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HUDSON RIVER PCBs REASSESSMENT RI/FS
RESPONSIVENESS SUMMARY FOR
VOLUME 2A: DATABASE REPORT
VOLUME 2B: PRELIMINARY MODEL CALIBRATION REPORT
VOLUME 2C: DATA EVALUATION AND INTERPRETATION REPORT

DECEMBER 1998

For

U.S. Environmental Protection Agency
Region II
and
U.S. Army Corps of Engineers
Kansas City District

Book 2 of 3

TAMS Consultants, Inc.
Limno-Tech, Inc.
TetraTech, Inc.
Menzie-Cura & Associates, Inc.

HUDSON RIVER PCBs REASSESSMENT RI/FS
RESPONSIVENESS SUMMARY FOR
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VOLUME 2C: DATA EVALUATION AND INTERPRETATION REPORT
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Comments

DB-1

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Hudson River Project
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Phone: 458-6619; FAX 458-1014

VIA OVERNIGHT MAIL

May 29, 1996

Douglas J. Tomchuk
Hudson River Remedial Project Manager
290 Broadway
20th Floor
New York, New York 10007-1866

RE: COMMENTS ON THE U.S. EPA HUDSON RIVER DATABASE

With your letter of April 18, 1996 you transmitted to GE copies of the CD-ROM containing the data compiled by the U.S. EPA for the Hudson River Reassessment RI/FS (RRI/FS) project. You requested comments on the database by May 29, 1996.

The database clearly represents a significant effort to compile analytical data from the Hudson River. The database appears to capture the majority of the data that GE is aware of. However, a number of large data sets have not been included. Attachment 1 is a listing of data sets that should be included in the database since they are relevant to the Hudson River RRI/FS. The major omission in the database is for information from the lower river. During the March 17, 1998 presentation by GE to the EPA project team and my subsequent letter to you dated March 30, 1998 we identified the data sets generated by GE on the Hudson river, including those GE data sets listed in Attachment 1. This data should have been provided to you in electronic or hard copy form. However, if you find you do not have this data in your files we will be glad to make it available to you (1)

In addition to adding the important historical data sets to the database, GE encourages EPA to update and distribute the database as new information becomes available. As you are aware, GE is collecting water samples on a weekly basis for PCB analysis. Additionally, the New York DEC obtains PCB levels in fish on a yearly basis in the entire Hudson river. This fish and water data collected over the next few years will be crucial to understanding the recovery rate in the river that will occur in the future as a result of the declining impact of the elevated loading from the Allen Mill in 1991 and 1992 as well as from the further anticipated reductions in PCB loading from ground water in the vicinity of Baker Falls. GE believes that this data will be critical to the calibration and validation of the EPA PCB model of the Hudson River. (2)

Even if the EPA chooses not to update the database with the information described in the Attachment 1 and the data yet to be collected. GE requests that all of these data be considered in the Hudson River RRI/FS and be placed into the site Administrative Record as it is made available to the agency. 3

If you have any questions or disagree with the recommendations please let me know.

Yours truly,

John G. Haggard

attachment

cc: Walter Demick, NYDEC
Anders Carlson, NYDOH
Ron Sloan, NYDEC
Paul Simon, U. S. EPA

ATTACHMENT
DATA SETS MISSING FROM THE U.S.EPA HUDSON RIVER DATABASE
MAY23, 1995

LOCATION/ PROGRAM	ORIGIN	MEDIA	PARAMETER	CURRENT FORM
Lower River, New York Harbor, Long Island Sound	GE/Harza 1988-1991	sediment, biota	PCB, pest, lipid,	dBase IV files
TIP TSS Survey	GE/OBG 1991	water	TSS	report, dBase IV files
Polygon (8)	GE/OBG 1990	sediment	PCB	dBase IV
EPA Lower River Helicopter Survey	EPA, 1976	sediment	PCB	EPA report
EPA Lower River Survey	EPA, 1981	sediment	PCB	EPA report
NYU Lower River Biota	NYU, pre-1982	biota	PCB	NYU Report

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U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Ocean Service
Office of Ocean Resources Conservation and Assessment
Hazardous Materials Response and Assessment Division
Coastal Resources Coordination Branch
Room 3137-C
26 Federal Plaza
New York, New York 10278

December 3, 1996

Doug Tomchuk
U.S. EPA
Emergency and Remedial Response Division
Special Projects Branch
NYSCB1
290 Broadway
New York, NY 10007

Dear Doug:

Thank you for the opportunity to review the Phase 2 Further Site Characterization and Analysis Preliminary Model Calibration Report (Volume 2B) for the Hudson River PCB Reassessment Remedial Investigation/Feasibility Study (RI/FS). The following comments are submitted by the National Oceanic and Atmospheric Administration (NOAA).

The Phase 2 Preliminary Model Calibration Report was prepared as part of the overall Phase 2 Reassessment RI/FS activities currently ongoing to provide further characterization and analysis of the Hudson River PCB Site which extends from Hudson Falls, NY to the Battery in New York Harbor. The Preliminary Model Calibration Report provides a description of these PCB modeling efforts and preliminary results from calibrations of the mathematical models to available field data.

The modeling work proposed is designed to answer three questions: 1) When will PCB levels in fish recover to acceptable human health and ecological risk levels under the current no action status of the site? 2) Can remedial activities in the Hudson River shorten this recovery period? 3) Will contaminated sediments currently buried become "reactivated" following a major flood and result in increased contamination to fish? The stated goal of the proposed modeling activities is to develop and field validate mass balance models for evaluating and comparing the impacts of continued no action, various remedial scenarios and hydrometrical events in terms of PCB concentrations in the water column, sediment and fish. The approaches proposed to achieve this goal include transport and fate modeling and fish body burden modeling of the upper and lower Hudson River.

The proposed transport and fate models include : 1) the Upper Hudson River PCB Mass Balance Model, 2) the Thompson Island Pool Hydrodynamic Model, 3) the Thompson Island Pool Depth of Scour Model and 4) the Lower Hudson River PCB Mass Balance Model. The proposed fish body burden models include: 1) the Bivariate Statistical Model for Fish Body Burdens (Upper Hudson River and Lower Hudson near Albany), 2) the Probabilistic Bioaccumulation Food Chain Model (Upper and Lower Hudson River near Albany) and the 3) the Thomann Food Chain Model for striped bass and white perch (Lower Hudson River). The overall conceptual approach to modeling conducted to date in Reassessment RI/FS involved the development and application of a suite of individual models to describe hydrology, solids dynamics and PCB dynamics in the environment, and fish body burdens.

The individual models were then coupled within an integrated modeling framework. The contents of the Phase 2 Preliminary Model Calibration Report are limited to descriptions of the individual models, descriptions of databases used for model applications, and preliminary calibration results for each model. As such, all results were deemed preliminary and with the exception of the TIP Depth of Scour Model were not meant for predictive purposes.

Specific Comments

1 Introduction

p. 1-1 A more detailed listing of commercial fishing bans and advisories for the Hudson river should be provided. Also recreational fish advisories should be addressed. As of Nov 26, 1996, the following NYSDOH advisories/bans were in effect and are based on PCBs: (1)

Hudson Fall to Troy Dam - Can fish but recommend you eat none (all fish)

Troy Dam to the Catskills - Eat none except American shad

Catskills to Upper Bay - Eat no more than one meal per month of American eel, Atlantic needlefish, bluefish, carp, goldfish, large and small mouth bass, rainbow smelt, striped bass, walleye, white perch and white catfish. For any other freshwater fish not included on the one meal per month list, the advisory is to consume no more than one meal per week. There is a commercial ban on American eel and striped bass.

2 Summary and Preliminary Conclusions

p. 2-4 Item 6: What are the three cases where segment-average values for the model output were significantly different than observed values? Were the predicted values significantly higher or lower than the observed values? (2)

Item 8: Why was the percent gain in water column solids mass greater during periods of low flow than high flow? (3)

p. 2-5 Item 13: The last sentence doesn't make sense. Lower chlorinated congeners are part of the total PCB value. Do you mean higher chlorinated congeners instead of total PCBs? Also this sentence should be relocated to item 12 or made into a separate item. (4)

p. 2-8 Item 3: Will differences in PCB tissue residues by fish sex, age or season collected be adressed in the Baseline Modeling Report? (5)

Item 5: The contributions of the water and sediment pathways appear to be determined by the model structure. For example, the model for brown bullhead assumed that sediment was the only exposure pathway. (6)

p.2-9 Item 3: "...the estuarine portion of the Lower Hudson River is influenced primarily by direct external loadings and loadings from the vicinity of NY city." This appears to contradict the conclusions of the Draft Data Evaluation and Interpretation Report (DEIR, in prep), which estimates that the Upper Hudson River PCB load represents about half of the total PCB loading in New York/New Jersey Harbor. (7)

p.2-9 Item 4: The conclusion that striped bass net PCB uptake occurs primarily between RM 18.5 and 78.5 is an artifact of the model, since the model did not consider the distribution of striped bass in the river above RM 80. (8)

p. 3-10 Section 3.62, first sentence: Insert (vertically) after "u and v". (9)

p.3-13 Section 3.7.1: Weren't the Phase 2 DEIR high resolution sediment cores selected because the locations/material were depositional in nature? These seem like inappropriate cores to include in a modeling effort to determine risk of resuspension or erosion of PCB contaminated sediments during high flow events. Their depositional nature would suggest that they would provide an underestimate of the actual depth of scour within the TIP. This model should include non-cohesive sediments and sediments falling between these two categories. (10)

p.3-17 There should be an indication that Thomann is revising the food chain model, what those revisions might or will entail and how such modification may impact model output. (11)

p. 4-1 Section 4.1 Para. 2: A description of the physico-chemical properties for the five selected PCB congeners should be provided. Explain the relevancy of the five selected congeners to the food chain model and ecological risk assessment. (12)

Section 4.2: Is there a concomitant increase in sediment total PCB concentrations to those in the water column between Ft. Edward and Thompson Island Dam (TID)? Also is there any explanation why this is not true year round as total PCB concentrations at Ft. Edward are equal to or greater than at TID at certain times of the year (i.e fall 1991, winter and spring 1993). (13)

Figure 5 The legend to this figure could be made clearer. Add "PCB" after transect, flow average and GE. Insert "daily" before "flow". (14)

p4-4 In the revised validated dataset, many of the BZ#138 values in water and sediment were qualified as below detection, resulting in Value2 = 0. What effect will these zero values have on the model output? (15)

p.4-6 Why wasn't an expanded dataset (1993 + historical) from USGS used for TSS and flow? (16)

p.4-7 Para 1: Isn't this inconsistent with using 1993 USGS data for estimating upstream TSS loading? Why not use historical + 1993 or historical only when 1993 data was unavailable? (see p.4-6 comment). (17)

Para 4 and 5: TSS data from Batten Kill was insufficient to define a time series, therefore measurements were averaged to yield a median TSS of 5.0 mg/l. Values are averaged to yield a mean not a median. In Para 4 the ungaged sources do not contribute to the overall mass balance of TSS but in Para 5 modeling indicates that Batten Kill and Fish Creek contribute significantly to the solids loads. Am I missing something? (18)

p. 4-8: Para 1: Figure 4-6(b) depicts total mass not percent. (19)

Para 3: Change "other tributaries" in last sentence to "Mohawk and Hoosic Rivers". (20)

Para 4: It is stated that PCBs are better correlated with TSS than with flow and that higher chlorinated congeners are better correlated with TSS than the lower chlorinated ones. Include the correlation coefficients in the text or refer to the table that contains them. (21)

p.4-9 Para 1: The high PCB measurement reported by GE for January 1993 was excluded from all PCB loading estimates because it was believed to be an outlier. An explanation should be provided as to this determination rather than citing a pending document. Were there qa/qc problems with the data or was it identified as an outlier by statistical methods? (22)

Para 2: How was the 10 ng/l PCB concentration derived? (23)

Para 4: Table 4-5 suggests that BZ#4 from upstream sources accounts for 48.8% not 27% of the load during spring high flow. In addition, 76.2% not 68% of the total PCB external load to the Upper Hudson occurs during spring high flow. (24)

p.4-10: Para 3: A statement is made about the negligible inputs of atmospheric PCB to the Upper Hudson. This statement should be supported with documentation. NOAA has requested that Bruce Brownawell, MSRC, SUNY Stonybrook, provide them information on local and regional PCB atmospheric inputs. This material will be forwarded upon receipt. It may be useful for pending modeling tasks. (25)

Para 4: Was temperature measured in surface or bottom water? Does water column stratification occur and if so is it accounted for in the model? (26)

p.4-11 Bruce Brownawell has more localized PCB atmospheric inputs (See p.4-10 above). They should be compared to the Green Bay estimates utilized in the modeling effort and a decision should be made as to which is the more appropriate value. (27)

p. 4-12 Para 2: The GE 1991 sediment data represent an average both vertically and horizontally. (28)

Para 3: Is bulk density on a wet or dry weight basis? (29)

p.4-13 The model appears to be sensitive to PCB sediment concentrations. How reasonable are the interpolations of GE 1991 PCB capillary column peak measurements to specific PCB congener concentrations? What affect does a change in concentration (i.e. 2x, 5x, 10x) of total or individual PCBs have on the model outputs? How valid is it to use one approach for BZ#4 and another approach for the other congeners? Is the assumption that the 10-25 cm layer is representative of the deeper 25-50 and 50-100 cm layers defensible based on sedimentation rates or dated cores? (30)

p.4-14 Section 4.5.2: What affect does median (vs. mean vs. maximum) parameter values for total PCBs have on the output? (31)

p. 6-8 The largest depth of scour predicted by the model was 2.5 cm or 1 inch and that the median depth of scour for a 100 year flood event was 0.16 cm. The conclusion drawn was that flood events will not erode PCB contaminated cohesive sediments to any large degree. As the input data was based on depositional sites experiencing little shearing, is this conclusion valid? (32)

p.7-1 Section 7.0. The Lower Hudson River modeling should be conducted on the updated version of the Thomann model. (33)

p.7-4 Do the cited references (Waldman 1988a,b) reflect the most current knowledge about striped bass migration patterns, i.e. above RM 80? (34)

p.7-9 Section 7.6.2 Para 2: River Segment 2 is "not sensitive" rather than "slightly sensitive" to loading according to the referenced table. Segment 2 is also not sensitive to volatilization. In the second to last sentence insert "quite" between "very" and "sensitive". (35)

p.7-10 Fig 7-7 is discussed as depicting the original Thomann model. Either it is not appropriately marked or missing from the figure. (36)

p. 8-18 Para 1: The model assumes that most water-column PCBs are associated with particulate organic carbon. This appears to contradict the Draft DEIR findings that (a) water-column PCB transport occurs largely in the dissolved phase, (b) the dissolved phase represents 80% of the water column PCB inventory in the Upper Hudson during most of the year (10 to 11 months) and (c) the majority of the Upper River PCB input to the water column is introduced upstream of RM 181.3 under low-flow summer conditions. This load is transported through the Upper Hudson to Troy with minor alterations and additions. This is particularly important because the summer low-flow period coincides with the summer feeding period for fish, which is their period of maximum exposure. Given the high bioconcentration factors for PCB congeners, any water-column dissolved PCB exposure could be significant, and all species, regardless of trophic level or feeding strategy, would have comparable exposure to any dissolved PCBs. This would be in addition to any dietary input. (37)

Table 9-2 The table should indicate whether the lipid and PCB concentrations are on a wet or a dry weight basis. It is assumed they are wet for the modeling exercise. (38)

Table 9-7 Values in the R2 column are two decimal places off. (39)

Fig 9-11 and 9-12 should include "0" for the y-axis. (40)

Fig 9-8 thru 9-13 should have 1:1 regression line drawn in. (41)

p.9-14 A more detailed description of the various model outputs for PCB fish burdens would have been useful. Note that the text incorrectly emphasizes that "the model appears generally to underestimate burdens [of Aroclor 1254 in largemouth bass] at River Mile 175, [and] overestimate[s] those downstream at River Miles 142-155. Fig 9-12 actually demonstrates that the model underestimates RM 142-155 and 189-193 at PCB concentrations of ≥ 500 ug/g lipid and overestimates PCBs at RM 160, RM 175 and RM 189-193 at concentrations <500ug/g lipid. In Fig 9-9, there were some over estimates and some underestimates for PCBs in large mouth bass at RM 189-193 while at RM 175 the model over predicted PCB tissue residues. In Fig 9-10, one out of five RM 189-193 PCB concentrations were overestimated by model. Fig 9-11 correlation is worse at higher concentrations where predictions were underestimates except at RM 175. Below 150 ug PCB/g lipid, the model prediction was a slight overestimate. Fig 9-16 and Fig 9-17 showed how the model overestimated largemouth bass Aroclor 1016 in 1979 and Arocior 1254 in 1979,1991-1992 respectively while Fig 9-19 showed the overestimate of PCBs in brown bullhead 1982-1992 (except1986) and underestimate in 1979 and 1980. (42)

p.9-15 58% should read 59%. (43)

p.9-16 Para 1. Reference should also be made to potential differences by sex. (44)

p.10-2 Is the data from the chironomid short-term study presented in this document? What information do they provide on the short-term relationship between water-column invertebrates and water-column sources? (45)

p.10-3 Section 10.2, Bullet 2: It should state that tissue is lipid normalized and sediment is organic carbon normalized. (46)

p.10-5 Para 2: The report states that "...the appropriate statistic for use in the BSAF calculations is a geometric mean sediment concentration." If benthic organisms have an equal opportunity to be exposed to a given sediment concentration, the arithmetic mean is the appropriate statistic, regardless of the distribution of sediment concentrations. Because the BSAF is assumed to be the same for all concentrations, each sample concentration should have equal weight in the calculation of the mean accumulation factor. Using a geometric mean value for sediment will likely result in over-estimation of the BSAF. This would also be true for the other estimated BAFs (e.g., FFBAF p. 10-20). (47)

p.10-5 Para 1: What affect does the assumption that forage dish feed on benthic organisms indiscriminately have on model outputs? How sensitive is the model to dietary input from within a given compartment? Benthic invertebrates may be sediment consumers, detritivores, omnivores, filter feeders or predators that could result in different patterns and concentrations of PCBs in invertebrate tissues. (48)

p.10-8... Section 10.2.3.: It was stated that "[t]he modeled and observed percentiles compare favorably." It is not clear what criteria are used to make this statement. Figures 10-16 and 10-36 are examples of comparisons that do not appear particularly favorable. (49)

p.10-7 Para 1: It appears that major peaks were more representative of the model maxima and the low peaks were bracketed by the model 50 and 90 percentile. It would be useful for the authors to include the 75 percentile in the figure as it may have characterized the smaller peaks better than the 50 or 90 percentiles. (50)

Para 2.: The means were from 0.2 to 0.5 not 0.5 to 1.5. (51)

Para 5: Chironomids have different feeding ecologies. Some are associated with the sediment but are predators (e.g. Ablabesmyia, Cryptochironomous, Procladius). Some filter feed (e.g. Polypedilum, Rheoranyrarsus), some spin nets to trap particles (Glyptotendipes), some eat Aufwuchs (e.g. Nanocladius) or detritus (e.g. Orthocladius). Therefore temporal changes in PCB water-column concentrations should be more closely correlated with purely filter-feeding or herbivorous chironomids than with sediment, sediment/epiphytic or predatory species. Have different congener patterns been observed for chironomids pursuing different feeding strategies? (52)

p.10-8 Biota to sediment goodness of fit plot described for BZ#4 is in a different format than Fig 10-16 and 10-20 for BZ#28 and BZ#52 respectively. (53)

The greatest differences in BSAF were observed at RM 100, RM 189 and RM 189.5. BZ#52 RM 100 similar to BZ#28. BZ#52 RM 189 and RM 189.5 pattern similar to BZ#4 but not BZ#28. Is this partially a result of benthic organisms collected at these stations and their feeding behavior? For example, the highest BSAFs were for chironomids, isopods and gastropods. Did these organisms dominate sites with the highest BSAFs on a river mile basis? (54)

p10-19 NOAA is concerned about combining the data from all fish samples with an average length of less than 10 cm to calculate a forage fish BAF. The majority of the fish samples in that size category were young-of-year spottail shiners. Other species, such as tessellated darters, smallmouth bass, etc. were represented by only a few samples and most likely have very different feeding behaviors. Using spottail shiners and other cyprinid species would provide data from all stations except river miles 47 and 26. In addition, it is likely that the feeding preferences for adult spottail do not apply for young-of-year fish. (55)

p.10-21... Tessellated darters and spottail shiners observed concentrations of PCBs (calibrated congeners, Aroclor 1016, 1254) were the highest. Is their food source more heavily contaminated? Do the congener patterns for forage fish spottail shiner and pumpkinseed sunfish reflect the concentrations found in their diet? What about for largemouth bass and white and yellow perch? Do they reflect the concentrations found in forage fish and invertebrates? (56)

p. 10-22 Para 1: "...with one spottail shiner at river mile 194.1..." Most of the fish samples collected in 1993 (probably all of the forage fish samples) represented composites of multiple individual fish. (57)

p.10-23 Para 3 second to last sentence: Insert Fig 10-63 through Fig 10-65 after "A second set of figures" (58)

p.A-11 Para 1: In the discussion about water depths, should the units be feet instead of meters? (59)

p. A-24. Under spottail shiner, the estimate dietary consumption is 50% water vs 50% sediment source while Table A-15 lists 75% from water and 25% from sediment. (60)

p.A-25 Para 1: "The data show that forage fish diet is primarily from water column organisms when averaged over the entire Hudson River." The information on feeding habits of forage fish (Table A-15) only showed data between Lock 7 and the Troy Dam. (61)

p.A-25 Para 3: The following statement raises a major concern about the development of this model: "...it is possible that the derived BAFs are artifacts of the model. ...[M]odel application can only confidently be accomplished through a greater understanding of the water column invertebrate box..." What can be done to reduce the uncertainty in the water column invertebrate compartment, "which impacts all subsequent compartments" and directly affects the application of the model? (62)

p.A-25 Para 5: Forage fish diet is 33 % benthic to 67% water column invertebrates but in Table A-16 the breakdown is 31% vs 69%. (63)

Please contact me at (212)637-3259 or Jay Field at (206)526-6404 should you have any questions regarding these comments.

Sincerely,

Lisa Rosman
NOAA Associate Coastal Resource Coordinator

cc: Shari Stevens, DESA/HWSB
Gina Ferreira, ERRD/SPB
Robert Hargrove, DEPP/SPMM
Charles Merkel, USFWS
Ron Sloan, NYSDEC

PL-1

ENVIRONMENTAL MANAGEMENT COUNCIL

PETER BALET
CHAIRMAN

GEORGE HODGSON
DIRECTOR

November 25, 1996

Mr. Douglas Tomchuk
U.S. Environmental Protection Agency
290 Broadway, 20th Floor
New York, New York 10007

Dear Doug:

Enclosed you will find Saratoga County EMC's comments on EPA's Phase 2, Volume 2B, "Preliminary Model Calibration Report" for the Hudson River PCB Reassessment RI/FS dated October 1996. These comments were prepared by Dave Adams and endorsed by the EMC at its November 13, 1996 meeting.

As I mentioned in our telephone conversation, the aforementioned report was not received in the Saratoga County EMC office until November 4, 1996. Due to the highly technical nature of the report and its late arrival in EPA's information repositories, the Saratoga County EMC recommends that EPA's public comment period be extended beyond the November 22, 1996 comment deadline to allow the public adequate time for review and comment.

The Saratoga County EMC would also appreciate a response to the enclosed specific comments/questions so the Council might better understand the USEPA's rationale on these matters contained within the Preliminary Model Calibration Report. The Saratoga County EMC is disappointed by the lack of response from EPA to our previous comment submittals.

Thank you.

Sincerely,

George Hodgson Jr.
Director

Enc.
cc: All EMC Members
Dave Adams
Darryl Decker
Judy Dean

10.0204

50 WEST HIGH STREET BALLSTON SPA N Y 12020 (518) 885 5381 EXT 4

November 22, 1996

Comments on EPA Phase 2 Report
Volume 2B - Preliminary Model
Calibration Report
Hudson River PCB's Reassment RI/FS
October 1996

Provided by David D. Adams
Member Saratoga County EMC and
Government Liaison Committee

Overall Comments

1. The organization of the report is awkward which makes review difficult and less efficient than it needs to be. Separating the tables and figures in a separate book from the text causes excess effort and lost time going back and forth between the two volumes. It would be much better to follow the more convential practice of integrating the tables and figures in appropriate places in the text. Also, the inclusion of specific information about each of the models in Section 3, the description of the overall approach, again makes review difficult as this model information in Section 3 is pertinent to the review of the subsequent sections in the report. This causes lost time and extra effort in looking back to locate the applicable information in Section 3. Section 3 should have ended with Section 3.4 and the subsequent model discussions integrated with the model discussions in the following section. Please consider these suggestions in the preparation of future reports. (1)

2. EPA has made public participation in the Reassessment process a major part of the reassessment effort. However, most (if not all!) of the interested public does not have the technical training to understand this report as written. It is recognized that reports of the type Volume 2B represents are fundamental and necessary to the reassessment process. It is not intended that these reports should be replaced by less technical reports. Rather, the recommendation is that a "concept summary" version be added which would be written in a mannner that would still convey the basic information that's in the "technical" version (e.g. Volume 2B as it now stands) but in a way that the less technically trained citizen could better understand. (2)

3. Presentation of the HUDTOX model is inadequate in that none of the formulas or mathematical relationships used in the model are included. Without that, it is not possible to get an adequate understanding of the model (3)

particularly the relationships between constants and variables, Reference to some other report such as "Ambrore, et.al." is not adequate as accessibility to these reports is difficult if not impossible for the general public. This comment also applies to some areas of the Fish Body Burdens modeling discussion. A good example in the report of the correct way to present a model is the presentation of the TIP Hydraulic Model. The presentation of the Lower Hudson Transport and Fate Model section also represents a better model presentation than that for HUDTOX.

4. The discontinuity in the early 1990's of the PCB concentration data vs time shows a definite need for the HUDTOX model to incorporate the effects of the PCB releases at Bakers Falls as no other reason appears reasonable to account for the sudden PCB increase in the early 1990's. It is not clear from the discussion in this report that the HUDTOX model is able to incorporate the Bakers Falls situation and/or that the EPA has the necessary data to include the effects of Bakers Falls. The need to consider the effects of Bakers Falls is especially urgent in view of the Fish Body Burden models being of a quasi steady state nature with a time span interval average of about 1 year and in view of the fall-off in PCB levels in the years leading up to 1992-93 and then the increase when the Bakers Falls sources came into play. Because of this behavior of the PCB concentrations, it is recommended that the study of PCB levels using the HUDTOX model be separated into two time periods. The first time period would be that up to 1992-1993 and would evaluate the HUDTOX and Fish Body Burden models ability to predict how PCB levels decrease when new PCB sources are zero or negligible. Then the HUDTOX model could be applied to the years after 1992-1993 and in the future to predict how PCB levels would decrease after the Bakers Falls source is eliminated by the remedial actions now underway. The model would have to incorporate the initial inputs of PCB's from Bakers Falls and then the subsequent drop of PCB input as the remedial actions take (or have taken effect). Assumptions would have to be made as to the timetable for elimination of the Bakers Falls source - perhaps it could be a parameter in the study. This approach should give a better prediction of the future than trying to make the HUDTOX model jump through the evident discontinuity that occurred in 1992-93.

5. The stated tendency of fish to accumulate higher chlorinated PCB's (see page 8-3 of Book 1) emphasizes the need to do the modeling on a congener basis and to include terms in the PCB transport and fate models for biodegradation of PCB's. Consideration of this biodegradation effect is necessary to accurately estimate the total uptake of PCB's in the fish, which so far, is the basis for EPA's Health Risk Analysis. The importance of considering the effect is shown by the stated sensitivity shown to biodegradation in the Lower Hudson River Model (page 7-9 of Book 1). As an aside, it is hoped that some day soon EPA will recognize that the health risk of all PCB's is not the same and modify the Health Risk Assessment procedure accordingly. 4

6. The discussions and formulas presented in Book 1 are based on the assumption that there is a direct one-to-one relationship between PCB concentrations in water and sediment to PCB levels in fish. The tendency of fish to accumulate higher chlorinated PCB's (see comment No.5) raises questions about this assumption. This tendency suggests that it may be necessary to include in the Fish Body Burden model terms to reference the time rate of PCB congener removal from fish (whether by excretion or metabolism) and to consider the age of the fish sampled. What has been done to evaluate 5

the need for including such effects in the model? If data are not available, at least a parameter study could be made using best estimates from the scientific literature to see if these effects are significant.

7. Book 1 should include a discussion as to why it was felt necessary to develop a new model for the Upper Hudson instead of applying the existing Lower Hudson model (or conversely, if a new model is needed for the Upper Hudson, why isn't it also used for the Lower Hudson?). (6)

Specific Comments

1. Section 3

a. Fig. 3-1: Explanation of the symbols used is needed for the Solids Balance & PCB Balance. While the arrows are self evident, the meaning of the symbol within the circle between boxes and the "omega looking" symbol at the sediment-water and sediment-sediment interfaces are not clear. (7)

b. Solids submodel, page 3-6: The discussion should include the rationale for the organic carbon fraction assigned to TSS to represent particulate organic carbon being a constant. Also, why do not tables 4.9 & 4.12 include this parameter? Some explanation as to why values for biotic solids loading due to primary production from the Lower Hudson are satisfactory to use in the Upper Hudson (even after temperature correction) should be provided. (8)

c. Toxic chemical submodel, page 3.6: It is not satisfactory to say that the Phase 2 database doesn't distinguish DOC bound PCB's from truly dissolved PCB's but it is important to do so and then drop the subject. Some explanation as to why this omission in the data is not significant to this reassessment is necessary. (9)

d. Toxic chemical submodel, page 3-7: The "other enhancements" made to simplify application of the model should be spelled out here as access to the reference cited is not readily available to the general public. (10)

e. Scour Model, page 3-13: Will the inability to model "subsequent transport and redistribution" of eroded sediments be of significant impact to the modeling results? If not, why not and if yes, how will the Reassessment accommodate this failing? (11)

2. Section 4

a. Page 4-11: The applicability of Green Bay data for PCB concentration in the air is questioned. If volatization is important, this assumption should be revisited and either data collected for the Hudson or the PCB air concentration made a paramenter in the study. (1)

b. Page 4-13: Why are no tables provided for PCB concentration in sediment layers 5-10 and 10-25 cm? (1)

c. Page 4-18: Values of V_s given here range from .25 to 3.05 so some (1)

explanation is needed as to why a value of 2.0 is the correct one for the Hudson.

i. Page 4-19: A more complete explanation or discussion of the basis for the "professional judgement " value of .22cm/vs for V_D is needed. (15)

e. Table 4-10: U_x is listed as a parameter for HUDTOX but is not used. The decision not to use U_x should be explained. (16)

f. Tables 4-13 through 4-17: The large variances shown in these tables are disturbing and some discussion of their significance is needed. For example, the t-test uses the assumption that the variances, T_x and T_y, are equal. It is usual to test this assumption using the "F" test. Has this been done and if so, what conclusions were reached? Should the analysis of variance method be used in addition to or in place of the t-test? (17)

Section 7

Page 7-3: Explain why Hydroscience values for horizontal dispersion coefficients are good values to use. Also explain the rationale for using ± 30% to adjust these coefficients for high and low flow years. (18)

Section 10

1. Page 10-23 and following: Why are not equations defining FFBAF, calculations of FFBAF, and FFBAF tables and/or figures provided as for other BAF's? (19)

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PL-2

ENVIRONMENTAL MANAGEMENT COUNCIL

PETER BALET
CHAIRMAN

GEORGE HODGSON
DIRECTOR

November 25, 1996

Mr. Douglas Tomchuk
U.S. Environmental Protection Agency
290 Broadway, 20th Floor
New York, New York 10007

Dear Doug:

Enclosed you will find Saratoga County EMC's comments on EPA's Phase 2, Volume 2B, "Preliminary Model Calibration Report" for the Hudson River PCB Reassessment RI/FS dated October 1996. These comments were prepared by Dave Adams and endorsed by the EMC at its November 13, 1996 meeting.

As I mentioned in our telephone conversation, the aforementioned report was no received in the Saratoga County EMC office until November 4, 1996. Due to the highly technical nature of the report and its late arrival in EPA's information repositories, the Saratoga County EMC recommends that EPA's public comment period be extended beyond the November 22, 1996 comment deadline t allow the public adequate time for review and comment.

The Saratoga County EMC would also appreciate a response to the enclose specific comments/questions so the Council might better understand the USEPA' rationale on these matters contained within the Preliminary Model Calibratic Report. The Saratoga County EMC is disappointed by the lack of response fro EPA to our previous comment submittals.

Thank you.

Sincerely,

George Hodgson Jr.
Director

Enc.
cc: All EMC Members
Dave Adams
Darryl Decker
Judy Dean

10.0209

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UNIVERSITY AT ALBANY
STATE UNIVERSITY OF NEW YORK

November 13, 1996

Mr. Douglas Tomchuk
US EPA - Region 2
290 Broadway - 20th Floor
New York, NY 10007-1866

RE: PMCR Comments

Dear Mr. Tomchuk:

The following comments are submitted in reference to the Upper Hudson Mass Balance Model of the PMCR (Sections 3.5 and 4, and I emphasize are based only on a brief review for consistency with my prior report to you (March 1994).

1) External solids loadings and resuspension (Sections 4.2, 4.4.2, 4.7, 4.8) TSS cannot be related simply to flow or discharge data. The correlation in Figure 4.13 is poor because of the sediment source-discharge-flow event timing relations described in my 1994 report for the upper Hudson. These relations are well displayed in the USGS data for the 1993 calibration period, which provided representative high discharge events. For the most part, TSS is in a depositional mode during events, i.e. the sediment concentration peak precedes the discharge peak, and sediment concentrations further are a function of event timing and sequence rather than absolute discharge. Resuspension of prior year deposited sediment is, of course, likely during a spring event but not on a continuous or timing/event independent basis as embodied in 4.6.2 items 4 and 5. Figure 4-4 shows that TSS has declined sharply during high discharge, but much more close interval sampling (< 1 day) is needed to adequately assess this feature. A careful analysis of the TSS-discharge decay curves and timing (instantaneous values) across many events might provide the proper relationship(s). (1)

The Solids Model calibration (4.7.1) appears to relate resuspension to a low-flow baseline condition, and an empirical factor based on mean river velocity. Apparently this is the basis (?) for the TSS mass balance of Figure 4-37, especially part (b). This is in turn critical to the PCB balance of Figure 4-40 and others derived from it. (It certainly does not follow from an examination of Figures 4-2, 4-4, 4-7, 4-10). The application of this calibration to the TIP, especially under high flow conditions, is (2)

questionable. The sediment provenance area and sediment of the TIP are unlike that at Stillwater and Waterford. It is also likely that the TSS composition under low flow conditions is not the same as at high flow. Further, TSS under low flow is not necessarily resuspended (Figure 4-37, non-event?). Taken together with the assumed TSS vs. discharge relation, I do not think this model has made a valid mass balance distinction between TSS loading via tributary and runoff inputs vs. true resuspension of river bed sediment deposited during the last spring event(s).

2) In the 1994 report I noted the very erratic nature of PCB loading during high flow events and the problem of inhomogeneous PCB flow distributions for sampling, especially at Ft. Edward or the Rogers Island locality. Figure 4-14, segment 3, aptly depicts this first aspect, and it is more fully amplified in the O'Brien and Gere reports (1993a,b,c,d; pg. R-8). PCB transport will be related to high discharge events merely by mass movement, but PCB water column concentrations at Ft. Edward remain erratic at any flow rate (Figures 4-14, 4-5, 4-2; Note paragraphs 3 and 4, p. 4-2; paragraph 4, p. 4-8; paragraph 1 and 2, p. 4-9. The outlier point is typical of episodic, erratic PCB release from the area between Bakers Falls and Rogers Island). For example, note the following PCB concentration data (USGS except as noted) for the Rogers Island station: (3)

USGS 1993 Water Year

Date	Total PCB as 1242 (ppb)
April 13	< .01, 0.8 same date
April 29	0.10, 1.1, 11.0 same date

1992 Water Year

April 22	0.125 (GE)
April 23	3.0

There is perhaps more chance of PCB "spikes" during high discharge, but overall this is unpredictable.

The model PCB calibrations of Figure 4-14 suggest further that adding peaks for high flow events will overestimate PCB concentrations, and hence total (integrated) loadings for the spring event. Flow averaged sampling appears to reduce the variability among samples, but does not change the lack of correlation between PCB, TSS, and flow noted by G.E. (P. 4-8, 4-9; Fig. 4-14, segment 3). The apparent increase in PCB concentrations between Ft. Edward and the T.I. dam has been noted previously (NYSDEC data; Barnes, USGS 1987) but may also be partly an artifact of sampling procedures. Random sampling of a time variable distribution with sharp high value peaks and longer low-value intervals will be biased towards underestimation of the integrated total (mass) when the sample exposure is very short, and "outlier" points are discarded. To this can be added river transect variation or flow inhomogeneity, and additional bias can arise due to a fixed sample point position. (4)

Downstream flow homogenization effects would tend to lessen these biases (e.g. T.I. dam) which are most acute at, and upstream of, Rogers Island.

Flow inhomogeneity at Ft. Edward has been documented by O'Brien and Gere (1993a,b,c; p. R-8), and previously by Tofflemire (1984, Northeastern Environmental Science, v. 3, p. 202-208. Why isn't the latter referenced here - it is certainly relevant?) As a result of the above factors I do not consider the Ft. Edward PCB data adequate for reliable upstream (or input) mass loading calibration. The T.I. dam data are better as a basis for Table 4-5 (p. 4-9), for example, but these data do not warrant the implication of Figure 4-40(B) in which the resuspended TIP PCB mass (less congeners BZ #4) approximates the Ft. Edward input. In this case the caveat of #2 (p. 4-26) is the operative factor, but not the only problem. (5)

3) TIP Depth of Scour Model (Section 6.2.2) Resuspension Experiments. How do we know that sediment samples sent to UCSB will recompact or otherwise approximate their physical state in the River when tested? How do we know that the act of core collection does not influence the subsequent shaker shear stress observations? (6)

Recommendations

1) The time sequence curves for TSS and flow at Ft. Edward and the TI dam in high discharge events need to be determined as a basis for meaningful mass balance estimates for the TIP. Probably more observations within the TIP in order to estimate external sediment and flow inputs (e.g. Moses Kill and spring runoff) will be needed. Regardless of the PCB loading, this information is needed as a direct check on the TIP erosion/resuspension estimates provided by the TI hydrodynamic model. It may also be necessary to sample the lower water column at elevated discharge to assess bedload transport if this component is not normally part of TSS determinations.

Another approach is to examine the TIP sediment cores in areas of predicted greatest PCB "hot spot" erosion for a similar effect, i.e. an erosional hiatus, during the last actual ~100 year event (1975-76). If erosion occurred a visual demarcation may be present; otherwise truncation of the Cs 137 time/stratigraphy scale should be noted. Deposition, on the other hand, was evident by a Cs137 reversal (arrival of former Ft. Edward dam sediment) as documented by Tofflemire and Quinn (1979, NYSDEC Tech. Paper No. 56; studies of numerous cores, sediment samples, and other data. Again, why isn't any of this body of work referenced?)

2) The uncertainties of PCB loading and water sample representation at Ft. Edward need to be resolved in order to obtain meaningful input data for examining PCB mass balance in the TIP. Integration of the PCB concentration vs. time relation is needed, but attempts to correlate this with TSS or discharge should be abandoned at Ft. Edward. Flow averaged sampling can improve integration, but the question of cross channel inhomogeneity remains. This needs to be evaluated before proceeding with any comparison of PCB loading at Ft. Edward vs. the TI dam. If resuspension is a

factor in TIP PCB loading, then a relationship with TSS can be looked for at the TI dam. However the same time sequence detail is needed as under recommendation #1. At the present time it appears the TIP data is too unconstrained for the fullest use of other potential insights such as changes in congener makeup - seasonally, annually cyclical, or high flow-low flow (?); or "tracking" PCB concentration spikes at Ft. Edward downstream.

I hope these comments are of some help. Please call if further discussion is desired. Also please indicate the distribution of these and other PMCR comments.

Very truly yours,

George W. Putman

JOHN E. SANDERS
33 Sherman Avenue
Dobbs Ferry, NY 10522
24 October 1996

Mr. Douglas Tomchuk
US EPA - Region 2
290 Broadway, 20th Floor
New York, NY 10007-1866

Attn: PMCR Comments

Dear Doug,

Herewith some comments about the PMCR draft copy that I received on 16 October 1996. I include my usual exercises that seem to fall into the category of tilting at the wrong-hyphen-usage windmills plus some other editorial-type notes.

My main comment about the modelling work deals with the use of Julian Days along the time axis on many of the graphs, starting with Figure 4-3. The range of days for the model-calibration period (01/01/93 through 09/30/93) is shown as zero through 300 and the label is "Julian Date." The only correct label for these numbers is "Julian Date (-2448989)". (A)

If the plan for later is to pick up other intervals on the same time-string base, then I think it would be better to use abbreviated forms of the correct Julian numbers, not any old arbitrary 0-300 with a subtraction of 2448989. Using the conversion factor for Julian Day = the DOS serial number for a date + 2415019, the Julian Day for 01 January 1993 becomes 33970 + 2415019 = 2448989. Correct-date Julian graphs for the model-calibration period thus start with 2448989 and end with 2449289 (the basis for the required subtraction mentioned above). This could be shortened to 989 through 1289 [with the horizontal axis label reading "Julian Date (+2448000)"]. Also, users should not forget that Julian Days begin at High Noon, not at midnight.

Other figures needing the above change are: 4-4, 4-5, 4-7, 4-8, 4-10 (each of the 8 little graphs), 4-11, 4-12, 4-14 through 4-31 (each of the 8 little graphs on each figure), 4-51 through 4-62 (ditto),

I enclose an example of a graph I worked up for Hudson River discharge expressed as yearly mean flows on a Julian-Date time axis. This graph was drawn by Quattro Pro from a spreadsheet that I compiled from U. S. Geol. Survey data + earlier years from the NYC Board of Water Supply. Since I drew this graph, I have updated the file to 1994. If you can use it, I can provide the file on a disk. (B)

I recently got hold of the proceedings volume of the 1963 Federal Inter-Agency Sedimentation Conference that contains Panuzio's oft-cited (but possibly little read) paper on lower Hudson River siltation. On p. 518-519, he gives the results of daily sampling of the river for suspended sediment at the Poughkeepsie water intake for the period 01 Sep 59 through 31 Aug 60. I never heard about this data set before. I do not recall ever seeing the data volume (TAMS/Gradient Oct. 1995 of the PMCR), so I do not know whether or not this is in your system. (The Panuzio 1963 reference is not in the PMCR list.) This data set might be a useful thing to have for model hindcasting.

I'm just home from a week in the hospital where I underwent major abdominal surgery. I hope to be recovered sufficiently to attend the meeting on 28 October 1996 in Albany. *

Cordially yours,

John E. Sanders

JES/s
Encl: PMCR comments
Graphics

20 Nov 96

* Obviously, I didn't make that meeting, but I am better now

Jes-

Comment numbers for PP-1.1 to PP-1.159 are given on the left of the page.

COMMENTS ON PMCR BY JOHN E. SANDERS (20 NOV 96)

Item	Location	Comment
01	Title, L.2, last word	An example of space and hyphen needed before a word to indicate word(s) left out. In this case, the left-out words are "Further" & "Site" so the correct usage is "Further Site Characterization and -Analysis"
02	Title, L3, middle	Hyphen needed between two words that modify- and precede a noun. In this case, "Model" and "Calibration" modify and precede "Report" so the correct usage is "Model-Calibration Report"
03	Contents, 1.3	No. 01 hyphen rule applies before "Organization." Should read: "Report Format and -Organization"
04	Contents, 2.1.2	Hyphen and space needed after a word to indicate left-out words, cf. No. 01; also another example of No. 02 hyphen needed. Thus: "Water Column and Sediment Models" should be "Water-Column- and Sediment Models" (to indicate the meaning for models of the water column and of the sediment).
05	Contents, 2.1.3	Hyphen error of No. 02 type: "Fish Body Burden Models" should be "Fish-Body-Burden Models."
06	Contents, 2.2.2	Hyphen-needed error cf. No. 01 (If "Sediment Erosion" refers to the Thompson Island Pool, i.e. words left out, then the correct usage is "Thompson Island Pool Hydrodynamics and -Sediment Erosion." Because of geographic name, "Thompson Island Pool" needs no hyphens.
07	Contents, 2.2.4	A double whammy; No. 02 hyphen needed between "Striped" and "Bass" before "Accumulation"; space and hyphen before "Striped" to indicate left-out words "Lower Hudson River." Thus to be: "Lower Hudson River PCB Mass Balance and -Striped-Bass Bioaccumulation"

08	Contents, 3.2	If meaning is "Modeling Goals and Modeling Objectives" then the correct form is "Modeling Goals and -Objectives" (cf. No. 01).
09	Contents, 3.5	Hyphen needed between "Mass" and "Balance;" type No. 02; should be "Upper Hudson River Mass-Balance Model"
10	Contents, 3.5.3	"Spatial-Temporal Scales" First correct-hyphen usage! Hooray!
11	Contents, 3.6.3	Gold star for correct usage cf. No. 10.
12	Contents, 3.7	No. 02 hyphen blunder; should read: "T I Pool Depth-of-Scour Model"
13	Contents, 3.7.3	What happened? Must be: "Spatial-Temporal Scales" as in Nos. 10 & 11.
14	Contents, 3.8	Here's a real hyphen challenge; the correct usage not being immediately clear. The question is, how many models? Is it two? A transport model and a fate model? Or only one? (i. e., model of transport and fate). If it's two models, then the correct usage is: "Transport- and Fate Model." If it's only one model of transport and fate, then the correct usage is: "Transport-and-Fate Model." You see, hyphens are important and I am not just making this stuff up. There are rules.
15	Contents, 3.8.3	Back on track again with "Spatial-Temporal Scales"
16	Contents, 4.2	Hyphen needed between "Water" and "Quality" (No. 02 type): should read "Historical Trends in Water-Quality Observations"
17	Contents, 4.3	Hyphen needed between "Preliminary" and "Calibration" before "Dataset" (No. 02 type): should read "... Preliminary-Calibration Dataset"

Comment numbers for PP-1.1 to PP-1.159 are given on the left of the page.

18	Contents, 4.4	Hyphen needed betweeen "Model" and "Input" before "Data" (No. 02 again): should read "Model-Input Data." (Note, this one is debatable; if "Input Data" are considered as a single word, then no hyphen is needed. I argue for the hyphen to contrast with possible "model-output data."
19	Contents, 4.4.1	"System-Specific Physical Data" is correct. Score another hyphen for the home team!
20	Contents, 4.8	Another No. 02, but with some possible debate. If "Component Analysis" is a single entity, then the correct form is" "Mass-Balance Component Analysis" (But if it is analysis of the components of the mass balance, then the correct version is: "Mass-Balance-Component Analysis")
21	Contents, 4.9	Same as 20, with result depending on status of "Sensitivity Analysis." Minimum-correct-hyphen usage is: "PCB-Model-Calibration Sensitivity Analysis"
22	Contents, 5.2	No. 02 again; to be "Model-Input Data"
23	Contents, 5.2.1	See No. 19. [But I wonder if somebody believes that whenever "system" and "specific" are used they should be hyphenated (as contrasted with hyphen required because they modify- and precede "Physical Data").]
24	Contents, 5.6.1	No. 02 again; should be "Rating-Curve Velocity Measurements." I also question use of "velocity" here. "Velocity" is a vector consisting of "celerity" along a particular direction. My guess is that "Celerity" is what is being discussed.
25	Contents, 5.7	Multiple No. 02: should be: "100-Year-Flood-Model Results" (but with poss. option on last hyphen if "Model Results" are

		an integral term). If it is the results from the model of the 100-year flood, then the way I show it above is the only correct form.
26	Contents, 5.8.2	No. 02 to be "Turbulent-Exchange Coefficient"
27	Contents, 5.9	See No. 24 re: "Velocity."
28	Contents, 6	See No. 12.
29	Contents, 6.2.1	No. 02 requires "Bottom-Sediment Distribution" here.
30	Contents, 6.3	If the "Uncertainty" refers to "Model," then No. 01 comes into play and the correct form must be "Model Parameterization and -Uncertainty" (Otherwise the only correct version is "Model Parameterization and Model Uncertainty.")
31	Contents, 6.4	A double-header bonanza for No. 02: Make it: "Depth-of-Scour Predictions at Selected Locations in Cohesive-Sediment Areas."
32	Contents, 6.5	No. 02 requires "Cohesive-Sediment Areas"
33	Contents, 7.	See Comment No. 14.
34	Contents, 7.2	See Comment No. 18.
35	Contents, 7.2.1	Gold star again for correct hyphen usage of "System-Specific Physical Data"
36	Contents, 8	OK as written. "Fish Body Burdens" gets no hyphens just because these words are used. But, this changes later.
37	Contents, 8.1	See Comment No. 08.
38	Contents, 8.4	No. 02 hyphen rule; hyphen is needed between "Bivariate" and "Statistical" modifying- and preceding "Model." Thus: "Bivariate-Statistical Model"

39	Contents, 8.4.1	No. 04 hyphen rule for words left out; hyphen and space needed after "Rationale" (assuming this word applies to the model). Also No. 38 applies here, too. Should be: "Rationale- and Limitations for Bivariate-Statistical Model"
40	Contents, 8.4.2	See No. 38.
41	Contents, 8.5	Hyphen error of type No. 02; should be: "Probabilistic-Bioaccumulation-Food-Chain Model" (assuming the reference is to a probabilistic model of bioaccumulation in the food chain).
42	Contents, 8.5.1	"Rationale and Limitations" are OK as written here, but cf. No. 39.
43	Contents, 9.	No. 02 hyphen; as in No. 38.
44	Contents, 9.1	No. 02 hyphen, plus I would use the words before the abbreviation BAF (it to be included in parentheses immediately following). Thus, the correct heading should read: "Data Used for Development of Bivariate-Bioaccumulation-Factor (BAF) Models"
45	Contents, 9.1.3	No. 02 hyphen, to read: "Water-Column Data"
46	Contents, 9.2	No. 02 hyphen, to read: "Results of Bivariate-BAF Analysis"
47	Contents, 9.3	Same as No. 46.
48	Contents, 10.	No. 02 hyphens to be added: "Calibration of Probabilistic-Bioaccumulation-Food-Chain Model"
49	Contents, 10.1.2	No. 02 hyphen for "Water-Column Invertebrates" (cf. No. 45)
50	Contents, 10.2	Multiple No. 02; to be: "Benthic-Invertebrate:Sediment-Accumulation Factors"
51	Contents, 10.3	Multiple No. 02; to be: "Water-Column-Invertebrate:Water-Accumulation Factors (BAFs)"

Comment numbers for PP-1.1 to PP-1.159 are given on the left of the page.

52	Contents, 10.3.2	See No. 49 for "...Water-Column Invertebrates"
53	Contents, 10.4	Cf. Nos. 50 & 51; should be "Forage-Fish:Diet-Accumulation Factors..."
54	Contents, 10.4.2	See No. 49 for "Water-Column Concentrations..."
55	Contents, 10.4.3	No. 02; to be "Forage-Fish Body Burdens..."
56	Contents, 10.5	Cf. Nos. 50, 51, & 53: to be: "Piscivorous-Fish:Diet-Accumulation Factors..."
57 p	Contents, 10.6.1	Hyphen No. 04 needed after "Ap-roach" to read: "Approach- and Calculations..."
58	Contents, 10.7	Hyphen No. 02 to read: "Summary of Probabilistic-Food-Chain Models"
59	Contents, 10.8	Hyphen No. 02; notice inclusion of "Model" in the string (modifies and precedes "Application"); to be: "Illustration of Food-Chain-Model Application"
60	Contents, 10.9	Hyphens Nos. 02 & 04: to be: "Comparison of Bivariate-Statistical- and Food-Chain Models." Can you guess the left-out word requiring the hyphen after "Statistical"? (Hint: its first letter is M.)
61	p. E-1, par 01, l.02	At last, done with the Contents! "No Action" before "decision" requires No. 02 hyphen. If you reject the hyphen, then the only correct thing to do is put a "(sic)" after "Action" to show you are quoting verbatim a wrong usage.
62	p. E-1, par 02, l.01	Need No. 02 hyphen after "mathemat-ical" to read "mathematical-model-ing efforts..."

63	p. E-1, par 02, l.02	Need No. 04 hyphen after "preliminary" to read: "...meant as a preliminary- or interim report."
64.	p. E-1, par 02, l.06	Sentence to be recast to show completed past action. Replace "When" with "After" and in next line, change "are" to "have been."
65	p. E-1, par 03, l.01	"Model-Calibration Report" (cf. No. 02)
66	p. E-1, par 04, l.01	Add hyphen after last word (No. 02)
67	p. E-1, par 04, l.02	Add hyphen & space after "health" (cf. No. 04)
68	p. E-1, par 04, l.02	Add No. 02 hyphen after "ecological" the phrase to read: "...meeting human-health- and ecological-risk criteria..."
69	p. E-1, par 04, l.02	Note: "continued No Action?" is OK as written; no hyphen here.
70	p. E-1, par 05, l.01	Same as No. 69. No hyphen needed in "No Action"
71	p. E-1, par 07, l.01	No. 04 hyphen & space needed after "useful"
72	p. E-1, par 07, l.02	No. 02 hyphen needed after "mass" the phrase to read: "...validate useful- and scientifically credible mass-balance models..."
73	p. E-2, par 01, l.04	See No. 14; should read "transport- and fate of PCBs..."
74	p. E-2, par 01, l.06	Ditto; No. 04 hyphen & space needed. to read: "...transport- and fate of PCBs"
75	p. E-2, par 01, l.08	Insert comma after interface. This is the first case of a systematic adherence to leaving out the comma before the final "and" in a string of more than two items. I see this usage a great deal, but think that even if some expert says it's OK, it tends to introduce ambiguity. I recommend changing throughout.

76	p. E-2, first BF heading	Needs hyphens as in Nos. 14 & 59; to read: "Transport-and-Fate-Model Development"
77	p. E-2, par 02, l.02	No. 75 comma needed after "solids dynamics"
78	p. E-2, par 02, l.03	No. 01 space & hyphen needed before "sediments" (if the ref. is to "river sediments")
79	p. E-2, par 02, l.04	Need a No. 04 hyphen & space after "diverse"
80	p. E-2, par 02, l.04	Ditto after "developing"
81	p. E-2, par 03, l.03	Insert No. 75 comma after (GE); this is a good example to show the need for my preferred comma usage. A comma before the first "and" eliminates any confusion with the second "and"
82	p. E-2, par 03, l.03	Need a No. 04 hyphen & space after "private;" I would change this line to read: "...(GE), and private- and academic research..."
83	p. E-2, par 04, l.01	Need No. 02 hyphen after "mass"; See also No. 09.
84	p. E-2, par 04, l.02	Recommend No. 75 comma after "solids"
85	p. E-2, par 04, l.02	No. 01 space & hyphen needed before "sediments"; See No. 78.
86	p. E-2, par 04, l.06	No. 04 hyphen & space needed after "physical"; to read "physical- and chemical properties."
87	p. E-2, par 04, l.08	Need No. 02 hyphen after "Phase" to read: "Phase-2 monitoring..."
88	p. E-2, par 05, l.01	"velocities;" See No. 24.
89	p. E-2, par 05, l.04	"Depth-of-Scour Model" (cf. No. 12)
90	p. E-3, first line	See No. 89.
91	p. E-3, par 01, l.04	See No. 89.
92	p. E-3, par 01, l.05	Insert No. 02 hyphen after "high" to read: "high-flow events."

93	p. E-3, par 01, l.01	First sentence to read: "An existing mass-balance model....was used for hydrology-, solids-, and PCBs in Lower Hudson River water and -sediments."
94	p. E-3, par 01, l.04	"individual PCB homologues" means what here? Were the PCBs expressed as Aroclors?
95	p. E-3, par 01, l.06	Change "re-calibration of" to "recalibrating."
96	p. E-3, 3rd BF hdg	To read: Development of Fish-Body-Burden Models
97	p. E-3, par 04, l.04	Insert space and hyphen before "sediments" (to indicate reference to left-out words Hudson River).
97A	p. E-3, 3rd BF hdg	See No. 38 for needed hyphens.
97B	p. E-3, par 05, l.01	See No. 97A.
97C	p. E-3, par 05, l.04	See No. 97A.
98	p. E-3, 4th BF hdg	See No. 41 for needed hyphens.
99	p. E-3, par 06, l.02	Same as No. 98.
100	p. E-4, par 01, l.01	Needs No. 04 hyphen after "historical."
101	p. E-4, par 01, l.04	Needs some No. 02 hyphens to read: "average-body-burden estimates."
102	p. E-4, par 02, l.02	Insert No. 75 comma after "range."
103	p. E-4, 1st BF Hdg	To read: "Thomann Food-Chain Model."
104	p. E-4, par 03, l.01	See No. 103; + add hyphens (Nos. 02, 04) to read: "PCB-transport- and fate model."
105	p. E-4, par 04, l.01	Change "Since" to "Because." (Reserve "since" for time usage--since 1974...)
106	p. E-4, par 04, l.03	Change "have" to "has;" the subject of this sentence is "number" (singular) not the object of the preposition of (i.e. "conclusions"). You can avoid this by finessing the "A-singular-of-plural" usage by "several preliminary conclusions have been drawn."

107	p. E-4, par 05, l.01	Must be "PCB-mass-balance model" (No. 02 hyphen fault).
108	p. E-4, par 05, l.02	Insert No. 75 comma after "dynamics."
109	p. E-4, par 06	**Huge question:** What is the timing of the HUDTOX simulation with respect to the recent, much-belated GE cleanup of the oozing PCBs from the old mill?
110	p. E-4, par 08, l.01	No. 2 hyphens needed to read "water-column concentrations" and "dissolved-phase PCBs."
111	p. E-4, par 08, l.03	Use of the words "appear to be" is totally inappropriate. Unless you have been hiding something, the words "must be" should be substituted.
112	p. E-5, par 01	**This point about pore-water (must add a No. 02 hyphen here) PCBs being flushed upward out of the sediments into the river is very important. What is being planned to test this hypothesis? Have the individual-congener "fingerprints" been investigated?**
113	p. E-5, par 01, l.04	No. 02 hyphen needed after "pore" to read "pore-water advective flux."
114	p. E-5, par 02, l.02	No. 02 hyphen needed after "river" to read "river-flow velocities." See also No. 24 about "velocities."
114	p. E-5, par 03, l.01	Need 2 No. 02 hyphens to read: "Thompson Island Pool Depth-of-Scour Model."
115	p. E-5, par 03, l.03	Need No. 2 hyphen after "cohesive."
116	p. E-5, par 04, l.01	See No. 114.
117	p. E-5, pars 03 & 04	I recommend transposing these two paragraphs to put the predicted depths of scour ahead of the total predicted-sediment/PCB scour.
118	p. E-5, par 05, l.01	Need No. 2 hyphen after "Bivariate" (See No. 38.)
119	p. E-5, par 05, l.04	Need No. 2 hyphen after "water" to read: "water-column concentrations."

120 p. E-5, par 04, l.04 — No hyphen after adverbs; thus none needed after "highly" before "chlorinated."

121 p. E-5, par 04, l.09 — See No. 119.

122 p. E-5, par 04, l.10 — Change "while" (a time term) to "whereas."

123 p. E-5, par 04, l.10 — Delete hyphen after bottom; change to read "bottom feeders." No basis for any hyphen here except duplication of wrong usage found in the literature.

124 p. E-5, par 05, l.12 — Need No. 2 hyphen after "water" and No. 04 hyphen after "column" to read: "water-column- and sediment pathways." (No. 04 hyphen needed to indicate that "pathways" was left out after "water-column." Otherwise, must read "water-column pathways and sediment pathways."

125 p. E-5, par 06, l.01 — Need No. 2 hyphens; See nos. 41. 98, 99.

126 p. E-5, par 06, l.06 — Need No. 2 hyphen after Bivariate; See nos. 38 & 97A.

127 p. E-6, BF heading — Needs No. 02 hyphen after "Baseline" to read "Future Baseline-Modeling Efforts."

128 p. E-6, par 02, l.01 — Need 2 No. 02 hyphens to read: "Preliminary-Model-Calibration Report."

129 p. E-6, par 02, l.02 — Need a No. 01 hyphen before "fate" to indicate connection to left-out "PCB;" thus to read: "PCB transport, -fate..." (or else it must read: "PCB transport, PCB fate...")

130 p. E-6, par 02, l.02 — Need a No. 75 comma after "fate."

131 p. E-6, par 02, l.03 — Need a No. 01 hyphen before "bioaccumulation;" (as in No. 129 to indicate th connection to left-out "PCB;" thus to read: "PCB transport, -fate, and -bioaccumulation" (or else it must read "PCB transport, PCB fate, and PCB bioac cumulation").

132 p. E-6, par 02, l.04 — Need a No. 02 hyphen after "more" to read: "more-definitive conclusions" (modifying- and preceding rule).

133 p. E-6, par 02, l.07 — See No. 14 hyphen discussion. I suggest it read: "transport- and fate mass-balance models."

134 p. E-6, par 02, l.07 — Need a No. 02 hyphen after "fish" and "body" to read "fish-body-burden models."

135 p. E-6, par 02, l.09 — Need 2 No. 02 hyphens to read: "preliminary-model-calibration work."

136 p. E-6, par 03, l.01 — No hyphen after "finely." (See No. 120.

137 p. E-6, par 03, l.03 — Need a No. 02 hyphen after "suspended" to read "suspended-solids data."

138 p. E-6, par 03, l.05 — A gold star for the hyphen in "long-term" modifying and preceding. But probably a No. 02 hyphen is needed before "hindcasting" (all precede "calibration."

139 p. E-6, par 04, l.01 — See No. 115.

140 p. E-6, par 05, l.01 — See No. 05.

141 p. E-6, par 05, l.03 — Insert No. 75 comma after "inverte-brates."

142 p. E-6, par 06, l.05 — See Nos. 05 and 140.

143 p. 1-1, par 02, l.04 — Need No. 04 hyphen after "manufactured "

144 p. 1-1, par 02, l.08 — No hyphen after "highly" (See No. 120.)

145 p. 1-1, pars 3/4 — **Shame on you for ignoring all the work NYS DEC did before EPA started doing anything constructive! You cite some this work on p. E-5 (par. 3 last line) as 1984 NYSDEC Survey (same as EPA 1984 Feasibility Study mentioned here?) Many problems may exist in using some of the NYSDEC work, but at the time when it was done, it was a major achievement.**

[I have started to skip through pages; it has taken me too long to la out my extensive hyphens tutorial. You'll probably ignore it anyway

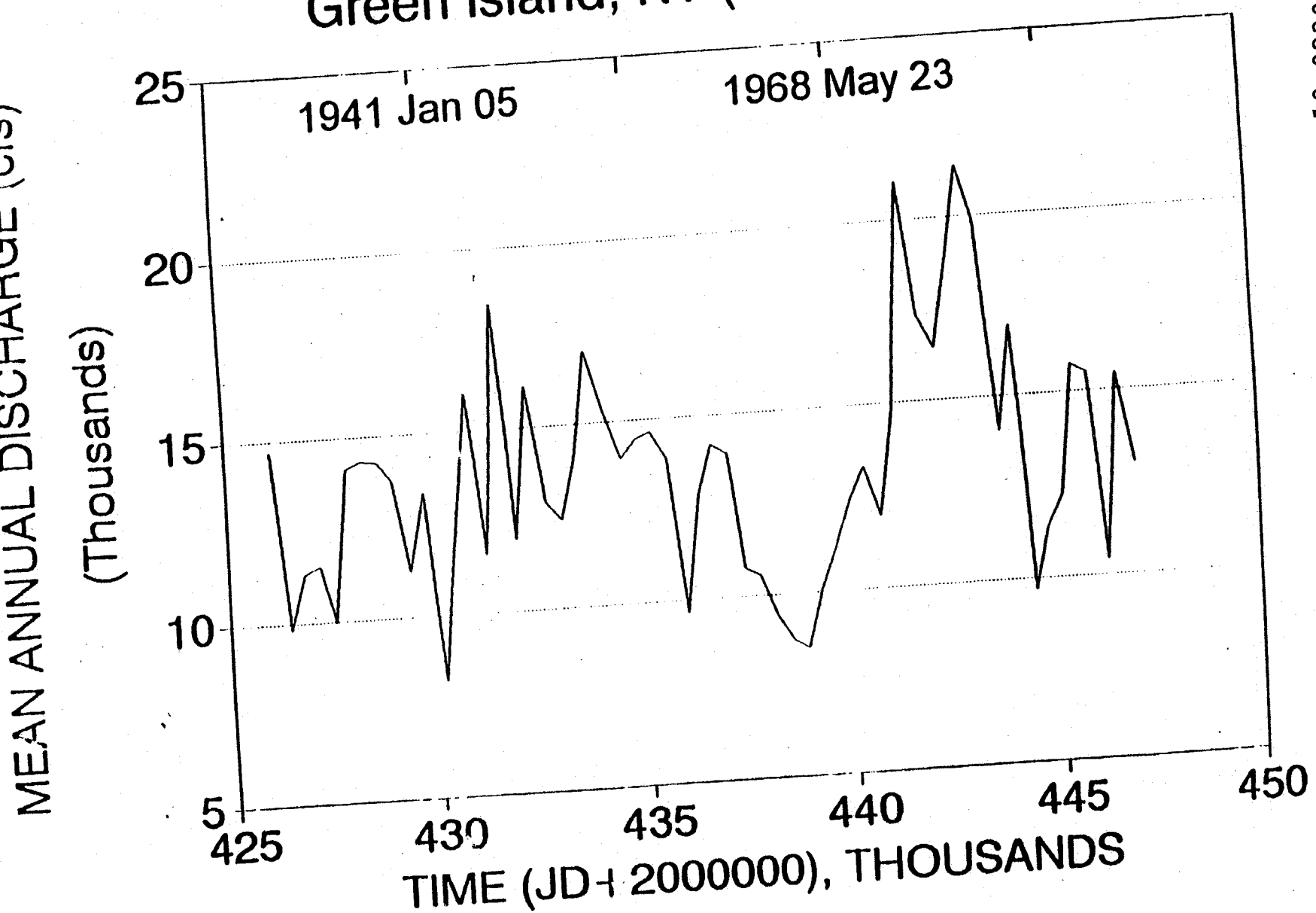
146 p. 1-2, par 01, l.05 — You get 50% for hyphens here; need a No. 02 hyphen after "water" to read "water-column sampling" and you get a rare gold star for the correct hyphenation of "flow-averaged" (modifying and preceding "composites").

Comment numbers for PP-1.1 to PP-1.159 are given on the left of the page.

147	p. 2-1, par 06, l.04	"homologues?" See No. 94.
148	p. 2-2, par 04, l.04	"homologues?" See Nos. 94 & 146.
149	p. 2-6, par 05, l.02	Delete hyphen after "vertically" See No. 120.
150	p. 3-5, par 02, l.05	Please spare us the use of "geometry" where you should employ "configuration;" "geometry" is a specific mathematical discipline. You could use it as an adjective as: "geometric configuration."
151	p. 3-5, par 02, l.08	A good place for a review of many hyphen faults. Should read: "Particle gross-settling-, resuspension-, and net-burial celerities." (Note insertion of a No. 75 comma after "resuspension-," and the change from "velocities" to "celerities" (No. 24).
152	p. 3-5, par 03, l.01	"geometry;" (See No. 150.)
153	p. 3-6, par 05, l.02	"Since" (See No. 105.)
154	p. 3-6, par 05, l.05	Change "unbound" to "nonbound." The prefix "un" implies that something was in one state, then changed to an opposite state, as in a tied shoelace that becomes untied. Thus "unbound" correctly means it was bound and then was bound no more. "Non" means it never was that way. A "nontied" shoelace is what is in the shoebox at the shoestore.
155	p. 3-7, par 03, l.02	"Since" (See Nos. 105 & 153.)
156	p. 3-7, par 05, l.01	"geometry;" (See Nos. 150 & 152.)
157	p. 3-7, par 05, l.07	Delete hyphen after "finely." See Nos. 120 & 149.
158	Fig. 1-3 Lower R corner	Rensselaer County is spelled with one N and two S's, not as shown.
159	Fig. 1-4 Upper R corner	See No. 158.

MEAN ANNUAL H.R. DISCHARGE

Green Island, NY (1929-1988)



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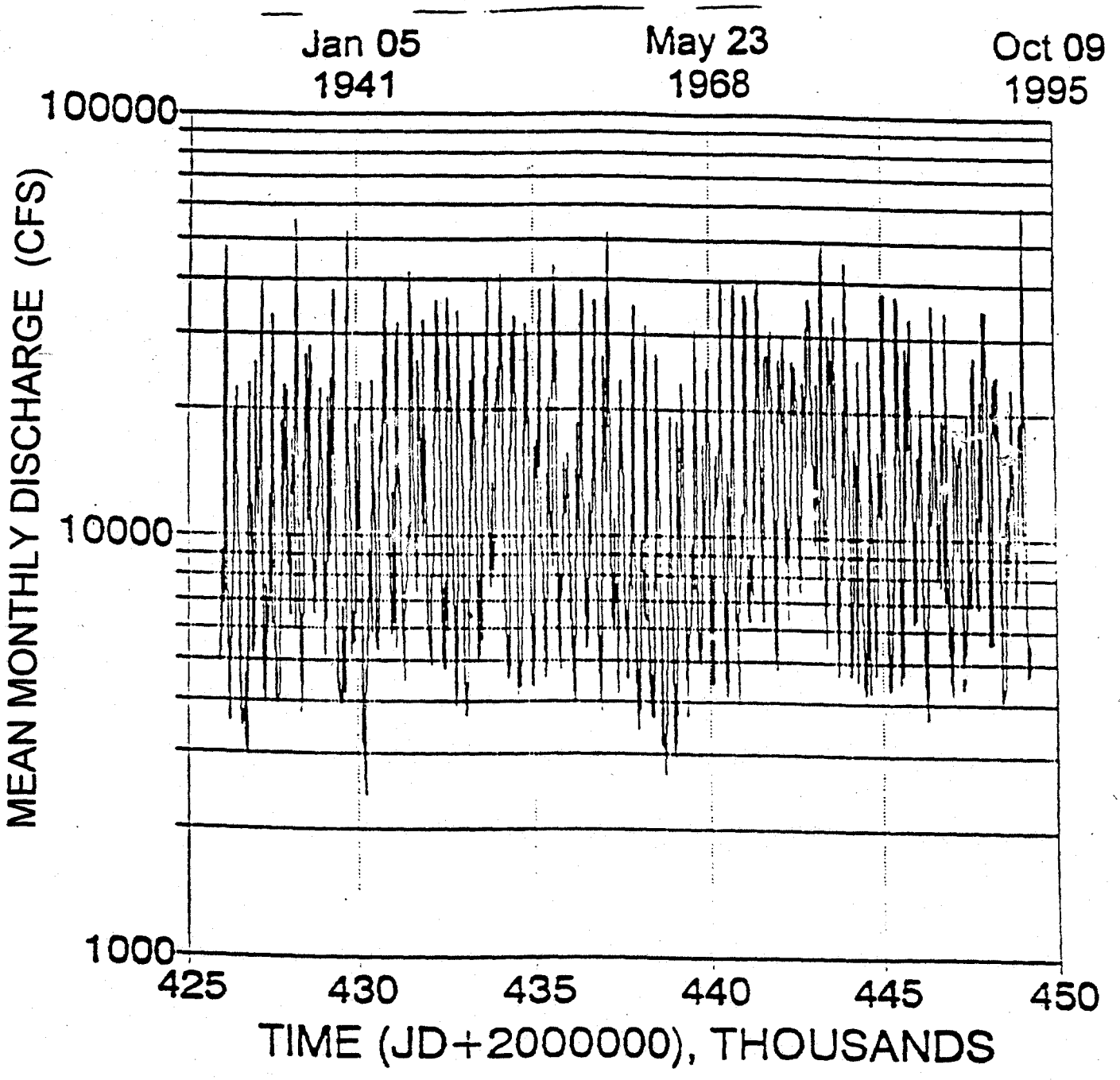
Jan 05
1941
May 23
1968
Oct 09
1995
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MEAN MONTHLY DISCHARGE (CFS)
425
430
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445
450
TIME (JD+2000000), THOUSANDS

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November 21, 1996

Mr. Douglas Tomchuk
Emergency and Remedial Response Division
U.S. Environmental Protection Agency
Region 2
290 Broadway - 20th Floor
New York, NY 10007-1866

Re: Hudson River PCBs Superfund Site: PMCR Comments

Dear Mr. Tomchuk:

Attached are General Electric Company's ("GE's") comments on EPA's "Phase 2 Report - Review Copy, Further Site Characterization and Analysis, Volume 2B - Preliminary Model Calibration Report, Hudson River PCBs Reassessment RI/FS" (October 1996) ("Report"). Please place this letter and the attached comments in the administrative record for the Hudson River PCBs Superfund Site ("Site").

The Report provides an overview of the current status of EPA's modeling effort for the Site, which is designed to assess the effect of possible remedial actions, including no action, addressing the PCB-contaminated sediments in the Upper Hudson River. GE applauds EPA's decision to provide an opportunity to comment on its modeling effort while it is still a work in progress and is in fundamental agreement with the Agency's stated goals for preparing and using these models, the the principles which guide the development of these models, and the Agency's intent to validate them against existing data.

