ERG

Eastern Research Group, Inc.

Communications

Data, Information, and Knowledge Management

Economic and Statistical Support

Emissions Inventory and Exposure Assessment

Engineering

Environmental Health

Environmental Management Systems

Environmental Measurements

Occupational Health and Safety

Regulatory Support

Community Environmental Planning

Equal Opportunity Employer
Printed on Recycled Paper

February 15, 2000

Dear Reviewers:

The following is a recap of what was presented at the Informational Meeting for the Peer Review of Hudson River PCBs Baseline Modeling Report. This meeting took place January 12 and 13, 2000 at the Holiday Inn Turf on Wolf Road in Albany, New York.

Please refer to the enclosed agenda, which specifies the presentations and their corresponding numbered packet.

You will also find three videos that were taken at the briefing. The videos correspond with the following times:

Tape #1:	Day 1: 8:30 AM - 5:00 PM (Site Tour included)
(missing):	*Day 2: 8:30 AM - 10:30 AM*
Tape #2:	Day 2: 10:30 AM - 11:30 AM
Tape #3:	Day 2: 12:30 PM - 3:00 PM

Please note there were technical difficulties with the video taping and sound quality on Day 2. Therefore, there is no video for 8:30 AM - 10:30 AM on Day 2.

If you have any questions or concerns, please do not hesitate to contact any of us here at ERG.

Thank you.

Sincerely,

Melanie Russo

Melanie Russo
Eastern Research Group (ERG)
110 Hartwell Avenue
Lexington, MA 02421
781-674-7248
781-674-2906:fax
mrusso@erg.com

EPA United States
Environmental Protection Agency
Region 2

Informational Meeting for the Peer Review of Hudson River PCBs Baseline Modeling Report

Holiday Inn Turf on Wolf Road
Albany, New York
January 12-13, 2000

Agenda

Meeting Facilitator: Jan Connery, Eastern Research Group, Inc.

WEDNESDAY, JANUARY 12, 2000

8:30AM	**Registration/Check-in**	
9:00AM	**Welcome Remarks** *Jan Connery, Eastern Research Group, Inc.*	
9:15AM	**Presentation on Site Background** *Doug Tomchuk, U.S. Environmental Protection Agency*	**SLIDE PACKET #1**
10:30AM	**Adjourn for Site Tour**	
11:00AM	**Board Bus for Site Tour**	
12:30PM	L U N C H (on own, bus will stop at local restaurant)	
5:00PM	**End of Site Tour/Return to Hotel**	

THURSDAY, JANUARY 13, 2000

8:30AM	**Presentation on Findings from Previous Reports** *Doug Tomchuk, U.S. Environmental Protection Agency*	**SLIDE PACKET #2**
9:15AM	**Presentation on Fate and Transport** *Victor Bierman and Scott Hinz, Limno-Tech, Inc.*	**SLIDE PACKET #3**
10:15AM	B R E A K	
10:30AM	**Continuation of Presentation on Fate and Transport** *Victor Bierman and Scott Hinz, Limno-Tech, Inc.*	**SLIDE PACKET #3**
11:30AM	L U N C H (on own)	
12:30PM	**Presentation of Bio-Accumulation** *Katherine von Stackelberg, Menzie-Cura & Associates, Inc.*	**SLIDE PACKET #4**
1:45PM	**Review the Charge to Reviewers, Address Questions and Comments from Peer Reviewers**	
3:00PM	Adjourn	

