COMMENTS OF THE GENERAL ELECTRIC COMPANY ON: PRELIMINARY MODEL CALIBRATION REPORT, REVISED APPENDIX B, MATHEMATICAL MODELING OF PCB FATE AND TRANSPORT FOR HUDSON RIVER PCB REASSESSMENT RI/FS: CURRENT MODELING WORK PLAN

I. USE OF DATA

A mathematical model of PCB fate, transport, and bioaccumulation within the Hudson River is only as reliable as the data upon which it is calibrated. While the Hudson River has been extensively studied over the last 20 years, there are a number of important data quality issues that need to be recognized and, if possible, quantified before rigorous model calibration can be conducted.

First, data comparability issues need to be addressed. These issues generally originate from changes in PCB analytical techniques over the years. Specifically, the development of PCB congener specific techniques in the late 1980s and early 1990s has made it possible to quantify individual PCB congeners. In contrast, much of the historic PCB data is based upon a PCB quantitation schemes that relied on pattern matching with commercial Aroclor products. This approach relied on the professional judgements of the analytical chemists and often missed important portions of the gas chromatogram. Most notably, the mono- and dichlorinated PCB congeners, those that make up a large proportion of the current sediment inventory and water column PCB transport, were not represented in much of the historical PCB data. A quantitative understanding as to what portion of the PCB spectrum the different data sets represent must be developed before rigorous model calibration can be conducted.

Second, the representativeness of the 1993 water column data set needs to be assessed. EPA's preliminary model calibration is based largely on water column data collected by the agency in 1993. These data represent a period immediately following a large-scale PCB loading event from the plant site area to the river that may have altered short-term PCB dynamics. For example, loadings from the plant site may have elevated surface sediment PCB concentrations

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and artificially elevated sediment-water interactions over that which occurred historically. Hence, calibration of the model to this data set may over predict sediment-water interactions. This may have a profound effect on the selection of appropriate remedial strategies for the system. To limit the impact of this potential bias, the models must be calibrated to the full data record for all media (fish, sediment, water column).

Finally, the water column data collected by the EPA in 1993 contains a sampling bias which future model calibration efforts must take into account. Data collected from the shore-based water column sampling station at Thomson Island Dam (TID) is biased high by approximately 60% and appears to vary seasonally. This is based on extensive water column monitoring within the area during 1997 and 1998. The sampling bias is likely the result of incomplete lateral mixing of a sediment PCB source located in a quiescent backwater area immediately upstream of the sampling station. The model calibration process must place greater emphasis on unbiased data collected from the TID region since fall 1997.

II. SEDIMENT TRANSPORT MODELING

The best way to simulate sediment transport in the Upper Hudson River is to use a mechanistic model that utilizes independent, data-based formulations to describe resuspension and deposition processes. The state-of-the-science in sediment transport modeling, combined within extensive Upper Hudson River data sets, makes it possible to successfully apply this type of model to the Upper Hudson River. EPA plans to use a mechanistic model, with site-specific data, to evaluate depth of scour in the Thompson Island Pool caused by rare floods.

The "Current Modeling Work Plan" indicates that an empirical procedure will be used to develop resuspension and deposition formulations in EPA's Upper Hudson River sediment transport model. Deposition and resuspension processes will be quantified by developing settling and resuspension velocity relationships that are functions of flow or velocity. The settling and resuspension velocity functions will be calibrated using suspended solids data collected during the 1994 spring flood. Complex spatial and temporal variations in resuspension and deposition processes will make credible development and calibration of settling and resuspension velocity functions, which yield accurate and realistic modeling simulations, extremely difficult. This empirical approach is problematic and should not be used.

If EPA chooses to use an empirical method for quantifying resuspension and deposition processes in the HUDTOX model, then the settling and resuspension velocity functions must be properly developed. At a minimum, credible development of the settling and resuspension velocity functions requires incorporation of the following processes and phenomena. (1) Bed armoring is a process that limits the amount of resuspension at a given bottom shear stress (current velocity) due to such factors as bed particle size heterogeneity and cohesive sediment properties. Neglecting bed armoring effects in the resuspension velocity function will cause significant overestimation of erosion during a flood. (2) The time history of bed properties affects the erosional characteristics of the sediment bed. A resuspension velocity function that ignores temporal changes in bed erosion properties will produce highly uncertain results. (3) Spatial and temporal variability in the composition of suspended solids, i.e., clay/silt/sand fractions, causes complex changes in deposition rates at a particular location. Neglecting water column composition effects on deposition processes will produce a settling velocity function that is unrealistic and inaccurate.

General Electric has developed an Upper Hudson River sediment transport model that is mechanistic and uses data-based formulations to realistically describe resuspension and deposition processes. This model has been rigorously calibrated and validated. Results from the GE model can be used to illustrate the extreme difficulty EPA faces in the credible development of settling and resuspension velocity functions.

A long-term simulation, from 1977 to 1998, of sediment transport in the Thompson Island Pool was performed with the GE model. Results of the long-term simulation were analyzed to determine the effective daily-average resuspension rate and settling velocity in a section of the Thompson Island Pool. The daily-average resuspension rates and settling velocities as a function of flow rate are presented on Figures 1 and 2, respectively. The underlying structure of the resuspension and settling velocity functions is non-linear and discontinuous. Superposed on this underlying structure is a stochastic component that is caused by temporal variations in resuspension and deposition. These results clearly demonstrate that credible development of empirical resuspension and settling velocity functions for use in EPA's HUDTOX will be very difficult, if not impossible.

III. MODEL-DATA COMPARISONS

The "Current Modeling Work Plan" provides a general description of the procedures to be used for model calibration. These procedures include calibration of the sediment transport model to TSS data collected in 1994 and 1997 and calibration of the PCB fate model to water column PCB data collected between 1977 and 1997 and sediment data collected in 1984, 1991 and 1994. Although it is important to compare the model to all of the available data, the manner of comparison and the particular focus given to portions of the data set are also relevant to the accuracy of the final model. In particular, the following model-data comparisons are critical to the development of the model.

A. Water Column PCB Concentrations During Flood Events

The work plan indicates that resuspension and deposition rates will be developed through calibration of the sediment transport model. However, the process of calibration only defines the difference between these rates (i.e., the net flux of sediment between the water column and the bed). Absent an independent definition of these sediment transport processes (as was done in the Depth of Scour Model), the proposed approach is insufficient to define resuspension and deposition rates. Further, even the difference between these rates is subject to uncertainty because errors in external solids loading will result in over or underestimation of the net flux of sediment between the water column and bed. To evaluate whether the chosen rates are reasonable, it is critical that the computed resuspension of PCBs be evaluated by comparison to data. This may be accomplished by comparing computed and observed water column PCBs during flood events. Data exist for a number of these events.

B. Long-Term Deposition Rates

The sediment transport model will be calibrated using data for the 1994 high flow event. This calibration will not evaluate whether the model computes accurate long-term (multi-year) sediment deposition and erosion rates. Such evaluation can be accomplished by simulating the period of record (1977-1997) and comparing the spatially-variable average net deposition to the net deposition rates that have been determined from sediment cores collected by EPA in 1992 (the "high resolution" cores). This comparison is important because burial of contaminated sediment is potentially the primary natural recovery process for the river.

C. Spatial Profiles of Water Column PCBs During Low River Flow

PCBs are transferred between the sediment and the water column during low flow by mechanisms that are poorly understood. As a result, this process is quantified through model calibration. Because the process is important to downstream PCB transport and exposure to biota, it is critical that rigorous calibration be conducted. This calibration involves adjusting the mass transfer coefficients defining the flux to reproduce the changes in water column concentrations observed between stations. Care must be taken to fit the seasonal changes in flux apparent in the data, as well as the changes that occur over the multiple years.

IV. PCB BIOACCUMULATION MODELING

There are two components to the bioaccumulation modeling program, the computation of average PCB levels in the fish, and the computation of the variability in PCB levels within fish populations. In the Preliminary Model Calibration Report (PMCR), EPA focused their attention on two steady state models, the Bivariate Statistical Model (BSM, used to compute average PCB levels) and the Probabilistic Food Chain Model (PFCM, used to compute average levels and variability). EPA was also exploring the use of a mechanistic model developed by Gobas to compute average PCB levels. In the "Current Modeling Workplan", EPA continues on this track, focusing on the steady state models, with continued exploration of the Gobas model as well as the model developed by QEA for General Electric Co.

Steady-state statistical models do not provide an appropriate basis for predicting average PCB levels in the upper Hudson River, and therefore are not an appropriate basis for a scientifically credible decision. A time-variable mechanistic model should be used. The uncertainty in average PCB levels can also be computed using a calibrated mechanistic model. Such a model has been developed and is being calibrated by General Electric Co. and is available to EPA. A copy of the slides from a platform presentation describing the QEA model, delivered at the Annual Meeting of the Society for Environmental Toxicology and Chemistry in November, 1997, is attached.