GE has a number of concerns about the models that EPA is developing. The solids mass balance underestimates solids loading from tributaries to the Upper River, overestimates resuspension and deposition rates, and improperly decouples net sedimentation from resuspension and deposition, all of which lead to an overstatement of the transfer of PCBs from solids to water. The PCB mass balance uses sediment data from 1991 to represent 1993 conditions, ignoring the substantial release of sediments and PCBs to the River from the Allen Mill during the interim. These and other problems with the fate and transport model will become more apparent as EPA

attempts to complete its "hindcasting" against the historical data. In addition, although EPA's steady-state, statistically-based bioaccumulation models may provide some useful information, the Agency should not use them as predictive tools because they ignore variability in the relationships among PCBs in water, sediment and biota; a time-variable, mechanistic food-web model, such as the Gobas Model, is more appropriately used for predictive purposes. Finally, although EPA's depth of scour model uses the right approach to analyze the resuspension of cohesive sediments during flood conditions, EPA has made several errors in developing this model and must take care in selecting an appropriate formulation for estimating resuspension of non-cohesive sediments. All these issues, as well as several others, are set out in detail in the attachment.

There are three issues that we emphasize in this letter. First, as the Agency acknowledges in the Report, its PCB mass balance cannot calibrate to the water column PCB data in the Thompson Island Pool ("TIP") without resorting to an untested hypothesis. With no supporting data, EPA assumes the existence of a spatially-limited groundwater influx through the TIP sediments that purports to flush a sufficient quantity of PCBs from the sediment to account for the mass imbalance of PCBs across the TIP. EPA must recognize, however, that there are other, equally plausible hypotheses that can account for this mass imbalance. For example, the release of a large volume of PCB-contaminated sediments from the Allen Mill between 1991 and 1993 could have deposited fresh PCBs into the TIP sediments and, combined with biodegradation of these PCBs, could provide the source of the "excess" PCBs found in the water column at the Thompson Island Dam. Alternatively, it is possible that the water column sampling stations are not identifying the true amount of PCBs that move through the TIP, either under-quantifying the amount of PCBs entering the pool or over-quantifying the amount leaving the pool.

All these hypotheses must be considered and tested if EPA is to rely on its model with any confidence to make predictions about potential courses of action. The mass imbalance of PCBs across the TIP affects PCB levels in the TIP and further downstream. Understanding the source of these excess PCBs is critical to understand the effects of various potential courses of remediation. Without a factual grounding for and understanding of the cause of the mass imbalance, the model will not accurately predict the fate and transport of PCBs into the future. If, for example, EPA assumes an untested groundwater influx, the model may suggest that remediation addressed to deeply buried sediments will reduce the bioavailability of PCBs in the Upper River. If, however, the apparent imbalance were the result of being unable to measure the full amount of PCBs passing Rogers Island, an intrusive remedy aimed at deep sediments would have no real benefit and could possibly worsen conditions in the River. As a result, EPA cannot use its model to make predictions until the issue of the mass imbalance of PCBs across the TIP is resolved.

As EPA is aware, GE is undertaking studies aimed at answering this question and identifying which of the possible hypotheses is the cause of the TIP imbalance. We intend to

provide the results of these studies to EPA as they become available and look forward to working with the Agency to resolve this critical issue.

Second, to ensure that one can have confidence in the models when they are used to predict the effects of various remedial alternatives, the models must closely match available data. To date, EPA has only calibrated its models against a temporally limited data set between January and September 1993. If EPA's models provide a close fit against the more extensive historical data set, then arguments for their use as predictive tools will be stronger. There are a number of tests to validate the models:

- Solids Balance: comparison of model predictions with data on the spatial patterns of TSS during low flow, temporal and spatial patterns of TSS and water column PCBs during flood events, and annual average solids loading passing Schuylerville, Stillwater and Waterford will all verify the solids balance.

- PCB Fate: comparison of model predictions with data on spatial patterns of water column PCBs during low flow and spatial changes in water column PCB composition will verify PCB flux from pore water and PCB loss by volatilization.

- PCB Loss: comparison of model predictions with data on long-term changes in surface sediment PCB levels, vertical profiles of PCBs in sediments, and PCB inventory in sediment will verify the loss of bioavailable PCBs from sediment.

- Overall Test of Model: comparison of model results with data on the annual average flux of PCBs passing Schuylerville, Stillwater and Waterford will provide an overall test of the model.

- Effect of Allen Mill Release: comparison of model results with data on the apparent increase in the PCB flux from Fort Edward to Thompson Island Dam/Schuylerville that occurred between the mid- to late-1980s and the 1990s will verify that the model reflects the effects of the Allen Mill release.

- Bioaccumulation Models: comparison of model results with data on temporal changes in predatory and forage fish at the TIP and Stillwater over a 15-year period and the response of the fish to the short-term changes in water column PCB levels in the early 1990s will verify the predictive power of the bioaccumulation models.

These comparisons will uncover any apparent biases and are essential to have confidence in the predictive power of the models.

Third, the proposed use of the Thomann model, which analyzes and predicts the body burden of PCBs in striped bass in the Lower Hudson River, raises fundamental issues about the scope and focus of the reassessment. The Report states, "The purpose of the Reassessment is to determine an appropriate course of action for the PCB contaminated sediments in the Upper Hudson River in order to protect human health and the environment." (Report at E-1) The scope and focus does not include any consideration of remedial action in the Lower Hudson. It is undisputable that there are a number of significant PCB discharges into the Lower Hudson River which affect PCB levels in fish, such as the striped bass, in the Lower River and that EPA has not identified any parties responsible for those Lower River discharges as PRPs in this matter. Presumably, the justification for this is found in the purpose of the Reassessment: its remedial scope and focus are confined to the Upper River. This scope is appropriate because, notwithstanding EPA's claim to the contrary in the Report (Report at E-1), the Site is confined entirely to the Upper River. See Administrative Record, NPL-U1-2-29 (EPA).

EPA must accept the constraints that are imposed as a result of the limited geographical reach of the Site and the Agency's choice to limit its review to the Upper River. It is reasonable to look at the effect of potential remedial measures in the Upper River to assure that a possible remedial course of action will not have adverse remedial effects on the Lower River or, at most, if there are adverse effects, that they are acceptable when weighed against other benefits.

Justifying Upper River remedial action on the basis of benefits to Lower River fish is an entirely different matter. If benefits to the Lower River are to be used to justify remedial action in the Upper River, there must be an investigation and evaluation of remedial alternatives, such as source control, in the Lower River, and a congruent recognition that responsibility for achieving these benefits falls on a much wider group of parties than the present PRPs; that wider group must be classified as PRPs and treated as parties to this proceeding.

EPA must be clear what its objectives in the Lower River are in this reassessment. If the objective is simply to avoid any increase in risk in the Lower River, the scope of the reassessment need not address sources of PCB discharge in the Lower River. If the objective is to decrease risk or attain a human health protection or an ecological risk reduction goal in the Lower River, EPA must address the Lower River sources of PCB discharge. EPA can not defend as cost-effective a remedy for the Lower River which examines only Upper River sources. It may well be that the cost effective remedy for the Lower River is control of Lower River sources, and the failure of the Agency to consider and analyze that obvious and plausible possibility will render clearly arbitrary any Upper River course of action which is justified on the basis of Lower River benefits. In addition, fundamental fairness is involved: the costs of a Lower River remedy should not be borne entirely by Upper River sources, thus providing a remarkable windfall to Lower River sources.

It follows that if EPA intends in any way to justify and support a remedial course of action in the Upper River by reference to benefits in the Lower River, it must investigate the sources of PCB discharge to the Lower River that contribute to the human health or ecological risk in the Lower River; and determine whether the cost effective remedy to obtain that beneficial reduction in risk is remedial action in the Upper River or the Lower River or a combination of the two. Such an investigation and determination calls for identifying the Lower River dischargers as PRPs so that, like GE, they can fairly express their views and provide the benefit of their expertise and analysis.

GE looks forward to working with the Agency to address the issues we have identified in these comments. In light of GE's own experience developing an integrated PCB fate, transport and bioaccumulation model for the Upper Hudson River, we are available to discuss our comments and the related issues with the Agency and to work with EPA to improve the predictive power of the models to ensure that a factually-based remedy is selected.

Sincerely yours,

Angus Macbeth
Thomas G. Echikson

attachment

cc: Richard Caspe (USEPA Region II)
Michael Zagata (NYSDEC)
Paul Simon (USEPA Region II)
Ann Rychlinski (USEPA Region II)
John Cahill (NYSDEC)
Ronald Sloan (NYSDEC)
William Ports (NYSDEC)
Walter Demick (NYSDEC)
Steven Hammond (NYSDEC)
Jay Field (NOAA)
Ann Secord (USFWS)
Al D'Bernardo (TAMS)
Victor Bierman (LimnoTech)
Charles Menzi (Menzi-Curie)
Jon Butcher (Tetra Tech)

COMMENTS OF GENERAL ELECTRIC COMPANY ON

PHASE 2 REPORT - REVIEW COPY
FURTHER SITE CHARACTERIZATION AND ANALYSIS
VOLUME 2B - PRELIMINARY MODEL CALIBRATION REPORT
HUDSON RIVER PCBs REASSESSMENT RI/FS
OCTOBER 1996

November 21, 1996

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

General Electric Company ("GE") submits these comments on the United States Environmental Protection Agency's ("EPA") "Phase 2 Report - Review Copy, Further Site Characterization and Analysis. Volume 2B - Preliminary Model Calibration Report. Hudson River PCBs Reassessment RI/FS" (October 1996) ("Report"). The Report describes the current status of EPA's modeling effort to predict the levels of PCBs in sediment, water and fish in the Upper Hudson River under various remedial scenarios, including no action.

It appears that GE and EPA agree on several important aspects of the modeling effort for the Hudson River PCBs Superfund Site. We agree generally with the objectives and focus of the modeling effort identified in the Report, as well as the Agency's conclusion that modeling is the appropriate way to address the questions of PCB fate. transport and bioaccumulation in the Upper Hudson. We also agree with EPA that the principle of "mass balance" should be the basis of its models and on the need to assure that model predictions are calibrated against and are consistent with the available data.

Notwithstanding this general agreement, there are several fundamental problems with EPA's models that should be corrected as EPA moves forward. We urge EPA to correct these problems and look forward to assisting the Agency in this endeavor. Given that the modeling effort is a "work in progress," we request that the Agency provide an opportunity to comment on its work in refining the models before they are used to make predictions about the

appropriateness of remedial action. The problems that EPA must address as it develops its model more fully are set out in detail in these comments and are summarized below:

1. There are three significant problems with the solids balance in EPA's fate and transport model. EPA has underestimated the solids loadings to the Upper River from the Snook and Moses Kills. EPA's deposition and resuspension rates, particularly during low flow, are too high and cannot be calibrated against the other solids parameters. Finally, the sedimentation rate is not integrated into the model as the net of deposition and resuspension, violating the principle of mass balance. (1)

2. The problems with the solids mass balance affect EPA's estimates of the PCB mass balance. By overestimating resuspension and deposition, underestimating tributary solids loadings, and decoupling sedimentation from the other solids parameters, the model overstates the transfer of PCBs from sediment to water, which, in turn, implies greater benefits from remedial actions aimed at sediments than will be the true case. (2)

3. GE has several other concerns with the PCB mass balance in EPA's model. The model's estimate of initial conditions of PCBs in the sediment are based on data that do not reflect the significant loadings of sediments and PCBs from the Allen Mill in 1991 to 1993. EPA's model also fails to consider the effect of PCB dechlorination in the sediments of the Upper Hudson. The manner in which EPA "corrected" GE's PCB data also appears to contain errors. (3)

Finally, the limited time period for which EPA has attempted to calibrate the model is insufficient to test the model's ability to represent the long-term fate of sediment PCBs.

4. EPA's model is unable to achieve a PCB mass balance across the Thompson Island Pool ("TIP") without resort to hypothesized mechanisms, particularly the introduction of groundwater flux of buried PCBs, for which there is no factual demonstration. There are other plausible hypothesized mechanisms that can explain the mass imbalance of PCBs across the TIP, including (1) inaccurate estimation of the PCB load across the TIP by GE's monitoring program, (2) increased surface sediment concentrations resulting from the Allen Mill release, (3) external load from dredge spoil sites, or (4) resuspension of surface sediments at low flows. Until the cause of the mass imbalance of PCBs across the TIP is understood, model predictions of remedial scenarios will not be sufficiently fact-based to be useful in addressing the key reassessment questions. GE is working to collect data to test all these hypotheses and will provide these data to EPA as they become available. (4)

5. The shortcomings in EPA's preliminary fate and transport model will become more apparent as EPA attempts to calibrate it against the historical PCB data in fish, water and sediments. For example, EPA's proposed groundwater inflow would result in greater quantities of PCBs moving into the water column from sediments than the historical water monitoring data show. Similarly, this mechanism would result in depletion of the PCB inventory at a rate that is much higher than the sediment data show. (5)

6. EPA should not use the two steady-state statistically-based bioaccumulation models -- the Bivariate Statistical Model and the Probabilistic Food Chain Model -- to make predictions because they ignore the short and long-term variability in the relationships among PCB levels in the water column, sediment and fish and do not attempt to describe or respond to the mechanisms by which fish bioaccumulate PCBs. Instead, EPA should use a time-variable, mechanistic food web model, such as the Gobas model, which explicitly incorporates variability in exposure, uptake and depuration of PCBs in fish and reflects real world bioenergetic and toxicokinetic mechanisms. GE has been developing such a model and offers to share this work with EPA as the Agency develops its food web model. (6)

7. EPA's depth of scour model to predict the effect of a 100 year flood on solids and PCBs in the Upper Hudson River is sound in its application of principles and its analytic approach. The model properly applies the Lick equations to the dynamics of cohesive sediment resuspension, but we believe there are some errors in the application of these equations. In addition, we recommend that EPA use a modified van Rijn model to model the resuspension properties of non-cohesive sediments in the Upper Hudson. (7)

8. EPA must test its models against the extensive data set for the Upper Hudson River to have any confidence in their predictive powers. Specifically, EPA should validate its: (8)

- Solids balance model against (1) spatial patterns of TSS during low flow, (2) temporal and spatial patterns of TSS and water column PCBs during flood events, and (3) annual average solids loading passing Schuylerville, Stillwater and Waterford.

- PCB fate model against (1) spatial patterns of water column PCBs during low flow and (2) spatial changes in water column PCB composition.

- Estimate of PCB loss against long-term changes in surface sediment PCB levels, vertical profiles of PCBs in sediments, and PCB inventory in sediment.

- Fate and transport model against the annual average flux of PCBs passing Schuylerville, Stillwater and Waterford.

- Estimate of the effect of the Allen Mill release against the apparent increase in the PCB flux from Fort Edward to Thompson Island Dam/Schuylerville that occurred between the mid- to late-1980s and the 1990s.

- Bioaccumulation models against temporal changes in predatory and forage fish at the TIP and Stillwater over a 15-year period and the response of the fish to the short-term changes in water column PCB levels in the early 1990s.

9. EPA has not clearly defined its objectives in using the Thomann model of PCB fate, transport and bioaccumulation in the Lower Hudson River. Given the present scope of the reassessment, EPA should only use this model to assess whether remediation in the Upper River would have an unacceptable adverse impact on the Lower River, and only after Thomann and Farley have completed their update of the model. (9)

GE commends EPA for providing this opportunity to comment on its modeling effort. As EPA recognizes, some of the topics in the Report are closely related to EPA's yet-to-be-issued Data Evaluation Report. As a result, we may revisit some of these topics as they are developed more fully in future reports.

I. INTRODUCTION

In 1989, Region II of the U.S. Environmental Protection Agency ("EPA") decided to reassess its 1984 decision under the Comprehensive Environmental Response, Compensation, and Liability Act ("CERCLA" or "Superfund") that no action should be taken with regard to sediments at the Hudson River PCB site (U.S. EPA, 1984). This reassessment is to determine what CERCLA action, if any, should be taken with regard to the PCB-contaminated sediments in the Upper Hudson River. The reassessment is focused on answering three central questions (U.S. EPA, 1996b; pg. 3-1):

10

1. When will PCB levels in fish populations recover to levels meeting human health and ecological risk criteria under continued No Action?

2. Can remedies other than No Action significantly shorten the time required to achieve acceptable risk levels?

3. Are there contaminated sediments now buried and effectively sequestered from the food chain that are likely to become "reactivated" following a major flood, possibly resulting in an increase in contamination of the fish population?

As a first step, the reassessment reviewed existing data (U.S. EPA, 1991) and collected new data. EPA has now turned to developing a fate and transport model and three associated bioaccumulation models for the Upper Hudson River to help answer these questions. In addition, the Agency has developed a separate sediment model for flood conditions and examined an existing model of PCB concentrations in striped bass in the Lower River. If successful, the modeling effort will replicate data reflecting known past conditions in the River - water flows, total suspended solids ("TSS") and PCB concentrations in water, and PCB concentrations in sediment and through the aquatic food chain up to the fish that people, birds, and other animals may eat. If successfully developed, EPA can then use the models to predict

the course of natural recovery with no intrusive remedial activity, as well as the future PCB concentrations in environmental media and aquatic biota under assumed remedial scenarios. In October 1996, EPA issued for review and comment its Preliminary Model Calibration Report ("Report") (U.S. EPA. 1996b).

These comments, prepared with the aid of HydroQual, Inc. (experts in modeling the behavior of contaminants in surface water and biota) set out General Electric Company's ("GE's") views regarding the Report. As the Agency recognizes, some of the topics addressed in the Report are not fully developed, and some are intertwined with issues to be addressed in the Data Evaluation Report, which the Agency has not yet issued. Consequently, as these topics are more fully developed and discussed in future reports, GE is likely to return to many of the issues addressed in these comments.

GE generally agrees with the fundamental objectives and focus that are the foundation for the present Report. GE largely agrees with EPA on the central questions which the reassessment should address (GE believes, however, that EPA needs not only to consider what impact a large flow will have on PCB levels in the River, but also whether and to what extent remedial efforts would mitigate these impacts). GE also agrees with EPA that modeling is the appropriate methodology for addressing the questions of PCB fate, transport and bioaccumulation in the Upper Hudson River and is the appropriate way to achieve the reassessment objectives. Moreover, GE agrees with EPA that mass balance is the appropriate principle on which to base the fate and transport model.

Based upon the information provided in the Report, we believe EPA and GE also agree on the basis by which a model should be judged: (1) its congruence with accepted scientific laws and principles; (2) the internal consistency of the physical, chemical, and biological mechanisms that are reflected in the model; (3) the plausibility and reasonableness of the professional judgments and assumptions used at points where scientific principle or relevant data do not constrain the modeler; and, most important, (4) its ability to replicate observations of the physical system being modeled over appropriate time and space scales.

Modeling provides a method for describing the relationship of elements in a complex natural system, such as the Upper Hudson River. It requires the modeler to analyze and describe the relations between the elements in the system. It develops knowledge of which elements have the greatest influence over the results of interest and which elements have the greatest uncertainty associated with them. This process allows a refined focus on those areas where data collection, laboratory experiments or refinement of judgment will be of greatest value – and in some cases will be essential – to produce modeling results that will be useful for decision-making. The validation of the model against known data provides an acid test for the ultimate value of the model and defines the degree to which one's confidence in the models' predictive power is warranted.

In its present iteration, many aspects of EPA's models appear to meet the evaluation criteria set out above, but there are others where the model clearly falls short. This may be the result of the EPA's models being works in progress, and we commend EPA for

seeking input during the development phase to help improve the quality of the Agency's effort. This is the spirit in which we submit these comments. Our comments address these central aspects of modeling and reflect, as well, the experience of GE and its consultants in attempting to construct GE's own PCB fate, transport and bioaccumulation model for the Upper Hudson River.

II. EPA's FATE AND TRANSPORT MODEL

EPA's fate and transport model attempts to model the mass balance of solids and PCBs in the Upper River. Four factors primarily control the calibration of this model: solids or sediment transport, PCB partitioning, upstream loading of PCBs, and initial sediment PCB conditions. Because these factors also control PCB dynamics in the river and the operation of the model, it is critical that the model accurately define them. GE and EPA have no material disagreement about PCB partitioning or what the data show as the upstream loading of PCBs (although a question remains as to the accuracy of that data, particularly after the Allen Mill discharges of 1991 to 1993). We do have clear differences of opinion on EPA's assumed initial sediment PCB conditions because the model uses 1991 sediment PCB data to reflect conditions in 1993, ignoring the large amount of PCB-containing sediment that entered the River upstream of the model boundary between September 1991 and March 1993 from the failure of the Allen Mill. This discharge probably affected surficial sediment conditions in the Thompson Island Pool ("TIP"). We also have several areas of significant disagreement with regard to solids (or sediment) transport issues and the associated behavior of PCBs. These are the central issues on which we focus our comments on EPA's fate and transport model.

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A. Solids Mass Balance

The physical-chemical fate and transport model that EPA has developed for the Upper Hudson River appropriately relies on the principle of mass balance. As both EPA and GE have recognized, solids transport is critical to the fate of PCBs in the River because of the affinity of PCBs for solids, the release of PCBs to the water column through sediment resuspension, and the burial of PCBs through net solids deposition. Development of a solids mass balance model that accurately simulates the loading, resuspension, deposition and transport of suspended solids and sediments in the Upper Hudson River is thus necessary to the calibration of the PCB model and to the model's ability to evaluate remedial alternatives. Without a detailed understanding of sediment transport, the model will not accurately predict the fate and transport of PCBs in the Upper Hudson River and thus will not materially assist EPA in its evaluation of alternatives.

The solids mass balance described in the Report has several significant shortcomings:

1. Solids loading to the River from Snook Kill and Moses Kill are underestimated;
2. Deposition and resuspension rates, particularly during low flow, are too high; and
3. The sedimentation rate is not integrated into the model as the net of deposition and resuspension, violating the principle of mass balance.

The solids mass balance is constrained by data on TSS concentrations and mass flux in the water column at various points in the River. From reach to reach, the TSS levels are controlled by solids loading from upstream and tributaries and by the sedimentation rate. The

sedimentation rate, in turn, is the net difference between solids deposition and solids resuspension. Thus, solids loading, deposition and resuspension, and sedimentation rate are all closely related in achieving the solids mass balance.

There also is an important link between the solids and PCB mass balances. Changes in the internal working of the solids mass balance model can have major impacts on the PCB mass balance. The PCB mass balance provides a check on the solids mass balance and *vice versa*. The effect of changes made in one aspect of the model must be considered in evaluating both aspects of the model. Consequently, many of the issues that arise in examining the solids balance estimates also arise in the context of the PCB mass balance estimates.

Solids Loading from the Tributaries

EPA has underestimated solids loadings from tributaries to the Upper Hudson River. Although EPA uses the proper approach for estimating loads from the upstream and major tributary sources, the method used to estimate solids loads from minor tributaries, particularly into the TIP, results in a significant underestimation of actual loadings. This is confirmed by data that EPA collected in 1994 and reported in the Database Report (U.S. EPA, 1995), but which EPA has not yet incorporated into its model.

The standard and accepted method for estimating solids loading is to use available TSS and flow rate data to develop a solids rating curve, which can then be used to predict solids loading as a function of flow rate. This is the method EPA used to develop solids loadings

relationships for the Upper Hudson River at Fort Edward (the upstream boundary), the Hoosic River, and the Mohawk River, and GE generally agrees with EPA's approach with respect to the loadings estimates for these sources. GE also agrees with EPA's use of the minimum variance unbiased estimator ("MVUE") to correct for log-linear regression analysis bias during development of the solids rating curve because this will provide increased accuracy in estimating solids loads.

Nevertheless, we believe that further analysis of the larger data set will improve the accuracy of these loadings estimates. First, with respect to the loadings estimate at Fort Edward, EPA should include all the available TSS data in the MVUE analysis. By relying only on the limited EPA Phase 2 1993 TSS data set, the validity of EPA's analysis is uncertain. EPA rejected both the earlier TSS data, claiming that the TSS-flow relationship had changed over time, and the TSS data GE collected in 1993, but the Agency failed to conduct a proper statistical analysis to ensure that it was appropriate to exclude these data. We are confident that such an analysis would show that EPA should include a large portion of the data set in the TSS-flow relationship, which will increase the power and accuracy of the regression. Second, EPA should validate its loadings estimates for all the tributaries and the upstream boundary with data collected in April, 1994 and other high flow periods. This validation is important to determine whether EPA's solids loadings estimates are correct.

EPA correctly recognized that Batten Kill and Fish Creek contribute significant solids loads to the Upper Hudson River (U.S. EPA, 1996b; pg. 4-7). The Agency estimated the

loadings from these tributaries by comparing them to and developing a ratio of the TSS-flow relationship developed for the Hoosic River. This is not an unreasonable first approximation, but EPA should test the validity of the approach by comparing predicted with observed loads in the Batten Kill during April, 1994.

EPA's method for estimating TSS loads for Snook Kill and Moses Kill, on the other hand, is fundamentally flawed. EPA improperly assumed a constant TSS value of 5 mg/l for these tributaries, ignoring the evidence that they contribute substantial solids. EPA should use the data from April, 1994 to establish the relationship of solids loading from these tributaries to loadings in the Hoosic River, similar to the approach used to estimate loadings from Batten Kill and Fish Creek. Although these data are limited, they do show that these tributaries can contribute significant loadings into the TIP, with peak values of over 200 mg/l.

EPA's assumed loadings value for the Snook and Moses Kills results in an implausible loading per unit drainage area (i.e., sediment yield) for these tributaries. During the 1993 calibration period, EPA's assumed rate results in a sediment yield of 1.1 metric tons/mi^2 for the Snook and Moses Kills, 100 times less than the calculated yield of 111 metric tons/mi^2 for the Hoosic River. This vast discrepancy cannot be accounted for simply by differences in soil type and land use along the Snook and Moses Kills and the Hoosic River and thus demonstrates the invalidity of the 5 mg/l assumption for the Snook and Moses Kills.

Solids Deposition and Resuspension

The formulations that EPA presently uses to simulate deposition and resuspension in the solids transport model are unsupported by generally accepted theory and will not produce accurate predictions of solids or PCB fluxes across the sediment-water interface. EPA must include resuspension and deposition formulations that are physically consistent with the observed behavior of sediments in both laboratory and field studies in its modeling framework before it uses the solids transport model to make predictions.

There are four fundamental problems with EPA's simulation of resuspension and deposition: (1) resuspension during low flows; (2) constant resuspension rate at high flow; (3) constant settling velocity; and (4) assumed resuspension rates based on judgment and not calibrated with supporting data. These invalid assumptions result in a model that overestimates resuspension of solids and PCB movement from the sediment bed into the water column.

First, laboratory and field studies on cohesive and non-cohesive sediment erosion properties show that resuspension only occurs when the bed shear stress exceeds some critical value, which depends upon the bed properties (Galiani, et al., 1991; Hawley, 1991; Hayter and Mehta, 1986; Parchure and Mehta, 1985; van Rijn, 1984; Araturai and Krone, 1976). Examination of bottom shear stresses predicted by a two-dimensional hydrodynamic model of the Upper Hudson River that GE is developing indicates that critical shear stresses are not exceeded at typical low flow rates. As a result, resuspension will be negligible in both cohesive and non-cohesive bed areas during low flows in the Upper Hudson River. This conclusion is

supported by modeling results, using calibrated and validated sediment transport models, in other riverine systems (Ziegler and Nisbet, 1994).

Second, use of a constant resuspension rate during high flows ignores the observed phenomenon of sediment bed armoring for both cohesive and non-cohesive sediments. Rather than continual resuspension at high flow, resuspension occurs only until the surface is depleted of resuspendable particles, leaving larger or cohesive particles at the surface that form an armoring layer for the particles below (Ziegler and Nisbet, 1994; Karim and Holly, 1986; van Niekerk, et al.). The assumption of a constant resuspension rate is also inconsistent with the resuspension formulation used in EPA's depth of scour model, which accounts for bed armoring of cohesive sediments. Neglecting bed armoring causes the fate and transport model to overestimate the resuspension of solids and PCBs during high flow events.

Third, EPA has assumed a constant settling velocity of 2 m/day to describe deposition rates in the Upper Hudson River. This assumption, however, does not accurately represent the dynamics of sediment deposition in the River. Laboratory studies on cohesive and non-cohesive sediments show that deposition rates vary with particle size and shear stress at the sediment-water interface, both of which change with river flow (Ziegler and Nisbet, 1994; van Rijn, 1984; Mehta and Partheniades, 1975). EPA should include these effects in the formulations used to simulate deposition in the solids transport model.

Fourth, specifying deposition and resuspension rates based on judgment and model calibration, without supporting data, can produce highly inaccurate solids fluxes between the water column and sediment. The accuracy of the flux rates is dependent on the accuracy of the solids loading estimates used in the solids mass balance. If tributary solids loadings are underestimated, as we demonstrated earlier for the TIP, the model will overestimate net resuspension in order to account for observed TSS levels.

This is illustrated by examination of the solids balance presented in the Report (U.S. EPA, 1996b; Figure 4-35). Net erosion of 9,100 MT is calculated during the simulation period. However, if Snook and Moses Kills have solids yields similar to the Hoosic River, as we believe they do, the solids loading would increase by about 22,000 MT. Instead of net erosion, the mass balance would indicate net deposition of about 13,000 MT.

The flawed deposition and resuspension rates used in the model are evident in EPA's attempts to calibrate the model. Only the net result of deposition and resuspension, and not the absolute values of deposition and resuspension, affect the water column solids balance. Thus, in the absence of an independent assessment of deposition or resuspension, efforts at calibration are circular: one parameter is played off against the other. For example, the Fort Edward to Stillwater solids balance during the low flow or "Non-Event" portion of the model calibration includes resuspension and settling fluxes that exceed the solids flux passing Stillwater (11,000 to 15,000 MT versus 10,000 MT). Because the presumed solids loading to the River between Fort Edward and Stillwater during this period approximately equaled the solids flux

passing Stillwater, even eliminating deposition and resuspension would not appreciably affect the solids calibration. Thus, the solids balance provides no basis for calibration of these processes.

In contrast, the PCB calibration is very sensitive to the absolute values of deposition and resuspension and does provide a basis for calibration of the solids balance. The comparisons of model and data in Figure 4-32 of the Report show that the model overestimates water column PCBs at low PCB concentrations. This demonstrates that the model overestimates the transfer of PCBs to the water column and, hence, the solids fluxes between the sediment and water column at low flow.

Sedimentation Rate

Another fundamental problem with the solids modeling framework is that the model defines the sedimentation rate independently of the net transport of solids across the sediment-water interface. The model assumes an external net sedimentation rate of 0.22 cm/yr, derived solely from profession judgement (U.S. EPA, 1996b). This rate is unrelated to the resuspension and deposition rates used in the model. Because sedimentation is tied directly to the net transport of solids across the sediment-water interface, EPA should restructure the model to calculate the sedimentation rate as the net difference between resuspension and deposition. This will bring greater internal consistency to the model.

The result of EPA's approach is that the solids transport model predicts net erosion during the calibration period. Although net erosion might be plausible for a short time period, it is inconsistent with data showing net sedimentation in the Upper Hudson River (HydroQual, 1995a). The model's prediction of net erosion also demonstrates that EPA has underestimated the solids loadings to the River. (11C)

B. Calibration of PCB Mass Balance

GE has a number of concerns with respect to the calibration of PCBs in EPA's model. First, the problems with the solids balance – namely, the underestimation of tributary loadings, the overstatement of the resuspension and deposition rates, and the decoupling of the sedimentation rate from the other solids parameters – cause the model to overstate the transfer of PCBs from sediments to water. Second, the initial conditions of PCBs in sediment are based on data that do not reflect the significant loadings of sediments and PCBs from the Allen Mill in 1991-1993, thus adding substantial uncertainty to the model's estimates. Third, EPA failed to consider or incorporate the documented occurrence of PCB dechlorination or degradation within the sediments. Fourth, there appear to be errors in EPA's "correction" of the GE PCB data to be consistent with EPA data. We address each of these issues in turn.

Relationship Between Solids Transport Components and PCB Fate Components (11D)

The inaccuracies in the solids transport model have significant implications to the PCB model. They result in overestimation of the transfer of sediment PCBs to the water column and underestimation of the reduction of surface sediment PCBs by burial. As explained in

Section II.A, we believe that the EPA model underestimates the solids loading from tributaries and overstates the resuspension and deposition rates. This, in turn, results in excess movement of PCBs from the sediment to the water column by way of desorption through instantaneous equilibration between resuspended particulate PCB and water column dissolved PCBs. Based on available information and generally accepted theory, we believe that the Report's conclusion that sediments have a dominant influence on water column PCBs is incorrect.

EPA can take the following actions to improve the accuracy of its PCB fate model:

- Use the 1994 TSS study to refine the solids loading estimates for all of the tributaries. Particular attention should be paid to the solids yields from Snook Kill and Moses Kill.
- Eliminate resuspension at low flows unless there is conclusive evidence that this phenomenon occurs in the Upper Hudson River. (11E)
- Incorporate the concept of bed armoring into the description of high flow resuspension. This is best accomplished by using the theory incorporated in the scour model.
- Calculate sedimentation as part of the solids mass balance.
- Incorporate the variation in solids load composition and deposition velocity with river flow. (11F)
- Calibrate and validate the sediment transport model against data for multiple floods.
- Validate the balance between solids loading and resuspension by comparing computed and observed water column PCBs during floods.

Initial Sediment Conditions

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EPA's model relies entirely on 1991 sediment sampling data to establish the initial composition and concentration of PCBs in sediments in 1993. The release of substantial quantities of fresh PCBs and sediment to the River between the fall of 1991 and the spring of 1993, combined with alteration of these fresh PCBs, undoubtedly resulted in a significant change in the composition and concentration of surface sediments in the TIP and perhaps elsewhere in the Upper River. GE estimates that the collapse of the Allen Mill in 1991 resulted in the release of substantial quantities of PCB-containing sediment from scouring of sediments in the Mill's tailrace tunnel. Since this occurred during a period of low flow in the Hudson River, it is likely that a significant portion of the sediment-bound PCB was deposited upstream of the Thompson Island Dam ("TID"). As a result, relying on data that do not reflect this significant event creates substantial uncertainty in the calibration of EPA's model. We recommend that the starting date for initial sediment conditions in the model calibration be at a point in time for which sediment data exist, such as 1991.

The impact of the changed sediment conditions may be evident in PCB concentrations in fish in the TIP. Comparisons of the changes in PCB content in brown bullhead, largemouth bass, and pumpkinseed in the TIP and at Stillwater following the 1991 and 1992 PCB releases shows a greater increase in the TIP, as shown in Figure 1. Given that water column concentrations were similar at the two locations, the impact in the TIP would only be greater if exposure concentrations in the sediments increased to a greater extent in the TIP than at Stillwater. The higher sediment concentrations might be reflected in the increased PCB levels in

brown bullhead and largemouth bass (both of which derive some of their PCBs from sediments) caught in the TIP compared to those caught near Stillwater; and the lack of any discernable difference in the PCB levels in pumpkinseed (which derives most of its PCBs from the water column) caught at these two locations. This suggests an increase in surface sediment concentrations of PCBs in the TIP following the discharges from the Allen Mill.

Analytical Issues

An important issue identified in the Report is an apparent discrepancy between the GE PCB data and the EPA data (U.S. EPA, 1996b; pg. 4-13). EPA believes that the GE data set significantly underestimates the amount of congeners BZ4 and BZ10. The GE methodology, which was based upon the EPA analytical method used in the Green Bay Mass Balance study, utilizes a DB-1 capillary column. With this column, PCB congeners BZ4 and BZ10 coelute in peak 5. The method used by EPA for the Hudson River, in contrast, is able to distinguish these peaks.

Knowledge of PCB congener composition is useful in evaluating the sources of PCBs that are responsible for the measured PCB load in the TIP water column because the various PCB sources may have different congener compositions. Studies have shown that the sediment PCBs have been subjected to extensive anaerobic dechlorination (Abramowicz, 1991; Brown, et al., 1987) and that the sediment PCBs are enriched in congeners with fewer chlorine atoms than the PCBs entering the pool at Rogers Island, which appear to be mainly undechlorinated Aroclor 1242.

Additionally, recent work (Fish and Principe, 1994) demonstrates that dechlorination may occur on relatively short time scales (6-12 months) and in surface sediments, not just deeply buried sediments. Congener BZ4 is produced during this process and high levels have been found in sediments. Because the EPA-developed analytical technique used by GE underestimates the amount of this congener present in the water column, the PCB load in the TIP does not appear as dechlorinated in reports of the GE data as it does in EPA's own data. In fact, the composition of PCBs in the TIP water in the GE data closely resembles unaltered Aroclor 1242 that has partitioned from sediment particles to the water column, whereas EPA's data suggest that the PCBs in the TIP water derive from dechlorinated PCBs.

GE is working to understand why the EPA Green Bay method underestimates these congeners. The 1994 Cook memorandum EPA provided to GE describes the differences in the EPA and GE method for many Aroclor standards. Based on our initial review, it appears that the Green Bay method used by GE was based on flawed assumptions concerning the amounts of certain congeners in the tested standards. Recent work by GE provides more accurate assessments of which congeners are present in each Aroclor standard. This information should allow a correction to be made to the existing GE data, and preliminary recalculations of congener levels in the various standards compared to those reported in the 1994 Cook memorandum are in much better agreement. When this analysis is completed, we will document our findings and any corrections applied to the data.

It is unfortunate that EPA did not communicate to GE its knowledge of this important discrepancy in a more timely way. For the last two years GE has continued to generate data using the Green Bay method under agreement with EPA as part of the Remnant Deposits Monitoring Program. If notified earlier, we could have altered our analytical method to be consistent with that used by EPA, thus eliminating, at least in part, the need to "correct" for different analytical methods.

Dechlorination/Biodegradation Issues

Work performed by GE (Abramowicz, 1991; Brown et al, 1987) and others (Quenson, et al., 1990) clearly demonstrates that naturally occurring microorganisms in the sediments of the Upper Hudson River have extensively altered PCBs in the sediment. Biodegradation in the anaerobic sediments has resulted in the extensive loss of chlorine, a result confirmed by the EPA high resolution coring data (U.S. EPA, 1995). This chlorine loss causes a reduced bioaccumulation potential compared to that of unaltered Aroclor 1242 and also a potential reduction in PCB toxicity. Additionally, researchers have found that in aerobic sediment, aerobic bacteria destroy the more lightly chlorinated PCBs. This process has generally been found to occur in aerobic surface sediments, but some researchers have also detected metabolites of this process in subsurface sediments (anaerobic) of the Upper Hudson River.

EPA's models neither incorporate nor acknowledge these potentially important fate processes. To use this information, one needs an estimate of the rates for these processes. Recent laboratory work conducted by Ken Fish of GE (Fish, 1996) demonstrates that the

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introduction of unaltered Aroclor 1242 in Hudson River sediments under expected River conditions can result in extensive dechlorination and degradation in less than one year. Because EPA will presumably use its model to project PCB levels decades into the future, these processes should significantly impact PCB levels in surface sediments, even if the rates of dechlorination and degradation seen in the laboratory are faster than those that occur in the River. As a result, EPA's models should account for dechlorination and degradation of PCBs.

These processes may also be important in understanding the fate of PCBs entering the river near Hudson Falls and their relationship to the PCB imbalance across the TIP. One hypothesis for the high PCB water column loading in the TIP (see Section II.C) is that PCBs may be entering the pool undetected and then settling into the surface sediments. According to EPA water data, the PCB load in the TIP appears to be derived from dechlorinated sediments. It may be that newly deposited PCBs are undergoing rapid alteration as shown by Fish's laboratory studies.

Lastly, one of the key objectives of the reassessment is to determine what levels of PCBs in fish are acceptable and when they will be achieved. Dechlorination affects which congeners are available to consumers of fish and the concentration or mass of those congeners. EPA's recently released PCB Toxicity Reassessment (U.S. EPA, 1996a) recognizes a reduction in toxicity with lower chlorination levels. Also, the PCB congeners of primary concern in the Hudson River, BZ77 and BZ126 (coplanar congeners), which are thought to exhibit dioxin-like toxicity, have been found to be dechlorinated in the Upper Hudson River. Thus, dechlorination

and biodegradation affect both the degree of exposure and the chemical to which people are exposed. Because these processes have been demonstrated to be occurring in the Upper Hudson, EPA should attempt to incorporate them into its modeling effort.

C. PCB Mass Imbalance in the Thompson Island Pool

As we pointed out in the Introduction, one of the valuable aspects of modeling is the identification of areas requiring further data collection or refinement of judgment. Balancing the PCB mass across the TIP is such a case. It is apparent that EPA has been unable to achieve a PCB mass balance across the TIP without resort to mechanisms that can be hypothesized but not factually demonstrated. GE has met the same obstacle in its modeling effort (HydroQual, 1995b). In EPA's model, PCBs are introduced into the TIP water column from four sources: 1) PCBs are diffused from sediment-pore water; 2) PCBs desorb from sediments that are resuspended; 3) PCBs enter the pool from upstream; and 4) pore water containing PCBs is driven into the water column by groundwater discharge. Diffusion from pore water is not in dispute. GE questions, to one degree or another, the values that EPA has used for other PCB transport mechanisms, and as discussed in Section II.A, we believe that the resuspension rate EPA used is too high. While we are in substantial agreement with EPA on the values used for upstream loadings, one must question whether those measurements have been able to capture the total loading source(s) because GE's upstream monitoring station may not be detecting discharges of dense oil. Finally, although we agree with EPA that groundwater discharge is a plausible hypothesis, the Agency must recognize both that it is only one of several hypotheses and that it

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has not been verified by field data. Further factual development and data collection is necessary before one can select the most likely hypothesis with confidence.

Consequently, GE is undertaking investigations to test all reasonable hypotheses for the PCB mass imbalance in the TIP. The PCB load in the TIP dominates PCBs in the water column downstream of the TIP. Knowledge of the source of the PCB load in the TIP is thus essential to determining whether and how the PCB load can be controlled. Regardless of GE's success in testing the hypotheses, EPA must be able to select a factually supported hypothesis. Otherwise EPA will lack a sound factual basis for its remedial decision, and any selected course of action will be arbitrary, with a very real probability that it will not have its intended consequences.

The hypotheses that must be tested in order to determine the cause of the mass imbalance of PCBs in the TIP include:

1. ***The mass and concentration of PCBs entering the TIP are markedly greater than the mass and concentration measured at the upstream Rogers Island monitoring station.*** This hypothesis - that PCBs escape detection at Rogers Island - is plausible because the known releases of PCB oil from the Hudson Falls plant area are denser than water, and the current monitoring program was not designed to detect or quantify dense oil phase PCBs. To the extent that PCB oil escapes detection at Rogers Island, either because it travels as part of an

unquantified bed load or as undetected pulse loadings, the present monitoring would underestimate PCB transport past Rogers Island. GE has conducted a number of monitoring studies this fall to address the issue of the representativeness of the current monitoring program. For these and the other hypothesis testing activity described in this section. GE will share the data and its analysis with EPA as the results become available.

2. ***The mass and concentration of PCBs passing the TID are markedly less than the mass and concentration measured at the TID monitoring station.*** Since we do not understand the mechanism by which excess PCBs enter the TIP, we can not be sure that the PCB monitoring conducted from the single point at the TID accurately represents PCB transport over the dam. Monitoring studies conducted this fall, including a longitudinal transect study following a single mass of water through the TIP, and water column monitoring conducted across the river near the TID, should provide insights into the representativeness of the TID monitoring station.

3. ***Groundwater inflow within the TIP is causing substantial release of PCBs from the buried sediments into the water column in the TIP.*** This hypothesis appears plausible because it can account for a portion of the excess PCB loading observed across the pool. The hypothesis has several weaknesses, however. First, as tested in the EPA model calibration, ground water advection is a spatially limited mechanism; it is invoked only in the TIP. Given the similarities between the TIP and downstream reaches, if groundwater were important to PCB releases in the TIP, one would expect it to contribute as well to PCB transport

in downstream reaches. Sediment diffusive flux alone, however, can account for PCB loading observed downstream of the TIP.

Second, the groundwater flux hypothesis cannot account for the temporal variability in the excess PCB loading from the TIP. The excess loading only appeared after the substantial discharges from the Allen Mill between 1991 and 1993. If groundwater advective flux is a significant contributor to PCB loadings in the TIP, then water column monitoring conducted prior to the event should contain some evidence of its existence. GE plans to evaluate the groundwater flux hypothesis by evaluating the groundwater system near the TIP and possibly deploying groundwater seepage meters within the TIP sediments.

4. ***There are markedly greater PCB concentrations in the surface sediments of the TIP (resulting from the 1991-1993 Allen Mill discharges) than reflected in the surface sediment data used in the model.*** This hypothesis is plausible as it accounts for the coincidence in timing with the Allen Mill discharges. Two of the EPA high resolution cores collected from the TIP in 1992 (after the initial Allen Mill discharges) show an increase in PCB concentrations near the sediment-water interface. These surficial sediment layers reflect recent PCB deposits. As stated in Section II.B, comparison of PCB content in brown bullhead, largemouth bass, and pumpkinseed in the TIP and at Stillwater before and after the 1991-93 releases shows a greater increase in the TIP than at Stillwater (see Figure 1). The brown bullhead

and largemouth bass derive more of their diet from the sediment than does the pumpkinseed. This suggests an increase in surface sediment concentrations of PCBs in the TIP following the discharges from the Allen Mill.

Higher surface sediment concentrations could increase the driving force for diffusive transport from the sediment to the water column and may account for some of the excess PCB observed in the River. This mechanism alone, however, cannot account for all of the excess PCB because the PCB congener pattern of excess loading reflects some degree of dechlorination. Therefore, a post-depositional process of PCB dechlorination is required to produce the PCB congener pattern of the loading. Although recently conducted laboratory experiments (Fish, 1996) indicate that dechlorination can occur at a rate sufficient to contribute to the excess loading as described above, extrapolation of these results to the field is not yet complete. These studies suggest, however, that the combined process of deposition of PCBs into surficial sediments followed by dechlorination is a possible cause for the excess PCB loading from the TIP.

5. ***A substantial mass of PCBs enters the TIP between Rogers Island and the TID from sources outside the Pool, such as dredge spoil sites.*** While this hypothesis is possible, it is unlikely because there is no physical explanation why the external load from these sources would be correlated in time with the discharges from the Allen Mill. The spatial pattern

of PCB loading within the pool as discerned from the longitudinal transect studies described above should provide further insight into whether the dredge spoil sites might contribute to the TIP PCB loading.

6. ***Resuspension of surface sediments introduces a substantial mass of PCB into the water column of the TIP.*** The EPA model invokes sediment resuspension during low flow periods to account for a portion of the excess PCB loading observed in the TIP. While this hypothesis may account for the temporal correspondence between the Allen Mill discharges and the excess PCBs emanating from the pool (the resuspended surface sediments may contain elevated PCBs originating from the Mill), it is counter to the generally accepted understanding of sediment transport processes. Under current theory and experience, surface sediments are not appreciably resuspended until river flow velocities produce a critical shear stress at the sediment-water interface. This critical shear stress occurs at river flow velocities substantially higher than those that occurred during the periods of excess loading. The marginal increase in TSS observed during the excess PCB loading periods can be accounted for by tributary loadings from the Snook Kill and Moses Kill. Indeed, the longitudinal transect studies conducted this fall substantiate this conclusion because TSS did not increase in the TIP until downstream of these tributaries.

D. Long-Term PCB Mass Balance

The current EPA model does not calibrate to the existing data for 1993, matching neither the low flow PCB data nor the PCB load at the TID. We have discussed the potential

III

reasons for this in prior sections. Indeed, the limited calibration period is insufficient to test the model's ability to represent the long-term fate of sediment PCBs, in particular the impacts of resuspension, sedimentation, dechlorination and biodegradation. Based on GE's own modeling and data evaluations, this problem will become more significant when EPA compares the model results with the vast array of historic PCB data in fish, water, and sediment (EPA refers to this as "hindcasting").

Two critical tests of the match between the historic data and the results of the current EPA model are likely to show unacceptable incongruity between the data and the model. The first test of the model is its congruence with the amount of PCBs present in the water column at Schuylerville in the mid- to late-1980s. If the EPA model were used, incorporating EPA's assumed low flow resuspension and groundwater inflow to move PCB from the sediment into the water column, one would expect approximately 100 ppt of PCB in the water column at Schuylerville during low flow in the summer months. In fact, the average value measured by the U.S. Geological Survey in 1988 and 1989 is 30 ppt. This is close to the amount one would estimate from diffusion alone.

The second test of the EPA model is its congruence with the inventory of PCB mass in the sediments over time. If significant amounts of PCB were moved into the water column from the sediments, as the EPA model assumes, there should be a discernible change in the PCB reservoir in the sediments or the depth profile of PCBs in the sediment. Three large scale sediment sampling events were carried out in the Upper Hudson in 1977, 1984, and 1991

which can be used to estimate the mass of PCBs in the sediments of the TIP. EPA has estimated that the TIP sediments contained about 32,000 pounds of PCBs in 1984 (U.S. EPA, 1996b, pg. 6-2). The EPA model estimates that 800 pounds of PCBs are lost from the sediments into the water column over the 270 days in 1993. If the same rate of loss were projected into the past (presumably an underestimate because PCB levels in the sediment would have been higher earlier), the total mass of PCB mass lost from 1984 to 1991 would be 8,000 pounds, or approximately 25% of the total inventory. This is inconsistent with the historic sediment data which show little change in PCB inventory over fifteen years.

Another way to compare the model results to the historic levels of PCBs in the sediment is to compare PCB depth profiles over time. Unfortunately, the current EPA model has decoupled sediment transport and net sedimentation rates (see Section II.A), making such a comparison difficult. EPA should link the sedimentation rate and the solids mass balance portions of the model. If the PCBs were being flushed out of the sediment, as the EPA model predicts, then the loss of bioavailable PCBs due to long term burial would be less significant than if less interaction between the sediment water column were occurring. Comparing the PCB profiles in the sediment over time to the model predictions should provide a check on the model assumptions.

Long term burial as the dominant mechanism for loss of bioavailable PCBs is consistent with the available data reviewed to date. As an illustration, consider the vertical profiles of PCB concentrations in TIP sediment shown on Figure 2. Each panel shows measured

sediment PCB concentrations, averaged over selected depth intervals, for the years 1977, 1984 and 1991. In the panel on the left, the PCB concentrations for each depth interval are plotted against the depth of the slice. The surface to 5 cm slice is plotted at a depth of 5 cm, corresponding to the depth at which material would be buried below a mixed "active layer" 5 cm deep. The other concentrations are plotted at the depth below the sediment-water interface of the mid-point of the associated sediment core slice. When plotted in this manner, the only obvious pattern in the data is that the surface concentrations decreased from 1977 to 1984 to 1991, and the deeper concentrations (50 to 70 cm) are relatively higher than the surface sediment concentrations.

The middle and right panels of Figure 2 show these same sediment PCB profiles, but with the measured profiles modified in the following manner. First, the surficial (0-5 cm) concentrations are reduced by 20%, corresponding to an upper bound limit to the potential degradation of PCBs associated with anaerobic dechlorination processes. (This decrease is only applied to the mixed surface layer, since this is the only layer likely to have relatively recently deposited, undechlorinated PCBs). Second, the 1977 and the 1984 PCB profiles are shifted downward to correspond to the depth of burial that would occur from the time of sampling (1977 or 1984) to 1991. This vertical translation corresponds to a long term average net sedimentation rate of 0.5 cm/year on the middle panel and 1.0 cm/year on the right hand panel. With these modifications applied to the data, the blurred image described by the untranslated profiles on the left panel comes into focus and a relatively distinct, unified profile emerges. This is consistent with the conclusion that burial has simply moved the PCB profiles measured in 1977 and 1984

down in the sediment, modified by some degree of dechlorination, possibly in combination with other loss processes, in the surface layer. The actual burial rate is difficult to discern with precision, but this analysis suggests that it is on the order of 0.5 to 1 cm/year. Since the PCB data are reach average results, this burial rate is indicative of a reach average long term net sedimentation rate. These data do not support EPA's hypothesis that PCBs are being "flushed" from the sediment at the high rate calculated by the EPA model.

* * *

Based on GE's evaluation of the EPA model, it is clear that the model will need significant revisions to calibrate properly to the historic data. The current EPA model greatly overestimates the amount of PCBs contributed to the water column by the old sediments. If left unchanged, future projections will show exaggerated benefits from sediment remediation projects if the projection focuses only on the present loss rate from buried sediments. If the predicted loss rate were continued into the future, the sediments would be largely depleted of PCBs in the near future, which implies that remediation is unlikely to shorten significantly the period required to achieve acceptable risk levels.

To complete the modeling effort and to answer the key questions for the Reassessment, the source of the TIP load imbalance must be understood. The Reassessment

cannot be completed in a defensible way until this is done. This will be a major focus of GE's efforts in 1997, and GE looks forward to working closely with EPA to unravel this important technical issue.

III. BIOACCUMULATION MODELS (12)

EPA is developing three bioaccumulation models to predict PCB levels in fish: The Bivariate Statistical Model ("BSM"), Probabilistic Food Chain Model ("PFCM"), and the Gobas Model ("GM"). Each has its strengths and weaknesses. The BSM and PFCM are essentially steady-state statistically-derived models that rely on examinations of historic PCB levels in sediment, water column and biota to ascertain the relationship among these natural compartments. Because they ignore the short and long term variability in the relationships among PCB levels in water column, sediment, and fish and do not attempt to discern the mechanisms by which fish bioaccumulate PCBs, these models will have limited utility for predicting PCB levels in fish in the future. The GM, on the other hand, is a time-variable, mechanistic food web model, which explicitly incorporates variability in exposure, uptake and depuration of PCBs and which, because it reflects real world bioenergetic and toxicokinetic mechanisms, provides a useful and easily checked predictive tool. For these reasons, GE urges EPA to develop and use a time-variable mechanistic food web model, such as the GM, using the statistical relationships developed through the BSM and PFCM, as well as the performance of the model in other systems, as external checks on its dynamics and output.

A. The BSM and PFCM Models

Structure of the Models

The BSM and PFCM are models that attempt to derive quantitative relationships between PCB levels in sediment, water, and fish through statistical analysis of Hudson River data. The BSM examines these data using multiple regression analysis to estimate average PCB levels in fish from PCB concentrations in sediment and water. The PFCM is similar, except that it involves characterizing the historic data and food web transfers within the River to estimate trophic transfer factors ("TTFs") between each link. Using Monte Carlo techniques, the model is intended to be used to estimate the mean and variation in PCB levels in top predators, given average exposure levels in sediment and water. Regardless, like the BSM, it is a statistically-based model.

The statistical, steady-state nature of these models limit their utility as predictive tools. Moreover, the inconsistency in their use of sediment PCB data undermines their validity. First, both models assume that PCB levels in the biota are near steady-state with regard to levels in the sediment and water. PCB levels in biota in the Upper Hudson River, however, have exhibited relatively slow long-term declines, as well as significant short-term changes. Lipid content of some species has also changed dramatically over time, exhibiting both long-term trends and year-to-year variation. Because PCBs tend to accumulate in lipid, the variability in lipid content results in changes in excretion rates, which, in turn, cause variation in PCB body burden on the scale of one to a few years. Ignoring these temporal changes in the system lends significant uncertainty to the validity of these models.

Second, both models ignore the causal mechanisms by which fish bioaccumulate PCBs. The primary advantage of the regression approach used in these models is that it is relatively simple. Only the site-specific data are required; no ancillary information on bioaccumulation processes is needed. This simplicity is also their primary disadvantage. While the PFCM, for example, explicitly incorporates variability in PCB levels in sediment, water, and biota to derive the TTFs, the model does not allow one to discern the cause for that variability. By failing to incorporate available information about the biological mechanisms for the variation in contaminant levels in fish, such as growth rate, size, lipid content, feeding behavior, and exposure levels, these regression models do not allow one to assess, for example, how PCB body burdens will change over time as the relative importance of sediment and water column PCB levels change.

Third, another flaw in the PFCM is that it requires having the answer to solve the problem. The observed variability in a fish population is input into the model in the form of the variability in the TTF, and the model then calculates the variability in the fish population. The model is circular.

Fourth, the model is improperly structured. It attempts to calculate variability (population variance) from uncertainty (standard errors of the mean TTFs). These metrics are incompatible, and the model results have no physical meaning.

Fifth, these models, as applied by EPA, incorrectly assume that surface sediment concentrations of PCBs have remained constant over time. In addition, the models rely on different and inconsistent sediment data: both models rely on a single year's sediment data - for the BSM, the 1991 GE data; for the PFCM, the 1993 EPA data. The inconsistency in data raises questions about the comparability of results from the two models. The assumption that temporal changes in sediment PCB concentration will not affect PCB levels in fish is flawed in light of the generally accepted understanding that surface sediment PCBs can contribute significantly to PCB levels in certain fish species. (The assumption is odd in a reassessment focused on whether or how remediation of sediments might reduce PCB concentrations in fish). Yet, EPA used a single set of sediment data to compare to all the historical data on PCB levels in water column and fish, thus compromising the validity of the statistical analysis. The appropriate approach is to couple the bioaccumulation modeling to the water and sediment exposure concentrations computed by the PCB fate model.

For the PFCM, EPA estimated BSAF values for benthic invertebrates using a limited number of cores and data from several species of invertebrates. Each species of invertebrate may feed in a different manner, leading to differences in exposure concentration. The distribution of invertebrates sampled may differ from the distribution of invertebrates actually consumed by forage fish. In addition, EPA estimates the trophic transfer from water column particulates to water column invertebrates using the historical multiplate and caddisfly data. EPA assumed that the fine fraction of material on the multiplates represents water column particulates, but this material may not represent particulates that caddisflies foraging just above

the sediment bed consume. Finally, EPA failed to consider the uncertainty associated with its assumption that the caddisflies are representative of the water column invertebrates in the diet of the forage fish.

Validation of the Models

EPA has not adequately validated the models:

(1) The Report presents temporal trends for pumpkinseed, brown bullhead and largemouth bass at river mile 175 but not for the TIP, where the BSM and data do not match as well.

(2) The Report compares BAF values estimated by the BSM with values calculated using the GM at other sites. While it is appropriate to compare values with other sites, EPA should make these comparisons against data from field populations of similar species in similar ecological settings, rather than values calculated using another model for another system. Moreover, because both the sediments and the water column are important sources of PCBs to the fish, EPA should compare both BAF and BSAF values with other systems, not just the BAF.

(3) The analyses used by EPA to test the BSM demonstrate that it will not be useful for predicting fish PCB levels. The Report gives values of the coefficients of determination of the regressions (r^2). The r^2 value is a measure of the proportion of variation in the data that is accounted for by the regression. In addition, the Report presents scatter plots of

observed versus predicted PCB levels. The Report does not present any other statistical analyses to evaluate goodness of fit. In addition, the scatter plots show problems with the predictive ability of the models:

- The slopes of these values are often less than one, indicating that there is a bias in their predictions.
- Predicted values are often higher than observed at low concentrations. (See Figures 9-8 to 9-13). This high bias will be critical when making predictions of future PCB levels in fish, when exposure levels should be reduced. Thus, the models' projections will be biased high.
- The pattern of observed versus predicted values differs among reaches. For example, within the TIP, predicted values vary little temporally while observed values have considerable variability. This suggests that the models do not provide accurate predictions of PCB levels within each pool.

B. The Gobas Model

A time-variable bioenergetics-based food web model such as the GM overcomes the major failings of the BSM and PFCM. The GM can represent key time-dependent features of the historical data: short term exposure changes and variations in lipid content and changes in sediment and water column concentrations over time. This results in a calibration that more accurately represents the relationships among PCBs in water, sediment and biota. Also, the validity of the model's coefficients can be evaluated because they have biological meaning. Finally, because the model is mechanistic, causes for differences between model and data can be explored, leading to further field measurements or experimental work to improve the model parameterization and predictive capability.

In the Report, EPA suggests that poor knowledge of many of the important model parameters hampers the GM approach (U.S. EPA, 1996b; pg.8-13). Actually a significant amount of information exists to provide adequate constraints on the model. All of the informational requirements for development of the GM can be met. Food web structure and fish natural history have been evaluated in the PFCM. The uptake and depuration rates of PCBs can be estimated from field and laboratory data and other modeling studies. Uncertainty and variability associated with these parameters can be used to generate predicted uncertainty and variability in fish PCBs. As a result, lack of data is not a valid reason not to develop the GM.

C. Recommended Approach

We recommend that EPA use a time-variable bioenergetics-based food web model, such as the GM, to estimate mean PCB levels, and that this model be coupled to the PCB fate and transport model to integrate the predictions of exposure and bioaccumulation. GE is developing such a model and believes that it would provide a solid basis for work in this area. We recommend that this model be further developed in a cooperative effort that takes advantage of the knowledge and expertise of both GE and EPA. Further, we recommend that EPA use the observed coefficients of variation in conjunction with the calculated mean PCB levels to describe the distribution of PCB levels for use in the risk assessment.

IV. DEPTH OF SCOUR MODEL

GE is in basic agreement with the approach EPA used to model the 100 year flood. The model is consistent in its characterization of the resuspension properties of cohesive

sediments and appropriately incorporates field data from the TIP. Nevertheless, EPA should correct several errors in the model.

First, the EPA model uses an improper method to calculate bottom shear stress distribution in the TIP: outputting predicted current velocities from the RMA-2V hydrodynamic model and using an external formula (Equation 5-3) to calculate shear stresses. This approach is inconsistent because Equation 5-3 predicts different bottom shear stresses than does from RMA-2V. The correct approach is to output the bottom shear stresses calculated by RMA-2V and use those values to calculate cohesive sediment resuspension. (13B)

Second, EPA did not properly use the Lick equation for calculating resuspension potential. The Lick equation calculates resuspension potential (ϵ), which is expressed as eroded sediment mass per unit area; i.e., grams/cm^2. Converting predicted resuspension potential at a particular location to a scour depth (Z_{scour}) requires application of Equation 3-7; i.e., $Z_{scour} = (\epsilon) / C_{bulk}$. In this equation, C_{bulk} is the *dry* bulk density (grams/cm^3), where (13C)

$$C_{bulk,dry} = (1 - P)\, \rho_{sed}$$

and P = porosity and ρ_{sed} = sediment particle density (≈ 2.65 grams/cm^3). The dry bulk density represents the dry sediment mass per unit bed volume and is also referred to as the bed solids concentration. Examination of EPA bulk density and solids data suggests that the EPA database lists $C_{bulk,\,wet}$, not dry bulk density. It is inappropriate to use wet bulk density ($C_{bulk,wet}$) to calculate Z_{scour}:

$$C_{bulk,wet} = P\, \rho_w + (1 - P)\, \rho_{sed}$$

where ρ_w = water density (≈ 1 gram/cm^3). The wet bulk density is the mass of water and sediment per unit bed volume. If EPA did use wet bulk density, it should convert those wet bulk density values to dry bulk density as follows:

$$C_{bulk,dry} \doteq \rho_{sed} (C_{bulk,wet} - \rho_w)/(\rho_{sed} - \rho_w)$$

Third, as previously discussed, an inconsistency exists between the treatment of cohesive sediment resuspension in EPA's solids transport model and in the depth of scour model. The depth of scour model uses a formulation, the Lick equation, that accounts for bed armoring effects and also utilizes Upper Hudson River resuspension data to determine site-specific parameter values. Eliminating the inconsistency between the two models and incorporating the Lick equation into the solids transport model is necessary to achieve credible solids transport simulations using EPA's solids transport model. 13D

Finally, a major uncertainty remains for the depth of scour model: how will EPA simulate non-cohesive resuspension? Research on suspended load transport of non-cohesive sediments has a long history, and researchers have proposed a wide variety of formulas and methods. The various formulas have been tested on a number of different data sets, from laboratory and field studies, and found to produce accurate results under a wide range of conditions. Thus, EPA must carefully screen these formulations to find one that is appropriate for the TIP. GE requests that it be informed of EPA's choice in sufficient time to comment before EPA develops its final product. 13E

One formulation that has produced reliable results is the van Rijn model for suspended load transport of sands (van Rijn, 1984). This model would be appropriate for the TIP with some modifications. The van Rijn model was developed for an ungraded bed; i.e., relatively uniform-size sand particles. The non-cohesive bed in the TIP consists of a wide range of particle sizes, with a significant fraction of coarse sand and gravel. Under these conditions, EPA needs to consider the effect of bed armoring due to heterogeneous bed composition and modify the van Rijn equations appropriately. Extensive research on non-cohesive bed armoring has resulted in the development of credible formulations which have been successfully applied in modeling studies on other rivers (Ziegler and Nisbet, 1994).

Realistically simulating non-cohesive suspended load transport in the TIP depends not only on the model formulations, but also on specification of bed property parameters and the flood hydrograph. EPA must determine the distribution of non-cohesive bed parameters (e.g., grain size distribution) in the TIP with extreme care because model results are very sensitive to input parameters. EPA also needs to include the effect of the flood hydrograph on non-cohesive erosion in the 100 year flood simulation. The steady-state flow assumption presently used is valid for approximating cohesive resuspension. Non-cohesive erosion, even with bed armoring, is rate-dependent, however, and total scour in the non-cohesive bed will depend on the flood hydrograph; a steady-state assumption will not yield credible results. (13F)

EPA will need to calibrate the depth of scour model after adding the non-cohesive component because of the uncertainty in the non-cohesive bed property parameters. EPA

collected an excellent TSS data set during April 1994 and should use it to demonstrate that the non-cohesive component of the depth of scour model is functioning with reasonable accuracy. Without some form of model calibration, predictions of non-cohesive sediment erosion during high flow events will be very uncertain and can not be used with confidence in evaluating the effects of the 100 year flood.

V. PREDICTIVE POWER OF THE MODEL (14)

The purpose of developing models in the reassessment is to understand the complex relationships of the natural elements operating in the Upper Hudson River and on that basis to predict the effect of possible future action and no action. EPA has calibrated its fate and transport model to a temporally limited data set collected between January 1 and September 30, 1993. There is a very extensive array of data for some parameters for ten years or more prior to 1993 and for the period since September 30, 1993. This presents a crucial and significant test of the predictive power of the EPA model. If the EPA model is able to provide a close fit to the data points before and after 1993, the arguments for its use as a predictive tool will be very powerful. If it is not possible to validate the model by a close fit to the data, its lack of usefulness for predictive purposes will be apparent. If this is the case, it should follow that further significant analysis, data collection, and model development will be necessary before it can be used by decision makers in the reassessment.

In determining whether the model meets an acceptable standard for predictive use, the model's ability to match the data closely in the following instances will be the acid test of success:

1. To validate the components of the solids balance, EPA should compare model results with data on:

   a. Spatial patterns of TSS during low flow periods, which will evaluate the balance between low flow solids loading and deposition;

   b. Temporal and spatial patterns of TSS and water column PCBs during flood events, which will evaluate the balance between high flow solids and resuspension; and

   c. Annual average solids loading passing Schuylerville, Stillwater and Waterford, which will evaluate the balance between solids loading and sedimentation.

2. To validate the flux of PCBs from pore water and PCB loss by volatilization, EPA should compare model results with data on:

   a. Spatial patterns of water column PCBs during low flow periods; and

   b. Spatial changes in water column PCB composition (based on the five congeners modeled).

3. To validate the mechanisms by which bioavailable PCBs are lost from the sediments, particularly the balance between losses to water column (diffusion and resuspension) and losses by burial, EPA should compare model results with data on:

   a. Long-term changes in surface sediment PCB levels;

   b. Long-term changes in the vertical profiles of PCBs in sediments; and

c. Long-term changes in PCB inventory in the sediments.

4. To provide an overall test of the model, EPA should compare model results with data on the annual average flux of PCBs passing Schuylerville, Stillwater and Waterford.

5. To test the model's ability to describe the impact of recent PCB releases from Hudson Falls, EPA should compare model results with data on the apparent increase in the PCB flux from Fort Edward to Thompson Island Dam/Schuylerville that occurred between the mid- to late-1980s and the 1990s.

6. Finally, to evaluate the food web structure and toxicokinetics of the bioaccumulation model, EPA should compare model results with data on:

a. Temporal changes in PCB concentrations in a predatory fish (largemouth bass) and in a forage fish (pumpkinseed) at the TIP and Stillwater over a 15-year period. In addition to overall fit between model and data, patterns in the quality of fit should be explored (e.g., differences among species, locations, time periods); and

b. Response of the fish to the short-term changes in water column PCB levels in the early 1990s, which will evaluate the relative contributions of water column and sediment PCBs and the uptake and loss ratio.

In assessing the capability of the model to match data, care must be taken to uncover any apparent biases. The current calibration exhibits several biases that are not discussed in the Report. For example, water column PCB concentrations are generally over-predicted at low flow and under-predicted at high flow. The over-prediction is likely due to the

inclusion of resuspension at low flow. The cause of the under-prediction at high flow is uncertain. It may be a real bias, or simply a slight mistiming. EPA should examine this issue as part of its recalibration efforts. The model also underestimates the solids loading passing Stillwater and Waterford during the non-event period. For the calibration period, the model is low by about 5,000 MT at Stillwater (U.S. EPA 1996b; Figure 4-11) and 30,000 MT at Waterford (U.S. EPA 1996b; Figure 4-12). These differences between model and data suggest an underestimation of low flow tributary solids loading. The Report presents the hypothesis that construction activities at Lock 1 temporarily increased solids loading, but gives no data supporting this hypothesis. Given the importance of the solids balance to long-term predictions, EPA needs to examine the possibility of and reasons for model bias. Finally, as discussed in Section III, fish PCB concentrations are overestimated at low levels. As with the other biases, cause must be determined, and the bias eliminated before EPA uses the model as a predictive tool.

VI. LOWER HUDSON PCB TRANSPORT AND FATE MODEL (15)

The cover letter to these comments addressed the question of what consideration of conditions in the Lower River is appropriate in a reassessment directed to what action, if any, should be taken with PCB-contaminated sediments in the Upper Hudson. As we noted, it is important to ensure that any remedial action in the Upper River has no adverse impact, or, at most, an acceptable adverse impact on the Lower River. It is not appropriate, however, to justify remedial action in the Upper River on the basis of benefits to the Lower River. If EPA is to consider benefits to the Lower River, it must examine remedial action in the Lower River, such

as source control, to assure that a remedy designed to achieve Lower River benefits is cost-effective. If the Agency follows the course of seeking benefits for the Lower River, it must also identify Lower River dischargers as PRPs. Thus, assuming EPA maintains the present limited focus of the reassessment, it must limit the examination of impacts on the Lower River and its fish to assuring that a remedy in the Upper River will not have an unacceptable adverse impact on the Lower River.

With regard to the Thomann model, GE does not believe that it indicates that a remedy in the Upper River would adversely impact the Lower River and therefore does not object to its use for that purpose. From the point of view of technical accuracy and soundness in model development, there are a number of comments that could be made. We recognize, however, that Thomann and Farley are in the midst of a thorough review of the model and believe it appropriate to wait for the conclusion of that review to determine whether there are any disputed aspects of the model that are of relevance to use for the limited purposes appropriate for this reassessment. We believe that EPA should also wait for completion of the revision of the Thomann model before using it in this reassessment.

EPA should also consider other analyses in addressing whether a remedy in the Upper River would have an unacceptable adverse impact in the Lower River. In particular, Chilrud (1996) has completed a quite different sort of analysis of PCBs in striped bass in the Lower Hudson. EPA should review Chilrud's work in the same context in which it has examined Thomann's model.

Finally, the Report states that EPA intends to extrapolate from striped bass modeling results (derived from the Thomann model) to estimate impacts on the short-nose sturgeon (U.S. EPA 1996, p. 8-3). It is not clear how EPA would carry out this extrapolation, and GE requests the opportunity to comment on whatever method EPA may propose. We are unaware of any data showing PCB levels in short-nose sturgeon in the Hudson, or data or analyses relating Upper River sources to PCB body burdens in Hudson River short-nose sturgeon. We are unaware of any data or analyses showing adverse impacts in the short-nose sturgeon population as a result of PCB exposure and uptake. Finally, we are unaware of what sort of adverse impact as a result of what sort of PCB exposure is claimed to occur in the short-nose sturgeon population. In fact, recent reports suggest that the short-nose sturgeon is now present in such abundance in the Hudson that its continued status as an endangered species may soon come to an end. All of these relationships need to be explicated before any defensible relationship between PCB-contaminated sediments in the Upper River and adverse impacts on the short-nose sturgeon population can be propounded.

VII. CONCLUSIONS AND RECOMMENDATIONS (16)

To determine what action, if any, is necessary to address the PCB levels in the sediments of the Upper Hudson River, EPA appropriately determined that it had to develop objective, quantitative tools to predict the future levels of PCBs in fish, water and sediment under various remedial scenarios, including no-action. EPA has made substantial progress in developing a physically- based mechanistic model that will allow it to make such predictions. This is a complex and resource intensive project, but a necessary one.

GE commends EPA for seeking input on the preliminary modeling effort before completing construction of its models or attempting to utilize its models to make predictions. Based on our review, we agree with much of EPA's approach, including:

1) The overall goals of the reassessment and the role of the model in meeting these goals;

2) The guiding principles for model development; and

3) The general criteria by which to judge the reliability of a model.