Hudson River PCBs Site Reassessment

Peer Review of the Baseline Modeling Report

January 12, 2000

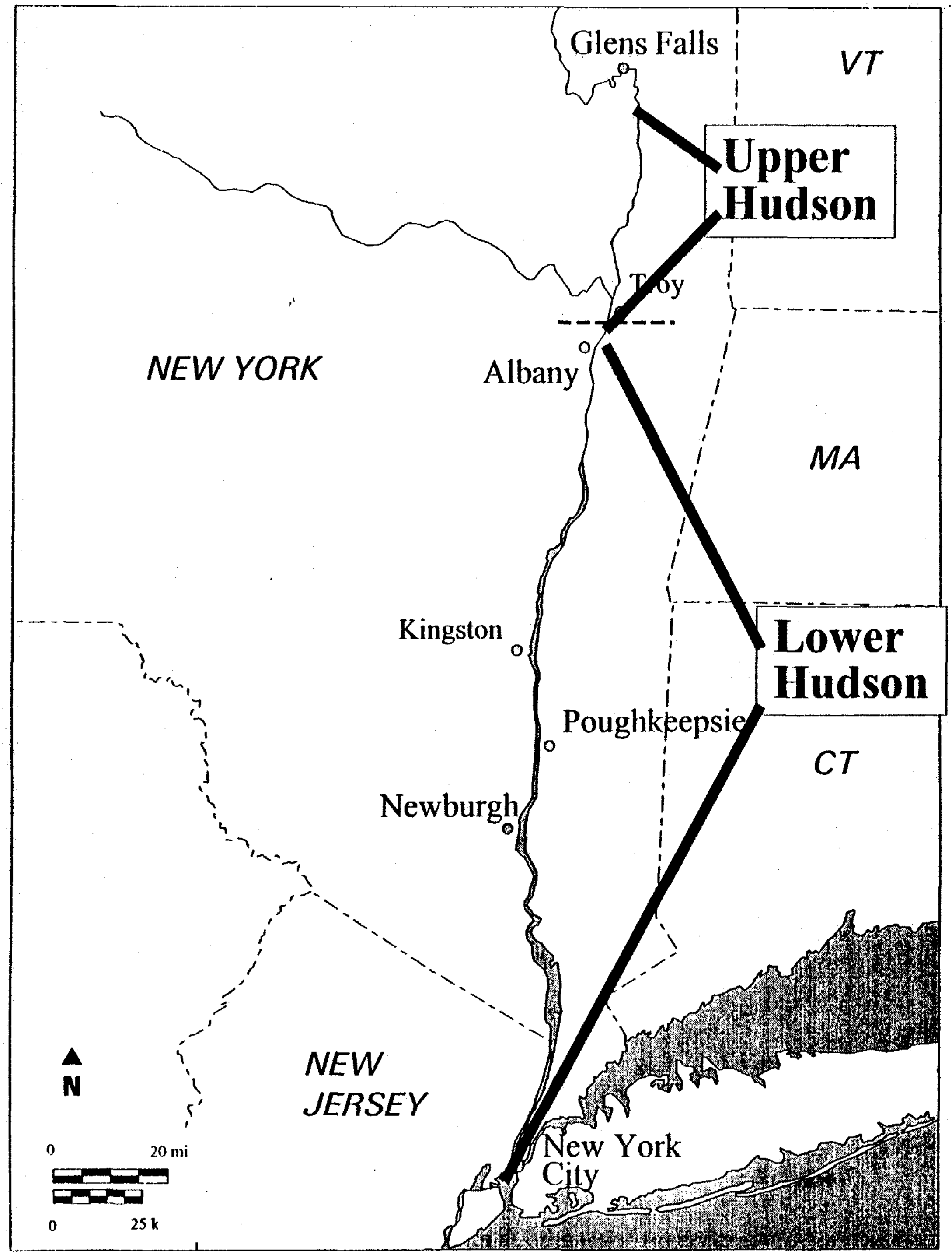
Douglas Tomchuk
USEPA - Region 2

