells in the upper Hudson area generally but near old PCB dump sites in particular or from public water supplies drawn from the Hudson River); (3) forage crops and vegetables grown near the upper Hudson River; (4) direct contact with highly contaminated sediments; and (5) the atmosphere.

Sediments/Water-Aquatic Food Chain-Fish-People

The most-direct and substantial source of PCBs into people is via eating contaminated fish. Accordingly, many fish have been caught and analyzed to determine both the geographic extent of such pollution and any changes through time (See Table 6 and Figure 25.). As mentioned, the publicity over the discovery in Hudson River fish of high levels of PCBs in 1975 prompted Commissioner Ogden Reid of NYS DEC to close the enti[re] upper-river sport fishery and the commercial fishery for stri[ped] bass and eels in the Hudson Estuary [a ban extended in 198[?] include the striped bass from Long Island Sound and the New York Bight after the US Food and Drug Administration (FDA) had changed its action level for banning fish from the marketplace from the 5 ppm established in 1975 to 2 ppm].

As noted in a previous section, US EPA's Superfund 1983 RAMP and its 25 Sept. 1984 R.O.D. for the upper Hudson River concluded that human health was sufficiently protected in New York State by enforcement of the fishing bans and a reliance on "nature's remedy," which they took to be operating in the river and which they hoped would eventually bring the average level of contamination of Hudson River fish below the FDA's action level of 2 ppm. Under Superfund II, this outrageous position of US EPA must be re-evaluated. Any honest evaluation must find that PCB-contaminated fish are still a human-health hazard and that human health is not sufficiently protected by relying on Walt Disney's Third Law (i.e., "wishing will make it so"). (See section comparing US EPA's Superfund human-health evaluations of the Hudson River PCB site in New York State and that in New Bedford, Massachusetts.)

One of the aspects about the whole topic of PCB pollution that has been personally frustrating to me (as well as to most members of the Advisory Committee) is the lack of fundamental understanding of the impacts on people of PCBs and what appears to be a manifest lack of interest in investigating this topic. Possibly the lack of easy-to-use analytical tools for precise measurements of PCB congeners in very small samples has deterred biomedical- and biochemical research. In any case, the most-recent and most-comprehensive summary of this topic (in McCreary, 1988) shows how little fundamental knowledge is available. Even the so-called human-health-effects study of PCBs completed in New Bedford, Massachusetts, in 1987 was nothing more than an investigation of blood levels in a randomly selected subpopulation compared with another subpopulation consisting of persons who ate large amounts of fish and other seafood. In my opinion, most of the so-called science connected with this study centered on the effort to collect a statistically random sample of New Bedford's population. When the first-phase results showed that the blood-level PCBs in the general population of New Bedford did not exceed those found nationwide, the second phase was dropped. No attempt was made to understand the results of the large experiment in which we all are participating, namely the effects on the human system of low levels of PCBs. [These remarks should not be interpreted as indicating I think that PCBs are "safe" compounds as far as human health is concerned. They are intended to indicate that I am in limbo on the topic; I simply do not know. I accept the data showing deleterious effects of PCBs on many organisms (Kimbrough, 1974) and the results of studies of workers in the capacitor-manufacturing plants (Warshaw, Fischbein, Thornton, Miller, and Selikoff, 1979; Wolff, Thornton, Fischbein, Lilis, and Selikoff, 1982). But I still feel uninformed].

Drinking Water

The relationship between PCBs and drinking water has been much studied and much solid information has been established, but nevertheless, it remains a subject of much public fear and trepidation. Involved are the New York State PCB "guideline;" ground water; and everyday public water supplies in Waterford and Poughkeepsie, and the drought-emergency water supply of New York City.

Yet to be set are official "standards" on PCBs in drinking water. The only "lighthouse" in the otherwise-dark night enveloping this topic is the New York DOH drinking-water "guideline" for PCBs: 0.1 part per billion.

The kind of preference of PCBs for becoming attached to certain kinds of sediment particles rather than remaining dissolved in water (as found by Brian Bush's samples near the Hoosic River, mentioned in a previous section) can explain why water that has passed through a standard filtration system at a water-treatment plant, or has seeped through the regolith (that is, has become ground water) generally lacks PCBs or shows only very low levels of PCBs.

If PCBs enter a water-treatment-plant's intake pipes, they usually leave the plant in the sludge. In former times, this sludge was dumped back into the body of water from which it came (only downstream of the intake pipe).

Further support for the concept that ground water passing through regolith gives up its PCBs to the sediment particles is contained in the contrast between the PCB contents of large lakes and those of rivers. The PCBs in the Great Lakes, for example, have been shown to come from rainfall. By contrast, the PCBs in rivers in the conterminous United States come from anthropogenic point sources. Streams are supplied by rainfall, but much of the water does not fall directly onto the surface of the streams. Before it gets into the rivers, most of the water first seeps into the ground. The inference is that the soil particles remove the PCBs from the rain water (Beeton, 1959, p. 56-57).

Ground water from wells in the upper Hudson River area typically tests low for PCBs, even from wells near old PCB dump sites.

In my opinion, in no technical matter related to the PCB situation in the upper Hudson River does a wider gap exist between the level of understanding held by members of the general public and that of the technical experts than the flow of ground water. In my experience, the general public is ill informed about the hydrologic cycle in general and about the nature of ground-water flow in particular. Accordingly, it is not easy to convey the rational basis for sound technical conclusions about the relationships between ground water and potential PCB contamination. For example, very few persons understand the differences between a ground-water recharge area (where the rainfall enters the system) and a ground-water discharge area (where water leaves the system) and how analysis of the flow of ground water between these two kinds of areas can be used to draw the firm conclusion that PCBs which might escape downward from the proposed encapsulation facility at Site 10 are not going to pollute local wells (Figure 30).

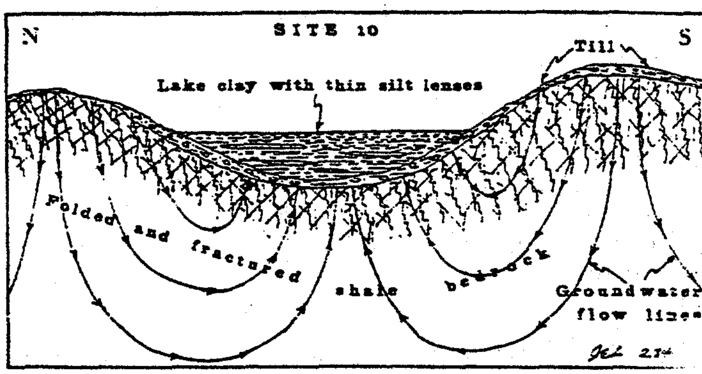

Figure 30. Schematic profile-section through Site 10 (the NYS DEC-proposed encapsulation site to receive PCB-contaminated materials, including dredge spoil to be removed from the hot spots of the Thompson Island Pool), southern part of Town of Fort Edward, New York (location 1175N-702E, Figure 4). Folded and fractured shale bedrock is overlain by Pleistocene till, which has been covered in the lowland by a valley fill consisting of lake clay and interbedded silt lenses that were deposited in former Lake Albany, during the retreat phase of the last glacier that entered the area (and melted away about 13,000 years ago). Curved lines with arrow barbs indicate the inferred direction of ground-water movement. Rainwater entering the ground on hills moves vertically downward from the hilltops and eventually curves back upward to reach the surface beneath the valley. This creates a positive upward pressure in the ground water beneath much of Site 10. As a result, ground water flows toward the site rather than away from it. This relationship is the best possible natural guarantee against the pollution of neighboring wells by any PCBs that might leak out of the bottom of the proposed encapsulation facility. (J. S. Sanders, Figure 3, p. 12 in Hudson River Foundation for Science and Environmental Research, 1984.)

I think that the contrasting views of the groundwater situation at Site 10 held by most local residents as opposed to views based on scientific information can be illustrated using what I shall call the "rowboat analogy." For the purposes of this analogy, the proposed encapsulation facility is the rowboat, and a possible leak in the bottom of this facility is the hole in the bottom of the boat. The differences with respect to such a possible leak in the bottom of the proposed encapsulation facility, the local residents' view of the ground-water situation, and the scientific evidence about the ground water can be compared with what would happen if one were to drill a hole in the bottom of the rowboat boat under different settings. In case (1), the rowboat is off the ground on a pair of saw horses and allowed to fill with rainwater. In case (2), the rowboat is out on the river. In case (1), a hole drilled in the bottom of the boat lets the water leak out downward. In case (2), the hole allows river water to flow into the boat.

The public remarks made by residents fearful that PCBs from Site 10 might leak downward and thus contaminate the ground water indicate to me that the speakers view the ground-water situation as in case (1) of the "rowboat analogy." That is to say, their fears are that via a supposed leak, PCBs would move downward into the ground water, exactly as the water in the rowboat on the saw horses would leak out through the hole in the bottom of the rowboat and drain onto the ground below. The positive ground-water pressure recorded in test wells to bedrock on Site 10 (MPI, 1980a), however, means to me that the correct "rowboat analogy" is case (2), the rowboat out in the river. If a hole were to form in the bottom of the proposed encapsulation facility at Site 10, ground water would flow into the hole from below; the PCBs would not be able get out downward.

US EPA's 1983 Superfund RAMP concluded that Waterford's public water supply should be evaluated from the point of view of the possible threat to human health from drinking water from the Hudson River. Over the years, many tests have been made by NYS DEC to monitor Waterford's water supply, most notably during 1977 and 1978, when the much-monitored NYS DOT channel-maintenance dredging of Fort Edward terminal took place. During these dredging operations, no changes in PCB level in Waterford's intake could be detected. NYS DEC also monitored PCBs at the intake of Poughkeepsie's water-treatment plant, but gave it up in 1980, when the observed values persistently dropped below the level of detection.

The 1983 Superfund RAMP lacks any mention of New York City's drought-emergency plan for tapping into the Hudson at Chelsea and pumping 100 million gallons per day into the Croton reservoir with only a minimum of treatment (and one that has generated controversy). For two weeks in the spring of 1989, New York City actually tapped the Hudson River to augment the water supply from its Catskill reservoirs, which as a result of lack of rainfall, stood very low levels.

Forage Crops And Vegetables

As mentioned, in 1981, during the preliminary work at Site 10, Buckley (1983) proposed that the PCBs found on plant leaves be used as a proxy for monitoring PCBs in the atmosphere. The basis of this proposal was Buckley's conclusion that the PCBs on the plant leaves arrived there from passive atmospheric fallout, as it were, and did not result from plant metabolism. Other workers have found PCBs in plants and have inferred that PCBs in the soil were taken up via plant metabolism (Weber and Mrozek, 1979; Fries and Marrow, 1981; Sawhney and Lester, 1984; Bush, Shane, Wilson, Barnard, and Dawn Barnes, 1986).

In 1985, a small-scale outdoor experiment was undertaken near Albany using beans and corn grown in 2 plots: (1) a control plot on the floodplain of the Normanskill at the NYS DOT Griffin Laboratory, Route 155, Guilderland, New York, where soil PCBs total 9.9 nanograms per gram; and (2) an experimental plot on Patroon Island, in the Hudson River, within the Erastus Corning Preserve, where soil PCBs total 145 nanograms per gram (Shane and Bush, 1989). On 02 July 1985 both plots were prepared and seeded with corn and soybeans. Already growing at Patroon Island were string beans and pinto beans.

Soy bean plants sprouted and grew from the seeds at b[illegible] locations, but at Patroon Island, no corn developed from [illegible] seeds. On 31 July 1985, 16 corn plants were translocated from the control plot to Patroon Island with root balls enclosed in polyethylene bags to isolate them from the soil at Patroon Island. Sampling of leaves began on 31 July and continued until 14 September, when the experiment ended with the harvesting and testing of available fruits.

The bean leaves showed mean values of PCBs that averaged 11 to 15 ppb; no changes with time were discernible. The amount of PCBs on corn leaves decreased with time. This result contrasts with the data from purple loosestrife at the experimental site, which accumulated PCBs over time (Bush, Shane, Wilson, Barnard and Dawn Barnes, 1986). The decrease in PCB concentration on the corn leaves was not a result of increased biomass, but of losses at the leaf/air interfaces. PCBs in the fruits were "considerably below the mean concentration for the respective leaves and were nearly undetectable in the corn kernels (Table 5). The difference in the concentrations of available PCBs at the two sites did not affect the amount accumulated in the corn kernels. The highest PCB content in the fruits was in the pods and husks at the experimental site and the husk concentrations, when compared to those at the control site demonstrate concomitant increase with available PCB soil concentrations. Notable accumulation could occur in these components at high soil concentrations of PCB" (Shane and Bush, 1989, p. 44-45). Thus, corn grown on PCB-contaminated soil should not be used for silage.

Although these experiments did not unambiguously resolve the questions of the air-versus-soil source of PCBs in plants, they did indicate that corn is capable of eliminating PCBs. As far as using PCBs on plant leaves as air monitors is concerned, Bush, Shane, Wilson, Barnard and Dawn Barnes (1986, p. 290) [illegible]cluded: "We suggest that if plants are to be used as air mo[illegible] the plants be grown from day zero in totally uncontaminate[illegible], and that the congener by congener (sic) transport and storage mechanisms of PCBs within the plant be studied to enable determination of the actual air pattern from plant leaf (sic) PCB data."

Direct Contact With Highly Contaminated Sediments

The chief places where people might come into direct contact with sediments highly contaminated with PCBs are the remnant deposits. The significance of this route from contaminated sediments to people was emphasized by US EPA's Superfund RAMP. As a result, EPA recommended that the remnant deposits be contained by capping them with 18 inches of soil However, US EPA's 25 Sept. 1984 R.O.D., indicates that

> "The appropriateness of further remedial action for these sites will be reexamined if EPA decides at a later date to take additional action with respect to sediments in the river."

In 1989, GE took over the assignment of implementing EPA's interim Superfund recommendation about the remnant deposit[illegible] According to information presented by DEC staff to the Advisor[illegible] Committee at its 24 July 1989 meeting, GE is planning to insta[illegible] some special mats rather than to use dumped clay to cover th[illegible] remnant deposits.

Atmosphere

On a nationwide basis, the atmosphere is the largest natur[illegible] source of PCB transport (Beeton, chm., 1979, p.18-25; Ta[illegible] PCBs are present in the atmosphere both as volatile con[illegible] and attached to dust particles. Careful work is required to dete[illegible] mine how much PCB belongs to each. For many purposes, th[illegible] distinction has not been made.

Table 14. PCB concentrations in air samples from selected localities in the United States (Beeton, Chm., 1979, Table 1.5, p. 20) compared with samples from New York State localities in upper Hudson River area (Hetling, Horn, and Tofflemire, 1978, Table 13, p. 33).

Location (date)	No. of samples	Range (nanograms per cubic meter)	Comment on Aroclor or other information
Vineyard Sound, MA (1973)	02	04 to 05	Calc. as 1254
University of RI (1973)		2.1 to 5.8	do
Providence, RI (1973)		9.4	do
Chicago, IL (1975-76)	04	3.6 to 11	4% as 1242; 97% as "vapor"
Lake Michigan (1976-78)	06	0.57 to 1.6	74% as 1242; 88% as "vapor"
Milwaukee, WI (1978)	02	2.7	59% as 1254; 27% as 1260; 84% as "vapor"
		Average	
Washington Co. offices			
(Nov. 76 to Jun 77)	31	990	Air pumped for 24 hr through a fluorisil column.
(Jul. 77 to Nov. 77	15	305	
Fort Hudson Nursing Home			
(Nov. 76 to Jun 77)	23	108	
(Jul. 77 to Nov. 77) 10	25		
Main Street, Fort Edward			
(Nov. 76 to Jun 77)	24	102	
(Jul. 77 to Nov. 77)	12	67	
Glens Falls			
(Nov. 76 to Jun 77)	32	<20	
(Jul. 77 to Nov. 77)	09	<20	
Warrensburg			
(Nov. 76 to Jun 77)	25	<20	
(Jul. 77 to Nov. 77)	07	<20	
Caputo dump			
Nov. 77)	05	3240	3 2.5-hr samples; 2 08-hr samples
Fort Miller dump			
(Nov. 77)	03	2160	08-hr samples
New Moreau facility			
(Nov. 77)	03	107	08-hr samples

CURRENT STATUS OF THE UPPER HUDSON RIVER PCB-POLLUTION PROBLEM

The current status of the upper Hudson River PCB-pollution problem can be stated simply: "Old Man River" just keeps rolling along, and in so doing, continues to transport PCBs downriver at a rate of at least 4 kg per day (figure based on Brian Bush measurements of July 1989 and presented to the 127th meeting of the Advisory Committee). Many people continue to believe that nature is solving the problem of PCB pollution in the upper Hudson River; that the river is "cleaning itself" (by depositing "clean" sediments on top of PCB-contaminated sediments and/or by bacterial "biodegradation" of the PCBs buried in the hot spots) and that nature's wonders should be allowed to continue without interruption. Residents of Washington County continue to be opposed to any plan to dredge PCB-contaminated sediments from the Thompson Island Pool (or anywhere else in the upper river) and to encapsulate them within the Town of Fort Edward. NYS DEC is rescoping its plans for dealing with the PCB-pollution problem by making preparations to deal not only with the material it hopes to dredge from the 20 hot spots in the Thompson Island Pool, as formerly, but also from the other 20 hot spots, and to be removed from some unremediated NYS DOT dredge-spoil disposal sites and from the remnant deposits. Moreover, it is preparing an application for the use of Site 10 not merely as an encapsulation facility, as formerly, but also as a work space for applying some as-yet-not-specified PCB-removal- and/or PCB-destruction process (and is still hoping to be assisted in dealing with the 20 hot spots in the Thompson Island Pool by the $17 million or so federal dollars remaining in the sec. 116 allotment). US EPA has so far shown no inclination to re-examine its "interim evaluation" made under Superfund I that eating fish contaminated with PCBs known to be spreading down the Hudson River is not a human-health hazard which requires immediate remedial action and New York State has shown no hint that it is willing to tackle US EPA to have EPA correct the manifest outrage it has therein perpetrated on New Yorkers. And, like the sleeping giant of children's fairy stories, New York City seems oblivious to the PCB situation in the Hudson River and to the lack of public-health concern for its citizens exhibited in the US EPA Superfund R.O.D. The biomedical-research community continues to seek fame and fortune in studying many subjects other than the effects of PCBs on human cells. The Hudson River PCB Settlement Advisory Committee continues to meet almost monthly (the July 1989 meeting was its 127th). Meanwhile, a few devoted investigators are continuing their research into such subjects as PCB transport, the effects on PCBs of anaerobic bacteria, and cyclicity of river flow. The Wright-Malta Corporation and other companies press ahead with their efforts to develop economically feasible PCB-destruction techniques for use with contaminated sediments. And the court in Riverhead, Long Island, has not yet conducted any evidentiary hearing in the matter of determining the amounts of money that GE will have to pay the commercial fishermen for lost income resulting from the fishing bans that grew out of PCB pollution in fish or to define the extent of the work GE will have to pay for to clean up the PCB-contaminated sediments in the upper river (as part of the "injunctive-relief" to which the Appeals Court ruled in January 1989 the fisherman are entitled). GE's scientists are on record as contending that in its proposed PCB hot-spot dredging project in the Thompson Island Pool, NYS DEC was planning to dredge the "wrong PCBs." (Possibly one outcome of the Riverhead court's proceedings will that GE will be given the opportunity to dredge the "right PCBs," namely all of them.) And, since January 1989, GE has displayed a new willingness to take over and to carry out EPA's Superfund interim recommendations for temporarily isolating the remnant deposits. [For an opposite reaction from GE, see US EPA R.O.D. of 25 September 1984, Remedial Alternative Selection with respect to Hudson River PCB Site; Glen (sic) Falls, New York.]. The following paragraphs elaborate on some of these remarks.