The PFCM is not constructed properly, resulting in computed distributions with no physical meaning. Variability in PCB levels should be computed directly from the extensive historical NYSDEC database. In fact, the NYSDEC data is even sufficient to estimate the uncertainty associated with estimates of variability.

These points are elaborated below.

A. Average levels

PCB levels in the sediment, water and biota of the upper Hudson River are not at steady state.

The Hudson River has exhibited extreme variation in exposure levels (water column in the early 1990s) as well as lipid content of fish (see the figures in the attached presentation). PCB levels in the food web do not respond immediately to changes in these parameters, so PCB levels measured in fish at any point in time may be in the process of responding to changes in exposure levels. That is, the steady state assumption is violated. Therefore, a time-variable model is required.

The calibration of the BSM indicates that it will not be useful in predicting fish levels without additional information.

The limitations of the steady state approach became evident in the calibration of the BSM presented in the PMCR. First, the BSM has no predictive power within Thompson Island Pool, based on the observation that there is no relationship between observed and computed largemouth bass Aroclor 1254 levels (Figure 9-12 of the PMCR). Second, the pattern of observed vs. predicted values differs among reaches. Without further study into the mechanisms underlying bioaccumulation, it is not clear why the bioaccumulation model should differ in its predictions among reaches. Finally, the model overpredicts at low concentrations (Figure 9-12). PCB levels are now declining in the Hudson River (Figure 1). Thus, it is anticipated that the model will overestimate the data in projections. Based upon these problems, it is clear that the model cannot provide useful predictions of natural recovery or of the impacts of remediation activities.

The statistical models can be improved only by the collection of additional data. Mechanistic models can also be improved by independently-derived constraints on parameter values.

The calibration of a mechanistic model is an exploration of the biological and chemical processes underlying the transfer of PCBs through the food web. Parameter values are constrained by the results of laboratory and field experiments: It is NOT true that the "knobs", or parameters, can be twirled arbitrarily. As for a statistical model, the collection of additional data may improve a calibration. However, that is the only way to improve a statistical model. All of our accumulated knowledge and understanding plays no part in the development and calibration of a statistical model, but aids in improving and understanding the behavior of a mechanistic model.

A mechanistic model can be and has been developed, and is available.

QEA has developed and is in the process of calibrating a mechanistic, time-variable, full life-cycle model of the bioaccumulation of PCBs in the aquatic food web of the upper Hudson River. Published species-specific values for respiration rates, species- and site-specific measurements of growth rates, extensive natural history information on diet and food web structure, as well as the results of several decades of laboratory and field research concerning toxicokinetic processes provide the information necessary to constrain and calibrate the model.

Should multiple models be used?

It is in general good scientific practice to check for consistency among differing approaches to a given problem. However, this is true only insofar as the modeling tools are developed properly and (at least to some degree) independently, and add useful information. As described in this document and in GE's original comments concerning the PMCR, there are serious limitations to the BSM and PFCM approaches that limit their utility. In addition, a mechanistic model incorporates *all* of the information that is in the steady state models (that is, measured PCB levels, dietary information), *as well as* ancillary information (bioenergetics, toxicokinetics, and time-variable processes).

Therefore, we suggest strongly that EPA's efforts focus on the use of a time-variable mechanistic bioaccumulation model. General Electric Co. has offered the use of the model developed by QEA.

B. Variability

The development of the PFCM confuses variability with uncertainty.

For example, the computed distribution of biota-sediment bioaccumulation factors (BSAFs) should provide a representation of the distribution of invertebrate PCB levels as seen by the fish. The BSAF distribution used in the PFCM was determined directly from the data, even though the variance in the data is due in large part not to the true variability in the sediment/invertebrate relationship, but to the uncertainty that arises because the sediment and invertebrate samples were not at collected at exactly the same location, because the species composition of the samples may not be the same as the species composition of the diet of the forage fish, and because of analytic uncertainty.

Because of this confusion, the resulting distribution of BSAF values has no physical meaning.

The PFCM requires the answer to solve the problem.

The predator/forage fish bioaccumulation factor (PFBAF) was determined using the observed distribution of predator PCB levels. However, the whole purpose of the model is to compute the distribution of predator PCB levels. Thus, the model provides no additional information beyond what is already in the data.

The PFCM is not predictive.

The parameters that determine the spread, or variance, of the computed PCB levels are constants that are validated by comparison with the distribution of the data. The computed spread and shape of each distribution will not change in the future, even as average sediment and water column PCB levels decline. Therefore, the model does not provide any information that is not provided by the data themselves.

Variability and the uncertainty in the variability should be estimated directly from the DEC data.

Because the PFCM does not add information and is improperly constructed, variability should be estimated directly from the data. There are many years of PCB data for three species at several locations. Collections often consisted of approximately 20 fish per species per location per year. These data are sufficient to estimate the average variability. They are even sufficient to estimate the uncertainty associated with estimates of variability.

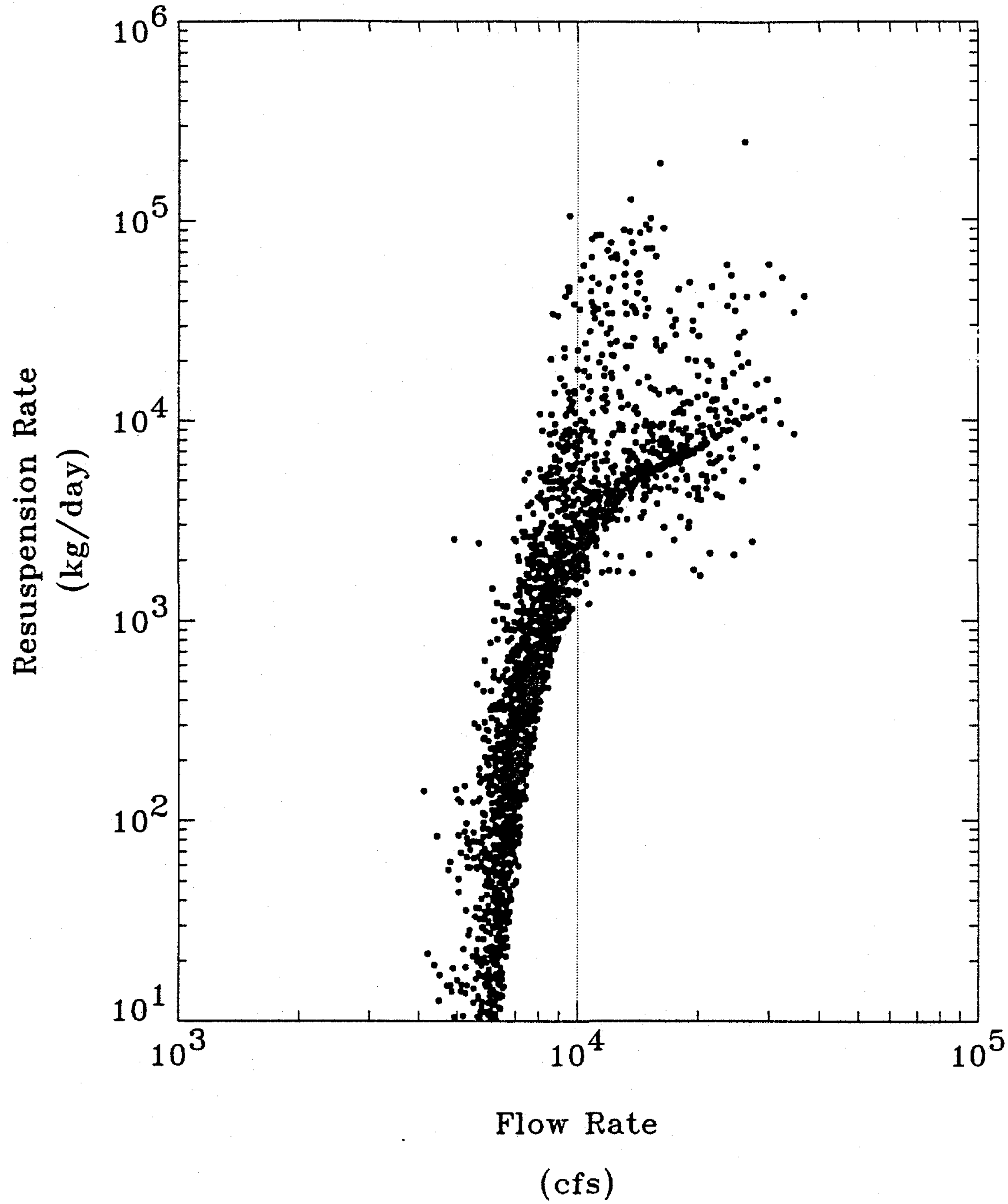

Figure 1. Predicted resuspension rates for a section of the Thompson Island Pool for the period January 1, 1977 to March 24, 1998.