The current iteration of EPA's models, however, will not provide a reasonable representation of PCB fate in the Upper Hudson River and cannot be used to address the key reassessment objectives. EPA must make modifications to the structure and calibration of its models. Additionally, the model effort has highlighted gaps in data that add significant uncertainty to the models. These need to be addressed before EPA can complete its modeling effort.

The two primary short-comings of the models are: 1) the assumed interaction between PCBs in the sediment and the water column, and 2) lack of knowledge concerning the source of a large portion of the PCBs entering the water column within the TIP. The first problem is largely a result of only using data from a 270 day period in 1993 to calibrate the model. The current model configuration results in a significant movement of PCBs from the sediment to the water column that is not consistent with current knowledge of processes affecting PCBs or with the historical data. Recalibration of the model to the large historic database will

provide further constraints in determining the long term interaction between the sediments and water column, and will show the impact of sediment burial as a PCB loss mechanism.

The second major problem is that EPA assumes that PCB loading to the water column in the TIP occurs by processes that either are not physically reasonable or are entirely speculative. The assumed high resuspension and deposition rates, particularly at low flows, are not supported by current sediment transport theory. This results in an unreasonably large amount of sediment bed/water column interaction and an exaggerated flux of PCBs from the sediments to the water. In addition, EPA makes an untested assumption that 30 cfs of groundwater moves through the sediments in the TIP forcing PCBs from the deeply buried PCBs into the water column.

EPA acknowledges that the source of the PCB load imbalance in the TIP is not known. This load imbalance is a significant portion of the PCB water column load in the Upper Hudson River, and the source of this load must be determined if predictions of future conditions are to have any validity.

Ultimately, the PCB levels in fish are of concern. EPA's work to date has focused on the statistical correlation between PCB levels in fish, water and sediment, but EPA's models do not describe the physical basis for this relationship. GE encourages EPA to develop a time-variable mechanistic food web model because of its far greater explanatory power and its

improved utility as a predictive tool compared to the statistical correlations EPA has prepared so far.

Before EPA uses the Thomann model, it must clearly define the objectives of this modeling effect and await the revisions that Thomann and Farley are preparing.

Based on these concerns, GE recommends that EPA take the following actions to complete its modeling efforts:

1. Develop and test by data collection, if necessary, the range of hypotheses that might explain the TIP load imbalance;

2. Refine the solids loading estimates for all tributaries, particularly for the Snook and Moses Kills;

3. Eliminate low flow resuspension and incorporate the concept of bed armoring into high flow resuspension. Also, incorporate solids composition into depositional velocity estimates;

4. Calculate, do not arbitrarily specify, net sedimentation using the difference between resuspension and deposition in the models solids balance;

5. Recalibrate the model using the full historical data set and the revised processes specified above. Specifically utilize:

    - Historic water column PCB levels;
    - High flow TSS and PCB values for multiple events (floods);
    - 1994 TSS data for tributaries;
    - PCB levels in sediment (total inventory as well as depth profiles) from the 1977, 1984 and 1991 surveys;

6. Develop and calibrate a time-variable bioenergetics-based food web model for fish in the Upper Hudson River:

7. Test the model by comparison to known data points to assure that each of its central elements is able to replicate the natural system the model is designed to imitate.

8. Clearly define the use of the Lower River model. and if appropriate. apply the revised model being developed; and.

9. Before using the revised models for predictive purposes. reissue the calibration report for additional comments.

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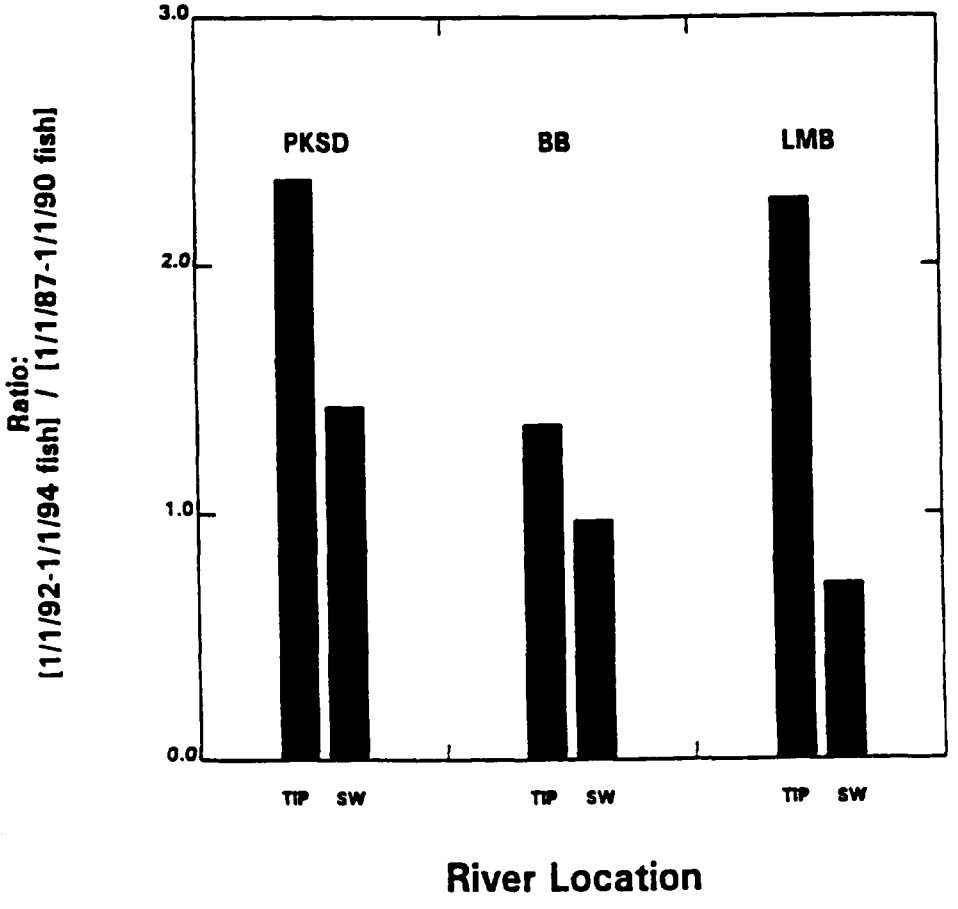

Figure 1. Ratio of Post-Release to Pre-Release Fish PCB Concentrations for Pumpkinseed (PKSD), Brown Bullhead (BB), and Largemouth Bass (LMB) in Thompson Island Pool (TIP) and Stillwater Pool (SW)

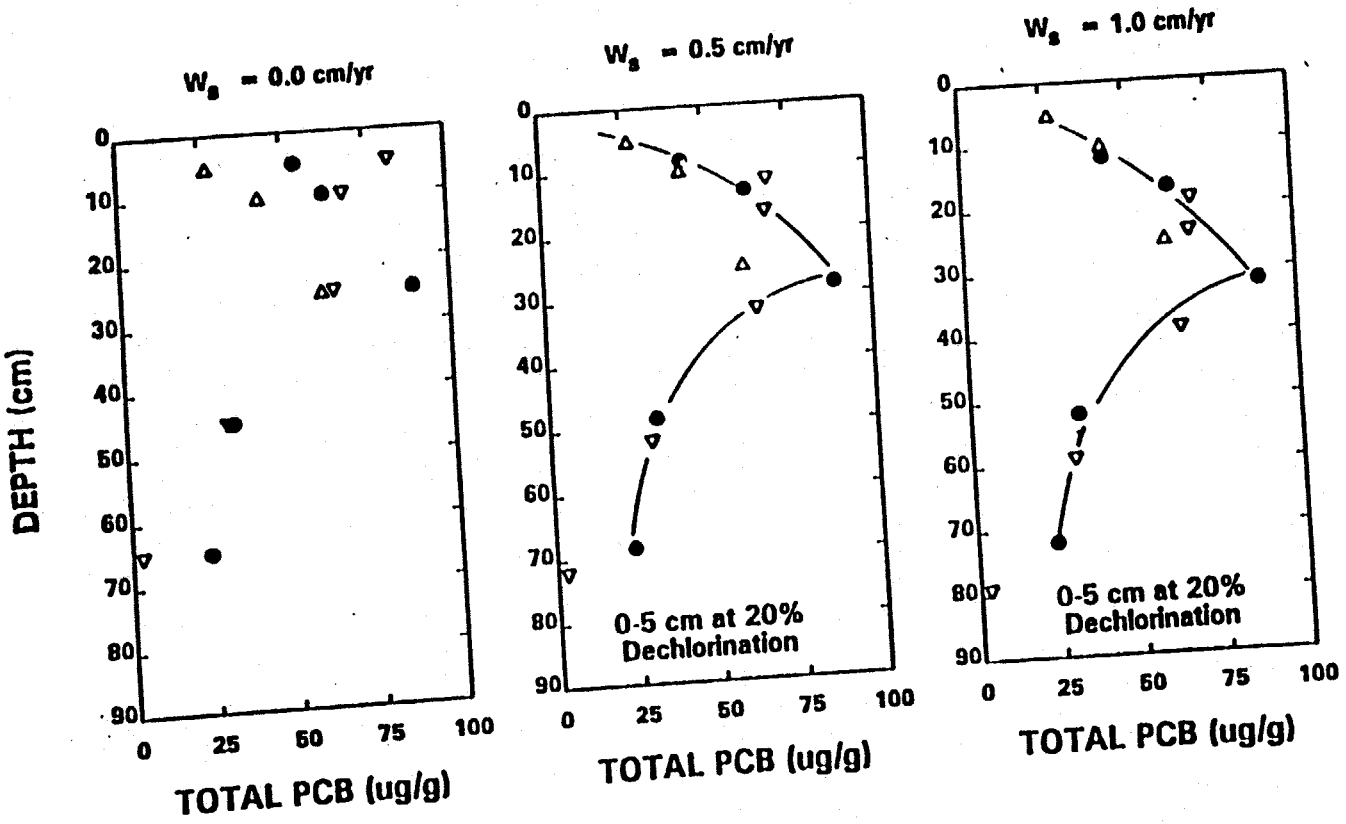

Figure 2. TIP Sediment PCB Profile (left) with Projected 1991 Profiles with Sedimentation and Dechlorination Mechanisms (center & right).

U.S. DEPARTMENT OF COMMERCE
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DF-2

June 3, 1997

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Dear Doug:

Thank you for the opportunity to review the February 1997 Phase 2 Report, Further Site Characterization and Analysis, Volume 2C - Data Evaluation and Interpretation Report (DEIR) for the Hudson River PCB Reassessment Remedial Investigation/Feasibility Study (RI/FS). The following comments are submitted by the National Oceanic and Atmospheric Administration (NOAA).

Summary

The Phase 2 DEIR Report was prepared as part of the overall Phase 2 Reassessment RI/FS activities currently ongoing to provide further characterization and analysis of the Hudson River PCB Site which extends from Hudson Falls, NY to the Battery in New York Harbor. The Reassessment RI/FS Work Plan, completed in September 1992, identified various data collection activities to support the reassessment effort. The February 1997 document presents geochemical analyses of water column and sediment data collected during the Phase 2 assessment and data from other sources including New York State Department of Environmental Conservation (NYSDEC), United States Geological Survey (USGS) and General Electric (GE).

The Phase 2 objectives were as follows: 1) estimate the current and recent PCB source contributions exclusive of the Upper Hudson River sediments 2) characterize the sources, movement and distribution of water column and sediment associated PCBs, and 3) examine PCB distribution and inventory within the Upper Hudson sediments.

General Comments

NOAA commends the authors of this report for a generally well thought-out site characterization and analysis effort. Overall, the report covered appropriate subjects and addressed them in a credible manner. The authors should be complemented for an executive summary which clearly highlights and explains the major conclusions of the Phase 2 reassessment and provides a conceptual model for the factors affecting the fate and transport of PCBs from the Upper Hudson to New York Harbor. NOAA's more specific concerns with the report are presented below.

Principal Congeners

The DEIR would have benefited from an early identification of congeners that are important for understanding the fate of PCBs in the system, including congeners that are important in fish and that represent the major contribution to each of the primary PCB homologues (i.e., di-hepta). Appendices A and B refer to the 12 principal target congeners as being the major focus of the

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that represent the major contribution to each of the primary PCB homologues (i.e., di-hepta). Appendices A and B refer to the 12 principal target congeners as being the major focus of the project. However, the report text primarily focuses on total PCBs or homologues, without much discussion of the 12 "principal" target congeners. Including the 12 "principal" target congener findings or representative congeners from each of the homologues in the report text might contribute to the overall interpretation by providing more detailed congener-specific analysis based on good quality data (i.e. exclusion of samples where data for important congeners were rejected or qualified as below detection). These congeners should be the focus of the discussions of congener-specific and homologue concentrations throughout the report. This would also make it possible to more easily identify samples with data quality problems and exclude them from analyses, where appropriate.

Implications of Data Quality Issues

The implications of data quality issues in the analyses of homologue compositions and congener patterns, especially below detection limit and blank contaminated data, should be explicitly addressed.

The treatment of below detection limit (BDL) data, missing or rejected data, and outliers, which may have affected the results and interpretations, was not discussed. It is difficult to determine how the qualifiers may have affected the results, including the calculation of totals and the interpretations of observed patterns. The interpretive report did not adequately refer back to the quality of the data, particularly as it might have affected data consistency and inter-comparability. For example, how were BDL values and rejected values treated in the homologue compositions and pattern analysis? Some of these values were for principal congeners and the laboratory-reported concentrations were quite high (and often these values were consistent with the data from other samples). Were data for the entire sample or only the individual congener excluded from the homologue and congener pattern analyses? What are the implications for the analysis, particularly for presentations of homologue compositions and congener patterns? 2A

All of the target congeners identified in the main report should be discussed in the usability appendices. For example, BZ#44 is not discussed in Appendix A or B, although it is used as an important example in Volume 1 Chapter 3. 2B

p. A-25-28. Most of the congeners had a statement that "The detection limit goal of 0.5 ppb was met for nearly all samples." However, several congeners (particularly the higher chlorinated congeners (BZ# 118, 138, 180) had a high percentage of samples qualified as below detection limit values due to blank contamination. Many of these were in samples with elevated total PCBs, and, based on the congener composition in other samples, these congeners were undoubtedly present. The implications for the data analysis and interpretation should be considered. 2C

Congener-Specific Loading

Analyses of PCB loading and PCB patterns should include a discussion of congener-specific concentrations as well as congener or homologue composition.

In many cases, the report relies primarily on the use of total PCBs and/or homologue PCBs to describe trends without any discussion of representative individual congeners. The presentation of data for a consistent suite of important and representative congeners would make the description of trends and comparisons of samples much clearer and easier to follow. 3A

BZ#118 was used to identify the presence of Aroclor 1254. However, according to the data from the analysis of Aroclor standards, BZ#118 is also a constituent of Aroclor 1242, though at a lower concentration. If the PCBs in the source areas were determined to consist of approximately 85% 3B

Aroclor 1242 and 10-15% Aroclor 1254, the contribution of BZ#118 from the two Aroclors would be essentially the same.

Reliance on PCB Composition Data to Estimate Loading

Much of the trend and PCB composition analyses relied on PCB congener patterns expressed primarily in relation to the concentration of BZ#52. While this approach is useful for comparison of congener patterns, and BZ#52 is known to be one of the more persistent congeners, the concentration of BZ#52 is also changing, which makes it necessary to also present the data on a concentration basis (preferably for selected individual congeners) to understand the changes in composition. For example, are the relative contributions of some congeners appearing to increase due to additional loading or due to a more rapid decrease of BZ#52? (4)

Presentation of the PCB composition data alone without concentration data can be misleading and may lead to erroneous conclusions. For example, in the last paragraph on p. 3-122, the following statement was made based on a comparison of congener patterns: "...the mixture at RM -1.9 contains substantially higher concentrations of the more-chlorinated congeners relative to RM 177.8." This statement would be correct if it referred to percent composition rather than concentration. Based on our analysis of surface sediment sections from the high resolution core data, the individual congener concentration data actually show that higher concentrations of these higher chlorinated congeners are found at RM 177.8 than at RM -1.9. For example, the average concentrations of BZ#101 and BZ#138 in the surface section of the two cores at Stillwater were a factor of 6.4 and 3.5 greater than their respective concentrations at RM -1.9. While some of the observed change in composition may reflect additional loading below Stillwater, the amount of additional loading cannot be determined without taking into account congener concentrations and the limitations of the conservative transport hypothesis.

Conservative Transport Assumption

The potential effect of physicochemical weathering processes on congener patterns should be discussed and evaluated with the available data. A relative loss of lower chlorinated PCBs with distance from a source area has been observed in New Bedford Harbor (Pruell et al. 1990) and Lake Hartwell, South Carolina (Farley et al. 1994). Similarly, summer water column transects "...show a gradual loss of mono- and dichlorohomologues as a water parcel travels from the TI Dam to Waterford " (p. 3-148). This is particularly important to consider for any assumptions of "conservative transport" and the analysis of congener and homologue patterns. (5)

Weathering was identified on p. 3-138 as potentially an important factor to consider in terms of estimating local loads: To some extent weathering of the PCB homologue pattern in the water column or soon after deposition may be responsible for the apparent local loadings since loss of lighter congeners would give the appearance of an additional local PCB load. However, on pp.3-162-164 an estimate of the percentage of contribution to NY Harbor (RM-1.9) sediments from the Upper Hudson source and NYC sewage effluent is based on a comparison of congener compositions assuming conservative transport (no changes in PCB composition due to weathering). Making the more realistic assumption that at least part of the change in composition can be accounted for by weathering of the material from the Upper Hudson, the percent contribution of PCBs in harbor sediments from the Upper Hudson would be higher than the 50% estimated.

Use of Physical Data

The report does not make good use of the physical data presented in Chapter 4 in the interpretation of the PCB data. For example, information on grain size and organic carbon together with the field descriptions can clearly indicate when the deposition of sediments has been episodic and allow for (6)

the arguments when the PCBs came from the same source by demonstrating a further level of consistency (sediment characteristics) among the samples.

Because the report presents little of the physical and conventional data, the reader has no independent means of assessing the reasonableness of the data. For example, the particulate organic carbon (POC) data were generated by applying a relationship developed for sediments. The resulting estimates of POC concentration in time and space and their comparison to suspended load are not presented. Do the data make sense compared to other data from the Hudson River or other systems?

Evaluation of PCB Sources above Rogers Island Thompson Island Dam (TID)

(7)

The discussion of the Hudson Falls Plant site and the Remnant Deposits as potential source areas rely on the reports prepared by O'Brien & Gere in their reports for GE with little independent analysis. For example, on p. 2-20 the conclusions of O'Brien & Gere about the "insignificance" of the contributions from the Remnant Deposits are presented verbatim. As the DEIR points out, there are several potential sources of PCB loading to the TIP and beyond in addition to the Hudson Falls source including:

- High concentrations of PCBs in sediment above Bakers Falls adjacent to the old Hudson Falls plant outfall. The reported total PCB concentrations in high resolution core 28 (RM197.1) was greater than 100 ppm, even in the surface section. According to O'Brien & Gere (1994), deeper sediment PCB results were as high as 22,000 ppm.

- PCB concentrations measured up to 44,800 ppm in soils at the base of a very steep cliff along approximately 1200 feet of shoreline in the vicinity of the Ft. Edward 004 outfall (Dames and Moore 1994). Up to 2,700 ppm PCBs were detected in surface (0-6") shoreline sediment samples in the same area (O'Brien &Gere 1995).

- The Remnant Deposit area including Remnant Deposit 1 (not capped), Remnant Deposits 2-5 (capped), and other sediment in the Remnant Deposit pool area

Considering the potential importance of this information for remedial decisions, NOAA strongly recommends that EPA conduct an independent critical analysis using the available data and also evaluate the adequacy of these data for determining the current and projected PCB loading from all of these potential sources.

The PCB composition of the Hudson Falls source was derived from a single high concentration water sample collected from the Remnant Deposit area during winter low-flow, low-temperature conditions (Transect 1). This assumption of compositional consistency over time was not evaluated, although the PCB composition in water column samples from the Thompson Island Pool (TIP) differed considerably between winter and summer low flow periods (see p. 3-88).

The Hudson Falls source has been characterized by GE as unaltered Aroclor 1242. Has an independent evaluation determined whether the congener composition of the sample is consistent with unaltered Aroclor 1242? The composition of the surficial sediment in the TIP is consistent with a mixture that also includes a smaller but significant amount of Aroclor 1254 type material. Reference to PCBs in the source areas as Aroclor 1242 (as in "unaltered Aroclor 1242") is misleading, particularly due to the importance of the higher chlorinated PCBs in fish throughout the river (including the TIP). Considering the fact that multiple potential sources may be contributing to the observed loading at Rogers Island, congener analysis of samples of the seeping oil could provide useful information on the composition of that source material.

Evaluation of Upper River Loading Below TID

Although the DEIR states that a "consistent gain and homologue pattern change shown in all three summer events strongly support the occurrence of an additional sediment-based load below the TI Dam," there is no substantial evaluation of sediment-based loading below the TID. The importance of a PCB sediment source below the TID should be evaluated, as it potentially contributes additional exposure to fish, which would be reflected in both the composition and concentration of PCBs in fish. (8)

Additional Data Needs

There are two major reasons that EPA should consider limited additional collections at this time: 1) to reduce uncertainty in the modeling projections; and, 2) to develop the baseline for long-term monitoring. (9)

Both the DEIR and the Model Calibration Report acknowledge the existence of important areas of uncertainty, particularly in terms of understanding the dynamics of PCB loading to the Thompson Island Pool. Understanding the dynamics of PCB loading to the Thompson Island Pool from all potentially significant sources, which may include sources associated with the Hudson Falls and Ft. Edward plant sites, Remnant Deposit 1 and any other remaining sediment deposits above Rogers Island, and Remnant Deposits 2-5, is necessary for the model to make credible long-term projections and therefore to be useful in the remedial decision-making process. Documenting the impact of on-going remedial actions associated with the Hudson Falls and Ft. Edward plant sites on the loading to the TIP and the PCB body burdens in fish will provide important supplemental information.

One of the ultimate goals of the Reassessment RI/FS is to evaluate the effect of remediation of PCB-contaminated sediments in Thompson Island Pool on the concentrations of PCBs in fish in the upper and lower Hudson River. Therefore, establishing a congener-specific baseline monitoring program of resident fish species from selected areas is essential. Monitoring fish provides a direct measure of the effectiveness of any remedial action and may help resolve some of the uncertainty associated with the assessment of PCB loading at different locations in the river. Because of the complexity of the system and the number of factors affecting PCB loading dynamics in the river, the monitoring baseline should include sampling from multiple years.

Limited additional data collection should not cause any delay in the process but may help avoid future delays resulting from high levels of uncertainty in the model projections that could be reduced by additional information. NOAA would be glad to assist EPA in developing plans for limited additional data collection efforts designed to reduce major sources of uncertainty and to provide the basis for long-term remedial-effectiveness monitoring.

Thank you for your continual efforts in keeping NOAA apprised of the progress at this site. Please contact me at (212) 637-3259 or Jay Field at (206) 526-6404 should you have any questions or would like further assistance.

Sincerely,

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DS-2

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John P. Cahill
Acting Commissioner

APR 25 1997

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Dear Mr. Tomchuk:

This letter transmits the New York State Department of Environmental Conservation's comments on the Hudson River PCBs Reassessment RI/FS Phase 2 Report-Review Copy Further Site Characterization and Analysis Volume 2C - Data Evaluation and Interpretation Report (DEIR) dated February 1997. The Specific Comments are arranged by the order they are found in the report and general comments are included at the end.

Specific Comments:

Executive Summary

P. E-1 to E-2: (Major Conclusions)

Conclusion 1: The area of the site upstream of the Thompson Island Dam represents the primary source of PCBs to the freshwater Hudson. This includes the GE Hudson Falls and Ft. Edward facilities, the Remnant Site area and the sediments of the Thompson Island Pool.

We agree with this conclusion. Additionally, it is important to understand that this Thompson Island Pool PCB load is altered by interactions between the sediments and the water column, as it is transported downstream. This gradual alteration to the water column load results in an increase in the proportion and overall amount of higher chlorinated PCBs. These higher chlorinated PCBs are more bioaccumulative and thus more important in impacting fish PCB levels.

It is logical to assume the same process responsible for releases of PCBs in the Thompson Island Pool are occurring in the rest of the Upper Hudson down to the Troy Dam. This would suggest that

the sediments in the Upper Hudson, downstream of the Thompson Island Dam, may be an additional significant factor in generating the PCB levels in the fish of this portion of the river, and the lower Hudson River. If this is the case, then the impact of the sediments in the entire Upper Hudson needs to be understood in order to evaluate a meaningful remedy. Otherwise, only addressing the Thompson Island Pool sediments, while potentially very beneficial, may be too limited an action to effectively address the PCB levels in the entire river's environment to an adequate level.

Conclusion 2: The PCB load from the Thompson Island Pool has a readily identifiable homologue pattern which dominates the water column load from the Thompson Island Dam to Kingston during low flow conditions (typically 10 months of the year).

We generally agree with this conclusion. It is important to recognize that there is a gradual shift in the water column PCB load as the water passes downstream, which is indicative of the interaction processes discussed above.

Conclusion 3: The PCB load from the Thompson Island Pool originates from the sediments within the Thompson Island Pool.

We agree with this conclusion and the Department believes that there is an important question to be answered related to this conclusion. Which sediments (the newly contaminated, or older sediments) are contributing the load, and in what proportion?

Conclusion 4: Sediment inventories will not be naturally "remediated" via dechlorination. The extent of dechlorination is limited, resulting in probably less than a 10 percent mass loss from the original concentration.

We agree with this conclusion. The major corollary to this conclusion is that dechlorination will have little or no effect other than in the highly concentrated PCB areas in the Upper Hudson. As a result, the water column downstream of the Thompson Island Dam carries a greater proportion of higher chlorinated PCBs. These types of PCBs are more readily bioaccumulative. The historical aroclor fish data and the 1993 & 1995 congener fish data support this tenet. PCB fish concentrations decrease with the distance downstream but the composition shifts to favor the more highly chlorinated portion of the PCB spectrum.

Section 2

P. 2-3: The last paragraph should be changed to read from the "significance of sediments" to significance of the site. The remediation of the shoreline has been completed and preliminary fish monitoring data indicates improvement. Additional fish data should be available in the future to evaluate conditions over time. (1)

P. 2-14: The report discusses estimating seepage rates. The estimated flow rate of "200 gpm" (2)

is higher than the mean monthly maximum values cited on page 2-15 and could be the permitted discharge rate for the wastewater (SPDES) outfall. We recommend that EPA use the 174 gpm value cited on page 2-15 for the estimate used in the report.

P. 2-12: The General Electric Fort Edward Plant Site is currently listed as a dump in the New York State Department of Environmental Conservation Listing of Inactive Hazardous Waste Sites (Site No.: 5-58-004). The referenced listing is somewhat misleading and the DEIR should recognize that the site is an existing capacitor manufacturing facility. (3)

P. 2-18: "Because it was not part of the containment program, any remaining contaminated sediment from Remnant Deposit 1 will be considered for possible remediation in the Phase 3 Feasibility Study." (4)

Does this mean that Remnant Sites 2-5 will not be considered for remediation in the Feasibility Study? It is our understanding that EPA would evaluate remedial alternatives for the remnant deposits if action is chosen for the river sediments. We recommend EPA determine if adequate information exists to evaluate remedial alternatives for the remnant deposits. Additional time and work may be required to obtain sufficient information in order to allow for evaluation and selection of remedy.

Section 3

P. 3-81 "Water column may also serve to remove a fraction of the PCB load but this appears unlikely in light of the near-conservative transport observed from the TI(Thompson Island) Dam to Waterford noted below." (5)

What process is/may be ongoing in the water column to account for this fractional load removal? Degradation? Volatilization?

P. 3-84: (Discussions of Flow-Averaged Events 5 and 6) "Both events indicate an increase in the water column load of approximately 18 to 39 percent (0.15 to 0.25 kg/day) between the TI Dam and Waterford." (6)

This is the first indication in the report that the segments of the Upper Hudson below the Thompson Island Dam contribute significant loads to the water column of the river under low flow conditions (see Conclusion 1 comment). Given that, on p. 3-81, there is introduction of the concept of some PCB load loss in the water column (presumably of the lighter congeners), the increase in load in these two events is (1) made up of heavier congeners than the Thompson Island Dam load; and (2) indicative of less altered, ie. lower concentration sediments, which have been found in the portion of the river between the Thompson Island Dam and Waterford.

P. 3-85 to 3-86: "The close match of the water column homologue pattern to that of the sediment identifies the sediments as the likely source of the water column load. The data suggest that the total PCB load at the TI Dam is not the result of a simple addition by the sediment to the

Rogers Island load. Rather it appears that some, if not all of the upstream load is stored within the Pool and that processes within the Pool serve to yield a load at the TI Dam principally derived from the sediments, either from dechlorinated sediment directly or from sediment porewater or both."

This statement raises multiple issues:

First, is it possible to predict/identify the fate of the newly stored Rogers Island load in the Thompson Island Pool? (7)

Second, since the statement strongly implies that there are physical/chemical/sedimentological processes that result in an exchange of the Rogers Island load for a new, readily identifiable load (the dechlorinated Thompson Island Pool load), are these physical/chemical/sedimentological processes unique to the Thompson Island Pool? That seems very unlikely. The process or processes that result in the load exchange seen in the Thompson Island Pool are almost certainly occurring in the other pools in the Upper Hudson. The process or processes may vary in magnitude due to physica' parameters such as contaminated sediment distribution and magnitude, channel depth/shape/variability, length of pool, water velocities and velocity variability, and other parameters which can control the sedimentation in the pools and the interactions between the water column and the sediments. (8)

The above leads to the third issue, which is a question "to what extent is the water column load seen in the Hudson River downstream of the Thompson Island Dam influenced by the contaminated sediments downstream of the Thompson Island Dam?" Is it possible that, while the Thompson Island Pool water column/sediment interactions set the initial load, that the appearance of conservative ("pipeline") transport in the Upper Hudson is actually indicative of a near equilibrium between load loss and gain across the other pools in the Upper Hudson River downstream of the Thompson Island Dam? While the mass load does seem conservative, the congener makeup changes. The relative proportion of higher chlorinated PCBs increases as you go downstream. (9)

P. 3-88: "In Transect 3, as the result of the onset of spring-flood conditions, scour provided more than 94 percent of the total water column PCB load seen at Waterford (a gain of 1554 percent). As noted in the detailed analysis in Subsection 3.2.5, this scour appears to be directly related to the increase in the Hoosic River flow and represents erosion of Hudson River PCB-bearing sediments within or near the Hoosic River delta and does not represent a PCB load originating in the Hoosic River."

According to the NYS Canal Corporation, which has recently (1996) performed sampling and dredging of Hoosic River delta sediments, the sediments of the Hoosic River delta contain very low levels of PCB. Scour of the delta itself, therefore, is likely not the source of the loadings seen in Transect 3. Rather, the scour of the sediments of the main stem of the Hudson itself, driven by the increase in Hoosic River flow, is the likely origin of the load increase seen in Transect 3. (10)

The observed increase in load in Transect 3, which originated downstream of the Stillwater monitoring location, is also a clear indicator of the ability of the sediments downstream of the

Thompson Island Pool to contribute to the PCB loads carried by the Upper Hudson, as discussed above consequently affecting the fish regardless of the Thompson Island Pool actions.

P. 3-88: "Essentially, the net TI Pool loading is consistent at around 0.65 kg/day excluding spring high flow. Only under spring high flow conditions is there no substantive TI Pool contribution."

Does this mean that, under spring high flow conditions in 1993, that the load increase across the Thompson Island Pool was not substantive as compared to the very high Rogers Island load, or that the increase in load was not significant given the ability to measure the load? Also, if the load increase was truly not substantive during spring high-flow conditions, does this mean that the load may be groundwater discharge driven, and was minimized by the high river stages present over this time period (which would minimize groundwater discharge to the river due to a lower head differential from the groundwater to the river)? or do the results indicate that this equates to residence time or dilution? (11)

P. 3-101: "These coring sites are not typical of the general sediment type found in the Hudson River; they are more consistently fine-grained and therefore represent only a small portion of the Hudson river sediments."

This brings up an important question. Are the sediments in the Thomson Island Pool, that are theorized to generate the Thompson Island Pool load, in areas where one could generate a core chronology? If not, then this would indicate that there are times when either there is no sedimentation, or events that result in the removal of part of the sediment column. (12)

P. 3-108: "The total PCB analysis of the high-resolution cores yields two major findings. First, there was a substantial decline in PCB levels between 1975 and 1982 followed by a plateau to 1990 in all regions of the Hudson River studied."

This agrees well with the historical fish PCB body burden data set, which adds credence to the finding.

P. 3-142: "It should be noted, however, that the difference in Rogers Island conditions relative to locations downstream may also be the result of the form of PCB release from the GE Hudson Falls facility."

Is the EPA confident that their water column data generated from the Rogers Island monitoring point is representative of the entire PCB load of the river at this point? May there have been transport of PCB oil past Rogers Island that is not represented in the data set? (13)

P. 3-147: "As indicated in Section 3.2, it appears likely that the load at the TI Dam is derived almost entirely from the sediment given the consistency of the total TI Dam load and its homologue pattern. This implies that some if not all of the unaltered PCB load originating above Rogers Island is stored within the sediments of the TI Pool and is replaced and augmented by older PCBs released

from the TI Pool sediments."

Again, this begs the question "what is the fate of the Rogers Island PCB load being stored in the Thompson Island Pool?" (14)

P. 3-151 Regarding the explanation of events that were occurring in April and May 1993. The combined sewer overflow (CSO) was fixed in the middle of May by Washington County and Niagara Mohawk. The significance of this is that water from the CSO was still flowing through the Allen Mill and discharging out the Tailrace Tunnel until this problem was fixed. This helps explain the observed PCB loading conditions. (15)

P. 3-152 to 3-153: (Paragraphs on the relative importance of recent plant site related loadings versus TI Pool sediment related loadings)

These paragraphs touch on several important points.

(1) Is it the current interpretation of the EPA that the relatively large GE plant site related loadings from September 1991 to June 1994 are not related to the increase in Thompson Island Pool loading over that time period? Or are the plant site loadings related, but it is not possible to quantify their relative importance? (16)

(2) The last sentence of this paragraph seems to state that the Thompson Island Pool sediments that were contaminated years ago, combined with the recently contaminated (by the recent plant site related releases) sediments, will be the primary source of PCB to the water column of the river. Is that happening now? (17)

(3) The statement is made on p. 3-153 that "...although the TI Pool load increased at about the same time as the Rogers Island load, the net TI Pool contribution merely doubled and has since dropped to its 1991 levels in spite of the roughly ten fold increase and decrease in the mean monthly Rogers Island Loading for the same period."

What would be the result of this comparison of the Rogers Island load and net Thompson Island Pool loadings on the basis of magnitude of load, rather than on the basis of proportional increase and decrease at each of the two monitoring points? In other words, why not discuss, and take into account in the interpretation, the magnitude of the loads at one point as compared to the other? (18)

P. 3-170: (Water column conclusion summary)

The Department generally agrees with the conclusion presented at the close of Chapter 3, with a few questions or comments.

Conclusion 7: "The source of the TI Pool load appears to be PCBs stored within the sediments." (19)

Which sediments? Is this old sediments, newly contaminated sediments from the source(s) above

Roger's Island, or both?

Conclusion 11: "Hudson River PCB transport appears to be relatively conservative from RM 188.5 at the TI Dam to RM 88.5 near Kingston with loses and gains amounting to no more than roughly 25 percent of the load at the TI Dam."

As discussed above, the Department believes that the same processes which result in the exchange of the Rogers Island load for the Thompson Island Dam load within the Thompson Island Pool are also going to result in some exchange of the Thompson Island Pool load within the other pools of the Upper Hudson downstream of the Thompson Island Dam. The increase in load across the rest of the Upper Hudson downstream of the Thompson Island Dam, coupled with a gradual loss of dechlorination products, seems to indicate some exchange in load between the Thompson Island Dam load and the progressively less dechlorinated sediments downstream of the Thompson Island Pool. Some effort should be expended to evaluate the potential for the sediments from the rest of the Upper Hudson River beyond the Thompson Island Pool to impact the water column PCB load in the Hudson River. This is needed because a key result of the ongoing modeling effort will be predicting the result of various remedial measures on future PCB fate and transport in the river. If the Thompson Island Pool is not the only pool in the Upper Hudson in which sediments significantly impact the water column PCB load of the river, then we need to know this and take it into account in the remedy selection process. We view this as an important concept coming from the review of the report. (20)

Section 4

P. 4-80: When discussing the relationship (in the freshwater lower Hudson) between the water column homologue pattern and that of the sediments, the statement is made that "...it appears that the close agreement between water and sediment is again the result of sediment-water exchange..." (21)

This again supports the importance, stated above, of the exchange between the water column and the sediments throughout the river, not just in the Thompson Island Pool.

P. 4-81: (First full paragraph) "During warm, low flow conditions, the Thompson Island Pool sediments are still locally important but, upon transport downstream, sediment-water exchange such as porewater transport and/or possible *in situ* water column processes modify the water column congener mixture yielding a less dechlorinated result."

We agree.

P. 4-82: (In discussing the newly deposited contaminated sediments, impacted by the recent GE plant site related loads) "It is more likely that these materials, in combination with the existing TI Pool sediment inventory, are responsible for the TI Pool source, *i.e.*, the source results from a combination of altered sediment and freshly deposited sediment whose net result is a mixture whose properties closely resemble those of 1984 sediment."

We agree. However, it will be important to quantify the magnitude and relative importance of the two loads for the purposes of remedy selection. We believe it may be necessary to perform additional sampling to determine the magnitude of each source. (22)

P. 4-82 to 4-83: "In this case, the greater the proportion of the water column load derived from freshly deposited, unaltered PCBs, the more altered (and therefore concentrated) the remaining sediment source must be in order to yield the properties of the water column mixture seen at the TI Dam."

Would the understanding of the relative magnitude of the loads out of the two potential source materials (newly deposited sediments vs. the old sediments) significantly change if there was rapid alteration of the freshly deposited PCB-bearing sediments? Or would this only allow the contribution from the old sediments to be, on average, from somewhat less altered sediments? (23)

P. 4-83: "The sediments of the Pool are clearly responsible for the Thompson Island load although the mechanism for transfer from sediment to water column is unclear."

"Downstream of the Pool, sediment-water exchange via porewater may be an important mechanism for the additional PCB loading noted during the summer. Given the complexities of sediment water exchange, it is likely that the TI Pool load results from a combination of resuspension settling and porewater exchange, involving recently deposited PCBs as well as PCB deposits that are ten years old and older. In light of the large existing PCB inventory whose viability is suggested by the geophysical and geochemical data presented here, it is likely that these sediments will continue to be the major PCB source to the freshwater Hudson for the foreseeable future. How long these sediments will continue to impact the Hudson on this scale is unclear but given the continual sediment release for at least 3 years after the remedial controls were installed at the Hudson Falls facility, it appears likely that this load will continue for several years, perhaps a decade or more."

Does this mean that the TI Pool load could go away (without remediation or other radical changes to the system) in less than ten years? That seems highly unlikely, given the trends in PCB water column load, fish flesh body burdens, and sediment PCB history in the dated cores. These all indicate that the PCB load carried by the river has been relatively stable (except for the increase associated with the 1991-93 event related to the GE plant sites) since around 1984. We find this conclusion to be questionable without knowing the basis for making it. It appears that once the mechanism or mechanisms are understood, EPA should have additional information to estimate a time frame. (24)

Does this mean that the porewater driven exchange is the only exchange mechanism responsible for the additional PCB loading seen downstream of the TI Dam? This also seems unlikely, given that the TI Pool load is theorized to be a result of "...resuspension settling and porewater exchange..." Why would resuspension and settling be limited to only the TI Pool? These same processes are probably occurring in the downstream areas. (25)

We caution EPA's interpretation that" ... continual sediment release for at least 3 years after the

remedial controls were installed at the Hudson Falls facility..." Remedial work continues to be active at this facility. The work completed in 1994 addressed some of the problems that were known at that time. The Department has not selected final remedy at this site and therefore remedial controls have not been installed other than the Interim Remedial Measures and pilot remedial work that has been completed. (26)

General Comments:

- Data Needs to Verify the Model:

EPA's report, and their consultant's presentation at the Scientific and Technical Committee meetings on March 25 and 26, 1997, acknowledge that the mechanism(s) and specific sources of PCB in the load observed coming out of the Thompson Island Pool sediments have not been determined. The report states, "these issues will be further addressed in the modeling efforts subsequent to this report." EPA's modelers indicated that computer modeling would be used to understand the significance of the various potential PCB sources to the water column. Thereby, EPA hopes to ascertain what sources are most important for causing the impacts to the environment. From this understanding EPA would then evaluate remedial options that most effectively deal with the important PCB sources. This modeling work will be qualified with an analysis of the uncertainty of this proposed work. However, EPA's modeling consultants are primarily relying on the data collected in 1993 to identify the sediments and processes responsible for the water column PCB load in the river, and in turn perform predictive model runs for various remedial options. (27)

EPA's proposed method to address this important issue raises a number of questions that warrant careful consideration. We propose that, rather than primarily relying on the 1993 data, EPA consider gathering some limited additional data to reduce the uncertainty of data being fed into the computer modeling effort. This information could also be helpful to identify the potential mechanisms that cause the observed PCB loading leaving the Thompson Island Pool. We are willing to meet with EPA to discuss gathering additional data.

The advantage with this approach is that it attempts to resolve an important issue through direct measurement while potentially complementing the modeling effort through direct verification. We realize that gathering this information may slightly alter the reassessment schedule or components of the schedule. However, we believe such data could reduce the uncertainties in the evaluation of remedial options under consideration and provide a more supportable basis for the decisions to be made regarding the sediments.

- Long-term monitoring:

We all recognize that the monitoring of PCBs in the Hudson River will have to be performed regardless of which remedial alternative is chosen. Therefore, we believe it is important that such a monitoring program begin now. Further EPA data gathering within such a monitoring program could also address a number of the known data gaps identified to date. (28)

The primary period of data collection for the Reassessment was 1993. There were dynamic conditions involved during this period, and it is generally acknowledged that large inputs of PCBs to the Hudson River above Rogers Island were still occurring. We believe the data gathered by EPA was important to help discern the processes involved during the period of data collection . This information further points to questions regarding which sources and mechanisms of PCB fate and transport in the River are important. While remedial progress continues at the General Electric Hudson Falls and Fort Edward Plant Sites, it is important to measure any observed changes to the loading conditions on a river-wide basis. We anticipate that ongoing remedial work will change the PCB loadings to the Hudson River observed at Rodgers Island. Measured changes in the PCB loadings, and the observed response, would certainly be important to predicting future conditions in the Hudson River. The long-term monitoring program could also be used to verify and evaluate the plant site loadings and response that would be measured, and also aid in the modeling of the impacts of various remedial alternatives.

Therefore it is important that monitoring begin now and address obtaining useful data for specific purposes. This type of monitoring should address the key areas where additional data would reduce the uncertainty with the modeling work and aid in continuing the important trends that have been monitored in the past. We are confident in the value of additional monitoring and we request EPA and its team of expert consultants design and implement the sampling and data collection program. We are prepared to actively participate in the effort to assist EPA in performing this work.

- Incorporate Ecological and Low Resolution Coring Data (29)

The data evaluation and interpretation report should eventually incorporate the ecological data(fish and macro invertebrate) and low resolution coring data gathered as part of the Reassessment. At a minimum the conclusions drawn from this information should be documented and reported.

- Information on Bioturbation

Enclosed are copies of papers regarding information on bioturbation. The Department of Health raised this as a potential mechanism that is worth researching to determine if it could explain the observed PCB measurements in the Thompson Island Pool.

The Department's technical staff would like to meet with you and your consultant to discuss these comments and understand EPA's view of any additional work that is necessary. The data demonstrates the impact the PCB contaminated sediments have on the Hudson River, especially those above Troy. We believe the work completed by EPA has significantly narrowed the focus of the remaining information needed to adequately identify and evaluate remedial alternatives. (30)

Please contact Mr. Stephen B. Hammond at 518-457-5677 to arrange such a meeting.

Sincerely,

David Sterman
Deputy Commissioner

Enclosures

cc: Robert Montione DOH w/encl.
John Davis DOL w/encl.
Lisa Rosman NOAA w/encl.
Anne Secord USF&WS w/encl.

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DL-1

SARATOGA COUNTY

ENVIRONMENTAL MANAGEMENT COUNCIL

PETER BALET
CHAIRMAN

GEORGE HODGSON
DIRECTOR

April 8, 1997

Mr. Douglas Tomchuk
U.S. Environmental Protection Agency
290 Broadway, 20th Floor
New York, NY 10007

Dear Mr. Tomchuk:

Enclosed you will find comments on the Phase 2 "Data Evaluation and Interpretation" report prepared by Saratoga County Environmental Management Council member David Adams.

Since the comments in the enclosure to this letter call into question the entire approach and conclusion of the "Data Evaluation and Interpretation" report, the Saratoga County EMC has decided to refrain from providing additional detailed comments.

The Saratoga County EMC is very concerned about the approach used by EPA in this report in drawing conclusions that can only be viewed by the general public as calling for dredging of sediments in the Hudson River if EPA's future health risk environment shows the need for remedial action. Such conclusions are most premature considering the work which remains to be done, and the comments made on various EPA reports, and most recently the serious and major concerns raised about the recently released "Data Evaluation and Interpretation" report.

The Saratoga County EMC has been dismayed by the lack of feedback from EPA on EMC comments made previously to EPA. EPA's statement in the cover letter to the "Data Evaluation and Interpretation" report that the Phase 2 report was divided into sections "to allow interested parties to comment on the reports prior to the incorporation of the work" into subsequent work would have real meaning and substance if EPA were to provide some feedback on previous comments, at least to indicate whether they have been rejected or whether they have been factored into subsequent work.

While the Saratoga County EMC is still looking for EPA responses to its previous comments, the EMC believes it is absolutely essential that EPA respond to the comments in the enclosure due to the fundamental nature of these concerns and their potential effects on the future study of the PCB problem in the Hudson River.

Sincerely,

Peter M. Balet
Chairman

Enc.
cc: Mr. Richard Caspe, Region II USEPA
Mr. Albert DiBernardo, TAMS
Mr. Darryl Decker, Government Liaison Committee

10.0318

April 7, 1997

Comments on EPA Phase 2 Report
Volume 2C - Data Evaluation and Interpretation Report
Hudson River PCB's Reassessment RI/FS February, 1997
David D. Adams, Member Saratoga County EMC and
Government Liaison Committee

1. The EPA report concludes the data show a PCB load at Thompson Island dam greater than the PCB load entering at Rogers Island and the sediments in the Thompson Island pool have been and are the major source of the PCB load at the Thompson Island dam. Further, the EPA report concludes the dechlorinated, buried sediments in the Thompson Island pool have been and still are a likely source of the PCB's in the water column based on homolog patterns and the level of PCB's in the water will not substantially decline until the sediments are depleted (likely to be decades per EPA) or remediated. The Saratoga County EMC strongly believes these conclusions must be revisited for the following reasons:

- o At the April 1, 1997 meeting of the Liaison Committee members, GE stated that the use of homolog patterns to pinpoint the source of PCB's is not sufficiently definitive and that congener "fingerprinting" is required. GE further stated that their analysis of the congener "fingerprints" in the water samples at Rogers Island and Thompson Island dam agreed and showed the PCB's in the water to be directly related to a non-dechlorinated Aroclor 1242 source. GE also stated the congener "fingerprint" of the dechlorinated sediments in the Thompson Island pool did not agree with the congener "fingerprints" of the water samples.

- o It is not clear if the data available relative to the PCB loading at Rogers Island are sufficient to completely define the PCB loading input to the Thompson Island pool from the GE Hudson Falls facility/Bakers Falls area. For example, information obtained by GE in the last six to nine months has shown drops of PCB oil entering the river. These drops could be carried along the river bottom into the Thompson Island pool and thus not be detected by the water samples. Therefore, EPA's conclusion that there must be a net source of PCB's from the sediments in the Thompson Island pool is suspect. (1)

- o EPA's data shows the PCB load in the water column at the Thompson Island dam to be about the same as the PCB loading at Waterford despite the indicted presence of PCB "hot spots" in sediment deposits between the Thompson Island Dam and Waterford. Therefore, EPA's conclusion regarding sediments in the Thompson Island pool as the major source of PCB's to the Hudson River requires that somehow the Thompson Island pool sediments behave differently than the sediments below the Thompson Island dam. However, no rationale or data are presented by EPA to justify such different behavior. (2)

- o EPA's approach predicts that the source of the PCB's in the Thompson Island pool is from buried sediments deposited in 1983 and prior years and not from more recent deposits. This source of the PCB's defies logic in that it is not clear how these deep deposits can both be the source of PCB's in the water and yet (3)

remain as "hot spots" over an extended time period. Logic would seem to dictate that the sediments most likely to interact with the water are the surfical sediments and not the buried sediments. Also, EPA's scouring analysis indicates very little of the "hot spot" sediments (none in the more highly contaminated deposits) are resupended even in a 100 year flood which would mean much less or none during normal river flows.

2. The discussion in item 1 suggests that a likely scenario for the source of the PCB's going over the Thompson Island dam is as follows:

> PCB's, primarily Aroclor 1242 are continuing to flow into the Hudson upstream of Rogers Island from the GE Hudson Falls site/Bakers Falls area. These PCB's, being largely hydrophobic, attach to surficial sediments in the Thompson Island pool. The lower chlorinated PCB's from the surficial sediments are preferentially transferred to the water column as would be expected from the partitioning coefficients for the various homologs. These PCB's then become the source of the predominately mono and di-chloro PCB's seen in the water at the Thompson Island dam, consistent with the "fingerprinting" work done by GE. In this scenario, the buried sediments in the Thompson Island pool became not a source of PCB's to the water but rather a sink for PCB's, removing the PCB's from active contact with the water column as sedimentation continues over time. This scenario is consistent with PCB "hot spots" remaining over long periods of time in the sediment and with the lack of contribution of PCB's to the water column from sediment "hot spots" below the Thompson Island dam. (4)

3. As previously noted in our comments on Volume 2B, it is not at all clear as to how EPA's model can handle the significant changes (one might say even a discontinuity) in PCB output to the Hudson River above Rogers Island starting in 1991. Drawing conclusions about the future water concentration of PCB's from water data that is post- 1991 and sediments data that pre-dates 1991 seems to be very difficult, if not impossible, and likely to lead to erroneous conclusions. Repeating our previous comment, EPA should divide its modeling effort into pre & post 1991 periods. (5)

4. Based on the discussion in comments 1,2,&3, it is absolutely necessary that EPA evaluate the possibility that continuing PCB inputs from areas above Rogers Island are the principal source of PCB's to the water column at Thompson Island dam and not the buried sediments in the Thompson Island pool If the source is from PCB's above Rogers Island, then the conclusions at the bottom of page 4-91 of Book 1 of Vol. 2C that the water column PCB level downstream of the Thompson Island dam will not substantially decline unless the sediments in the Thompson Island pool are depleted or remediated is completely wrong. If the source of the PCB's is from above Rogers Island, the correct approach to reducing PCB levels below the Thompson Island dam is to eliminate or significantly reduce the PCB inputs to the Hudson River as GE is now working to do. In fact, there is recent evidence that the GE effort to stop the PCB inputs above Rogers Island is succeeding in reducing water column PCBs at the Thompson Island dam. Certainly the statement on page 4-91 of Book 1 about the rate of depletion of PCBs in the sediment implies sediment removal if remediation is deemed necessary. If the PCB source is not the sediments in the Thompson Island pool, removal of the sediment by dredging would not achieve the desired result of reducing PCB's in the water column and indeed may cause just the (6)

opposite effect as well as possibly cause major ecological damage to the Hudson River.

5. EPA's statement that dechlorination is not effective in reducing the mass of PCB's in the Hudson River misses the point about the importance of dechlorination. Obviously the removal of a few chlorine atoms from the PCB molecule is not going to significantly reduce the PCB mass. What is important is the difference in behavior between mono and di-chloro PCB's and higher chlorinated PCB's. First is the evidence that the lower chlorinated PCB's are not retained as much in fish as the higher chlorinated PCB's thus reducing the PCB input to people eating the fish. Second, EPA's recent re-evaluation of the cancer risk from PCB's shows a major reduction in cancer risk from the lower chlorinated PCB's. Since EPA data shows the water column to be dominated by the lower chlorinated PCB's, both these factors serve to reduce the cancer risk from eating fish. On page 4-51 of Book 1, EPA cites literature which purports to show that less chlorinated congeners cause neurological impairment and developmental damages. Information presented by GE at the April 1, 1997 Liaison Committee Meeting indicated that subsequent studies have either not confirmed the effects suggested by EPA or have shown observed effects to be attributable to reasons other than PCBs. EPA should produce evidence that has been accepted by the scientific community that PCB's produces neurological or developmental effects before implying such effects can be caused by less-chlorinated PCB's. (7)

6. The use of congener "finger printing" should be applied to PCB data (water columns, sediment and fish data) from the Lower Hudson and the NY/NJ Harbor. The finger printing is necessary to either confirm EPA's contention about the significant PCB input to these areas from the Upper Hudson or show that lower Hudson and NY/NJ harbor sources are the reason for the PCB contamination in these areas. (8)

DC-1

O.A. Borden & Sons, Inc.

Dairy & Fruit Farm

RD# 1 Box 153 Schaghticoke, NY 12154 (518) 692-2370 or 753-4186

April 11, 1997

Doug Tomchuk, RPM
USEPA, Region 2; Attn:DEIR Comments
290 Broadway, 20th floor
New York, NY 10007

Dear Sirs:

As chairman of the Agricultural Liaison Committee, I have been involved with this process for some time. I firmly believe that w are well on the way to correcting the PCB problem in the Hudson River. Unfortunately I'm not sure that the EPA or the Superfund have had much to do with it except for encouraging GE to take action. Remedial action taken by GE at the Hudson Falls plant site and Allen Mills site seem to be making a substantial difference in the PCB levels in the water column.

My comments on these reports at this time are mainly procedural and are briefly as follows:

1. Public participation seems to be of little importance in this project; we had almost no time to view the documents before the EPA meeting in Albany and only TAMS view of data was presented. (1)
2. No indication of when and what conclusions would be drawn in these reports. For instance, we could conclude first that the water column PCB load is decreasing before we look at where the remaining load is coming from. (2)
3. This is obviously a controversial project: why do we avoid looking at all opinions? Why do public comments come due before we are exposed to differing opinions that arose in the Science and Technical Committee? (3)
4. Why do obvious fresh sources of PCB contamination get ignored in this process? (4)
5. How can you possibly put so much importance on 1993 data when so much remedial work has been done since then? (5)

Sincerely,

Thomas A. Borden

Thomas A. Borden
Chairman
Agricultural Liaison Group

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Mark F

RD1 Box 229
Fort Edward,
N.Y. 12828
April 11, 1997

DC-2

To: United States Environmental Protection Agency

Regarding: U.S. EPA Hudson River PCBs Reassessment
Response to Phase 2 Data

My comments regarding this phase are really short and simple - Do NOT Dredge! (1)

I am very disillusioned at the political maneuvering that are being generated by the activists groups. It is too bad money and politics become intertwined with a dissemination of this magnitude. Somewhere commonsense and a realistic approach to the impact a dredging project would have on the surrounding communities along the Hudson River need to be addressed. Somewhere the impact on the daily industry needs to be considered.

(cont)

(Cont) Page 2

The site designated for the "dump" site within a 35,000 sq. mile agricultural district. Somewhere, someone needs to be accountable for the millions of dollars spent on a project that made no sense in the 70's or the 80's or today. Then the scare was cancer. Today the scare is behavioral problems!

Perhaps we should be so wise as to let Mother Nature heal the wounds society has inflicted on the Hudson River. Perhaps we should concentrate our efforts on stopping any further pollution.

Somewhere, somehow, someway - this project needs to be put into perspective!

Marilyn Kulver
Co-Chair Ag Friends Soc.
Dairy Farmer
CEASE
Fort Edward Town Board Mem.

15 Burgoyne Avenue
Hudson Falls, New York 12839
April 9, 1997

Douglas Tomchuk
US EPA - Region 2
290 Broadway - 20th Floor
New York, NY 10007-1866

Dear Doug:

Given the information contained in the Data Evaluation and Interpretation Report as well as the information discussed at the most recent Science and Technical Committee meeting, I offer these comments for the record. On page 4-90, Volume 2C Book 1 of 3, it is stated, "Given the large inventory of existing PCBs as well as the possibility of additional PCB inventory from the recent releases from the Bakers Falls area, it is not possible to strictly define the exact nature of the sediments responsible for the TI Pool load or the exact mechanism or mechanisms for sediment to water column transfer." This statement goes to the heart of the reassessment. I believe that we have all agreed that the failure of the gate at the Allen Mills was an event that had a tremendous impact on the PCB levels in the upper Hudson. It is imperative that we distinguish between the non dechlorinated PCBs coming from the Allen Mill site and the older dechlorinated PCBs buried in the sediments. There must be a quantification of the amount of PCBs released as a result of the gate failure and a quantification of the results of all actions taken by General Electric, with New York State's Department of Environmental Conservation oversight, since 1991. (1)

I have a real concern for the credence give the pore water (ground water flux) theory. As I have read through volumes of material generated over the last 20 years, this is a phenomenon which has never before been identified. How can we possibly believe that the ground water flux theory is unique to the Thompson Island Pool and not to other areas of the Hudson? I question if this ground water flux theory has been invented in order to make numbers fit in areas where there are amounts that just cannot be accounted for. (2)

I also feel compelled to say that we need responses to comments in a timely fashion. Meetings are scheduled to discuss the documents as they are released, but we have no way of knowing what comments are being received by EPA and how those comments are being addressed.

In conclusion, since the Thompson Island Pool has become the focus of study, the precise location of all sources and the magnitude of their contribution must be known in order to lead us to an informed ultimate decision.

Sincerely yours,

Sharon Ruggi

Sharon Ruggi

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DC-4

UNIVERSITY AT ALBANY
STATE UNIVERSITY OF NEW YORK

April 11, 1997

Mr. Douglas Tomchuk
US EPA Region 2
290 Broadway - 20th Floor
New York, New York 10007-1866

Re: DEIR Comments

Dear Mr. Tomchuk:

Unfortunately I was away on business during the recent Hudson River STC meeting and unable to attend. At the risk of repeating some points possibly raised at the meeting, I will exercise the option to comment further as offered in the letter of February 13 accompanying Vol. 2C of the Phase 2 Report.

In my view the most serious shortcomings of the present stage of the Phase 2 investigation are the mass balance calibrations obtained and applied to the Thompson Island (TI) pool, and the consequent process interpretations derived therefrom. I have noted two of the major data inconsistencies (suspended solids and PCB mass loadings) in my previous letter of November 13. and add the following comments:

I. Assumed mass balance PCB loadings, and to a lesser extent suspended solids (TSS) loadings, to and within the TI pool are in error, and result in an unrealistic interpretation of TI pool processes and dynamics. A conclusion, based on the Phase 2 calibration, that the TI pool generates a significant increase in total annual PCB loading beyond that passing Ft. Edward is almost certainly wrong because of inconsistencies with other data and observations -- both historical, and some of those cited in Phase 2. In brief, some of these are as follows.

   1) A comparison of the PCB concentrations of TSS at higher flow rates (>300 m^3/s) with the tops of sediment cores (e.g. Rogers Island and TID RM 188.5) would indicate that the coexisting water column PCB concentrations at Rogers Island are higher (median and maximum by 3x) than at the TID (Table 3-19). (1)

2) Two dated cores in the TIP establish an annual sedimentation rate of ~ 1 cm/yr., which agrees well with other estimates of net sedimentation. A net or prevailing state of scour cannot exist in the TIP, and a net loss of resuspended sediment cannot be argued as a PCB loading dynamic, especially at low flow. (Table 3-18). (2)

3) An inference of a significant pore water diffusion "contribution" to PCB loading driven by groundwater flow is not supported by any evidence. Diffusion alone is incapable of such an effect since other studies indicate a mm range at best; a comparison of discharge estimates at various River stations provides no indication that groundwater recharge to the River in the TIP is any more a factor there than elsewhere downstream -- including other stretches with PCB "hotspots". A major fault zone, potentially capable of transmitting groundwater, underlies the Champlain Canal terminus at Ft. Edward, but this is upstream of most of the TIP. Finally, any continuing PCB mass net discharge flux from TIP sediment older than 1-2 years would progressively lower TIP hot spot concentrations. No evidence of this exists in comparisons of sediment core profiles of different ages. (3)

4) If PCB loading increases in transit of the TIP, why is no similar effect observed below the TID where other substantial hot spots exist? The concept of a PCB loading "pipeline" between the TID and Waterford is inconsistent with the observations of water column total PCB-TSS relations at high flow, a condition of net annual sedimentation in the upper Hudson, and observed PCB concentrations of core tops. (4)

5) Historical data comparisons of PCB concentrations in water samples at Rogers Island versus Schuylerville, and at Rogers Island versus the TID (also Phase 2, vol. 2B, Fig. 4-2, 4-5), reveal many exceptions to a presumed trend of an increase in concentrations or PCB loading along the TIP. Such a trend is best displayed in data at low flow, and is very dubious at high flow (e.g. Vol. 2C, Table 3-16; Transect 4, Flow Average #1). Even at low flow, exceptions are common (e.g. Table 3-16; Transect 1, Flow Average #3; Vol. 2B, Fig. 4-2). Clearly, sample representation relative to flow rate and event timing is a problem with all the data, and a basic weakness in estimating annual loadings at any station. For example in Table 3-23, note that estimated annual PCB loadings at Schuylerville (below TID) are greater than Ft. Edward 1977-1985, and then abruptly reverse 1986-1993 (1990-93 relative to Waterford). This shift may merely reflect a change in USGS sampling procedure (personal communication, C.R. Barnes) rather than any change in the TIP or River processes. Another illustration of the problem is the very large variance of the observed (USGS and GE) PCB concentration data at Ft. Edward, at both low and high flow. This variance reflects erratic PCB pulse or "spike" discharges from or near the source; all too often high values have been discarded as anomalous in estimates of mean or annual loadings, which can lead to large errors at high flow rates. (5)

II. My letter of November 13 noted the problem of representative sampling for estimating PCB mass balance in calibration of the TIP. Upon reviewing Vol. 2C this problem looms even more forcefully; my view now is that much or all of the Phase 2 PCB loading data for the Ft. (6)

Edward - Rogers Island sample site is unreliable and cannot be used for meaningful model calibration. This view derives from: 1) a consideration of the variance shown in analyses from this site, as outlined above; 2) available information as to the sampling methods employed in Phase 2 (flow averaged and transect sampling); and 3) known physical sources of variance at the site which make representative sampling difficult.

Variance due to the latter includes cross channel and vertical inhomogeneity in PCB distribution in the River at any point in time, and any effect of changes in flow rate and water temperature on the distribution. This variance is separate from that of the variation in PCB source (Hudson Falls) discharge, and both are included in the observed variance of (1) above.

A more or less persistent cross channel variation effect at Ft. Edward was described by Tofflemier (references in November 13 letter), and further demonstrated in dye injections by G.E. The sampling studies of O'Brien and Gere also showed that non-persistent and unpredictable vertical and cross channel variations were present relative to both (east and west) margins of the River. as well as the Rogers Island channels.

Some idea of the combined variance is found in the historical data, especially that of the USGS when both channels at Rogers Island were sampled (water column) from the Rte. 197 bridge. It should be noted that this is instantaneous sample point site variance; time dependent variance (e.g. 15 observations, March 31 - April 29, 1993 high flow event) of PCB loading is an additional component of the total variance. Relative to total variance, the Phase 2 Ft. Edward calibration data in essence assumes a knowledge of the time dependent PCB loading without any knowledge of the various components of variance referred to above.

In short, any competent statistician would be in agony if confidence limits were required on the Phase 2 PCB data simply because no analysis of the components of total variance has ever been made. Without such knowledge, the relevance of individual sample results is obscure, whether transect, water column. or flow averaged; and the reliability is unknown.

In respect to Phase 2, a scenario whereby TSS from the spring high discharge event is annually deposited in the TIP and subsequently desorbs partially altered PCB to the TIP at low flow (any net scour being restricted to erodable or unstable sites of prior year deposited sediment in the first spring high discharge event), seems equally compatible with the cited data, including a possible TID PCB net discharge > Ft. Edward at low flow.

III. The problem of relating TSS to discharge was also noted in my November 13 letter. The Phase 2 model calibration assumes a linear regression, which is incorrect, and until an algorithm is developed to incorporate flow event peak and sequence timing, such calibration is also in error. In addition. the mass balance model for PCB vs. TSS in the TIP assumes the two may be related as an estimator of scour or resuspension of sediment (Vol. 2C: 3.2:4). An analysis of all the historic data for TSS vs. PCB concentration (water column) shows no relationship at any station, especially at high flow. therefore PCB loading cannot be used to

(7)

infer scour or resuspension even if such is present. Further, possible shifts in PCB homologue or congener distributions which might bear on this issue are non diagnostic in Phase 2 (Vol. 2C, book 1, p. 3-48, 49).

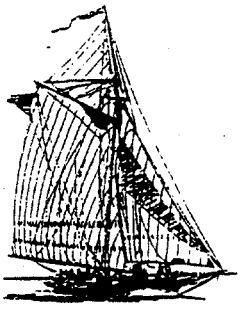
I would be happy to discuss any of the above in more detail at the next STC meeting. In the meantime, it might be helpful if I could be provided with the physical details of the on-site water sampling procedures beyond the descriptions in the Phase 2 Report.

Very truly yours,

George W. Putman

cc: W. Nicholsen
J. Haggard
J. Davis

DP-1



Hudson River Sloop CLEARWATER, Inc.

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April 9, 1997

Douglas Tomchuk
US EPA - Region 2
290 Broadway - 20th Floor
New York, NY 10007-1866

Attn: DEIR Comments

Dear Mr. Tomchuk,

Hudson River Sloop Clearwater, Inc. is a 501(c)(3) organization, founded in 1966, with the mission to preserve and protect the Hudson River and its watershed. We currently have some 10,000 members, most from the Hudson Valley, but also from 44 states and 9 countries.

Clearwater has been involved with the Hudson River PCB contamination issue for the last two decades. We are grateful for the opportunity to participate in the reassessment process and are confident it will lead to a favorable Record of Decision. We applaud the EPA for taking the time and energy needed to collect and analyze the vast amount of data presented in the Phase 2 report.

In general, we support the conclusions presented by the Data Evaluation and Interpretation Report (Phase 2). They are: (1) the area of the site upstream of the Thompson Island Dam represents the primary source of PCBs to the freshwater Hudson; (2) the PCB load from the Thompson Island Pool has a readily identifiable homologue pattern which dominates the water column load for the Thompson Island Dam to Kingston during low flow conditions (typically 10 months of the year); (3) the PCB load from the Thompson Island Pool originates from the sediments within the Thompson Island Pool; (4) sediment inventories will not be naturally "remediated" via dechlorination. These four major conclusions come as welcome news and are a confirmation of our long-held convictions. It was also encouraging to have General Electric's rhetoric exposed as the "myths" that they are.

Clearwater does disagree with the EPA on one point: The time to depletion of the Thompson Island Pool PCB inventory (last sentence of Executive Summary). According to this EPA report, there exists in the pool between 19.6 and 14.5 metric tons of PCBs. An average of those two numbers yields an estimate of 17 mt, or 37,500 pounds. Using averages from EPA's data in table 3-24, it appears that approximately 3 pounds of PCBs go over the Thompson Island Dam every day. This results in an annual estimate of 1,100 pounds. If one were to assume linear depletion rates with no "diminishing returns," **the time required for depletion would be almost 4 decades** instead of the single decade suggested by EPA in the last sentence of their Executive Summary. We hypothesize, however, that the actual depletion of Thompson Island Pool PCBs is likely to be characterized by diminishing rates of contamination, with the effect of prolonging for an indefinite time the constant (though diminishing) recontamination of the lower Hudson, with the **probable loss of fisheries and extension of human health risks for additional decades**. One must also remember that the "armoring" of the remnant deposits, a temporary solution which already allows PCBs to leach into the river, may begin to break down, with resulting elevated PCB released over time. Furthermore, there remains as unquantified "very large amount" (DEC 1996) of PCBs in inventory in the shale bedrock below GE's Hudson Falls plants, which has been contributing approximately 1/2 pound per day to the river's burden (about 30%). Remediation efforts at Hudson Falls, conducted by GE contractors under the oversight of DEC, may be slowing the rate of seepage, but the prospect of complete stoppage are highly uncertain. (1)

We suggest that it would not be unreasonable to contemplate a time horizon of PCB contamination in the Hudson River a century or longer in duration. The only prospects for curtailing this threat to biological and human health lie in dredging and treatment of sediment from the upper Hudson hot spots, removal and treatment of the remnant deposits, and continued remediation of the Hudson Falls seeps.

In conclusion, Clearwater is pleased with the majority of the Data Evaluation and Interpretation Report (Phase 2) and would request that the time to depletion of the Thompson Island Pool PCB inventory be reexamined for possible errors in calculation.

We are looking forward to the next phase of the reassessment process. If you have any questions regarding our comments, please call. Thank you for your time.

Sincerely,

Andre Mele
Environmental Director

COPY

13 Roweland Avenue
Delmar, New York 12054-3037
November 11, 1994

Doug Tomchuk
Regional Project Manager
PCB's REASSESSMENT
US Env. Prot. Agency Region 2
26 Federal Plaza
New York, New York 10278

Dear Mr. Tomchuk:

I am a resident of the Town of Bethlehem, Albany County, New York.

Our town water supply serves approximately 20,000 residents and several large industries.

In 1995, an additional new source of supply (up to 6 MGD) will supplement our upland source. The new source will be an infiltration gallery approximately 1000' long 20' wide 30' deep and located parallel to within 30' of the west side of the Hudson River. The infiltration gallery is located 17 miles south of the Troy Dam opposite the Village of Castleton.

I understand that EPA is currently evaluating the Human Health Risk from PCB's in the Hudson River.

Our new water source will serve our community sometime in 1995. Very limited sampling of the new source indicates that concentrations of PCB's are within acceptable limits. A local citizen's group "Clearwater For Bethlehem" believes that the potential Health Risks from PCB's should be more thoroughly evaluated with particular reference to our new water source.

Attached is a letter dated 11/29/93 from Mr. John Dunn of the NYS Dept. of Health to Mr. Fred Sievers of NYS Conservation Department. Mr. Dunn notes that the avenue of water travel is vertically through the river bottom and then horizontally via sand/gravel. Our new water source could result in PCB exposure of our residents. Is it possible that water travel through Hudson River bottom sludge containing PCB's will increase our level of exposure that would not be encountered from a direct Hudson River intake? (1)

A limited number of samples have been collected over a relatively short time frame. Significant changes in the water chemistry between river water and infiltration gallery water have been noted. The ammonia concentrations exceed 2.0 ppm and phosphate and carbon dioxide levels increased significantly. The total organic carbon following chlorination ranges from 7-13 ppm.

The town consultants have recommended an ozone dose of 2 to 3 ppm to treat the water. This dose is, in part, to remove iron (over 5 ppm) and manganese (o.5 ppm). Would this ozone dose produce toxic ozone by-products in the presence of PCB's? (2)

You have scheduled a report due May 1995 on the Human Health Risk Assessment of Hudson River PCB's. Can you include an evaluation of the risk from PCB's in connection with withdrawal of water via the infiltration gallery which will serve as a source of water for Bethlehem? (3)

You can get additional information on source, sampling results and the schedule for operation from-

Ms. Sheila Fuller, Supervisor
Town of Bethlehem
445 Delaware Avenue
Delmar, New York 12054

I would appreciate a reply.

Very truly yours,

Sherwood Davies

SD/mbd

c.c. Ms. Sheila Fuller, Supervisor, Town of Bethlehem
Ms. Linda Burtis, Clearwater For Bethlehem

13 Roweland Avenue
Delmar, New York 12054-3037
April 5, 1997

Douglas Tomchuk
US EPA - Region 2
290 Broadway - 20th Floor
New York, New York 10007-1866

Re: DEIR Comments
USEPA Data
Evaluation and Interpretation
Report (DEIR) on Hudson River
PCB's Superfund site

Dear Mr. Tomchuk:

I offer the following comments on the above referenced report. The DEIR fails to provide data on any interpretation on porewater migration into the Hudson River ground water aquifer.

In 1996, the Town of Bethlehem, Albany County began withdrawing 2.0 to 3.0 MGD from a horizontal well (infiltration gallery) adjacent to the Hudson River. This ground water source is under the influence of a surface water (Hudson River). The well is located on the west side of the Hudson River opposite the Village of Castleton. Attached is a copy of a letter to you dated November 11, 1994 furthur describing the Bethlehem supply.

The following data and conclusions from the DEIR indicates that PCB's in the porewater of bottom sediments exceed drinking water limits and that migration into ground water can contaminate potable water supplies. (1)

* PCB's can transfer to the water column involving porewater exchange i.e. the transport of PCB's to the water column via interstitial water found within the river sediments (E-4).

* The flux of PCB's from the sediment porewater must also be considered as a potential PCB source to the water column (3-49).

* On the basis of this PCB "fingerprint" it was concluded that the Thompson Island Pool sediments represented the major source to the water column...(E-4.