Is Nature "Curing" The PCB-Contamination Problem In The Upper Hudson River?

The lower concentrations of PCBs measured in the water and the fish in the Hudson River since their 1977 maxima and also the distribution of PCBs with depth in sediment cores (highest PCB concentrations not at water/sediment interface, but 10 cm or so below this interface, as in BC-11, Figure 18, A; see also Figure 15; plus the presence at depth in certain hot-spot sediments of distinctive patterns of PCB congeners that differ from the congener patterns in the surface sediments and the patterns found in the sediments in the estuary) are welcome indications that the worst effects of the mid-1970s floods are behind us. These relationships have prompted the idea, now widely believed, that nature is curing the Hudson River's PCB-contamination problem. The concept was expressed in EPA's 1984 Superfund R.O.D. by the phrases: "natural recovery" and "natural assimilative capacity." Two contrasting natural processes are thought to be involved: (1) covering of PCB-contaminated sediments by "clean" sediments; and (2) "biodegradation" of the PCBs in buried sediments by anaerobic bacteria. I review the origins and wide circulation of the ideas based on these two processes and then show that their significance with respect to the PCB-pollution problem in the upper Hudson River ranges from fallacious to trivial.

Origin of the concepts

The idea that PCB-contaminated sediments are being covered by "clean" sediments began to circulate in the early 1980s in the documents prepared for the environmental-permit proceedings associated with NYS DEC's proposed hot-spot dredging project. For example, it was implied in 1982 (in Comment No. 6 on the draft of US EPA's Environmental Impact Statement on the Hudson River hot-spot dredging project) by a member of US EPA's peer-review panel in the following query: "Will the 'stable' hot spots now covered by clean sediment be dredged? Will these hot spots remain stable during storm events if left untouched?" After it had appeared in the scientific literature in 1983 (Schroeder and Barnes, 1983, p. 16), it was picked up in many newspaper reports (and thus has become embedded in the public mind), and has become one of Congressman Solomon's recurrent assertions.

Similarly, the wide circulation of the term biodegradation began with the publication in technical journals of research reports that showed aerobic bacteria were capable of destroying PCBs (=mineralizing of Alexander, 1981, p. 132). These research results were reported in the public press and circulated widely. The recent spate of press reports centered on the interpretation of congener patterns in core samples of upriver sediment in which the lower-chlorinated congeners predominate. One favored explanation was that such congener patterns had been created by anaerobic bacteria. This interpretation was strengthened by laboratory experiments carried out by microbiologists from Michigan State University (supported financially by GE). Late in 1988, Quensen, Tiedje, and Boyd (1988) published a paper in the prestigious technical journal Science showing how in laboratory experiments, anaerobic bacteria reacting with PCB-polluted Hudson River sediments had produced a congener pattern which matched those found at depth in the hot-spot cores. The laboratory experiments were carried out with sediments having PCB concentrations of Aroclor 1242 of 14, 140, and 700 ppm (dry-wt. basis). They proved that, at the highest concentration, anaerobic bacteria are capable of selectively dechlorinating higher-chlorinated PCB congeners and thus of converting these to lower-chlorinated PCB congeners. Less-pronounced changes took place in the sample at 140 ppm, and not-noticeable changes in the sample at 14 ppm (Quensen, Tiedje, and Boyd, 1988, p. 753). The meta- and para chlorines were removed but the molar concentration of PCBs was not decreased. Thus, PCBs were not destroyed; the process demonstrated is selective reductive dechlorination, not PCB destruction. However, PCBs can be biodegraded by aerobic bacteria. The products of these bacteriological experiments are susceptible to biodegradation by aerobic bacteria. Thus, Quensen, Tiedje, and Boyd concluded: "Hence it is likely that most PCBs can be biodegraded by a suitable sequential anaerobic-aerobic process" (1988, p. 754).

The press reports based the published results of these experiments did not mention the newly discovered process of selective reductive dechlorination of PCBs. Instead, the press fixed on the term, "biodegradation," as used at the end of the article by Quensen, Tiedje, and Boyd and also by J. F. Brown, Jr., and others (1984, p. 176-177, for example). The public impact of these press reports was to implant the idea that anaerobic bacteria are destroying the PCBs in the hot-spot sediments in the upper Hudson River. A contrasting view, originating with Brian Bush, that under the natural temperature conditions prevailing in the sediments beneath the upper Hudson River, bacterial action on PCBs is insignificant, received no more than local circulation.

Sedimentologic aspects: "covering with clean sediments" and base-level control of sediment behavior

The idea that the PCB-polluted sediments are being covered by clean sediments consists of two important and independent sedimentologic components: (1) the bottom is being built upward by additions of new sediment; and (2) the new sediment added lacks PCBs. I examine component (1) here and discuss component (2) in the following section on geochemical-microbiological aspects.

Those who have been advocating the idea that PCB hot spots are being "covered by clean sediments" have not discussed an absolutely fundamental principle of sedimentation: control by base level. Rather, their ideas seem to suggest that they visualize the conditions in the pools behind the upriver dams as being analogous to those within a beaker in a chemistry laboratory within which sediment can be added to build up new layers and none escapes.

The evidence that PCBs attached to sediments that were scoured from the floor of the Thompson Island Pool pass through to the estuary means only one thing: these sediments are bypassing the lower pools. Whatever areas these suspended sediments bypass are not likely candidate sites for layer-by-layer accumulation of "new" sediments. If further evidence is required, it is close at hand. Only a few cores collected from the upper river by Richard Bopp and colleagues from the Lamont-Doherty Geological Observatory of Columbia University and analyzed from the point of view of utilizing anthropogenic tracer materials, have yielded results comparable to those found in many parts of the estuary or in the Albany turning basin. To me, this rarity of finding geochemical tracers distributed as in the favorable areas means that sediments are not being deposited by the layer-by-layer mechanism.

Geochemical-microbiological aspects: insights based on congener-specific analyses

Given the doubts just expressed about the general lack of applicability of the layer-by-layer model to most upriver areas, what about the other part of the "covering-by-clean-sediments" idea, namely that the "new" sediments are clean? At first glance, this idea seems valid. After all, new sediments continue to be transported down the upper Hudson River. And, because GE's capacitor-manufacturing plants are no longer discharging PCBs, as they were between about 1950 and 1977, one can reasonably expect that the new sediments passing these plants would be "clean."

The congener-specific analyses by Bopp and by Bush indicate that the transfer of PCBs from contaminated bottom sediments to overlying water causes a major shift in the congener pattern away from the higher-chlorinated varieties and toward the lowe chlorinated kinds (See Figure 24). Sediments that scavenge th dissolved congeners out of the water preserve the water pattern. Not much is known yet about various clay minerals and PCB congeners interact or how other factors, such as the water temperature, pH, and the dissolved oxygen (or lack of it), may affect any interactions between minerals and PCB congeners. Despite these gaps in understanding the behavior of the PCB congeners, enough has already been established to support the conclusion that fine sediments in the upper Hudson River, even the newest of the new, commonly contain high concentrations of PCBs.

Bopp's congener-specific PCB analyses from the estuary, where concentrations are much lower than in the upriver hot spots, indicate that the distinctive upriver subsurface hot-spot congener pattern in which lower-chlorinated congeners predominate, is not present. In other words, the congener pattern present at the water/sediment interface persists downwards in the cores (Bopp, Simpson, Deck, and Kostyk, 1984). This relationship provides further evidence in support of the conclusion that the PCBs from the subsurface upriver hot spots have not been circulating to downriver localities.

Are The PCBs In The Hot Spots The "Right" PCBs To Dredge?

During the hearings conducted by Hudson River Siting Board II, GE received Full-Party Status in opposition to NYS DEC's proposal to dredge the 20 hot spots from the Thompson Island Pool. The line of argument pressed by GE's attorneys was based largely on Dr. J. F. Brown's results from the pattern of PCB congeners found in the buried hot spots he sampled and analyzed using the capillary-column technique. The substance of GE's case was summed up by Ron Unterman, a microbiologi formerly of the GE Research Center, Schenectady, in his rem made in a PBS 1 1/2-hour special TV program entitled "Th Hudson Chronicle" (broadcast by Channel 17 Schnectady on 22 May 1989). According to Unterman, in applying for permission to dredge the hot spots, NYS DEC was proposing to dredge "the wrong PCBs." By this, he meant the PCBs that are contributing to the downriver transport. As indicated in a previous section, if the central objective is to put an end to the ongoing PCB transport into the estuary out of the upper river, then the hot spots are not the places to dredge. The point was being argued at Hudson River Siting Board II's hearings because DEC was trying to [e]stablish the need for the project by referring to the continuing [dow]nriver transport of PCBs and that a PCB taken out of the upper river and securely encapsulated was a PCB that was not going to spread down the river. I think the point is sufficiently clear that a need has been demonstrated to clean all the PCB-contaminated sediments out of the upper Hudson River north of the Thompson Island Dam, and possibly from other upriver localities, as well. A need exists to deal with both the source of the ongoing downriver PCB transport (coming from the surficial layer of sediment that I think is being subjected to the "thrashing-carpet" mechanism during floods), and the PCB "time bomb" represented by the buried hot spots. More PCBs are concentrated in the hot spots than elsewhere. Accordingly, if one is not in a position to carry out the entire clean-up job in a single project, then logic and cost-effectiveness considerations dictate that the first effort be made to keep the PCBs in the hot spots from ever spreading. The evidence that anaerobic bacteria are getting rid of the buried PCBs in the hot spots on a large enough scale to preclude the necessity for getting these sediments out of the river is not yet convincing to me. Accordingly, I doubt the wisdom of hoping that anaerobic bacteria can eliminate these buried PCBs before the next big flood transports another surge of them into the estuary and spreads many of the rest of them all over the bed and banks of the upper river.

Encapsulation vs. Final Treatment of PCB-Contaminated Dredge Spoil

Opponents of DEC's hot-spot dredging plan that includes use of an encapsulation site in the Town of Fort Edward, Washington County, led by Congressman Solomon, have repeatedly raised the point that encapsulation is the least-preferable option and that a project proposing encapsulation should be opposed on that [ba]sis alone. As long as encapsulation is all that is contemplated, [Con]gressman Solomon stands opposed because he considers [th]at choice as a DEC "dump-and-run" operation. Many of his constituents share his view. Congressman Solomon has pledged to me that he will support a plan that includes final destruction of the PCBs.

If the hot-spot dredging is carried out according to the provisions of Sec. 116 of the Clean Water Act Extension, then the final determination about what happens to the dredged debris is up to the Administrator of EPA. In Hudson River Siting Board II, the EPA determination was "encapsulate."

In the new round of permit applications being prepared by the PSG of NYS DEC, Commissioner Jorling has instructed the staff to include a request for permission to treat the dredged debris to recover and/or destroy the PCBs. He has also ruled that cost-benefit calculations be made.

Connection Between PCB-Polluted Upriver Sediments And PCB Pollution Of The Hudson Estuary

As has been shown, PCBs from upriver have and continue to be sources of PCBs to the Hudson Estuary. The cessation in 1977 of the GE PCB discharges and the dredging of the massive amounts of PCB-contaminated debris from the remnant deposits that invaded Fort Edward in 1974 and 1976 have deactivated two enormous sources of PCBs. Nevertheless, PCB-contaminated sediments on the banks and bottom of the upper river north of the Thompson Island Dam continue to be sources of PCB pollution to the Hudson Estuary.

In their ongoing research program for using geochemical tracers to understand sediment movement in the estuary, Bopp [an]d Simpson have been able to use PCB measurements from [sed]iment cores in New York harbor and vicinity to calculate the proportions of PCBs coming from upriver and those coming from local sources, largely from sewage-treatment-plant outfall pipes. They calculated that between 1971 and 1976, 75 percent of the PCBs in New York Harbor came from the upriver sources, whereas PCBs from sewage-treatment plants amounted to about 25 percent. "Detailed analysis of the cores at mp -1.65 and 88.6 indicates that by the mid 1980's, the relative importance of these two sources had reversed. Total PCBs in the mp -1.65 core were present at about 1.5 ppm while (sic) the core at mp 88.6 had decreased to about 0.8 ppm. Since (sic) at peak levels the harbor core had about half the total PCB concentration of the upstream core, local New York Metropolitan area inputs now appear to dominate the supply of total PCBs to New Hork Harbor sediments" (Bopp and Simpson, 1988 ms., p. 4-5). The supply of PCBs from the treatment plants in the mid-1970s was calculated to be sufficient to contaminate the harbor sediments to the level of 0.8 ppm in the absence of any upriver source (Bopp, 1979 ms.; Bopp, Simpson, Olsen, and Kostyk, 1981, p. 215). By the mid-1980s, this proportion had dropped to 0.5 ppm (Bopp and Simpson, 1988 ms., p. 7).

Bopp and Simpson have identified two areas where extensive deposits of PCB-contaminated sediments are present: (1) in New York Harbor, and (2) south of Rondout Creek, Kingston (from M. P. 85 to 93). About 23,000 kg of PCBs have been estimated to be present in New York Harbor (Bopp, 1979 ms., accuracy judged to be within a factor of 2). A comparably accurate estimate of 21,000 kg of PCBs in the reach near Rondout Creek has been made on the basis of cores collected in 1986 (Bopp and Simpson, 1988 ms., p. 5-6).

Legal/Political/Administrative Matters

I conclude this long summary of the status of the Hudson River PCB-pollution situation with remarks about four matters falling into the legal-political-administrative realm. These are: DEC's difficulties in obtaining site permits, the reorientation and rescoping of DEC's planning set in motion by Commissioner Jorling's ruling of 09 January 1989; contrasts in federal laws which sanction in-place capping of remnant deposits but disallow such capping of NYS DOT PCB-contaminated dredge spoil simply on the grounds that such materials have been moved out of the river; and the commercial fishermen's class-action lawsuit against GE.

Problem of obtaining site permits

DEC's attempts to obtain the necessary permits from siting boards under the hazardous waste law have been beset with difficulties. Some of these have been of their own making; others have been created by others, such as the legislature. In Hudson River Siting Board I, the proceedings began before DEC had put all the required legal pieces into their proper places. DEC has now put the missing pieces in place. In addition, the internal organization of DEC that grew out of the conflict-of-interest decision over Hudson River Siting Board I, has passed a rigorous test. A major factor in any siting board case is likely to be local land-use zoning. In Hudson River Siting Board I, the NYS DEC position that the state could override local zoning was not supported by judicial review. Accordingly, in preparing for a second application, DEC staff made local zoning one of their key screening factors. Because of zoning considerations, in preparing their second permit applications, NYS DEC staff did not include Site 10. Midway through the work of Hudson River Siting Board II, the legislature revised the law about the State's ability to override local zoning. In effect, the passage of this law brought Site 10 back into consideration. It is to be the requested site in the next permit-request proceeding.

The official document reporting the decisions and comments of Hudson River Siting Board II contain statements based on factual errors. Without trying to isolate these here, I simply raise the point that members of siting boards whose minds are made up on the issues before them are not likely to be interested in facts that support a contrary position.

DEC's outlook on Hudson River PCB problems in light of Commissioner Jorling's ruling of 09 January 1989

When he ruled on the outcome of Hudson River Siting Board II's report and recommendations, Commissioner Jorling returned to the goal of upriver rehabilitation that had been recommended by the NYS DEC staff and the Settlement Advisory Committee. As recommended in 1978, the rehabilitation program was to include construction of an encapsulation facility large enough to accommodate: (1) dredge spoils from all 40 of the upriver hot spots; (2) the remaining remnant deposits; and (3) dredge spoils from certain NYS DOT sites. In addition, it was to be large enough to receive debris dredged from future NYS DOT channel-maintenance operations that encountered PCB-contaminated sediments. Commissioner Jorling's ruling also formalizes what had been a firm position by NYS DEC staff, namely that the proposed encapsulation be considered as only a temporary measure until an affordable PCB-destruction process became available.