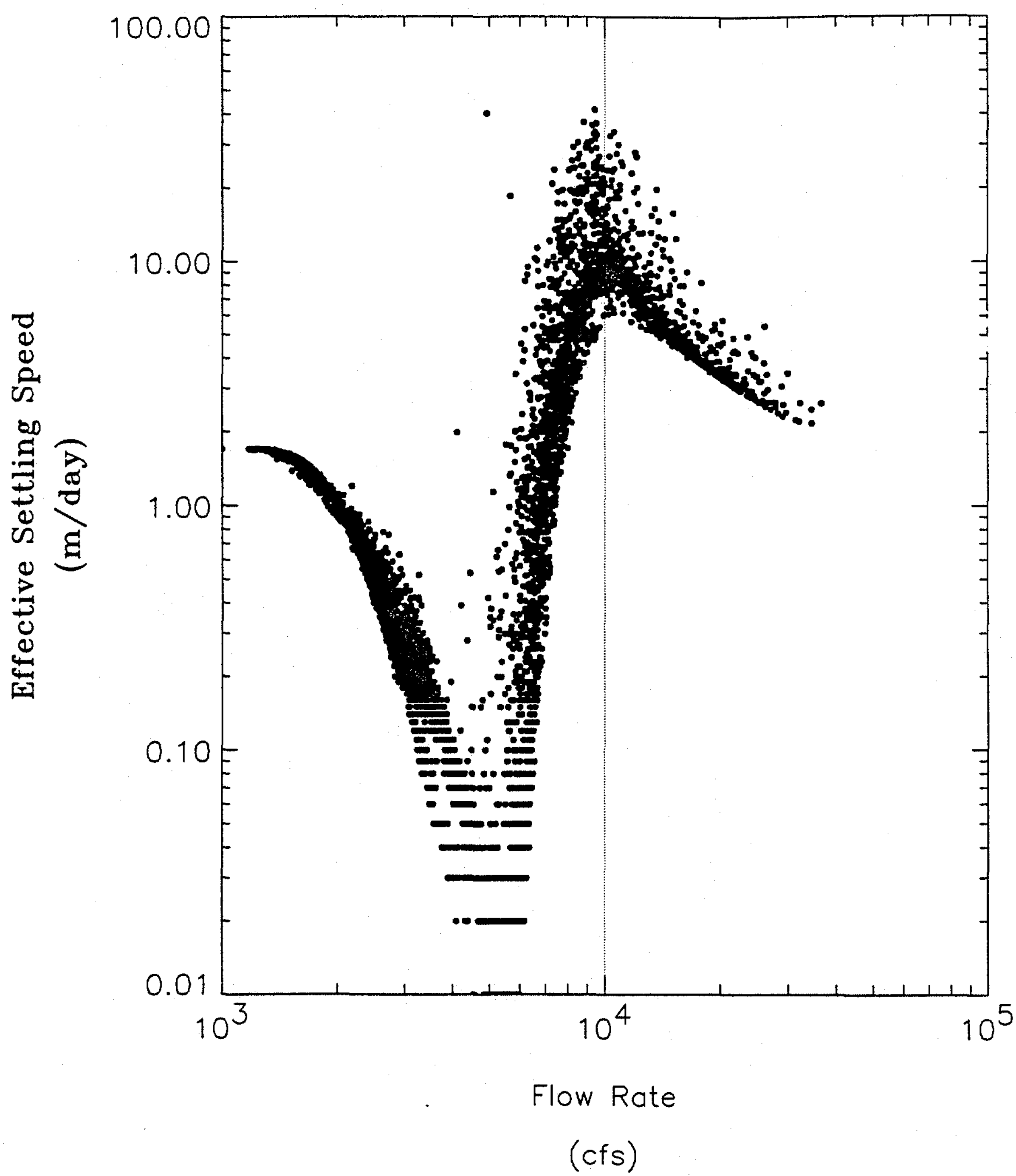

Figure 2. Predicted effective settling speeds for a section of the Thompson Island Pool for the period January 1, 1977 to March 24, 1998.

Development of a Quantitative Bioaccumulation Model for PCBs in Fish from the Upper Hudson River

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John Connolly
HydroQual, Inc.

John Haggard
General Electric Co.

November 18, 1997

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GOAL

- To Predict Changes in PCB Levels in Hudson River Fish Under:
  - natural recovery
  - remediation

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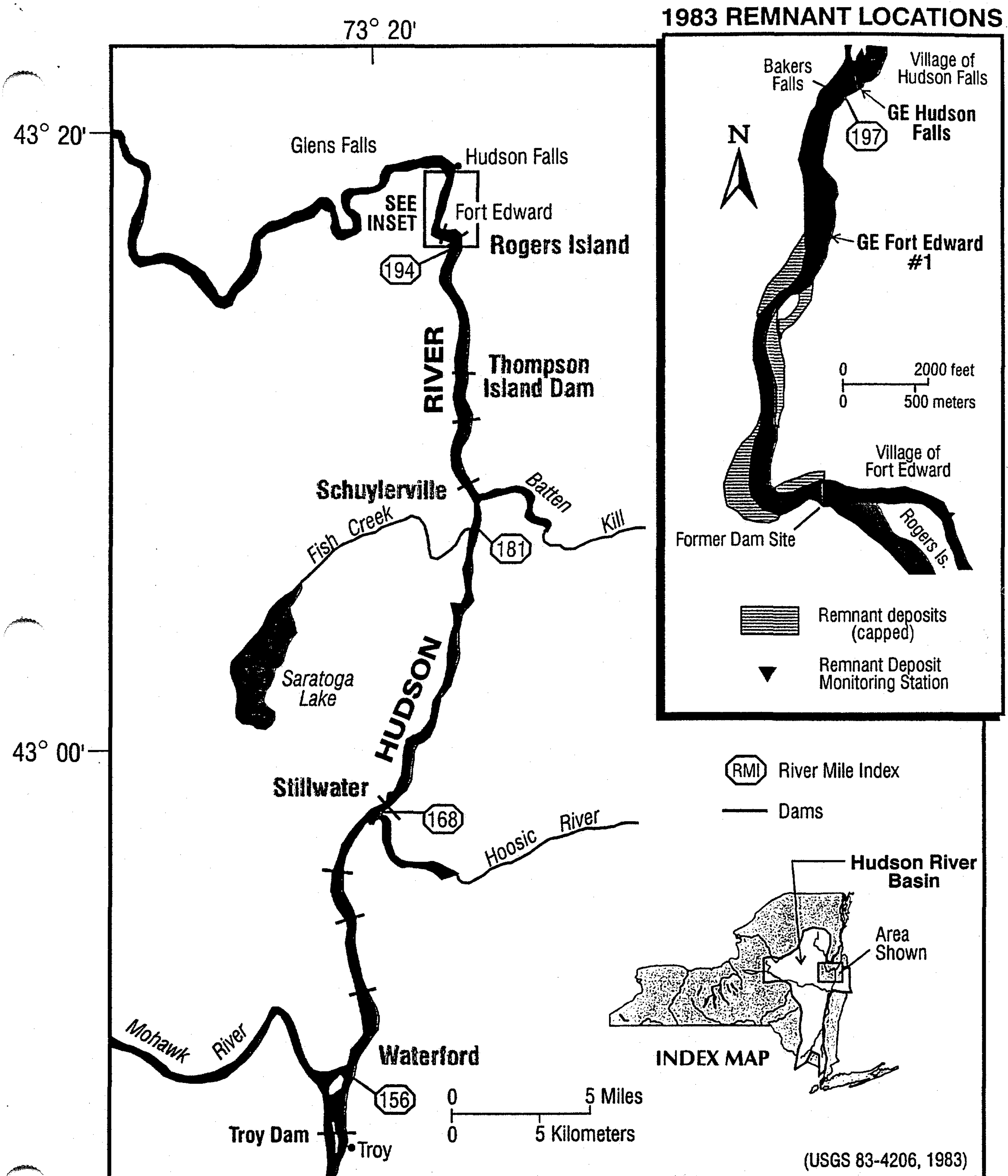
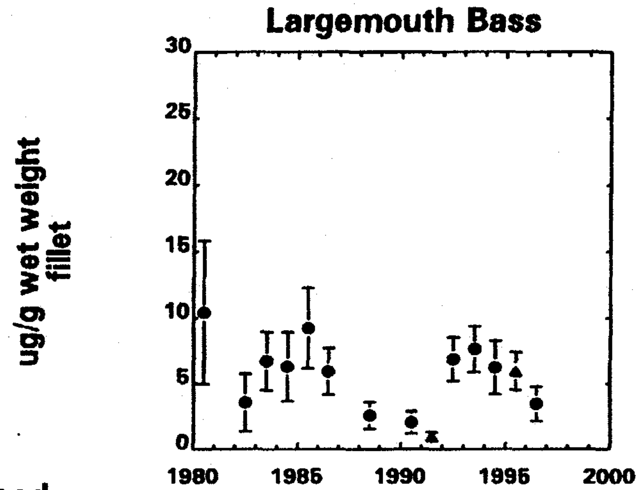
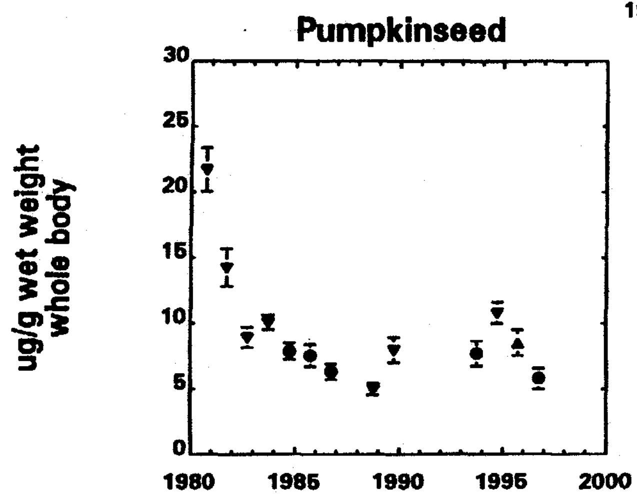
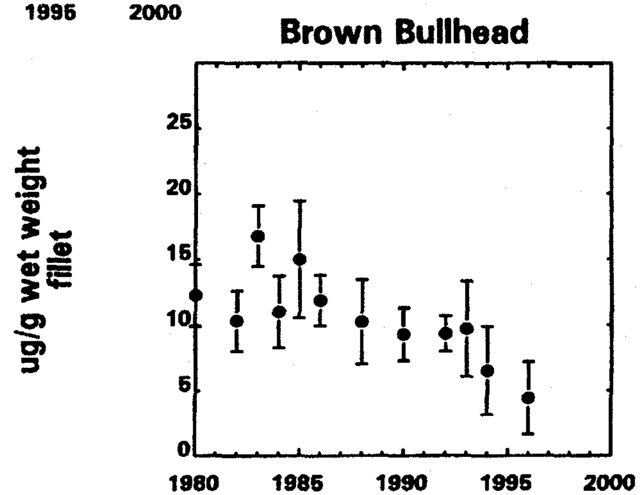