* Porewater samples from the Great Lakes were found to be 10 to 500 times greater than the water column concentrations (3-49).

* Porewater results yielded a total median composited PCB concentration of 6.43 ug/L (ppb) from a sediment with a median value of 17,000 ug/Kg)(ppb) (3-49).

*Total PCB's in the 3.5 foot depth of bottom sediments at the Albany Turning Basin R.M. 143.5 ranged from 1,000 ug/Kg to 18,000 ug/Kg with an average value of 4,000 ug/Kg (Figure 3-61).

* PCB's are hydrophobic and tend to bind preferentially to organic carbon present in suspended solids in the water column, or in the sediments in the river bottom (3-46).

* Based on a 1 liter sample, PCB Congeners in the water column are detected at levels of 0.5 to 1.0 ng/L (ppt) and total PCB's are detected at levels of 10 ng/L (ppt) (B-24).

Extrapolating data from the DEIR, PCB's in porewater from sediments in the Albany area ranges from 380 ng/L to 6,800 ng/L (ppt). New York State's Maximum Contaminant Level (MCL) for PCB's in potable water is 500 ng/L with a USEPA goal of zero.

The Water Quality Regulations (Surface and Groundwater Classification and Standards) of the New York State Department of Environmental Conservation has established standards for PCB's in groundwater. Section 703.5 establishes a standard of 100 ng/L in groundwater. Section 703.6 establishes a groundwater effluent standard of 100 ng/L which would apply to a point source such as Hudson River bottom sediments.

The laboratory reporting results on samples collected from the Bethlehem well failed to report total PCB's. Thus no comparison can be made as to PCB's in porewater reported by the USEPA and the Town's PCB analysis of the well water.

High concentrations of organic carbon and nitrogen and a variable turbidity in the well water indicates the influence of water "filtering" through Hudson River bottom sediments.

The DEIR confirms the environmental persistance of PCB's in the bottom sediments and a concentration of PCB's in the porewater much greater than that found in the water column.

Bethlehem's well is within the zone of influence of the PCB's bottom sediments. These sediments represent a point source of contamination.

The Hudson River PCB's Superfund site represents a health risk to residents of the Town of Bethlehem. The USEPA Human Health Risk assessment report to be released in December 1997 will be incomplete if it fails to evaluate the health risk from PCB contamination of groundwater sources adjacent to the Hudson River.

Very truly yours,

Sherwood Davies

SD/mbd

Enc.

c.c. Richard L Brodsky, New York State Assemblyman

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PACE ENVIRONMENTAL LITIGATION CLINIC, INC.

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ADMINISTRATIVE ASSISTANT
MARY BETH DISTEFANO

April 11, 1997

Mr. Douglas Tomchuk
US EPA Region II
290 Broadway, 20th Floor
New York, NY 10007-1866

Re: Hudson River PCBs Data Evaluation and Interpretation Report

Dear Mr. Tomchuk:

We represent Hudson Riverkeeper Fund, Inc. (Riverkeeper), a not-for-profit conservation organization whose purpose is to conserve and enhance the beauty, quality and life of the Hudson River, its tributaries and the New York City watershed. Riverkeeper supports the major conclusions found in the Data Evaluation and Interpretation Report (DEIR).

We believe that the significant source of Hudson River PCBs is the Upper Hudson River. The Upper Hudson River, particularly the GE sites at Fort Edward and Hudson Falls, acts as a faucet for the PCB contamination in the Lower Hudson River. EPA's data demonstrates that the source of PCBs from the Mohawk and Hoosic Rivers was less than 20% of the total PCB load, even during 100-year flood events.

Additionally, we support the EPA's evaluation that the PCBs located in sediment will not be naturally remediated by dechlorination. We agree that the "hot spot" sediments are a potential and recurring source of PCBs in the water by resuspension.

Riverkeeper believes that the EPA is correct in determining that the water column PCB levels in the Lower Hudson River will not substantially decline beyond current levels until the active PCB-laden sediments are remediated.

Hudson Riverkeeper Fund, Inc., supports the major conclusions in the DEIR. We encourage remediation efforts be taken to remedy the PCB concentrations found in the Hudson River.

Sincerely,

Annette Boehlje

Annette Boehlje
Legal Intern

DP-5

SCENIC HUDSON INC

April 11, 1997

Vassar Street
Poughkeepsie, NY 12601-3091
914-473-4440
FAX 914-473-2648
email: scenichu@mhv.net

Mr. Doug Tomchuk
Emergency and Remedial Response Division
U.S. Environmental Protection Agency
290 Broadway, 20th Floor
New York, NY 10007-1866

Re: Data Evaluation and Interpretation Report for the Hudson River PCBs Site

Mr. Tomchuk:

This letter constitutes Scenic Hudson's comments on the Data Evaluation and Interpretation Report (DEIR) of EPA's Phase 2 Reassessment for the Hudson River PCBs Site.

As you know, Scenic Hudson has a Technical Assistance Grant (TAG) from EPA to aid our participation in the Reassessment. It is our intention to reserve the bulk of the TAG for analysis of human health and ecological issues as well as remedy evaluation and selection. With the limited TAG funds allocated to the DEIR, we are working with our advisor to prepare interpretive materials to help the public understand the DEIR beyond simply the key findings.

The DEIR is an impressive document. It is without question the most thorough and authoritative analysis of the PCB contamination in the Hudson River to date. In documenting the nature and extent of contamination for this site, EPA has vastly surpassed typical Superfund investigations in the amount and quality of data, scope of analysis, and scientific rigor.

The DEIR is an important step forward because it effectively clears much of the confusion and controversy regarding sources and dynamics of PCB in the Hudson River. In particular, it establishes that the Thompson Island Pool sediment "hot spots" are a significant source -- in fact the dominant source -- of PCBs to the river. In addition, dechlorination has reduced the PCB mass in sediments less than 10 percent and, therefore, "no action" is not a viable means of ameliorating human health and ecological risks.

The conclusions of the DEIR reflect a considerable weight of evidence. Several lines of investigation using numerous sources of data (including abundant data supplied by GE) combine to a form cohesive and consistent understanding of the dynamics of PCBs in system. There are still aspects of the system that are understood incompletely. However, the central DEIR conclusions derive from robust empirical datasets. In carrying out the investigation, EPA cooperated with the New York State Department of Environmental Conservation, members of the Scientific and Technical Committee, and General Electric, which provided extensive data and exhaustive scrutiny.

It is noteworthy that the data show patterns over time and over distance moving downriver from the sources of contamination. Because the study period encompasses several seasonal cycles and one-time events such as floods, increased releases from the plant sites in the early 1990s, and attenuating releases from the plant sites in 1993, EPA has been able to gain a better understanding of the history and dynamics of the system. Moreover, analysis of the types of PCBs enables EPA to distinguish between releases from the sediment hot spots, the plant sites, tributaries, and New York Harbor sources.

Please call me or Josh Cleland at (914) 473-4440 with questions of comments. Thank you.

Sincerely,

Cara Lee

Cara Lee
Environment Director

/rmm

DG-1

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April 11, 1997

Mr. Douglas Tomchuk
U.S. Environmental Protection Agency
Region II
290 Broadway, 20th Floor
New York, New York 10007-1866

RE: DEIR Comments

Dear Mr. Tomchuk

General Electric Company ("GE") is pleased to submit these comments on EPA's February 1997 Data Evaluation and Interpretation Report ("Report") for the Hudson River PCBs Reassessment Remedial Investigation/Feasibility Study.

Recent technical meetings between the Agency and its contractors and GE and its contractors have been extremely helpful and productive in clarifying and resolving critical issues. Our comments would have been more extensive but for this dialogue. We believe there needs to be an ongoing dialogue to both share and test various technical positions developed as the reassessment continues.

The reaction of the public to the release of the Report - and particularly to its Executive Summary - suggests that it was taken to be a completed Remedial Investigation ("RI"). Of course, it does not meet that description. There are important conclusions that are stated so broadly that they are not helpful in the context of remedial analysis. For instance, a major source of PCBs at the Thompson Island Dam is identified as the sediments of the Thompson Island Pool, but the particular class or category of sediments is not identified as it must be for useful analyses in the remedial context. Other conclusions focus on one aspect of an issue while neglecting other equally or more important aspects. The remedial importance of dechlorination is limited to discussion of reduced PCB mass, ignoring reduced toxicity and bioaccumulation. The half of the annual load of PCBs which is perceived to originate in the Thompson Island Pool sediments is analyzed at length, the half originating near the Hudson Falls plant site is given short shrift. Data issues essential to remedial analyses are left unaddressed or glibly brushed

aside: what is the present and future load coming from recent releases near the Hudson Falls site and what is the fate of such releases in the Thomspon Island Pool?

In short, despite the very considerable effort that clearly has gone into the development of this Report, a great deal of very important work remains to be done. Most important, interpretation of data must be tested in the context of rigorous fate and transport modeling which will constrain interpretations with consistent and plausible mechanisms.

We are continuing to review the Report and encourage the Agency to consider any additional comments we may have in the context of our continuing dialogue. We believe that with ongoing cooperation and exchange of data analyses and modeling approaches, the final outputs can result in an RI that forms a sound basis for selecting and testing remedies that are based on the realities of PCB fate and transport in the Upper Hudson.

Please place a copy of these comments in the Administrative Record for the site.

Sincerely,

FOR GENERAL ELECTRIC COMPANY

Angus Macbeth

cc: Richard Caspe (USEPA Region II)
John Cahill (NYSDEC)
Paul Simon (USEPA Region II)
Ann Rychlinski (USEPA Region II)
Frank Bifera (NYSDEC)
Ronald Sloan (NYSDEC)
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Al DiBernardo (TAMS)
Victor Bierman (Limno Tech)
Charles Menzie (Menzie-Cura)
Jon Butcher (Tetra Tech)

COMMENTS OF GENERAL ELECTRIC COMPANY ON

PHASE 2 REPORT - REVIEW COPY
FURTHER SITE CHARACTERIZATION AND ANALYSIS
VOLUME 2C -
DATA EVALUATION AND INTERPRETATION REPORT
HUDSON RIVER PCBs REASSESSMENT RI/FS
FEBRUARY 1997

April 11, 1997

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COMMENTS OF THE GENERAL ELECTRIC COMPANY TO THE UNITED STATES ENVIRONMENTAL PROTECTION AGENCY CONCERNING THE PHASE 2 DATA EVALUATION AND INTERPRETATION REPORT FOR THE HUDSON RIVER PCBs SUPERFUND SITE (FEBRUARY 1997)

I. INTRODUCTION AND EXECUTIVE SUMMARY

The General Electric Co. ("GE") is pleased to submit these comments to the United States Environmental Protection Agency ("EPA") on the "Phase 2 Report - Review Copy, Further Site Characterization and Analysis, Volume 2C - Data Evaluation and Interpretation Report, Hudson River PCBs Reassessment RI/FS" (February 1997) ("Report"). The Report presents EPA's analysis of the sediment and water column data collected during Phase 2 of the Remedial Investigation ("RI") of the Hudson River PCBs Superfund Site ("Site") Reassessment, as well as historical data collected by GE, the United States Geological Survey ("USGS") and others.

The Report is part of EPA's Reassessment, which seeks to determine the sources, transport and fate of PCBs in the Upper Hudson River for the purposes of remedial analysis. The Report analyzes the data collected in the RI and presents conclusions concerning the sources, transport and fate of PCBs in the Hudson River. If the Agency finds that the PCBs pose a risk that it believes would be prudent to abate, the evaluation and interpretation of the data should aid in determining where the PCBs come from, how they move through the river system, and how they leave the system. This, in turn, should form the basis for addressing the remedial questions of what will

happen to the system without further intrusion and whether any particular remedy would abate any perceived risk more quickly than natural recovery.

Fundamental to these determinations is a technically sound analysis of the data. The Report does not provide a persuasive account of the data, and GE respectfully submits that several primary conclusions of the Report are incorrect as a result of flawed, incomplete or incorrect analyses. The Report is notably unhelpful in answering the central questions that the Reassessment must address -- the questions of source, transport, fate, and remedial alternatives.

We start with the four major conclusions that the Agency drew from the data analysis and set forth the basis for our disagreement:

1. The area of the site upstream of the Thompson Island Dam represents the primary source of PCBs to the freshwater Hudson. This includes the GE Hudson Falls and Fort Edward facilities, the Remnant Deposit area and the sediments of the Thompson Island Pool. Report at E-2.

The Report describes the PCB load that passes the Thompson Island Dam ("TID") as moving in "pipeline" fashion, with little or no loss of PCBs from the water column, to the freshwater Hudson downstream of Troy. We disagree with this conclusion in two regards. First, the sediments downstream of the TID contribute significantly to the water column load as measured at Waterford. (1) During low flow, this contribution is on the order of 33%. Second, external sources contribute to the PCB load in the freshwater Hudson, particularly downstream of Troy. The Albany core analyzed in the Report indicates that 15% to 25% of the PCB load found at Albany originated downstream

of the TID and not in the aged sediments of the river. Both facts are inconsistent with the theory of a conduit between the TIP and the freshwater Hudson. This correction is important. The remedial analysis must recognize that elimination of the PCB load at the TID will not eliminate the PCB loadings downstream of the TID.

2. The PCB load from the Thompson Island Pool has a readily identifiable homologue pattern which dominates the water column from the Thompson Island Dam to Kingston during low flow conditions (typically 10 months of the year). Report at E-3.

This conclusion suffers from two misleading omissions. First, the Report shows that approximately 36% of the total annual PCB load passing the TID occurred in the two-month high-flow period. Second, the high-flow load does not show the homologue pattern seen during low flow and clearly originates upstream of the Thompson Island Pool ("TIP"). (2)

These additions are important. The remedial analysis must recognize that eliminating the low-flow PCB load at the TID or eliminating the PCB load originating in the TIP will not eliminate 50% of the annual PCB load passing the TID. Only if conditions during the sampling period are unrepresentative of present conditions will this not be the case. The Report suggests, without factual demonstration from the data, that loading above the TIP has been substantially reduced since the sampling period. To conduct a remedial analysis with confidence, one must know whether that is in fact the case. This determination cannot be made until the effects of the remedial work GE has conducted can be fully evaluated.

3. The PCB load from the Thompson Island Pool originates from the sediments within the Thompson Island Pool. Report at E-4.

This conclusion is too vague to be useful in the remedial context. The Report postulates that the TIP load originates in highly dechlorinated sediments deposited before 1984 or in undechlorinated sediments more recently deposited. In order to know which of these distinct sediment classes might be a candidate for remedial action, one needs to know which class contributes the PCBs to the TIP load. This is important because each class supports distinct remedies. The Report is of no help on this issue. (3)

More fundamentally, there is no evidence to support the conclusion that the TIP load originates from PCBs in highly dechlorinated, highly concentrated sediments. No realistic mechanism exists to resuspend these PCBs from the sediments into the water column, and the congener pattern of these sediments does not match the pattern of the TIP load.

GE believes that the increase in PCB load across the TIP originates partially from the surficial sediments of the TIP (particularly from PCBs deposited from upstream of Rogers Island in the recent past) and partially from the PCB load that passes Rogers Island undetected and only later detected up at the TID after reprocessing through the surface sediments. This limits the contribution from the sediments to amounts congruent with mechanisms that transfer PCBs from sediments to the water column; provides a more persuasive match to the congener pattern at the TID; and takes into account the major releases to the river following the 1991 collapse of the Allen Mill.

The source of the PCB load at the TID is of central importance to the remedial analysis. If current and recent releases from upstream of Rogers island are the source of the load at the TID, the remedial analysis must focus on sources upstream of Rogers Island. If the source of the load at the TID is PCBs deposited in the sediments of the TIP several years ago, the remedial analysis is likely to focus on the sediments of the TIP.

4. Sediment inventories will not be naturally "remediated" via dechlorination. The extent of dechlorination is limited, resulting in probably less than a 10 percent mass loss from the original concentrations.

This conclusion focuses on the wrong issue, mass. Dechlorination reduces the potential toxicity and bioaccumulation of the affected PCBs. Dechlorination will reduce the carcinogenicity of the PCBs; it can reduce the toxic equivalency of the PCBs by more than 90%; and it will reduce the bioaccumulation of the PCBs between 4 and 35 fold. Because of these effects, dechlorination (4) makes a very substantial contribution to remediation and must be considered in the food-web modeling and risk assessment. Finally, the major conclusions fail to address sedimentation that buries PCBs and effectively removes them from the food chain and is an important remedial process in the dynamics of the river.

The arrangement of the Report's conclusions makes it difficult to grasp clearly EPA's view of PCB sources, transport and fate in the Upper Hudson. We attempt here to array what we believe are the Report's central positions in an order that reflects sequential movement in the river:

1. During periods of low flow, PCBs enter the TIP from above Rogers Island and are stored in the TIP, despite the fact that this stored PCB load averages approximately one-third of those PCBs that pass the TID during low flow.

2. During low flow, PCBs from relatively undechlorinated, aged surface sediments (which do not include PCBs entering the TIP in the immediate past) or PCBs from dechlorinated and highly concentrated sediments deposited before 1984 are the source of the PCBs passing the TID.

3. During low flow, the PCBs that pass the TID dominate the freshwater Hudson to Kingston.

4. During high flow, PCBs originating upstream of Rogers Island pass through the TIP and dominate the freshwater Hudson to Kingston.

5. Approximately 36% of the annual PCB load passes the TID during high-flow events. The Report suggests that this load may now be substantially reduced as a result of source-control remediation projects at GE's plant sites.

Apart from the points made in the analysis of the Report's major conclusions, this is not a plausible account of the behavior of PCBs in the river for the following reasons:

* The Report offers no persuasive account or explanation of the fate of the PCBs entering the TIP from above Rogers Island during low flow. (4A)

* The Report ignores established mechanisms of deposition and volatilization in describing the fate of PCBs below the TID. (4B)

* The Report treats similar reaches of the river in a dissimilar fashion. For instance, the report claims that sediment conditions immediately above the TID significantly contribute PCBs into the water column but similar sediment conditions below the TID do not. (4C)

* The Report assumes that the conditions observed in 1993 are representative of long-term conditions in the river and ignores the atypical impacts of the large loading of PCBs to the river in the 18 months following the collapse of the Allen Mill in September 1991. (4D)

In these comments, we offer our own account of the behavior of PCBs in the Upper Hudson, based on our analysis of the data.

Our account makes the following improvements on the one provided in the Report:

* It incorporates plausible mechanisms for the movement of PCBs through the river. (4E)

* It treats portions of the river with similar conditions in a similar manner.

* It recognizes the major known changes in PCB loading to the river over time.

* It addresses all the major processes, including sedimentation, at work in the river.

* It uses a more comprehensive array of data to test and constrain our evaluation of the data and the conclusions derived therefrom.

These comments focus on testing the analyses and conclusions in the Report against these benchmarks, and emphasize the importance to remedial analysis of the issues raised herein.

It is apparent that the most significant unresolved matter is the source of the PCB load at the TID at low flow which cannot be accounted for by PCBs measured at Rogers Island and PCBs expected to be diffused from the aged sediments of the TIP. GE has been and is engaged in the data collection and evaluation essential to reaching a sound answer as to the source of the unaccounted-for load. It is likely that undechlorinated Aroclor 1242 from the Allen Mill collapse and the bedrock seeps near the GE Hudson Falls plant site has entered the TIP undetected, particularly during higher flow events, and has been deposited in the Pool, contributing substantially to the unaccounted-for PCB load at the TID. This interpretation takes account of the large-scale Allen Mill release, addresses the fate of the PCBs measured at Rogers Island, avoids implausible mechanisms for PCB mobilization within the TIP and is supported by a variety of lines of additional evidence, such as the match with the congener fingerprint of the PCBs at the TID and the congener fingerprint of PCBs found in TIP fish.

Downstream of the TIP it is also important to recognize the effects of deposition and volatilization as well as external sources. While the size of the PCB load may not be substantially altered between the TID and Troy, PCBs are lost and other PCBs added to the load from sediments. In addition, the significant contribution of external sources, particularly in the tidal Hudson, must be recognized, a point we have emphasized with the Agency in the past.

The importance of the high-flow load to remedial analysis must also be recognized and addressed. The high-flow load described in the Report underscores the importance of determining the magnitude and duration of PCB releases upstream of the TIP now and over the past several years. Yet the Report is unable to address this significant issue due to lack of data. To answer the question, GE has been engaged in collecting and analyzing data following the major remedial projects at its plants.

In order to complete a technically defensible remedial analysis, EPA must develop a consistent and physically plausible explanation of the data and then test that explanation against a calibrated and validated model to ensure that the true sources of PCBs to fish, wildlife and humans are identified. The explanation of the data needs to take into account all the processes at work in the river that are relevant to remedial analyses. Where questions central to remedial analyses cannot be answered with the data presently at hand, additional data must be obtained to resolve the issues so that we can have full confidence in the conclusions reached on the basis of data interpretation and evaluation.

II. NEITHER DIFFUSION OF PCBS FROM AGED SURFACE SEDIMENTS NOR RESUSPENSION OF HIGHLY DECHLORINATED, HIGHLY CONCENTRATED PCBS CAN ACCOUNT FOR THE PCBS THAT PASS THE THOMPSON ISLAND DAM AT LOW FLOWS.

The Report concludes that the PCBs passing the TID at low flow are a major source of PCBs to the freshwater Hudson. Consequently, determining the source of these PCBs is essential to the remedial analysis of the Reassessment.

The Report concludes that the sediments in the TIP provide most, if not all, of the PCBs passing over the TID during low flow. The Report, however, does not specify what sediments are believed to be the source of these PCBs. Whether PCBs are derived from surface sediments (0-1 cm), near surface sediments (0-8 cm), deep sediments, hot spots or other areas is critical to understanding the ultimate source of PCBs to the water column in the TIP and downstream of the TID. The Report hypothesizes two possible sediment sources: (1) porewater diffusion of relatively undechlorinated PCBs at low concentrations in the surface sediments or (2) resuspension of extensively dechlorinated PCBs deposited before 1984. Neither source can account for all the PCBs at the TID for at lest three reasons. First, there is an insufficient mass of PCBs in the aged surface sediment to account for the increased PCB load measured across the TIP. Second, there is no erosive mechanism to resuspend a sufficient quantity of dechlorinated aged sediments to provide the increased load across the TIP and, if such erosion had occurred, sediment bed elevations would be very different from what has been measured. Finally, the congener pattern of the extensively dechlorinated sediments does not match the pattern of the TID load.

A more careful analysis shows that there is a load passing the TID at low flow which cannot be accounted for by the loads measured at Rogers Island and diffusion from surface sediments in the TIP. This unaccounted-for load is similar to undechlorinated Aroclor 1242 and is probably related to PCB loadings from the vicinity of GE's Hudson Falls plant. The identification of and explanation for this unaccounted-for load is perhaps the most fundamental difference between GE's and EPA's view of what is happening in the TIP.

A. Diffusion of PCBs from surface sediments deposited in the Thompson Island Pool before 1991 cannot account for the increase in PCB load across the Thompson Island Pool. (5)

One of the Report's hypothesized sources for the increase in PCB load across the TIP is the diffusion of PCBs from porewater in aged surface sediments to the overlying water column. This process can account for only a portion of the load of PCBs measured at the TID. A simple mass balance calculation demonstrates that if porewater diffusion were providing all the PCBs apparently coming from the TIP (the net increase in PCBs between Rogers Island and the TID), the reservoir of PCBs in surface sediments (as measured in 1984) would be nearly depleted by now. The high resolution cores, however, do not reflect any significant depletion of PCBs from these sediments.

In this mass balance calculation, we assume that the net increase in PCBs between Rogers Island and the TID (the increased load across the TIP) comes from PCBs in the surface sediments of the TIP. This calculation uses measured annual paired loadings from Rogers Island and the TID

from 1993 to 1996 using corrected GE data (see Appendix A)[1] and employs a conservative measure of the active surface layer (0-8 cm). Our analyses indicate that the active surface layer is 0-5 cm. The mass of PCBs in the surface sediments was estimated using the results of the Report's analysis of the 1984 sediment data. The depletion of surface sediment PCB homologues was based on the following calculation:

$$\text{Year in which the surface sediment reservoir is depleted} = \frac{\text{Inventory}}{\text{Flux rate}} + 1984 \qquad (1)$$

The surface sediment inventory was computed as follows:

$$\text{Surface sediment inventory} = \frac{c_{ss}}{w_s} \cdot D \cdot A \cdot 10^{-6} \qquad (2)$$

in which:

c_{ss} = surface sediment PCB homologue concentration

w_s = average specific weight for sediments in the Upper Hudson = 0.77 g/cm^3 (Report at 4-30);

D = depth of the surface layer = 8 cm

A = area of TIP = 2,000,000 m^2 (Report, Table 4-7)

The results of this mass balance calculation are presented in Table 1 and show that, by now, all monochloro and dichlorobiphenyls would have been depleted from the surface sediments. This

[1] We have not used the period from 1991-1993 in light of the unusually high loadings to the River during this period resulting from the releases from the Allen Mill.

is particularly significant since current water column measurements show a continuing source of mainly mono- and dichlorobiphenyls from the TIP, the same congeners that would have been depleted without continued loading from the upstream source. The significant reserves of PCBs remaining in the surface sediments of the TIP in 1991[2] and in the samples collected by EPA indicate that PCBs fluxed from the surface sediments must comprise a relatively minor component of the total increase in PCB load across the TIP in the 1990s.

B. Resuspension of highly dechlorinated, highly concentrated PCBs from the Thompson Island Pool sediments is implausible and cannot account for the increase in PCB load across the Thompson Island Pool. (6)

EPA's other hypothesis -- that highly dechlorinated PCBs at concentrations greater than 120 ppm and deposited prior to 1984 are the source of the increased PCB load across the TIP -- is also implausible. The mass of PCBs in these sediments is insufficient to maintain the increased load of PCBs across the TIP during low flow, and there is insufficient erosion in the TIP to expose and resuspend such sediments. In any event, the composition of PCBs in these sediments does not match the TID load on a congener basis.

[2] HydroQual has calculated that the average PCB concentration in surface sediments (0-5 cm) of the TIP was about 30 ppm in 1984 and 20 ppm 1991.

1. Resuspension of dechlorinated PCBs is inconsistent with the Thompson Island Pool bathymetry.

The Report's hypothesis that "dechlorinated" sediments may be the source of the increased load across the TIP relies on the mechanism of "resuspension" to place these PCBs into the water column. As resuspension is a surface sediment process, this hypothesis requires that the PCBs originate from areas with surface sediments containing PCBs in sufficient concentrations to match the homologue pattern of PCBs found at the TID. The Report concluded that these PCB concentrations had to be greater than 120 ppm. Simple mass balance calculations, however, show that the increased load could only have been provided by erosion to depths of over 75 cm on average. Such erosion is implausible and unreasonable. Had it occurred, it would have resulted in changes in sediment bed elevation levels between 1984 and 1991 that are not seen in measured levels.

To evaluate whether the resuspension of PCBs from these deposits is plausible, we made an estimate of the surface area in the TIP containing PCB concentrations exceeding a conservative value of 100 ppm (A_{100}). The kriging analysis of the NYSDEC 1984 data presented in the Report provides an estimate of approximately 69,000 m^2 (Figure 1) of river bottom in the TIP where such deposits occur. The average vertical profile of PCBs within these areas was constructed using results from the 1984 NYSDEC cores (Figure 2). The average TIP loading increase over the 1993 and 1996 period would require an estimated loading from the sediments of 254 kg/yr since 1984 (W_{pcb}) (Table 2).

The following equation provides a calculation of total sediment mass scoured from these areas on an annual basis:

$$W_{sed} = \frac{W_{pcb}}{C_{100}} \qquad (3)$$

where W_{sed} is the mass of sediment loading required on a yearly basis and C_{100} is the actual average surficial sediment PCB concentrations in areas with concentrations greater than 100 ppm. The depth of scour required to achieve these PCB loading estimates can then be calculated as follows:

$$D_t = \frac{W_{sed}}{\rho_s A_{100}} \qquad (4)$$

where D_t is the depth of scour in year t (cm) and ρ_s is the bulk density of the sediment (g/cm^3). Both C_{100} and ρ_s vary as simulated scour removes surface sediments and exposed sediments of varying PCB concentration and bulk density.

Figure 3 presents the depth of scour required on an annual basis to achieve the concentrations necessary to maintain the TID load. As can be seen, approximately 75 cm of sediments within these areas would have to have been eroded between 1984 and 1993 to provide the increased load across the TIP. EPA's analysis of its geophysical data indicates that such massive scour has not occurred. Indeed, these data indicate that the aged dechlorinated sediments are largely intact (report at 4-91).

2. Resuspension of dechlorinated PCBs is inconsistent with the minimal resuspension of PCBs in the Thompson Island Pool at low flows. (7)

The Report's hypothesis that highly dechlorinated surface sediments are the source of the increased load across the TIP is implausible because it requires significant erosion of these sediments during low flow, when such erosion is known not to occur.

Laboratory and field studies on the resuspension properties of cohesive sediments from the TIP show that a critical shear stress exists below which erosion does not occur (HydroQual, 1995). Similarly, resuspension of non-cohesive sediments will begin once the bottom shear stress exceeds a certain critical value, which is typically greater than the cohesive critical shear stress (van Rijn, 1984). Bed armoring processes. in both cohesive and non-cohesive bed areas, will also limit the amount of sediment eroded at a particular flow rate (Karim and Holly, 1986; Rahuel et al., 1989; Ziegler and Connolly, 1995). The result of these well-established sediment processes and observed measurements is that sediment resuspension under low flow conditions is very limited, and once the flow rate is below a particular value, no resuspension occurs.

Sediment transport studies in various riverine systems have shown that the concept of no or negligible erosion of the sediment bed during low flow conditions is valid. An effective method for quantitatively evaluating resuspension and deposition processes in a river is to use a calibrated and validated sediment transport model to predict solids fluxes across the sediment-water interface under various flow conditions. A sediment transport model of the TIP has been developed, calibrated and validated by HydroQual for GE. This model has also been successfully used by EPA in

contaminated sediment studies of the Fox River in Wisconsin (Gailani et al., 1991), Saginaw River in Michigan (Cardenas et al., 1995) and Buffalo River in New York (Gailani et al., 1996), in addition to other riverine applications by HydroQual (Ziegler and Nisbet, 1994, 1995). These past studies have shown that this model, if properly calibrated, can simulate sediment transport processes with sufficient accuracy to use it as a diagnostic tool to study resuspension and deposition fluxes in the Upper Hudson River under low flow conditions.

The sediment transport model was thus used to predict resuspension and deposition fluxes in the TIP under low flow conditions. Model simulations show that negligible gross resuspension of the cohesive sediment bed occurs for flow rates less than 5,000 cfs (Figure 4). To further investigate resuspension and deposition dynamics during low flow conditions, a simulation was performed for a constant flow rate of 3,200 cfs at Rogers Island. This flow rate corresponds to the mean value at Fort Edward during the EPA sampling periods in May and June of 1993. The data from this period were the primary basis for the low-flow resuspension hypothesis proposed in the Report. Model results show that net deposition, with only a minimal amount of resuspension, occurs in the TIP at this flow rate. The gross resuspension flux in the TIP is about 1,000 times smaller than the gross deposition flux, and the sediment that is eroded comes from a thin, surficial layer (approximately 10 μm thick) that is composed of loosely-consolidated, recently-deposited sediment (Figure 4). These results, combined with the observed resuspension properties of sediments, demonstrates the implausibility of the Report's hypothesis that relatively high gross deposition and resuspension rates, producing a small net change in water column solids load, caused the observed changes in PCB loading through the TIP during the 1993 low-flow periods.

3. The congener fingerprint of the PCBs at the Thompson Island Dam shows that dechlorinated PCBs are not the source; rather the source is likely relatively unaltered Aroclor 1242.

The Report relies on homologue fingerprinting, combined with its two "dechlorination" indices, to identify pre-1984 sediments as a possible source of the increased load of PCBs across the TIP. There are two significant problems with the Report's analysis. First, while a crude composition match of PCB TIP load to dechlorinated, aged sediments on a homologue basis can be made, a much better match can be made on a congener basis or with the relatively undechlorinated PCBs in surface sediments. Second, the Report relies on a simplistic "geochemical" analysis that purports to show that all PCBs within the freshwater portion of the Hudson River can be derived from a mixture of fresh and biologically dechlorinated Aroclor 1242. This analysis fails to recognize that partitioning can also account for changes in PCB composition observed in the river, leading to a better understanding of the PCBs seen at the TID. (8)

For the first point, we have examined the similarity between the congener composition of the total water transect samples and the sediment samples that represent potential sources to the water. The TIP high-resolution core slices with more than 100 ppm of PCB were used to represent the more highly contaminated and dechlorinated sediments of the TIP. The surface slices of the TIP high-resolution cores were used to represent the surface layer. The percent weight of each congener in each total water column sample at TID was plotted against its average percent weight in the dechlorinated sediments (Figure 5) and against its average percent weight in the surface sediments (Figure 6). In these figures all congeners that were not detected were placed on the axes. In both

cases, there is a positive relationship between water and sediment. However, the scatter about the relationships is much greater for the dechlorinated sediments. That is, the congener composition of the water column is more similar to relatively undechlorinated surface sediments than to more contaminated dechlorinated sediments. Accordingly, contrary to the Report's hypothesis, the TID load cannot originate from the more contaminated, dechlorinated TIP sediments.

To the second concern, when partitioning between solid and dissolved phases is incorporated into the analysis, as can be seen from a graphical analysis, the dechlorination indices ("indices") used in the Report indicate that particulate and dissolved PCBs sampled at the TID originate from different mixes of sources, and both include significant contributions of relatively unaltered Aroclor 1242.

Index values for sediment samples, dissolved and particulate water column samples, and Aroclor standards are plotted in Figure 7, similar to the index plots provided in the Report. The index values of the particulate PCBs sampled at Rogers Island and at the TID (filled squares and circles on Figure 7) center on Aroclor 1242 (large open square symbol at the position (0.14,0.00), demonstrating that the source of these PCBs is unaltered or very slightly altered Aroclor 1242.

Partitioning of PCBs between the solid and the dissolved phases can alter the composition of PCBs and therefore the values of the indices. To demonstrate this, the original Aroclors (large open square symbols) and the dissolved material that would result from partitioning from original Aroclor sorbed to particulate material (large open triangles) are plotted on Figure 7. The

composition of dissolved partitioned material was computed using partition coefficients derived from data set forth in the Report. Computed dissolved partitioned Aroclor samples are always to the right and above the original Aroclors. In addition, the dissolved partitioned Aroclor 1242 and 1016 samples lie close to the scatter of sediment samples, demonstrating that in the Upper Hudson, simple partitioning can result in dissolved water column samples with index values similar to dechlorinated sediments. That is, when the indices employed in the Report are applied to water samples, they do not necessarily characterize dechlorination.

Computed dissolved PCBs partitioned from dechlorinated sediments also appear within the scatter of the sediment data, to the right of the sediment source. For example, the large inverted triangles represent the average aged surface sediment concentration in the TIP computed from the 1991 GE data (0-5 cm depth; filled: sediment, open: computed dissolved partitioned material). A comparison of the positions of computed partitioned Aroclor 1242 and 1991 TIP surface sediments suggests that the degree of dechlorination of the source material for dissolved PCB samples can be characterized from the position of a dissolved sample on this plot. However, in contrast to the method used in the Report, the measured dissolved samples must be compared with the computed positions from fresh and dechlorinated particulates.

The dissolved PCBs sampled at Rogers Island are located within the scatter of the sediment data, slightly to the right of their respective particulate samples. In general, the Rogers Island samples do not lie as far right as partitioned Aroclor 1242 and lie slightly below dissolved partitioned Aroclor 1254. This suggests that dissolved material at Rogers Island may be a

combination of partitioned Aroclors 1242 and 1254 and that this material does not originate from dechlorinated sediment.

The dissolved PCBs sampled at the TID are also located within the scatter of the sediment data, between the computed dissolved materials partitioned from the 1991 surface sediment data and from Aroclor 1242. Thus, dissolved PCBs at TID are not likely to originate entirely from dechlorinated sediments; they are more likely to originate from a combination of sources that on average is less dechlorinated than the partially altered 1991 surface sediments. As a result, unaltered or very slightly altered Aroclor 1242 must be an important contributor to dissolved PCBs at the TID, a fact that the Report does not recognize.

III. THE PCB LOAD AT HIGH FLOW ACCOUNTS FOR MORE THAN ONE THIRD OF THE ANNUAL LOAD OF PCBS THAT PASS THE THOMPSON ISLAND DAM AREA. THIS LOAD ORIGINATES NEAR GE'S HUDSON FALLS PLANT SITE.

A. There is no dispute that discharges from the vicinity of the Hudson Falls site contributed at least half of the annual PCB load to the Thompson Island Dam and downstream areas in the form of undechlorinated Aroclor 1242.

The Report's analysis of water column PCB monitoring data collected during the 1993 spring high flow event showed that an estimated 250 kg of PCBs originating upstream of the Roger's Island monitoring station were transported through the system. This represents approximately 36 percent of the total PCBs which passed TID for the entire year and all the TID load at high flow. This PCB load differs from the loading from the TIP in that it is largely in the particulate matter phase and exhibits a PCB congener distribution of non-dechlorinated Aroclor 1242, similar to that observed within the Allen Mill and entering the river from bedrock fractures. (9)

More specifically, the spring high flow event data collected by the EPA demonstrate that a major portion of the total PCB loadings to the system originate from the Hudson Falls plant site area and occur over a very short time frame. Such time variable PCB loading from Hudson Falls is further supported by the observation that the flow weighted average PCB loading from upstream of Roger's Island was approximately 50% of that measured during a transect monitoring event collected under similar flow conditions. The Report attributes this difference to the variable loading dynamics associated with the GE Hudson Falls source. That is, short term PCB loadings captured by the transect sampling were not present in the flow-averaged event samples. Moreover, as the transect 4 data were collected after the river reached an initial peak of approximately 20,000 cfs (Figure 8),

we believe that the EPA data underestimates the actual loading from the Hudson Falls Plant site area. This is because we believe that PCBs are mobilized at lower flows along the rising limb of the spring event hydrograph than that sampled.

Although the EPA water column data suggest that the spring high flow event loading passes through the system, the EPA high resolution sediment cores show recent deposition of non-dechlorinated Aroclor 1242 similar in composition to that mobilized during the spring high flow event. These observations are consistent with current understanding of sediment depositional processes: sediments are generally deposited during elevated flow events. This is significant because it suggests a link between the Hudson Falls Plant Site area loadings and surface sediment PCB levels, which control the sediment water column interaction and biota PCB exposure levels.

B. GE has undertaken extensive remedial work at the Hudson Falls site but the extent of the source reduction and control is presently unknown.

In September 1991, elevated river water levels of PCBs were detected by GE upstream of the TIP. Intense subsequent investigations localized the source area to the eastern shoreline near river mile 196.8, in the vicinity of the GE Hudson Falls plant site. The results of these investigations revealed the presence of active seeps of Dense Non-Aqueous Phase Liquids (DNAPL) along the eastern cliff face and the rock face of the eastern raceway within the Allen Mill. In addition, free phase PCB oil (Aroclor 1242) and oil contaminated sediments (up to 70,000 ppm) were found within the Mill and the tailrace tunnel. (10)

A number of different remedial measures have been implemented to mitigate the seepage of PCBs from the vicinity of the plant site to the River: 1) DNAPL seepage from the rock face of the eastern raceway is now routinely captured; 2) hydraulic control of conduits through the Mill was achieved in 1993; 3) a slurry wall was constructed within the eastern raceway in 1994 to reduce seeps from this region; 4) removal of DNAPL and oil-contaminated sediments from the Allen Mill containing 50 tons of PCBs was completed in 1995; 5) DNAPL-recovery wells have been installed in the vicinity of the plant site that have recovered more than 8000L of DNAPL to date; and 6) barrier wells utilizing hydraulic control to further reduce DNAPL transport through subsurface fractures are being installed. These remedial efforts have reduced the PCB loading of undechlorinated Aroclor 1242 to the Hudson River, but it is not yet possible to determine the degree of control that has been achieved or to predict how much PCB is still likely to enter the River.

IV. DURING BOTH HIGH AND LOW FLOW, A SUBSTANTIAL PORTION OF THE PCBS PASSING THE THOMPSON ISLAND DAM ORIGINATES FROM NEAR THE HUDSON FALLS PLANT SITE.

The Report demonstrates that during the Phase 2 sampling period, Aroclor 1242 recently entering the river from the area of the Hudson Falls plant site makes up almost all of the PCB load at the TIP during high flow and that high flow loads make up more than one third of the annual PCB load at the TIP. The data show that this Hudson Falls source also contributes a substantial portion of the PCB load at the TIP during low flows. First, some PCBs are measured at Rogers Island entering the TIP during low flow. Next, mass balance shows that a PCB load passes the TID during low flow that cannot be accounted for by the sum of the load entering the TIP and the load attributed to diffusion from the aged sediments of the TIP as they were prior to 1991. Next, the PCB congener fingerprint of this unaccounted-for load indicates that its likely source is undechlorinated Aroclor 1242. The PCB fingerprint of the fish in the TIP corroborates this, also indicating an undechlorinated Aroclor 1242 source. The fluctuation from year to year of the unaccounted-for load at the TID since 1992 clearly suggests a close connection between the releases from the Hudson Falls site area and the magnitude of the unaccounted-for load. Monitoring results at Rogers Island do not reflect a PCB load congruent with identifying the Hudson Falls sources as the origin of the unaccounted-for load; but EPA's 1993 data, 1992 GE data, and a comparison of load behavior in 1995 and 1996 all indicate that unaltered fresh PCBs are flushed into the TIP as flows rise at Hudson Falls. Such time-variable flows are likely to pass Rogers Island undetected by a weekly sampling program. GE is presently collecting data to evaluate this proposition.

10A

A. At low flow, there is a PCB load at the Thompson Island Dam that is unaccounted for by the sum of the measured load entering the Thompson Island Pool and the load that would be diffused from aged Thompson Island Pool sediments.

1. Calculation of unaccounted-for load by mass balance.

The data show a PCB load at the TID that is not accounted for by the sum of the measured PCB load entering the TIP and the load that would be diffused from the aged sediments. The existence and magnitude of the unaccounted-for load at the TID can be determined by subtracting from the water column PCB load at the TID (1) the load attributable to sediment porewater diffusion and (2) the water column load of PCBs entering the TIP at Rogers Island. The diffusive fluxes of PCB congeners from the surface sediment were calculated using GE's 1991 surficial sediment PCB data and EPA's equilibrium partitioning concepts, including the use of temperature-corrected partitioning coefficients. The water column PCB load increase across the TIP was calculated by subtracting water column PCB loads at Rogers Island from those at the TID using paired Rogers Island and TID water column samples from the corrected GE database (Appendix A) for 1991-1996 and daily average USGS flow measurements.

(11)

The following mass flux equation calculates the diffusive flux of individual PCB congeners from TIP sediment porewater to the water column:

$$J_s = K_f A_s (C_d' - C_{wc}) \qquad (5)$$

where J_s is the diffusive mass flux of individual PCB congeners (kg/day), K_f is the sediment/water exchange coefficient (m/day), A_s is the sediment surface area of the TIP (m^2), C_d' is the mean

surficial sediment porewater PCB concentration (kg/m^3) calculated from the 0-5 cm section of sediment cores collected in 1991, and C_{wc} is the water column PCB concentration (kg/m^3).

Total dissolved porewater PCB concentrations (C_d') contain two components: freely dissolved PCBs (C_d) and that adsorbed onto dissolved organic carbon (C_{doc}):

$$C_d' = C_d + C_{doc} \tag{6}$$

Freely dissolved PCBs are in equilibrium with PCBs sorbed to sediment organic carbon. This relationship is described by:

$$C_d = \frac{C_s}{f_{oc} K_{oc}} \tag{7}$$

where C_s and f_{oc} are the mean surficial sediment (0-5 cm) PCB concentration (mg/kg) and fraction organic carbon calculated from the 1991 sediment survey data, respectively, K_{oc} is the organic carbon-based PCB partition coefficient (L/kg) calculated using EPA water column partitioning data and corrected for temperature using temperature correction functions appearing in Appendix A. C_{doc} is in equilibrium with C_d and can be calculated as:

$$C_{doc} = C_d m_{doc} K_{doc} \tag{8}$$

where m_{doc} is the porewater dissolved organic carbon concentration (mg/L) calculated as the mean surficial sediment (0-5 cm) TIP dissolved organic carbon measurements from the 1991 sediment survey, and K_{doc} (L/Kg) is the equilibrium constant describing partitioning between freely dissolved

PCBs and PCBs adsorbed to dissolved organic carbon, which was assumed equal to 0.1 K_{oc}. Substituting Equation 7 and 8 into Equation 6 yields the following expression for porewater PCB concentrations:

$$C_d' = (1 + m_{doc} K_{doc}) \frac{C_s}{f_{oc} K_{oc}} \quad (9)$$

Using Equations 5 and 9, the sediment diffusive flux equation becomes:

$$J_s = K_f A_s \left| \left((1 + m_{doc} K_{doc}) \frac{C_s}{f_{oc} K_{oc}} \right) - C_{wc} \right| \quad (10)$$

Equation 10 allows calculation of sediment diffusive flux of PCB congeners from known sediment PCB congener concentrations using principles of equilibrium partitioning.

The sediment water exchange coefficient (K_f) can be estimated by substituting the water column PCB congener flux estimates for the summer low flow period of 1991 into Equation 10 and adjusting K_f to minimize the sum of differences in individual PCB congener loading estimates. Negative PCB congener loadings due to detection limits for the higher PCB congeners in water column samples are disregarded (Figure 9; panel d).

Based upon 1991 sediment PCB measurements including PCB congener concentrations, the sediments of the TIP can contribute through diffusive mechanisms an estimated 200 to 300 g/day of PCBs to the water column for 1991 to 1996 (panel b; Figures 10 through 15)[3]. The PCB congener distribution of this load is shifted toward the lighter end of the congener spectrum due to the relatively low K_{oc} values for the lightly chlorinated PCBs.

When the actual PCB load increase across the TIP is calculated for periods after 1991, more PCB is present than can be explained by the diffusion calculation. The water column PCB congener load increase across the TIP (J_{wc}) can be calculated for the summer low flow periods (June -August) of 1991-1996 using the following expression:

$$J_{wc} = Q_{ri}(C_{tid} - C_{ri}) \qquad (11)$$

where Q_n is the daily average flow recorded at the Rogers Island monitoring station on the day of sampling, and C_{tid} and C_{ri} are the individual corrected PCB congener concentrations (Appendix A) at the TID and Rogers Island monitoring stations, respectively.

[3] Sediment diffusion load varies due to differences in mean summer surface water temperatures and their effect on K_{oc}.

The unaccounted-for load at the TID (J_u) can be calculated on a PCB congener basis by subtracting the estimated diffusive flux of PCBs (J_s) from the difference in water column PCB loadings between the TID and Rogers Island as follows:

$$J_u = J_{wc} - J_s \qquad (12)$$

The results of this calculation for the summer low-flow period (June-August) of 1991 to 1996 are presented on a homologue basis in Figures 10 through 35 (Panel c). The 1992 unaccounted-for PCB load was 559 g/day. This is twice the surface sediment diffusive flux calculated using the 1991 surface sediment PCB data. This increased to approximately 1000 g/day in 1993 and 1994 and declined in 1995 to less than 250 g/day. In 1996 the unaccounted-for PCB load was approximately 1200 g/day.

B. The fingerprint of the unaccounted-for load at the Thompson Island Dam indicates the likely source is undechlorinated Aroclor 1242.

The composition of this unaccounted for load indicates its probable source. On a homologue basis, this unaccounted-for load was dominated by dichlorobiphenyls and generally resembled the homologue mass loadings attributable to diffusion from surface sediments (Figures 10 through 15; panel c). Assuming the unaccounted for PCB load is derived exclusively from a surficial sediment diffusional process, one may calculate the expected mean surface sediment and porewater PCB composition which would produce this load by diffusion. (12)

The sediment phase PCB homologue distributions required to produce the unaccounted for PCB load were calculated on a yearly basis for the summer low flow period (June-August) for 1992 through 1996 and monthly for 1996. These results are summarized in Tables 3 and 4 and presented as PCB homologue distributions in Figures 10 through 15, panel d.

As can be seen in these Tables and Figures, the homologue composition of the unaccounted-for load closely resembles Aroclor 1242. The congener composition of the unaccounted-for load is markedly similar to surface sediment PCB congener distributions (Figure 16) and deviates considerably from deep dechlorinated sediments on the TIP (Figure 17). These data indicate that the unaccounted-for load from the TIP originates from an undechlorinated Aroclor 1242 source.

C. The PCB fingerprint in the TIP fish is consistent with PCBs recently entering the river above the Thompson Island Pool.

Analysis of PCBs in fish supports the conclusion that the source of the unaccounted-for load at the TID is relatively undechlorinated PCBs, and the homologue and congener composition of the fish provides a way to identify PCB sources to the food web. (13)

Two analyses were performed to test whether fish body burdens are representative of PCBs originating in sediments containing dechlorinated or relatively undechlorinated PCBs. First, using the GE bioaccumulation model, the relationship between the homologue composition in fish and the homologue compositions of surface sediments and the water column can be explored. One may assume that varying degrees of dechlorination in exposure sources result in differing homologue

distributions in the fish. These compositions can be computed and compared with the observed composition in TIP fish in order to characterize the likely composition of the exposure sources. Second, congener-based fingerprinting indices can be used to assess the similarity in PCB composition between surface sediments and fish.

The total PCB bioaccumulation model developed by HydroQual was modified to compute bioaccumulation on a homologue-specific basis. Table 5 identifies the sources of the parameter values for individual homologues. To characterize the homologue composition of the exposure sources, several model simulations were performed using exposure concentrations and distributions derived from TIP data. Table 6 identifies the basis for the derivation of the exposure values.

Figures 18 through 21 computed and observed homologue distributions in fish. Model results for pumpkinseed were compared with pumpkinseed data collected in the TIP after 1989. Model results for largemouth bass were compared with largemouth and smallmouth bass data collected in the TIP after 1989 using fish greater than 400 g. The dashed lines represent the spread of the mean of the data +/- two standard errors.

The data best match pumpkinseed homologue distributions computed using the surface slice of the high-resolution cores and the measured water column distribution (Figure 18). The largemouth bass distributions computed using either surface slices, 0-2 cm (Figure 18) or the 0-5 cm layer (Figure 19) best reproduce the observed distributions. As the degree of dechlorination in the exposure sources increases, the model results diverge from the measured homologue distributions

(Figures 18 through 21). Thus, the PCB composition of the fish is most consistent with a relatively unaltered source.

Several indices of dechlorination have been developed (Appendix C). These are ratios between the proportions of individual congeners in a sample. The numerator is the proportion of a congener that is dechlorinated and the denominator is the proportion of a congener that is left relatively unmodified by dechlorination. For each ratio, congeners within the same homologue group are used, so that partitioning and bioaccumulation differences are minimized. The degree to which these ratios indicate dechlorination can be tested by comparing their values to other indices of dechlorination in sediments; for example, the number of chlorines per biphenyl. They are found to be indicators of dechlorination in sediments. The ratios can be used in a diagnostic fashion to compare samples collected from sediment, water and fish.

These ratios decline as dechlorination proceeds. For example, four of these ratios are plotted against the number of chlorines per biphenyl (Cl/BP) using high-resolution core sediments from the Upper Hudson (Figure 22). The dashed lines indicate values of the ratios and Cl/BP for Aroclor 1242. The ratios in the sediments approach the Aroclor 1242 value in samples in which Cl/BP approaches the Aroclor 1242 value. In addition, values of the ratio decline in dechlorinated sediments.

Figure 23 presents the values of these four ratios in fish collected from the TIP by NOAA in 1993. Comparison of the fish ratios with the sediment ratios in Figure 22 indicates that slightly

altered Aroclor 1242 is the source of PCBs to these fish. Similar results are obtained with fish caught in earlier years.

D. The behavior of the unaccounted-for load is consistent with the Allen Mill collapse and seeps from the bedrock.

Having established that the source of the unaccounted-for PCB load at the TID appears to be relatively undechlorinated Aroclor 1242, possible sources for these PCBs must be explored. The releases of DNAPL PCB oil from the Allen Mill and/or the bedrock seeps near GE's Hudson Falls facility are the likely sources and the temporal parallels between the behavior of the unaccounted-for PCB load and the sources near Hudson Falls suggests a close connection between the two. (14)

The USGS and GE data sets provide a 20-year record of water column PCB data that can be used to assess long-term spatial and temporal patterns of PCB loadings in the upper Hudson River. Historical loadings from the TIP were estimated from the corrected USGS PCB data. Low flow PCB loading from the TIP was calculated as the difference in PCB loadings based on paired flow and PCB data at Schuylerville and Fort Edward during periods of flow less than 10,000 cfs at Fort Edward from 1980-1989 (Figure 24).[4] Loads for the period 1991-1996 were calculated using paired flow and PCB data collected as part of GE's water column monitoring program.[5]

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[4] The USGS record did not contain data from the Fort Edward or Schulerville Station at flows less than 10,000 cfs for 1990 - 1995. Large loadings calculated for 1977 - 1979 period were excluded in this figure to highlight observed changes between the late 1980s and early 1990s.

[5] GE collected data in 1991 to provide preliminary estimates of the bias in the USGS methodology and to "correct" historical USGS water column PCB records (see Attachment 1).

The PCB loads from the TIP declined steadily from approximately 1.2 lbs/day during the early 1980s to an estimated 0.5 lbs/day in the late 1980s (Figure 24).[6] These data document the recovery of the system from the impacts of process discharges and the erosion of PCB-contaminated sediments after the removal of the Fort Edward Dam in 1973. The principal processes contributing to this recovery likely included the reduction of PCB deposition from sources within the remnant reach of the River and the deposition of clean solids from the tributaries.

Summer low flow loadings in 1991, prior to the September 1991 Allen Mill collapse, were comparable to the loadings calculated using the USGS data for late 1980s (Figure 24). In 1992, low flow PCB loadings from the TIP increased by a factor of 4 from an estimated 0.5 lbs/day in the late 1980s to approximately 2 lbs/day (Figure 24).

Thus, the unaccounted-for load from the TIP is temporally correlated with PCB releases from the Allen Mill. Considering its estimated magnitude, the Allen Mill release is likely the cause of this increased loading. PCBs discharged from the Mill were likely transported downstream and deposited within the surficial sediments of the TIP and subsequently released to the water column

[5] (continued...) The GE data have been corrected for the analytical bias in quantitation of peaks 5, 8, and 14, which contain coeluting congeners BZ#4 and 10, BZ#5 and 8, and BZ#15 and 18, respectively.

[6] PCB levels monitored at Schuylerville were used to infer PCB levels at the TID for the periods in which data were unavailable.

as a dissolved phase loading through the processes of partitioning between sediment and oils and sediment porewater, with subsequent diffusion into the overlying water.

Under this scenario, loadings from the TIP should decline as the 1991-1993 loads are eluted from the surficial sediment porewater, buried by the deposition of clean solids, dechlorinated and transported out of the TIP. The unaccounted-for PCB load originating in the TIP declined from approximately 1.0 kg/day in 1993 to less than 0.25 kg/day in 1995 (Figure 12 through 14, panel c). This reduction suggests that the system was recovering from loadings from the Allen Mill between 1991 and 1993. The 1996 unaccounted-for PCB loadings increased from 1995 levels to approximately 1.2 kg/day. This suggests that between 1995 and 1996 additional PCBs originating upstream were deposited on surficial sediments in the TIP.

E. The monitoring at Rogers Island appears to understate the PCB load entering the Thompson Island Pool.

It is clear that the unaccounted-for load of PCBs in the TIP resembles unaltered Aroclor 1242. The most likely source of this material is located upstream in the vicinity of Hudson Falls. (15) However, for this source to explain this unaccounted-for loading requires that the PCB pass the monitoring station at Rogers Island undetected. Given that the PCBs from this source are dense, nonaqueous phase liquids (DNAPL) and the limited monitoring, this is likely the case.

First, the presence of DNAPL in the vicinity of the Hudson Falls Site is well established. Numerous river bed seeps were exposed upon the dewatering of Baker's Falls when Adirondack Hydro Development Corp.'s hydroelectric facility was being constructed along the western shore of the Falls. Recent work at GE's Hudson Falls plant has shown that PCB DNAPL oils are transported through bedrock fractures and enter the Hudson River from river bed seeps adjacent to the Hudson Falls plant site. These seeps represent a significant source of PCB DNAPL to the River. At one of these seeps (Seep 13), discovered within the Baker's Falls plunge pool during an underwater inspection by divers, an estimated 16 liters (22.5 Kg) of PCB DNAPL oils were collected over a period of 3-1/2 months beginning in September 1996 (Figure 25).[7] Second, the weekly monitoring at Rogers Island will not detect events of limited duration that might mobilize PCBs for this region of the river, such as high flow events.

1. Flushing of DNAPL during high flow is likely to escape detection at Rogers Island.

Oil-phase loads from the Allen Mill and the bedrock seeps introduce indeterminate errors in water column monitoring designed to measure particulate and dissolved phase PCB loads. The behavior of DNAPLs within natural aquatic systems is not well understood. It is likely that DNAPL oil droplets from bedrock fractures will behave in a manner similar to particles possessing the same diameter and density and likely will settle onto the river bed during low flows. As flow velocities

[7] Localized groundwater pumping efforts appear to have mitigated PCB losses through Seep 13 (Figure 25).

along the sediment/water interface increase during periods of elevated flow, the DNAPL droplets will become resuspended in the water column and will be transported downstream. Such resuspension occurs almost instantaneously at the point when critical sheer velocities are reached at the sediment bed surface. It is possible that oil discharges near the Hudson Falls Plant Site accumulate within quiescent regions of the river adjacent to the site and are mobilized during high flow events.

There is evidence for flushing of significant amounts of PCBs from the River in the EPA high flow water column transect study. PCB loading from the region upstream of the TIP during this event contributed approximately 18 Kg/day PCB, primarily in the particulate phase. This particulate phase PCB transport occurred in the absence of sediment resuspension. These data generally support the hypothesis that oil phase PCB loading may be occurring during periods of high flow. EPA monitoring did not occur on the rising limb of the event hydrograph (Figure 8) and probably missed the peak PCB load, because critical sheer velocities for oil resuspension were likely reached prior to the EPA sampling. Similar high flow data collected by GE in 1992 showed elevated PCB loadings from upstream of the TIP with little or no evidence of sediment scour (Figure 26). Finally, neither the EPA water column monitoring program nor the GE high flow monitoring program collected sediment bed load samples. Such loads are likely to represent a significant portion of PCB DNAPL transport, particularly during periods of high flow. As observed in the EPA transect data, particulate PCB loads from upstream are preferentially deposited within the TIP. This

indicates surface sediment PCB contamination mechanisms which are consistent with the increased loads following the Allen Mill collapse and DNAPL PCB seeps from the Hudson Falls area.

Seasonal patterns in the unaccounted-for PCB loading at the TID in 1996 also suggest that PCB oils collect near the Hudson Falls Plant Site and are mobilized during high flow events. Monthly calculations of the unaccounted-for TIP load for 1996 indicate that, prior to the April high flow event, PCBs within the water column could largely be derived from sediment diffusive mechanisms considering the 1991 surficial sediment PCB concentrations (Table 4). Following the spring high flow period, an unaccounted-for load was apparent, varying in magnitude from 0.6 to 2.0 Kg/day during April through August and decreasing steadily to less than 0.2 Kg/day by October (Table 4). This seasonal variability and correlation with spring high flow suggests that PCB loadings from the vicinity of the Hudson Falls plant site are associated with high flow events. This is supported by the observation that the unaccounted-for loadings in 1995, a low flow year in which spring high flows never exceeded 15,000 cfs, were considerably lower than the 1994 and 1996 unaccounted-for loads.

2. Hydro plant operation likely causes flushing from Baker's Falls plunge pool.

Another possible method for PCBs to enter the TIP from sources in the vicinity of Hudson Falls undetected is related to the operation of the newly constructed hydroelectric facility at Baker's Falls. In front of the turbine intakes this facility has trash racks which are cleaned every few days.

During the cleaning process, a water bypass structure is used which discharges significant amounts of water into the plunge pool at the base of Baker's Falls. This has been observed to transform the plunge pool from calm to turbulent.

Divers have observed PCB oils seeping into the plunge pool and accumulating on the river bed. The flushing of water into the plunge pool during the trash rack cleaning is likely to move PCBs downstream in pulses that would not be detected by the weekly monitoring at Rogers Island unless coincidentally synchronized with the trash rack cleaning. In the Fall of 1996, one round of monitoring was conducted to coincide with this cleaning and was intended to monitor the potential movement of a pulse of PCBs downstream. PCB levels at Rogers Island increased from 15 ppt to 42 ppt. Since flow conditions are generally low during the cleaning, it is likely that PCB oil would be deposited in to the pool and would only later be detected in "dissolved" form at the TID. GE is conducting additional sampling this spring and summer to determine the importance of this transport mechanism.

3. GE is working to resolve the Rogers Island measurement issue.

Preliminary results of the PCB DNAPL transport study conducted by GE in the Fall of 1996 (HydroQual, 1996) suggest that PCB DNAPL oils emanating from Hudson Falls are retained within the reach of the river between Hudson Falls to the TID. This is based on the observation that only 2 percent of the fluorescent particles (selected to represent PCB DNAPL) were transported

downstream of the TID (Figure 27). To the extent that these fluorescent particles simulated DNAPL transport, these data suggest that DNAPL originating from Hudson Falls is largely retained within the river upstream of the TID. Moreover, preliminary analysis of fluorescent particle size distribution data indicates that particles with an average diameter of approximately 100 *um* constitute the majority of the mass of particles retained within the Hudson Falls to Fort Edward reach of the river. These larger particles were not transported downstream under the flow conditions during the study (est 800-8000 cfs) suggesting that oil droplets with mean particle diameter of greater than approximately 100 *um* are retained near Hudson Falls at flows less than 8,000 cfs and are likely transported downstream during higher flow periods. Additional analysis of these data is underway, and a full report will be submitted to EPA.

Additionally, as reported to EPA, GE is undertaking an extensive data collection program focused on this potential loading mechanism. Due to the importance of the unaccounted-for TIP loading in evaluating remedial options, it is imperative that the source be determined.

V. THE CONTRIBUTION OF PCB SOURCES DOWNSTREAM OF THOMPSON ISLAND DAM MUST BE RECOGNIZED AND QUANTIFIED

The Report concludes that PCBs in the water column are conservatively transported downstream from the TID to the freshwater tidal Hudson with little or no loss or gain. This implies that sediments downstream of the TID or other external sources of PCBs, such as a point source or tributary, are insignificant. This is inaccurate. Consequently, the significance of the load passing the TID is overstated and the benefits of reducing that load will be overstated. A more careful analysis demonstrates that sediments in the reaches of the Upper River below the TID are important PCB sources and that the contribution of the PCBs passing the TID decreases downstream. In the freshwater portion of the lower Hudson, EPA's own analysis shows that external sources of PCBs contribute significantly to the sediment -- for instance, 25 percent at Albany.

A. PCBs passing the TID are decreased downstream by volatilization and deposition.

The Report contends that the PCBs passing the TID are transported downstream from Reach 7 through Reach 1 and into the Lower River with little or no loss in PCB mass: the data indicate "the occurrence of quasi-conservative transport of water column PCBs (i.e., no apparent net losses or gains) throughout the Upper Hudson to Troy" (Report at E-3), and that the PCBs "pass relatively unaltered, as through a conduit, through the length of the Upper River during winter and spring conditions" (Report at 3-87). GE agrees that the net load of PCBs in the water column does not vary markedly through these reaches of the upper Hudson River; however, we disagree that the region

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above the TID sets water column PCB concentrations and loads downstream of the TID to Kingston. The Report's conclusion rests on an incomplete consideration of the physical transfer processes which affect the fate and transport of PCBs in the Upper Hudson River.

The fate and transport mechanisms relied on in the Report to explain spatial patterns in PCB loadings in the various reaches of the Upper Hudson River are inconsistent. The Report hypothesizes various mechanisms to describe PCB dynamics within the TIP during the different water column monitoring events. For example, sediment deposition, sediment resuspension, porewater diffusion, and groundwater advection are cited as possible causes of changes in PCB loading patterns across the TIP. In contrast, reaches downstream of the TID are described as a pipeline in which upstream loads are transported downstream with very little sediment/water interaction. Interpretation of the spatial and temporal patterns observed in the data should be described from a consistently applied mechanistic perspective. There is no sound explanation for why sediments within the TIP would be highly reactive while sediments downstream of TIP containing similar PCB concentrations and subjected to similar physical forces would behave differently. Moreover, the more plausible account for both the TIP and the downstream reaches is that which the Report implies downstream of the TID: aged, dechlorinated PCBs in sediments deposited several years ago make a very limited contribution to the PCBs found in the water column.

Several transport mechanisms change water column PCB loads in the Upper Hudson River, including particulate settling, volatilization, dilution due to tributary solids, and inputs from local

sediments. Deposition zones and several so-called PCB "hot spots" are found in a number of locations downstream of the TID, indicating that settling of PCB-contaminated particles occurs in this region. Volatilization of dissolved-phase PCBs will occur at all locations in the river and at all times, with the transfer rate across the air-water interface varying spatially and temporally, depending upon local conditions. Addition of tributary solids and flow will dilute water column PCB concentrations in the main stem of the Upper Hudson; however, the additional tributary solids will also reduce the PCB load due to partitioning of dissolved PCBs onto uncontaminated tributary sediments and subsequent deposition of these solids. Tributary sediment loadings to the River occur downstream of the TID (HydroQual, 1995), are significant, and result in reduced PCB transport. These processes reduce water column PCB loads downstream of the TID. These losses are offset to some degree by the addition of PCBs to the water column from the sediments in Reaches 7 through 1.

The impacts of fate processes can be evaluated in the context of a mass balance model. EPA's report does not contain such an analysis. The GE model, however, has been used to examine the fate processes acting upon PCBs in the upper Hudson River: transport with the river flow; adsorption-desorption among dissolved, particulate and colloidal phases; settling and resuspension of the particulate phase; diffusion between the water column and the surface sediment and within the sediment; volatilization from the water column dissolved phase to the atmosphere; and burial of sediment-associated PCBs through sedimentation. This model has been compared to water column and sediment data over a 14-year period at locations throughout the Upper River. Based on the

model's ability to reproduce these data using well-accepted descriptions of the fate processes, it can be used to examine PCB dynamics within the system.

Figure 28 compares the three EPA estimates of loading through the Upper Hudson River for the June to August 1993 period with the model simulation for the same period. The dashed-line profile represents the conservative transport of PCBs that EPA claims exists from the TID to Troy. The model shows a 19% loss of PCBs in the downstream direction that is the net result of volatilization, net deposition of solids and sorbed PCBs, and the addition of PCBs to the water column from downstream sediments and, to a lesser degree, by downstream tributary inputs. This net loss is small enough to be within the uncertainty bounds of the data. The EPA data collection in the summer of 1993 found an approximately 20% increase in the PCB load between the TID and Waterford. This was a period during which the increase in the PCB load across the TIP reflected the impact of the Allan Mill release. Conditions downstream of the TID may also have been influenced by the same event.

Figure 29 provides further clarification of the origins and fate of the TID PCBs in the river during this period. Here, the lower limit of the shaded region represents the profile of water column PCB load without a sediment source in Reaches 1-7. PCB load in the river decreases by 45.1% between Thompson Island Dam and Waterford. This decrease is a result of the combined effects of settling (the unshaded region, 17.4%) and volatilization (the shaded region, 27.6%). Considering the results of Figures 28 and 29 together, the sediments in Reaches 7 - 1 contribute 32.3% to the

downstream load passing Waterford with upstream sources and TIP sediments contributing the remainder.

B. In the freshwater Lower River, external sources contribute significantly to the PCB load.

The Report uses a simple dilution model (PCB/^{137}Cs) to estimate the contribution of Upper River PCBs to PCBs in the sediments of the freshwater Lower River and to support its contention that PCBs are conservatively transported from the TID to Kingston. The methodology is flawed because it fails to account for the increasing solids yield from the drainage basin below the TID and the losses of PCBs to volatilization and deposition, as described in the previous section, and cannot explain the variability of cesium data upstream of Stillwater. EPA should have recognized these deficiencies and abandoned this approach when it could not describe the change in PCB/^{137}Cs between the TIP and Stillwater. (17)

The Report's PCB/^{137}Cs model is based on an assumption of uniform distribution of cesium in sediments throughout the Hudson River. While this uniformity of cesium inputs from tributaries may be true at any given point in time (cesium levels are known to be decreasing over time), the demonstration of this spatial uniformity using data on Figure 3-63 from the Report is wrong because the cesium data upstream of Stillwater are inexplicably variable and frequently at levels much higher than downstream. This is an instance where the Report's analysis is not consistently applied throughout the river system. The dilution analysis did not work in the segment of the river upstream

of Stillwater; therefore it was only employed downstream of Stillwater, ignoring what is arguably the most important part of the River from a PCB source standpoint.

Further, the data downstream from Stillwater should not necessarily be expected to be uniform, over a fixed depth interval. This is because spatial variation in deposition rate would make the sediments in this fixed 0-2 cm layer representative of different time periods at different locations, and hence different cesium levels. Moreover, the presence of a mixed surface layer with varying mixing depths at different locations would also complicate the assignment of sediments to a known time period. These difficulties are compounded when PCB and the (PCB/^{137}Cs) are considered, because again, the 0-2 cm layer which is assumed to represent sediment deposited between 1991 and 1992 is not necessarily representative of this period. The analysis also neglects the decrease in PCB concentrations in the water column resulting from net deposition and volatilization from the water column, processes which are partially offset by sediment sources of PCB. Accordingly, simple dilution by tributary solids cannot account for all of the decrease in downstream PCB sediment concentrations.

Significant increases in the solids load due to tributary inputs as one moves downstream also invalidate the Report's simplified dilution analysis. The sediment yield, i.e., annual sediment load per square mile of drainage area, increases by about a factor of five between Fort Edward and the Federal Dam at Troy (Phillips and Hanchar, 1996). The large sediment load from tributaries in the Upper Hudson River enhances the deposition of PCB-contaminated solids in the river and modifies

the rate of change of the PCB/cesium ratio from that which would occur by simple dilution. Both of these effects complicate the PCB/cesium analysis and undermine the Report's dilution hypothesis.

EPA used comparisons between the PCB composition in the high resolution core collected at RM 177.8 near Stillwater and cores in the lower River to imply the contribution of upper River PCBs to the PCBs in the lower River. The Agency characterizes this contribution as that of the "combined TI Dam load" (report at. 3-120), although, as discussed earlier, the load from the Upper River to the Lower River reflects contributions from sediments below the TIP as well. Using cores collected at Albany and Kingston, the Agency concludes that the importance of the Upper River PCB source has varied over time, being most important during the period between 1975 and 1981 and less important more recently. Comparison of the congener patterns in the top sections of the Albany and Stillwater cores reveals differences that were attributed to the addition of other Aroclors between Stillwater and Albany. Simple mixing of the Stillwater core composition with the PCB compositions of Aroclors 1016 and 1260 was used to imply that about 22 percent of the PCBs in the core were derived from non-Stillwater sources.

The EPA analysis of the Albany core probably underestimates the contribution of sources other than the Upper River. Any Aroclor 1242 (the most widely-used mixture) entering the river between Stillwater and Albany was attributed to the Upper River. Further, the composition of the Albany core top is biased toward the upper River because of the high loadings from the upper River that occurred in the fall of 1991 and summer of 1992. Thus, it is likely that sources other than the

upper River contribute substantially to the PCBs in the sediments of the lower River. The conclusions of the report fail to cite the evidence of other loadings that it found in its own analysis and thus mischaracterized the importance of upper River sources to PCBs in the lower River.

VI. SEDIMENTATION AND DECHLORINATION ARE IMPORTANT REMEDIAL PROCESSES

The Report understates the importance and benefits of natural recovery processes, including sedimentation and PCB dechlorination/biodegradation. These processes combine to reduce the availability of PCBs to the water column and biota and reduce the toxicity and bioaccumulation of the PCBs that remain. GE has explained to EPA the importance of sedimentation in previous submittals (HydroQual, 1995, GE/HydroQual, 1996), and we will not repeat these here.

The Report fails to recognize dechlorination as an important risk-reduction process and this failure is reflected in the Report's misplaced emphasis on mass rather than toxicity and bioavailability. The importance of dechlorination is not mass reduction but its effect in reducing the toxicity and bioaccumulation potential of PCBs. The indices used in the Report to measure dechlorination fail to capture the complexity and variability of dechlorination processes and are insensitive measures of dechlorination.

The Report also overlooks microbial PCB dechlorination in the sediment of the Hudson River as a critical tool for distinguishing the source of PCBs to specific receptors. Dechlorination produces unique, congener-specific changes in PCB congener distributions that permit precise source identification, as is described in detail in Appendix C. Briefly, this Appendix identifies several peak ratios that can "fingerprint" PCB sources in more than 30 species of Hudson River fish collected during a 16-year period. This analysis shows that PCBs in the fish of the TIP have not undergone

dechlorination because they have been continually exposed to a supply of fresh PCBs reaching that section of the river from the Hudson Falls source. This finding underscores that the aged, buried, dechlorinated PCBs in "hot spots" are not the predominant source to Upper Hudson River fish. Instead, the fish are accumulating recently deposited PCBs with a composition very similar to unaltered Aroclor 1242 (and with bioaccumulation and toxicity properties similar to those of Aroclor 1242), consistent with a known source of undechlorinated Aroclor 1242 in the vicinity of the GE Hudson Falls plant.