Contrasts in US law: simple covering of the remnant deposits is allowed whereas simple covering of NYS DOT PCB-contaminated dredge spoil is a violation

Federal laws contain provisions that members of the Advisory Committee have found difficult to accept. The singularities of the laws became apparent during the legislative hearings conducted over the NUS Corporation's Superfund RAMP. Vice Chairman Glowka asked what was the basis for the recommendation that capping the remnant deposits in place was acceptable to US EPA, whereas at the same moment, the Enforcement Branch of Region II, US EPA, was citing as a violation NYS DOT's virtually identical capping of PCB-contaminated dredge spoil previously dredged out of the river. The US EPA Regional Administrator Jacqueline Schaefer replied that the capping proposed came under one federal law (TOSCA), whereas because the dredge spoils had been moved from the river bottom, they came under the provisions of a different federal law (CERCLA). In other words, capping contaminated sediments that are in place is acceptable, but capping dredge spoils having identical concentrations of PCBs is a violation. Or, what is good for the TOSCA goose is not good enough for the CERCLA gander.

The commercial fishermen's lawsuit against GE

On 30 October 1985, in Riverhead State Supreme Court, the State Commercial Fishermen's Association, joined by the East Hampton Town Baymen's Association, the Montauk Boatmen's Association, and the United Fishermen's Association, filed a class-action lawsuit against GE. In this suit, they seek payments for lost income resulting from the fishing bans based on PCBs in the fish, indemnification in the amount of $10 million in punitive damages, and a cleaned-up Hudson River. It is not necessary to review here all the preliminary skirmishes. What does seem important with respect to the future PCB situation in the Hudson River, however, is the ruling handed down in January 1989 from the appeals court. This ruling, by a 5 to 0 vote, supported the decision that the fishermen's case had merit and that they were entitled to payments for lost income and "injunctive relief" over the PCBs from the GE plants in the fish. Although this case has not yet been concluded, it would appear that one possibility is that the judge in Riverhead, Long Island will force GE to clean up the PCB-contaminated sediments in the upper Hudson River. This court will also make the decision about the size of the payments from GE to the commercial fisherman for lost income resulting from the bans on fish resulting from PCB contamination and for any punitive damages levied.

Unresolved Scientific Problems

Three major unresolved issues related to the future of the PCB-pollution problem in the upper river are: (a) the depth to which floods dynamically dilate the riverbed sediments in the upper Hudson; (b) the significance of the selective dechlorination of PCB congeners by anaerobic bacteria; and (c) whether or not the flow of the Hudson River varies cyclically with a principal period of 20 years. A fourth topic in this category of unresolved scientific problems is the human-health effects of low levels of PCBs.

Depth of flood effects on bed sdiments in upper Hudson River

The depth to which a flood flow dynamically dilates bed sediments determines the thickness of buried PCB-contaminated sediments that will be exposed to the water column. Such exposure is only temporary and stops after the flood has crested. However, before they are placed back on the bed of the river again, the dilated sediments move some distance downriver. The 1984 resurvey of the hot spots in the Thompson Island Pool showed that the locations of the boundaries of the hot-spot sediments beneath their surficial layer of less-contaminated sediments have not been shifted since they were emplaced by the two big floods of 1974 and 1976. This result is consistent with the expectation that no such shifting should have taken place because the post-1976 floods have not attained the flow levels of the pre-1976 floods. What is not known is the size of a flood required to extend the level of dilated sediments down to the level of the buried PCB hot spots.

"Biodegradation:" significance of selective dechlorination of PCBs by anaerobic bacteria

Congener-specific analyses of PCBs in selected hot-spot sediments and follow-up bacteriological studies have shown further that the low-chlorine PCB congers found only in these hot-spot sediments beneath their surficial cover could have resulted from the actions of anaerobic bacteria. Such low-Cl congeners have not been found downriver; they offer additional proof that locations of the boundaries of the hot spots defined in 1978 have not changed. What is yet to be determined is the minimum PCB concentration at which the anaerobic bacteria are capable of selectively dechlorinating the high-Cl PCB congeners. In the experiments carried out at Michigan State University, reductive dechlorinization was reported to been active in samples having PCB concentration of 700 ppm. It was less noticeable in a sample having 140 ppm of PCB (Aroclor 1242), and not notceable in the sample with 14 ppm of PCB (Quensen, Tiedje, and Boyd, 1988). But, no such selective dechlorinization has been found at concentrations of 50 ppm in experiments carried out by Dr. Rhee in the New York State Department of Health. Brian Bush contends that selective dechlorination is a temperature-dependent phenomenon that proceeds extremely slowly at the environmental temperatures in the upper Hudson River. Experiments with anaerobic bacteria carried out by Rhee and Bush in the new Moreau encapsulation site showed that the effects of anaerobic bacteria on the encapsulated sediments have been minimal.

The topic of bacterial significance has also been clouded by the results of Brian Bush's experiments under aseptic conditions in which he mixed clean clay with PCB-polluted Hudson River water. The congener-specific chromatogram resulting from the effects of this clay and Hudson River water are identical to those produced in the Michigan State experiments with anaerobic bacteria.

The controversial 20-year flow cycle

The possibility that a 20-yr. cycle exists in discharge variation in the upper Hudson River has been reported by mathematical analyses of monthly discharge means. The staff of US EPA have rejected this possibility, arguing that the statistical base on which it rests is inadequate. Based on my own research about the periodicity of the orbit of the Sun around the center of mass of the solar system, whose principal period averages just under 20 years (19.8 yr.; the Saturn-Jupiter lap cycle), I accept the cycle interpretation. If a 20-yr. flow cycle does exist, then the prediction is that remedial dredging in the early 1990s will be done against a background of rising river discharges and thus of rising ambient PCB values in the water, in the suspended sediments, and in the fish. Because of all the delays over finding funding from "sources other than GE," and in the difficulties encountered in the two Siting Board proceedings with respect to Certificates of Public Necessity and NYS DEC permits, the opportunity to carry out the proposed PCB hot-spot reclamation-demonstration project against a natural background of declining PCB values has been squandered. Rather than being able to claim credit for the results of a dredging project liberally assisted by natural causes, I predict that if NYS DEC carries out the proposed hot-spot dredging project in the 1990s, they will be tied in knots trying to explain why PCB values in the river after the dredging project are higher than they were before. Such higher PCB values, which I predict will accompany higher river discharges, would be unrelated to any dredging. But, because the higher values can be expected to appear in a post-dredging time frame, they are likely to be blamed on the dredging ("post hoc, ergo propter hoc").

Effects of PCBs on people

As mentioned, few, if any, fundamental scientific data exist about the effects of PCBs on people. The whole topic of PCBs in the environment involves important decisions that should be based on such data. Until such times as these data become available, the decisions about what to do with PCBs will be made on the basis of laws that were written without the benefit of valid data on this vital topic.

CONCLUSIONS

The upper Hudson River is one of the nation's most extensively PCB-polluted waterways. Before the problem of PCBs was recognized generally and belatedly acknowledged by the New York State Department of Environmental Conservation, channel-maintenance dredging by the New York State Department of Transportation removed PCB-contaminated sediments containing an estimated 160,000 pounds, or about 30 percent of the PCB mass estimated to have entered the river. In 1973, NYS DEC assented to the request by the Niagara Mohawk Power Company to remove the aging and deteriorating Fort Edward Dam, the first dam downstream of the wastewater-discharge pipes of the two GE plants that were discharging PCBs into the upper Hudson River. Exposed when the dam was removed were wood-laden deposits that had soaked up large quantities of PCBs. These were named the remnant deposits. They soon began to be eroded and to accumulate in the channel of the Fort Edward barge canal. A series of high flows began in December 1973, after the canals had closed for the winter. The period of high flows culminated in a large flood in mid-April 1974. Fort Edward was inundated by an estimated 800,000 cubic yards of debris eroded from the remnant deposits. In the 1974-75 clean up of Fort Edward, no mention was made of PCB pollution.

In September 1975, following publication of articles by Robert Boyle on the PCB pollution in Hudson River fish, NYS DEC Commissioner Ogden Reid announced that NYS DEC had found high levels of PCBs in Hudson River fish. He closed the entire fishery in the upper river and the commercial fishery for striped bass and eels in the lower river. In addition, he commenced an administrative action against GE as the PCB polluter. Despite the focus on PCBs, the subject of the debris at Fort Edward did not come up in the proceeding.

As a result of the historic Settlement Agreement reached in 1976 between GE and NYS DEC, New York State received a $3 million payment from GE and was obliged to match this amount "in cash or in kind" to carry out an immediate comprehensive study of the extent of PCB pollution and to use unexpended funds for rehabilitating the river if the Advisory Committee, established by the Settlement Agreement, concluded that such rehabilitation was practical and desirable. Should the recommended rehabilitation cost more than the money available in the Settlement Fund, DEC agreed to use its best efforts to seek funds "from sources other than GE" to help pay for the recommended rehabilitation.

At its first meeting, on 26 October 1976, DEC staff asked if the Advisory Committee thought it could be in position by March 1977, to make a "go" or "no-go" recommendation on DEC's proposal to dredge the PCB-contaminated sediments out of the upper river. (The March date was set as being as late as possible so that a "go" decision could enable remedial dredging to begin in the 1977 work season.) After learning that the New York State constitution mandates the continued existence, thus of dredging, the canal system, the Advisory Committee voted to exclude the required channel-maintenance dredging from any ban it might recommend about PCB-cleanup dredging. Moreover, in January 1977, the Committee learned about the extent of previous NYS DOT dredging in the upper river, that it was already too late to start PCB-cleanup dredging in 1977, and that NYS DOT had already begun the required advanced planning for a channel-maintenance dredging operation in Fort Edward to deal with the second surge of sediments from the remnant deposits north of the former Fort Edward Dam. Upon learning all these things, the Committee voted to defer the requested decision about PCB-cleanup dredging, to monitor the upcoming channel-maintenance dredging, to build a new PCB-containment facility at Moreau (and not to spread any more PCB-contaminated dredge spoil on Rogers Island in the Village of Fort Edward), and thus to have before it the results of a small-scale "dress rehearsal" of an upriver dredging operation.

The Advisory Committee was instrumental in reorienting the thinking of the NYS DEC staff and of NYS DEC's prime contractor, Malcolm Pirnie, Incorporated (MPI) on the remnant deposits and their PCB pollution. As a result of Committee recommendations, MPI carried out further sampling in the remnant deposits, discovered the extremely polluted Area 3A, and added to its list of alternatives presented to DEC. A haul road was built down the east wall of the Hudson valley to accommodate work vehicles. The highly contaminated debris from Area 3A was trucked to the new Moreau containment facility and a complete rock riprap was built along the shore of Area 3, using stone blocks from a nearby quarry.

In June 1978, after the Advisory Committee had reviewed the results of the Fort Edward channel-maintenance dredging, which demonstrated that most sediments stirred up by dredging, being subject to the law of gravity, are pulled back to the bed of the river in less than a mile from the dredge and that no effects of dredging could be detected at stations 2 miles or more downriver from the active dredge. Accordingly, even the most-skeptical anti-dredging members joined in the unanimous recommendation that DEC proceed at once to plan for the first phase of upriver rehabilitation by dredging the upper-river PCB hot spots (concentrations in excess of 50 ppm). Thereafter, NYS DEC proceeded to carry out that part of the Settlement Agreement involving the seeking of funds "from sources other than GE" to pay for the proposed dredging project.

NYS DEC sought $30 million from US EPA in 1978 and was offered the possibility of a grant of $100,000 for research. By a 1980 vote of Congress amending the CWA as part of the CWA extension by adding Sec. 116, Hudson River PCB Reclamation Demonstration Project, NYS DEC succeeded in imposing on US EPA the NYS DEC request to transfer $20 million from the Clean Water Act's construction-grants program to pay for the federal share (75 percent, to be matched by 25 percent state funds) of the proposed hot-spot dredging project. The authorization for this use of the CWA funds carried a 30 September 1983 deadline and a provision that before Sec. 116 funds would be fully committed, the US EPA Administrator had to make a determination on the matter of Superfund "availability." The amendment specified that no Sec. 116 money would be spent for the dredging project if money from Superfund became available.

Although US EPA became the lead agency in this Hudson River Reclamation-Demonstration Project, NYS DEC's part was to obtain the Certificate of Environmental Necessity and Public Safety, and the SPDES permits for building an encapsulation site, as required by state laws; and the dredging permit from the COE. After MPI had screened 42 sites, the final candidate became a site in the southern part of the Town Fort Edward, known in NYS DEC documents as Site 10. The 1981-82 Siting Board (Hudson River Siting Board I) recommended to NYS DEC Commissioner Robert F. Flacke that he grant the required Certificate and NYS DEC permits. He did, but these were voided on appeal by local opponents; this decision was affirmed by the Appellate Division of the New York State Supreme Court after an appeal by NYS DEC. In the proceedings of Hudson River Siting Board I, GE was content to be an observer; they did not apply for party status.

On 30 December 1982, about two weeks after the signing of CERCLA (PL 96-510, CERCLA), US EPA Administrator Anne M. Gorsuch determined that Superfund money was "available" for remediating the PCB contamination of the upper Hudson River and that all activities which had been started using Sec. 116 funds must stop. In September 1983, US EPA's contractor for the Superfund RAMP assessment recommended no action with respect to the hot-spot dredging proposal. As the statutory deadline for Sec. 116 funds neared, New York State *et al.* filed a lawsuit against US EPA to extend the deadline to enable the new US EPA Administrator William S. Ruckelshaus time to reassess the Gorsuch determination. Ruckelshaus determined that because Superfund money had been found "not available" for the proposed dredging, that Sec. 116 funds were "available" after all. He agreed to allow the balance of the disputed Sec. 116 funds to be spent for the hot-spot dredging project if NYS DEC (1) resurveyed the hot spots in the Thompson Island Pool and (2) obtained permits for a secure encapsulation site. NYS DEC resurveyed the hot spots in the Thompson Island Pool in 1984, and in 1987, Governor Mario Cuomo appointed a second Siting Board (Hudson River Siting Board II) to hear NYS DEC PSG's request for a site in northern Fort Edward (Site G of NYS DEC documents). In the proceedings of Hudson River Siting Board II, GE filed for and was granted full party status in opposition to NYS DEC's proposal. In early January 1989, Hudson River Siting Board II approved in principle the need for the proposed dredging, but rejected Site G as an encapsulation site for the PCB-contaminated dredge spoil.

While all these governmental activities have been taking place, the Hudson River has been (and still is) continuing to acquire a load of PCBs from the contaminated bed sediments north of the Thompson Island Dam. At low levels of discharge (366 cubic meters per second at Rogers Island, which is usually corresponds to a discharge at Waterford of 600 cubic meters per second), the PCBs are dissolved out of the polluted bed sediments. At greater discharges, the river erodes the contaminated sediments themselves. The sediment particles scavenge the dissolved PCBs out of the water column. The amounts of PCBs per year washed over the dam at Waterford and into the estuary have dropped from about 2 tonnes in the late 1970s to 1 tonne and less in the 1980s. Until 1983, PCB values in fish correspondingly declined but thereafter, fish PCB levels have closely reflected the quantity of water flowing down the river.

These declines have been accepted as evidence that the river is "cleaning itself." Two mechanisms supposedly contributing to this natural cleaning are: (1) in the upper river, new "clean sediments," are believed to be covering "old," PCB-contaminated sediments (a view I refer to as "covering with new blankets"); and (2) anaerobic bacteria are believed to be "biodegrading" the PCBs from the hot spots. I contend that the sedimentologic evidence as well as the geochemical data do not support either of these two widely believed mechanisms. Instead, I think the evidence favors the view that the reactions between the river and its bed sediments are best described by what I refer to as the "thrashing-the-same-old-carpet" model, in which the big-flood contaminated sediments are reworked by later floods, which so far, have not equalled the levels of the 1974 and 1976 large floods. The geochemical data, based on congener-specific analyses of PCBs, are now considered to be ambiguous on the subject of "biodegradation" but are not ambiguous on one very important point. Biodegredation or not, geochemical data prove that the buried hot-spot sediments have not and are not contributing to the post-1976 escape of PCBs into the estuary.

I conclude that four factors, virtually ignored in the discussions of the post-1976 declines, are chiefly responsible. These are: (1) As a result of NYS DEC's action against GE that led to the 1976 Settlement Agreement, in 1977, GE ceased discharging PCBs into the river; (2) in 1975-76 and again in 1977-78, NYS D dredged 855,000 cubic yards of highly contaminated sedime. out of the river near Fort Edward (plus another 234,620 cubic yards from 1951 through 1963, for a total of 1,026,160 cubic yards, estimated to contain 160,000 pounds of PCBs; (3) in 1975, and again in 1978, NYS DEC carried out remedial actions with respect to the remnant deposits, initially just to prevent further erosion but, after the Advisory Committee had reoriented the thinking of DEC and its prime contractor MPI, not only to prevent further erosion but also removal and safe encapsulation at new Moreau of 14,000 cubic yards of the most highly contaminated debris from Area 3A, estimated to contain 24,000 pounds of PCBs; and (4) from 1978 to 1982, less water has been flowing in the river, Since 1983, the PCB content of striped bass caught in the Hudson estuary has averaged about 4 ppm, but has fluctuated with river discharge. The 1980s values of PCBs in striped bass are less than the pre-1984 FDA action limit of 5 ppm but more than the current action limit of 2 ppm.