UPPER HUDSON RIVER

FOOD WEB MODEL-
TOTAL PCB AT STILLWATER







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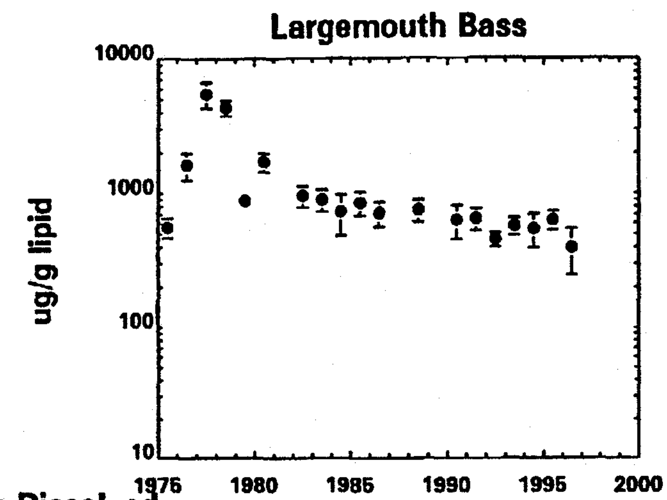
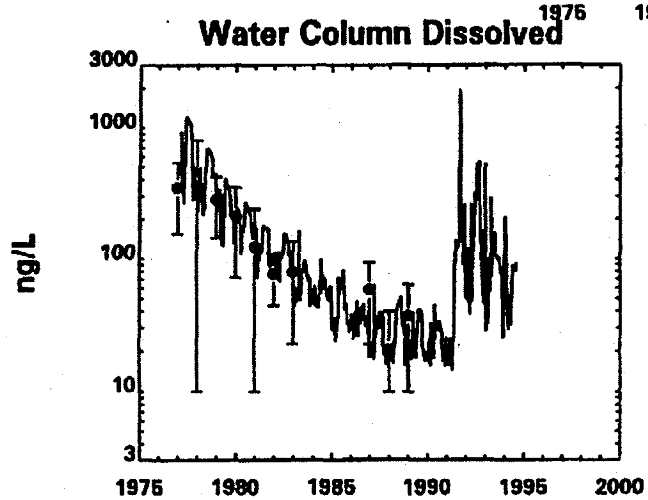
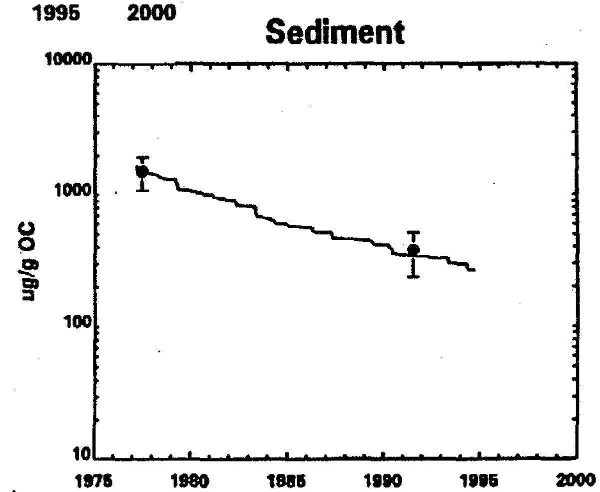
FOOD WEB MODEL-
TOTAL PCB AT STILLWATER







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APPROACH:

Develop a Toxicokinetic Model:

- Time-Variable
- Physiologically-Based
- Full Life-Cycle
- Full Food Web

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INFORMATION NEEDED:

- Food Web Structure
- Exposure Sources
- Fish Movement
- Model Parameters
- Calibration Data

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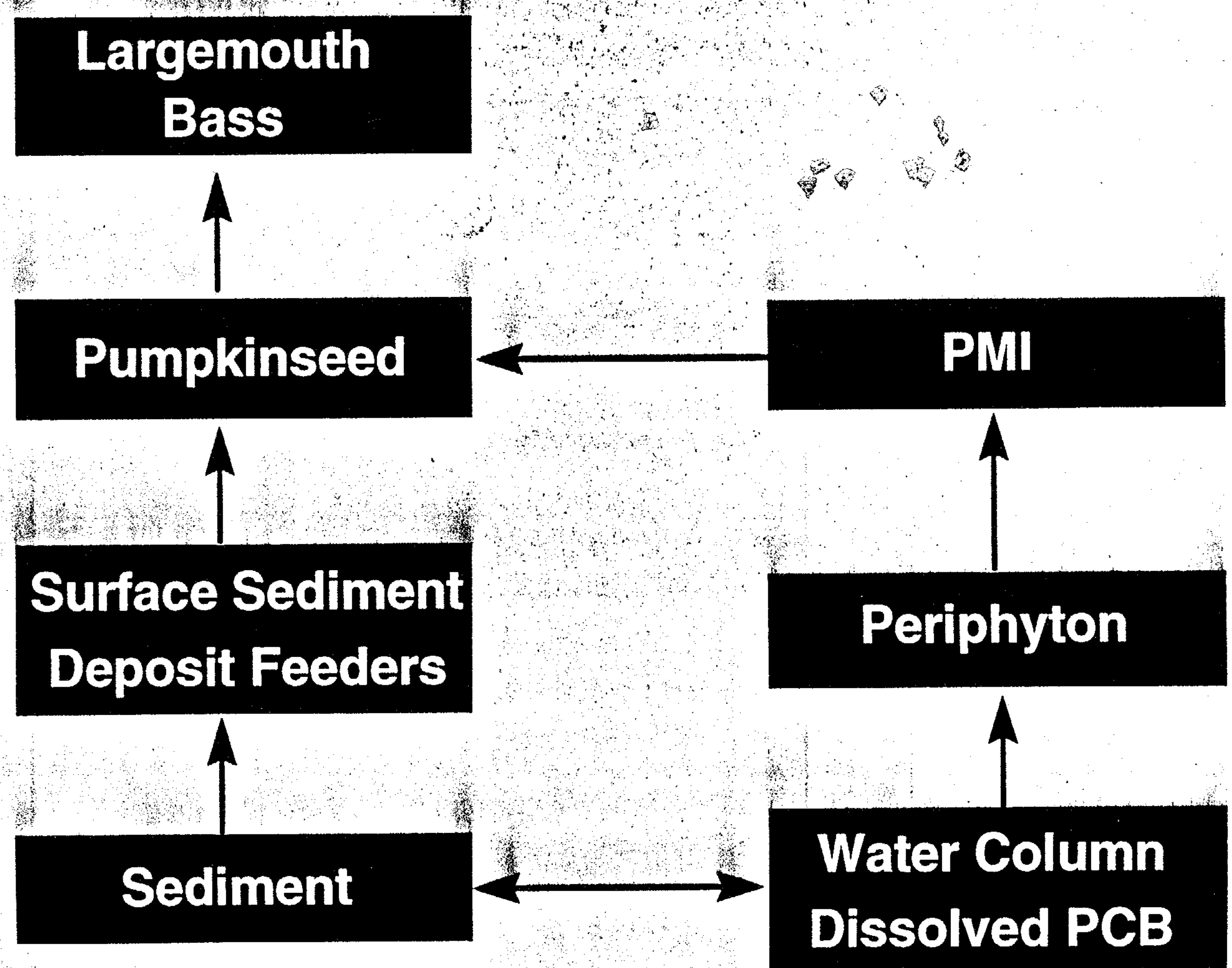
FOOD WEB STRUCTURE