10.2372

Hudson River PCBs Site Reassessment

- Site Background
- Data

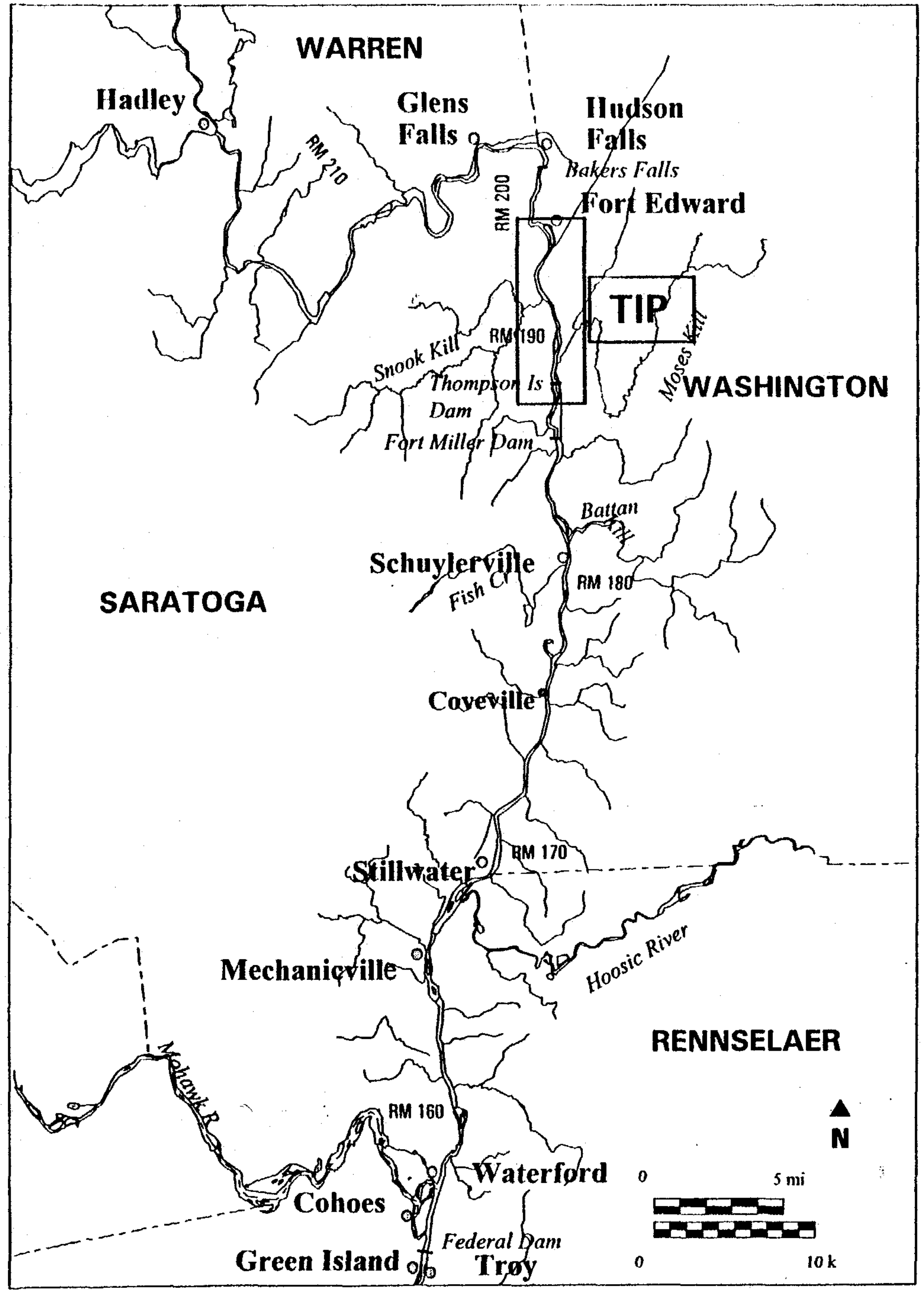
- Findings from Previous Reports
- Charge