The US EPA Record of Decision (R.O.D.) over the Superfund assessment of the Hudson River PCB site was published on 25 July 1984, just one month after the US FDA changed its action level of PCBs in fish from 5 ppm to 2 ppm. Despite the continued presence of PCBs in fish at levels above the FDA action limit, the US EPA R.O.D. found that the continued spread of PCBs into the Hudson estuary does not constitute a public-health hazard. I conclude that the continued existence without challenge of this EPA R.O.D. is a gross insult to the people of New York. I characterize it as the 1989 equivalent of the infamous 1789 remark ascribed to Marie Antoinette: "Let them eat cake" but in the form of "Let them eat (and drink) PCBs."

The evidence about the 1976-1989 isolation of the buried hot spots and the derivation of the continuing PCB load of the ri from the surficial layer of sediments that overlies the hot sp poses a dilemma for NYS DEC. The compelling justification dredging the PCB-contaminated hot spots, particularly those from north of the Thompson Island Dam, is to prevent another large flood, to be expected in the 1990s, from repeating the environmental disasters wrought by the 1974-1976 floods. In other words, the prime objective is to defuse the ticking PCB "time bomb" represented by the buried hot spots. But, for DEC to mphasize this point in its arguments in favor of carrying out the hot-spot dredging program is to draw attention to DEC's less-than-salutory role in the 1973 removal of the Fort Edward Dam. Be that as it may, I compare the hot spots and their overlying surficial layer of PCB-contaminated sediments to a series of "pillows" (=the hot spots) and to the "feathers" spread around from previously broken pillows (=the contaminated surficial layer). Given limited resources and the inability to launch a single project to deal with both, I conclude that in its efforts to try to remove the PCB "pillows," DEC has made the correct choice. In the proceedings of Hudson River Siting Board II, GE argued that DEC was proposing to dredge "the wrong PCBs." By this, GE was referring to what I call the "feathers." Two contrasting objectives clearly are involved: (1) to pick up what is left of the "feathers," from which the river is currently acquiring its load of PCBs and thus contribute to an immediate, further decline in PCBs going into the estuary and hence into the fish; or (2) to remove the "pillows," and to thus prevent a large flood from spreading more feathers hither and yon. A single, partial dredging will not accomplish both desirable objectives. DEC's proposed hot-spot dredging project must be clearly seen and advocated for what it is, namely an effort to deal only with the "pillows." It should be unambiguously divorced from the equally valid, but entirely separate short-range objective of bringing about a further decline in PCBs derived from the "feathers." I think that much of the inconclusive argument that has developed over merits of the proposed hot-spot dredging project is a produc confusion between these two contrasting objectives.

Upstate opponents of the proposed dredging project are content with the no-action alternative. They consider that time is on their side. Moreover, if no remedial action is ever taken, then the possibility exists that the PCB-contaminated sediments will all wash away from their existing upstate locations and be transported downstate. Upstate residents view with this prospect with considerable satisfaction.

If NYS DEC is ever able to carry out its proposed hot-spot dredging project, then the earliest date for beginning work is probably 1993 or 1994. This is about 20 years after the high-water flows of the early and mid-1970s. According to the disputed concept that a 20-year flow cycle exists, dredging done in the early 1990s will be done against a background of flows much larger than those of the 1980s. The possibility of doing the dredging project during the low-flow decade of the 1980s has been squandered. Thus, even if the PCB "pillows" are successfully and cleanly removed from the river in the 1990s, the predicted higher flows can be expected to derive larger future amounts of PCBs from coming into contact with the remaining "feathers." If such a successful removal of the "pillows" were to be followed by an increased PCB load from the "feathers," this circumstance doubtless would be interpreted by many as proof that, as they had feared and said many times all along, dredging of the PCB hot spots caused more harm to the river than good.

Possibly as a result of the not-yet-settled lawsuit against GE by the commercial fisherman, now before the State Supreme Court in Riverhead, Long Island, GE will be forced to deal with "the right" PCBs in the upper Hudson River. I argue that the "right" PCBs to dredge include both those in the "feathers," which are contributing to the continued PCB pollution of the fish, as well as those in the "pillows," which loom as unexploded PCB "time bombs" in the upper river hot spots.

RECOMMENDATIONS

The Hudson River PCB Settlement Advisory Committee provides a model for how a committee of dedicated, unselfish experts not linked to a given bureaucratic entity can provide an overview of complex situations that tend to become fragmented because agency actions are driven by particular programs and/or particular sources of funds. Such a committee can also serve as an institutional memory that is valuable in view of the short lengths of service of many key agency personnel.

I consider it an urgent matter to bring about a reevaluation of the US EPA R.O.D. of 25 Sept. 1984. Based on his remarks made at a meeting with environmental groups on 10 February 1989, NYS DEC Commissioner Jorling's attempt to establish a sound intellectual basis for the whole upriver PCB-pollution situation does not include any effort by NYS DEC to pressure US EPA to carry out the terms of SARA and to revisit its Superfund (I) conclusions. The fact that during the brief drought emergency of early 1989, New York City received DEC permission to do so and for a few weeks, augmented its drinking-water supply by tapping into the Hudson River, illustrates a significant human-health dimension to the continued presence of PCBs in the Hudson River that was not considered in EPA's 25 Sept. 1984 Superfund I R.O.D. about the PCB problem. I think it unlikely that NYS DEC can carry out any significant rehabilitation of the upper Hudson River unless US EPA reverses its previous R.O.D. and finds (as it did in August 1984 with respect to PCB pollution in New Bedford, Massachusetts) that the continuing transport of PCBs away from a polluted-sediment source and into the fish that are eaten by people constitutes a threat to human health.

NYS DEC should develop a public-relations campaign that clearly sets forth the contrasting PCB situation in the upper river that I have compared to the "feathers" and the "pillows." The arguments in favor of the proposed hot-spot dredging project are simply and only to defuse the unexploded "PCB time bomb" represented by the PCBs in the hot spots (the "pillows," of my analogy). The PCBs in these "pillows" must absolutely be prevented from becoming additional batches of PCB "feathers." Despite the potential embarrassment that it may bring over past actions, DEC should stop shying away from emphasizing the necessity of removing the PCB "pillows" and stop confusing this necessity with the important need to pick up as many as possible of the PCB "feathers" that are still left over from the regrettable bursting of the two big "pillows" in the mid-1970s.

This recommended public-relations campaign should also be aimed at dispelling widely believed concepts that I think the scientific evidence demonstrates are totally erroneous. I refer to the notions that the upper Hudson River is "cleaning itself" by covering old PCB-contaminated sediments with "new" PCB-clean sediments and/or that anaeraobic bacteria in the hot spots are "biodegrading" and thus destroying the PCBs therein.

The "new" sediments entering the system at the upper end may be "clean," but they stay that way only until they pass over Bakers Falls. Thereafter, merely by coming into contact with river water that has dissolved PCBs from flowing over the PCB-contaminated surficial layer in the contaminated reach north of the Thompson Island Dam, they become "infected" with PCBs Not only are any "new" sediments thus not able to remain "clean," the evidence that the sediment load acquired north of the Thompson Island Dam is bypassing the pools from there to the estuary, means that the depositional model implied by the concept of covering by "clean" sediments (in my analogy, the "covering-with-new-blankets" model), although appropriate in a laboratory beaker, is almost totally inapplicable to the upper river.

Geochemical data from congener-specific analyses lend additional proof to the conclusion that the PCBs in the hot-spot "pillows" are not contributing to the PCB load that the river is deriving from the PCB "feathers." Moreover, Brian Bush's recent aseptic experiments of mixing clean clay with Hudson River water containing dissolved PCBs has yielded chromatograms identical to those GE claims are created only by anaerobic bacteria. This result, plus the results of experiments carried out with anaerobic bacteria by personnel from the NYS DOH, which show the great importance of temperature on the rates of reactions by anaerobic bacteria, cast grave doubt on the notion that anaerobic bacteria are "biodegrading" significant amounts of PCBs in the buried hot spots.

In order to obtain the maximum information from future USGS monitoring of the river, NYS DEC should try to persuade the USGS to upgrade its PCB laboratories so future analyses of samples from the Hudson river can be comparable to those now being made by Brian Bush in the NYS DOH laboratories.

Only an aroused public demand for ridding the Hudson River of its PCB burden is likely to stimulate public officials into taking significant actions to rid the upper Hudson of its PCB-pollution problem.

ACKNOWLEDGMENTS

Dr. Mark Brown, of NYS DEC, has helped in many ways by providing information and by reading and commenting on a draft of the detailed outline. Russell Mt. Pleasant, also of NYS DEC, assisted in making copies of various drafts of the manuscript for distribution to the Advisory Committee and in answering my many questions about the history of the PCB situation. John Dergosits, who on 01 July 1989 succeeded Russell Mt. Pleasant as Project Manager for the proposed hot-spot dredging project, has also provided documents and cooperative assistance about several figures. In response to my written request to Commissioner Jorling for review by the DEC legal staff of my remarks about the State environmental laws, Carl Dworkin, Counsel for the DEC PSB, set me straight on several points in which I was mistaken and offered helpful comments about my presentation. I have benefitted greatly from Mr. Dworkin's assistance, but if the final version is still not just right, it is my responsibility, not his. Although I have submitted several drafts of the manuscript to Messrs. Mark Brown, Russell Mt. Pleasant, John Dergosits, and other DEC officials, I have received official written notice that Department considers it inappropriate for staff to comment on material coming from the Advisory Committee.

The members of the Hudson River PCB Settlement Advisory Committee have read various drafts of the manuscript and some members have made many very helpful comments. Dr. Clifford

Rice, in particular, gave me the reactions of the participants at the Marine Board's meeting to his oral presentation of the Hudson River case study. Karen Scelzi has been a careful reader and has offered many helpful comments. Dominick Pirone gave me a copy of one of Robert Boyle's influential 1975 articles and has been a useful sounding board for some of my analogies. I have tried to incorporate all Committee suggestions, but nevertheless, I assume full responsibility for the final version.

Mr. Robert Boyle, of Cold Spring, New York, and a long-time champion of a clean Hudson River, sent me his 1970 article on coastal game fish from Sports Illustrated Magazine, shared with me some of the background on his 1970s efforts to get DEC to act on the PCB pollution, and read a few pages from my manuscript that dealt with his activities.

Dr. David Kopaska-Merkel, of the Northeastern Science Foundation, Troy, critically reviewed the draft of the long version and the revised manuscript submitted for publication. He has suggested many improvements in my presentation.

Stephanie Sanders Sullivan allowed me the use of her computer and printer in Washington, D. C., on 17 February 1989 on which I wrote the first draft of the Executive Summary of the paper submitted to the Marine Board of the National Academy of Sciences. Although no Executive Summary appears in this paper, my writing of such a summary in February served as a basis for the order of presentation used here.

I thank Dr. G. M. Friedman, President of the Northeastern Science Foundation and Distinguished Professor of Geology at Brooklyn College of the City University of New York, for his encouragement and support in manuscript preparation and in copying. Several versions, including the final one, were printed on the Foundation's laserjet printer.

Personnel at the Columbia University Law Library were very helpful in providing me with a copy of the section of the New York State Constitution dealing with canals and in assisting my searches for congressional documents relating to federal regulatory legislation. Similarly helpful was the librarian of the Rensselaer County Courthouse law library in Troy.

Dr. Brian Bush, New York State Department of Health and SUNY Albany, generously gave me copies of his recent reprints and manuscripts containing the results of the congener-specific analyses from his laboratory and on PCB toxicity.

My colleague, Richard Bopp, generously provided me with a copy of the manuscript of the Bopp-Simpson paper: "Contamination of the Hudson River--the sediment record," submitted to the Marine Board of the National Academy of Sciences for publication the in the proceedings of the May 1988 symposium on marine pollution.

Cara Lee, of Scenic Hudson, Poughkeepsie, gave me the copy of the New York City Board of Water Supply's 1929-1976 table of monthly averaged flows at Green Island, from which I was able to prepare Table B-2.

The editor of Northeastern Environmental Science, Peter Buttner, made many helpful comments and rendered much-needed assistance to my struggling efforts to use personal computers to maximum effect in word processing. Buttner insisted that my preliminary sketch for Figure 18, C was not correct, even though I had drawn it from a photograph. As a result, I consulted the original peel, and was able not only to render the strata more accurately, but to gain what I think is a true understanding of what this remarkable peel records. He instructed his computer to render a graph that I redrafted as Figure 23.

Sarah Johnston, formerly of the Hudson River Sloop Clearwater, Inc, and now of the New York State Attorney General's division of Environmental Law, has contributed numerous helpful suggestions about the Hudson River PCB situation over the years I have known her. I stand in awe of her keen insights into all aspects of the PCB problem and the efforts DEC has made toward rehabilitation.

Sheila Kopaska-Merkel, editorial assistant of Northeastern Environmental Science, has endured with good cheer the many changes I have made en route to the final printed version. I thank her enormously for her careful and patient efforts.

Finally, I thank my wife, Barbara W. Sanders, for insisting that if I felt that continued service on the Hudson River PCB Settlement Advisory Committee was important, that I give it an appropriately high ranking in making personal priorities. She has accepted graciously the resulting subtraction of my time from sundry domestic activities.

SELECTED DOCUMENTS AND REFERENCES ON HUDSON RIVER PCB-POLLUTION SITUATION

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APPENDIX A: BASE MAPS AND LOCATION SCHEMES

Base Maps

Several sets of base maps have proved to be useful in all stages of the investigations concerning the PCB-pollution problem of the upper Hudson River. Among these are: (a) standard U. S. Geological Survey (USGS) topographic maps; (b) river-navigation charts; and (c) special large-scale maps prepared for particular detailed studies.

USGS topographic maps

Three sets of standard USGS topographic maps provide coverage of the areas of interest. These are: (1) the regional 1- x 2-degree maps on a scale of 1/250,000 with 100-foot contour intervals; (2) the 15-minute topographic quadrangle maps on a scale of 1/62,500 with 20-foot contour intervals; and (3) the 7.5-minute topographic quadrangle maps on scale of 1/24,000 with 10-foot contour intervals in most places near the upper Hudson River. An index map showing the names of these maps is available free on request from the U. S. Geological Survey. The areas of chief interest in this paper are located on the Hudson Falls and Fort Miller 7 1/2-minute quadrangles (their common boundary lies along latitue 43 degrees 07 minutes 30 seconds north; shown on Figure 4).

River-navigation charts

The U. S. Lake Survey, of the U. S. Army, Corps of Engineers (COE), publishes charts of the New York State Barge Canal System. The set for the Champlain Canal is on a scale of 1/20,000, with scattered depth soundings in feet and with contours of the high ground near the river at 40-foot intervals. These charts show the buoys and other navigation aids, but lack any grid system.

Large-scale maps made for special studies

Large-scale maps drawn from aerial photographs flown especially for mapping requirements have been prepared for parts or all of the upper Hudson River in connection with specialized studies. A topographic map on a scale of 1/1200 with 2-foot contour interval of the area from Hudson Falls to Fort Edward was prepared in April 1974 by the COE in connection with the studies that were undertaken following the 100-year flood. The high waters associated with this flood scoured approximately 800,000 cubic yards of debris that had become exposed as a result of the removal of the Fort Edward dam in the summer of 1973. Debris eroded from upstream of the former dam, from what have been named the remnant deposits (discussed at length in several sections of the text), was deposited at Fort Edward.

As a working tool for plotting the results of investigations made after the GE-DEC settlement, Normandeau Associates (1977) prepared a new topographic map of the upper Hudson river on a scale of 1/2400, with grid squares based on the New York State 10,000-foot system (explained in a following section). This new map was paid for by the GE Settlement Fund.

Location Schemes

Two methods have been employed extensively for specifying locations: (a) river miles, and (b) the New York State grid system. Brief explanations follow.

River miles

The system based on river miles begins with Mile 0 at the Battery, New York City (See Figure 2.), and increases along the centerline of the channel in an upcurrent direction. The buoys and other navigation aids on the river are referenced to this miles-from-the-Battery scheme.

The New York State grid system

The New York State 10,000-foot grid system is in wide use in the New York State Department of Transportation (DOT) forms the X-Y coordinate system in the DEC computer-map programs for processing information about samples collected from the upper river. Locations are specified by reference to two coordinates, with distances measured in feet. By convention, the first coordinate stated is the north distance, and the second, is the east distance from the reference point. (This order is known to surveyors as "northing" and then "easting"). The upper Hudson River lies within the New York east zone. Reference marks at 10,000-foot intervals appear along the margins of the USGS 7.5- and 15-minute quadrangle maps. I have added the approximate locations of 10,000-foot grid squares to the location maps of Figures 3 and 4.

The USGS 15- and 7.5-minute maps are marked with three grid systems: latitude-longitude; New York Coordinate System based on 10,000-foot squares; and Universal Transverse Mercator (UTM) metric. The 1- x 2-degree maps show only the latitude-longitude, and UTM metric grid coordinates.

I will assume that any interested reader has access to the USGS 7.5-minute topographic maps and with these in hand, can use the New York State 10,000-foot grid marks to find locations. Accordingly, important places mentioned in the text will be referenced by citing two coordinates of the grid system and stating the name of the appropriate 7.5-minute quadrangle map.

Table B-1
Brief Anthropogenic History

(Compiled from various sources: MPI reports, NY Times Index, Robert Boyle's writings and personal communications, and original documents.)