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EXPOSURE SOURCES

- Dissolved PCBs in the Water Column
- Particulate PCBs in the Water Column
- Particulate PCBs in the Sediment

EXPOSURE SOURCES - KEY ISSUES

- Relative Importance of Water Column vs. Sediment Bed Particulates

  Dietary Composition (published and EPA data)
  - Pumpkinseed - mixed diet
  - Brown Bullhead - bottom feeder
  - Largemouth Bass - predator

  Model Calibration

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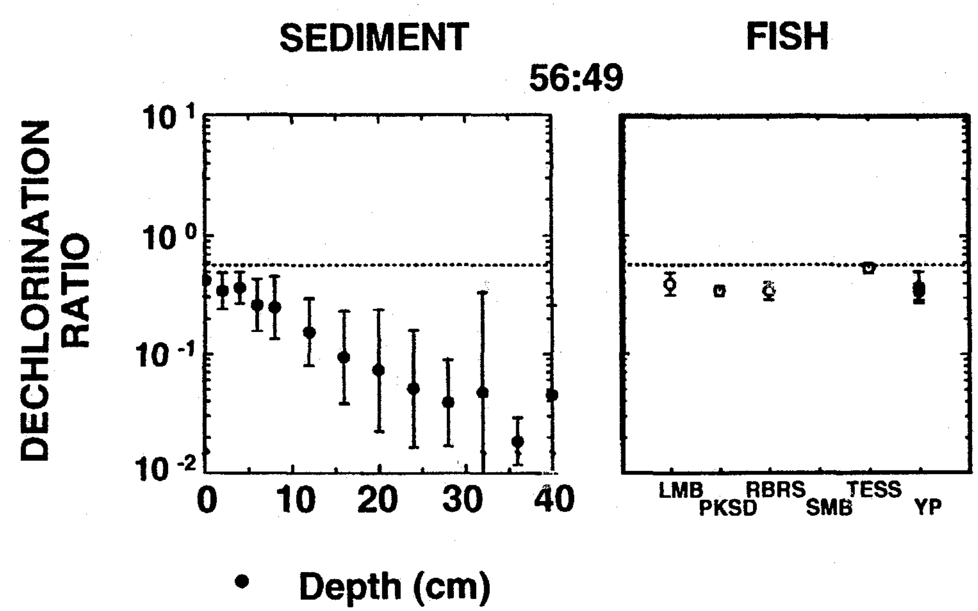
EXPOSURE SOURCES - KEY ISSUES

- Depth of Bioavailable Sediment

  Natural History of Benthic Invertebrates - Most Feeding Probably Occurs in the Top 2 cm

EXPOSURE SOURCES - KEY ISSUES

- ...Depth of Bioavailable Sediment
  Congener Signatures of Fish and Sediments



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EXPOSURE SOURCES - KEY ISSUES

- ...Depth of Bioavailable Sediment

Performance of Homolog-based PCB Models (later)

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FISH MOVEMENT

- Limited by Dams
- Fish are exposed to pool-average sediment and water PCB levels

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MODEL PARAMETERS

Base of the Food Web:

	BASIS
• Benthic invertebrate BAF	UHR data (EPA)
• Particulate/periphyton BAF	UHR data (EPA)
• Water Column invertebrate BAF	Green Bay Data

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MODEL PARAMETERS

UPPER TROPHIC LEVELS:	BASIS
• Fish respiration	Published species-specific laboratory data
• Fish Growth	UHR data (GE)
• Fish lipid content	UHR data (NYDEC)
• Chemical assimilation effeciency (gut)	Published measurements
• Chemical assimilation efficiency (gill)	Previous experience

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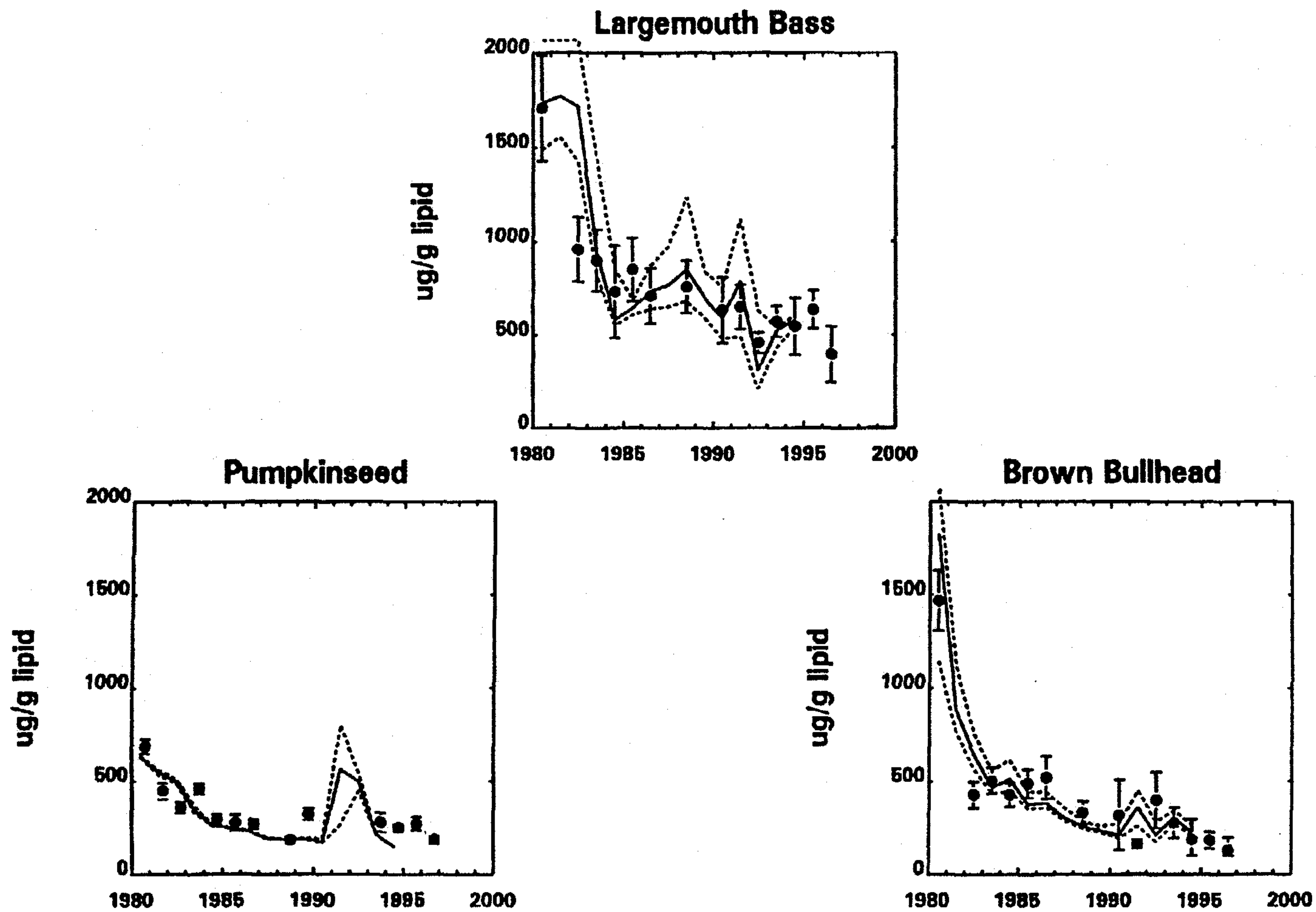
FOOD WEB MODEL- TOTAL PCB AT STILLWATER