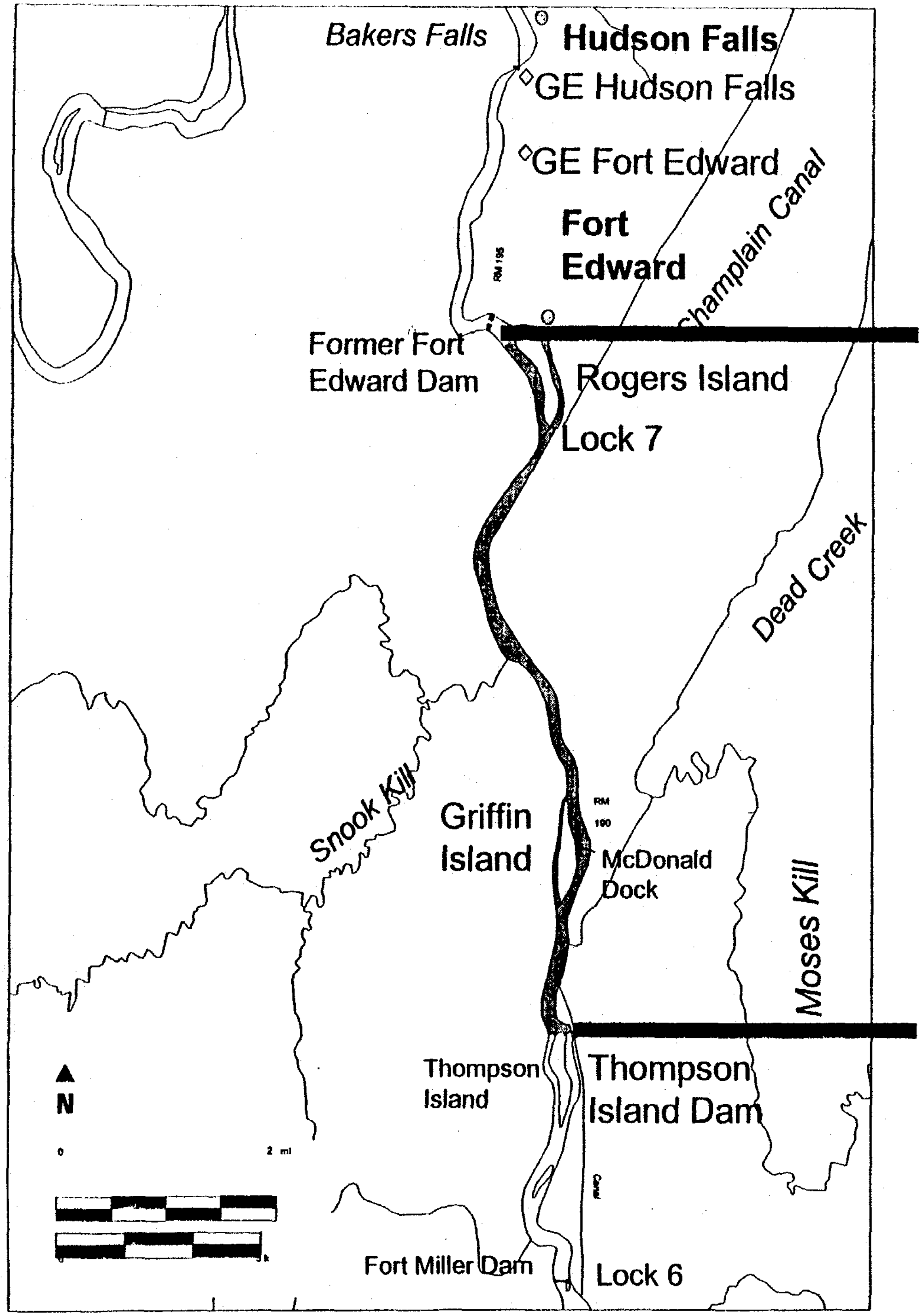
Upper and Lower Hudson River

10.2373

10.2374



Upper Hudson River