Chronological Table

Date	Event
Sep 1822	The Fort Edward Dam was completed to provide water via feeder canal to Old Champlain canal.
1843	Old feeder canal abandoned when new one was built from Glens Falls into the New Champlain canal.
1845	Fort Edward Dam sold to local interest for water power.
1888	New York Harbor Act passed.
1898	Fort Edward dam enlarged into a rock-filled timber-crib dam 586 feet long and 19 feet high. The enlarged dam backed up a water pool that was about 2.5 miles long and 400 to 800 feet wide.
]	Federal Refuse Act passed; illegal to dump wastes into navigable waterways. Whistle-blowing citizens entitled to 50 percent of fines levied on guilty polluters as a bounty for reporting violations.
'	GE started using PCBs in capacitors at Fort Edward
?	GE started using PCBs in capacitors at Hudson Falls
]	Niagara-Mohawk Power Corporation purchased the Fort Edward Dam to build a hydroelectric generator.
;	New York voters approved a $1 billion bond issue to clean the state's waters. Proposed clean-up plans were ...m up by the N Y State Water Resources Commission ...d approved by the Federal Water Pollution Control Administration. The initial project was to establish standards and to apply them to the Hudson River (and other waterways).
;	Hudson River Fishermen's Association founded; begin citizen's actions against polluters of Hudson River under long-forgotten laws against dumping (New York Harbor Dumping Act of 1888 and Federal Refuse Act of 1899). Arthur Glowka, of the HRFA, designed, and the HRFA distributed, 10,000 "Bag-a-polluter" prepaid postcards addressed to the HRFA by which citizens could report locations and times of pipes that were discharging pollutants into the Hudson River and its tributaries.
3	Federal Power Commission (FPC) grants Niagara-Mohawk a license to operate a hydroelectric generator at the Fort Edward Dam.
3.	A stone dike constructed to protect a section at the S end of the Fort Edward dam that had experienced significant settlement and deterioration from floods and old age.
9	NY State scientists discover high levels of PCB contamination in Hudson River fish. Reports suppressed within NYS Department of Conservation.
)	Floods breached stone dike in two places.
	Niagara-Mohawk engages Dames & Moore to conduct a foundation study for proposed replacement gravity dam. 18 core borings drilled close to existing dam; some showed that the bottom of the pool next to the dam was ...ered by soft organic silt and paper waste ranging in ...ness from 2 to 14 feet.

Date	Event
May 1970	Author Robert Boyle assembles specimens of fish from US coastal waters, including striped bass from Hudson River, for tests by WARF Labs, Madison, WI, to determine levels of pesticide residues and PCBs.
26 Oct 1970	Sports Illustrated (SI) published article by Robert Boyle with results of fish tests; elevated levels of pesticide residues and of PCBs found.
Nov 1970	Robert Boyle sends copy of 26 Oct 1970 SI article entitled: "Poison roams our coastal seas" to Carl Parker, Chief of Bureau of Fisheries, NYS DEC.
Dec 1970	Clarkeson, Clough & Associates determine the extent of sediments to a distance of 300 feet upriver from the Fort Edward Dam. They found: (a) brown, fibrous sludge (similar to that found in the Dames and Moore borings), and (b) black sandy silt. They found very little organic silt and that the quantity of the brown, fibrous sludge varied from day to day according to the changes in water level and speed of the flow. Elevated levels of lead, cadmium, arsenic, mercury, copper, and zinc were found in 8 samples.
1971	Both GE plants switched from Aroclor 1242 to Aroclor 1016.
1972	Congress passes Federal Water Pollution Control Act of 1972 (PL 92-500; "Clean Water Act" or CWA); amendment of 18 Oct 1972 takes away the bounty-hunting aspects of the 1888 New York Harbor Act and the 1899 Federal Refuse Act. US EPA established.
18 Dec 1972	GE files application for permit from US EPA for permission to dump 30 to 47.6 lb/day of PCBs into Hudson River.
1973	New York State Legislature established NYS DEC; Henry Diamond named as first Commissioner.
24 Mar 1973	Acting under Sec. 21(b), Water Quality Act of 1970 (P. L. 91-224), personnel from NYS DEC granted a DEC Water-Quality Certificate in connection with application to remove Fort Edward Dam.
1973	US Food and Drug Administration (US FDA) established 5 ppm as limitation of PCB content in the edible parts of fish.
14 Jun 1973	FPC issued an order approving the requested removal of Fort Edward dam.
26 Jun 1973	Henry Diamond sworn in as first Commissioner of NYS DEC.
Jul-Oct 1973	Niagara-Mohawk removes Fort Edward Dam.
04 Oct 1973	Debris eroded from area of former Fort Edward Pool starts to block navigation channel; NYS DOT personnel make depth survey of channel near Lock 7.
Dec 1973	High-water flows begin the "experiment" in spreading PCB-tagged sediment throughout the Hudson River system.
09 Dec 1973	Diamond resigns as commissioner; is replaced by First Deputy Commissioner James L. Biggane, sworn in on 28 Dec 73.
15-16 Apr 1974	A big flood (max. flow at Hadley, 16,300 cu. ft./sec on 15th) eroded an estimated 850,000 cu yd of debris from remnant deposits and transported it downriver. Fort Edward terminal clogged with ca. 790,000 cu yd of debris; navigation channel blocked for ca. 3/4 mi downstream. Town of Fort Edward's two water lines that crossed at the dam were exposed and several sanitary sewer outfalls and the water-supply intake at the Scott

Paper Company (Fort Edward) were blocked. The debris that had accumulated at the north end of Rogers Island reduced the flow into the east channel to such an extent that wastewaters discharged from the sewer pipes that had not been blocked were not being flushed away downstream. The 94 rock-filled timber cribs, formerly used for logging classification, became fully exposed.

Apr 1974 — NY State Attorney General filed damage suit against Niagara-Mohawk Power Corp. alleging violation of the NYS DEC permit and other violations.

26 Apr 1974 — FPC issued an "Order Providing for Hearing and Prescribing Procedures" for hearings that began on 29 May in Glens Falls and continued intermittently in Washington, D. C.,and/or Albany, until 08 Jan 75, when they were adjourned sine die. These hearings were intended to show that the conditions set forth in their license for removal of the Fort Edward Dam had been complied with.

02 May 1974 — New York State Legislature voted $5 million in its supplemental budget for emergency cleanup of Fort Edward terminal and repair of the broken water main.

Apr-Dec 1974 — NYS DOT channel-maintenance dredging removes 260,000 cu. yd of debris from channel near Rogers Island, Fort Edward.

Jul 1974-Jan 1975 — NYS DOT contractor removes 250,000 cu. yd. of debris from East channel, Fort Edward.

Oct 1974-Jul 1975 — NYS DOT contractors carry out bank-stabilization measures in Areas 3, 4, & 5 of remnant deposits. Rock from timber cribs placed along banks of Areas 3 & 4; dumped rock fill used in Area 5.

Nov 1974 — Hugh Carey elected Governor of New York.

08 Jan 1975 — Ogden Reid becomes Commissioner of NYS DEC in Carey administration.

31 Jan 1975 — US EPA grants GE a PCB-discharge permit for 30 lb/day of PCBs into the upper Hudson River.

May-Nov 1975 — NYS DOT contractors dredge 130,000 cu. yd. of debris from West Channel, Rogers Island; and shape bank and seed 2400 linear ft. along shore in Area 2, remnant deposits.

Jun 1975 — Robert Boyle publishes article in Audubon magazine entitled: "Of PCB ppms from GE and a SNAFU from EPA and DEC."

Aug 1975 — Robert Boyle publishes article in Sports Illustrated Magazine (issue of 01 Sep 1975) entitled: "Poisoned fish, troubled waters."

08 Aug 1975 — NYS DEC Commissioner Ogden Reid announced that high levels of PCBs had been found in NY fish.

08 Sep 1975 — NYS DEC commences administrative proceeding against GE, alleging violations of NY State Env. Conservation Law (ECL), secs. 11-0503, 17-0501, and 17-0511. Prof. Abraham Sofaer appointed as Hearing Officer.

23 Sep 1975 — Commissioner Reid closed the Hudson River fishery (sport fishing in upper river and commercial striped-bass fishery in the Hudson Estuary).

05 Oct 1969 — Preliminary hearings begin; Party Status sought by NYS Department of Commerce, Natural Resources Defense Council, Hudson River Fishermen's Association, Hudson River Sloop Restoration, and Federated Conservationists of Westchester County.

19 Nov 1975 — Hearing Officer Sofaer issued a decision and opinion admitting all applicants as parties under certain conditions and limitations.

09 Feb 1976 — Hearing Officer Sofaer issued an interim opinion. He dismissed GE's alleged violations of 11-0503, but sustained those of 17-0501 and of 17-0511.

27 Mar-09 Apr 1976 — Two-week flood begins, with max. flow at Hadley on 02 Apr of 31,000 cu. ft./sec. Another 200,000 cu. yd. eroded from remnant deposits and transported to Fort Edward.

29 Apr 1976 — Gov. Cary fires Ogden Reid as NYS DEC Commissioner.

30 Apr 1976 — Gov. Carey names Peter A. A. Berle as Acting Commissioner of NYS DEC.

26 May 1976 — Peter A. A. Berle sworn in as NYS DEC Commissioner.

01 Sep 1976 — NY State Environmental Quality Review (SEQR) Act takes effect; among other things, this act requires state agencies to prepare Environmental Impact Statements (EIS) prior to *taking any action that may affect the environment significantly.*

07 Sep 1976 — Hearing Officer Sofaer sends long memorandum to NYS DEC Commissioner Peter A. A. Berle, recommending that NYS DEC accept the proposed settlement under which NYS would be awarded its objective no. 1 (cessation of PCB discharges); would drop objective no. 2 (penalties); and would settle with respect to objective no. 3 (rehabilitation). GE also agreed to cease PCB discharges by 01 July; to build wastewater-treatment facilities at its plants; to carry out $1 million worth of in-house environmental research, much of it devoted to PCBs; and to pay $3 million in cash to New York State to establish a Settlement Fund for studies and/or rehabilitation of the upper Hudson River. New York State agreed to match the GE $3 million in cash or in kind and to establish a Settlement Advisory Committee of independent experts, governmental, and private representatives to advise the Commissioner of NYS DEC on all matters related to the studies and/or rehabilitation of the upper Hudson River and expenditures from the Settlement Fund. The agreement further stipulated that GE had not violated any law, that the $3 million was not a fine or penalty, and that New York State would not pursue GE further over the PCB pollution of the Hudson River.

08 Sep 1976 — Comm. Peter Berle signs Settlement Agreement with GE.

30 Sep 1976 — 94th Congress, 2nd session, passed the Resources Conservation and Recovery Act of 1976 (RECRA)

11 Oct 1976 — 94th Congress, 2nd session, passed the toxic-substances control act (TOSCA). Among other things, this act banned PCBs in the United States. It was signed into law as PL 94-469.

21 Oct 1976 — RECRA signed into law as PL 94-580.

26 Oct 1976 — Hudson River PCB Settlement Advisory Committee holds first meeting; Raul Cardenas elected chairman; Dominick Pirone, Recording Secretary.

19 Nov 1976 — PCB Settlement Advisory Committee elects John E. Sanders as co-chairman.

mid-Dec 1976 — US EPA Region II Edison Lab. carries out screening survey of sediments in Hudson Estuary; 29 short cores collected from winch-equipped survey helicopter. Analyses for PCBs made in Edison Lab. showed values ranging from 11 to 50 mg per kg (expressed as Aroclor 1016) in topmost 7.6 cm; the bottom segments of the cores (18-25 cm depth) showed low or not-detectable PCB values.

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Advisory Committee sends recommendation to Comm. Berle that no significant remedial dredging is possible in the summer of 1977 because of insufficient lead time for necessary preliminary work.

03 Jan 1977

The Committee's requested decision about a recommendation related to rehabilitation by dredging will be delayed until after the results are in from the channel-maintenance dredging scheduled for Fort Edward terminal.

04 Jan 1977 — NYS DEC arranged helicopter overflight of the upper Hudson River for member of the Advisory Committee.

25 Feb 1977 — Cardenas resigned as Chairman of PCB Settlement Advisory Committee; Sanders succeeds him as Chairman. Dwight Sangrey elected as new co-chairman.

27 Apr 1977 — The Committee recommended that the river be extensively monitored during this 1977 dredging, and insisted that no dredge spoil be placed on Rogers Island, as proposed in the Malcolm Pirnie (MPI) report, but rather that all spoils be contained in a state-of-the-art encapsulation site, the "new Moreau" facility. The Committee recommended expenditures from the Settlement Fund be used to pay for whatever "extra" features the new Moreau facility might require in order to contain the PCB-polluted sediments safely--over and above whatever NYS DOT had already planned.

24 May 1977 — US EPA published its rules for handling PCBs under TOSCA.

14 Nov 1977 — Remnant-deposit subcommittee (Sanders, Darmer, and Stellato) make site visit to remnant deposits.

Jun 1978 — PCB Settlement Advisory Committee unanimously recommends to NYS DEC Commissioner Peter Berle that the final rehabilitation of the upper Hudson River requires removal of remnant deposits, dredging of the 40 hot spots north of Troy, and encapsulation of these PCB-contaminated materials (along with those from certain NYS DOT dredge-spoil sites) in a secure site. The estimated cost of doing these projects is $40 million. The Committee urged the NYS DEC Commissioner to proceed with attempts to secure federal funds to assist in the upper-river rehabilitation program.

15 Jul 1978 — A new law, "Industrial Hazardous Waste Management Act of 1978" takes effect in New York State. This law states conditions for an application to NYS DEC for the applicant to use a given site to store hazardous wastes. After NYS DEC has determined that the Certificate application is complete, the Commissioner of NYS DEC notifies the Governor, who must appoint a Facilities Siting Board pursuant to Environmental Conservation Law (ECL) Sec 27-1105 to conduct an adjudicatory hearing on the Certificate application. Simultaneously, the Commissioner shall appoint a Hearing Officer to preside. This law also directed the Commissioner of NYS DEC to promulgate rules and criteria for guiding Siting Boards and to have them in final form by 15 July 1979.

26 Jul 1978 — PCB Settlement Advisory Committee and NYS DEC conduct a public-in-formation meeting at Hudson Falls High School auditorium to explain the basis for the Committee's unanimous recommendation to the Commissioner of NYS DEC that he pursue the hot-spot dredging project as a means of rehabilitating the upper Hudson River. The meeting was attended by an estimated 240 persons; public discussion of about 3 hours' duration followed the opening presentations. Congressman Gerald Solomon suggested that a one-year moratorium be placed on any construction activities related to the proposed project so that all questions raised by the audience could be fully answered first.

Aug 1978 — Ca. 14,000 cu yd of highly contaminated debris (PCB levels in the 10,000-ppm range) removed from Area 3A of remnant deposits and encapsulated at new Moreau facility. The eastern shore of the Hudson River along Area 3 was armored with a sturdy riprap of quarried stones.

15 Sep 1978 — NYS DEC applied to US EPA for Step 1 Construction Grant of $1,275,000 to prepare final plans and specifications of the proposed Hudson River PCB-reclamation/demonstration project for dredging 20 hot spots in the Thompson Island pool.

19 Sep 1978 — NYS DEC submits State Priority List for CWA Title II, Sec 201 construction-grant funds; Hudson River PCB Reclamation project placed No. 1 on priority list for FY 1979 funding.

10 Oct 1978 — US EPA Region II transmits Step 1 grant application to US EPA Washington (to Thomas Jorling), requesting a determination of the eligibility of the PCB project for Section 201 funding.

11 Oct 1978 — US EPA approves State Priority List for CWA Sec 201 funds, but adds note that the Hudson River PCB project is under review to determine Sec. 201 eligibility and, if not found to be eligible, must be removed from the State Priority List.

27 Nov 1978 — NYS DEC files additional application with US EPA Region II for grants to carry out dredging of PCB hot spots in Hudson River, requesting consideration under CWA Title I, Sec 105 (Research and demonstration) and CWA Sec 115 (Removal of in-place toxicants from navigable waterways).

09 Dec 1978 — US EPA Region II transmits NYS DEC's application for CWA Title I funds to US EPA Washington for review.

23 Dec 1978 — Gov. Carey fires Berle as NYS DEC Commissioner; names Robert F. Flacke Commissioner.

08 Jan 1979 — US EPA Washington (Jorling) notified US EPA Region II (Beck) that CWA Sec 201 does not authorize construction-grant funds for removing in-place toxicants, such as PCBs, from navigable waterways, such as Hudson River; cites congressional intent to fund such projects under CWA Title I, Sec 115, but that US EPA does not expect any funds for Sec 115 during FY 1979 or FY 1980.

08 Feb 1979 — US EPA Region II informs NYS DEC that US EPA Washington has lost NYS DEC's Title-I grant application.

16 Feb 1979 — NYS DEC submits second copy of lost Title-I application to US EPA Washington.

30 Mar 1979 — US EPA Region II returns NYS DEC's application for funds from CWA Title II Sec 201 with notification that US EPA Washington has found the proposal to be ineligible for funding under Sec. 201.

20 Apr 1979 — NYS DEC received copy of memo from US EPA Washington to US EPA Region II that Title I funds for research are not available in the amount requested but that EPA would consider funding a research grant in the amount of $100,000 to $150,000.

15 Jul 1979 — Deadline for final promulgation of NYS DEC's rules and criteria to govern Hazardous Waste Facilities Siting Boards; rules and criteria in draft form only.

Fall 1979 — US EPA Region II rejects several channel-maintenance dredging applications by the Port of New York and New Jersey on the grounds that the PCB contents of the sediments to be dredged exceed treaty-defined limits for ocean dumping.

Fall 1979 — Save-Our-Port coalition formed to mobilize support for needed harbor-dredging projects.