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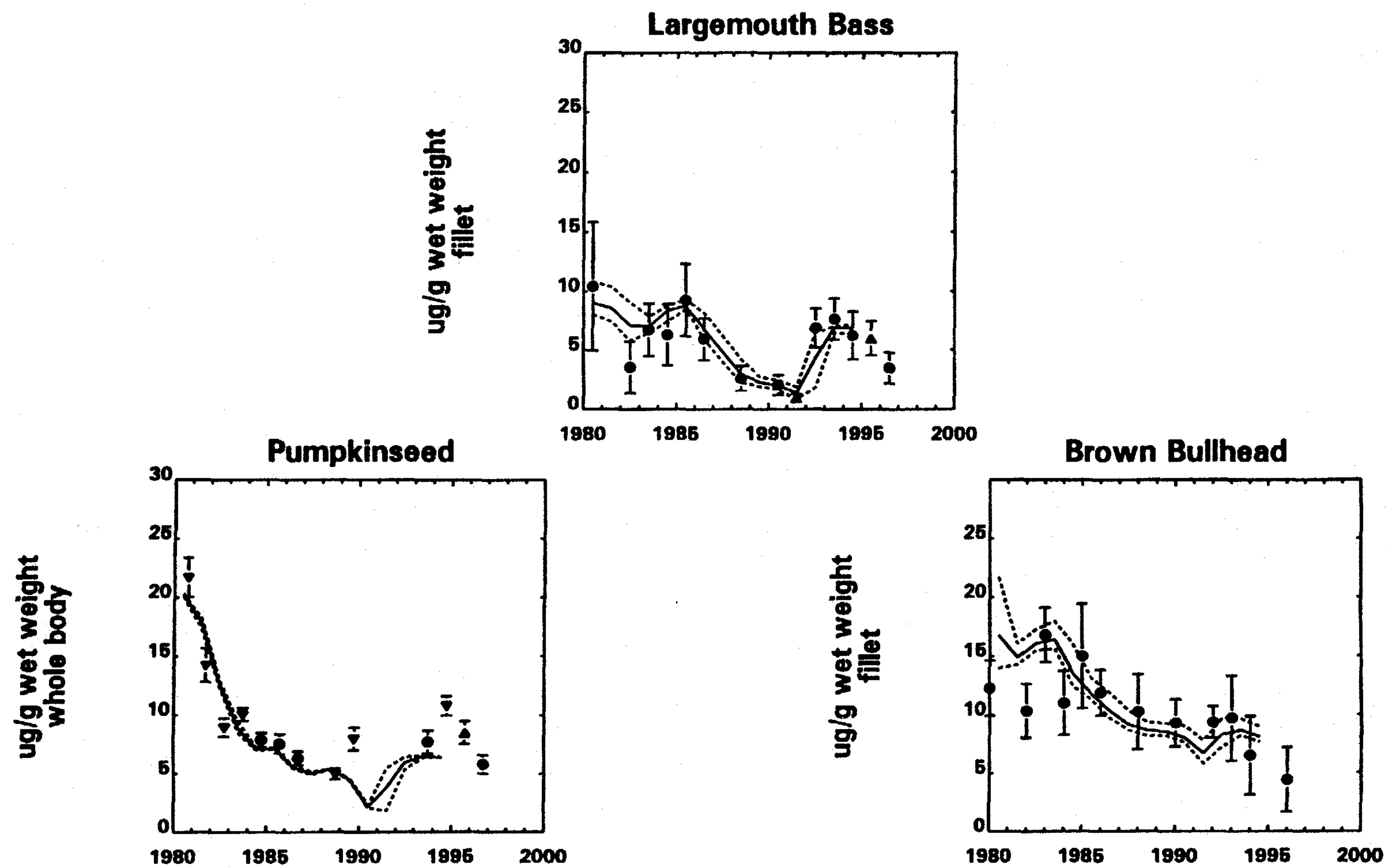
FOOD WEB MODEL-
TOTAL PCB AT STILLWATER



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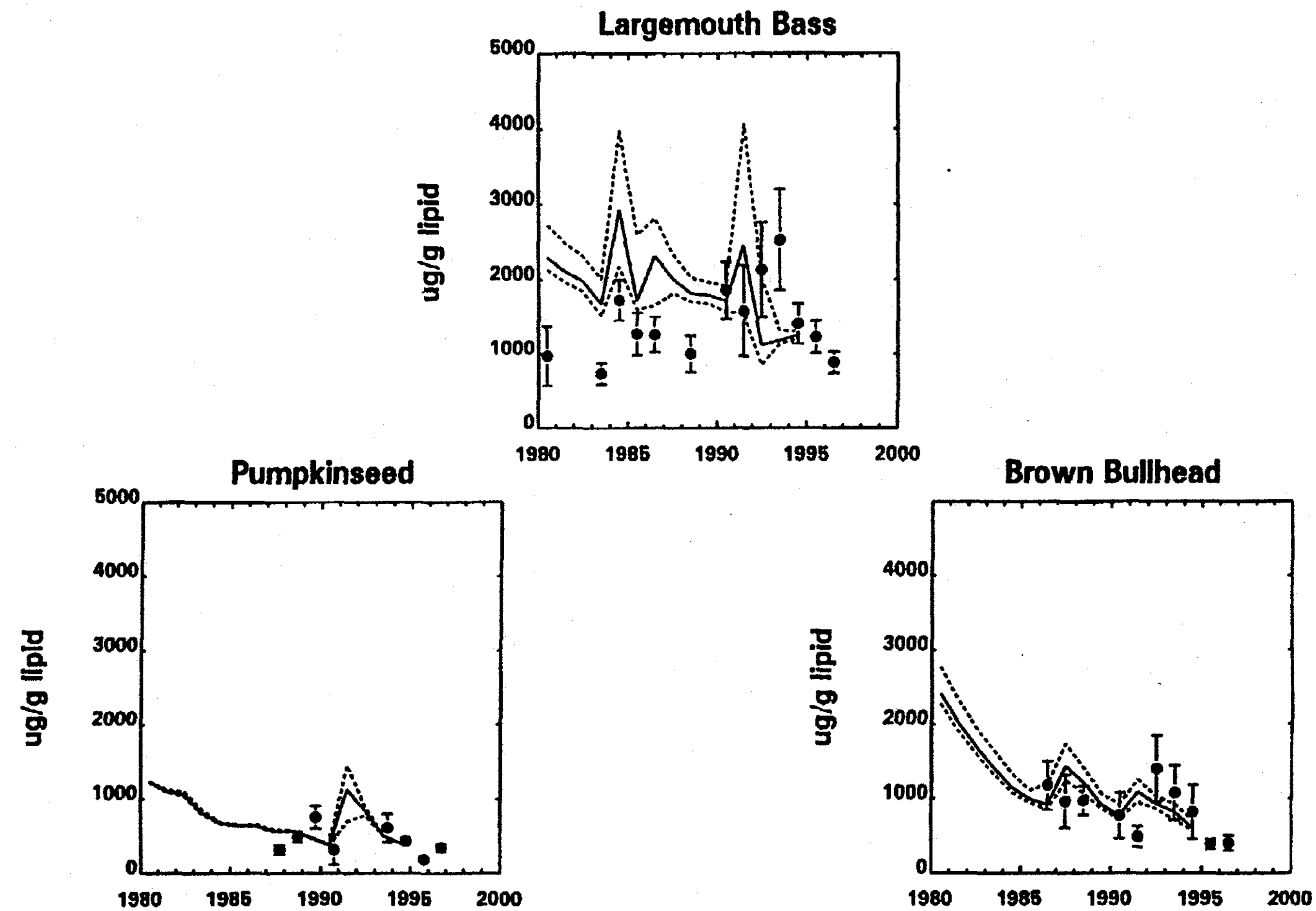
FOOD WEB MODEL- TOTAL PCB AT TI POOL