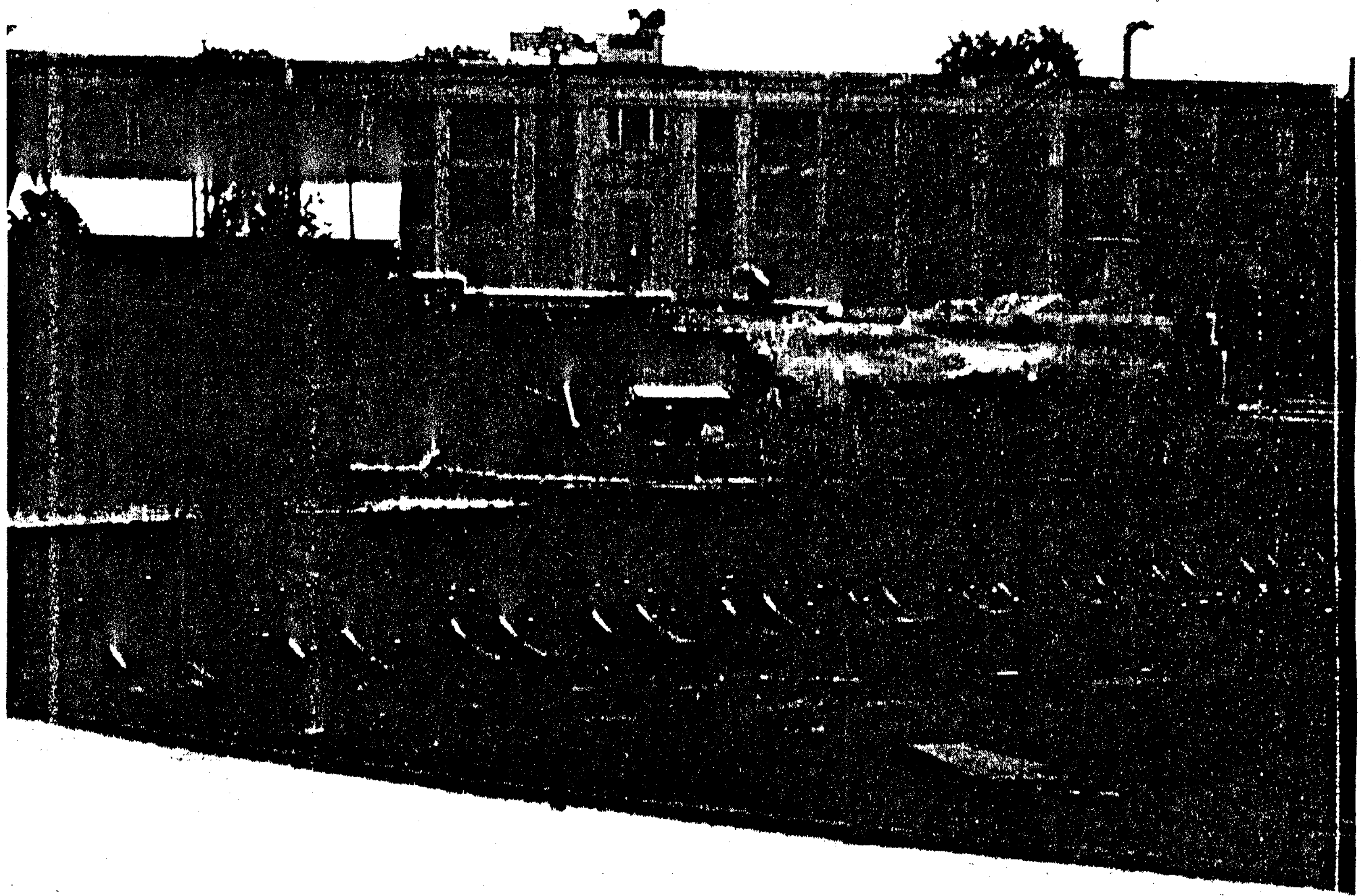


Thompson Island Pool

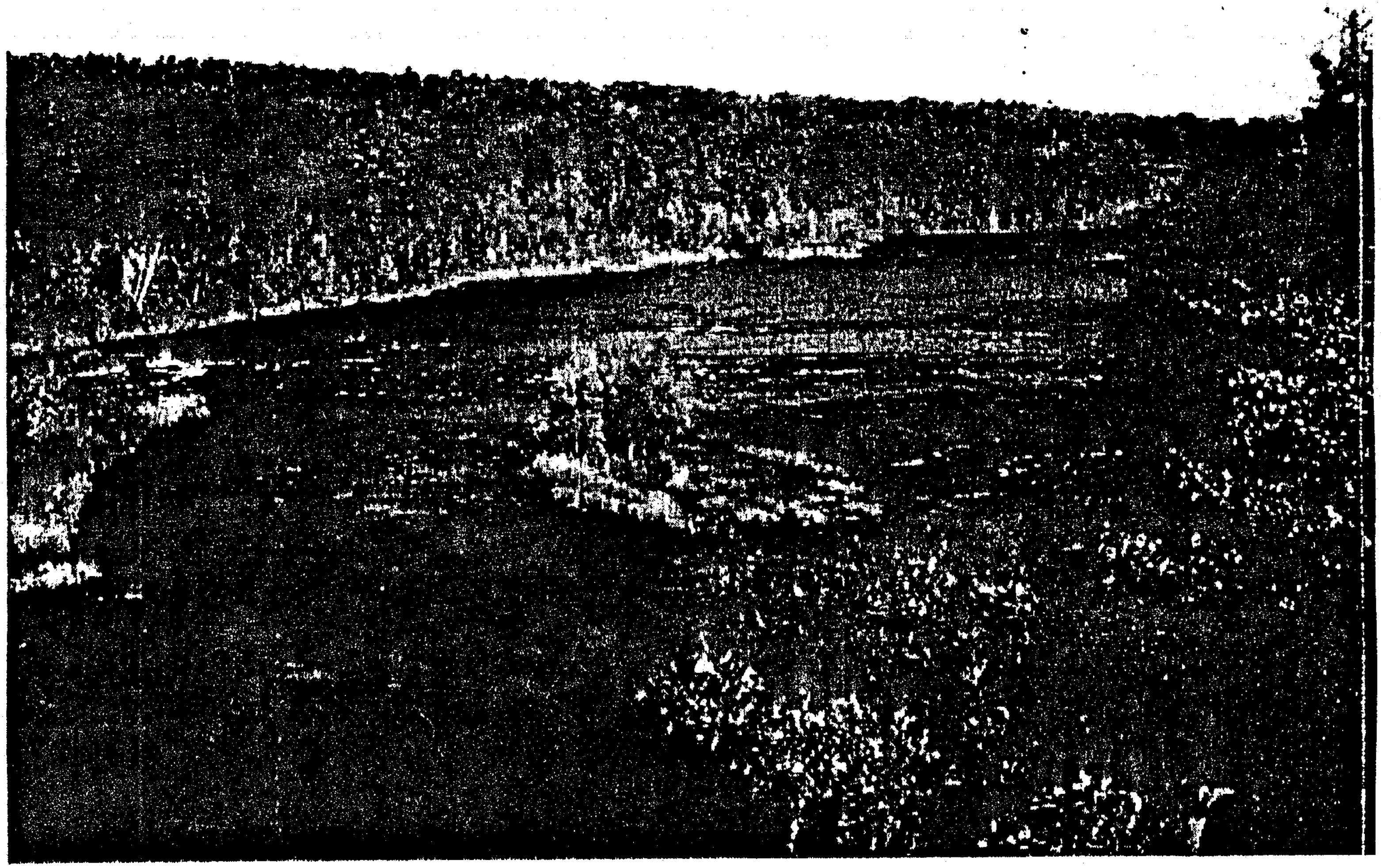
10.2375

10.2376