31 Oct 1979 — Congressman Stratton introduces H. R. 5767 to amend Title I of CWA to authorize a demonstration project for the reclamation of the Hudson River using construction-grant funds from Title II, Sec. 201.

28 Jan 1980 — US EPA approves NYS DEC's FY 1980 State Priority List, with Hudson River PCB project as No. 1.

11 Feb 1980 — US EPA (Charles Warren) letter to Gov. Carey recognizes need to clean up the PCB problem in the Hudson River.

15 May 1980 — US House and Senate Committee reports issued on bills to extend Clean Water Act (CWA).

House Committee on Public Works and Transportation reports favorably on H. R. 6667, which does not mention the Hudson River PCB project.

Senate Committee on Environment and Public Works reported favorably on a committee bill, S. 2725. Sec. 3 of S. 2725 included an amendment to the CWA Title I, a new sec. 116, authorizing the US EPA Administrator to negotiate with New York State for a PCB reclamation-demonstration dredging project in the upper Hudson River, with the 75 percent federal share of funds to be taken from money previously allotted to New York State under sec. 201 (construction of sewage-treatment plants).

20 Jun 1980 — US EPA Administrator Douglas Costle writes to Sen. Jennings Randolph, Chairman of Senate Committee on Environment and Public Works urging that Sec. 3 of S. 2725, under Committee consideration, which authorized use of CWA Sec. 201 funds to dredge PCBs from the Hudson River, not be approved as it would establish a precedent that could "jeopardize the integrity of the construction grants (sic) program."

25 Jun 1980 — US Senate passes S. 2725 (extension of the CWA) by a vote of 93 to 0.

01 Oct 1980 — US House of Representatives takes up S. 2725. Differences between H. R. 6667 and S. 2725 reconciled by adopting an agreed-upon substitute bill; Senate also passes the substitute bill. The substitute bill includes the provisions of S. 2725 with respect to the Hudson River PCB dredging project, except it places a $20 million limit (not $50 million), adds a 3-yr time limit, and specifies that the EPA Administrator must make a final determination about funds-- those made available under the new Sec. 116 are not to be used if funds become available under Superfund.

21 Oct 1980 — Extension of CWA signed into law as P. L. 96-483 (Clean Water Act Amendment).

02 Mar 1981 — US EPA approves NYS DEC's application for a Step-I grant proposal of $1,722,000 from the $20 million transferred to CWA Sec 116 from Sec 201 funds to carry out preparatory work for the Hudson River PCB Reclamation-Demonstration project. In view of the federal commitment of $20 million (instead of the $30 million sought for the upper-river rehabilitation program projected), NYS DEC staff re-scope the proposed rehabilitation project to include only the 20 hot spots in the Thompson Island Pool. Left out are any further treatment of the remnant deposits, certain NYS DOT dredge-spoil sites, and 20 other hot spots.

25 Sep 1981 — Siting Board I pre-hearing conference held; attorney for Washington County CEASE, Inc., (CEASE is an acronym for "Citizen Environmentalists Against Sludge Encapsulation") files for full-party status in the hearings and moves to have proceedings terminated on grounds that hearing is premature because NYS DEC has not completed statutory requirement for promulgating final rules and criteria to guide Siting Boards. CEASE admitted as a full party, but its motion for termination is denied.

04 Nov 1981 — Siting Board I evidentiary hearings begin on NYS DEC's application to use Site 10, in southern Fort Edward, to encapsulate PCB-contaminated dredge spoils to be dredged from 20 hot spots in Thompson Island pool. These hearings span 22 days.

Nov 1981 — NYS DEC applied to US EPA for remaining $18.2 million of CWA Sec 116 allocation to proceed with the PCB hot-spot dredging project.

28 Dec 1981 — US EPA Administrator Anne M. Gorsuch signs EPA Agency Order 2200.4 that mandated external peer review for all documents attributable to EPA and prepared by an EPA employee, consultant or grantee for distribution outside the Agency.

21 Jan 1982 — Siting Board I's evidentiary hearings end.

22 Apr 1982 — Siting Board I voted affirmative recommendation to Commissioner of NYS DEC to grant the requested Certificate of Environmental Safety and Public Necessity and necessary DEC permits for using Site 10 to encapsulate dredge spoil from PCB-contaminated hotspots in Hudson River PCB-reclamation-demonstration project. Siting Board I listed 16 conditions to be met in connection with the proposed project.

Aug 1982 — Washington County CEASE, Inc., filed a court challenge to the Siting Board's actions on permit for Site 10 on three grounds: (1) The Siting Board was constituted and holding hearings prior to the required promulgation of final rules and criteria for guiding Siting Boards (deadline of 15 July 1979 had not been met by NYS DEC; in 1981, these were still in draft form); (2) The decision illegally overrode local zoning regulations; and (3) the Commissioner of NYS DEC had appointed as his representative to the Siting Board and its Chairman, Richard A. Persico, who continued to serve as Chief Counsel to DEC while being Chairman of the Siting Board, and thus was in a position of conflict of interest.

08 Oct 1982 — NYS DEC resubmits application for balance of CWA Sec 116 funds to proceed with the PCB hot-spot dredging project.

31 Oct 1982 — US EPA publishes FEIS that recommended favorably the proposed PCB hot-spot dredging project.

Nov 1982 — Mario Cuomo elected Governor of New York State.

03 Dec 1982 — 96th Congress, 2nd session, passed the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), known as "Superfund."

11 Dec 1982 — Superfund bill signed into law as PL 96-510.

30 Dec 1982 — US EPA Commissioner Anne Gorsuch issues Record of Decision (ROD) on NYS DEC's application for the balance of the CWA Sec 116 funds. She determined that the balance of the Sec. 116 funds are "not available" and that funds for dealing with the Hudson River PCB-pollution problem under Superfund "are available."

12 Jan 1983 — Henry G. Williams named as NYS DEC Commissioner in Cuomo Administration.

Feb 1983 — US EPA notifies GE that under the terms of CERCLA (Superfund), GE is designated as the "responsible and liable party" for the PCB contamination of the upper Hudson River.

05 May 1983 — US EPA met with GE to discuss agency's intention of listing the Hudson River PCB site on the Superfund National Priorities List (NPL).

10 May 1983 — US EPA releases study showing level of PCBs in human body tissues in USA has "declined dramatically" since 1977. US EPA links the decline to 1976 Federal regulations banning PCBs and subsequent EPA rules phasing out PCBs.

18 July 1983 — Judge Thomas Mercure, NY State Court of Special Term, voided the Certificate granted for Site 10 by the Siting Board, sustaining all 3 grounds cited by CEASE's appeal. NYS DEC appeals this decision to the Appellate Division of the New

York Supreme Court.

Aug 1983 State of New York; Hudson River River Sloop Clearwater, Inc.; Scenic Hudson, Inc.; Natural Resources Defense Council, Inc.; The Hudson River Fishermen's Association; John Mylod; and Hon. Richard Ottinger file a lawsuit against US EPA to "stop the clock" re. the 30 Sep 1983 deadline for the use of CWA Sec 116 funds for the PCB hot-spot dredging project.

08 Sep 1983 US EPA published a proposed update of the NPL that included the PCB-contaminated upper Hudson River.

23 Sep 1983 US EPA and contending parties sign a consent order in connection with the lawsuit; begin negotiations on a settlement.

29 Sep 1983 US EPA Administrator William Ruckelshaus sends letter to NY Congressional delegation who had met with him on 26 July 1983 stating the Agency's determination about rejecting the dredging option for mitigating the Hudson River PCB contamination under Superfund and indicating that because Superfund had been found to be "not available," for dredging PCB-contaminated sediments, he would consider a re-application by NYS DEC for the Sec 116 funds his predecessor had determined were "not available," but only if two conditions were met: (1) NYS DEC must re-survey the hot spots in the Thompson Island pool; and (2) NYS DEC must have available a suitable secure landfill site and have acquired the appropriate Certificate and permits.

27 Oct 1983 US EPA issues Notice Letter to GE as "a responsible and liable party" for PCB pollution of upper Hudson River under terms of CERCLA (Superfund).

20 Jan 1984 Hudson River Foundation (HRF) convenes a workshop in New York City to review all issues related to the proposed PCB-dredging project. Because of the unsettled lawsuit over the Gorsuch ROD, representatives of US EPA and the NUS Corp. do not attend.

08 Mar 1984 Appellate Division, NY Supreme Court, upheld Judge Mercure's decision, thus voiding the Certificate and permits for Site 10.

08 Mar 1984 HRF hosts meeting at Saratoga, NY among residents of Washington Co., NYS DEC staff, and Executive Committee of PCB Settlement Advisory Committee to seek common ground for discussion of issues related to proposed encapsulation facility at Site 10, Ft. Edward. In view of the decision of the Appellate Division of the NY Supreme Court, announced earlier in the day, Washington County residents think there is nothing to negotiate.

10 May 1984 US EPA and parties to the lawsuit signed a settlement agreement and the lawsuits were dismissed. US EPA agrees to make a grant of ca. $18 million of CWA Sec. 116 funds to State of New York for dredging and secure encapsulation of PCB-contaminated sediments from the 20 hot spots in the Thompson Island pool. In a new Step-1 grant, NYS DEC agreed to carry out the recommended resurvey of these 20 hot spots, to identify and carry out environmental studies of new candidate encapsulation sites and to acquire the necessary site permits. A deadline of 11 May 1988 for NYS DEC's activities was agreed to.

25-27 Jun 1984 American Toxics Disposal, Inc. (ATDI) carries out PCB-stripping experiments on Hudson River hot-spot sediments in experimental facility, Waukegan, IL. PCB level in sediments reduced to >2 ppm, but ATDI scientists are not able to satisfy US EPA Region V that they can account for the whereabouts in their apparatus of the stripped PCBs.

20 Aug 1984 US FDA lowers tolerance limit of PCBs in fish from 5 ppm to 2 ppm.

27 Aug 1984 Normandeau Associates begins collecting samples from a 125-ft triangular sampling grid in the Thompson Island Pool; by end of effort on 19 Nov 1984, 1037 new samples are collected, of which 537 were cores.

25 Sep 1984 US EPA issues Record of Decision (R.O.D.), "Remedial Alternative Selection with respect to Hudson River PCB Site; Glen (sic) Falls, New York." EPA found that the fishing bans "should reduce the threat to consumers while the fish population continues its natural recovery during the interim evaluation period. It is projected that the natural assimilative capacity of the river will continue the downward trend in the levels of PCBs found in the river." Given this determination that the downriver spread of PCBs did not constitute a potential human-health hazard, US EPA recommended no action be taken with respect to the proposed hot-spot dredging project.

03 Oct 1986 U. S. Senate passes Superfund Amendments and Reauthorization Act of 1986 (=SARA).

08 Oct 1986 U. S. House of Representatives passes Superfund Amendments and Reauthorization Act of 1986 (SARA).

27 Oct 1986 President Reagan signs SARA into law as PL 99-499.

09 Jan 1987 As first major bill in 100th Congress the House passes the Clean Water Bill by a vote of 406-8.

12 Jan 1987 NYS DEC's Chief Administrative Law Judge, of NYS DEC's Regulatory Review Group, issued Certificate of Completion on Project Sponsor Group's application to use Site G, in northern Fort Edward, for an encapsulation site to receive PCB-contaminated dredge spoils to be dredged from the 20 hot spots in the Thompson Island pool.

Notice of completion issued on the completion of the NYS-DEC/US EPA Region II joint Draft Supplemental Environmental Impact Statement (DSEIS) along with notice of joint Legislative Hearings to be held in February.

22 Jan 1987 Gov. Cuomo reported ready to replace Comm. Williams with Thomas C. Jorling.

U. S. Senate passes Clean Water Bill by a vote of 93-6.

31 Jan 1987 Pres. Reagan vetoes Clean Water Bill.

Gov. Cuomo appoints Industrial Hazardous Waste Disposal Facility Siting Board (=Hudson River Siting Board II); Irwin King, of DEC, appointed Chairman; Administrative Law Judge Daniel E. Louis is designated to be the Hearing Officer.

03 Feb 1987 Gov. Cuomo announces appointment of Thomas C. Jorling as Commissioner of Environmental Conservation.

04 Feb 1987 U. S. House of Representatives votes to override presidential veto of Clean Water Act (by 401-26).

05 Feb 1987 U. S. Senate votes to override the presidential veto of Clean Water Act (by 86-14); bill becomes Water Quality Act of 1987, PL 100-04.

24 Feb 1987 Joint Legislative Hearings on DSEIS held in Poughkeepsie.

25 Feb 1987 Joint Legislative Hearings on DSEIS held in Fort Edward.

26 Feb 1987 Judge Louis convenes Issues Conference; applicants for Party Status include in opposition, General Electric Co. (GE); Washington County CEASE, Inc.; Sharon Ruggi; Eleanor Burch; the Kingsbury Chamber of Commerce; the Town of Waterford, and the New York Farm Bureau; in support, Scenic Hudson, The Hudson River Sloop Clearwater, the

Hudson River Fishermen's Association.

20 Mar 1987 Judge Louis announces that two issues required adjudication before formal testimony can be heard: (a) the compatibility of the proposed project with local zoning regulations; and (b) whether any conflict exists between the project and New York State's Agriculture and Markets Law and any locals laws related to the agricultural district.

19 May 1987 Siting Board II's Adjudicatory Hearings begin.

24 May 1987 NYS DEC releases news story indicating that the cost of the proposed hotspot dredging project has now risen to $40 million. Because of the cap on the Federal share, NYS will make up the difference (from environmental bond-issue funds).

09 Jun 1987 GE announces its scientists have found that micro-organisms are breaking down PCBs in some Hudson River hot spots.

25 Jun 1987 NYS Senate confirms Thomas C. Jorling as Commissioner of NYS DEC.

14 Jul 1987 NYS Department of Agriculture & Markets Commissioner Donald Butcher holds public hearing in Fort Edward on subject of agricultural impact of proposal for use of Site G.

Aug 1987 NY State adopts new hazardous-waste law that enables hazardous-waste-facility requirements to override local zoning and land-use regulations and also directs NYS DEC to submit to the Legislature and the Governor, a report recommending appropriate forms of aid and assistance to localities affected by hazardous-waste facilities.

12 Nov 1987 Resources Conservation Corp. (RCC) completes lab test report on the effects of its procedure using the reverse immiscibility with temperature of triethylamine (TEA) with oil/water mixtures on two Hudson River samples [a composite from Hot Spots 2 and 20 in the Thompson Island Pool (PCB content of 22 ppm) and from Area 5, Remnant Deposits (PCB content of 960 ppm)]. After treatment, the PCB content of the hot-spot sample was 1.9 ppm, and that of the remnant-deposit, 40 ppm. The PCBs extracted from the sediments were concentrated in the oil fraction.

19 Nov 1987 NYS DEC Commissioner Thomas Jorling rules that new amendments to NYS Environmental Conservation Law (ECL) prevent local zoning/land-use regulations from being a basis for rejecting a hazardous-waste-disposal facility; directs PSG to review sites it had considered but rejected on grounds of zoning conflicts.

15 Dec 1987 U. S. Army, Corps of Engineers, holds Public Hearing in Fort Edward on PSG application as related to Rivers and Harbors Act and Clean Water Act.

20 Jan 1988 New York State Energy Research and Development Authority (NYS ERDA) and Zurn Industries, Inc. (partner with Wright-Malta, Corp.) sign cost-sharing research agreement to carry out experiments with Wright-Malta's rotor steam gasifier for destroying PCBs in contaminated sediments and generating electricity with combustible gases formed.

27 Jan 1988 ALJ rules that Site 10 is now an economically and technically feasible alternative and that PSG must develop a comparative study of Site 10 and Site G.

14 Apr 1988 ALJ and Siting Board conduct joint Legislative Hearing on PSG's comparative study of Site 10 and Site G.

27 Apr 1988 ALJ finds no issues need to be heard relative to the comparative assessment.

20 Sep 1988 ALJ recommends approval of the PSG proposal to Siting Board.

09 Jan 1989 Siting Board accepts finding that dredging of PCB hot spots and encapsulation of dredge spoil are environmentally necessary, but that proposed Site G is inadequate; Board rejects PSG's permit applications.

09 Jan 1989 Commissioner Jorling accepts Siting Board's recommendation; directs PSG to reapply for use of Site 10, but with sufficient capacity to manage not only the contaminated materials from the 20 hot spots in the Thompson Island Pool, but also from the remnant deposits, from certain NYS DOT dredge-spoil sites, and from the other 20 hot spots between Thompson Island Dam and Troy (see 02 Mar 1981); and to apply not only for secure encapsulation but also for use of a final-treatment process under SARA (Superfund II).

Table B-2. Discharge of Hudson River at Green Island, NY, Oct. 1929-Sep. 1986, expressed as average value on a monthly basis. (New York City Board of Water Supply and U. S. Geological Survey; Julian Days and dates of lunar perigee-syzygy alignments taken from F. J. Wood, 1978, Table 16; F = Full Moon at perigee; N = New Moon at perigee.)