A. Dechlorination is an important mechanism in reducing the bioaccumulation and toxicity of PCBs.

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There are environmentally important benefits to dechlorination:

-- Dechlorination reduces the tendency of PCBs to bioaccumulate.

-- Dechlorination sharply reduces the levels of the particular PCB congeners that appear responsible for producing potential risks to wildlife and humans.

-- Dechlorination of the more heavily chlorinated PCB congeners to lightly chlorinated congeners facilitates biodegradation and provides a route for the ultimate destruction of PCBs.

The benefits of dechlorination are discussed at greater length in Appendix D. In summary, dechlorination reduces both the total chlorine level of the PCB mixture and the concentration of specific coplanar congeners. Reduced chlorine level results in significant reductions in PCB carcinogenic potential (USEPA, 1996). For mixtures containing only mono- through

tetrachlorobiphenyls, carcinogenic potential has been reduced 100 fold. Coplanar congeners can determine acute toxicity, and dechlorination in Hudson River sediments has been shown to reduce the concentration of these congeners by up to 97 percent (Quenson, et al, 1992b). Dechlorination also dramatically reduces the potential for environmental receptors to be exposed to PCBs in PCB-contaminated Upper Hudson River sediments. Dechlorination reduces the bioaccumulation potential of this mixture four to 35 fold. It also facilitates aerobic biodegradation by converting the mixture to readily degradable congeners.

The insensitive dechlorination indices developed in the Report, which only measure the final phases of dechlorination, are incapable of measuring these benefits because potential toxicity, carcinogenicity and exposure are reduced by even modest levels of dechlorination as the initial stages of dechlorination provide disproportionate reductions in these endpoints.

B. The Report's Dechlorination Indices are Flawed and Insensitive.

The Report characterizes PCB dechlorination in terms of two indices: a so-called "molar dechlorination product ratio" and a "fractional change in molecular weight". PCB homologue distributions can be affected by other known physical processes, such as the selective extraction into the water column, in addition to microbial dechlorination and by different mixtures of Aroclors. Laboratory experiments show that when water is passed over Aroclor 1242, the extracted PCBs are generally enriched in the lower homologues, particularly BZ 1, 4, 8, 10 and 19 that were used in the (19)

Report in calculating molar dechlorination product ratios, and these same congeners are depleted in the other phases. The enrichments observed in the water phase, relative to the tetrachlorobiphenyls, are about 40-fold for the monochlorobiphenyls, 10-fold for the dichlorobiphenyls and 3-fold for the trichlorobiphenyls. Thus, no simple index of homologue distribution, whether expressed as "product" ratios or as mean molecular weight, can provide definitive information about the dechlorination state of PCBs formed in a water-extract, and all statements regarding the extent of dechlorination in media susceptible to such extraction based on these indices are questionable.

An additional serious shortcoming of the "molar dechlorination product ratio" is its insensitivity, due to the selection of only "terminal" dechlorination products, to assess the extent of dechlorination. Due to this insensitivity, it is capable only of detecting extensive dechlorination in sediments containing the dechlorination activity that carries out nearly complete removal of *meta* and *para* chlorines from congeners with 2-4 chlorines per biphenyl (described above as the activity limited to the upper Hudson River). It would barely register dechlorination in sediments containing only moderate dechlorination activity, and it would completely miss those sediments containing the dechlorination activity found throughout the upper and lower Hudson that carries out partial dechlorinations of higher PCB congeners (i.e., those with 4-7 chlorine atoms per biphenyl), but producing very little of the lower homologues (with only 1-2 chlorines). As this other dechlorination activity still produces significant reductions in toxicity and exposure, its benefits as well as its detection are completely missed by the analysis in the Report.

An illustration of the insensitivity in this flawed dechlorination index is the impact of dechlorination of BZ 8. The most abundant congener in Aroclor 1242, BZ 8 is dechlorinated to BZ 1. However, this activity would be completely missed in EPA's molecular dechlorination product ratio because the sum of these congeners never changes due to dechlorination. Moreover, many of the other most abundant PCB congeners in Aroclor 1242 would be dechlorinated to BZ 1 *via* BZ 8. Therefore, this methodology would not detect the final chlorine removal step.

C. Dechlorination Occurs at Concentrations Less Than 30 ppm.

The Report relies on the analysis shown in Figure 4-22 to conclude that dechlorination does not occur predictably at PCB concentrations <30 ppm. This misrepresents the data. The data clearly show that the majority of upper river sediments samples register as dechlorinated, even with the insensitive dechlorination index used in the Report. Moreover, the analysis shows that the majority of the lower river samples lie below the line, demonstrating that the approach is inappropriate for the lower Hudson. For the upper Hudson data at <30 ppm (0.8 to 30 ppm), nearly 80% of the samples displayed on the graph are above the molar dechlorination product ratio (MDPR) for unaltered Aroclor 1242. This fraction would only increase as more sensitive dechlorination indices are utilized. For the lower Hudson, ~75% of the samples <30 ppm lie below the MDPR for unaltered Aroclor 1242. It has been well established that the contribution of more highly chlorinated Aroclors increases in the lower Hudson, particularly in the estuary region (EPA Phase 1 Report). The addition of higher Aroclors would both invalidate the application of the MDPR analysis and

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predictably drive this measure below that of Aroclor 1242. The peak ratio methods described in Appendix C overcome both of these limitations, as they are a more sensitive index to identify dechlorination (able to detect a variety of dechlorination processes, including Process B, B', C, H, and H' dechlorination), and they are relatively insensitive to partitioning and variable Aroclor compositions.

Numerous studies in the laboratory and the field have detected anaerobic PCB dechlorination over a broad range of concentrations (reviewed in Bedard and Quensen, 1995). Figure 30 shows that anaerobic PCB dechlorination has been observed in controlled laboratory studies at concentrations as low as 10 ppm (Abramowicz *et. al.*, 1993; Fish, 1996, Rhee *et. al.* 1995). Taken together, the studies demonstrate that there is a linear relationship between PCB concentration and dechlorination rate without a threshold concentration.

Although field studies of PCB dechlorination are limited by analytical detection limits at low concentrations, longer incubation times in the field have permitted the detection of PCB dechlorination at even 5 ppm (Table 1, Abramowicz *et. al.*, 1996). These researchers noted that even at the lowest concentration range analyzed (5-10 ppm), 63% of the samples still met the established criteria for extensive dechlorination.

Additional support for environmental dechlorination at low concentrations has been obtained through direct comparisons of surface PCB congener profiles in the Hudson River to Aroclor 1242

and completely dechlorinated Aroclor 1242 congener profiles. A sediment sample was collected from the TIP site known as H7. A fraction of this sample was extracted and analyzed for PCB content and the measured concentration was 6.2 ppm. From the PCB distribution, the number of chlorines per biphenyl (Cl/BP) was 2.71. Since Aroclor 1242 contains 3.26 Cl/BP, even at this low PCB concentration some dechlorination took place in the environment.

The use of intra-homologue peak ratios to assess dechlorination at various PCB concentrations is shown in Figure 31. Four peak ratios are utilized (BZ 56/49, 23-34-/24-25-CB; BZ 60/49, 234-4-/24-25-CB; BZ 66/49, 24-24-/24-25-CB; BZ 74/49, 245-4-/24-25-CB). These ratios represent the change in the dechlorination sensitive tetrachlorobiphenyls (mono-*ortho* substituted) to the more resistant tetrachlorobiphenyl congener 24-25-CB (di-*ortho* substituted). The result of this peak ratio analysis demonstrates that significant dechlorination occurs at all concentrations, even at sub-ppm levels. There is also a clear trend demonstrating more extensive dechlorination at higher PCB concentrations, consistent with laboratory experiments.

D. Dechlorination has not stopped in the Hudson River.

The Report incorrectly states that dechlorination has stopped in the Hudson River, based upon the analysis of high resolution cores (Report at 4-70). This conclusion is flawed since the indices used to monitor dechlorination are insensitive to some dechlorination processes and since it ignores the ongoing dechlorination of fresh Aroclor 1242 in surficial sediments. Evidence for

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dechlorination in surficial sediments exists in several forms. First, surficial sediments collected from the "fluff" layer from the TIP display Pattern A dechlorination (described in Appendix C). Second, microcosms that simulate the fate of fresh Aroclor 1242 in Hudson River sediments display Pattern A dechlorination at early time points (4-6 weeks, Fish, private communication). Third, fish in the TIP display a PCB distribution consistent with Pattern A dechlorination. This pattern is likely the result of the initial stages of dechlorination, with more extensive dechlorination occurring over longer time periods, when additional burial sequesters this material.

These surficial biotransformations (Process A initially and Process Y later) and subsurface dechlorinations (Process C) which were observed in microcosm experiments (Fish and Principe, 1994 and Fish, 1996) demonstrate rapid dechlorination and degradation of Aroclor 1242 in Hudson River surface sediments. The changes observed in these physical river models closely correspond to changes observed in the environment.

Additional evidence to demonstrate that dechlorination is still occurring in the upper Hudson is found in Figure 32. This Figure represents the application of the intra-homologue peak ratios to the EPA Phase 2 high resolution sediment cores. To minimize the impact of concentration on the rate of dechlorination, only a narrow concentration range was utilized (all 3-30 ppm core segments from all Upper Hudson high-resolution cores). Note that the extent of dechlorination continues to change in a smooth continuum with increasing depth in the core. This data demonstrates that the extent of dechlorination strongly correlates with increasing depth and increasing age of the sediment,

inconsistent with the Report's claim that dechlorination has stopped in the upper Hudson. These analyses also demonstrate the strength of peak ratios as effective indices of anaerobic PCB dechlorination in environmental media, assessing concentration and temporal effects even under conditions when partitioning, variable Aroclor compositions, or modest level of dechlorination are present, conditions that can confound other dechlorination indices.

VII. CONCLUSIONS AND RECOMMENDATIONS

In order to evaluate remedial options properly, EPA must understand the sources, transport and fate of PCBs in the Upper Hudson River. This Report provides a geochemical analyses of the data, based on several inconsistent hypothesis, that do not provide a realistic and accurate view of the river system.

The Report offers various hypotheses to explain the spatial and temporal patterns in the PCB data. Many of the hypotheses are incompatible, and the Report chooses from among them to reach overall conclusions. In most cases, the choices are based on qualitative arguments that are not rigorously evaluated. In these comments, we have presented technical arguments that refute the primary hypotheses that form the basis of the Report's conclusions. Our arguments are based on geochemical fingerprinting techniques similar to those used by EPA; a quantitative determination of the PCB fate mechanisms required by the hypothesis; and PCB mass-balance calculations. The last two types of analyses are a requirement of hypothesis-testing because they examine the plausibility of the stated hypothesis.

Because EPA's approach to data interpretation is restricted to a geochemical examination of the data, it is sufficient for developing hypotheses but not for testing them. The Agency must acknowledge this limitation and conduct further analyses to test the hypotheses within the framework of the mass-balance model currently under development. As we have done in our

evaluation of the Report conclusions, the Agency must use the model to examine the consistency of each hypothesis with the estimated rates and magnitudes of relevant fate processes and with historical information regarding the spatial and temporal distributions of PCBs in water, sediment and fish. An integrated interpretation that accounts for all the sources and losses of PCBs is necessary to develop conclusions about the relative importance of the various PCB sources and the rate of recovery.

The utility of the Report and its conclusions are fundamentally undermined by its numerous inconsistent statements. An exhaustive review of each of such statements is beyond the scope of these comments, but the examples set out below demonstrate this shortcoming:

- The Report hypothesizes resuspension of dechlorinated sediments from the TIP despite its own analysis that explains that resuspension is not occurring. On pages 3-62 and 3-63, the Report concludes that resuspension of TIP sediments is of limited importance to the load measured at the TID because there is no evidence of resuspension during low flow and during high flow, when resuspension would be expected, the load above Rogers Island is transported relatively unaffected through the TIP. Notwithstanding this sound conclusion, the Report later hypothesizes that a possible source of the increased load across the TIP seen most prominently during low-flow periods is resuspension of sediments containing highly concentrated, highly dechlorinated PCBs. This hypothesis, presented as one of the primary conclusions of the Report, is obviously inconsistent

with the observation made at 3-62 and 3-63 that resuspension within the TIP is not an important process.

- The Report emphasizes the importance of sediments as PCB contributors to the TIP and de-emphasizes its own analysis that shows that the current sources near Hudson Falls are more important. On page 3-90, the Report describes the mass of PCBs provided by the different internal and external sources in the Upper River in 1993: 370 kg from the sources above Rogers Island; 225 kg from the TIP; 25 kg from the "Schuylerville" source; and 83 kg from scour from the Hoosic-driven scour of surficial sediments during Transect 3. Using these figures, the sources above Rogers Island provide approximately 50% of the annual load during 1993. This fact, however, is ignored in the Report's primary conclusions, which, in particular, attribute increased loads to the TIP sediments):

> "The PCB load from the Thompson Island Pool . . . dominates the water column from the Thompson Island Dam to Kingston during low flow conditions" (Report at E-3);

> "The sediments of the Thompson Island Pool strongly impact the water column, generating a significant water column load (as documented in Chapter 3) whose congener pattern can often be seen throughout the Upper Hudson" (Report at 4-91).

- The Report dismisses the importance of the more recent load originating near Hudson Falls attributed to 1991 - 1993-era loads from the Allen Mill, which the Report concludes have been essentially eliminated:

> "Recent remedial efforts by GE have greatly decreased the PCB loads originating above Rogers Island. As a result, the total annual loads to the water column have decreased but the importance of the TI Pool load has increased." (Report at 3-91).

Not only are there no data to support this conclusion, it ignores the likelihood that the large releases from the Mill were deposited above and within the TIP, where they are now contributing to the water column.

- The Report is inconsistent in its reliance on different mechanisms above and below the TID. On the one hand, the Report posits a number of possible physical mechanisms within the TIP -- settling or volatilization of the load entering the TIP and porewater diffusion or resuspension of TIP sediments -- to explain the increased loading of PCBs across the pool. At the same time, the Report appears to ignore or discount these same mechanisms in the area below the TID in reaching the conclusion that the load at the TID is transported without significant loss of PCBs to the water column through the rest of the freshwater Hudson. Yet, the sediments in the areas above and below the TID are very similar, and the Report itself identifies an increase in PCB load downstream of the TID during low flows (Report at 3-84). It is unreasonable to invoke these processes where they tend

to support one's conclusions, but ignore them when they do not comport with those same conclusions.

In order to complete a technically defensible remedial analysis, EPA must develop a consistent and physically plausible explanation of the data and then test that explanation against a calibrated and validated model to ensure that the true sources of PCBs to fish, wildlife and humans are identified. The explanation of the data needs to take into account all the processes at work in the river that are relevant to remedial analyses. Where questions central to remedial analyses cannot be answered with the data presently at hand, additional data must be obtained to resolve the issues so that we can have full confidence in the conclusions reached on the basis of data interpretation and evaluation.

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TABLES

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Table 1.

Surface Sediment PCB Reservoir Depletion under 1993-1996 Average Thompson Island Pool Load

Homologue	Mass of PCBs in TIP Surface Sediments in 1984[1,2] (MT)	Load from TI Pool[3] (MT/year)	Time to deplete the sediment reservoir (Years)
1	0.58	0.055	1995
2	1.4	0.117	1996
3	1.0	0.062	2000
4	0.41	0.016	2009
5	0.13	0.002	2040
Sum	3.52	0.25 = 0.69 kg/day	

(1) Mass of total PCB in surface sediments = surface sediment concentration* x specific weight of sediments* x 8 cm depth x area of TI Pool*
* Values based on EPA analysis.

(2) Homologue mass based on homologue composition of EPA low resolution cores

(3) Load from TI Pool = Load at TI Dam - load at Rogers Island; all GE data, 1993-1996.

Table 2.

Average PCB Loading Across Thompson Island Pool from 1993 to 1996[1]

Year	Number of Paired Samples	Average PCB Load [kg/year]
1993	49	202.2
1994	34	296.9
1995	45	84.3
1996	57	406.6
Overall	**185**	**253.9**

[1]Loadings calculated from GE database (corrected for analytical bias), based on daily average flows measured at Fort Edward and differences between paired water column PCB concentrations from samples collected at Fort Edward and Thompson Island Dam.

Table 3.

Magnitude and Composition of the Unaccounted for Summer PCB Load from Thompson Island Pool

Year	Unaccounted-for PCB Load [kg/day]	Unaccounted-for Solid Phase PCB Homolog Distribution [WT%]									
		Mon	Di	Tri	Tet	Pen	Hex	Hep	Oct	Non	Dec
1991	0.05	5.9	0.1	38.8	32.1	22.8	0.3	0.0	0.0	0.0	0.0
1992	0.56	11.8	19.9	42.1	23.4	1.8	1.1	0.0	0.0	0.0	0.0
1993	0.99	7.5	17.8	28.8	31.7	12.1	2.2	0.0	0.0	0.0	0.0
1994	0.97	9.3	22.4	33.8	28.0	6.4	0.2	0.0	0.0	0.0	0.0
1995	0.23	2.3	14.8	29.1	35.4	15.0	3.3	0.0	0.0	0.0	0.0
1996	1.18	4.4	18.3	36.9	29.4	9.4	1.6	0.0	0.0	0.0	0.0

Table 4.

Magnitude and Composition of the Unaccounted-for Monthly PCB Load from Thompson Island Pool During 1996

Month of 1996	Unaccounted-for PCB Load [kg/day]	Unaccounted-for Solid Phase PCB Homolog Distribution [WT%]									
		Mon	Di	Tri	Tet	Pen	Hex	Hep	Oct	Non	Dec
Jan	0.54	3.6	17.4	43.1	31.9	3.7	0.2	0.0	0.0	0.0	0.0
Feb	0.13	0.6	26.2	36.9	28.6	7.5	0.1	0.0	0.0	0.0	0.0
Mar	0.60	3.4	15.6	33.5	35.3	11.2	1.0	0.0	0.0	0.0	0.0
Apr	2.05	4.3	11.6	38.3	38.2	6.7	0.7	0.0	0.0	0.0	0.0
May	1.80	5.6	19.6	34.7	31.5	7.8	0.8	0.0	0.0	0.0	0.0
Jun	2.06	4.9	15.6	35.9	30.9	11.1	1.6	0.0	0.0	0.0	0.0
Jul	0.68	4.9	28.4	35.1	21.2	8.7	1.7	0.0	0.0	0.0	0.0
Aug	0.92	3.9	19.1	40.3	30.4	4.7	1.7	0.0	0.0	0.0	0.0
Sep	0.56	2.3	17.9	33.0	32.3	13.7	0.8	0.0	0.0	0.0	0.0
Oct	0.27	23.9	42.0	12.7	16.0	4.9	0.5	0.0	0.0	0.0	0.0
Nov	0.38	19.2	40.1	19.1	12.4	8.3	0.8	0.0	0.0	0.0	0.0
Dec	0.19	0.0	35.6	38.2	10.2	13.7	2.2	0.0	0.0	0.0	0.0

Table 5.

Information Sources for Homolog-Specific Parameters of the Bioaccumulation Model

Parameter	Data Source
Benthic invertebrate/sediment accumulation factors	EPA invertebrate data, unsorted total, all samples
Water column invertebrate/water column particulate trophic transfer factors	Green Bay zooplankton/phytoplankton trophic transfer factors
Water column particulates/dissolved partition coefficient	EPA partitioning data as analyzed by HydroQual
Assimilation efficiencies at the gut and gill	Values applied in the Green Bay model

Table 6.

Exposure Sources for Homologue-Based Bioaccumulation Model for TIP

	Figure # (Simulation #)			
	18 (h24)	**19 (h23)**	**20 (h25)**	**21 (h26)**
Exposure basis:	Realistic water, top 2 cm of sediment bed	Realistic water, top 5 cm of sediment bed	Realistic water, heavily dechlorinated sediments	Heavily dechlorinated sediments and water
Water column dissolved tPCB concentration	20 ng/L (TIP late 1980s)	20 ng/L (TIP late 1980s)	20 ng/L (TIP late 1980s)	computed from water column particulates(1)
Water column dissolved homolog composition	Avg of summer data 91-96 at Ft.Edward and TIDam	Avg of summer data 91-96 at Ft.Edward and TIDam	Avg of summer data 91-96 at Ft.Edward and TIDam	Computed from water column particulates(1)
Water column particulate tPCB concentration	Computed from dissolved(1)	Computed from dissolved(1)	Computed from dissolved(1)	Same as sediment bed particulates
Water column particulate homolog composition	Computed from dissolved(1)	Computed from dissolved(1)	Computed from dissolved(1)	Same as sediment bed particulates
Sediment particulate tPCB concentration	400 ug/gOC (TIP late 1980s, fate model)	400 ug/gOC (TIP late 1980s, fate model)	400 ug/gOC (TIP late 1980s, fate model)	400 ug/gOC (TIP late 1980s, fate model)
Sediment particulate homolog composition	TIP EPA hires cores, top slice	TIP 1991 GE data, top slice	TIP EPA hires core slices with <2 Cl/BP	TIP EPA hires core slices with <2 Cl/BP

(1) Water column dissolved composition was computed from particulate composition (and vice versa) using partition coefficients based on analysis of EPA data.

FIGURES

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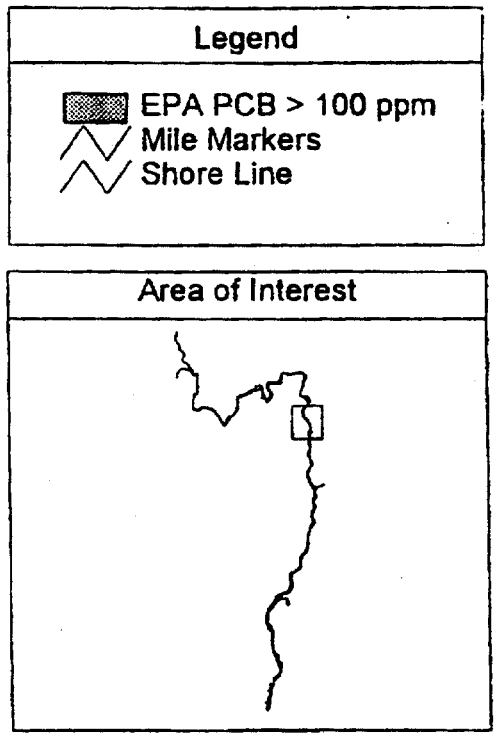
Area ID	Area (sq ft)
A1	4832
A2	53974
A3	65993
A5	47595
A6	129309
A4	8206
A7	166642
A8	41458
A9	5936
A10	223165

Total Area = 69,409 sq. m

(Total TIP = 1.93E+06 sq. m)



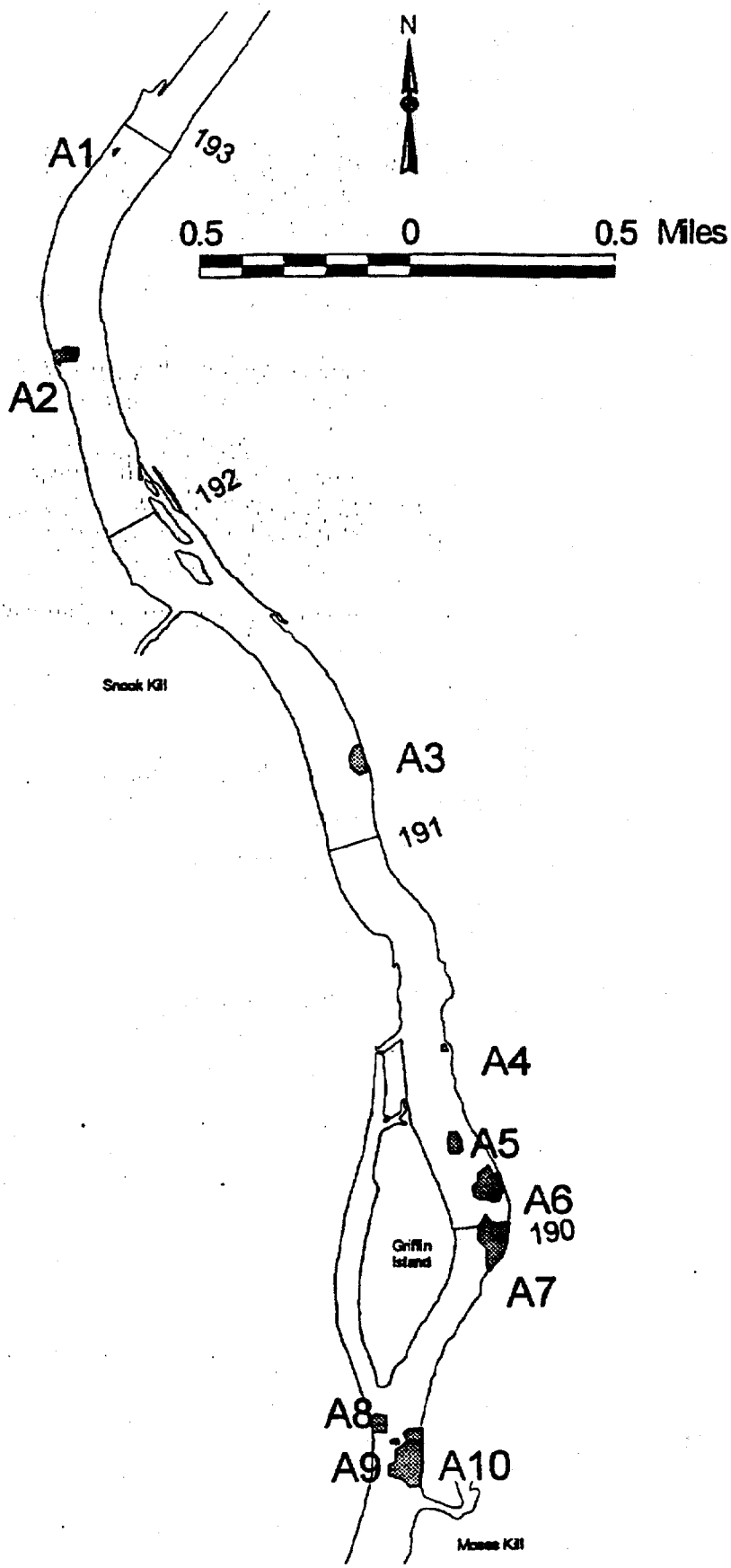


Figure 1. Areas of TIP with surface sediment PCB concentrations greater than 100 ppm.

HydroQual, Inc.

10.0432

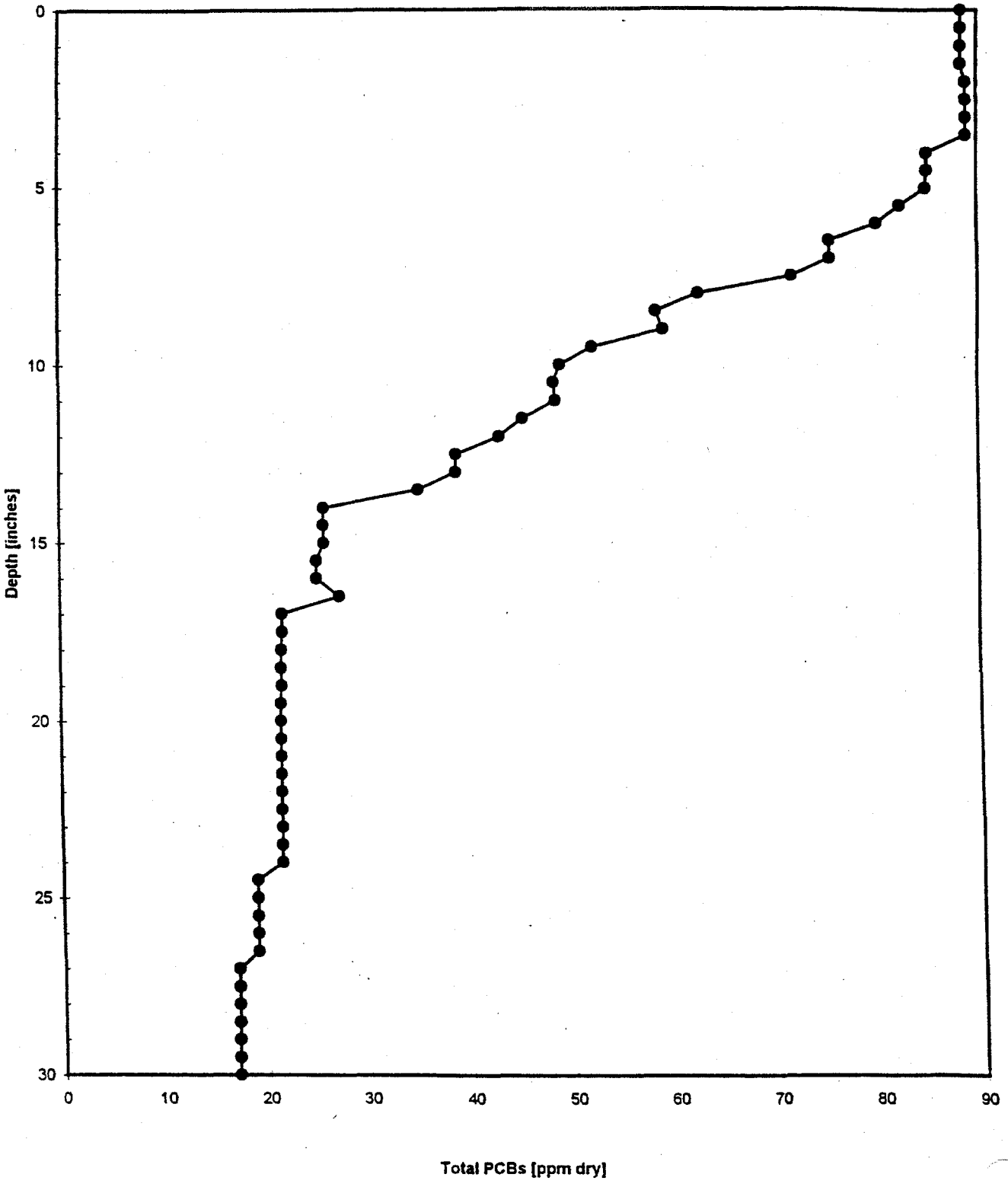


Figure 2. Average 1984 sediment PCB profile for areas with surface sediment PCBs greater than 100 mg/Kg.

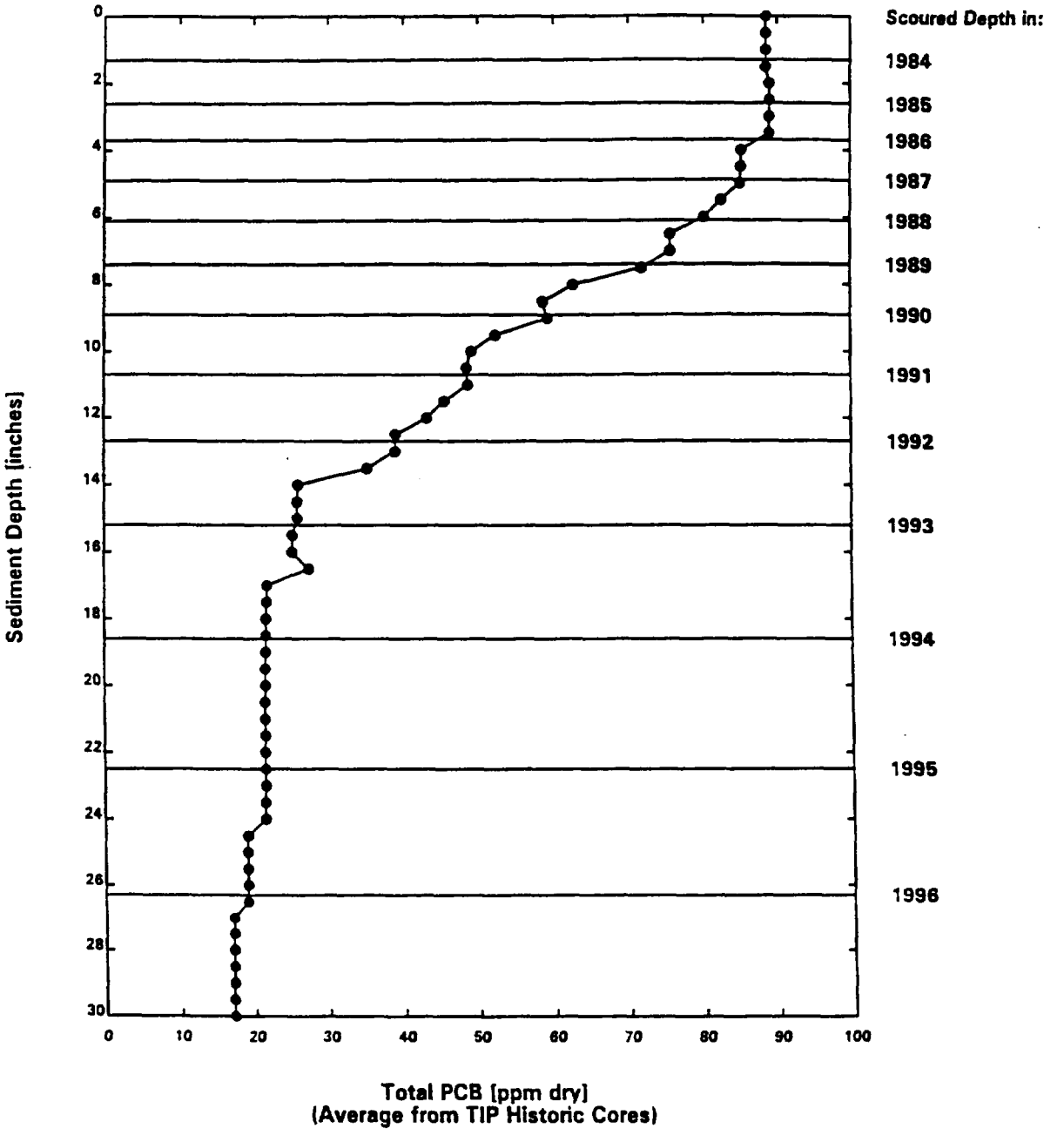


Figure 3. Annual sediment scour depths required to achieve water column concentrations necessary to maintain the TIP load.

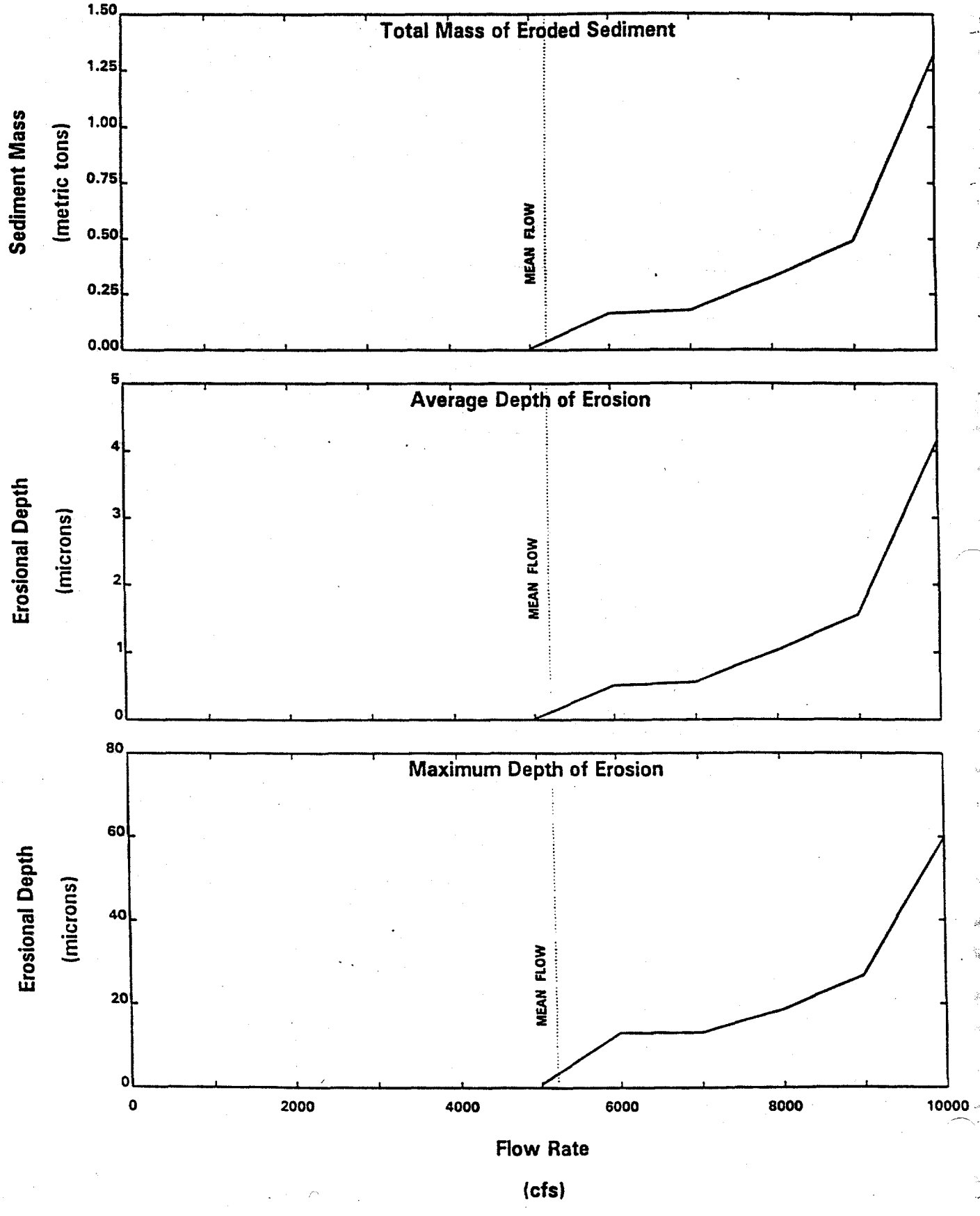
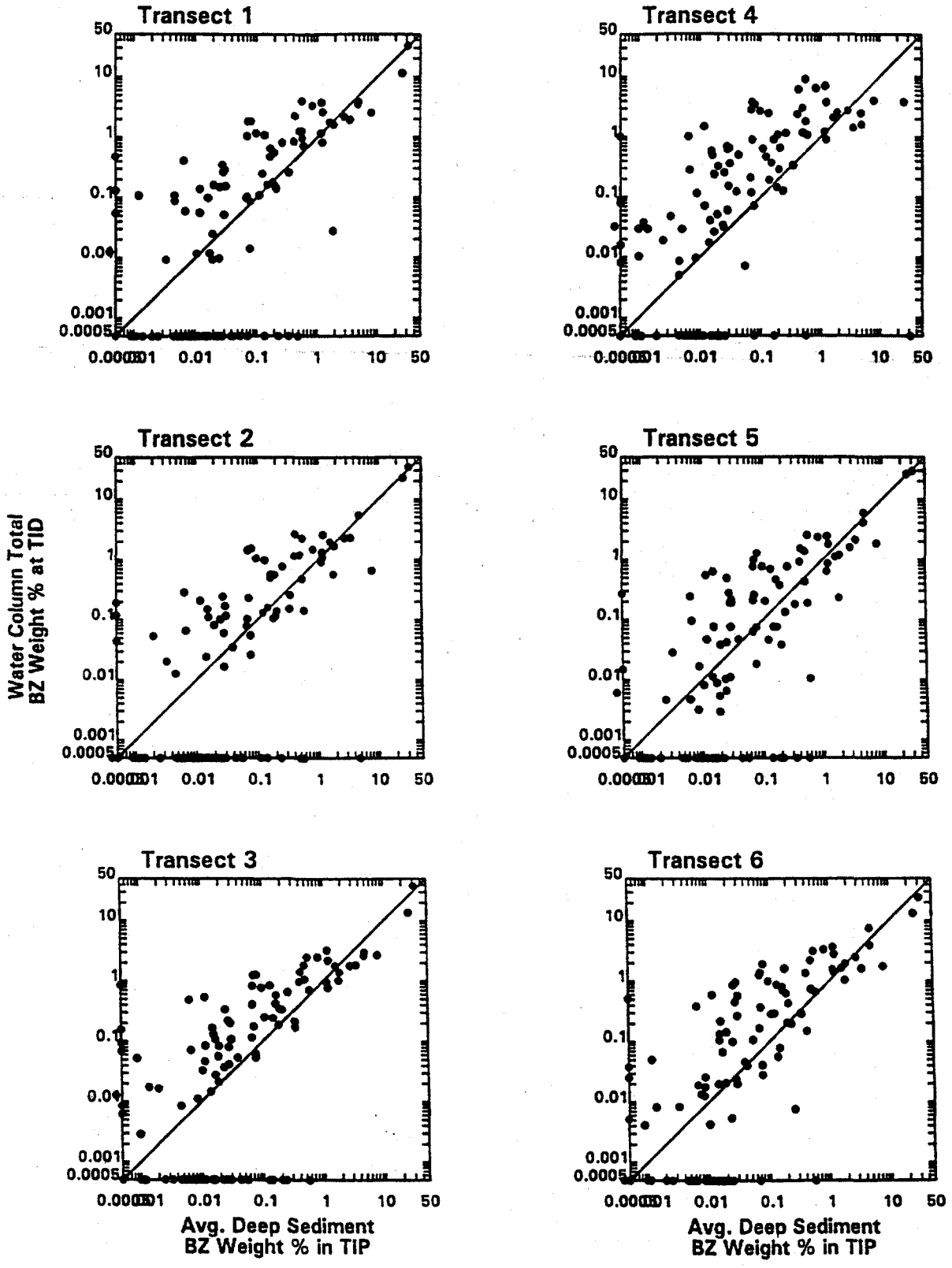


Figure 4. Predicted cohesive sediment bed erosion in the TIP under low flow conditions.

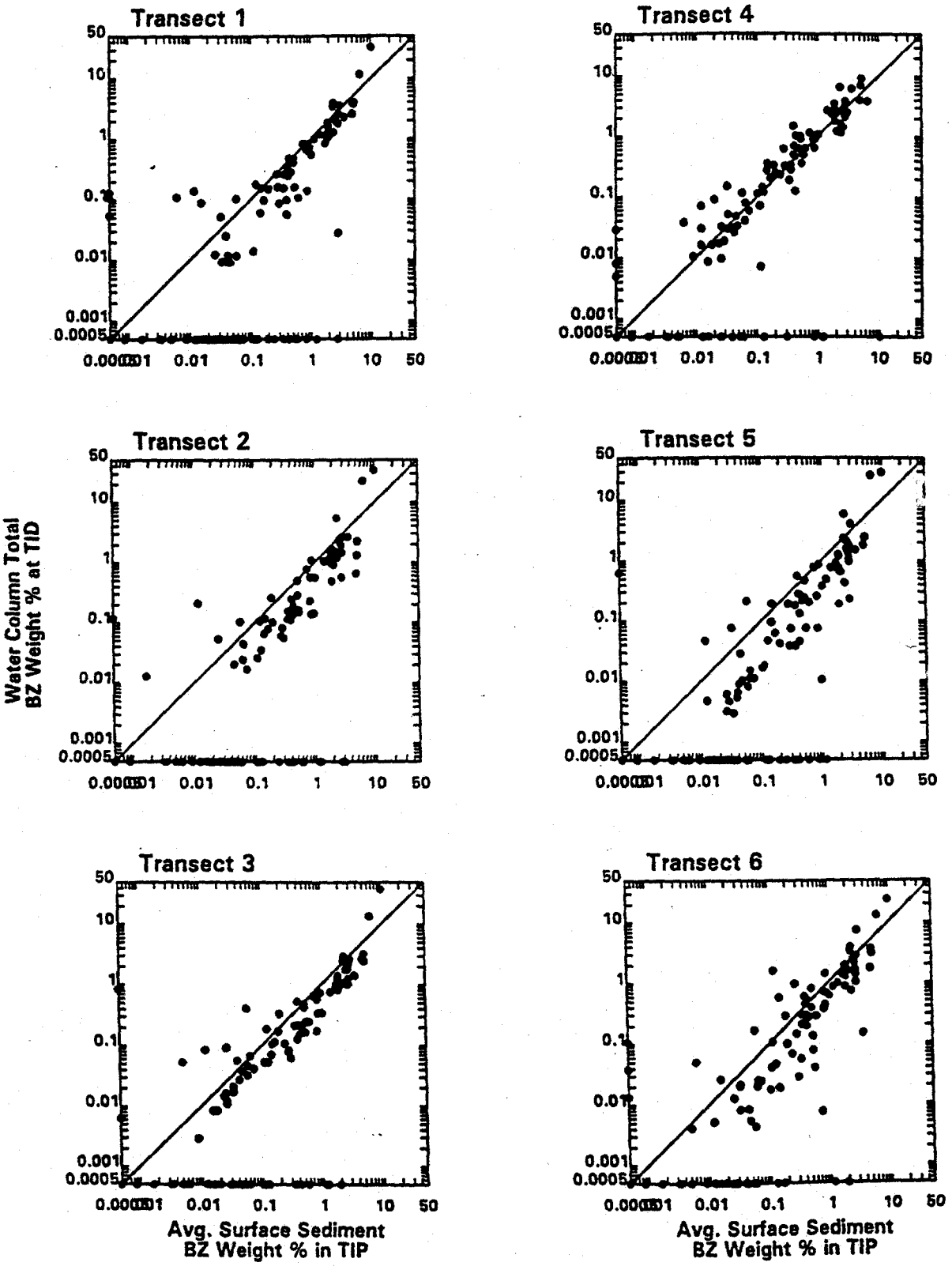


Total Water Column Data Source: EPA Phase 2 Transect Studies at TID

Deep Sediment Data Source: EPA Phase 2 High Res Core slices in TIP
with tPCB > 100 ppm

10.0436

Figure 5. Comparison of TID water column PCB signature with TIP deep dechlorinated sediment.



Total Water Column Data Source: EPA Phase 2 Transect Studies at TID

Surface Sediment Data Source: EPA Phase 2 High Res Core slices in TIP

10.0437

Figure 6. Comparison of TID water column PCB signature with TIP surface sediments.

Figure 7. Molar dechlorination product ratio versus fractional molecular weight change relative to Aroclor 1242.

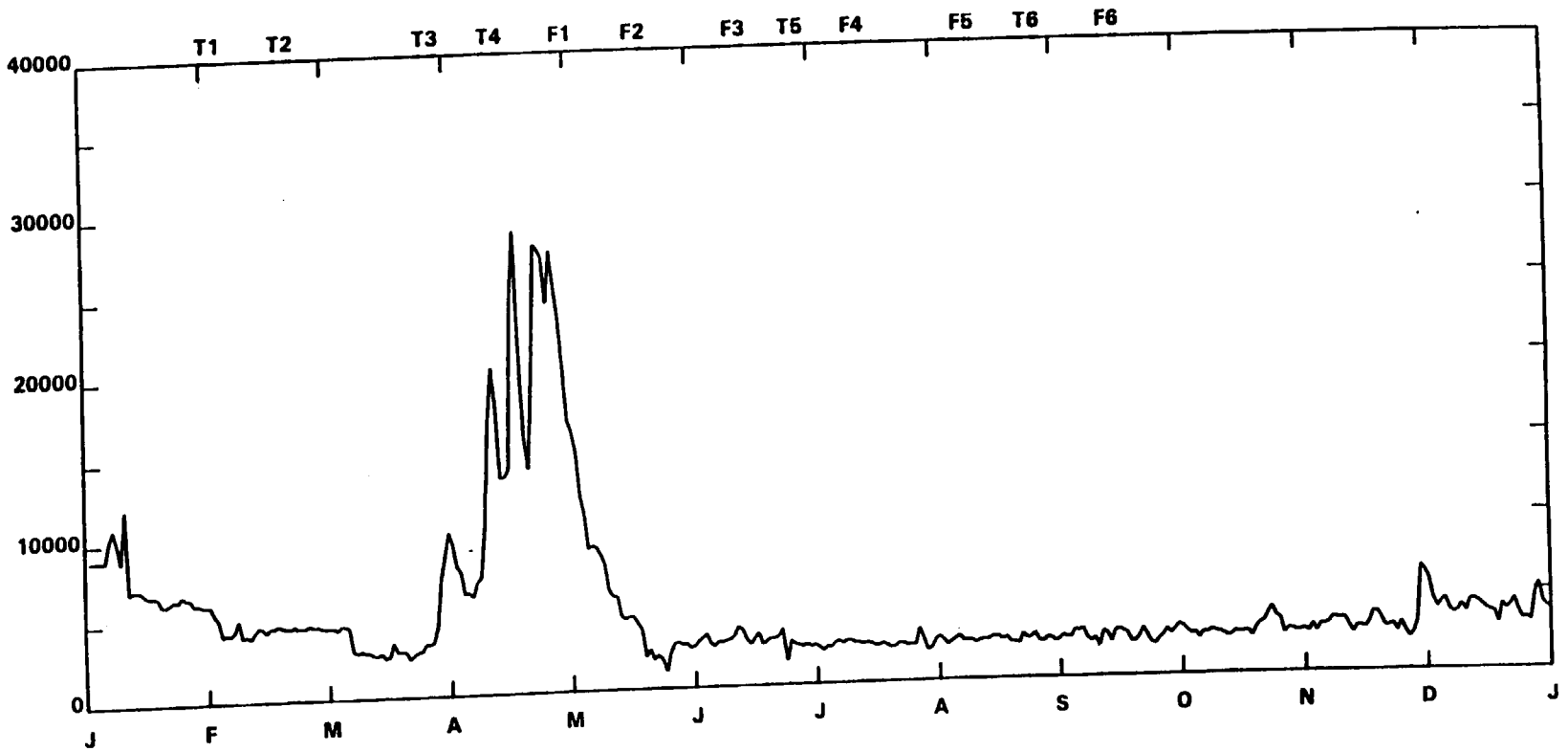
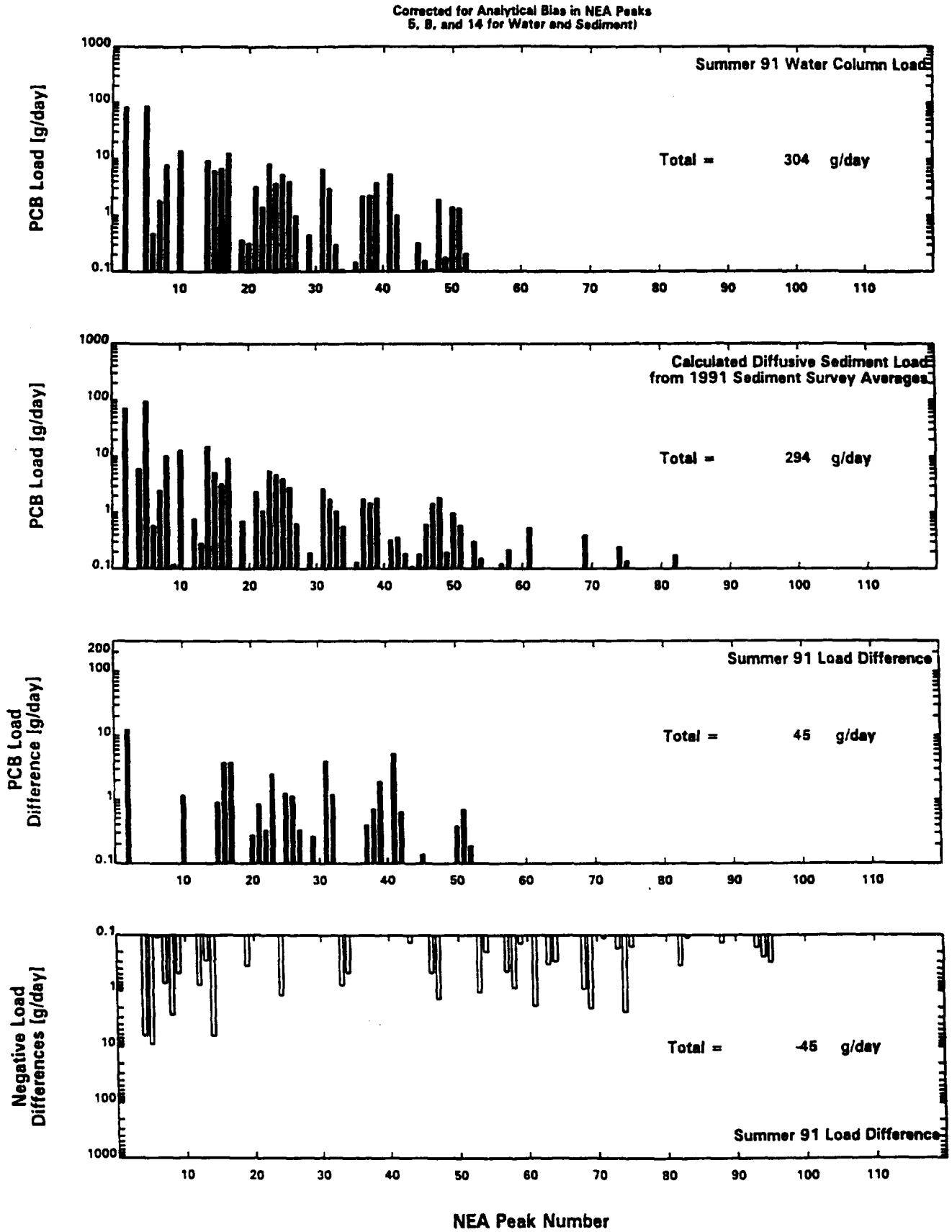


Figure 8. Location of EPA sampling events relative to 1993 hydrograph.



Kf = 0.005 m/day. Note, negative water column loads are not included.

10.0440

Figure 9. Summer 1991 congener peak TIP PCB loading - a) water column load; b) calculated diffusive sediment load; c) unaccounted-for load; d) negative congener loadings.

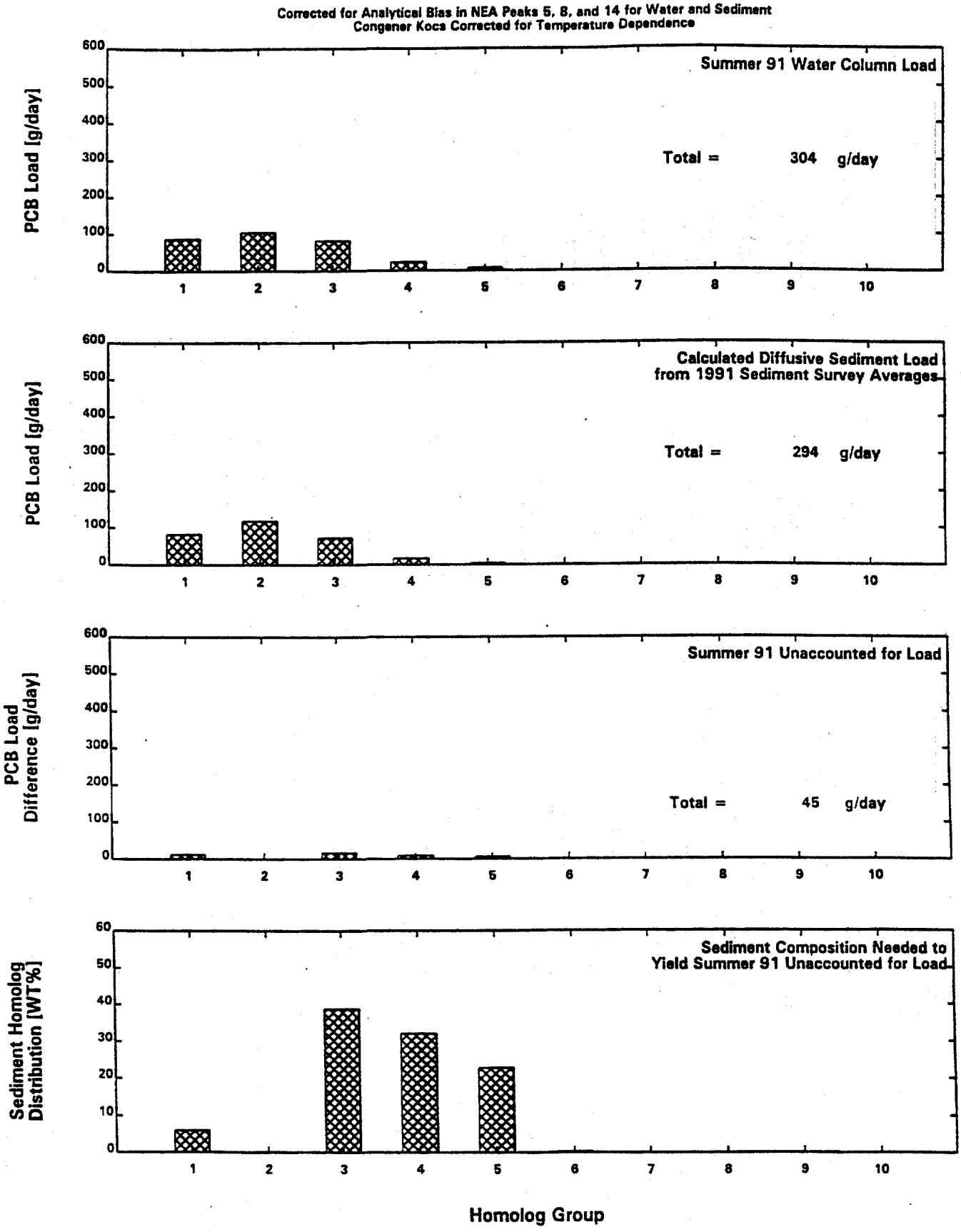


Figure 10. Summer 1991 TIP PCB homologue loading - a) water column derived load; b) calculated diffusive sediment load; c) unaccounted-for load; d) sediment composition required to yield unaccounted-for load.

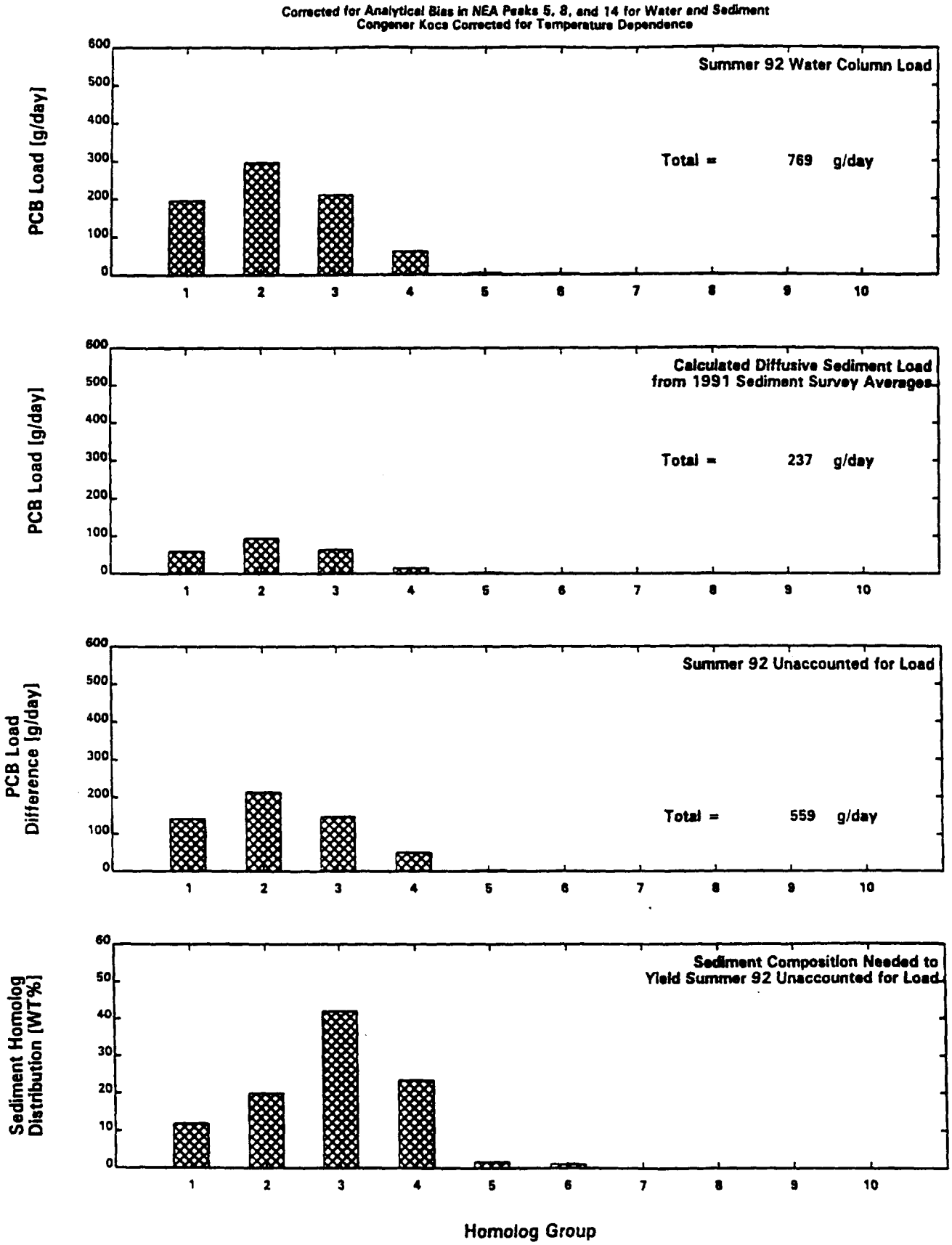


Figure 11. Summer 1992 TIP PCB homologue loading - a) water column derived load; b) calculated diffusive sediment load; c) unaccounted-for load; d) sediment composition required to yield unaccounted-for load.

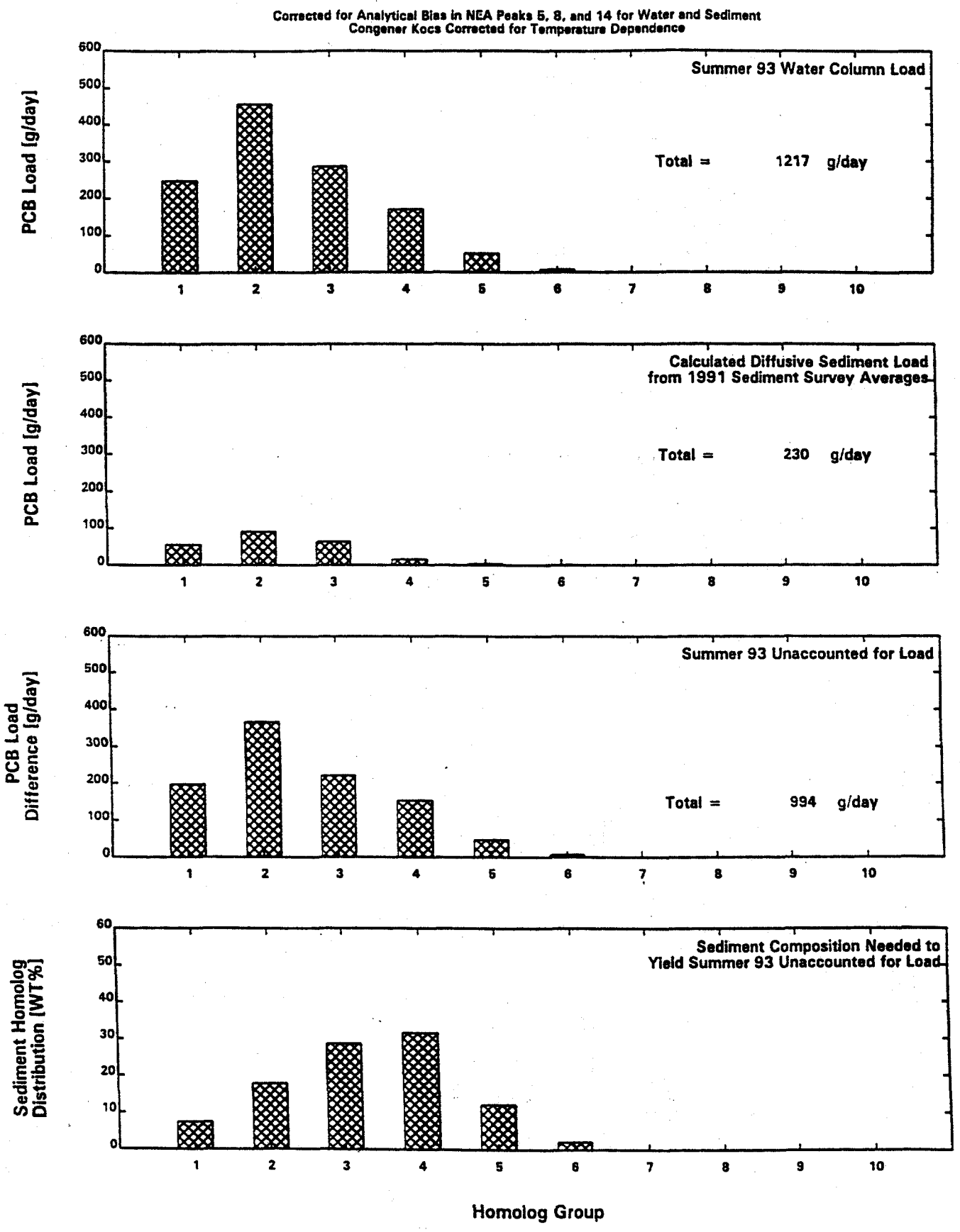


Figure 12. Summer 1993 TIP PCB homologue loading - a) water column derived load; b) calculated diffusive sediment load; c) unaccounted-for load; d) sediment composition required to yield unaccounted-for load.

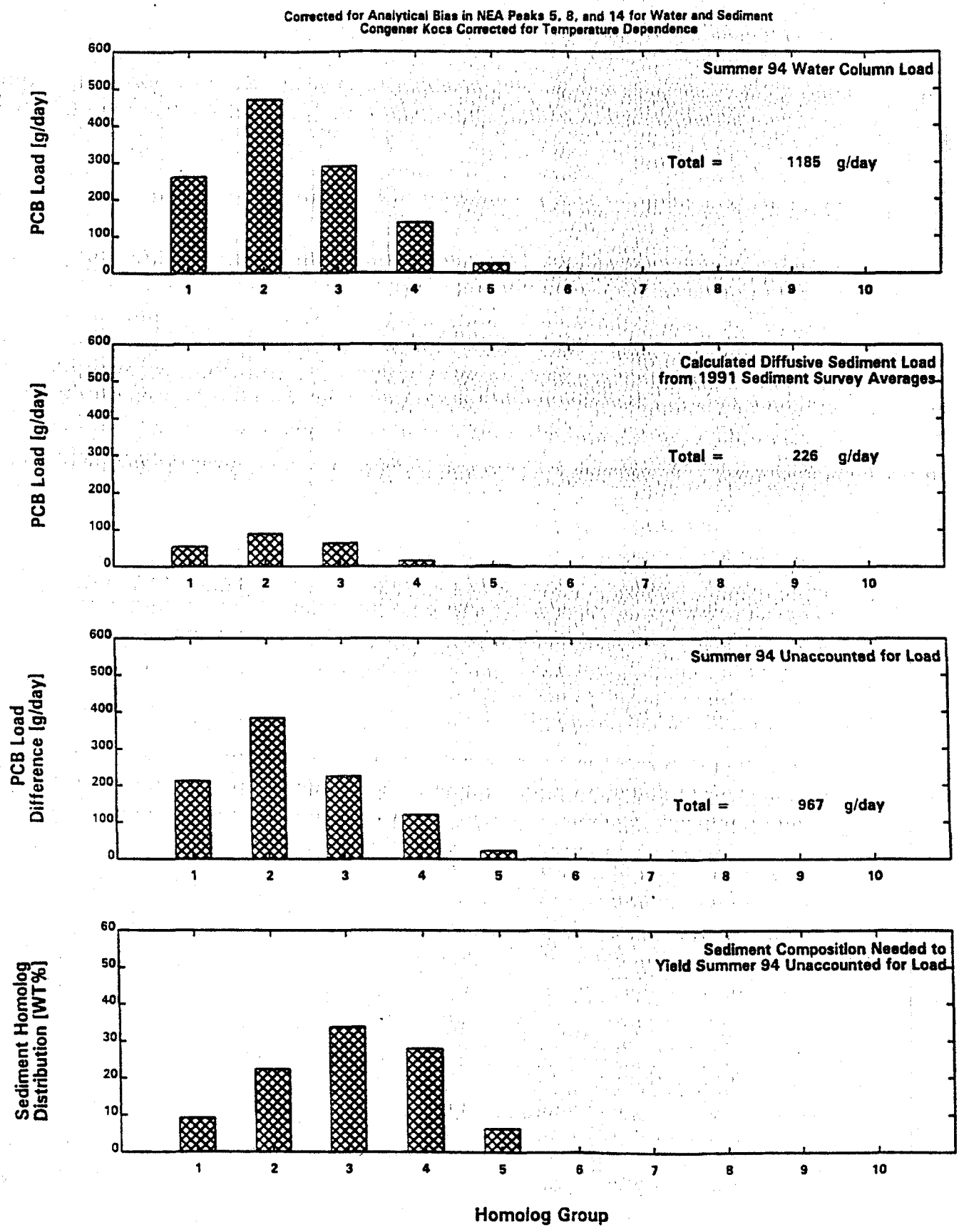


Figure 13. Summer 1994 TIP PCB homologue loading - a) water column derived load; b) calculated diffusive sediment load; c) unaccounted for load; d) sediment composition required to yield unaccounted-for load.

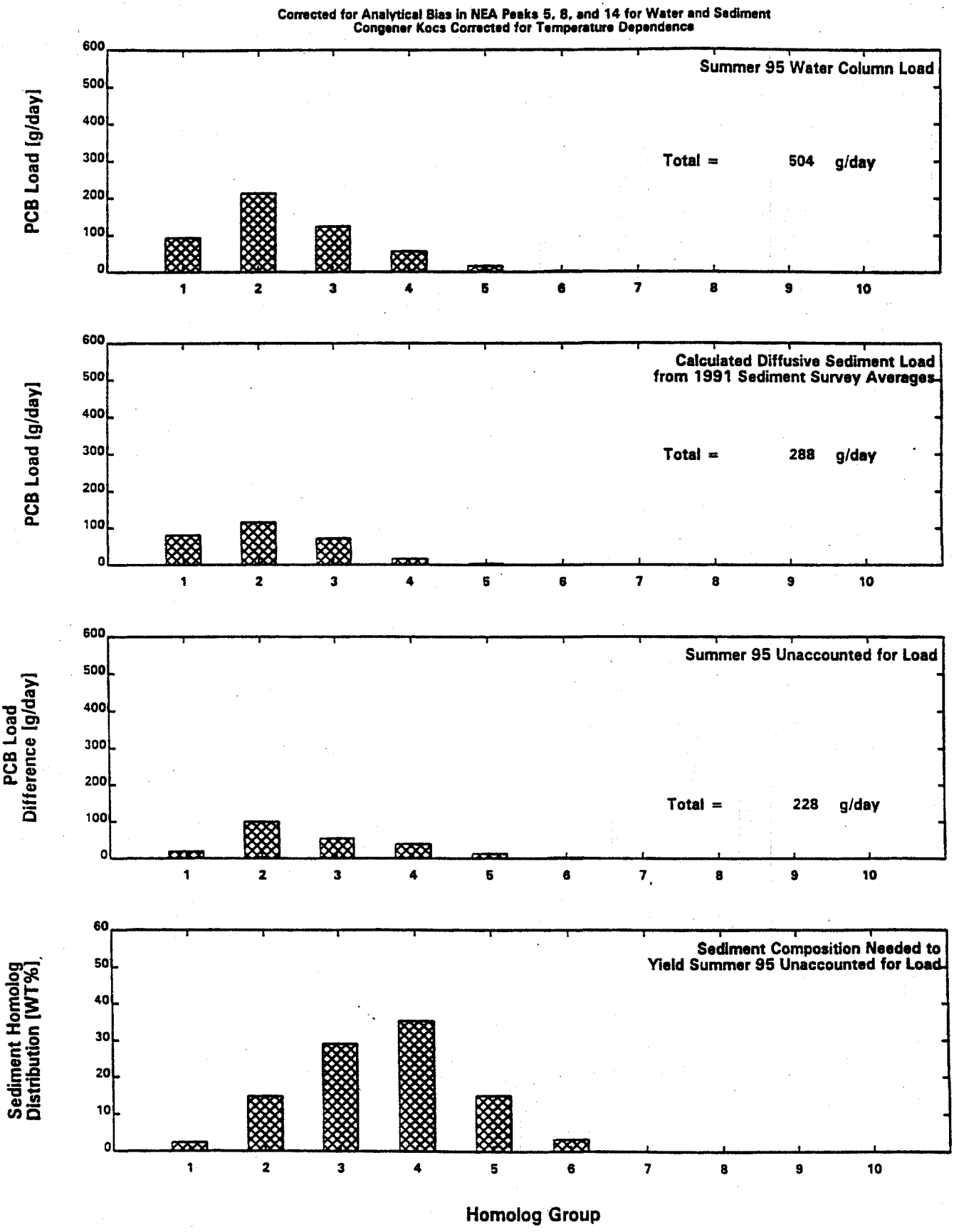


Figure 14. Summer 1995 TIP PCB homologue loading - a) water column derived load; b) calculated diffusive sediment load; c) unaccounted for load; d) sediment composition required to yield unaccounted-for load.