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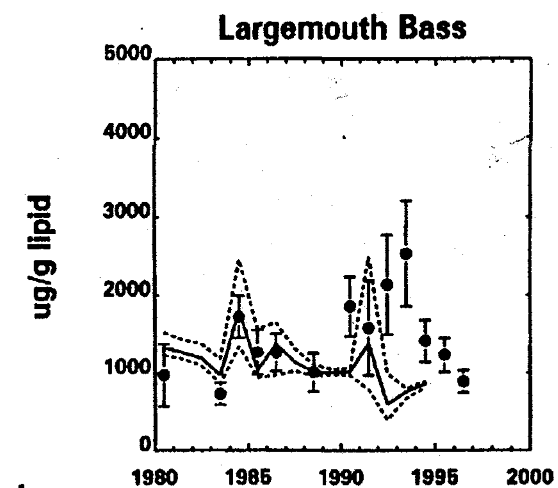
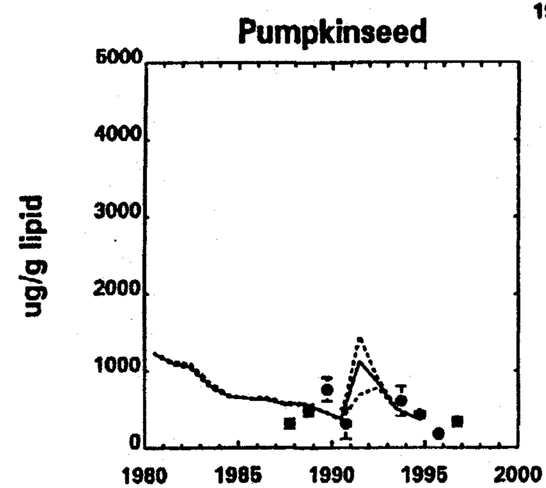
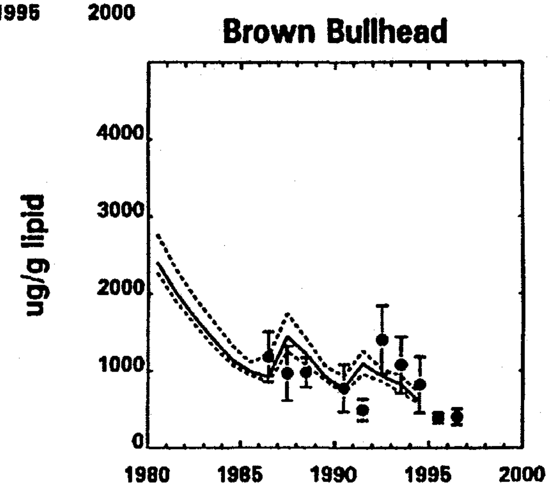
FOOD WEB MODEL-
TOTAL PCB AT TI POOL







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USE OF THE MODEL IN A DIAGNOSTIC MODE

- Homolog-based models were used to estimate the depth of bioavailable PCBs in the sediment bed.

  Values for additional parameters were estimated from published information:

  - Chemical assimilation efficiency (gut)
  - Chemical assimilation efficiency (gill)

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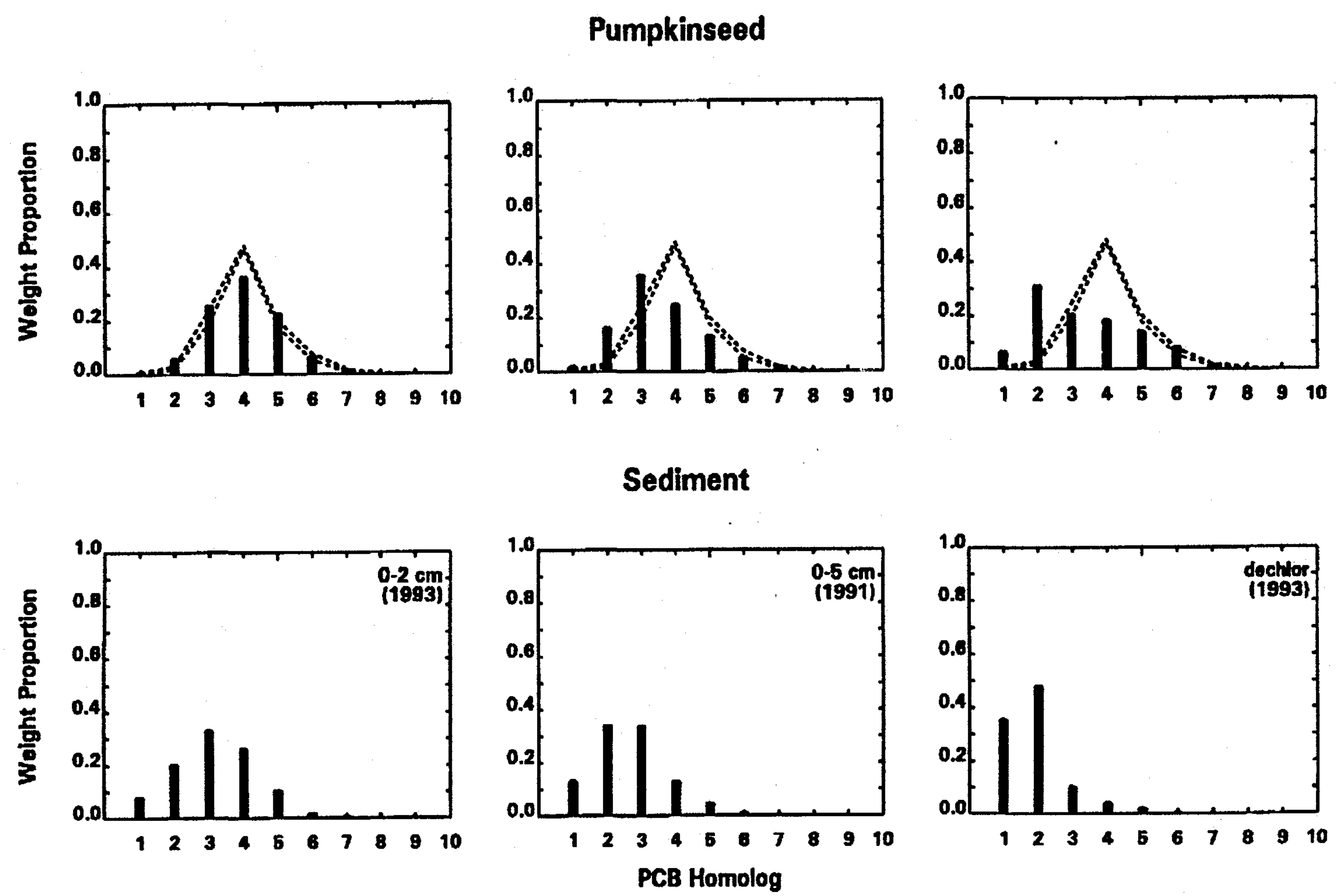
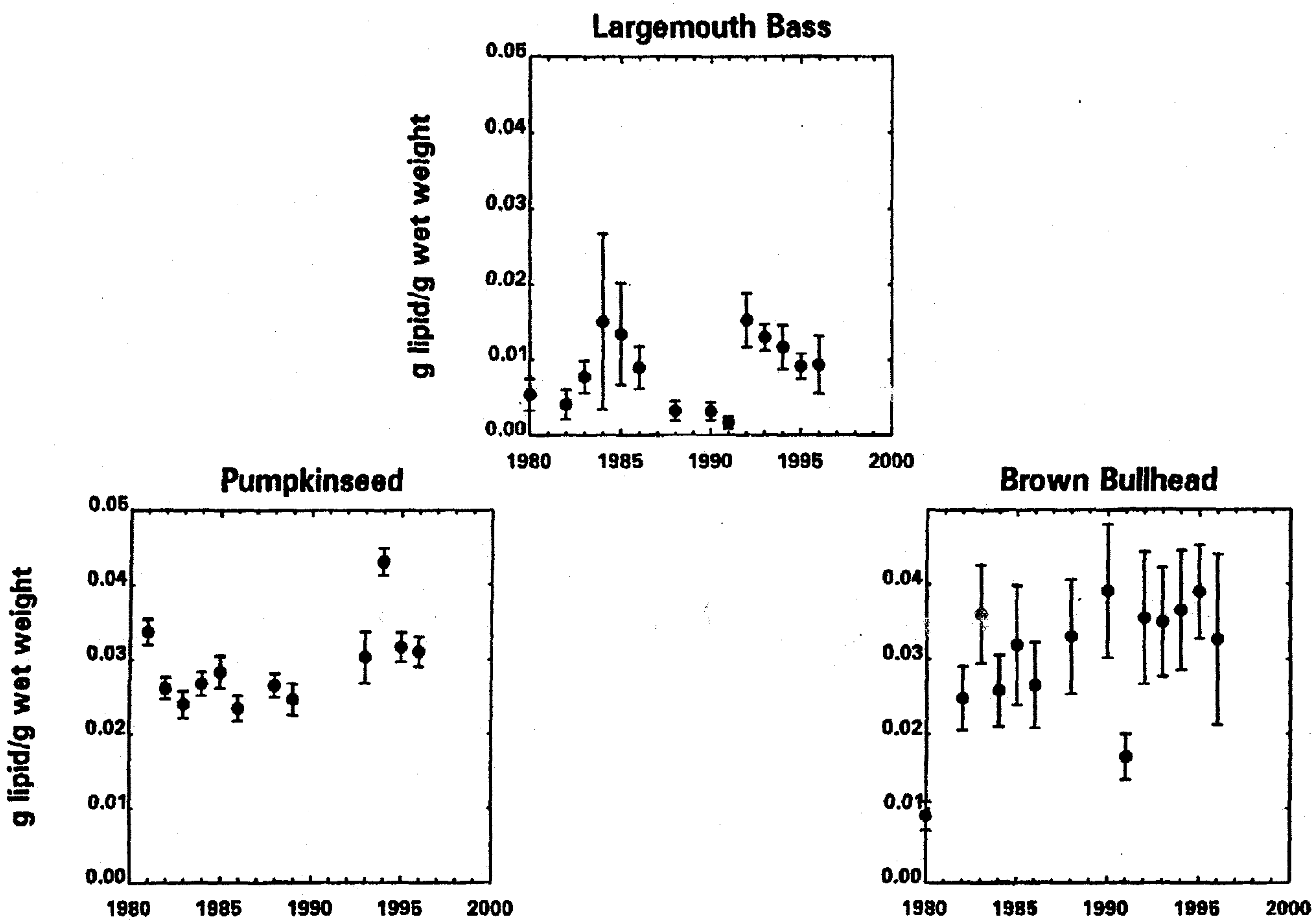
Steady State Food Web Model
Pumpkinseed in Thompson Island Pool