Year	Month	JD (mid month)	Discharge (HR at Gr. Is.) (cu.ft./sec; av. of daily values for month)	P/S dates
1929	Oct	242 5900	04944	
	Nov	5931	06192	
	Dec	5961	07706	
1930	Jan	5992	09238	242 5991 F
	Feb	6023	06839	6020 F
	Mar	6052	36882	
	Apr	6083	48002	
	May	6113	27788	
	Jun	6144	08538	
	Jul	6174	06260	6183 N
	Aug	6205	03581	6213 N
	Sep	6236	04635	
	Oct	6266	06062	
	Nov	6297	08396	
	Dec	6327	10028	
1931	Jan	6358	196[illegible]4	
	Feb	6389	14081	6375 F
	Mar	6417	22435	6404 F
	Apr	6448	18459	6434 F
	May	6478	10672	
	Jun	6509	08804	
	Jul	6539	04720	
	Aug	6570	03481	
	Sep	6601	037[illegible]	6597 N
	Oct	6631	03582	6626 N
	Nov	6662	03563	
	Dec	6692	04612	
1932	Jan	6721	03113	
	Feb	6752	02961	
	Mar	6781	09280	6789 F
	Apr	6812	22961	6818 F
	May	6842	14210	6848 F
	Jun	6873	08543	
	Jul	6903	11826	
	Aug	6934	05216	
	Sep	6965	05892	
	Oct	6995	13920	7101 N
	Nov	7026	25589	7040 N
	Dec	7056	12563	
1933	Jan	7087	12962	
	Feb	7118	11077	
	Mar	7146	15648	
	Apr	7177	40420	
	May	7207	12898	7202 F
	Jun	7238	05189	7232 F
	Jul	7268	03946	7261 F
	Aug	7299	05840	
	Sep	7330	07675	
	Oct	7360	05819	
	Nov	7391	07068	
	Dec	7421	09695	7423 N
1934	Jan	7452	12417	7453 N
	Feb	7483	06132	
	Mar	7511	19129	
	Apr	7542	33232	

Year	Month	JD (mid month)	Discharge (HR at Gr. Is.) (cu.ft./sec; av. of daily values for month)	
	May	7572	09345	
	Jun	7603	06675	7615 F
	Jul	7633	04124	7645 F
	Aug	7664	03919	7674 F
	Sep	7695	04162	
	Oct	7725	04672	
	Nov	7756	07247	
	Dec	7786	09150	
1935	Jan	7817	18525	
	Feb	7848	10686	7837 N
	Mar	7876	22772	7867 N
	Apr	7907	18661	
	May	7937	16947	
	Jun	7968	08478	
	Jul	7998	22032	
	Aug	8029	07737	8029 F
	Sep	8060	06484	8058 F
	Oct	8090	06468	
	Nov	8121	17045	
	Dec	8151	13962	
1936	Jan	8182	09066	
	Feb	8213	05996	
	Mar	8242	55305	8251 N
	Apr	8273	31742	8280 N
	May	8303	13720	
	Jun	8334	05118	
	Jul	8364	03871	
	Aug	8395	03739	
	Sep	8426	04546	8442 F
	Oct	8456	09253	8472 F
	Nov	8487	14968	
	Dec	8517	14386	
1937	Jan	8548	26756	
	Feb	8579	15400	
	Mar	8607	10841	
	Apr	8638	27949	
	May	8668	23278	8664 N
	Jun	8699	11239	8693 N
	Jul	8729	08035	
	Aug	8760	07416	
	Sep	8891	06517	
	Oct	8821	08479	
	Nov	8852	12963	8856 F
	Dec	8882	12508	8885 F
1938	Jan	8913	13259	
	Feb	8944	21900	
	Mar	8972	22311	
	Apr	9003	17851	
	May	9033	09450	
	Jun	9064	05135	9077 N
	Jul	9094	06194	9107 N
	Aug	9125	06420	
	Sep	9156	21205	
	Oct	9186	08682	
	Nov	9217	09234	
	Dec	9247	23479	
1939	Jan	9278	09532	9269 F
	Feb	9309	13831	9299 F
	Mar	9337	22473	
	Apr	9368	37747	
	May	9398	14455	
	Jun	9429	06682	
	Jul	9459	04534	
	Aug	9490	04164	9491 N
	Sep	9521	03930	9520 N
	Oct	9551	03997	
	Nov	9582	06822	
	Dec	9612	06676	
1940	Jan	9643	04368	
	Feb	9674	04178	9683 F
	Mar	9703	08346	9712 F
	Apr	9734	51799	
	May	9764	23414	
	Jun	9795	12614	
	Jul	9825	09419	
	Aug	9856	05199	
	Sep	9887	06578	
	Oct	9917	05515	9904 N
	Nov	9948	10786	9934 N
	Dec	9978	18449	
1941	Jan	243 0010	14198	
	Feb	0041	11225	
	Mar	0067	10250	
	Apr	0098	23136	243 0096 F
	May	0128	04719	0216 F
	Jun	0159	03354	
	Jul	0189	02817	
	Aug	0220	02403	
	Sep	0251	03931	
	Oct	0281	05083	0288 N
	Nov	0312	07825	0317 N
	Dec	0343	09352	0347 N
1942	Jan	0374	08843	
	Feb	0405	05854	
	Mar	0433	21815	
	Apr	0464	23181	
	May	0494	10802	0510 F
	Jun	0525	12810	0539 F
	Jul	0555	05597	
	Aug	0586	05270	
	Sep	0617	08073	
	Oct	0647	11887	
	Nov	0678	16056	
	Dec	0708	17233	0701 N
1943	Jan	0739	15050	0731 N
	Feb	0770	15299	0760 N
	Mar	0798	32211	
	Apr	0829	24573	
	May	0859	39983	
	Jun	0890	14324	
	Jul	0920	07397	0923 F
	Aug	0952	09108	0952 F
	Sep	0983	05794	
	Oct	1013	06565	
	Nov	1044	12754	
	Dec	1074	09244	
1944	Jan	1105	05397	1115 N
	Feb	1136	06226	1144 N
	Mar	1165	28128	
	Apr	1196	31659	
	May	1226	15355	
	Jun	1257	11783	
	Jul	1287	06219	
	Aug	1318	04464	
	Sep	1349	05865	1336 F
	Oct	1379	07437	1366 F
	Nov	1410	07888	
	Dec	1440	08475	
1945	Jan	1471	10490	
	Feb	1502	09868	
	Mar	1530	41645	1528 N
	Apr	1561	21289	1558 N
	May	1591	29810	
	Jun	1622	14394	
	Jul	1652	11353	
	Aug	1683	07326	
	Sep	1714	11010	
	Oct	1744	25782	1750 F
	Nov	1775	22757	1779 F
	Dec	1805	15418	
1946	Jan	1836	15204	
	Feb	1867	10079	
	Mar	1895	32270	
	Apr	1926	10640	
	May	1956	18280	1942 N
	Jun	1987	15820	1971 N
	Jul	2017	06334	
	Aug	2047	05684	
	Sep	2078	04883	
	Oct	2108	07497	
	Nov	2139	07747	
	Dec	2169	090[illegible]	2163 F
1947	Jan	2200	15143	2193 F
	Feb	2231	15802	
	Mar	2259	21100	
	Apr	2290	34448	
	May	2320	35724	
	Jun	2351	26650	2355 N
	Jul	2381	12522	2385 N
	Aug	2412	07475	
	Sep	2443	05148	
	Oct	2473	04780	
	Nov	2504	07302	
	Dec	2534	07752	
1948	Jan	2565	05902	2577 F
	Feb	2596	10637	2606 F
	Mar	2625	36276	
	Apr	2656	25948	
	May	2686	19698	
	Jun	2717	12312	
	Jul	2747	07176	
	Aug	2778	05956	2769 N
	Sep	2809	03891	2798 N
	Oct	2839	04307	
	Nov	2870	08757	
	Dec	2900	14002	
1949	Jan	2931	33938	
	Feb	2962	21966	
	Mar	2991	19016	2990 F
	Apr	3022	17325	3020 F
	May	3052	10038	
	Jun	3083	04686	
	Jul	3113	03673	
	Aug	3144	03957	
	Sep	3175	05219	3182 N
	Oct	3205	05755	3212 N
	Nov	3236	08620	
	Dec	3266	14817	
1950	Jan	3297	23363	
	Feb	3328	13619	
	Mar	3356	22146	
	Apr	3387	30219	3374 F
	May	3417	14296	3404 F
	Jun	3448	08107	
	Jul	3478	05029	
	Aug	3509	05217	

Year	Month	JD (mid month)	Discharge (HR at Gr. Is.) (cu.ft./sec; av. of daily values for month)	
	Sep	3540	09616	
	Oct	3570	05635	
	Nov	3601	11311	3595 N
	Dec	3631	19946	3625 N
1951	Jan	3662	16390	
	Feb	3693	23922	
	Mar	3721	23223	
	Apr	3752	40454	
	May	3782	11233	3783 F
	Jun	3813	07536	3817 F
	Jul	3843	13512	3847 F
	Aug	3874	08579	
	Sep	3905	08223	
	Oct	3935	10194	
	Nov	3966	20643	
	Dec	3996	20340	4009 N
1952	Jan	4027	24983	4038 N
	Feb	4058	17882	
	Mar	4087	20982	
	Apr	4118	41468	
	May	4148	21990	
	Jun	4179	14429	
	Jul	4209	07166	4201 F
	Aug	4240	05366	4230 F
	Sep	4271	05168	4260 F
	Oct	4301	04530	
	Nov	4332	04879	
	Dec	4362	14946	
1953	Jan	4393	15420	
	Feb	4424	18338	4422 N
	Mar	4452	30290	4452 N
	Apr	4482	28553	
	May	4512	33039	
	Jun	4543	06146	
	Jul	4573	04131	
	Aug	4604	04994	4614 F
	Sep	4635	04347	4644 F
	Oct	4665	04708	4673 F
	Nov	4696	05121	
	Dec	4726	12393	
1954	Jan	4757	09634	
	Feb	4788	21754	
	Mar	4816	18514	
	Apr	4847	31722	4836 N
	May	4877	25689	4865 N
	Jun	4908	14343	
	Jul	4938	04972	
	Aug	4969	04350	
	Sep	5000	06413	
	Oct	5030	05012	5028 F
	Nov	5061	14517	5057 F
	Dec	5092	16884	
1955	Jan	5123	11416	
	Feb	5154	11948	
	Mar	5182	27075	
	Apr	5213	38093	
	May	5243	09721	5249 N
	Jun	5274	08332	5279 N
	Jul	5304	04530	
	Aug	5335	06456	
	Sep	5366	04949	
	Oct	5396	19970	
	Nov	5427	21311	5441 F
	Dec	5457	11856	5471 F
1956	Jan	5488	09976	
	Feb	5519	08409	
	Mar	5548	18642	
	Apr	5579	43510	
	May	5609	23534	
	Jun	5640	13153	
	Jul	5670	06287	5662 N
	Aug	5701	04769	5692 N
	Sep	5732	08002	
	Oct	5762	07084	
	Nov	5793	08446	
	Dec	5823	15006	
1957	Jan	5854	12336	5855 F
	Feb	5885	11386	5884 F
	Mar	5913	15586	
	Apr	5944	15746	
	May	5974	10066	
	Jun	6005	05377	
	Jul	6035	06265	
	Aug	6066	04939	6076 N
	Sep	6097	04010	6106 N
	Oct	6127	04718	
	Nov	6158	06868	
	Dec	6188	18601	
1958	Jan	6219	13631	
	Feb	6250	10371	
	Mar	6278	18691	6268 F
	Apr	6309	37891	6297 F
	May	6339	15801	
	Jun	6370	09348	
	Jul	6400	05653	
	Aug	6431	05345	
	Sep	6462	06550	
	Oct	6492	09693	6490 N

Year	Month	JD (mid month)	Discharge (HR at Gr. Is.) (cu.ft./sec; av. of daily values for month)	
	Nov	6523	12077	6519 N
	Dec	6553	09514	
1959	Jan	6584	13407	
	Feb	6615	12257	
	Mar	6643	19277	
	Apr	6674	35867	6681 F
	May	6704	11967	6711 F
	Jun	6735	06283	
	Jul	6765	04262	
	Aug	6796	03819	
	Sep	6827	04013	
	Oct	6857	09817	
	Nov	6888	22891	6903 N
	Dec	6918	26561	6932 N
1960	Jan	6949	16701	
	Feb	6980	16621	
	Mar	7009	12671	
	Apr	7040	51621	
	May	7070	14341	
	Jun	7101	10621	7095 F
	Jul	7131	06552	7124 F
	Aug	7162	05888	
	Sep	7193	11011	
	Oct	7223	06734	
	Nov	7254	07619	
	Dec	7284	06969	7287 N
1961	Jan	7315	04205	7316 N
	Feb	7346	13058	
	Mar	7374	19548	
	Apr	7405	23218	
	May	7435	17438	
	Jun	7466	13148	
	Jul	7496	07578	7508 F
	Aug	7527	06207	7538 F
	Sep	7558	05739	
	Oct	7588	04556	
	Nov	7619	06721	
	Dec	7649	08105	
1962	Jan	7680	10295	
	Feb	7711	07383	7700 N
	Mar	7739	17265	7730 N
	Apr	7770	34805	7759 N
	May	7800	14775	
	Jun	7831	04824	
	Jul	7861	03410	
	Aug	7892	04748	
	Sep	7923	03844	7922 F
	Oct	7953	06483	7951 F
	Nov	7984	09310	
	Dec	8014	09830	
1963	Jan	8045	06867	
	Feb	8076	06274	
	Mar	8104	18795	8114 N
	Apr	8135	31365	8143 N
	May	8165	14835	8173 N
	Jun	8196	06093	
	Jul	8226	03936	
	Aug	8257	04616	
	Sep	8288	03739	
	Oct	8318	03645	
	Nov	8349	05517	8335 F
	Dec	8379	07285	8365 F
1964	Jan	8410	09618	
	Feb	8441	07343	
	Mar	8470	26965	
	Apr	8501	25765	
	May	8531	09446	8527 N
	Jun	8562	03834	8557 N
	Jul	8592	03146	
	Aug	8623	03313	
	Sep	8654	02890	
	Oct	8684	02982	
	Nov	8715	03285	
	Dec	8745	06111	8749 F
1965	Jan	8776	05329	8778 F
	Feb	8807	09123	
	Mar	8835	09138	
	Apr	8866	19295	
	May	8896	08324	
	Jun	8927	03588	8940 N
	Jul	8957	03097	8970 N
	Aug	8988	02927	9000 N
	Sep	9019	04024	
	Oct	9049	07318	
	Nov	9080	18695	
	Dec	9110	10665	
1966	Jan	9141	08145	
	Feb	9172	11645	9162 F
	Mar	9200	23105	9192 F
	Apr	9231	15645	
	May	9261	18425	
	Jun	9292	08285	
	Jul	9322	03689	
	Aug	9353	04248	9354 N
	Sep	9384	05645	9383 N
	Oct	9414	05862	
	Nov	9445	07057	
	Dec	9475	09133	