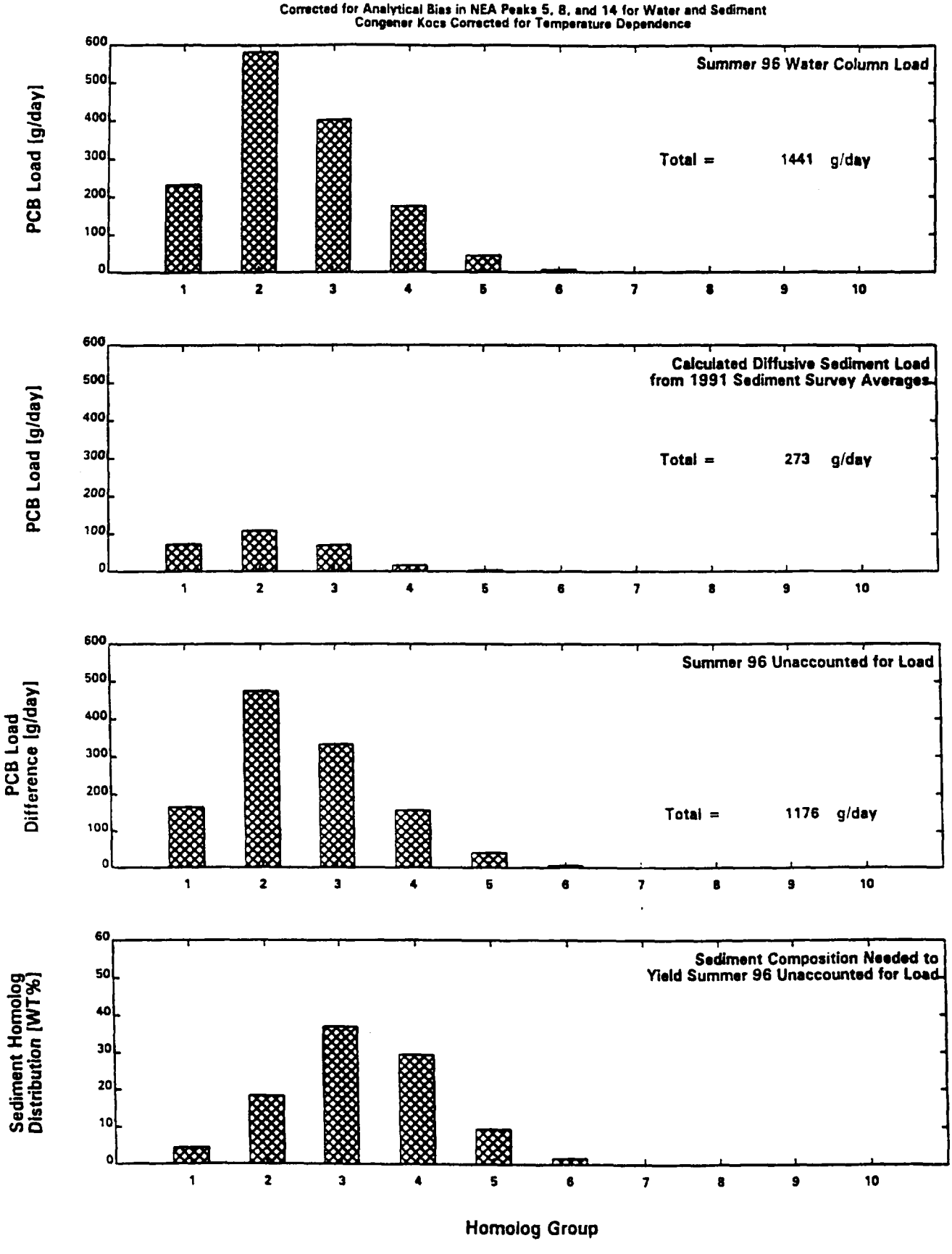


Figure 15. Summer 1996 TIP PCB homologue loading - a) water column derived load; b) calculated diffusive sediment load; c) unaccounted for load; d) sediment composition required to yield unaccounted-for load.

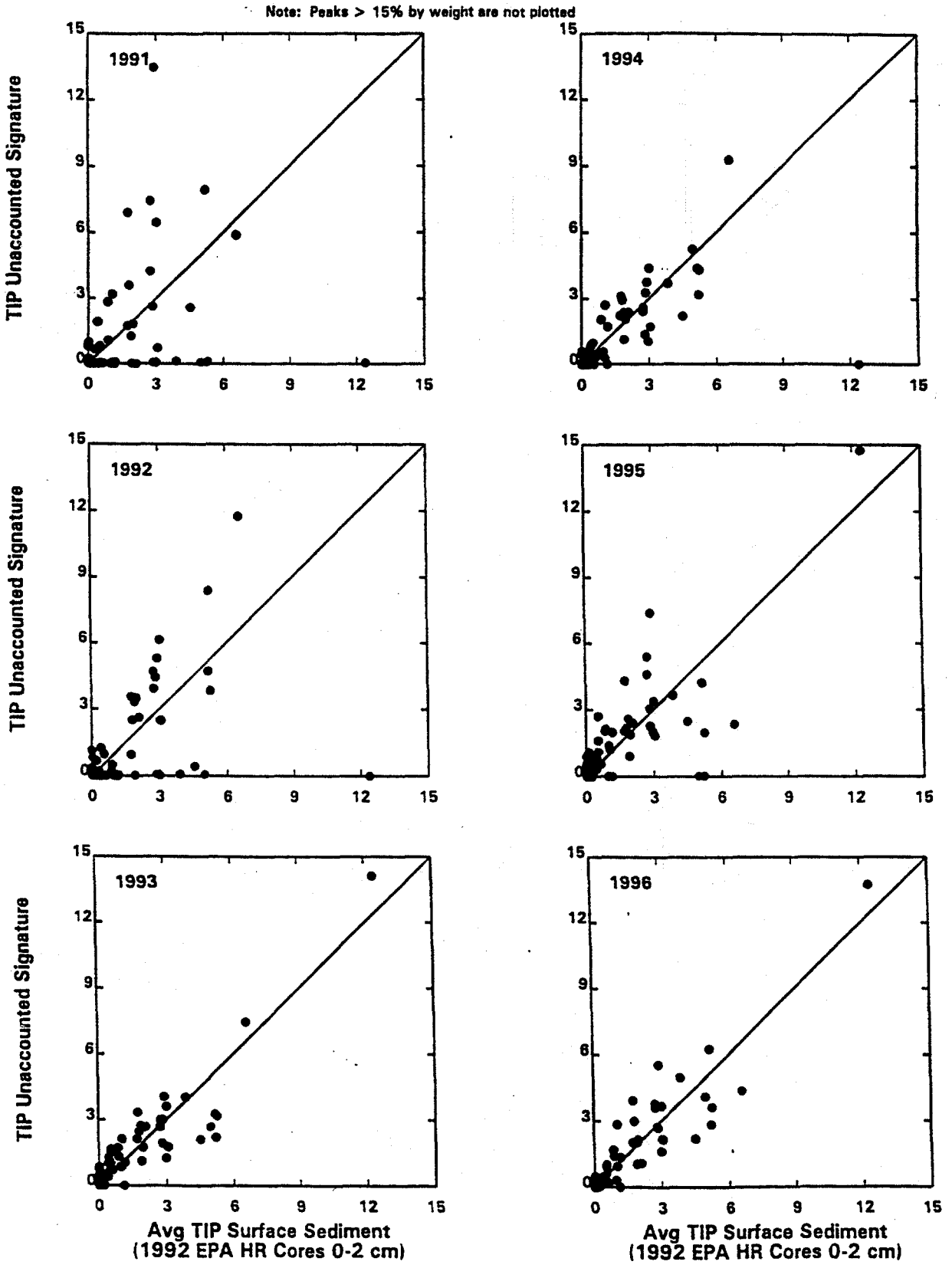


Figure 16. Comparison of PCB congener composition between average TIP surface sediments and unaccounted-for TIP load (summer 1991 - 1996).

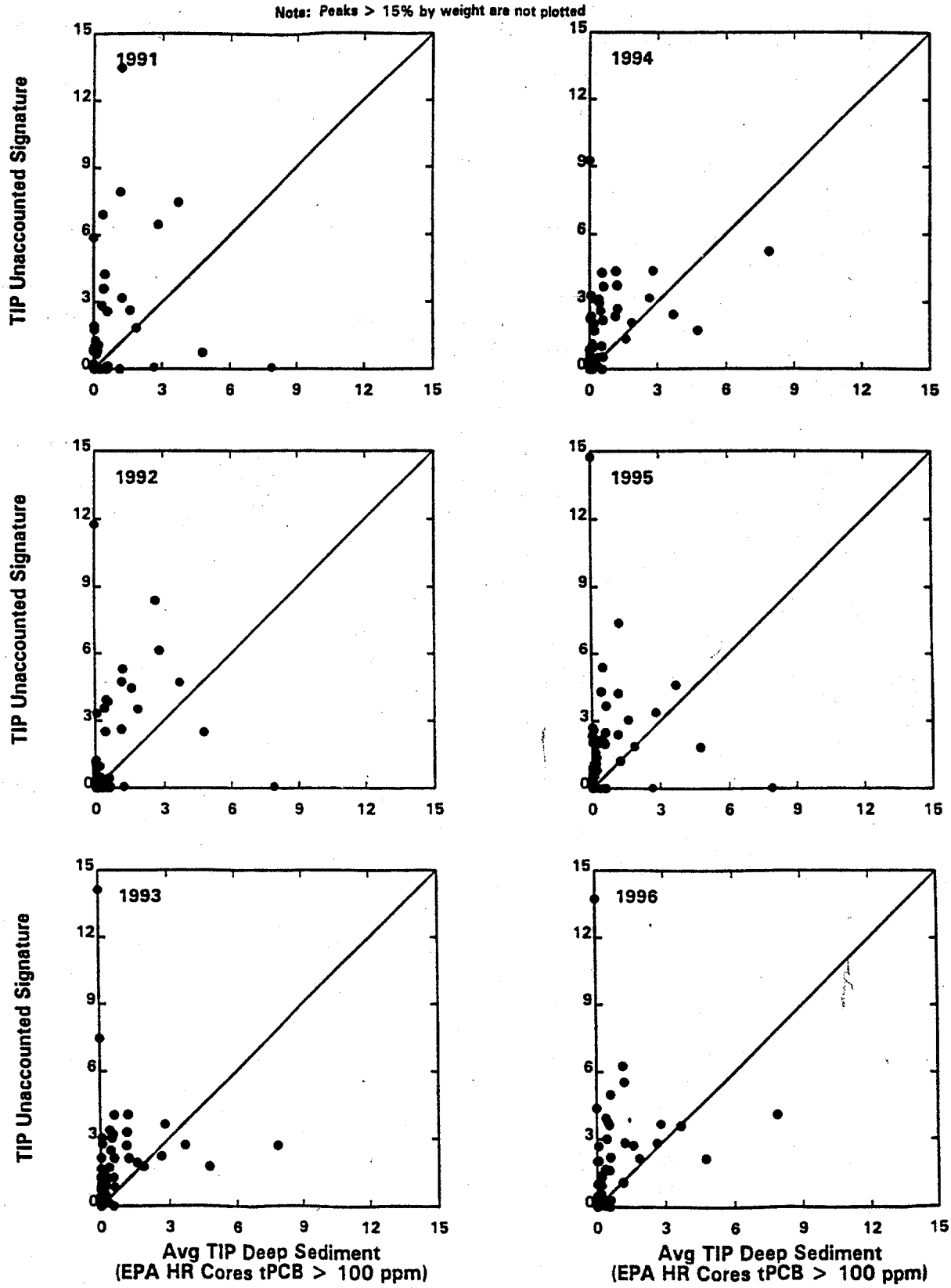


Figure 17. Comparison of PCB congener composition between average TIP deep dechlorinated sediments and unaccounted-for TIP load (summer 1991 - 1996).

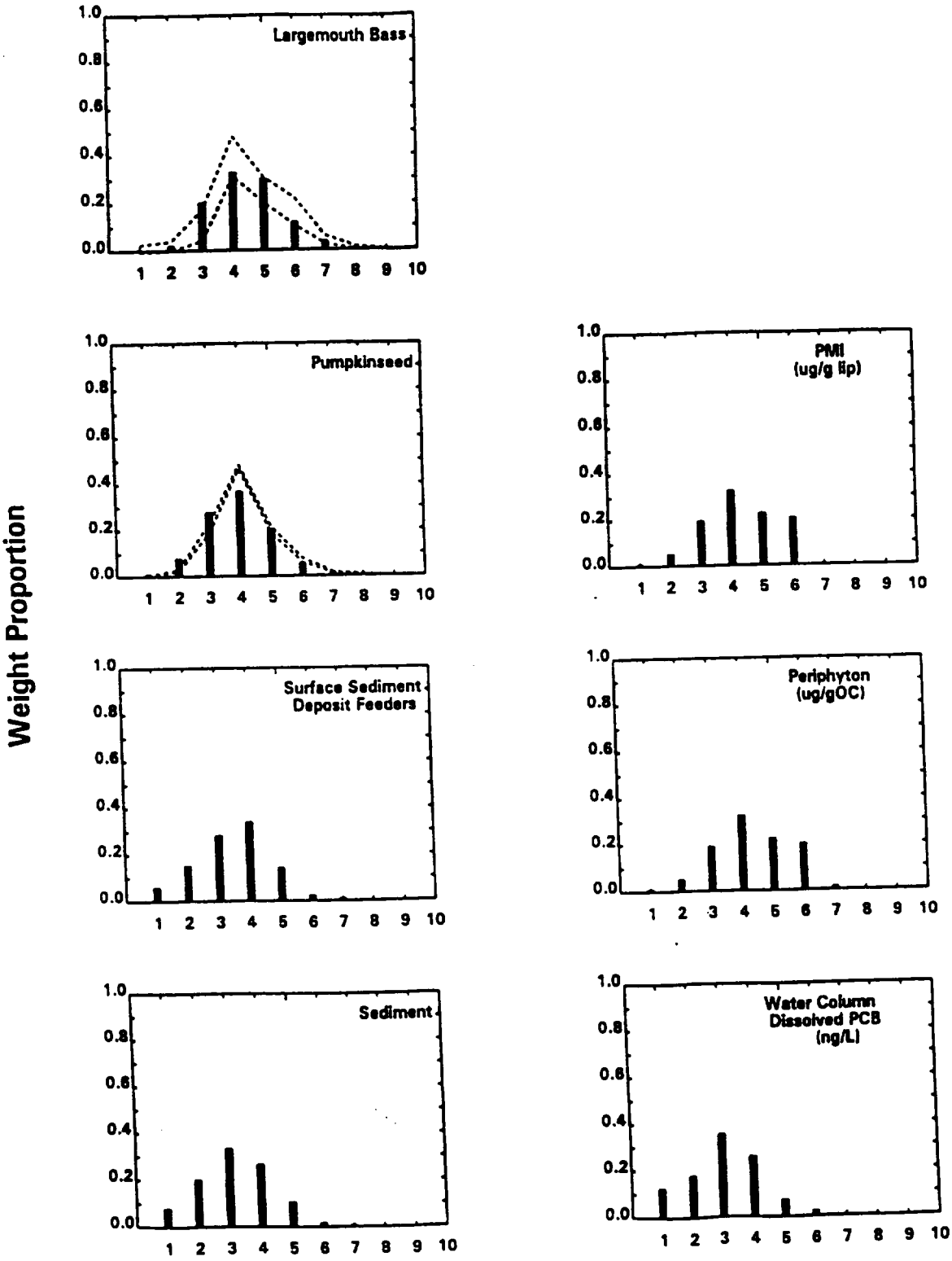


Figure 18. Steady state food web model simulation of TIP (exposure: realistic water, top 0-2 cm of sediment, see Table 6).

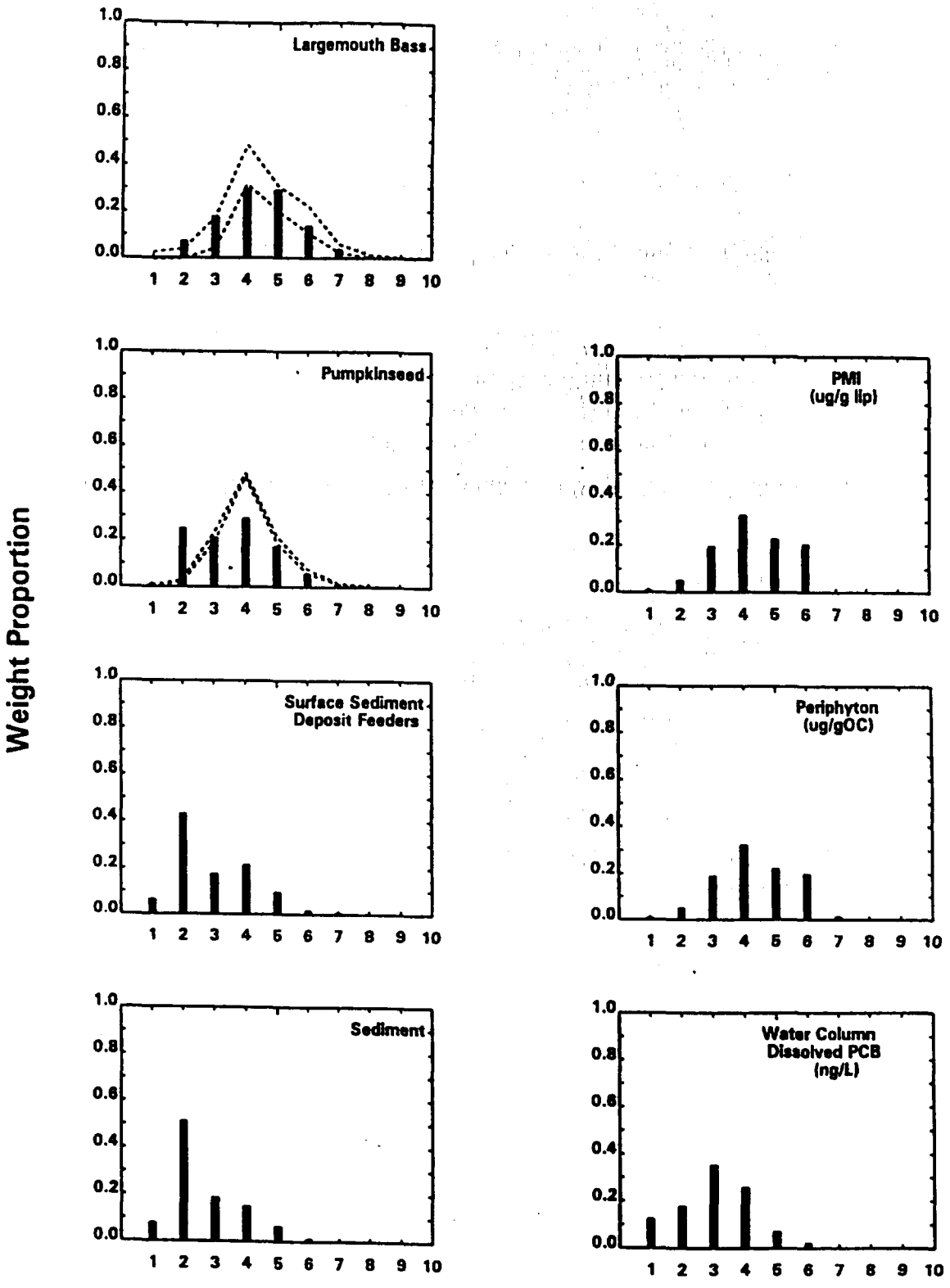


Figure 19. Steady state food web model simulation of TIP (exposure: realistic water, top 0-5 cm of sediment, see Table 6)

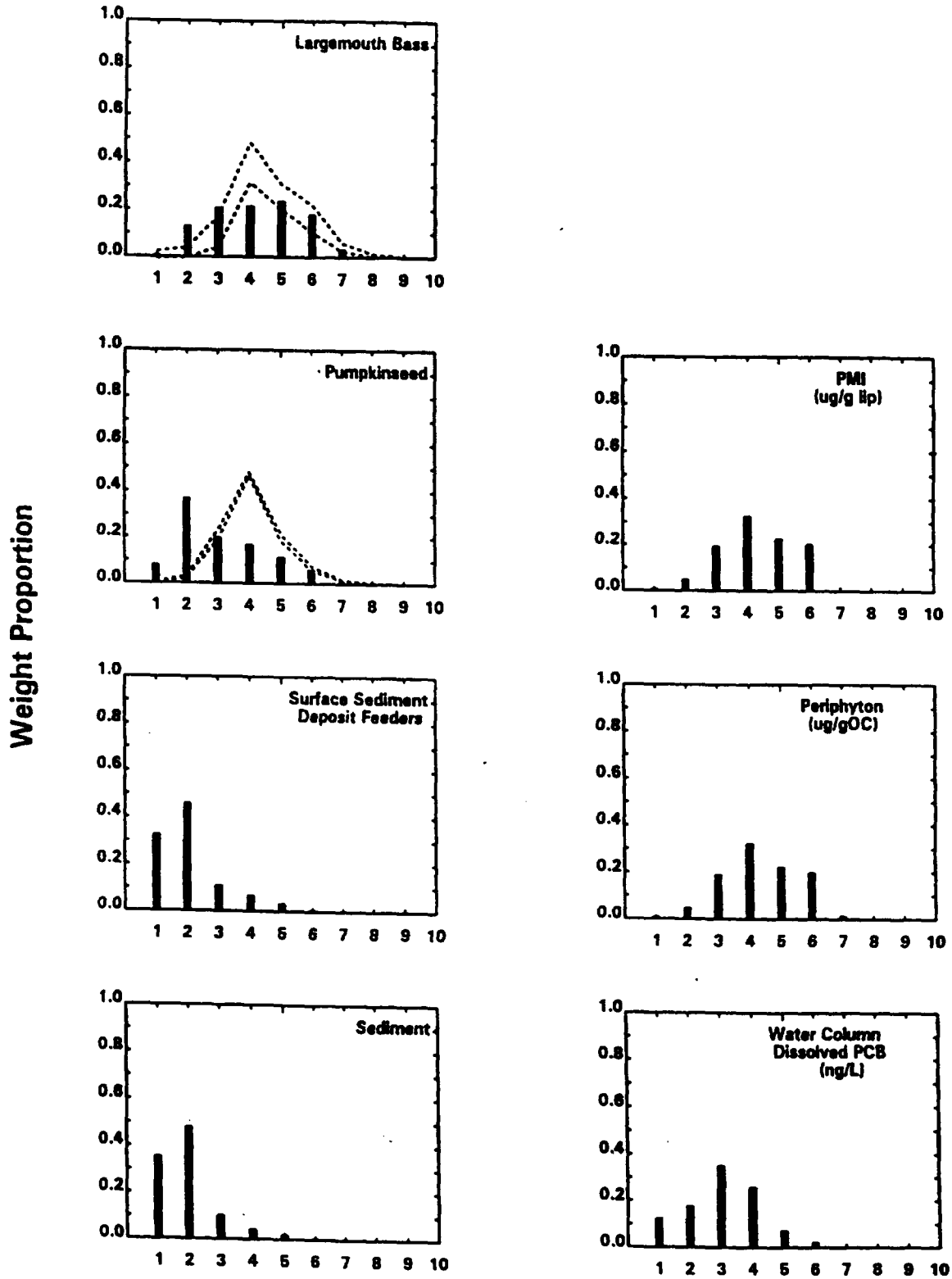


Figure 20. Steady state food web model simulation of TIP (exposure: realistic water, heavily dechlorinated sediments, see Table 6).

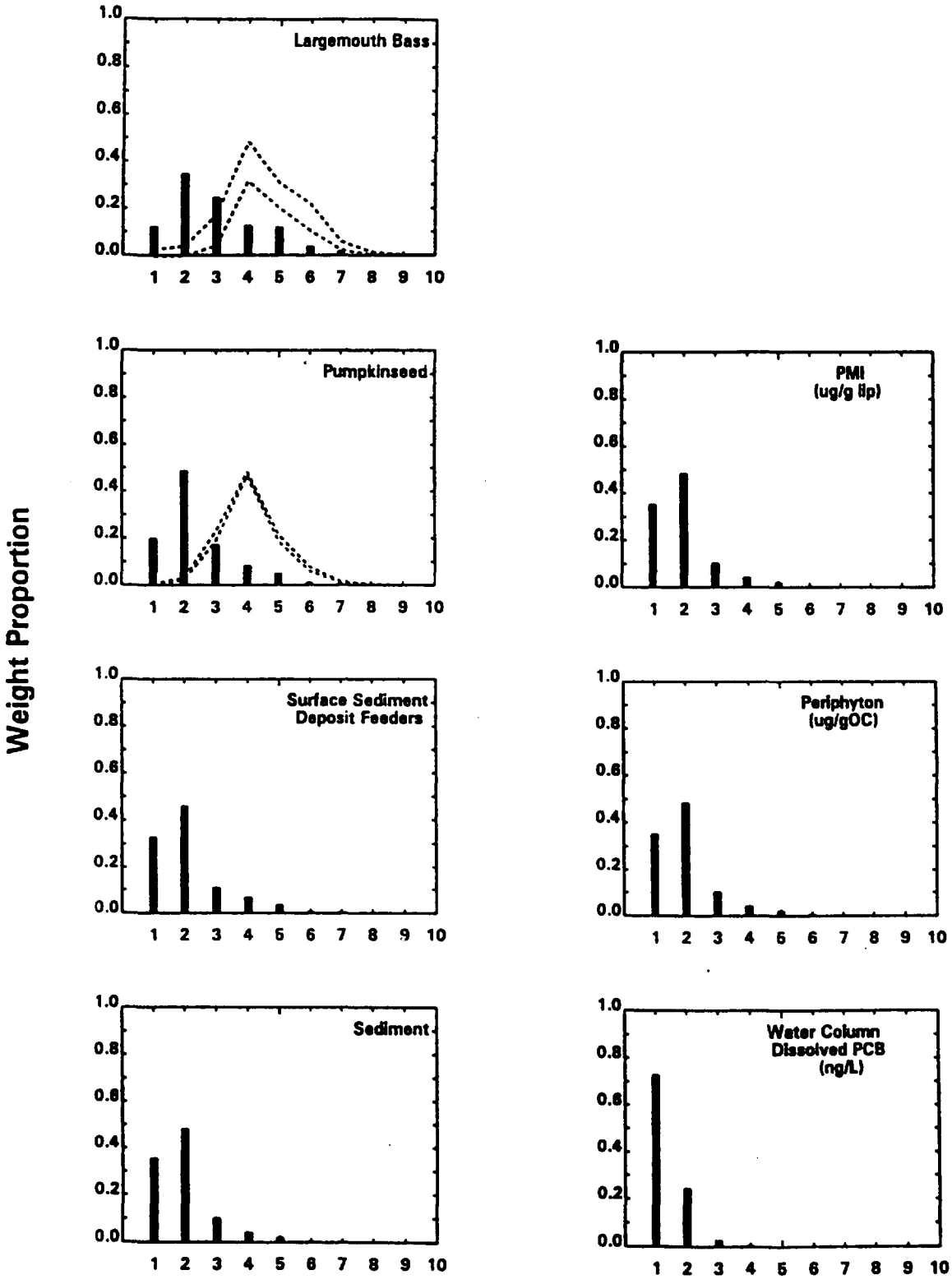


Figure 21. Steady state food web model simulation of TIP (exposure: heavily dechlorinated sediments and partitioned water, see Table 6).

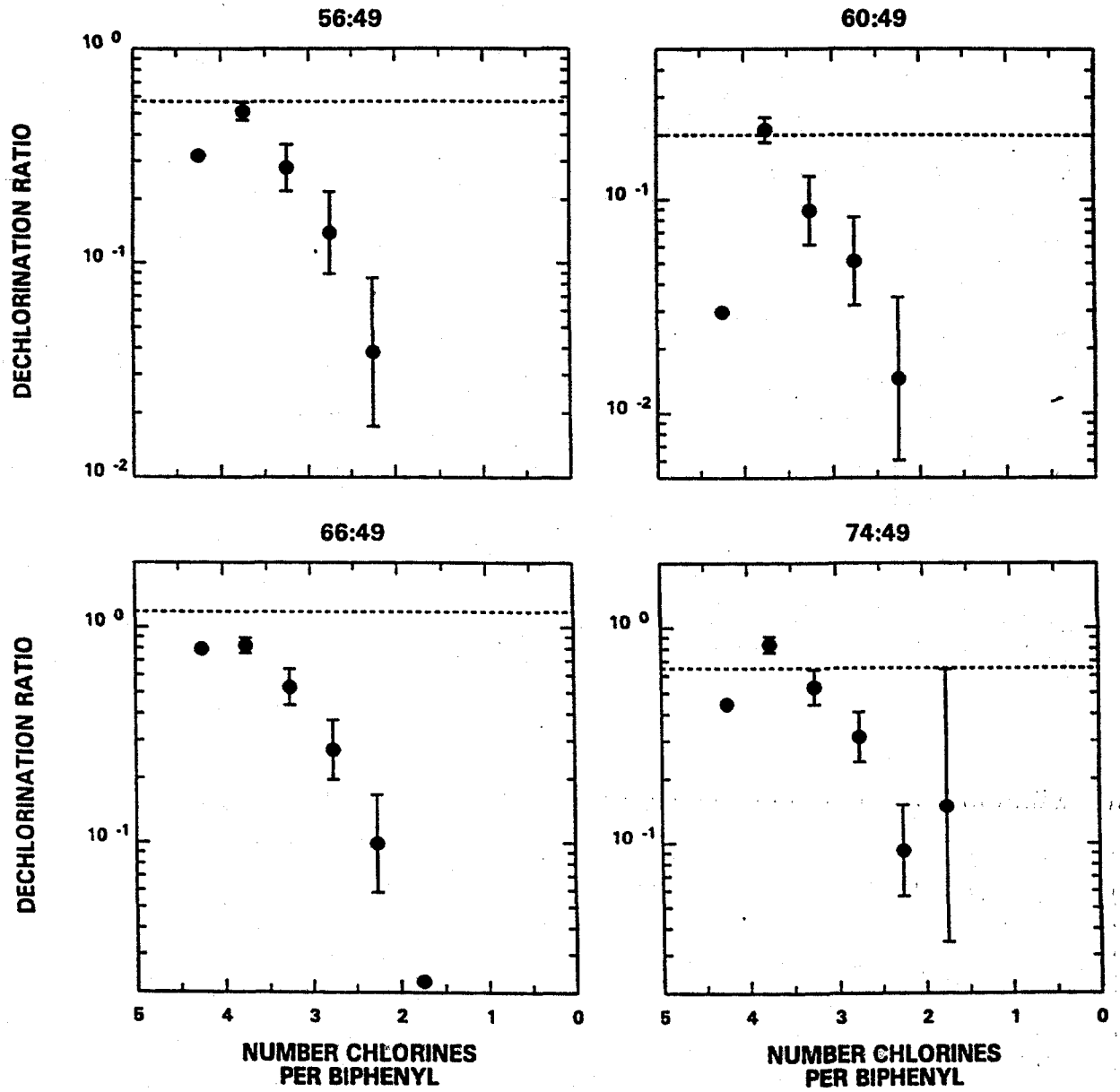


Figure 22. Relationship between PCB congener dechlorination ratios and number of chlorines per biphenyl in EPA Phase II high resolution sediment cores.

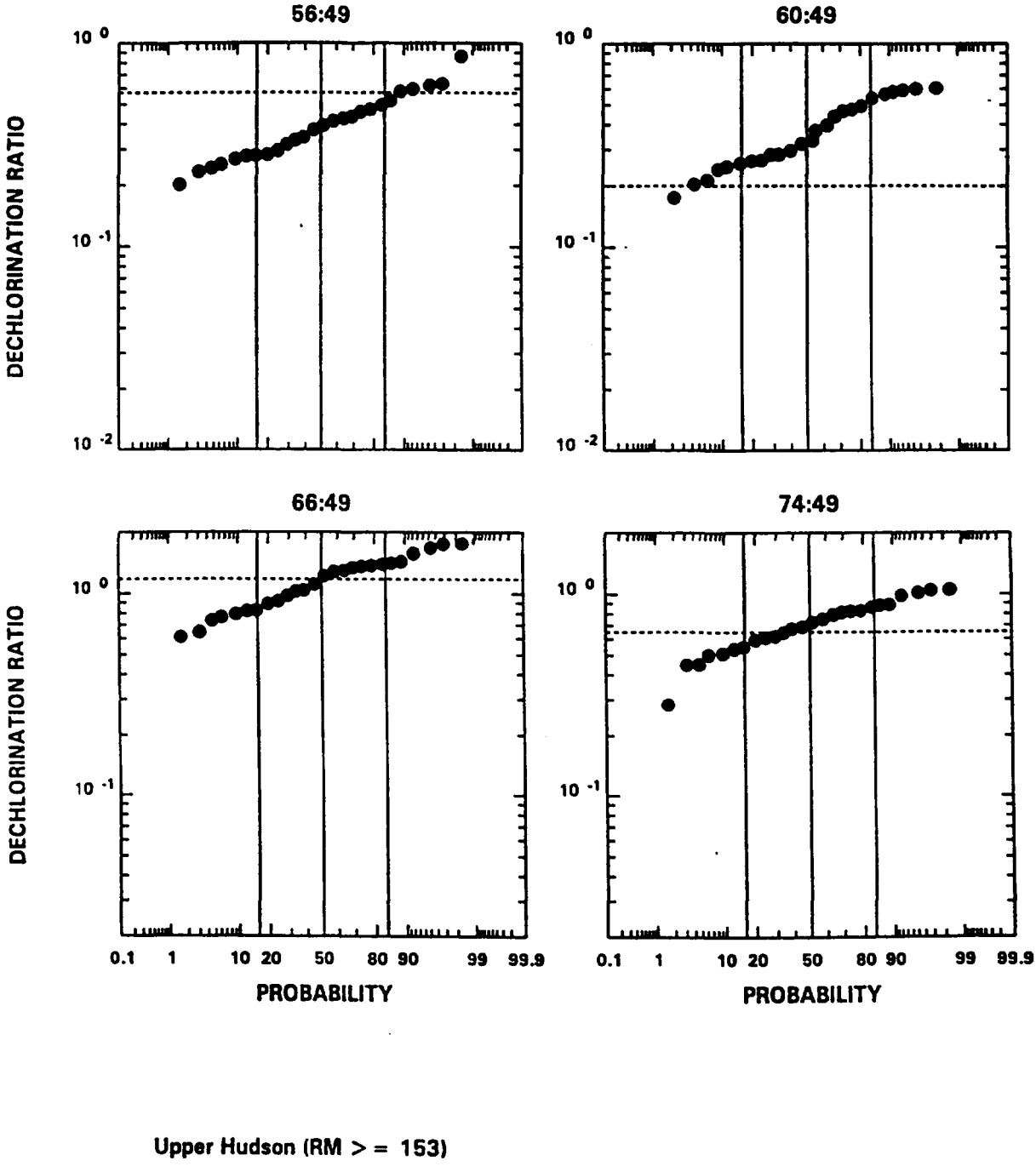
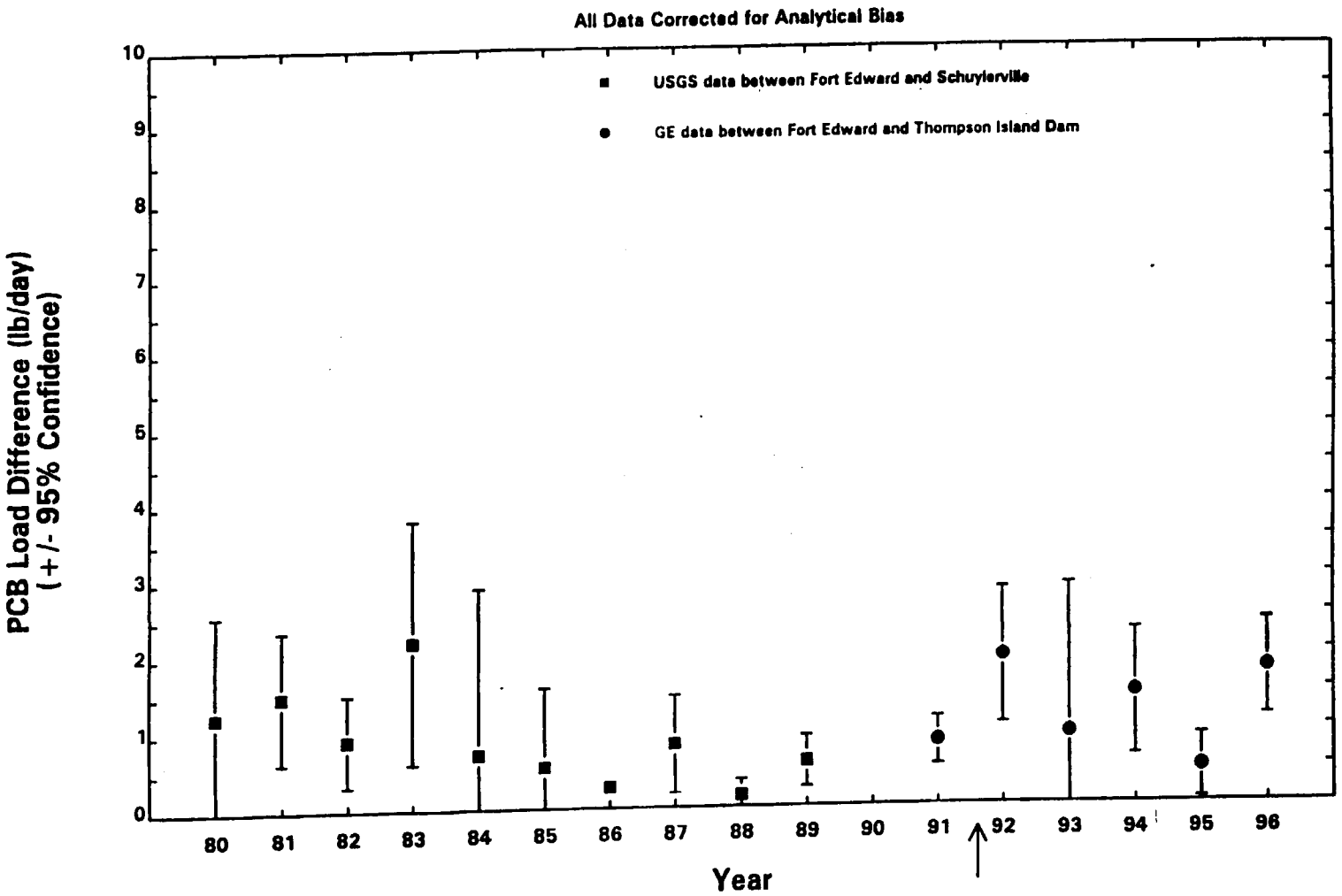


Figure 23. Probability distribution of PCB congener dechlorination ratio in 1993 NOAA fish samples.



Flow at Fort Edward < 10,000 cfs. High loads from 9/91 to 12/91 excluded

(gur nua. rage reg. oad 198 96). (( )

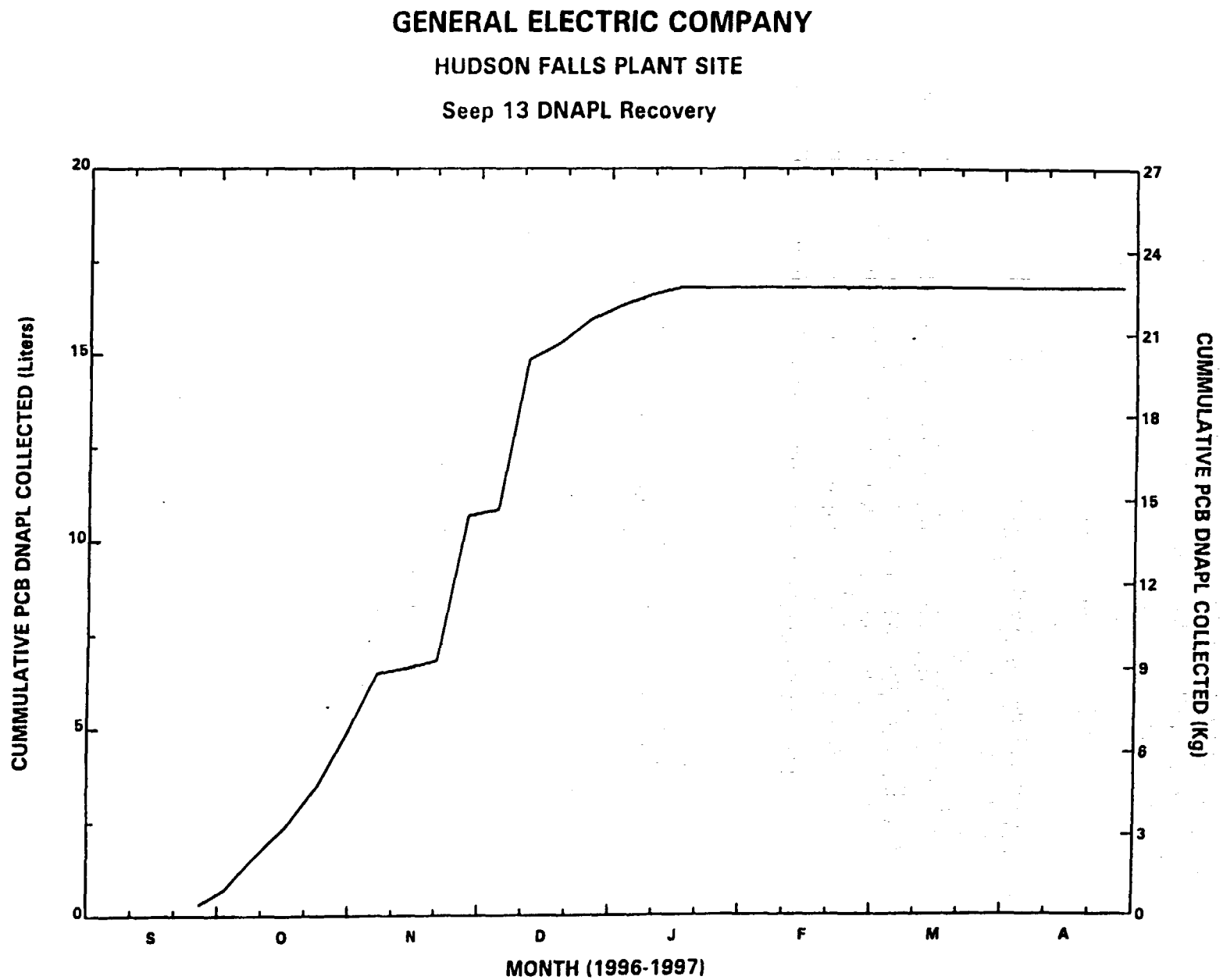
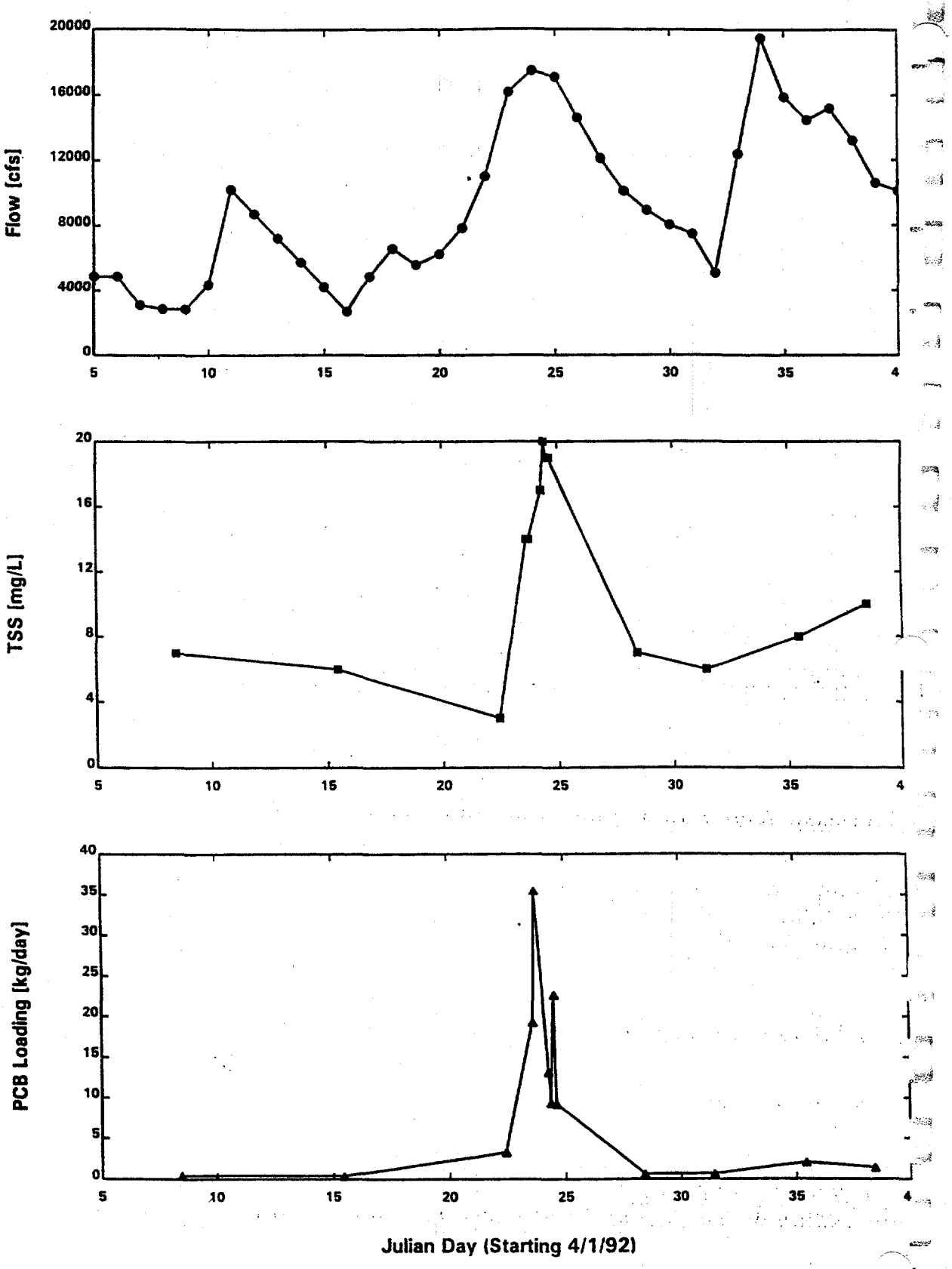


Figure 25. Cumulative PCB DNAPL oils collected from seep 13 (1996-1997).



PCB data are corrected for analytical bias

Figure 26. PCB and solids transport during 1992 spring high flow.

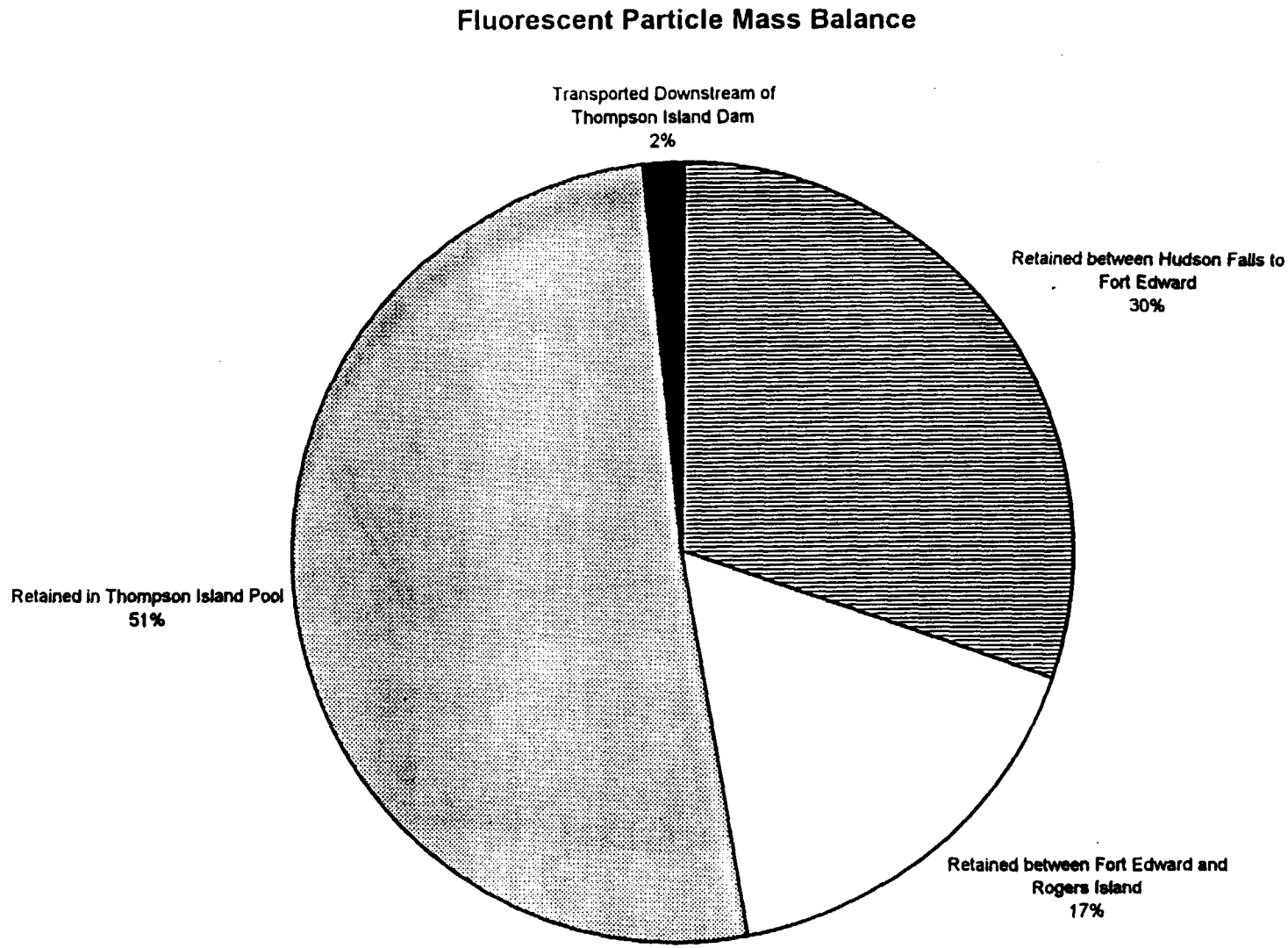


Figure 27. PCB DNAPL transport study fluorescent particle mass balance.

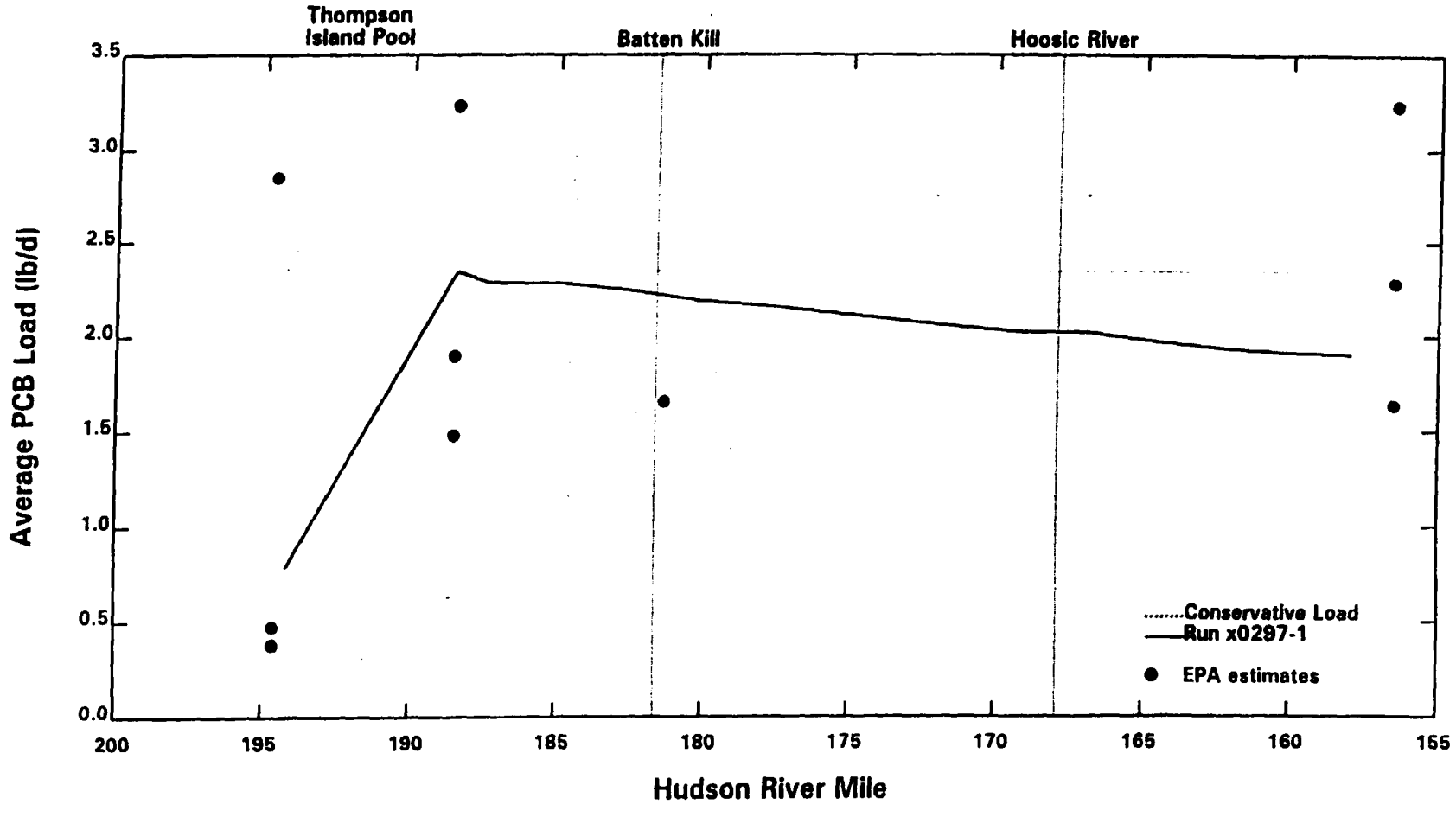


Figure 28. Predicted average June-August 1993 Hudson River PCB loading profile (river mile 195 - 155).

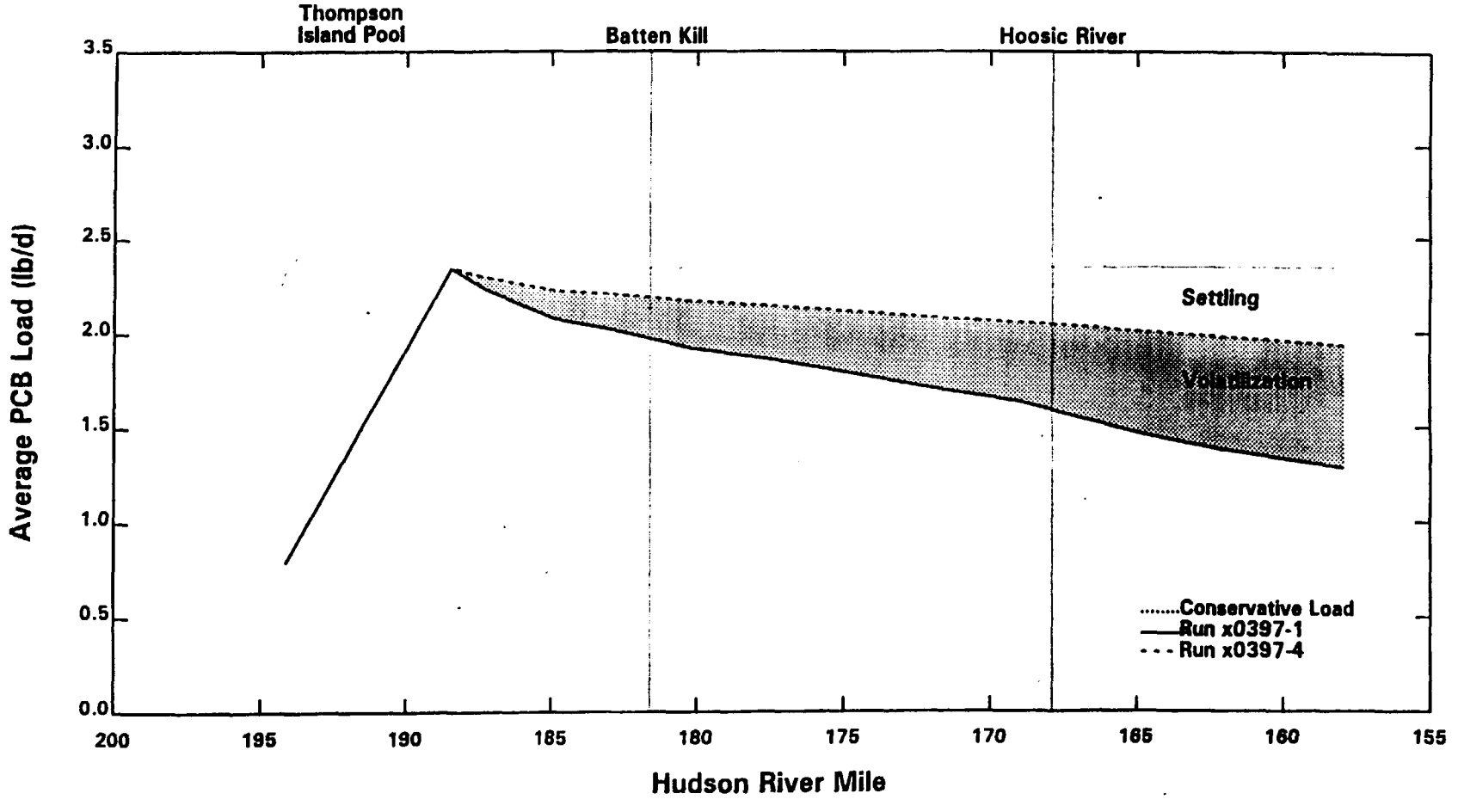


Figure 29. Predicted settling and volatilization components of average June-August 1993 Hudson River PCB loading profile (river mile 195-155).

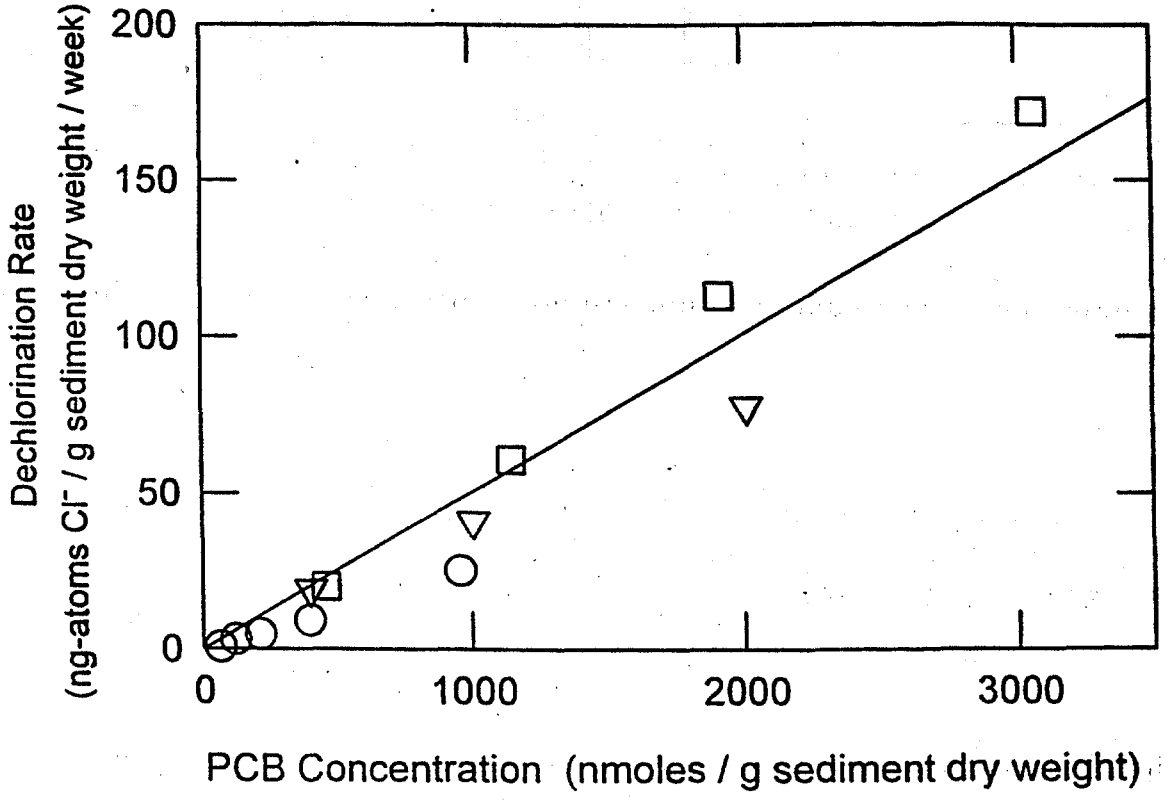
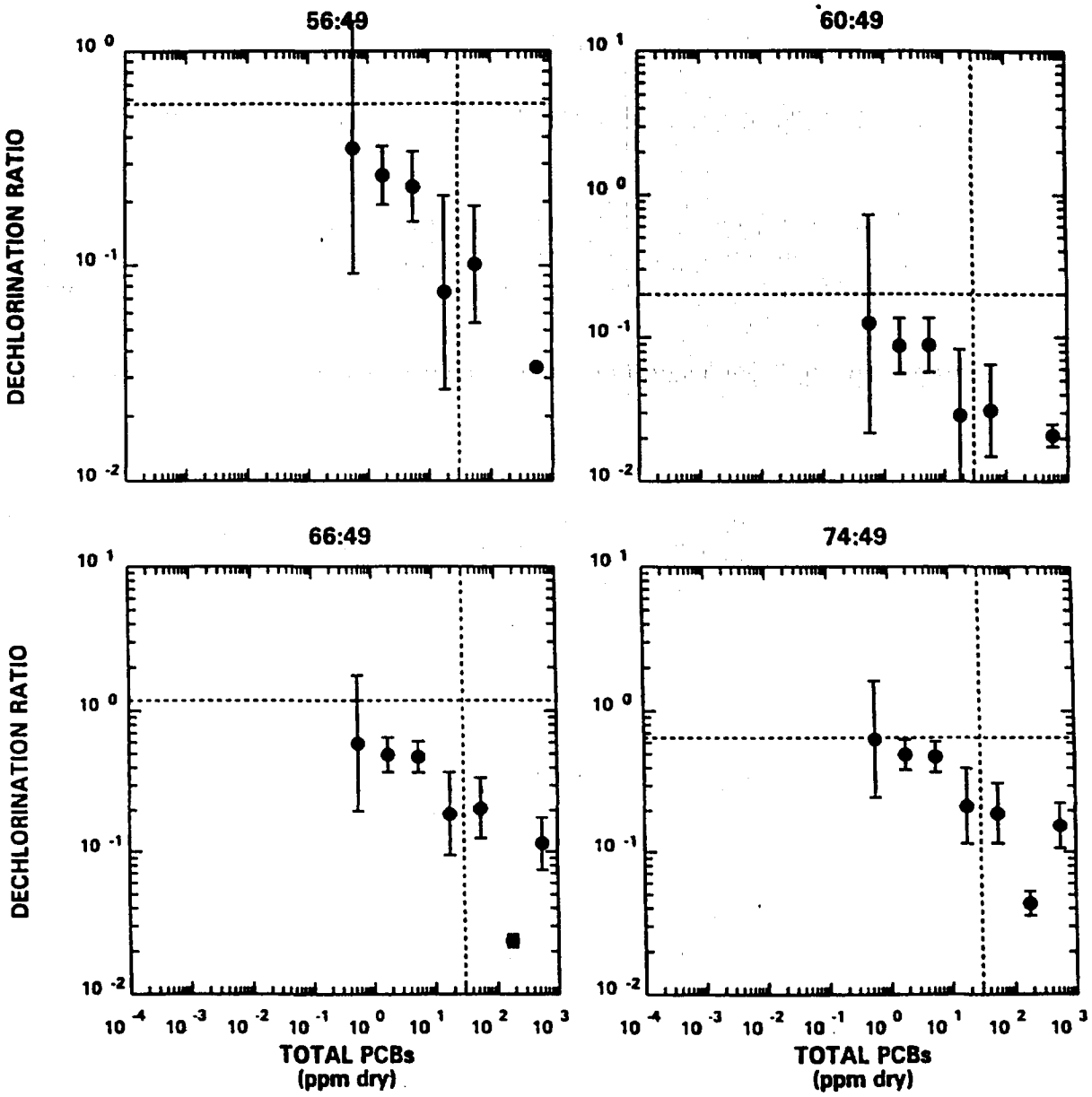


Figure 30. Absolute amount of chlorines removed from PCBs as a function of concentration.



USEPA Phase II High Resolution Sediment Core Data (UPPER HUDSON)
Data are Geometric Means +/- 2 Standard Errors (0.5 log unit bins)
Vertical Dashed Line Represents Total PCBs = 30 ppm dry
Horizontal Dashed Line Represents Ratio in Aroclor 1242

Figure 31. Intra-homologue PCB dechlorination peak ratio as a function of PCB concentration.

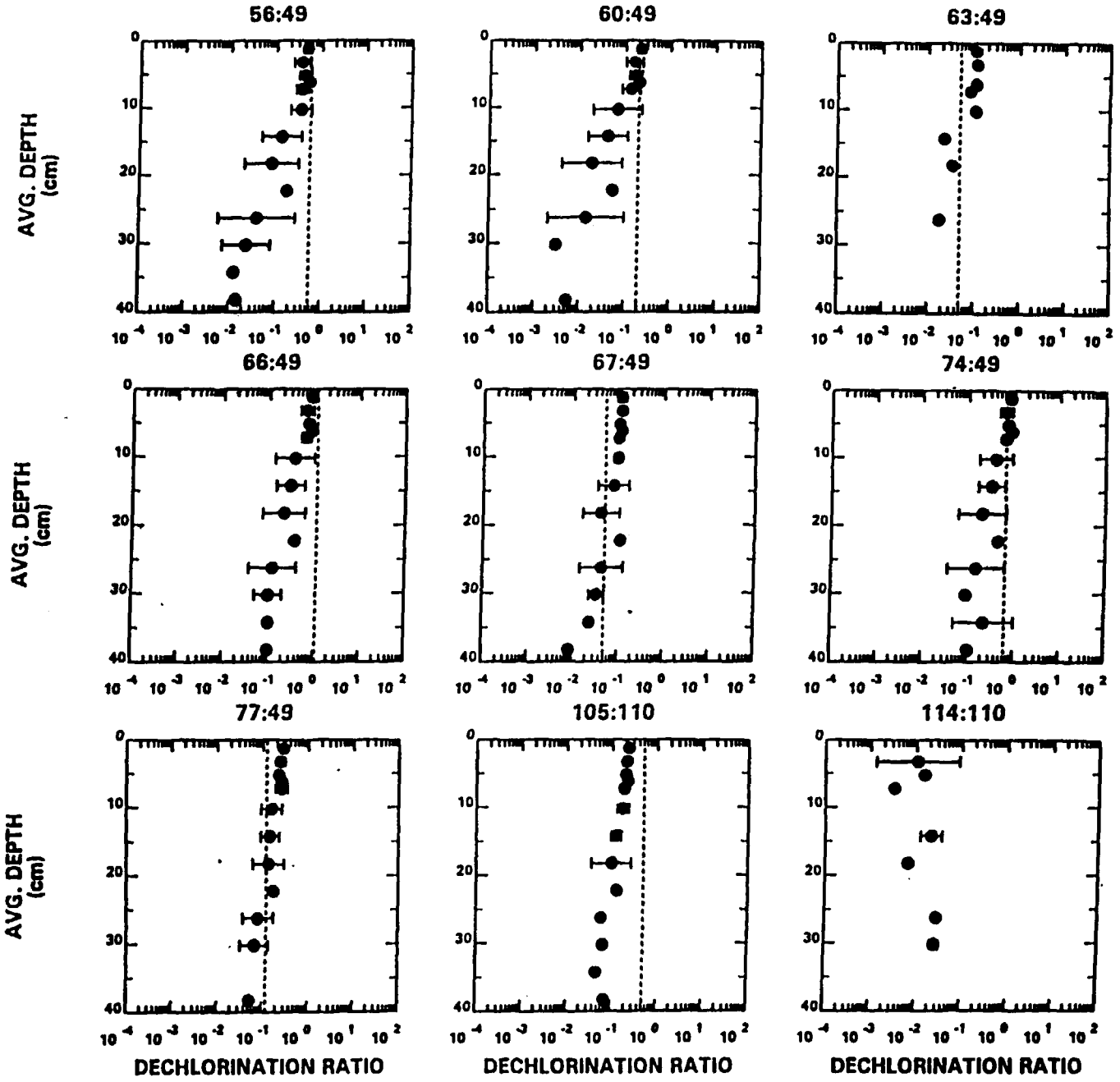


Figure 32. Intra-homologue PCB dechlorination peak ratio as a function of sediment depth for core segments with total PCB less then 30 ppm.

APPENDICES

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APPENDIX A

SUMMARY OF ANALYTICAL BIAS CORRECTIONS FOR USGS AND GE DATABASE

Corrections for analytical biases in both the USGS and GE water column databases were developed to support the data analyses presented in this document. Summaries of the rationale and data used to develop these corrections are presented below. More detailed reports documenting the development of these corrections will be presented in the future.

A. Quantification of The Analytical Bias in The USGS Data

The USGS data contains analytical biases, however, we believe that these biases can be bounded and used to "correct" the existing database. The analytical biases within the USGS database relate to the packed column methodology for PCB separation employed during the period of 1977 to 1989. This separation and quantitation method failed to resolve the mono-chlorinated biphenyls as they elute with the solvent peak on the packed column. Based upon the PCB loading patterns observed in the Hudson, this bias would tend to underestimate the PCB loading from sediment porewater, which is enriched in mono-chlorinated biphenyls.

In anticipation of these potential biases, GE analyzed a subset of the water column data collected over a five month period during 1991 by both congener methods (NEA608CAP) and

packed column USGS methods (Schroeder and Barnes, 1983). These paired data provide a means of quantifying the low bias in the USGS data.

Based upon linear regression analysis of the difference between paired USGS and capillary column PCB data and the weight percent of homologues quantified by the capillary column method, the low bias in the USGS data (Figure A-1) appears to be strongly correlated with the concentration of mono-chlorinated biphenyls in the sample (Figure A-2). Addition of dichlorinated biphenyls to the regression strengthens the correlation suggesting that a portion of the bias may also be attributable to an underquantification of the dichlorinated biphenyls (Figure A-3). Therefore, it appears that the bias associated with the USGS data is directly related to the concentration of mono-, and to a lesser extent, the dichlorinated biphenyls. Since there is no direct measure of the mono-chlorinated biphenyls in the historical USGS data, a straight linear regression between capillary column and USGS total PCB concentrations was performed to assess the analytical bias in the USGS data. This regression was performed for each sampling station due to differences observed in mono- and dichlorinated PCB concentrations at the different stations in subsequent congener PCB monitoring programs.

The results of the regression analyses for the different stations appear in Figure A-4. At the Fort Edward station, where water column samples contain only a small amount of mono- and di-chlorinated biphenyls, the low bias in the USGS methodology is estimated at 29 percent (bias determined by the slope of the relationship). Similarly, PCB measurements by USGS methodologies underestimate Schuylerville PCB concentrations by an estimated 40 percent. Stillwater and

Waterford correction factors were similar to those of Schuylerville. Biases at downstream stations are greater than those calculated for the Fort Edward station due to the higher proportion of mono-chlorinated biphenyls in samples from these downstream stations. These correction factors were applied to the USGS data for the entire period of record (1977-1995). The corrected data were then used to analyze long term spatial and temporal patterns in PCB loading in the upper Hudson River, specifically, the historical loading observed from the TIP region of the river.

B. Quantification of the Analytical Bias in NEA Peaks 5, 8, and 14

Comparison of 1993 water column PCB concentrations measured at the Fort Edward and Thompson Island Dam stations by GE with those measured in the EPA Phase II study suggested that analytical biases were present in the GE data set. Although total PCB levels and homologue distributions in the two data sets exhibited consistency in magnitude and temporal trends, examination of specific dechlorination products suggested that analytical biases are manifested in individual PCB congeners. Differences between GE and EPA data for capillary column peak 5 (PK5), which contains PCB congeners 2,2' dichlorobiphenyl (BZ4) and 2,6 dichlorobiphenyl (BZ10), are especially evident in the 1993 data from TID (Figure A-5).

Biases in individual congeners may significantly affect data analyses used in developing an understanding of PCB fate and transport mechanisms in the Thompson Island Pool (TIP). For the case of PK5, the low bias of the GE data (Figure A-5) causes the TIP loading to be underestimated.

and may significantly affect conclusions drawn from data analyses regarding the relative importance of sediment diffusive flux and dechlorination as PCB fate and transport mechanisms.

The primary cause of analytical biases in the GE data is related to the capillary column (DB-1) method used to separate PCB congeners. Coelution of congeners with differing relative response factors (RRFs) causes DB-1 results to be sensitive to the assumption made regarding their relative amounts within the given peak. Also, coeluting congeners can cause the shape of a chromatograph peak to deviate from an ideal Gaussian distribution, resulting in area calculation errors. Biases in the GE data set were also attributed to errors in the original Mullin calibration of the PCB standard used in DB-1 analyses. The weight percent of peak 5 components within the 25:18:18 mixture of Aroclors 1232, 1248, and 1262 of the Green Bay Mass Balance Study mixed Aroclor standard (US EPA, 1987) was apparently miscalculated.