FISH LIPID CONTENT AT STILLWATER



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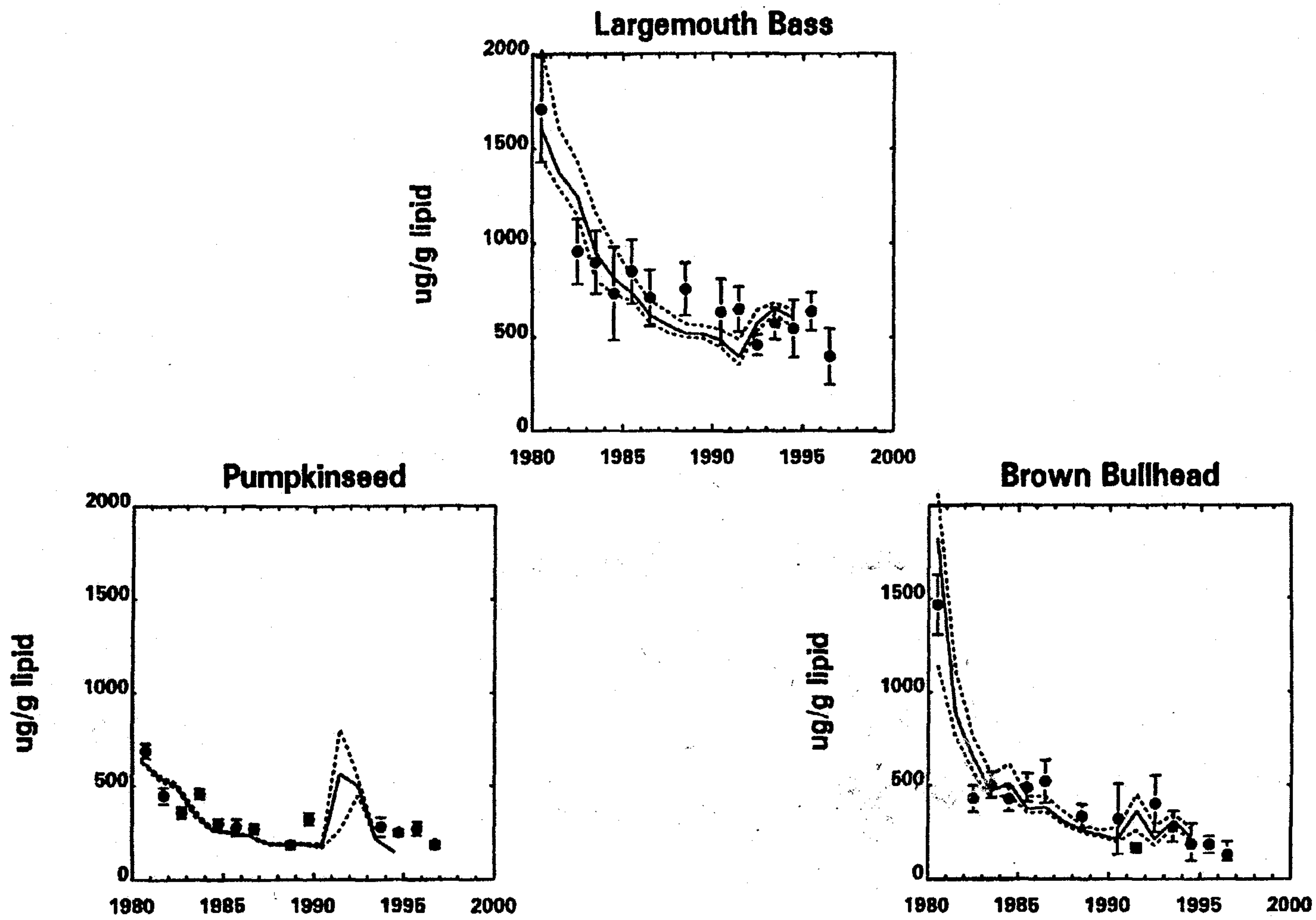
FOOD WEB MODEL-
TOTAL PCB AT STILLWATER



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CONCLUSIONS

- Year-to -year variation in wet weight-based PCB concentrations is due largely to variation in fish lipid content.
- Year-to-year variation in lipid content affects the apparent long-term trends in fish PCB level.
- Species-specific responses to the events of 1991 are due largely to differences in trophic position and body composition.

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CONCLUSIONS (continued)

- PCB sources to the largemouth bass in T. I. Pool are incompletely understood.

- The food web is probably exposed to PCBs within the top 2 cm of the sediment bed.

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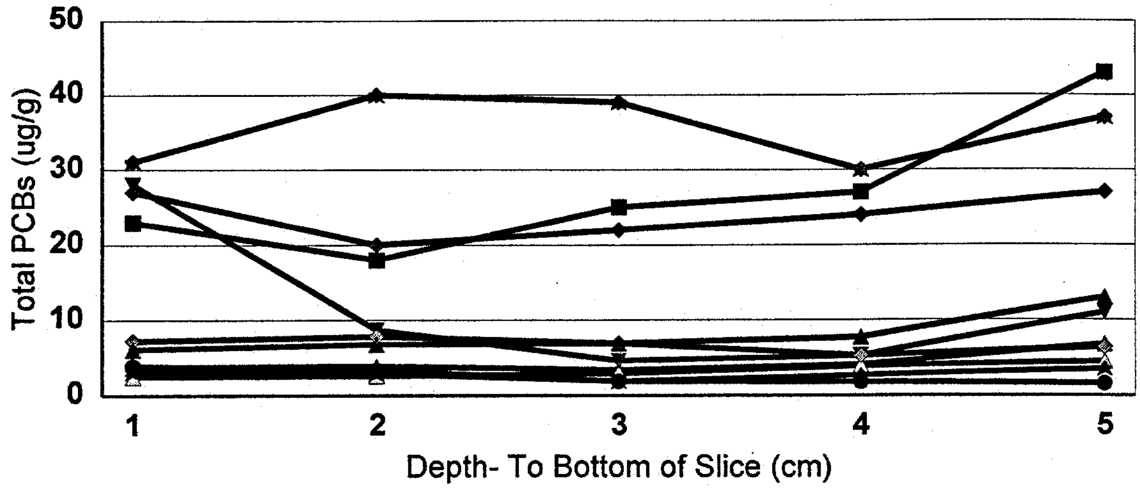
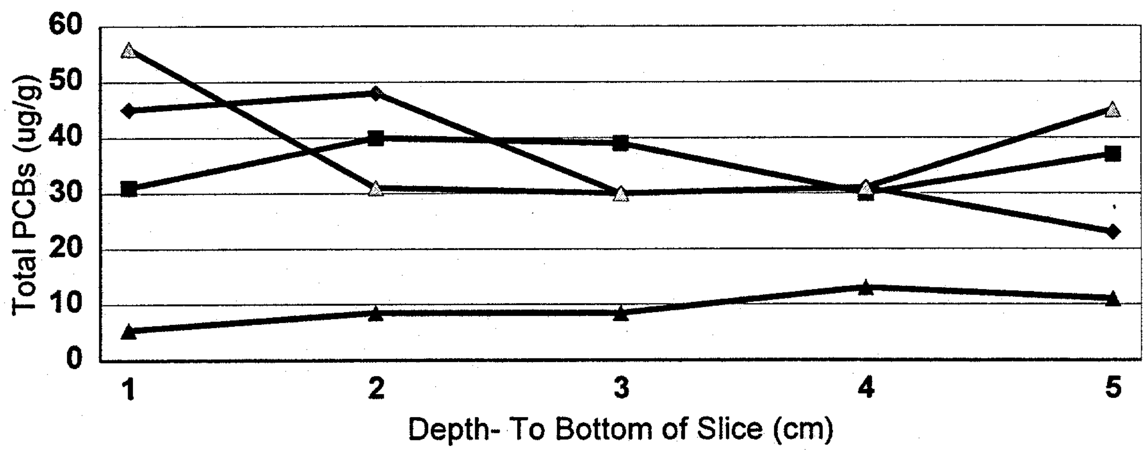
GE Cores
PCBs in Top 5 cm



GE Cores
PCBs in Top 5 cm



GE Cores
PCBs in Top 5 cm