11.2850

Year	Month	JD (mid month)	Discharge (HR at Gr. Is.) (cu.ft./sec; av. of daily values for month)	
1967	Jan	9506	09631	
	Feb	9537	07648	
	Mar	9565	11375	9575 F
	Apr	9596	30955	9605 F
	May	9626	17095	
	Jun	9657	06212	
	Jul	9687	05090	
	Aug	9718	05764	
	Sep	9749	04949	
	Oct	9779	06988	9767 N
	Nov	9810	11755	9797 N
	Dec	9840	16525	
1968	Jan	9871	08882	
	Feb	9902	09528	
	Mar	9931	24875	
	Apr	9962	18315	
	May	9992	18505	9989 F
	Jun	244 0023	15725	244 0018 F
	Jul	0053	09810	
	Aug	0084	04455	
	Sep	0115	04478	
	Oct	0145	05173	
	Nov	0176	14400	0181 N
	Dec	0206	15600	0210 N
1969	Jan	0237	11680	
	Feb	0268	12760	
	Mar	0296	17470	
	Apr	0327	40730	
	May	0357	20910	
	Jun	0388	09995	0402 F
	Jul	0418	05430	0432 F
	Aug	0448	06102	
	Sep	0479	04133	
	Oct	0509	04856	
	Nov	0540	14270	
	Dec	0570	11800	
1970	Jan	0601	08206	0594 N
	Feb	0632	15340	0624 N
	Mar	0660	15060	
	Apr	0691	39350	
	May	0721	14550	
	Jun	0752	06404	
	Jul	0782	05997	
	Aug	0813	03923	0816 F
	Sep	0845	06165	0845 F
	Oct	0875	08186	
	Nov	0906	09333	
	Dec	0936	11390	
1971	Jan	0967	09002	
	Feb	0998	12110	1008 N
	Mar	1026	20220	1037 N
	Apr	1057	37270	
	May	1087	35240	
	Jun	1118	07334	
	Jul	1148	06233	
	Aug	1179	08929	
	Sep	1210	09315	
	Oct	1240	07811	1229 F
	Nov	1271	07291	1259 F
	Dec	1301	17000	
1972	Jan	1332	13410	
	Feb	1363	10930	
	Mar	1392	26860	
	Apr	1423	37960	1421 N
	May	1453	40520	1451 N
	Jun	1484	29630	
	Jul	1514	18380	
	Aug	1545	07616	
	Sep	1576	06309	
	Oct	1606	07291	1613 F
	Nov	1637	26150	1643 F
	Dec	1667	27010	1672 F
1973	Jan	1698	26210	
	Feb	1729	20460	
	Mar	1757	29410	
	Apr	1788	30960	
	May	1818	27600	
	Jun	1849	13050	1834 N
	Jul	1879	10390	1864 N
	Aug	1910	05591	
	Sep	1941	04791	
	Oct	1971	05650	
	Nov	2002	08280	
	Dec	2032	26320	2027 F
1974	Jan	2063	22010	2056 F
	Feb	2094	18640	2085 F
	Mar	2122	20730	
	Apr	2153	30170	
	May	2183	22960	
	Jun	2214	08791	
	Jul	2244	11780	2248 N
	Aug	2275	06359	2277 N
	Sep	2306	10390	
	Oct	2336	09053	
	Nov	2367	17069	
	Dec	2397	19305	
1975	Jan	2428	25997	2440 F
	Feb	2459	19399	2469 F
	Mar	2487	23649	
	Apr	2518	25527	
	May	2548	20098	
	Jun	2579	12964	
	Jul	2609	07376	
	Aug	2640	08791	
	Sep	2671	16980	2661 N
	Oct	2701	23400	2691 N
	Nov	2732	22500	
	Dec	2762	18780	
1976	Jan	2793	14740	
	Feb	2824	31260	
	Mar	2853	31690	2853 F
	Apr	2884	36760	2883 F
	May	2914	31800	
	Jun	2945	15220	
	Jul	2975	15280	
	Aug	3006	14630	
	Sep	3037	09573	
	Oct	3067	23230	3075 N
	Nov	3098	17930	3104 N
	Dec	3128	14080	
1977	Jan	3159	07956	
	Feb	3190	08032	
	Mar	3218	43540	
	Apr	3249	49560	
	May	3279	16020	3267 F
	Jun	3310	07325	3296 F
	Jul	3340	05735	
	Aug	3371	05439	
	Sep	3402	14410	
	Oct	3432	30140	
	Nov	3463	23440	
	Dec	3493	26480	3488 N
1978	Jan	3524	26310	3518 N
	Feb	3555	14120	
	Mar	3583	21870	
	Apr	3614	33560	
	May	3644	18730	
	Jun	3675	09954	3680 F
	Jul	3705	04643	3710 F
	Aug	3736	05976	
	Sep	3767	06195	
	Oct	3797	08608	
	Nov	3828	08020	
	Dec	3858	10700	
1979	Jan	3889	20160	3902 N
	Feb	3920	11850	3931 N
	Mar	3948	44240	
	Apr	3979	38120	
	May	4009	19570	
	Jun	4040	08318	
	Jul	4070	04644	
	Aug	4101	05248	4094 F
	Sep	4132	07800	4123 F
	Oct	4162	11080	
	Nov	4193	16420	
	Dec	4223	15190	
1980	Jan	4254	09044	
	Feb	4285	04527	4286 N
	Mar	4314	22380	4315 N
	Apr	4345	26430	4345 N
	May	4375	09676	
	Jun	4406	06796	
	Jul	4436	05080	
	Aug	4467	04596	
	Sep	4498	04170	4507 F
	Oct	4528	05586	4537 F
	Nov	4559	08542	
	Dec	4589	09632	
1981	Jan	4620	05239	
	Feb	4651	30060	
	Mar	4679	12340	
	Apr	4710	13580	4699 N
	May	4740	11580	4728 N
	Jun	4771	05973	4758 N
	Jul	4801	04943	
	Aug	4832	04717	
	Sep	4863	08224	
	Oct	4893	16120	
	Nov	4924	13950	4920 F
	Dec	4954	11350	4950 F
1982	Jan	4985	11330	
	Feb	5016	12750	
	Mar	5044	21890	
	Apr	5075	38300	
	May	5105	12510	5112 N
	Jun	5136	15240	5142 N
	Jul	5166	06421	5171 N
	Aug	5197	04396	
	Sep	5228	04310	
	Oct	5258	04394	
	Nov	5289	06926	
	Dec	5319	08244	5334 F
1983	Jan	5350	09154	5363 F
	Feb	5381	12440	
	Mar	5409	20500	
	Apr	5440	37540	

Year	Month	JD (mid month)	Discharge (HR at Gr. Is.) (cu.ft./sec; av. of daily values for month)	
	May	4740	11580	4728 N
	May	5470	36620	
	Jun	5501	12640	
	Jul	5531	04480	5526 N
	Aug	5562	05477	5555 N
	Sep	5593	04685	5585 N
	Oct	5623	05432	
	Nov	5654	11970	
	Dec	5684	28220	
1984	Jan	5715	10880	
	Feb	5746	26190	5747 F
	Mar	5775	16430	5777 F
	Apr	5806	33180	
	May	5836	29810	
	Jun	5867	14750	
	Jul	5897	10200	
	Aug	5928	06226	5939 N
	Sep	5959	06695	5969 N
	Oct	5989	06393	5998 N
	Nov	6020	09779	
	Dec	6050	15810	
1985	Jan	6081	15530	
	Feb	6112	11260	
	Mar	6140	20520	
	Apr	6171	16110	6161 F
	May	6201	08206	6190 F
	Jun	6232	05530	
	Jul	6262	04696	
	Aug	6293	03657	
	Sep	6324	06033	
	Oct	6354	07181	6353 N
	Nov	6385	14800	6382 N
	Dec	6415	11650	6412 N
1986	Jan	6446	10860	
	Feb	6477	12660	
	Mar	6505	35710	
	Apr	6536	24110	
	May	6566	12070	6574 F
	Jun	6597	14260	6604 F
	Jul	6627	08037	
	Aug	6658	10840	
	Sep	6689	07698	
	Oct	6719	11890	
	Nov	6750	19230	
	Dec	6780	18510	6766 N
1987	Jan	6811	09274	6796 N
	Feb	6842	07104	
	Mar	6870	21380	
	Apr	6901	34710	
	May	6931	05505	
	Jun	6962	06170	

Year	Month	JD (mid month)	Discharge (HR at Gr. Is.) (cu.ft./sec; av. of daily values for month)	
	Jul	6992	05728	6988 F
	Aug	7023	04178	7017 F
	Sep	7054	12040	
	Oct	7084	17860	
	Nov	7115	16050	
	Dec	7145	15710	
1988	Jan	7176	09468	7180 N
	Feb	7207	12340	7209 N
	Mar	7236	16280	
	Apr	7267	16830	
	May	7297	12620	
	Jun	7328	04340	
	Jul	7358	04627	
	Aug	7389	04910	7401 F
	Sep	7420	05779	7431 F
	Oct	7450		
	Nov	7481		
	Dec	7511		
1989	Jan	7542		
	Feb	7573		
	Mar	7601		7593 N
	Apr	7632		7622 N
	May	7662		
	Jun	7693		
	Jul	7723		
	Aug	7754		
	Sep	7785		
	Oct	7815		7814 F
	Nov	7846		7844 F
	Dec	7876		
1990	Jan	7907		
	Feb	7938		
	Mar	7966		
	Apr	7997		8006 N
	May	8027		8036 N
	Jun	8058		
	Jul	8088		
	Aug	8119		
	Sep	8150		
	Oct	8180		
	Nov	8211		
	Dec	8241		8228 F
				8257 F

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EUSTASY, NOT EUSTACY

David C. Kopaska-Merkel
Northeastern Science Foundation
affiliated with Brooklyn College
of the City University of New York
PO Box 746, Troy NY 12181-0746

On the occasion of my reading the new Special Publication of the Society of Economic Paleontologists and Mineralogists on the subject of Sequence Stratigraphy (Wilgus and others, 1988) I became curious about two alternate spellings of a word which appears on nearly every page of the book. The word lies at the heart of sequence stratigraphy; it refers to absolute sea-level change. Of the 23 papers in the book, 12 use *eustasy*, 2 use *eustacy*, 8 avoid using the term at all, and one uses both forms.

What, I wondered, is the correct spelling of this term, which has been bandied about with such freedom in the geological literature of the past decade? In the absence of a consensus, one might follow the most recent authority: the AGI Glossary of Geology (3rd edition, 1987) spells it *eustasy*. The first edition of the same reference (1972) used the letter *c*. Most ordinary dictionaries only list *eustatic*, and thus avoid the *s* vs *c* question. The more up-to-date spelling is thus *eustasy*. Because the majority of authors in Wilgus and others (1988) agree with the 3rd edition of the AGI Glossary, the weight of numbers, as well as the force of modernity, appears to be on the side of *eustasy*.

However, one need not rely on majority rule or most-recent authority. The rule of priority may also be consulted. Eustasy comes from the same root as does isostasy, which is always spelled with three *s's* (AGI Glossary of Geology, 1957, 1972, 1987; Webster's New Collegiate Dictionary, 1974; and numerous other sources). The Greek root is *stasia*, which means "condition of standing", and this is also spelled with an *s*.

Thus, on multiple lines of evidence (weight of numbers, most-recent glossary citation, comparison with the cognate isostasy, and comparison with the Greek root) *eustasy* is shown to be the correct spelling. Stratigraphers take heed!

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BOOK REVIEWS

David C. Kopaska-Merkel, Book Review Editor

SEA-LEVEL CHANGES

Sea-level changes: an integrated approach, Cheryl K. Wilgus, Bruce S. Hastings, Christopher G. St. C. Kendall, Henry W. Posamentier, Charles A. Ross, and John C. Van Wagoner, eds.: Society of Economic Paleontologists and Mineralogists Special Publication No. 42, 1988, 407 pp, including 14-pg index, ISBN 0-918985-74-9, hardbound. $54 to SEPM members, $64 to nonmembers.

Sea-level changes: an integrated approach is essentially a successor volume to the epochal AAPG Memoir 26 on seismic stratigraphy. Many of the players are the same, but some new faces have been added, and a number of inconsistencies or unanswered questions have been dealt with. The discipline has undergone considerable evolution since 1977; the name has changed from *seismic stratigraphy* to *sequence stratigraphy*, which reflects a broadened data base that now includes a great variety of sedimentologic, stratigraphic, paleontologic, geochemical, and seismic approaches. In addition, the overall level of writing, quality of illustrations, and clarity of thought is far superior in the present work. The new volume is also, in a sense, a companion to SEPM Special Publication #41, **Sea-level fluctuation and coastal evolution**, which was published in 1987 (reviewed in *Northeastern Environmental Science* volume 6, number 2). However, this earlier work lies squarely in the area of modern coastal studies, and is only loosely tied to the essentially stratigraphic models of depositional sequences and their control by relative sea-level change, which are the subject of Spec. Publ. 42.

Sea-level changes: an integrated approach constitutes the proceedings of a 4-day conference which was held in 1985. Publication was considerably delayed (which may account for the high production- and editing quality evident in the printed result) but in this field, a 4-year delay is by no means catastrophic. The title of the volume is well-chosen; the bulk of the book does indeed constitute an integrated approach to the analysis of sea-level changes.

The book is divided into four parts, which are of unequal length and importance. Parts 1, 2, and 4 are devoted to conceptual studies, whereas Part 3 is descriptive in nature. Part 1, *Analysis of sea-level changes*, comprises three papers which investigate different aspects of the data upon which sequence analysis depends. The first paper is the most general. In it, Christopher G. St. C. Kendall and Ian Lerche cogently discuss the assumptions that underlie the methodologies of sequence stratigraphy, and endeavor to instill in the reader a healthy skepticism with which to approach the more partisan papers comprising the bulk of the volume. Sierd Cloetingh presents an intriguing analysis of the potential control of third-order sea-level cycles by intraplate tectonic stresses. This subject has received less attention than it deserves. Douglas F. Williams concludes Part 1 with a review of the application of stable isotopic data to stratigraphic analysis. Williams infers that the oxygen-isotope record is in general agreement with (and therefore supports the eustatic control of) published coastal onlap curves. However, there seems to be no reason to believe that the isotopic record is any more accurate than the onlap curves.

In Part 2, *Sea-level changes and sequence stratigraphy*, seven papers, all written by the Exxon group, present the updated version of the theory of sequence stratigraphy and its control by eustatic sea-level change. This is the theoretical meat of the book and it can be slow going. The concepts are complex, and the authors of most of these papers are afflicted with a tendency toward occasional imprecise use of their own technical terminology. Nevertheless, by dint of perseverance and much flipping back and forth, I was able to absorb a modern synthesis which is far more sophisticated than that presented in AAPG Memoir 26. The first two papers in Part 2 cover the fundamentals of the method, definitions of terms, and the new concept of accommodation. Accommodation concerns the availability of space below base level in which sediment may be deposited, as well as the changing distributions and amounts of accommodation with changes in relative and absolute sea level. Different kinds of sequences and sequence boundaries, the depositional-system tracts which make up sequences, and which are themselves composed of smaller scale parasequences, are also described and their implications explored.

A new geologic time scale is presented in the next paper (by Haq and others). A major source of error in the development of any time scale is the construction of biochronozones from stacked biozones on which inter-regional correlation is largely based. The problems with this method, extensively discussed in the biostratigraphic literature, are barely mentioned by Haq and others. The fundamental problem is the identification of synchronous boundaries for stacked biozones so that they can be converted to biochronozones, which have time-parallel boundaries and can be used for global correlation. There is no way to do this accurately, although there are ways to assess the amount of error involved in this procedure. Error can be reduced as the database is expanded, but it can never be eliminated.

The differences between clastic and carbonate depositional systems are also investigated at length in a series of three papers in Part 2. The first two papers are long and involved, but cover the subject for clastic depositional systems admirably. The paper on carbonate systems, by J.F. Sarg, is an excellent contribution to the subject, but presents some difficulties. First, Sarg defines the sequence-boundary types differently than do the authors of the two papers on clastic depositional systems. Specifically, for clastic systems, the depositional shoreline break is used to distinguish type 1 and type 2 sequence boundaries (which differ in the extent of associated subaerial erosion), whereas Sarg uses the platform- or bank margin for this purpose. This idea has merit, because clastic and carbonate systems differ in the nature of sediment generation and the location of the major source of sediment. The datums are directly related to the locations of primary sediment sources (from the shoreline for clastics, but from the shelf margin for carbonates) and from this perspective the use of two different datums for the two kinds of systems is justified. However, the use of different datums for clastic and carbonate systems will undoubtedly lead to considerable confusion and misuse of terms.

Second, Sarg totally neglects one of the major controls on carbonate deposition: the influence of biologic factors. These are not simply a function of climate, a factor considered explicitly by Sarg, because they are also affected by (1) geologic age, due to the non-reversability and broadly progressive nature of biotic evolution; (2) the input of terrigenous sediment, which affects the growth of sediment-producing organisms; and (3) the effects on organismal growth of upwelling and currents. Biotic factors are especially important to carbonate buildups, which dominated low- and middle-latitude shelves, especially shelf margins, for much of the late Proterozoic and Phanerozoic (Fagerstrom, 1987).

The last paper in Part 2 concerns condensed sequences, ch have a particular significance for the correlation of open- an microfossil zonations to the physical stratigraphy of conti- tal shelves.

glaring omission from this Part is the complete ier. of any mention of PACs (punctuated aggradational les). PACs are roughly comparable to parasequences, but PACs defined by Anderson and Goodwin in the Devonian of v York (e.g., Goodwin and Anderson, 1985) do not corre- ond on a one-to-one basis with parasequences defined at the ne sections by other workers (G.M. Friedman, unpubl. obser- ions). It would have been extremely useful to see a careful nparison of these two approaches to unconformity-bounded atigraphy (both inextricably linked to the concept of relative -level change) in this "integrated" volume.

Part 2 contains abundant colored figures, mostly draw- is, which are very ... colorful. The use of color greatly en- nces the ease of interpretation of some of the figures, but in iny cases the color is superfluous. It appears that a certain dget was available for the printing of color illustrations, and the thors were going to use every penny, By God!

Part 3 comprises 10 examples of applications of se- ence stratigraphy to sedimentary rocks ranging in age from ddle Ordovician to Tertiary. These studies exhibit a conspicu- s lack of any analysis of sources of error or of validity of thods. For example, Cisne and Gildner, in their study of ddle Ordovician epeiric sediments, cannot distinguish between bal and large-scale regional sea-level changes, but make no ention of this fact. Ross and Ross present an elegant global atigraphic study of late Paleozoic sediments. However, they p this analysis with the absurd suggestion that because the sil record is rendered incomplete by the occurrence of numer- s unconformities, geologists may be led astray and may misin- pret the record as demonstrating punctuated evolution with a ghly irregular mutation rate. This may be so, but such a mis- ke d only be made by scientists completely uninformed of undamentals of evolutionary theory, and especially the incip of the punctuated-equilibria/gradualism controversy, carefully enunciated by Eldredge, Gould, and many others er the last decade. A perusal of Ross and Ross' paper reveals that they cite none of the evolutionary literature, and in fact, do not even mention evolution outside of the abstract and conclu- sions.

The last part, Part 4, concerns *Application concepts of sea-level change*, and comprises three papers which address different refinements of the sequence-stratigraphic method. A.G. Plint discusses the significance of sharp-based shoreface se- quences and "offshore bars" in the Cardium Formation of Alberta; Timothy A. Cross uses the model of sedimentological control by sea-level change and the concept of accommodation to explain the distribution of coals; and V. Kolla and D.B. Macurda, Jr. inves- tigate the implications of sea-level change, tectonic setting, sediment grain size, and basin size and gradients for timing and distribution of turbidity currents in deep-sea fan systems.

Would I buy this book? Unquestionably yes. The price is right (SEPM publications are always a bargain) and the contents list is both diverse and comprehensive. Despite some problems noted in this review, most of the papers included here stand out as important contributions to a young and evolving field. A plethora of color figures delight the eye, even though nearly half of them would be as useful in black and white (and they would photocopy better). Most of the photographs and seismic lines are of top quality, and all authors have resisted the temptation to mark up seismic lines with a broad-tipped pen. Whether you think you already understand sequence stratigraphy, or if the whole subject is a complete mystery, this book is for you.

Fagerstrom, J.A., 1987, The evolution of reef communities. New York, John Wiley & Sons, 600 p.

Goodwin, P.W. and Anderson, E.J., 1985, Punctuated aggrada- tional cycles: a general hypothesis of episodic stratigraphic accumulation: Jour. Geology, v. 93, p. 515-533.

David C. Kopaska-Merkel
Research Scientist
Northeastern Science Foundation
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