Preliminary attempts to "correct" the GE database for analytical biases were focused on the revised Mullin calibration of the Green Bay Standard (Mullin, 1994). However, temporal trends in 1993 GE water column data recomputed with the revised calibration did not compare well with EPA data. Remaining differences were attributed to differences in RRFs among individual congeners within a given DB-1 peak containing coeluting congeners, as the ratio of coeluting congeners can be altered upon dechlorination or by other processes.

To further explore the coelution issue, peaks with coeluting congeners were first ranked based on their potential for analytical bias. Archived extracts from Hudson River water column

samples were then reanalyzed in the laboratory to separate out coeluting congeners from selected target peaks. Regression analyses were used to quantify single peak analytical biases by relating DB-1 measurements to congener sums.

Peaks targeted for reanalysis were ranked by a surrogate parameter chosen to reflect their contribution to PCB loadings in the TIP and the effects of coelution. For peak *I*, containing $j=1,...,n$ coeluting congeners, the potential bias index, Φ, was defined as the product of its relative range in congener RRFs and its average weight percent (*WTID*) in 1991-96 summer low flow GE water column PCBs measured at TID:

$$\Phi_x = WTID_x \left(\frac{RRF_{\Phi\Pi\acute{\epsilon}\,\epsilon\varpi} - RRF_{\Phi T\phi\epsilon\varpi}}{\sum_{\varpi\Theta}^{\Phi} \frac{RRF_{\varpi}}{n}} \right) \times 100\%$$

The DB-1 peaks with the five highest Φ's are listed in Table A-1.

Table A-1.

DB-1 PCB Peaks with the highest potential for analytical bias in the GE water column dataload. Congener RRFs obtained from Table 7-IV (Erickson, 1992).

DB-1 Peak #	IUPAC Congener #s				Congener RRFs				Relative Range in RRFs (%)	Avg TID WT%	Φ
	1st	2nd	3rd	4th	1st	2nd	3rd	4th			
5	4	10			0.037	0.262			150.03	10.15	1523
8	5	8			0.119	0.206			53.54	7.90	423
14	15	18			0.107	0.313			98.10	3.68	361
25	20	21	33	53	0.724	1.060	0.361	0.447	107.93	3.16	341
17	16	32			0.447	0.278			46.62	5.68	265
26	22	51			1.094	0.600			58.28	2.82	164

1993 water column data for the five peaks listed in Table A-1 were compared with measured values from the EPA data set and the largest biases were found to be in peaks 5 (low), 8 (high), and 14 (low). Therefore, these peaks were selected as target peaks for further analyses.

Laboratory separation of the congeners within target peaks was performed on a CP-SIL 5/C18 (C18) gas chromatograph column, manufactured by Chromopack, Inc. This column was selected primarily on its ability to resolve low molecular weight PCB congeners including those coeluting in peaks 5, 8, and 14.

Historical archived GE Hudson River water column sample extracts selected for laboratory reanalysis included recent samples (1995-1996) with total PCBs greater than 40 ng/L collected from FE, TID, and the Hudson Falls plunge pool, and historical paired samples collected from FE and TID

during the summer low flow periods of 1991-1996. The paired samples chosen for reanalysis exhibited a strong TIP loading signal (i.e., large difference in total PCBs between FE and TID). The selected data set enabled examination of the variation in single peak correction factors for different time periods and sampling locations. and for data that were expected to have significantly different PCB compositions.

Comparison of results from DB-1 analyses of archived extracts with original data indicated that the laboratory achieved good analyte recovery (i.e., storage loss was not significant). Extracts were reanalyzed on the C18 column. and linear regression analyses were performed to relate C18 congener sums with DB-1 results. Regression analyses for the three target peaks (PK5, PK8, PK14) are plotted in Figure A-6. Results from the regression plots suggest that the analytical bias in the target peaks is systematic and independent of sample time and location (i.e., correlation coefficients close to unity and small y-intercepts). Based on these results, correction factors were developed to account for analytical biases in peaks 5 (3X), 8 (0.5X), and 14 (1.5X). Regression statistics for the three target peaks are summarized in Table A-2.

Table A-2

Statistics for regression of DB-1 and C18 data.

DB-1 Peak #	Structure of PCB Congeners	Reanalyzed Extract Data			Regression Statistics				
		Number	Max Conc. [ng/L]	Min Conc. [ng/L]	Slope	y-Intercept [ng/L]	R^2	Standard y-Error [ng/L]	Significance F (P-value)
5	2,2' + 2,6	38	30.7	0.0	2.94	1.4	0.931	5.8	1.7E-22
8	2,3 + 2,4'	38	102.7	0.0	0.47	0.3	0.995	0.9	9.9E-44
14	4,4' + 2,2',5	38	83.8	0.9	1.53	-1.2	0.996	1.6	3.0E-45

The correction factors developed from regression line slopes were applied to the 1993 GE water column data set for comparison with GE data from the same period. 1993 total and target peak PCB water column concentrations are plotted in Figures A-7 and A-8 for the FE and TID sampling stations, respectively. Inspection of Figures A-7 and A-8 suggests that application of the correction factors to the GE data set dramatically improved its comparability with the EPA data. This improvement is most notable for PCB data collected at TID.

APPENDIX B

DNAPL SOURCES IN THE VICINITY OF HUDSON FALLS

Source Identification:

In September 1991, elevated river water levels of PCBs were detected by GE upstream of the contaminated sediments in the TIP. Intense investigations localized the source area to the eastern shoreline near river mile 196.8, in the vicinity of the GE Hudson Falls plant site. Access to this area was hampered due to complex site geography, the presence of a steep cliff and the Baker's Falls, a 150 year old mill (Allen Mill) in poor structural condition and several hydraulic conduits.

The results of these investigations revealed the presence of active seeps of Dense Non-Aqueous Phase Liquids (DNAPL) along the eastern cliff face and the rock face of the eastern raceway within the Allen Mill. In addition, free phase PCB oil (Aroclor 1242) and oil- contaminated sediments (up to 70,000 ppm) were found within the Mill and in the tailrace tunnel (the tailrace tunnel, a 200 foot tunnel discovered below the Mill in the fall of 1992, outlets into the plunge pool at the base of Baker's Falls).

As part of the reconstruction of the Baker's Falls dam by Adirondack Hydro Development Corporation, the eastern portion of the Falls was dewatered in the first quarter of 1996, revealing additional seeps in the river bottom.

Remediation:

A number of different remedial measures have been implemented to mitigate the seepage of PCBs from the vicinity of the plant site to the River. It is now recognized that DNAPL is present in fractured bedrock below the site. Remedial efforts are briefly summarized below: 1) DNAPL seepage from the rock face of the eastern raceway is now routinely captured; 2) hydraulic control of conduits through the Mill was achieved in 1993 to allow access and additional investigation of the Mill; 3) a slurry wall was constructed within the eastern raceway in 1994 to reduce river seeps from this region; 4) removal of DNAPL and oil-contaminated sediments from the Allen Mill containing 50 tons of PCBs was completed in 1995 (this material represents approximately twice the amount of PCBs estimated to reside in all of the TIP sediments); 5) construction of a WWTP to allow expansion of recovery efforts at the site in 1995; 6) installation of DNAPL-recovery wells in the vicinity of the plant site that have recovered >8000L of DNAPL to date; and 7) the ongoing installation of barrier wells utilizing hydraulic control to further reduce DNAPL transport through subsurface fractures. Clearly these remedial efforts have reduced the PCB loading of undechlorinated Aroclor 1242 to the Hudson River, but it is not yet possible to determine the degree of control that has been achieved.

Recent Efforts:

Additional chemical characterization of DNAPL fluids from seeps and subsurface wells has recently been undertaken to aid DNAPL control efforts at the site. Chemical characterization of these fluids by GC/MS has identified the major chemical components of the DNAPL in the bedrock at Hudson Falls to be Aroclor 1242 (PCBs), phenyl-xylyl ethane (PXE), bis-(2-ethylhexyl) phthalate

(BEHP) and trichlorobenzene (TCB). The level of PCBs in the DNAPL ranged from 12 to 100 weight percent. The other components also varied considerably. Although there was considerable variation in the composition of the DNAPL recovered from different locations at Hudson Falls, the composition of the DNAPL falls into four distinct categories.

The four categories of DNAPL recovered from 38 different locations, including wells and in-river seeps, can be defined as 1) PCBs only (primarily PCBs), 2) all components (PCBs, PXE, BEHP and TCB), 3) all components less TCB (PCBs, PXE and BEHP), and 4) low PCBs (containing less than 50% PCBs, and variable quantities of PXE, BEHP and TCB). The presence of these four categories of DNAPL suggest that there are at least four unique DNAPL reservoirs present in the vicinity of the plant site. These DNAPL reservoirs are located as follows and are shown in Figure B-1:

TABLE B-1

Chemical characterization of DNAPL reservoirs in the vicinity of the Hudson Falls Plant Site.

DNAPL composition	Location
PCBs only	Seeps 1 & 5; vertical seep control borings in tunnel; Eastern Raceway
All components	Seep 13; RW-104; angled seep control borings in tunnel
All components less TCB	RW-100 & east of RR tracks
Low PCBs	Bldg 1 & south of John St.

Note that the river seeps fall into two distinct reservoirs. Seep 13 was discovered in the fall of 1996 by divers at the base of Baker's Falls. DNAPL collected from this river seep totaled over 16 liters by early January 1997. This represented ~0.5 lbs/day of potential PCB loading to the river that was being captured since its discovery in late 1996. The location and chemical characterization of this seep was distinct from the other river seeps, suggesting additional controls would be necessary to capture this material. Recovery well RW-104 was installed to capture this material and it quickly began capturing DNAPL with the same chemical composition as that previously collected from Seep 13. Moreover, production ceased from Seep 13 in nearly the same time frame. The new recovery wells in the Eastern Raceway, installed as a portion of the barrier wells near the River's edge, may also be capturing DNAPL that is impacting Seeps 1 and 5.

These recent results suggest that targeted remedial activities at the Hudson Falls site are currently reducing the upstream source responsible for the contamination of surface sediments in the TIP. As these surface sediments represent a source of PCBs to the biota and water column from the TIP, impacting the upstream source (undechlorinated Aroclor 1242) should have a direct benefit on water and fish PCB levels. The negative impact on both of these media was observed after the Allen Mill releases in 1991-1993. We would expect correspondingly positive impacts on both media due to the recent controls implemented on the Hudson Falls plant site.

APPENDIX C

APPLICATION OF INTRA-HOMOLOGUE PEAK RATIOS TO CHARACTERIZE PCB SOURCES

ABSTRACT

The origin of the persistent PCB levels in Hudson River fish has remained controversial: primarily, we believe, for lack of chemical "fingerprinting" procedures that would permit distinguishing between alternative sources for the fishes' PCBs. Past attempts to provide such fingerprinting via descriptions of PCB congener distribution or principal components analysis have been generally unproductive; largely, it now appears, because of data confounding by variabilities in such processes as elutriation, bioaccumulation, and depuration. Since these processes impact much more heavily on inter-homologue ratios than on intra-homologue, or isomer, ratios, we have explored the use of isomer ratio data sets as information indicators of the environmental alteration state, and hence environmental pathways, taken by the fishes' PCBs. Examination of over 300 such data sets, determined for the PCBs in Hudson River fish belonging to 30 species, 21 genera, and 11 families, collected over a 200-mile stretch of the river over a 16-year period, showed that the resident fishes' isomer ratio "fingerprints" have generally corresponded to those of the local surficial sediments in all sections of the river, except as altered by metabolic processes that were found characteristic of 9 of the 21 genera studied. Since 1977, the PCBs of the fish of the Thompson Island Pool (upper Hudson River Reach 8) have exhibited surficial sediment Pattern A, indicative of recently deposited Aroclor 1242. Those of fish taken a hundred miles downstream in the mid-estuary have instead exhibited subsurficial sediment dechlorination Pattern H', indicative of PCB

compositions, such as hydraulic fluids, that had long been present in the sediments. In between, there has been a smooth transition in pattern, indicating a decrease in the extent of fish PCB dechlorination with decreasing distance from the known source of undechlorinated Aroclor 1242 input at Hudson Falls.

INTRODUCTION

The Hudson River is the major waterway draining eastern New York State (Figure C-1). Its fish have been known to be carrying elevated levels of PCBs (polychlorinated biphenyls) since 1970 (1). All industrial uses of PCBs ceased in the 1970's and the levels of PCBs in Hudson River fish have declined only slowly since the mid 1980s. Continuing controversies as to the sources of the fishes' PCBs revolve around such questions as: whether the PCBs in upper Hudson fish are coming from old local high level sediment deposits ("hot spots") or from ongoing drainage from rock fractures under a contaminated plant site; whether the PCBs in lower Hudson resident fish are coming from old deposits in the local sediments or from ongoing inputs from the upper Hudson; and whether the PCBs in lower Hudson migratory fish are coming from either of these sources, or from the sediments and sewers of the New York metropolitan area.

The commercial PCB products (e.g. Aroclors) that were released into the environment were complex mixtures of isomers (PCBs of the same Cl-Number) and homologues (PCBs of different Cl-Number), which are generically referred to as congeners. The original distributions of such congeners can be altered by biological processes in each of the environmental compartments through which the PCBs may pass, e.g., by aerobic microbial biodegradation near the sediment surface

(4,5,6); by anaerobic microbial dechlorination in subsurficial sediments (7,8,9,10); by limited microsomal metabolism in some fish species (11); and by more extensive microsomal metabolism in crustaceans, piscivores, and man (11, 12). Since each of these processes alters the PCB congener distribution in a different way, it should, in principle, be possible to identify the set of niches through which any environmental PCB has passed *via* observable alterations in congener distribution.

In practice, this has generally proved difficult, primarily because K_{ow}-dependent phenomena such as evaporation, elutriation, bioaccumulation, and depuration, as well as variations in Aroclor proportions in the original release, can produce variations in homologue distributions large enough to obscure the effects on congener distribution produced by niche-specific biological activities. It occurred to us, however, that this problem could be minimized by simply using isomer ratios rather than congener levels as indices of chemical composition. Accordingly, we undertook to determine enough PCB isomer ratios on enough types of fish samples to determine whether an isomer ratio data set could indeed provide a robust indicator of PCB source and alteration history.

MATERIALS AND METHODS

Site Description. - The lower 156 mi. (251 km) of the Hudson River, from Troy to New York City, is a tidal estuary herein referred to as the lower Hudson (see Figure C-1). The next *ca.* 80 mi. (*ca.* 125 km), i.e., the lower part of the upper Hudson, consists of a series of dammed stillwaters called "reaches," numbered in order starting from the Federal Dam at Troy. Distances along the Hudson are measured as "river miles" (RM) starting from the Battery at the southern end of

Manhattan Island (New York City). Several descriptions of the contamination of the Hudson River by PCBs have been published (13, 14, 15, 16, 17).

Fish Data Used. - The fish samples or analytical data used in this study came from collections made by seven other investigators:

1. From R.J. Sloan of the New York State Dept. of Environmental Conservation (DEC) we obtained about 800 archived analytical extracts of fish from his 1977-82 collections (2) that had been returned by his analyst after low resolution packed column analysis. We selected 75 specimens that reflected a variety of fish species, PCB levels, and Aroclor ratios and submitted them to Northeast Analytical Services of Schenectady, NY (NEA) for DB-1 capillary gas chromatographic (GC) analysis by described procedures (18). These analyses revealed that a few of the extracts, notably those of the goldfish and eels, had been allowed to dry out and lost lower congeners, but that most still exhibited homologue distributions in accord with the original "Aroclor" determinations.

2. From P.A. Jones, also of DEC, we obtained splits of the fathead minnow samples collected in his 1985 study (19) of Hudson River PCB uptake by caged minnows, which were analyzed at GE (18).

3. From J.M. O'Connor, then of New York University, we obtained the original packed column GCs of the *gammarus* collected in 1980 as a part of the NYU Hudson River Survey (20).

He also supplied us with a dozen lower Hudson striped bass, collected in 1985, that were analyzed at GE (18).

4. From B.K. Shephard, then of Harza Engineering Co., we obtained both NEA GCs and data for samples of sediments, Hester-Dendy (periphyton) plates, dialysis bags, invertebrates, and fish collected during his 1988-1998 survey of PCBs in the lower Hudson River, New York Harbor, and western Long Island Sound.

5. From J.G. Haggard of General Electric we obtained 90 frozen fish that had been collected from upper Hudson Reaches 1-11 by Law Environmental Services in 1990. These were submitted to NEA for a 118-peak DB-1 analysis (18), along with a separate analysis for congener 77, which is not well resolved from PCB 110 on DB-1.

6. From W.A. Ayling of O'Brien and Gere Engineers, Inc. of Syracuse, NY we obtained NEA chromatograms and data for fish, invertebrates, and sediment surface scrapings collected from the Thompson Island Pool in May, 1992, eight months after the major PCB loading event of September, 1991 (21).

7. From L.J. Field of NOAA, Seattle, WA, we received 145-congener dual column PCB data files for 115 fish samples that he had collected in collaboration with RJ Sloan (DEC) at ten collection stations between RM 40 and 200 on the upper and lower Hudson in the autumn of 1993.

The sediment reference samples for A, B, C, H and H' alterations were taken from individual core sections that exhibited these patterns as previously described (7-9).

Data Processing. From each PCB congener data set we calculated, if not already provided, the total PCB level, the PCB/lipid ratio, the levels of the homologue groups, the ratios between successive homologue groups, and the ratios of about 40 of the stronger single congener peaks to those of a selected isomeric reference congener, as well as site and species averages. The selected reference congener(s) were, for the tri-CB (hereinafter CB(s) = chlorobiphenyl(s)), the sum of PCBs 28 + 31 (these are normally the highest and second highest level tri-CBs, respectively; but they elute so closely on a DB-1 column that we were concerned about the reliability of the peak splitting calculation); for most tetra-CBs, PCB 49 (which maintains a relatively constant level during the early stages of dechlorination); for the tetra-CB PCB 70, which is readily metabolized by the AP-ICT activity, the non-metabolized PCB 74 (which is also more similar in K_{ow} to PCB 70 than PCB 49); for most penta-CBs, the rather slowly dechlorinated PCB 110, with PCB 99 as a non-metabolizeable alternate; and for the hexa-CBs, PCB 153.

Adjustment for Reference Congener Depuration - We noted that the ratio between isomers 74 and 49, which differ somewhat in water solubility, became elevated in individual fish that were heavily depurated, as indicated by low levels of di- and tri-CB's. In such fish the elevation in log (PCB 74/PCB 49) averaged about 0.2 times that in log (tetra-CB/tri-CB). Accordingly, a possible depuration adjustment to the 74/49 ratio was calculated on that basis.

RESULTS

Table C-1 lists the fish species examined, abbreviations used, and metabolic alteration patterns observed. Table C-2 presents the mean values of the upper and lower Hudson River fish PCB homologue levels and selected PCB isomer ratios for the 1977-78, 1990, 1992, and 1993 fish collections, along with reference values for a 90:10 Aroclor 1242:1254 mix and Hudson River sediments exhibiting alteration patterns A, B, C, H, and H'. The variability of all tetra-CB and some penta-CB homologue levels, and the upper Hudson PCB isomer ratios involving penta- and hexa-CBs was low (5 - 20% Relative Standard Deviation (RSD)). Tri- and hexa-CB homologue levels, and the other isomer ratios involving tetra-, penta-, or hexa-CBs displayed somewhat greater variability (20 - 40% RSD). Generally, however, the % RSD's were only about half as great for the isomer ratios as for the homologue levels. Much of this remaining variance in the Table C-2 isomer ratio data, which arose from measurements of the PCBs in many different species of fish, taken over large geographical ranges, could be correlated with specific variables. These will be considered in turn.

Variations arising from PCB depuration. - Some of the individual fish collected from the upper Hudson in November, 1990 showed levels of tri-CBs that were reduced to as little as 10% of their usual values, and displayed even greater reductions in di-CBs. Such reductions in lower homologue levels occurred most frequently in walley (WAL), smallmouth bass (SWM), and largemouth bass (LMB), and significantly influenced the average lower homologue levels reported for 1990, since SMB had been selected as the species to be measured in triplicate in every reach of the upper Hudson. The depurative losses could have resulted from either a late-season cessation of

feeding, or from periods of feeding in uncontaminated tributary streams. These losses were much less prominent in the 1977-1978, 1992, and 1993 collections. However, the observation of the effects they might have on the PCB 74/49 isomer ratio prompted the inclusion of a possible 74/49 ratio adjustment for depuration in Table C-2.

Variations arising from atypical Aroclor inputs. Occasional fish in most collections exhibited congener profiles clearly divergent from the majority. Thus, most of the very lightly contaminated (<1ppm) fish taken from above Glens Falls showed only the broad homologue distribution pattern and DDE content characteristic of atmospheric deposition, as did also the local sediments, those of the Mohawk River, and those of some mountaintop peat from the summit of Mt. Algonquin (elev. 5114') in the Adirondacks. However, two (out of 17) of the 1993 NOAA fish collected in this area exhibited patterns resembling Aroclor 1242, one showed the pattern of Aroclor 1268, and one 1990 fish showed Aroclor 1260; all probably reflecting exposure to local areas of low level contamination with these Aroclors. One of the 1990 Reach 8 LMB showed the low total PCB level and broad homologue distribution of the upstream region, indicating recent translocation. Both the 3 - 4 year age group of the 1982 Albany pumpkinseed (PKS) and the 1980 NYU *gammarus* collections from several lower Hudson stations showed substantial levels of Aroclor 1260, indicating the occurrence of a significant, but short-lived, Aroclor 1260 contamination event around 1980.

Of more general significance, the homologue distributions in Table C-2 showed that there were higher levels of penta-, hexa-, and hepta-CBs in the lower Hudson than in the upper section, and also higher ratios of hexa- and hepta- to penta-CBs, which would not have been effected by

elutriative, evaporative, or depurative losses of lower congeners. Evidently, the original source of the lower Hudson River fish PCBs had been an Aroclor mix containing higher proportions of more heavily chlorinated Aroclors than that contaminating the upper Hudson.

Variations correlatable with fish species or genus. The PCBs in certain of the fish species showed consistent depletions of particular groups of congeners, thus defining an alteration pattern (AP), presumably arising from a species-specific PCB metabolizing activity (Table C-1). The commonest, Pattern AP-ICT (for *Ictalurus*, the first genus in which noted) was previously designed "P450-1A-like" (11); however, that term now seems better restricted to the somewhat different pattern seen in higher animals (12). AP-ICT shows a marked reduction in PCB 70 (and hence the 70/74 ratio) and lesser reductions in PCBs 16, 17, 18, 22, 27, 33, 40, 49, 56, 91, 97, and possibly 101, 110, and 174; all of them congeners with adjacent unsubstituted 4-positions. By contrast, AP-PET (for *Petromyzon*) showed reduced levels of the 4,4'-substituted PCBs 28, 74, 118, 105, 128, 167, and 156, and also of PCBs 49, 52, and 174, leaving the peak given by the coeluting pair, PCBs 64 + 71, as the strongest in the chromatogram. Pattern AP-ESX (for *Esox* where it appeared occasionally) showed clear reductions in every resolved congener carrying a 2, 3-dichlorophenyl group, i.e., PCBs 22, 40, 42, 44, 56, 82, 84, 97, and 129. Pattern AP-LEP (for *Lepomis*) showed clear reductions in just two of the above, namely, PCBs 40 and 44. Finally in AP-CAT (for *Catostomus*) the only clear reduction was in congener 52. Thus, the only observed fish alteration patterns that would affect a PCB 74/49 isomer ratio were AP-ICT and AP-PET.

A very different set of variations was observed in the anadromous (migratory) fish of the lower Hudson River. The STB (for Striped Bass) and AMS (for American Shad) all showed substantial levels of DDE, sometimes accompanied by DDD or DDT; *trans*-nonachlor, sometimes accompanied by α- and γ-chlordane; and other pesticides as well, generally producing enough interfering peaks in the tri- through hexa-CB range to make calculation of isomer ratios from GC-ECD data problematical. The observed pesticide/PCB ratios generally corresponded to those seen in the sediments of the New York metropolitan area, including western Long Island Sound, which is where these species overwinter. Conversely, the two Atlantic tomcod (ATT) examined, both collected at RM 41 in January, 1978, showed only low levels of Aroclor 1242-like PCB contamination, without any pesticides, not even the low level of DDE present in the lower Hudson.

Variations due to biodegradation/dechlorination state. Congener distributions in Hudson River subsurface PCB dechlorination Patterns B and C (7,8,10) and H and H′ (9,10) have been previously described. Generally speaking, Pattern C dechlorination, which gives the most extensive conversion to mono- and di-CBs, is seen in the most heavily contaminated sediments of the upper Hudson; Patterns B and B′ are seen in somewhat less heavily contaminated sediments as far downstream as Albany; and the rather selective Patterns H and H′ are uncommon in the upper Hudson, but dominant in most of the more lightly contaminated lower Hudson (9). Bedard has argued that these patterns may all result from the dechlorination activities of just three microbial strains, all separable in anaerobic laboratory cultures, designated M, Q, and H or H′ (10), with most dechlorination of the higher congeners coming from the H/H′ activity. This could explain why the patterns of higher congener loss are essentially identical for the observed alterative patterns B, C,

H, and H', even though the distributions of the more lightly chlorinated PCB congeners formed are quite different.

The columns on the left side of Table C-2 present the homologue distributions and selected PCB isomer ratios for some representative specimens of subsurface sediment PCBs exhibiting those patterns, along with comparable data for a 90:10 Aroclor 1242:1254 mix, selected as a representative example of an unaltered Aroclor release. The marked compositional changes effected by anaerobic dechlorination are evident.

Geographical variations in dechlorination state. Surficial PCB alteration Pattern A was noted as far back as 1984 (7), but was not seen free from admixed Pattern B until recently. It has now been observed in the 0-1 cm. sediment layers and "fluff" layers collected in the Thompson Island Pool at the same time as the 1992 fish sampling, and repeatedly reproduced in the upper (0-5mm.), presumably microaerobic, sediment layers in laboratory microcosms where upper Hudson sediments were spiked with fresh Aroclor 1242 (21). The Pattern A alteration appeared in the microcosms within six weeks. Its microbiological basis is uncertain; one speculation is that it arises from a combination of an oxygen-tolerant, *meta*-selective dechlorination process followed by an aerobic biodegradation of the most of the dechlorination products. In sediments, it appears to effect limited removal of PCBs 17, 18, 33, 97, 99, 101, 153, and 167 without attacking 40, 44, 56, 60, 66, 70, 74, 87, 105, 114, or 128, and to result in increases in 47, but not in 19 or 27. Its most sensitive indicator is a depression in the ratio 33/28+31, or if separately measurable, just 33/28. Such depressions,

usually paralleled by increases in the 47/49 ratio, are almost universally observed in PCBs recovered from aquatic environments.

Table C-2 shows that in general the isomer ratios observed in upper Hudson fish fell between the values for fresh Aroclor and Pattern A altered PCB, with no obvious contribution from the subsurface Pattern B and C PCBs, with their high levels of dechlorination product PCBs 19 and 27, and low levels of readily dechlorinated PCBs 74, 87, 97, and 105. By contrast, the Table C-2 data for isomer ratios in lower Hudson River fish generally fell between the values for dechlorination patterns H and H', indicating as much dechlorination as in the local sediments.

The 1993 NOAA analyses by a dual column procedure permitted resolution of a number of congeners that were less readily quantified by the NEA single column analyses. Table 3 presents mean isomer ratios, calculated from the NOAA data, for 17 PCB isomers known (9) to be sensitive to Pattern H/H' dechlorination at various stations between the Thompson Island Pool (RM ~192) and Iona (RM 40). The levels of all of the dechlorination-sensitive congeners were found to decrease with distance downstream: most rapidly in the case of the toxic coplanar PCB 77; quite slowly for congeners 118 or 138; and with the major mono-*ortho* tetra-CBs 56, 60, 66, 74, and penta-CB 105 in between.

The 1993 EPA water and sediment analyses by the same procedure, as presented graphically in Figs. 3-73 to 3-80 of a recent report (17), were noted to show the same changes for congeners 56, 60, 66, 70, and 74. Their levels in upper Hudson water at RM 177.8 were similar to those in

undechlorinated Aroclor 1242, while those in lower Hudson Pattern H/H' - dechlorinated sediments at RM 143.5, 88.5 or 43.2 were only half as great.

Figure C-2 shows the trend for unadjusted 74/49 ratios not only for the 1993 NOAA fish, but also for the 1990 and 1992 fish collections, the 1985 caged minnow study, and the 1989 *gammarus*, periphyton, and dialysis bags. In all cases there appeared a smooth transition between values characteristic of the Pattern A sediment surface of the Thompson Island Pool and the Pattern H/H' dechlorinated sediments and water of the lower Hudson.

DISCUSSION

Utility of isomer ratio analysis. The above results show that PCB isomer ratio analysis can be used to identify and quantify the niche-specific biological alteration processes to which an environmental PCB release may be subjected. These processes include the ubiquitous but enigmatic, possibly microaerophilic, microbial alteration process A at the sediment surface; the well-characterized subsurficial anaerobic microbial dechlorination processes leading to alteration patterns B, C, H or H'; the genus-dependent fish PCB alteration processes leading to the patterns AP-ICT, AP-PET, AP-CAT, AP-ESX, and AP-LEP described above; and the microsomal P4502B-like alteration process exhibited by many crustaceans (which are frequently prey of the fish examined here) as well as by higher vertebrates (12). Characterization of such processes can be useful in defining the set of environmental niches through which a PCB composition has passed on its way from point of release to accumulation in a fish.

One complication of isomer ratio analysis is interferences between the effects of different processes, especially as they effect the reference congeners used. For example, reference tri-CB 31, reference tetra-CB 49, and possibly penta-CB 110 are all potentially subject to metabolism by the AP-ICT system, and the first two of these also to losses under conditions of heavy depuration. We have presented here a procedure for correcting the 74/49 ratio for such losses of PCB 49 as a possible adjustment. An alternative would be to simply avoid the use of heavily depurated individuals, or of lampreys, eels, icterids or goldfish, in making quantitative determinations of local PCB alteration state *via* isomer ratio analysis.

Previously, the most popular approach to handling environmental PCB congener distribution data has been by principal components analysis. This defines PCB composition in terms of two or three enigmatic "principal components." These may permit the grouping of samples into related sets, but do little to explain the chemical nature of the differences. It is now evident why this happens: there are simply many more significant alteration processes affecting PCB composition than there are mathematically resolvable "components," so that the resolved "components" inevitably represent combinations of the effects of multiple alteration processes in various proportions.

Sources of the PCBs in Hudson River fish. The PCB (and pesticide) "fingerprinting" provided by isomer ratio analysis, along with data from other environmental studies, shows that the PCBs in Hudson River fish originate from four readily distinguished sources.

The first, and least important of these, is atmospheric deposition. This PCB source is characterized by homologue and pesticide distributions that are very different from those of the other sources. and is responsible for the low level PCB (and DDE) contamination seen in the fish and sediments of the upper reaches of the Hudson, the Mohawk River, and presumably other tributaries as well.

The second identifiable source consists of the sewers and sediments of the New York Metropolitan area, which is where two important anadromous fish of the lower Hudson, the striped bass (STB) and the American shad (AMS) spend the winter before migrating upriver to spawn. These sediments are known to contain substantial levels of DDT-derived, chlordane-derived, and other pesticide residues (13), as well as PCB mixtures reflecting heavy contributions from Aroclors 1254 and 1260, which were particularly extensively used in railroad and substation transformers in that area. The 1978, 1982, and 1985 STB and AMS in our collection generally showed PCB homologue distribution and pesticide/PCB ratios comparable to those of the sediments of New York Harbor and western Long Island Sound, indicating the significance of those sources.

The third distinguishable source consists of the moderately Pattern H/H'-dechlorinated PCBs of the sediments of the lower Hudson, which exhibit an isomer ratio "fingerprint" closely matching that of the lower Hudson resident fish. These PCBs have been there a long time. Radionuclide dating has shown that most were deposited in the 1950's and 1960's (14) and elevated levels in fish were seen in 1970 and 1973 (1), all before the removal of the Ft. Edward dam and sediment scouring/redeposition events of 1974-76 caused the heavy PCB contamination of the upper Hudson

(16). One original source is the formerly extensive industrial usage of PCB-based hydraulic systems in many of the riverside communities. Available Monsanto sales records for 1957-1977 document purchases by such users of over 3 x 10^6 lbs. of PCB products, especially the hydraulic fluid Pydraul A-200, an Aroclor 1242-1248 blend. Releases of such compositions into the river would result in the moderate elevations in higher homologue levels exhibited by lower Hudson sediments and fish (Table C-2). A less plausible source would be inputs of dissolved PCBs eluted from upstream deposits, since these are depleted, rather than enriched, in the higher homologues (17), and substantially undechlorinated, as noted above.

The fourth fingerprintable source of the 1977-1993 Hudson River fish PCBs consists of Aroclor 1242-like compositions that have been on the surface of the sediments of the Thompson Island pool only long enough to have undergone a limited Pattern A alteration, thus indicating a continuing deposition. The ultimate source of this PCB input may be Aroclor 1242 seeping from the fractured bedrock near the former capacitor manufacturing plant at Hudson Falls. Seepage from this reservoir is now known to have been entering the River as droplets of undechlorinated oil-phase Aroclor 1242 that contaminate surface sediments of the Thompson Island Pool. There, the PCBs soon undergo Pattern A alteration and partial extraction into the water column and its biota, leading to the appearance of undechlorinated Pattern A PCBs in the fish. Eventually, of course, ongoing sedimentation covers each increment of PCB and allows anaerobic microbial dechlorination to the Pattern B- or C-dechlorinated PCBs of the local subsurface accumulations.

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APPENDIX D

BENEFITS OF PCB DECHLORINATION

Reduced Toxicity. The toxic effects produced by PCBs in inbred strains of laboratory rodents, and possibly in a few wildlife species, are now generally recognized to be mediated by binding to a particular cytoplasmic protein, called the Ah-receptor (AhR), which has the ability to induce expression of cytochrome P450 isozymes 1A1, 1A2 and 1B1, and several Phase 2 drug-metabolizing enzymes as well. The magnitude of this AhR-agonist activity is most commonly determined by measuring the ability of a PCB congener (or other toxicant of concern) to induce the expression of cytochrome P4501A1 in a test animal or cell culture, as indicated by ethoxyresorufin-O-deethylase (EROD) activity, and generally reported as "toxic equivalency," e.g., the ratio of the EROD activity exhibited by the test congener to that exhibited by dioxin, which is the strongest known AhR agonist. Using this test, and direct measures of toxic response, the particular PCB congeners that are the most active of Ah-receptor agonists have been found to be those lacking *ortho* substituents, such as the "coplanar" congeners having substitution patters 34-34, 345-34, and 345-345 (Safe, 1992). Several "near coplanar" analogs of these congeners, i.e., mono-*ortho* substituted analogs such as 234-34, 245-34, and 2345-34, may also have some AhR-agonist activity [Safe, 1992], but this is much weaker than that of the coplanar congeners in rodents, and often undetectable in other species.

The particular types of PCB dechlorination activities present in the subsurface "hot spots" of the upper Hudson have been found to result in dramatic reductions in the levels of the toxic

coplanar and near coplanar congeners (Quensen *et al.* 1992a; Quensen *et al.* 1992b). The net effect of these reductions, as measured by the EROD activity of the dechlorinated mixture, was a 97% loss of toxic equivalency. In general, the percent toxicity decrease was much greater than the percent decrease in *meta* and *para* chlorine level. It has also recently been shown that microbial dechlorination markedly reduced or eliminated the adverse effects observed with Aroclor 1242 on mouse gamete fertilization (Mousa *et al.*, 1996). The reductions in concentrations of coplanar PCB congeners in environmental samples due to microbial anaerobic dechlorination has now been documented in several sediments, including the Hudson River, Sheboygan River, Waukegan Harbor, and Lake Ketelmeer (reviewed in Bedard and Quensen, 1995).

In the case of the lower Hudson River fish PCBs, Table C-3 of Appendix C shows that the relative levels of the one coplanar congener measured (PCB 77; 34-34 CB) were only 10-20% of those in the PCBs of Thompson Island Pool fish, and those of several "near coplanar" congeners between 10 and 35% of such values, indicating a >80% overall loss of toxic equivalency, despite the very modest level of dechlorination in the local sediments.

Reduced Carcinogenicity. Currently, the EPA employs a default assumption, that any positive finding in a high dose rodent bioassay implies a proportionate human cancer risk. In the most recent statement of application of this policy to PCB risk assessment (USEPA, 1996) the Agency recognizes that Aroclors 1016, 1242, and the higher Aroclors 1254/1260 can differ considerably in their calculated carcinogenic potency, with upper-bound cancer slope factor (CSF) values of 0.07, 0.4, and 2.0 per mg/kg-day, respectively. However, the Aroclor 1242 CSF value of

0.4 is applicable only for Aroclor 1242 uptake by inhalation. For sediments or fish contaminated by Aroclor 1242, EPA uses the CSF value (2.0) as it would if they were contaminated with Aroclor 1254 or 1260. Likewise, the guidance document recognizes that the CSF may be sharply increased, and in proportion to toxic equivalency, by the presence of coplanar or near coplanar congeners with AhR-agonist activity, but does not allow for a reduction in the CSF when the levels of toxic congeners have been reduced. Thus, although the current guidelines permit the risk assessor to ignore the beneficial effects of PCB dechlorination upon presumed cancer risk, they also clearly indicate the presumed cancer risk is dependent upon both the overall degree of PCB chlorination (which may be moderately reduced by dechlorination) and the content of toxic congeners (which is sharply reduced by dechlorination, as indicated above).

Reduced Exposure via Aerobic Degradation. The aerobic bacterial biodegradation of PCBs is widely known and has been well studied (Abramowicz 1990; Bedard, 1990; Alder, 1993; Bedard and Quensen, 1995; Furukawa, 1986). Numerous microorganisms have been isolated that can aerobically degrade a wide variety of PCBs, although the more lightly chlorinated congeners are preferentially degraded. These organisms attack PCBs via the well known 2,3-dioxygenase pathway, converting PCB congeners to their corresponding chlorobenzoic acids. These chlorobenzoic acids can then be readily degraded by indigenous bacteria, resulting in the production of carbon dioxide, water, chloride, and biomass. (Harkness, 1993).

The ability of native microbes to aerobically metabolize PCBs has been demonstrated in a field test in the Hudson River. There are two lines of evidence that strongly indicate that natural

aerobic PCB biodegradation is occurring in the upper Hudson River. First, significant aerobic PCB biodegradation was observed in the field without the addition of microorganisms, nutrients, or supplemental oxygen (although mixing was performed) in the field test. (Harkness, 1993) This result suggested that these sediments contain all the necessary elements for *in situ* aerobic activity. To prove this hypothesis, a sensitive analytical method was developed to detect chlorobenzoic acids, the intermediate products of aerobic PCB biodegradation, in undisturbed cores taken from the River. PCB metabolites were found in all PCB contaminated samples, but not in any of the uncontaminated sediments from further upstream (Flanagan and May, 1993). Moreover, the concentrations and congener distributions of the observed chlorobenzoic acids closely matched the predicted degradation products from the PCBs mixture in the samples .

The detection of chlorobenzoic acids of aerobic PCB biodegradation in contaminated upper Hudson River sediments provides persuasive evidence that aerobic PCB biodegradation occurs naturally in the environment. This finding is consistent with previous studies indicating that aerobic PCB-degrading bacteria with broad congener specificities are widely distributed in contaminated soils and sediments. It could be argued that the PCB biodegradation metabolites observed by the Flanagan and May (1993) study represent evidence of ongoing aerobic biodegradative activity, remnants of past activity, or both. There is evidence to suggest that the metabolites are formed in ongoing biodegradative activity since in a microcosm study, designed to mimic unperturbed Hudson River conditions, the same chlorobenzoic acids are formed and then degraded in the course of approximately 3 months. (Fish, 1996).

Reduced Bioconcentration. The lightly chlorinated PCB congeners resulting from dechlorination in Hudson River sediments (e.g., 2-CB and 2-2-CB) display an approximately 450-fold reduction in their tendency to bioconcentrate in fish, as compared to the more highly chlorinated tri- and tetra-chlorinated PCBs present in the original Aroclor 1242 mixture. (Abramowicz, 1994). Thus, natural anaerobic PCB dechlorination reduces the potential risk associated with PCBs via direct reductions in carcinogenic potency, dioxin-like toxicity, and exposure.

Reduced Bioavailability. An additional reduction in PCB exposure results from long-term contact of PCBs with sediment particles, and consequent reductions in bioavailability. It is well established that the desorption of many nonionic organic compounds from sediment display bimodal kinetics; a "labile fraction" of the contaminant desorbs readily, while a "resistant fraction" desorbs orders of magnitude more slowly (Karickhoff and Morris, 1985). This phenomenon has been observed with PCBs both in spiked and environmentally contaminated sediments (Carroll et al., 1994, Coates and Elzerman, 1986, Witkowski, et al., 1988). The desorption kinetics of PCBs from environmentally-contaminated Hudson River sediment and spiked sea sand using XAD-4 (polystyrene bead resin) as a "PCB sink" is shown in Figure D-1. PCB levels on the y-axis are normalized to the starting PCB levels of the sand and sediment before desorption (13 and 25 ppm, respectively). PCBs from Aroclor 1242 spiked sand were readily desorbed (85% in 8 hours). In contrast, roughly half of the PCBs from H-7 sediment desorbed within the first 8 hours (the labile fraction), with little additional desorption observed over the remaining 162 hours (Carroll et al., 1994). The slowly desorbing fraction represents the proportion of PCB molecules that have diffused into the organic material of the sediment over an extended period of time. Under these conditions

PCB molecules are not available to bacteria and other river biota making them resistant to uptake and degradation. Longer-term desorption experiments demonstrated that resistant fraction PCBs desorb from Hudson River sediment with a half life of approximately 1 year (Carroll et al., 1994).

The bioaccumulation model developed by HydroQual for GE was used to compute total PCB concentrations in fish for a variety of sediment and water column homologue compositions and concentrations. Depending on the relative concentrations in the sediment and water, as well as on the structure of the food web, dechlorination can lead to reductions in total PCB concentration of between 4 and 35-fold lower than with relatively undechlorinated exposure sources.

APPENDIX E

ADDITIONAL COMMENTS AND CLARIFICATIONS

1. Dechlorination Pattern H/H'

The Report recognizes that a variety of more highly chlorinated PCB congeners are very susceptible to losses (pg. 3-119), but instead of recognizing this as a widespread example of anaerobic dechlorination (pattern H and H'), it hypothesizes an unknown selective degradation process that favors these tetra-chlorinated congeners (BZ 56, 60, 70, and 74). In fact, the data displayed to demonstrate this unknown selective degradation (Figures 3-73 to 3-75) are further evidence that dechlorination occurs at low concentrations (down to 1 ppm). Due to the insensitivity of the dechlorination indices used by EPA, the Report fails first to identify this process as process H/H' PCB dechlorination, and more important, fails to recognize its widespread occurrence. Although this pattern is uncommon in the upper Hudson, it is widespread in areas of low contamination in the lower Hudson. Process H/H' dechlorination does not produce significant levels of the terminal PCB dechlorination products, but even such modest dechlorination significantly reduces potential exposure, toxicity, and carcinogenicity, as the initial stages of dechlorination provide disproportionate reductions in these endpoints. 22

2. Partitioning

One major failing of the analysis of equilibrium partitioning performed by the TAMS/CADMUS/Gradient group is the inclusion of the Remnants and Rogers Island Stations in the determination of global partition coefficients. The stations above the TI Dam show much 23

different behavior from those below the dam. Figure E-1 shows the average and range of total PCB partition coefficients for Transects 002-006 vs. river mile. Note the relatively constant values for K_P beginning at the TI Dam of about 50000 l/kg and the distinctly higher values upriver. This difference cannot be attributed to a change in organic content of the solids. Figure E-2 shows estimated log K_{OC} values plotted against log K_{OW} (as reported by Hawker and Connell). For the Thompson Island Dam, Schuylerville, and Waterford stations, the K_{OC} pattern is relatively uniform throughout all transects, and is reasonably well represented by K_{OW}. The Fort Edward station estimates show a much different pattern, being generally higher than the other stations and exhibiting a higher degree of variability.

The Report states on pp. 3-13 and 3-14: "Noticeable in all transects are the generally consistent values for $K_{P,a}$ and $K_{POC,a}$ estimates for most congeners within a given transect beginning at Station 5, the TI Dam (RM 188.5). This suggests that approximate equilibrium conditions are established within the Pool and remain consistent throughout the remainder of the freshwater Hudson. The results for Rogers Island, Station 4, are distinctly different from those downstream and probably reflect its proximity to the Hudson Falls source resulting in a lack of water column equilibrium partitioning." The Report further states on p. 3-20, "All congeners tend to show increased estimates of $K_{POC,a}$ at RM 196.8 (Rogers Island) [note: Rogers Island is actually at RM 194.6], which may represent presence of non-equilibrated sediment in these samples."

This observation of markedly different partitioning above and below the TI Dam is apparent and the conclusion of partitioning non-equilibrium above the TI Dam and equilibrium below is valid.

With this conclusion, it is incorrect to include Remnant and Rogers Island data in the determination of equilibrium partition coefficients. Estimates including this data will yield partition coefficients well above equilibrium.

The analysis of the temperature dependence of partition coefficients (p 3-16) is based upon historical data reported in Warren, et al (1987). It is not clear why this data was used to determine the temperature dependence of partition coefficients when the Phase 2 data collected covers a sufficient range in temperature to determine temperature dependence directly. Figures E-3 and E-4 show log K_{oc} vs 1/T for congeners 10 and 27.

It should be noted that these values of temperature have been corrected to ambient river temperature. Figures E-3b and E-4b show log K_{oc} vs 1/T for congeners 10 and 27 based on the temperature reported in the Phase 2 data. That this temperature is not ambient is evident by the large temperature differences within transects as well as the reporting of high (~20 degC) temperatures in the early Spring surveys. Figure E-5 shows a comparison of ambient TI Dam water temperature data collected by OBG as compared to those reported in the Phase 2 transect data. In all transects the reported Phase 2 temperature is higher than ambient. It is not clear when and where the Phase 2 temperatures were taken, especially in relation to the time of filtration of water samples. If the filtration was performed before samples reached equilibrium at the higher temperatures, values of $K_{oc}(20)$ will be biased high.

3. Volatilization

The equation used to determine PCB volatilization during low-flow conditions is inappropriate for river systems. Eq. 3-33 (Report at 3-55) is an empirical model developed by Hartman and Hammond from their studies of San Francisco Bay. This model is driven solely by wind shear and is only appropriate for large open water bodies such as lakes and bays where water velocities are minimal and there exists sufficient fetch to generate appreciable surface shear forces. 24 Even under extreme low-flow conditions in the Hudson River (~1000cfs) flow-induced shear dominates gas exchange. The equation developed by O'Connor and Dobbins (Eq. 3-34) is an appropriate model for rivers.

Additionally, these models only estimate the liquid film transfer coefficient. Prevailing theory holds that gas exchange across a gas-liquid interface is subject to both a liquid and gas film resistance. For substances with a high Henry's constant, such as oxygen, the liquid film resistance dominates and it can be assumed that the overall transfer coefficient is equal to the liquid film transfer coefficient. This assumption is incorrect for PCBs and other chemicals with much smaller Henry's constants. Gas film resistance must be considered for PCB volatilization.

The conclusion at 3-56 in the Report that there exists no seasonal dependence on gas exchange is not accurate. Both ice cover and temperature variations play a major role in volatilization, whereas wind does not. As the Report states at 3-55, "during the winter months when ice cover is extensive, the effective gas-exchange rate is reduced to near zero." At 3-56, it further states, "K_L increases by approximately a factor of two between 0°C and 25°C as a result of the

temperature dependence of water viscosity." Both these observations are accurate. Wind, however, will not appreciably affect gas exchange in the Hudson River for reasons discussed above. The net effect is a significant seasonal variation in PCB volatilization.

4. Analytical Issues (EPA Appendix C)

Pg 1 - 14.

The congener-specific PCB analysis method lists 126 congeners which can be measured, as listed in Table 1-4. Inspection of the list reveals some whose possible reported presence should be regarded with suspicion: PCBs 12 and 126 should appear in Aroclors at very low levels, and their ECD response factors are low, making any reported detection suspect, especially as they have no *ortho*- chlorines and would not be expected to build up as bacterial dechlorination products of other, more abundant congeners. PCB 20 coelutes with PCB 33 on the HP-5 column and with PCB 28 on the octyl column, and would therefore appear difficult or impossible to quantify in the system described. 25A

PCBs 23, 58, 69, 96, 140, 143, 169, and 184 have been found to be present at only trace levels in Aroclors, and are unlikely dechlorination products, (Frame, G.M., Cochran, J.W., and Bøwadt, S.S., J. High Res. Chromatogr., 19, (1996) 657 - 668), so any reported values of these should be viewed with skepticism.

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Pg. A-1

Principal target congeners are listed as 1, 4, 8, 10, 18, 19, 28, 52, 101, 118, 138, and 180. Those in bold and underline have some analytical problems acknowledged in the report and additional ones noted here below. 25B

Those underlined only are measurable only with the octyl/Apiezon system, and some of the values might be affected by the problems of retention time instability noted both by Aquatec and GE-CRD in 1993 with octyl columns.

PCB 1. This is a critical congener contributing substantially to the dechlorination index defined by PCBs 1,4,8,10 and 19 *using dechlorination products only*. PCB 1 has a very low ECD relative response factor, and interferences or substandard detector operation can introduce large errors into its quantitation. In section A.5.4, mention is made that SDG 169803 samples did not display peaks for BZ-1 on the octyl column, but the results from the HP-5 column were accepted on the grounds that the peak is expected. The octyl non-detect probably represents substandard operation of the detector on that column at that time rather than a column problem, and highlights the potential for detection and quantitation problems for this congener when using ECD quantitation.

PCB 8. This congener was separable from PCB 5 on octyl/Apiezon L only, and considerable problems in quantitation confirmation were encountered until the coelution criterion with PCB 5 was relaxed.

PCB 18. This is a critical congener assessing the amount of Aroclors 1016/1242 present. Data had to be requalified for this congener (see pg A-26) based on the known general presence of this in these sediments, and GC-ITD confirmation. Note however that *quantitation* of this congener is suspect, even if its presence is reasonable on the grounds of its general appearance in these sediments and the GC-ITD confirmation. In section A.5.2.7 it is stated that "TAMS/Gradient considered quantitative differencs between the GC-ITD and GC-ECD results less than a factor of 5 acceptable, while differences greater than five times were considered unacceptable and associated results rejected." Quantitative uncertainty of this magnitude may not require rejection of a finding of detection of this key congener, but it renders its use in quantitative modeling highly suspect.

PCB 118. When the shift was made from octyl to Apiezon L, the potential for a small difference due to coelution with PCB 122 on Apiezon which does not occur on octyl was ignored. This will likely cause only a minor quantitative error.

PCB 138. The fact that PCB 138 coelutes on both octyl and HP-5, but not on Apiezon L, with substantial amounts of PCB 163 when they come from Aroclors 1254 or 1260, was not recognized. This could cause discrepencies between data collected before and after 1993, when the shift from octyl to Apiezon L was made. In some fish the relative rates of metabolic clearance of 138 and 163 differ strongly, so failure to realize that both could be present in the peak in varying amounts can result in quantitative difference errors if calibration was only against a 138 standard.

In the listing of 126 congeners measurable in the dual column system in Table 1-4, it is not clear why PCB 46, 2,2',3,6-tetrachlorobiphenyl, (present at ~0.4 weight% in Aroclor 1242, and cleanly resolvable from all other Aroclor congeners on both the HP-5 and octyl columns) was dropped from the list of non-target congeners as noted at the top of page A-12. This congener should have been clearly iidentified and reported in this study.

Section A.5.2.2, pg. A-12.

In the corrections to relative response factors obtained by measurement of the actual congeners in 1993 and 1994 for congeners previously quantified only against the PCB 52 response, there is no indication of how stable and comparable the previous responses being corrected actually were. Individual congener's ECD response factors can easily vary by as much as a factor of 2 on different detectors at different times, especially if temperature and/or carrier make-up flows are changed. One needs to know how well these variables were controlled over the whole period of data gathering to assess how consistent the quantitation and the quantitative correction which was retroactively applied to the non-target congeners is. 25C

On pg A-3 it is stated for core tops collected in 1992 that "RPI dried and archived core tops (0-2 cm) from these cores for eventual PCB congener analysis." Aquatec subsequently analyzed a small subset. The behavior and congener distributions of PCBs in the topmost layers of Hudson River sediments is critical to evaluation of competing models of their fate and transport. How were these samples dried? Excessive drying, especially in air with heat, can result in uncontrolled losses of *mono-* and *di-* chloro PCBs which are major components of EPA's dechlorination index.

On pg. A-4 appears the statement "Aquatec extracted sediment samples with hexane, and performed applicable cleanup procedures prior to analysis by GC/ECD, as detailed in Appendix A3 of Phase 2A SAP/QAPP." Reference to the latter document reveals that the protocol for sediments requires Soxhelet extraction with *hexane/acetone.* Which solvent was used? Hexane extraction alone is inadequate to remove all PCBs from sediments unless they are previously dried so strenuously as to risk losing by evaporation substantial amounts of lower congeners, which are critical to assessing dechlorination processes. A call to Kurt Young of ITS Environmental in Colchester, VT (successor company to Aquatec Chemistry Division) on 3/14/97 elicited the statement that the information to answer this question was stored in a warehouse, not instantly accessible, and in any event would require EPA authorization to be made available. A request for information to resolve this question was made orally by phone to Douglas Tomchuck of the EPA on the same date. As of 4/1/97 no reply has been received by GE-CRD.

5. Miscellaneous Issues

Report at 4-49: The document states that remobilization by sediment resuspension or porewater displacement can serve to return PCBs to the water column long after any point source contributions have been eliminated.

Response: EPA failed to determine the depths of the scour and porewater displacement contribution to the water column. Answering these questions will give an index of relative sediment PCB importance as a function of depth. 26A

Report at 4-50: The document states that in general, aerobic processes affect only the lightest congeners, and are ineffective at altering heavy congeners under environmental conditions.

Response: It should be pointed out that several microorganisms including MB1, H850 and L400 have been enriched from the Hudson River and are capable of degrading PCBs containing as many as six chlorines. In addition, there are several later remarks suggesting significant amounts of degradation may have taken place in some instances. It should be pointed out that Flanagan and May (1993) showed that PCB metabolites have been found throughout the river even in relatively deep sediments and that these metabolites are short lived, with lifespans on the order of weeks (Fish, 1996) in physical models of the Hudson River. This points to the possibility that biodegradation does take place even in non-surficial sediments. 26B

Report at 4-50: The document states that in the absence of oxygen, the only biotransformation possible is dechlorination.

Response: It has been repeatedly found in surface sediment microcosm sediments that both aerobic and anaerobic PCB biodegradation takes place (Fish, 1994; 1996). This has a significant impact because the surface sediments are where the newest releases of PCBs are settling and where the fish are getting their PCBs from. There is the potential for decrease in chlorine content and mass reduction in this layer. 26C

Report at 4-51: The document states that the dechlorination process is more effective on the heavier PCB homologues.

Response: No generalizations about PCB dechlorination are valid except that there is no conclusive evidence for *ortho*- dechlorination in the Hudson River. A good review of the literature offered in Bedard and Quensen (1995). 26D

Report at 4-51: The document states that there is no reduction in the total number of PCB molecules.

Response: There is ~3 mole% of PCBs that can be reductively dechlorinated to biphenyl and then easily degraded, namely the dioxin-like congeners including 34-4-CB, 4-4-CB, 34-34-CB, 345-34-CB. The dechlorination of these congeners would significantly reduce the risk associated with toxicological effects. 26E

Report at 4-51: More chlorinated congeners are often associated with carcinogenic endpoints while the literature suggests that less chlorinated congeners are more likely to produce neurological impairment and developmental damage.

Response: The Battelle rat bioassay demonstrated that chlorine content does affect potential carcinogenic potential in rats, and that potency is markedly reduced as compared to previous estimates. This study served as a basis for EPA's recent reassessment of PCB cancer slope factors. 26F

Furthermore there have been questions regarding the validity of the neurological impairment studies as these studies are generally considered flawed and they have not been reproduced in six separate attempts.

Report at 4-51: The document states that little evidence has been demonstrated for anaerobic degradation in sediments.

Response: As discussed above, the presence of metabolic PCB biodegradation products in anaerobic sediments is indicative of degradation processes even at low oxygen concentrations. The transient nature of these metabolites also indicates that at least some low level of the degradation process occurs. 26C

Report at 4-52: The document states that the issue of anaerobic dechlorination will be revisited in a Phase 3 report, incorporating the results of both high and low resolution coring.

Response: This provides EPA and its contractors with an opportunity to develop and use more sensitive dechlorination indices. 26H

Report at 4-88: The document concludes that the degree of *in situ* PCB dechlorination is not a function of time but rather dependent upon the total PCB concentration within the sediment.

Response: This conclusion is based in part on the use of an insensitive index of dechlorination, and the lack of understanding dechlorination biochemistry. A more detailed analysis of the data using a more appropriate index of dechlorination would show that concentration effects the rate as has been shown in lab studies (Abramowicz et al., 1993; Rhee et al., 1995) and microcosm studies (Fish, 1996). Sokol et al. (1994) and Rhee et al. (1995) indicate that the belief that *in situ* dechlorination may not occur in areas with relatively low PCB contamination is based on "dechlorination potential" and by definition is flawed. The phrase dechlorination potential is defined as relating to the length of the lag phase before which dechlorination occurred. This definition is not an indication of the dechlorination potential of a congener at a given concentration, but an indication of the acclimation time for anaerobic microorganisms to respond in laboratory studies. Note that this investigation only addressed BZ 138 and BZ 21. In the case of BZ 138 which is 0.15-0.54 wt % of Aroclor 1242, no dechlorination was detected below 35 ppm, but the investigators probably did not run the experiment long enough to overcome the lag time for acclimation observed in these experiments. In comparison, these investigators looked at the concentration effects of dechlorination of BZ 21, which does not exist in Aroclor 1242, but they did show a 70% decrease in concentration in 7.5 months of incubation. Even at 4 ppm in the latter paper, the concentrations used to evaluate the concentration were somewhat high, but complement rates found by Abramowicz et al. (1993) who used a mixture of Aroclors 1242, 1254 and 1260, and Fish (1996) who used much lower concentrations of Aroclor 1242 in test tube microcosms. When all of these data are combined, they produce an interesting correlation that passes through the origin as discussed above.

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Report at 4-52: The document introduces the concept of measuring the degree of dechlorination resulting from PCB storage based on PCB sources and usage.

Response: This dramatically overestimates the usefulness of simply comparing final products to the starting congener mix and underestimates the complexity of the task. It ignores the fact that there are a variety of selectivity processes and sets the stage for using an inappropriate index of dechlorination. Even if this methodology did work, it would rely upon the homogeneous mixing of the Aroclors throughout the Hudson River with a single pair of reference points, namely Aroclor 1242 and completely dechlorinated Aroclor 1242. Earlier in the document, it is stated that as much as 25% of the load south of Waterford is Aroclor 1254. Thus, their estimate of molecular weight is underestimated by ~6%. This may at first glance appear to be trivial, but is most likely part of the reason for the unusually low (<0% dechlorination) indices calculated for the lower Hudson River. There is also an extensive discussion of PCB partitioning to porewater and the water column on a congener basis. After such an extensive discussion on these principles, it is surprising that the indices of dechlorination do not account for "washout" of the lighter congeners from sediment and porewater. In fact, congeners used to calculate MDPR are up to 10x more likely to be lost to the water column than are the heavier ones. 26J

Report at 4-49 to 4-56. The use of BZ 8 as an indicator peak itself poses some serious problems. First of all it is the most abundant congener in Aroclor 1242. Thus even at the onset of dechlorination, small changes in a large peak of the chromatogram will meet with uncertainty. In addition, if BZ 8 is dechlorinated to BZ 1 there would be no change in the MDPR. 26J1

Report at 4-56: The document states that MDPR is a measure of the number of affected PCB molecules.

Response: MDPR is a measure of the last one or two dechlorination steps for mixtures containing 3.26-3.7 chlorines/biphenyl. Dechlorination via processes H' and H that are active in the lower Hudson River (where the PCB concentration is generally lower) primarily attacks higher homologues and will not be picked up by this index of dechlorination. Therefore, a significant percentage of PCB molecules could be affected by these processes and still be missed by EPA's analysis. 26K

Report at 4-57: The document states that due to the lack of *ortho*-chlorine removal, the dechlorination process is theoretically limited in its ability to reduce the PCB sediment inventory.

Response: The dechlorination processes that are known to occur in the Hudson River serve to reduce the ability of PCBs to bioaccumulate an important risk-reduction benefit. This also ignores the possibility of other loss mechanisms, such as photo-destruction and biodegradation. In fact, the latter two are mentioned later to account for the <25% of the PCB alterations in the lower river. If the Agency believes that these are the processes responsible for <25% of the PCB alterations in the lower river, there is no reason to believe that they are not also occurring in other parts of the river. Furthermore, Fish (1994, 1996), has shown that in surface sediments, combined reductive dechlorination and aerobic degradation serve to reduce a significant amount of mass in as short as 140 days. Both indices of dechlorination will tend to account for this as either no net mass loss or 26L

even as mass gain (in the case of aerobic degradation with little dechlorination) as shown in MDPR vs. ΔMW at low concentrations in the lower Hudson River samples.

Report at 4-59: The mean molecular weights of Phase 2 sediment samples with low concentrations of dechlorination products have been found to be close to that of Aroclor 1242, indicating that processes other than dechlorination have not greatly modified the sample PCB content.

Response: Alternatively, both higher and lower homologues are lost due to process H' and H or moderate process C, M or Q (as their chromatograms indicate) plus loss of lighter congeners from degradation and partitioning. The Agency's analysis could result in insignificant changes in MDPR and ΔMW. 26V

Report at 4-60: The document states that the sensitivity of MDPR has a larger range (relative to ΔMW), and thus is more sensitive to changes in the PCB congener composition.

Response: The congeners used to measure the MDPR have the lowest response factors by electron capture detection and are the most insensitive measure and thus most susceptible to uncertainty, especially for BZ 1. In addition, any dechlorination due to *para* attack on BZ 8 will not be evident from the calculation. This is 7.65 weight percent of the total PCBs in Aroclor 1242. 26N

Report at 4-62: The document states: "The Lower Hudson sample MDPRs tend to cluster just below the Aroclor 1242 value of 0.14. The mean MDPR for the Lower Hudson is 0.11, suggesting the presence of a minor contribution by heavier Aroclors, or more likely, possible loss of BZ 1, 4, 8, and 19 prior to deposition due to their generally greater solubility and degradability. The congener pattern comparisons made in Chapter 3 (Subsection 3.3.3), suggest that both processes probably occur to some degree. It is important to note the absence of any significant degree of dechlorination in the sediments of the Lower Hudson. Based on this observation, it would appear that dechlorination will not decrease the sediment PCB inventory of the Lower Hudson.

Response: The paragraph immediately discusses the Upper Hudson and ignores the possibility that same loss mechanisms (partitioning and degradation) would reduce mass. It is scientifically invalid to have one set of paradigms for one reach of the river and another set for other parts. 260

Report at 4-65: The document states that there is a maximum decrease of 26% mass due to dechlorination.

Response: This does not account for any of the degradation that was suggested earlier in the document, for which Flanagan and May (1993) have found evidence. Furthermore, Fish (1994, 1996) have shown this in a physical model of the Hudson River in the laboratory. 26P

Report at 4-69: The document states that no significant change in ΔMW occurs in PCB concentrations less than 30000 ug/kg.

Response: If there were slow steady-state dechlorination with steady washout of mono-trichlorobiphenyls, one would expect the plots of ΔMW vs. PCB concentration to look as they do. 26Q

Report at 4-70: This presents a discussion on the age of sediments and degree of dechlorination as a function of sediment age. The document does not address the upstream source and low-level recent contamination of the newest sediments. 26R Also the "sampling" is skewed: there are >2x the number of "new sediment samples" than "old sediments" used to construct Figure 4-28a. Furthermore, the discussion of concentration effects on dechlorination should take into account the different processes and end products expected as a function of concentration. In particular, processes B,B' and C are common in the Upper Hudson and can lead to non-selective extensive dechlorination, whereas processes H' H and A are more selective with different end products.

Table C-1. Species-Characteristic PCB Alteration Patterns Observed in the Hudson River.

Family	Common name	Abbr.	Species name	Alt'n. Pattern
Lampreys (Petromyzontidae)				
	Sea Lamprey	SLP	*Petromyzon marinus*	AP-PET
Freshwater Eels (Anguillidae)				
	American Eel	AME	*Anguilla rostada*	AP-ICT
Herrings (Clupidae)				
	American Shad	AMS	*Alosa sapidissima*	None
Bullhead/Catfish (Ictaluridae)				
	Brown Bullhead	BRB	*Ictalurus nebulosus*	AP-ICT
	Yellow Bullhead	YBH	*Ictalurus natalus*	AP-ICT
	White Catfish	WCF	*Ictalurus catus*	AP-ICT
Suckers (Catostomidae)				
	Northern Hogsucker	NHS	*Hypentelium nigricans*	AP-CAT
	White Sucker	WSR	*Catostomas commersoni*	AP-CAT (a)
Minnows (Cyprinidae)				
	Carp	CAR	*Cyprinus carpio*	None
	Goldfish	GLF	*Carassius auratue*	AP-ICT
	Golden Shiner	GSH	*Notemigonis crysoleucas*	None
	"Minnows"	MMM	*Cyprinia spp.*	None
	Fathead Minnow	FHM	*Dimephales promelas*	None
Pikes (Esocidae)				
	Chain Pickerel	CHP	*Esox niger*	AP-ESX (a)
	Northern Pike	NOP	*Esox lucius*	None
Codfish (Gadidae)				
	Atlantic Tomcod	ATT	*Microgadus tomcod*	AP-ICT
Temperate Bass(Moronidae)				
	Striped Bass	STB	*Morone saxatilis*	None (b)
	White Perch	WPR	*Morone americana*	None (b)
Sunfishes (Centrarchidae)				
	Largemouth Bass	LMB	*Micropterus salmoides*	None (b)
	Smallmouth Bass	SMB	*Micropterus dolomieui*	None (b)
	Rock Bass	RKB	*Amblophites ropestris*	None
	Black Crappie	BLC	*Pomoxis nigromaculatus*	None
	White Crappie	WCR	*Pomoxis annularis*	None
	Bluegill	BLG	*Lepomis macrochirus*	AP-LEP
	Longear Sunfish	LSF	*Lepomis megalotis*	AP-LEP
	Pumpkinseed	PKS	*Lepomis gibbosus*	AP-LEP
	Redbreast Sunfish	RBS	*Lepomis auritus*	AP-LEP (b)
Perches (Perchidae)				
	Yellow Perch	YPR	*Percha flara*	None
	Walleye	WAL	*Stizostedion vitreum*	None
	Tesselated Darter	TES	*Etheostoma olmstedi*	None

(a) Distinction alteration seen in some, but not all, individuals

(b) Some individuals showed weak and variable AP-ICT-like depressions in PCB 70, and occasionally also P450 2B-like depressions in PCB 110, presumably altered in prey species.

Parameter	Reference Distributions						Upper Hudson River Means								Lower H.R. Means			
	Aroclor	Dechlorination Patterns					1977-1978		1990		1992		1993		1977-1978		1993	
	90:10	A	B	C	H	H'	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%	Mean	%
	Wt%	Wt%	Wt%	Wt%	Wt%	Wt%	Wt%	RSD	Wt%	RSD	Wt%	RSD	Wt%	RSD	Wt%	RSD	Wt%	RSD
Footnotes —	1	2	2	2	2	2	3		4		5		6		7		8	
No. of Fish in Mean -							n=18		n=29		n=15		n=36		n=16		n=46	
Homolog Distribution																		
% 1 Cl	.40	8.61	7.20	20.84	.90	1.03	.20	**	.37	**	.21	**	.47	**	.04	**	.01	**
% 2 Cl	12.96	13.89	33.76	48.01	16.77	10.79	3.86	*	1.90	**	2.52	*	2.26	*	2.41	**	1.44	*
% 3 Cl	42.14	31.72	33.38	19.39	39.36	42.72	23.49		18.39		24.35		19.79		18.56		18.93	
% 4 Cl	30.95	32.11	16.02	5.95	23.86	28.75	45.44		46.19		46.28		46.90		43.78		36.84	
% 5 Cl	9.05	8.79	6.81	2.66	11.99	11.28	15.85		19.54		15.95		21.53		20.02		24.35	
% 6 Cl	3.88	3.83	3.03	2.01	6.50	3.64	8.42		10.26		7.69		7.04		11.25		13.95	
% 7 Cl	.61	.85	.55	.70	1.27	1.22	2.07		2.66	*	2.23	**	1.81		3.26		4.88	*
% 8 Cl	.01	.19	.15	.18	.24	.26	.40		.55	**	.60	**	.36	*	.49	*	1.33	*
% 9 Cl	.00	.06	.10	.16	.10	.31	.17	*	.12	**	.15	**	.05	**	.17	**	.23	*
Mean %RSD all 2Cl-9Cl								38		64		68		38		45		42
Isomer Ratios PCB/PCB	Mean	Mean	Mean	Mean	Mean	Mean	Mean	RSD	Mean	RSD	Mean	RSD	Mean	RSD	Mean	RSD	Mean	RSD
Trichlorobiphenyls																		
19/28+31	.06	.10	.49	1.76	.09	.04	.07	**	.06	**	.02	**	.09	*	.08	**	.10	
18/28+31	.68	.29	.43	.97	.93	.55	.15		.12	*	.13		.16		.27	*	.34	
17/28+31	.31	.23	.42	.27	.46	.33	.21		.13	*	.13		.12		.22	*	.26	
27/28+31	.06	.09	.28	1.18	.10	.06	.10		.06	**	.03	*	.09	*	.11	**	.12	
26/28+31	.08	.14	.32	.33	.21	.18	.18		.12		.10		.16		.16		.24	
33/28+31	.43	.35	.22	.36	.20	.12	.11		.25		.24		.21		.12		.20	
22/28+31	.19	.33	.07	.10	.15	.07	.11		.26		.27		.17		.11		.11	
Tetrachlorobiphenyls																		
52/49	1.40	1.36	1.32	1.80	1.24	1.00	.99		1.29		1.24		1.01		1.06		.97	
47/49	.39	.56	.74	1.12	.70	.79	1.06		.72		.64		.51		.85		.56	
44/49	1.26	1.37	.08	.27	.68	.28	.48		.78		.98		.51		.64		.44	
40/49	.36	.34	.04	.07	.25	.19	.13		.15		.16		.08	*	.11		.02	**
74/49	.61	.73	.04	.25	.33	.22	.70		.94		.83		.78		.50		.38	
74/49 adj.	.61	.71	.06	.39	.38	.26	.52		.59		.62		.52		.34		.26	
77/49	.13								.12	*			.10				.03	*
70/74	2.21	2.76	1.86	1.15	1.52	1.64	.76		1.89		2.30		1.41		.72	*	1.17	
Pentachlorobiphenyls																		
101/99	1.69	1.93	3.07	3.04	1.80	1.88	1.31		1.69		1.76		1.50		1.40		1.42	
87/101	.67	1.03	.53	.35	.33	.22	.48		.80		.82		.48		.42		.61	*
101/110	.91	.53	.49	.55	.76	.99	1.15		.71		.69		.96		.99		1.06	
99/110	.54	.28	.17	.18	.42	.53	.88		.42		.41		.64		.67		.75	
97/110	.48	.29	.06	.08	.21	.19	.36		.31		.28		.36		.25		.28	
87/110	.61	.54	.26	.19	.25	.22	.55		.57		.55		.48		.41		.63	*
118/110	.98	.87	.63	.72	.69	1.13	1.69		1.28		1.15		1.19		1.22		1.26	
105/110	.59	.74	.17	.21	.25	.31	.69		.91		.83		.63		.39		.49	
Hexachlorobiphenyls																		
146/153	.14	.26	.60	.73	.15	.26	.22		.24		.27		.34		.21		.36	
141/153	.18	.41	.00	.00	.12	.07	.12		.26		.29		.18		.13		.10	
138+163/153	1.10	1.43	3.83	1.91	1.04	1.17	1.29		1.27		1.34		1.38		1.15		1.04	
128/153	.25	.25	.17	.09	.19	.16	.22		.22		.21		.26		.15		.15	
187/153	.11	.03	.00	.06	.09	.07	.09		.03		.03		.09		.07		.10	**
156+171/153	.17	.42	.16	.12	.14	.15	.23		.32		.39		.19		.14		.12	
Mean %RSD (29 Ratios)								17		30		26		22		29		39

1. Mixture of Aroclors 1242:1254 in ratio of 90:10
2. Means (n = 1 of sediment core values: A (3); B (3); C (1); H (3); H' (1)
3. 6 BRB, 12 LMB. 1977-78. Upper Hudson Mile 175
4. 1 AME, 3 BLC, 3 CAR, 2 CHP, 1 LMB, 1 NOP, 2 PKS, 3 RBS, 3 RKB, 3 SMB, 3 WAL, 1 WSR, 3 YPR. Autumn 1990. Upper Hudson Mile 191
5. 2 BRB, 2 CHP, 2 PKS, 2 RKB, 2 SMB, 2 WSR, 1 YPR. May 1992. Upper Hudson Miles 174, 188, 192
6. 6 LMB, 13 PKS, 6 RBS, 6 TESS, 4 YPR. NOAA Autumn 1993. Upper Hudson Mile 192
7. 5 BRB, 3 LMB, 2 SMB, 2 WCF, 3 WPR. 1977-78. Lower Hudson Miles 112, 126, 153
8. 3 BRB, 3 LMB, 8 PKS, 6 RBS, 3 SMB, 3 WCF, 19 WPR. NOAA Autumn 1993. Lower Hudson Miles 143, 135, 123, 88, 40
9. ADJ = 74/49 ratio adjusted for greater elution of PCB 49, as estimated from trichlorobiphenyl/tetrachlorobiphenyl ratio change

* Indicates RSD in range of 50% - 70%; ** indicates RSD > 70%

Table C-2. Mean Values of PCB Homologue Levels and Isomer Ratios in Upper and Lower Hudson River Resident Fish Collected 1977-1993.

		Isomer Cl Level -	Tetrachlorobiphenyls							Pentachlorobiphenyls				Hexachlorobiphenyls					
		No. of Ortho- Cls -	1	1	1	1	1	1	0	1	1	1	1	2	2	1	1	2	1
		BZ#/BZ#	56/49	60/49	63/49	66/49	67/49	74/49	77/49	105/110	114/110	118/110	123/110	128/153	138/153	156/153	157/153	158/153	167/153
NOAA Station	River Mile	Species	(no.)																
2,3,4	192	Pumpkinseed	(13)	.37	.37	.11	1.13	.06	.69	.09	.40	.07	.82	.01	.26	1.43	.17	.03	.17	.08
		All Species	(36)	.42	.44	.12	1.25	.07	.78	.10	.47	.09	.90	.01	.26	1.38	.16	.03	.16	.09
8	176	Pumpkinseed	(5)	.28	.26	.08	.85	.04	.55	.05	.33	.04	.73		.21	1.35	.13	.02	.12	.07
		All Species	(11)	.29	.29	.09	.89	.04	.59	.05	.39	.06	.83		.20	1.31	.13	.02	.11	.06
10	143	Pumpkinseed	(4)	.21		.08	.64	.02	.44	.04	.31	.03	.76		.16	1.12	.10	.01	.09	.20
		All Species	(18)	.20	.19	.08	.65	.04	.46	.04	.32	.04	.81		.15	1.05	.09	.01	.09	.10
11	135	White Perch	(4)	.25	.18	.09	.74	.05	.56	.04	.29	.05	.69	.00	.16	1.11	.10	.02	.11	.06
12	123	White Perch	(5)	.18	.15	.08	.54	.02	.40	.03	.24	.04	.71		.14	.95	.08	.01	.09	.09
15	88	Pumpkinseed	(4)	.10		.06	.31	.00	.24	.01	.17	.00	.61		.12	.92	.07		.07	.04
		All Species	(19)	.09	.10	.08	.42	.02	.31	.01	.23	.02	.72		.17	1.08	.08	.02	.09	.11
17	40	White Perch	(5)	.12	.05	.05	.35	.02	.21	.02	.14	.01	.52		.13	.85	.06	.01	.07	.06

(a.) Ratios of PCB isomer levels as reported by Aquatech; not translated into Northeast Analytical equivalents as in Table 2.

Table C-3. Downstream Declines in 1993 NOAA Fish PCB Isomer Rations (a.) that are Reduced by Subsurface Dechlorination Processes.

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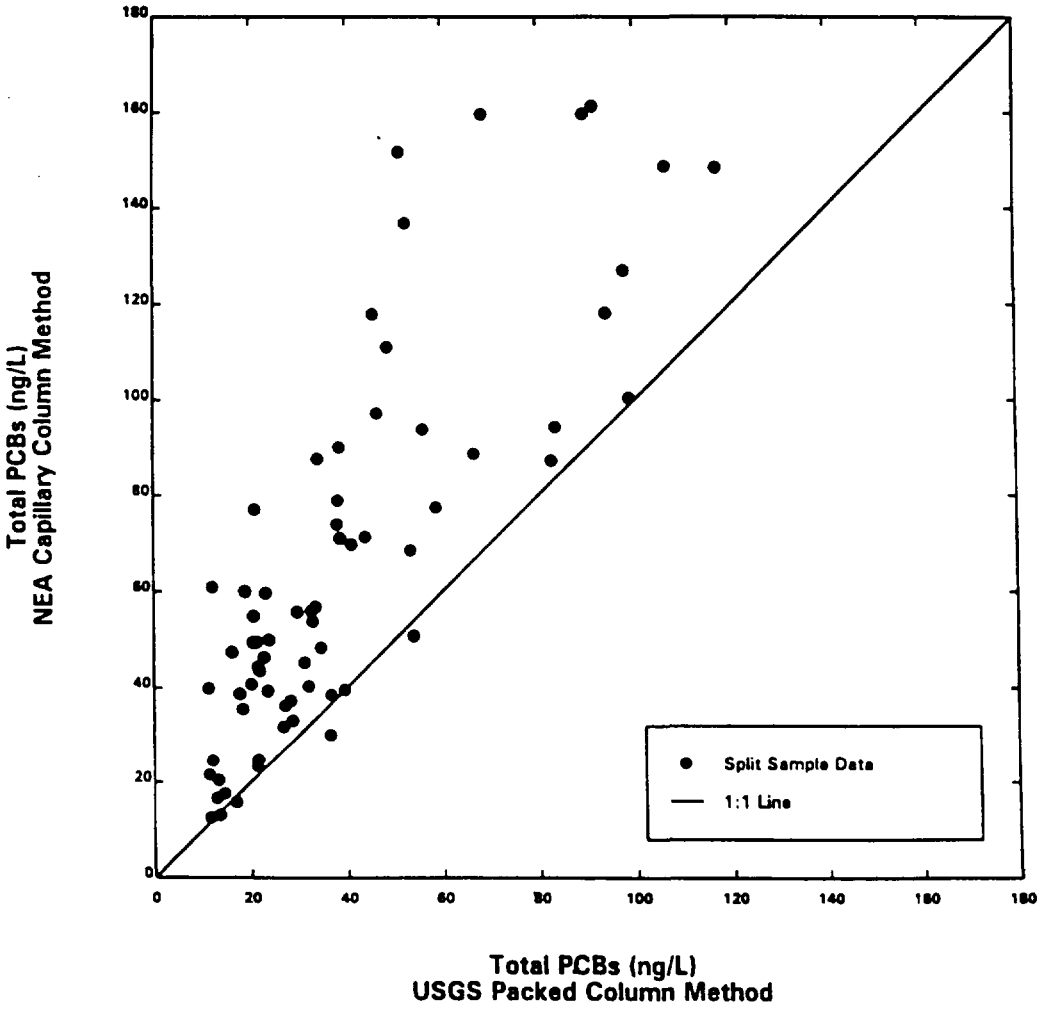


Figure A-1. Comparison of water column PCB concentrations calculated by the NEA capillary column method versus the USGS packed column method.

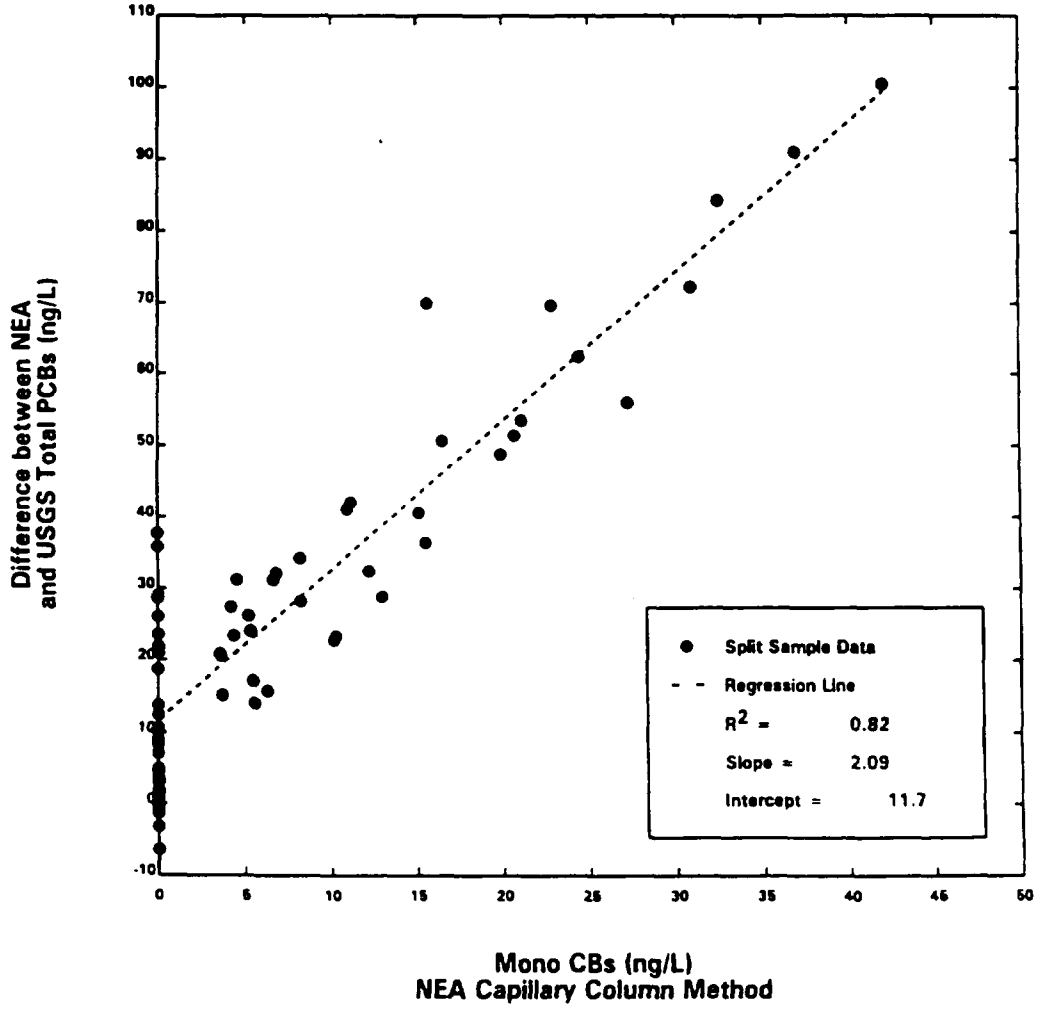


Figure A-2. The correlation of differences between NEA and USGS total PCBs and monochlorobiphenyls.

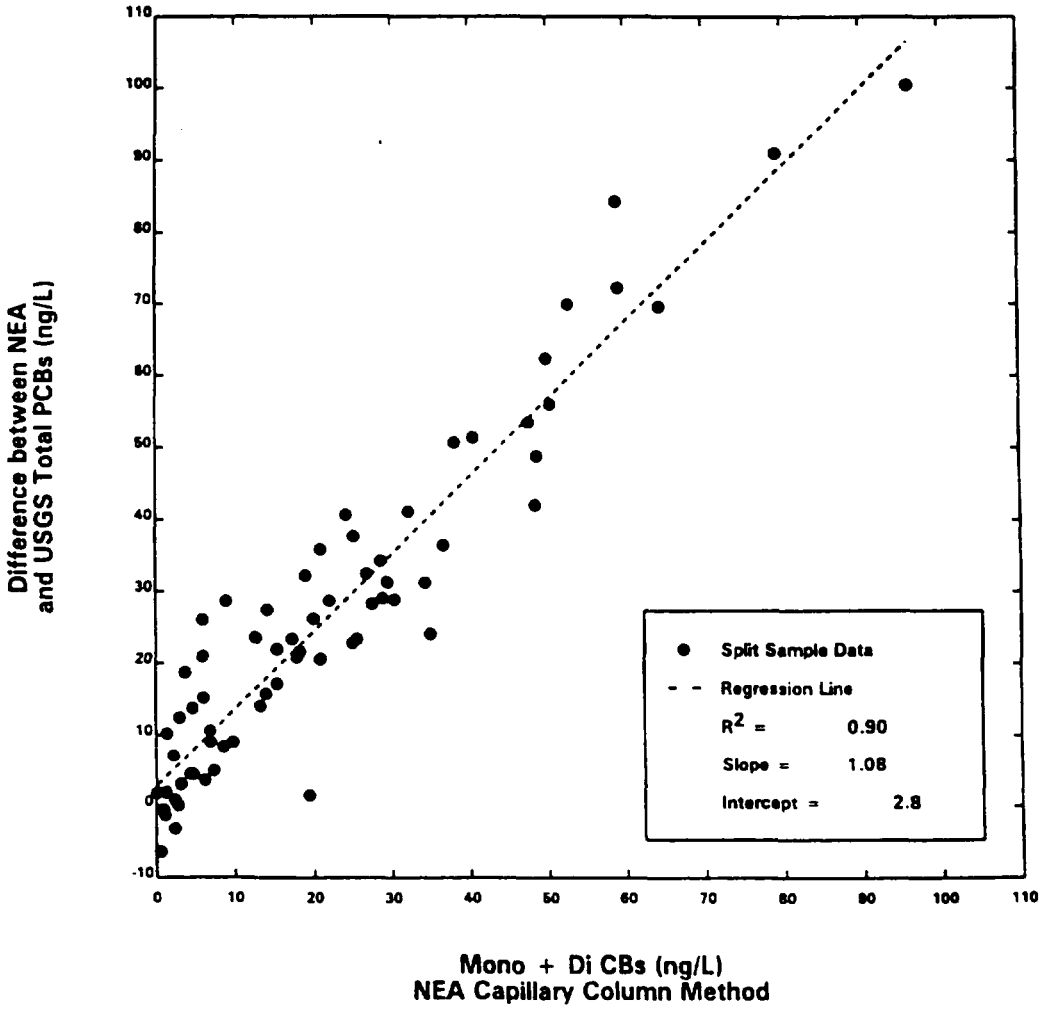
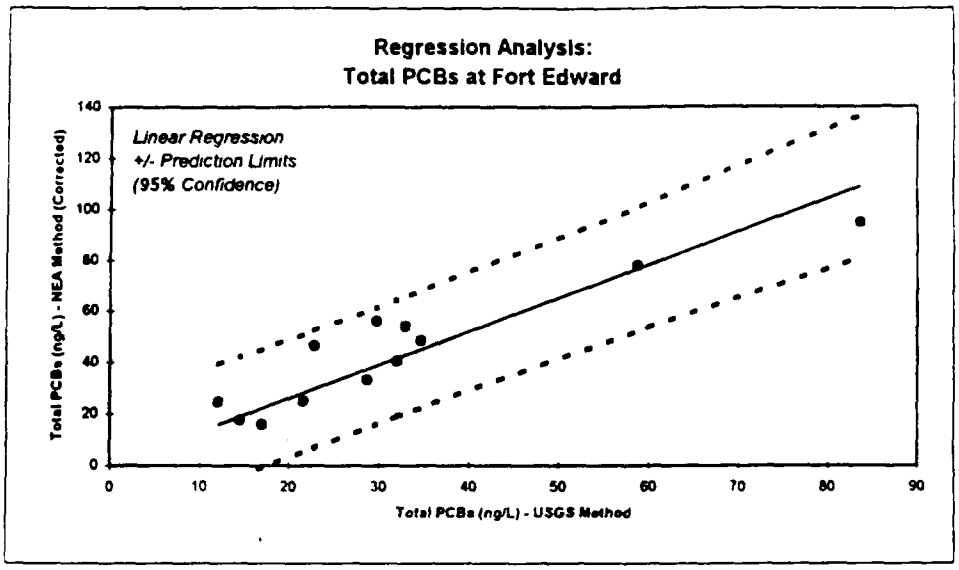
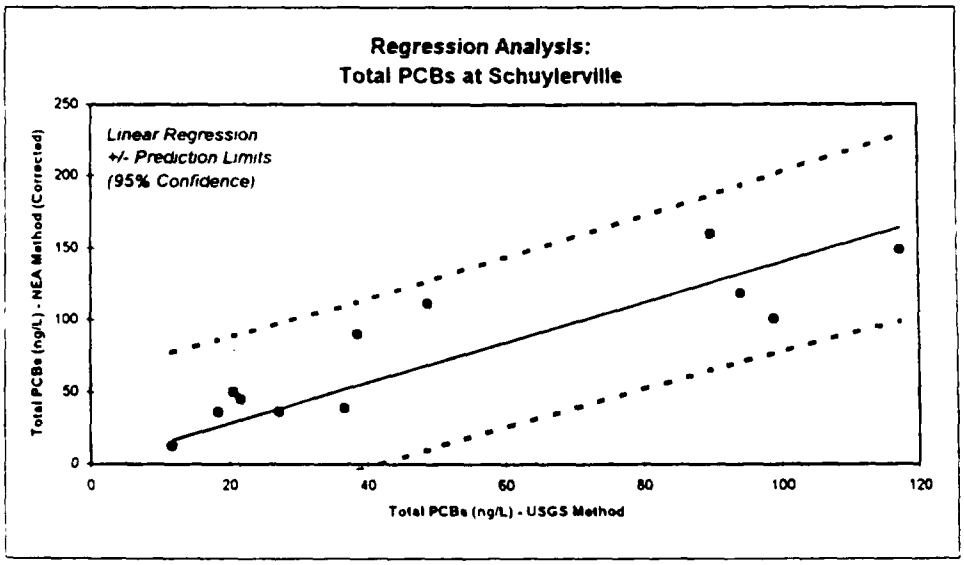


Figure A-3. The Correlation of differences between NEA and USGS total PCBs and monochlorobiphenyls plus dichlorobiphenyls.





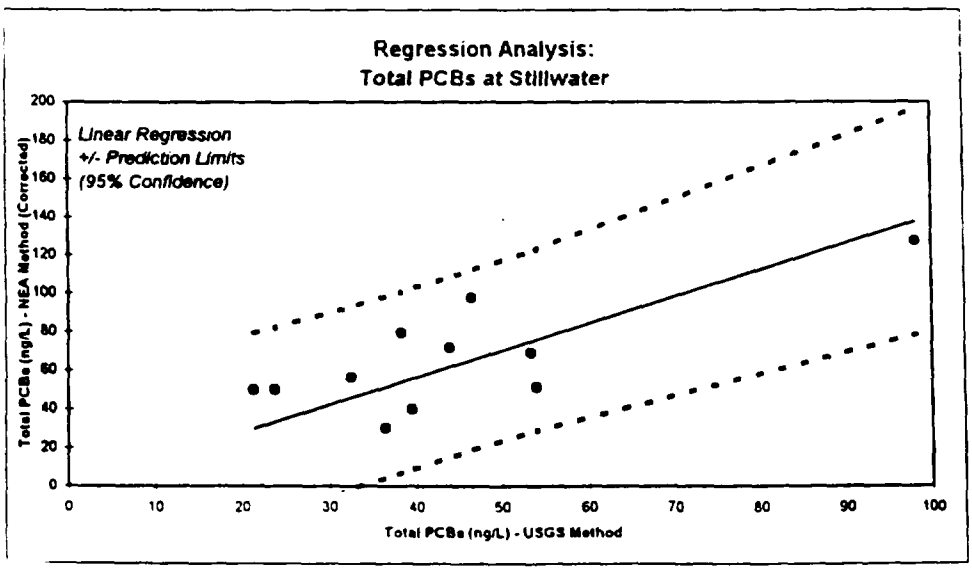


Figure A-4. Comparison of total water column PCB concentrations calculated by the NEA capillary column method versus the USGS packed column method at Fort Edward, Schuylerville and Stillwater.

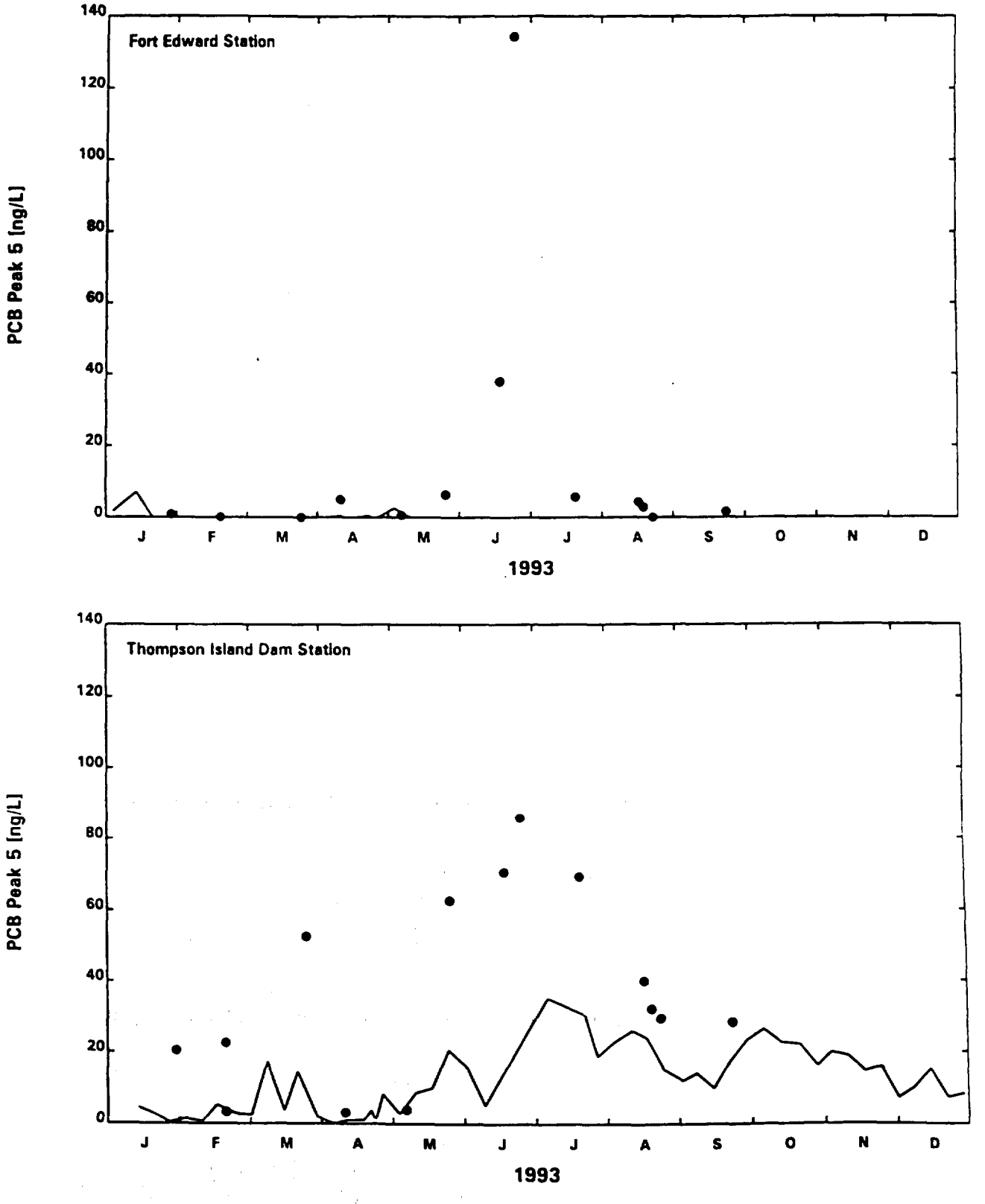


Figure A-5. Comparison of GE and EPA analyses of 1993 water column DB-1 capillary column peak 5 components (BZ#4 plus BZ#10) collected at Fort Edward and the Thompson Island Dam.

● EPA Data ——— GE Data

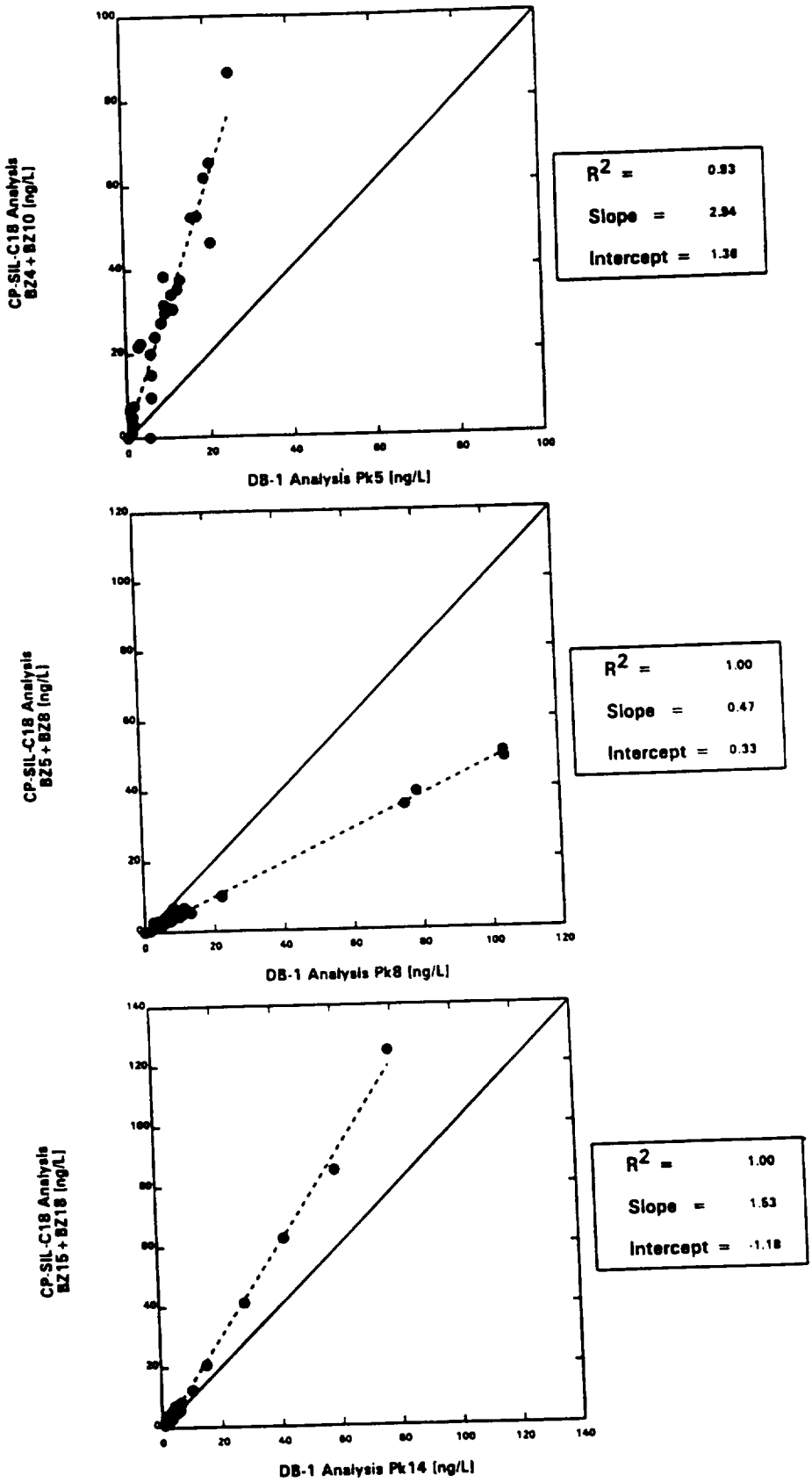


Figure A-6. Comparisons of top: CP-Sil-C18 BZ#4 plus BZ#10 analysis to DB-1 peak 5 analysis; middle CP-Sil-C18 analysis of BZ#5 plus BZ#8 to DB1 peak 8 analysis; bottom, CP-Sil-C18 analysis of BZ#15 plus BZ#18 to DB1 peak 14 analysis.

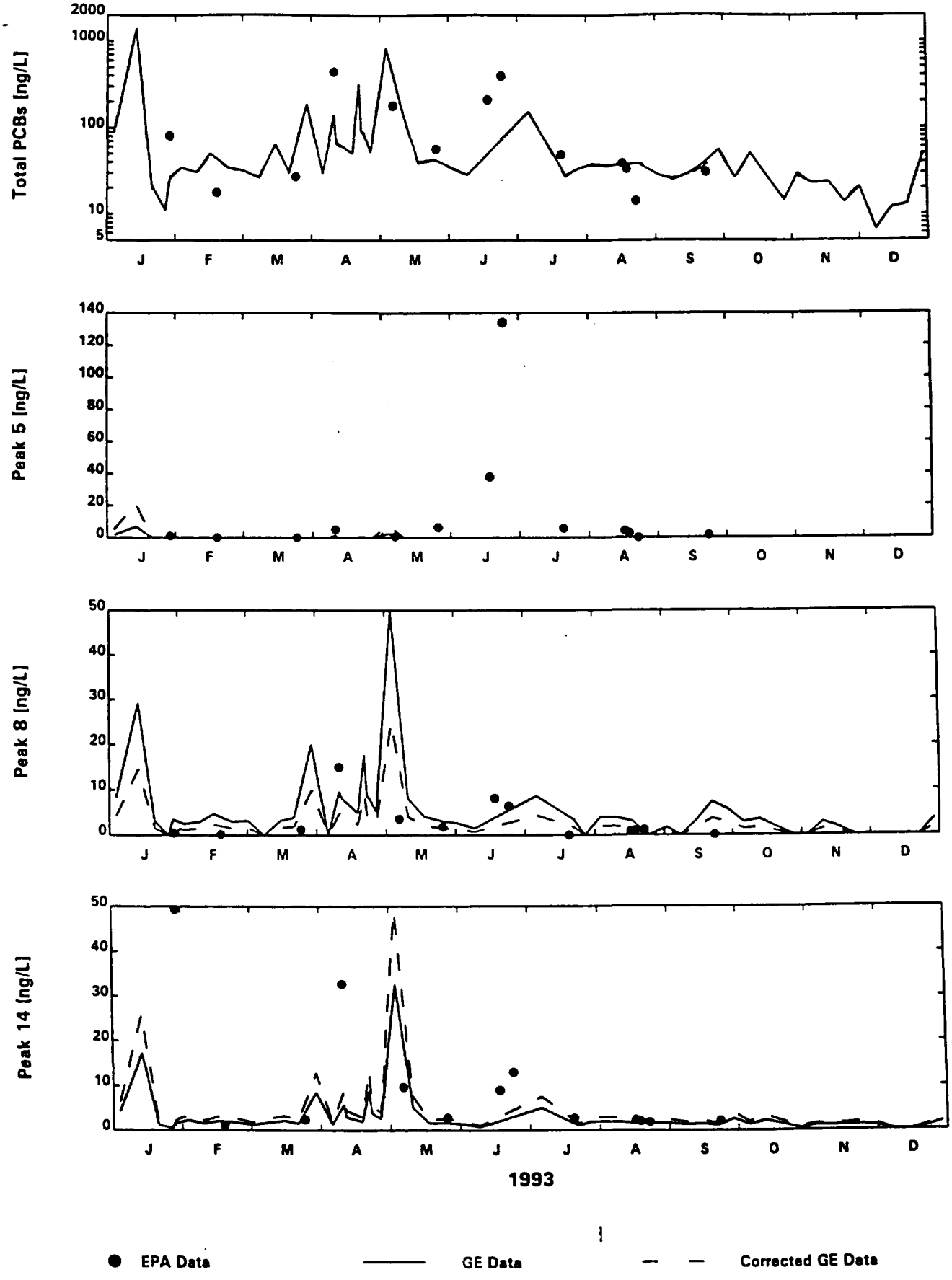


Figure A-7. Comparisons of EPA, GE and corrected GE temporal 1993 water column concentrations of total PCBs, peak 5 (BZ#4 plus BZ#8), peak 8 (BZ#8) and peak 14 (BZ#15 plus BZ#18) at Fort Edward.

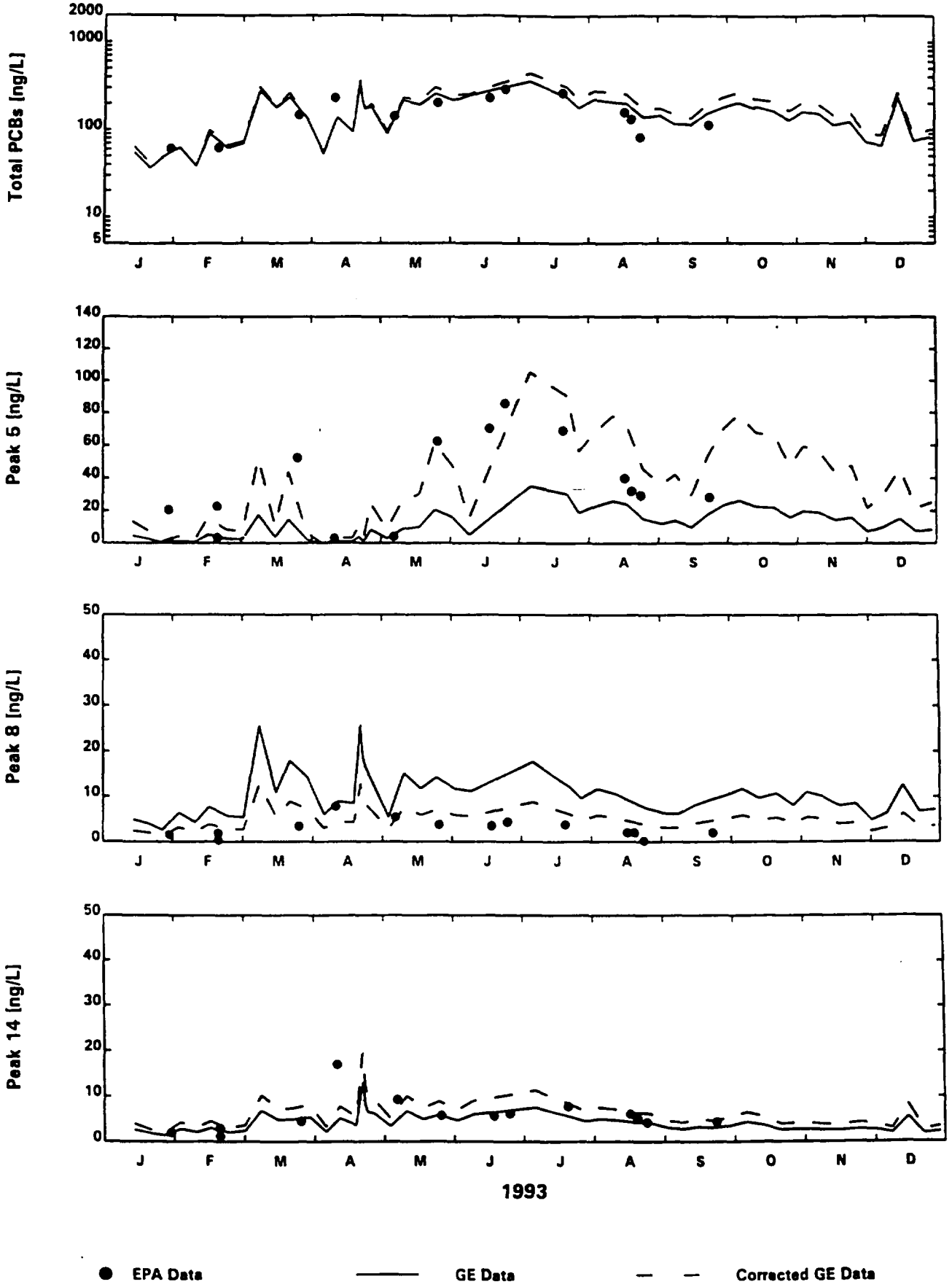
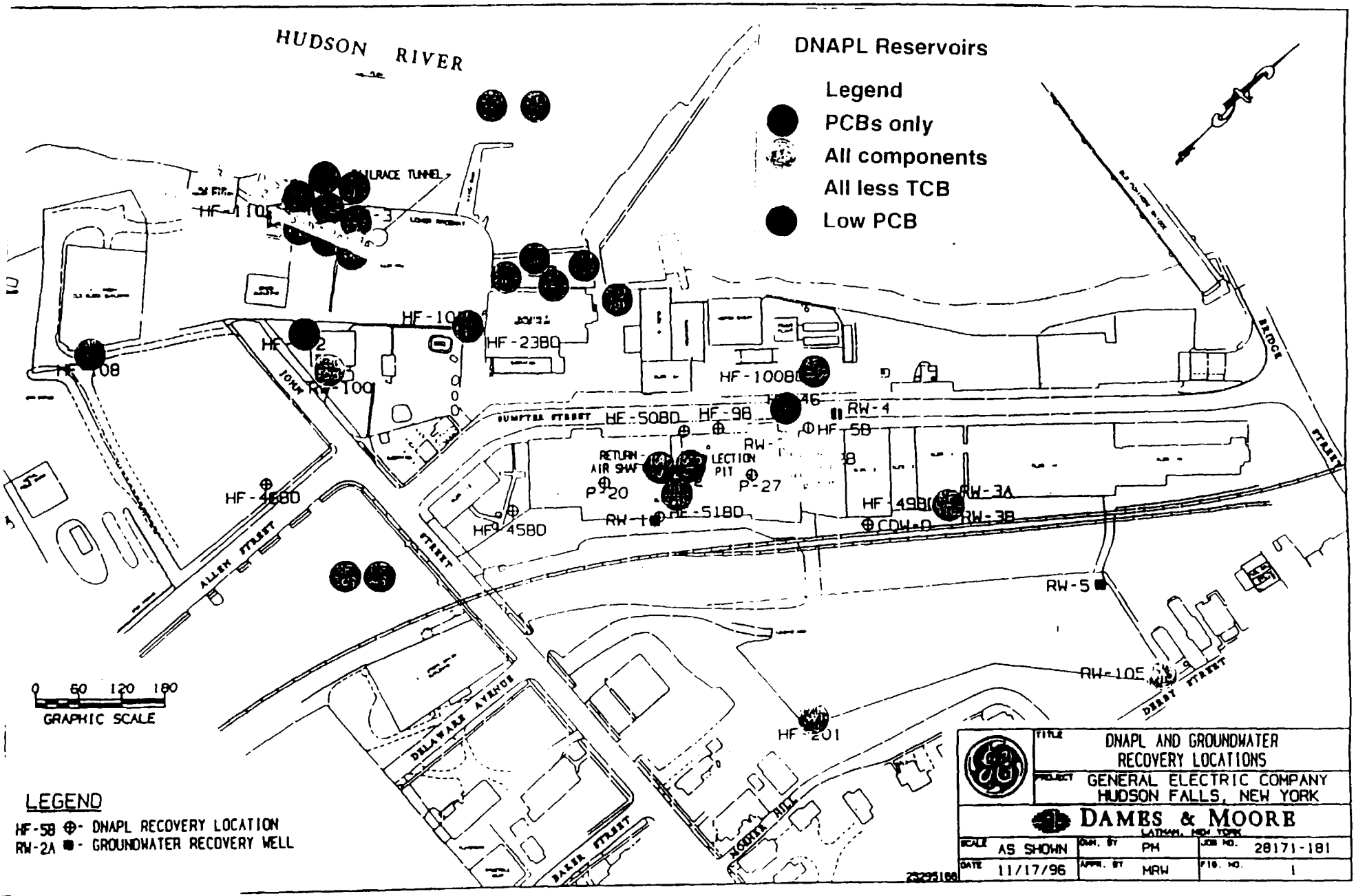


Figure A-8. Comparison of EPA, GE and corrected GE temporal 1993 water column concentrations of Total PCBs, peak 5 (BZ#4 plus BZ#8), peak 8 (BZ#8) and peak 14 (BZ#15 plus BZ#18) at the Thompson Island Dam.

Figure B-1 Map of Hudson Falls plant site indicating locations of DNAPL and groundwater recovery locations which are color coded for composition.



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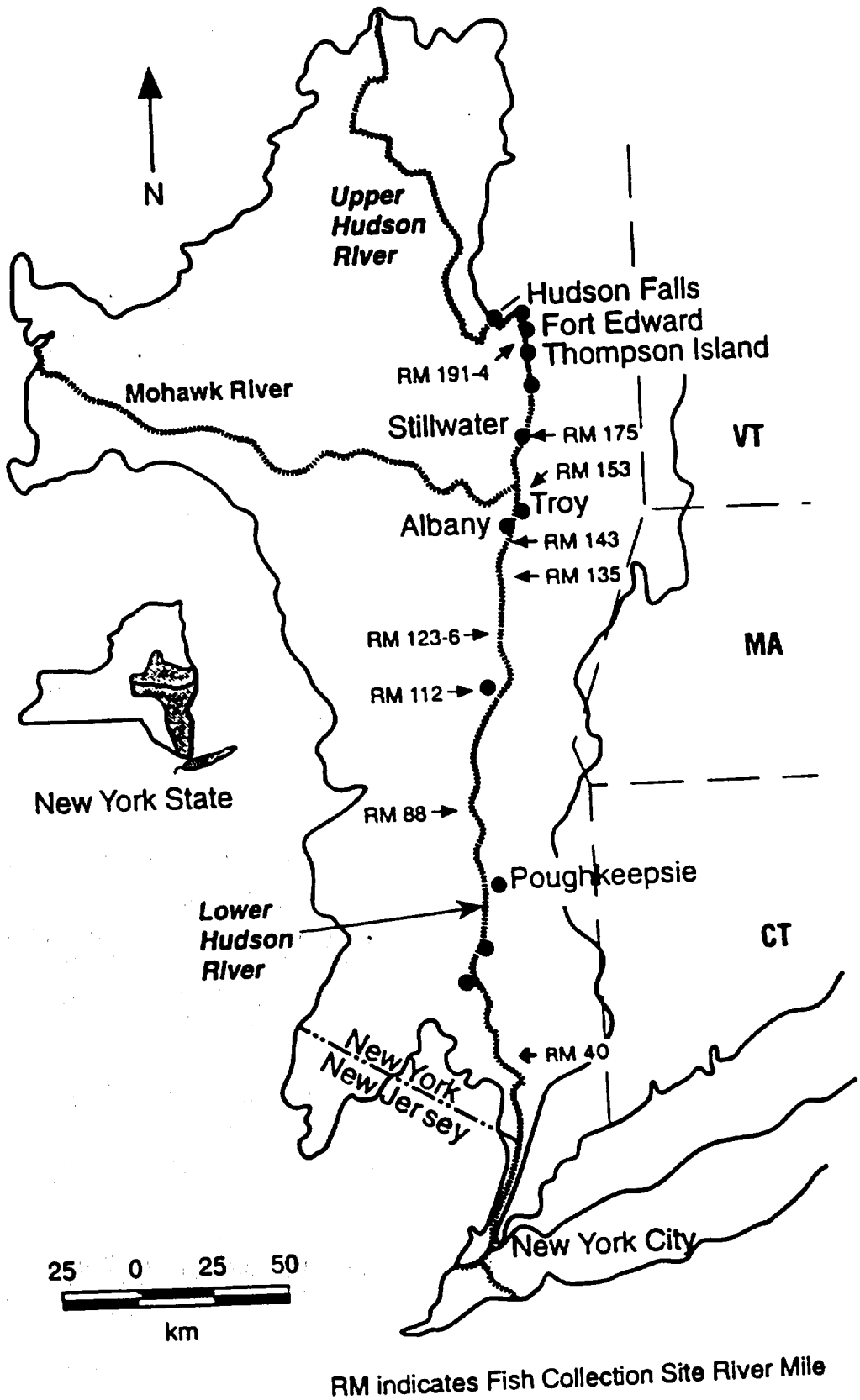
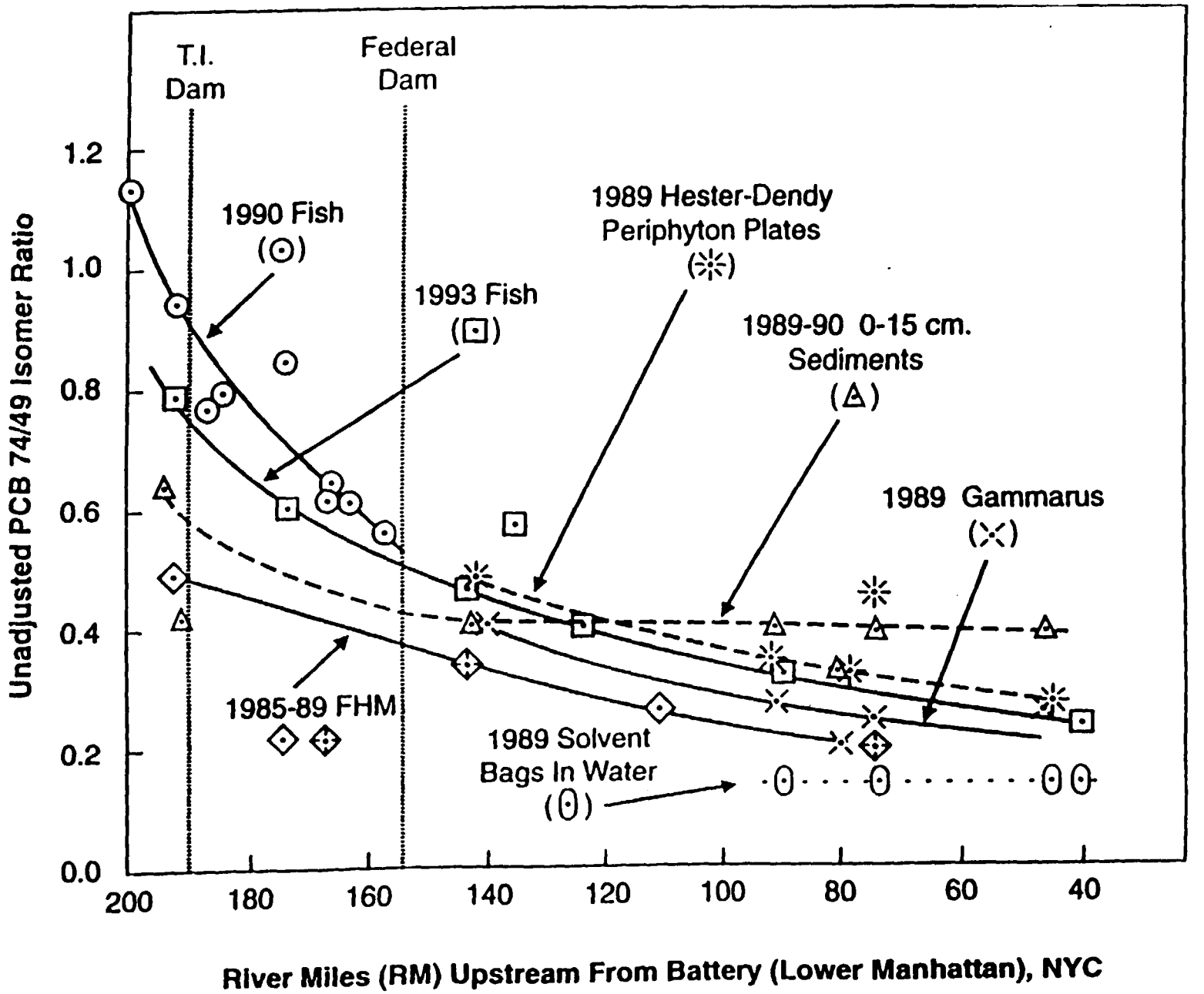


Figure C-1. Hudson River Drainage Basin.

10.0531



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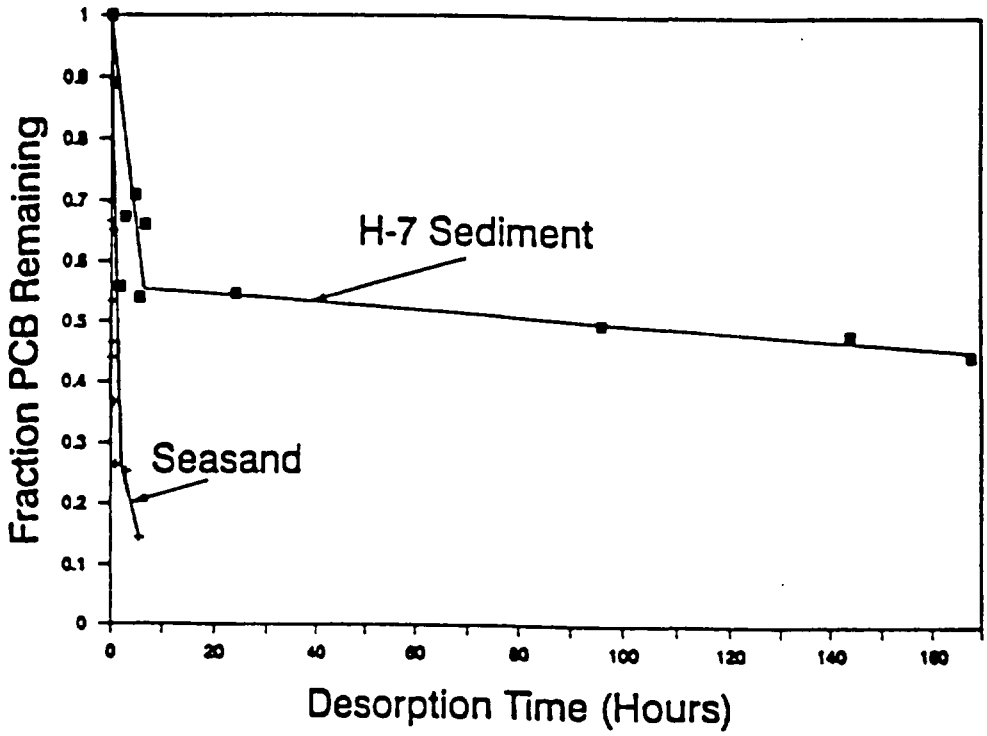

Figure D-1. Desorption of PCBs from H7 sediment compared to spiked sea sand.

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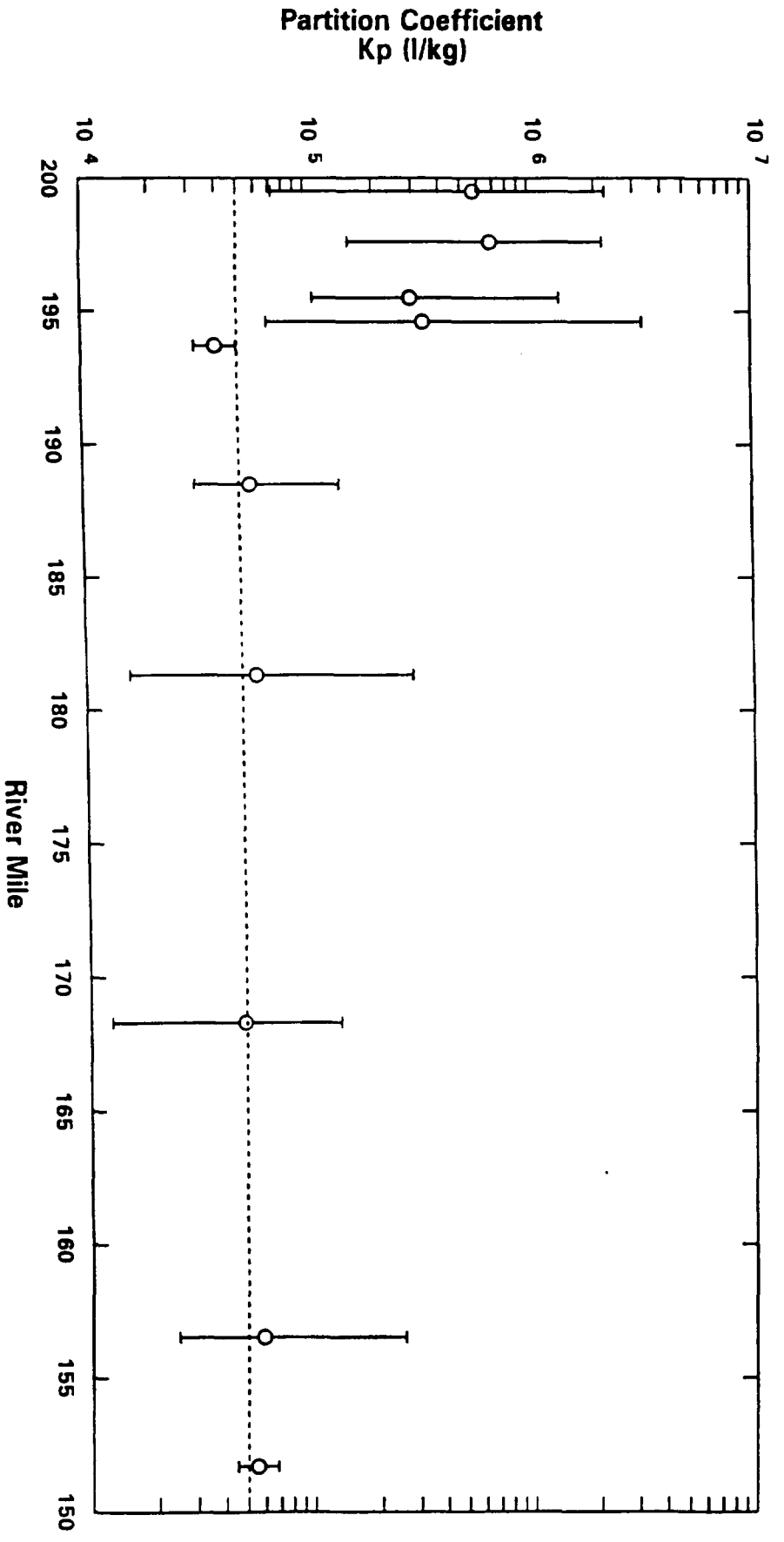

Figure E-1. Partition coefficients as a function of river mile calculated from EPA Phase 2 water column monitoring transect studies 2-6.

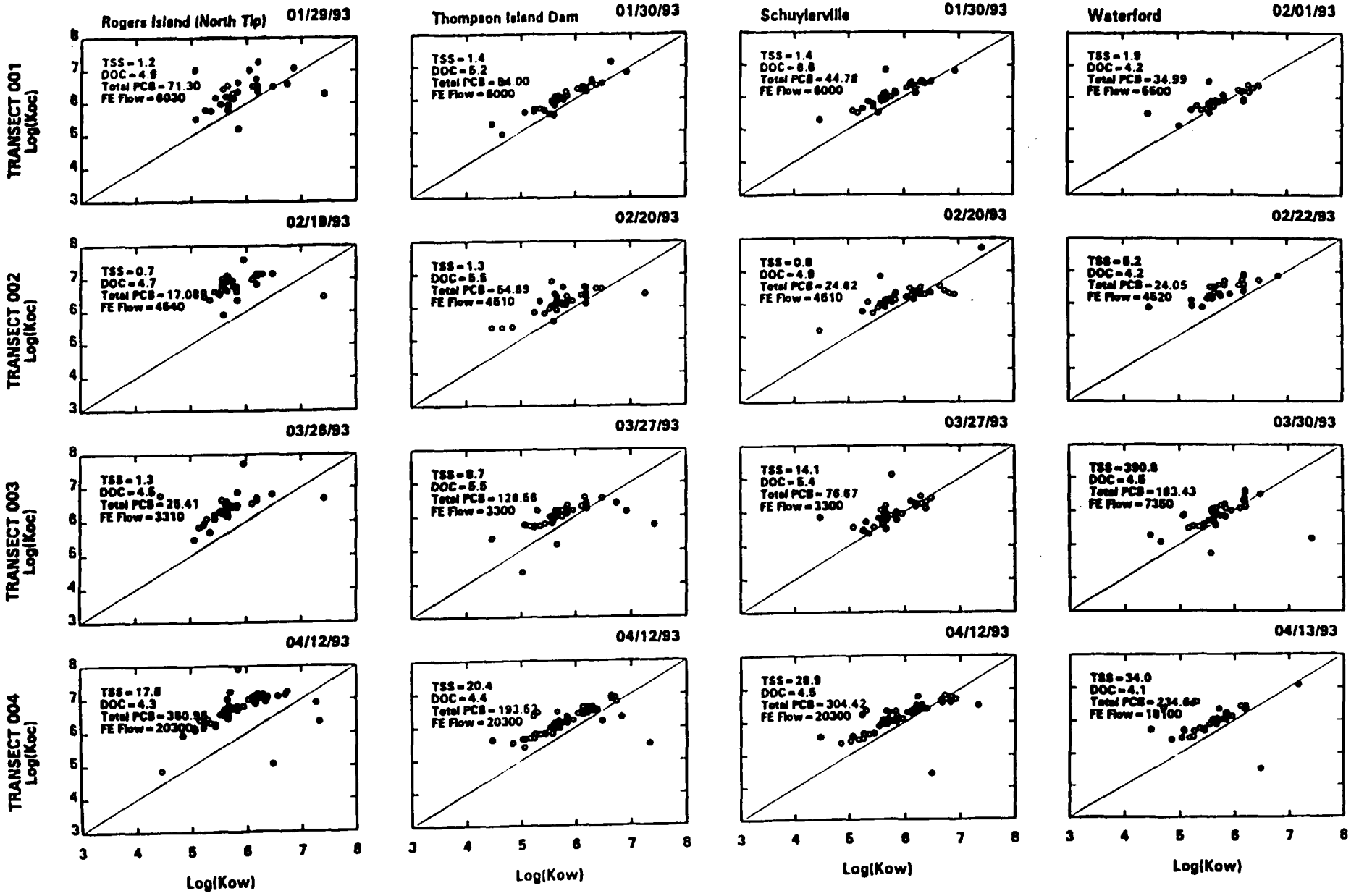

Figure E-2. The relationships between K_{oc} and K_{ow} at Rogers Island, the Thompson Island Dam, Schuylerville and Waterford from Transects 1-8; Tss in mg/L, Total PCBs in ng/L and Fort Edward in cfs.

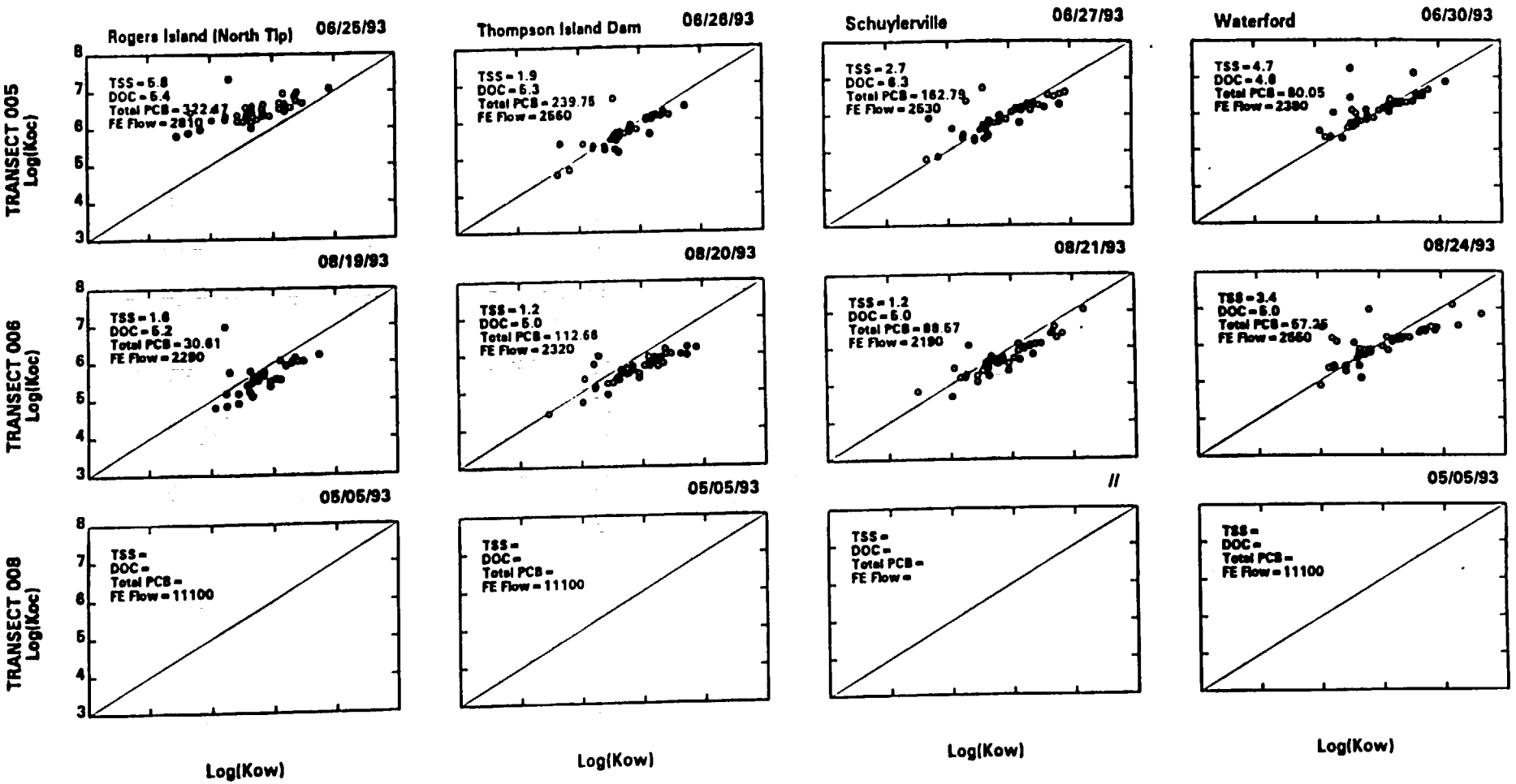

Figure E-2 (continued). The relationships between K_{oc} and K_{ow} at Rogers Island, the Thompson Island Dam, Schuylerville and Waterford from Transects 1-8; Tss in mg/L, Total PCBs in ng/L and Fort Edward flows in cfs.

Log Koc as a function of inverse Temperature

Congener 10

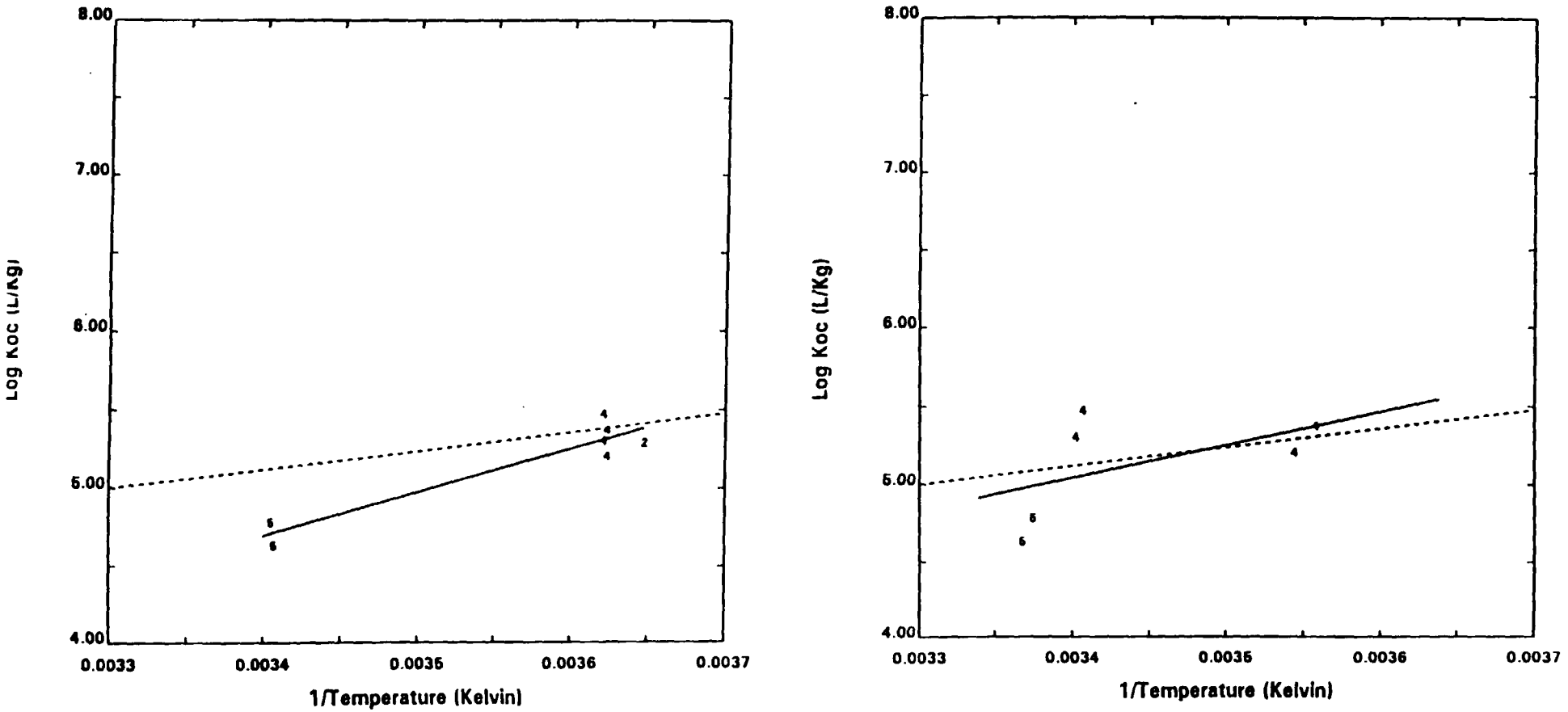

Figure E-3. Log K_{oc} of BZ#10 as a function of inverse temperature. Only Transect studies 1-6 from the Thompson Island Dam to Waterford: Left, with temperature correction; Right, without temperature correction.

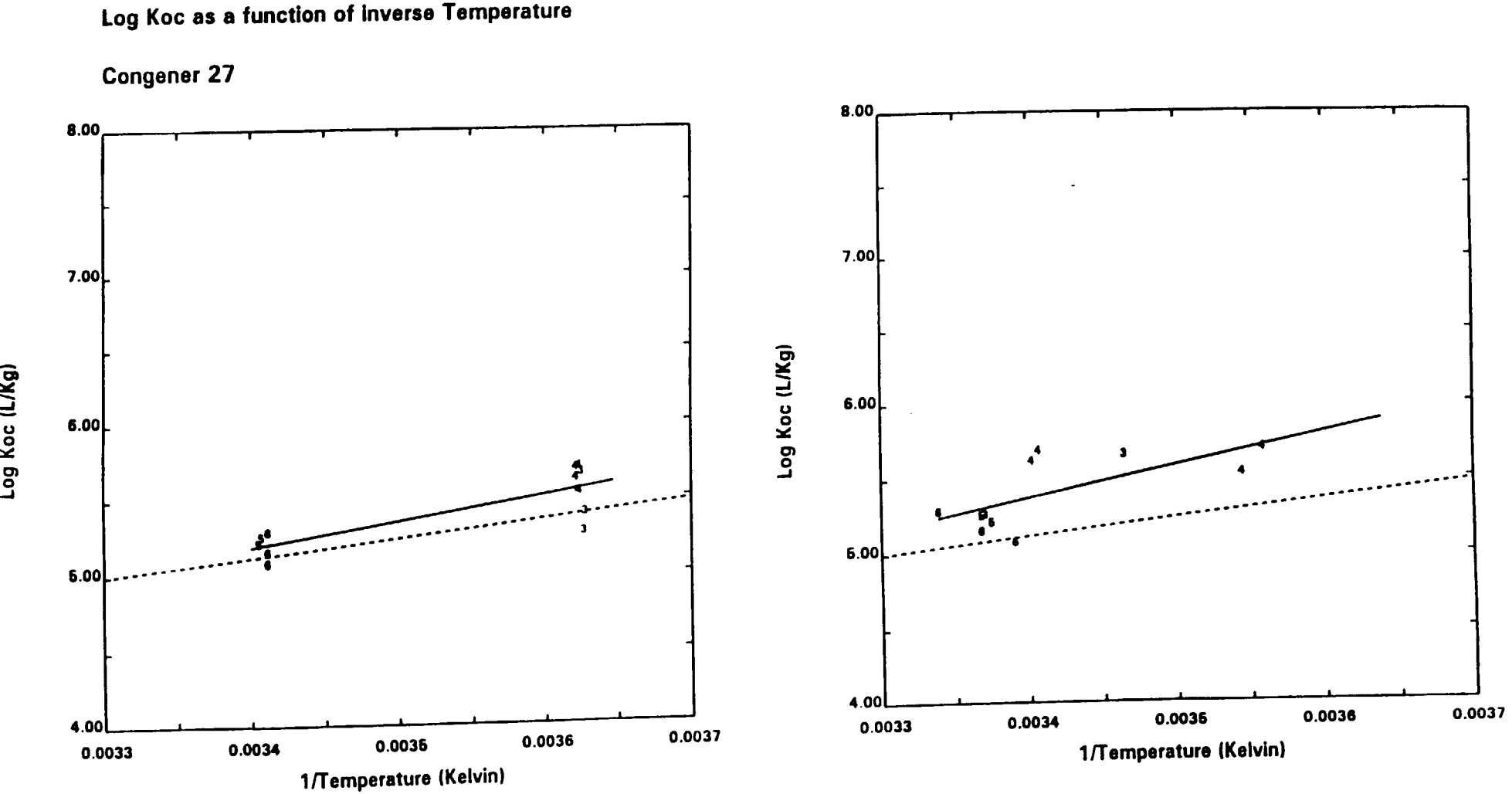

Figure E-4. Log K_{oc} of BZ#27 as a function of inverse temperature. Only Transect studies 1-6 from the Thompson Island Dam to Waterford: Left, with temperature correction; Right, without temperature correction.

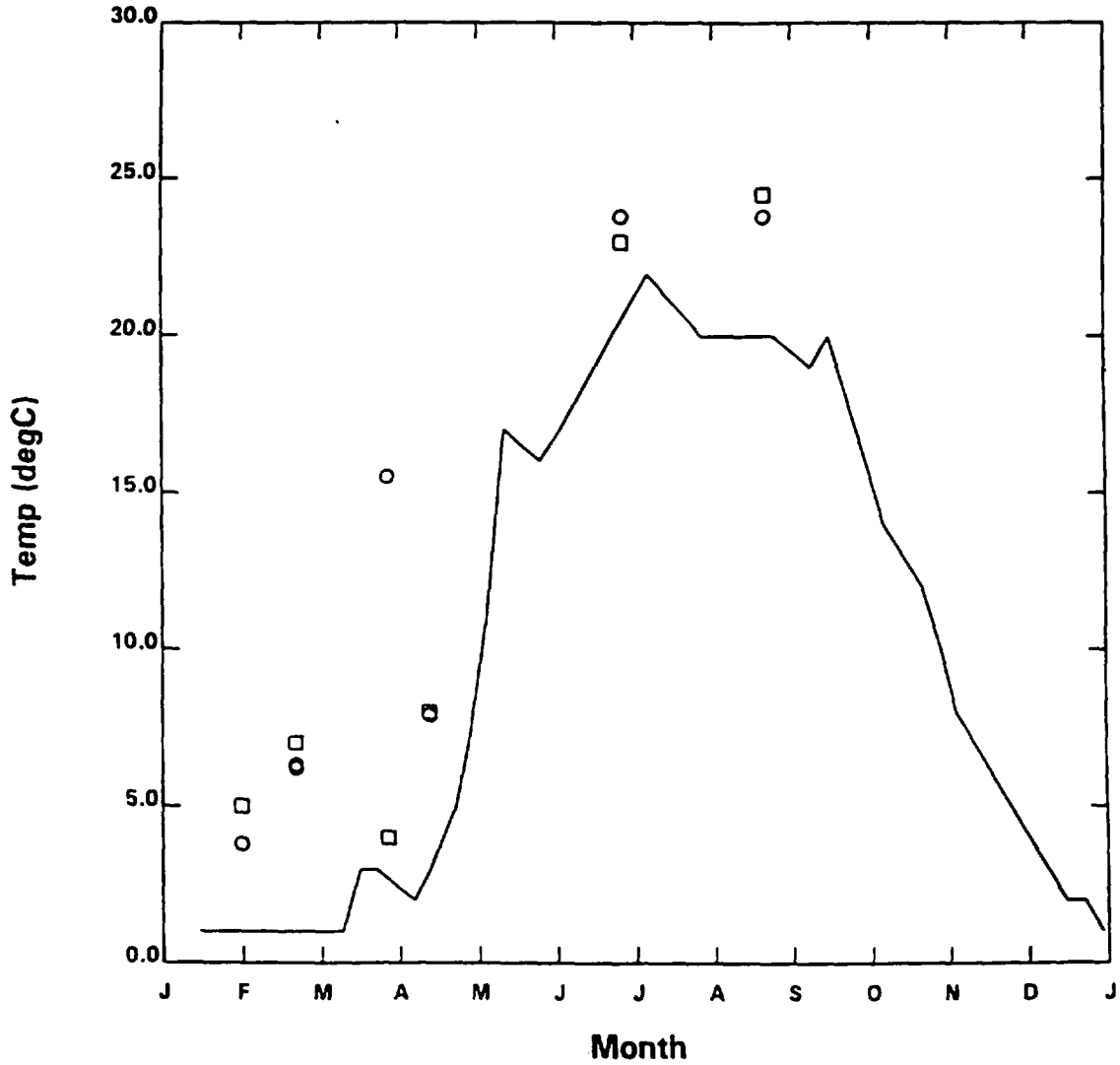

Figure E-5. Temporal temperature profile in 1993 at the Thompson Island Dam: Line GE data, ○ EPA pH meter, □ EPA DO probe.