GE Hudson Falls Plant Site - Bakers Falls Dam



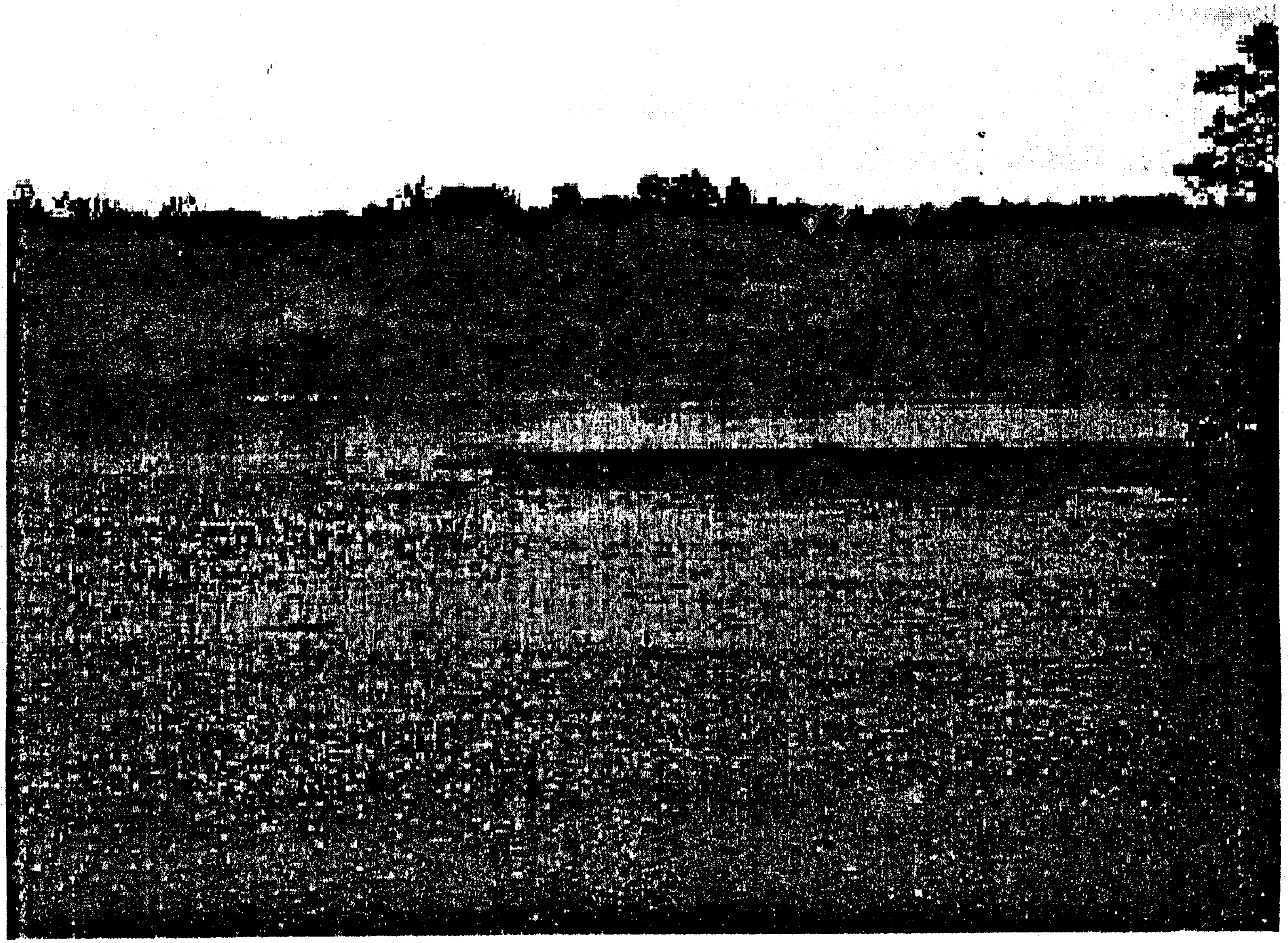
Upper Hudson River - Looking Upstream from Fort Edward



10.2377

Remnant Deposit 5 and Location of Former Ft. Edward Dam

Upper Hudson River -Thompson Island Pool

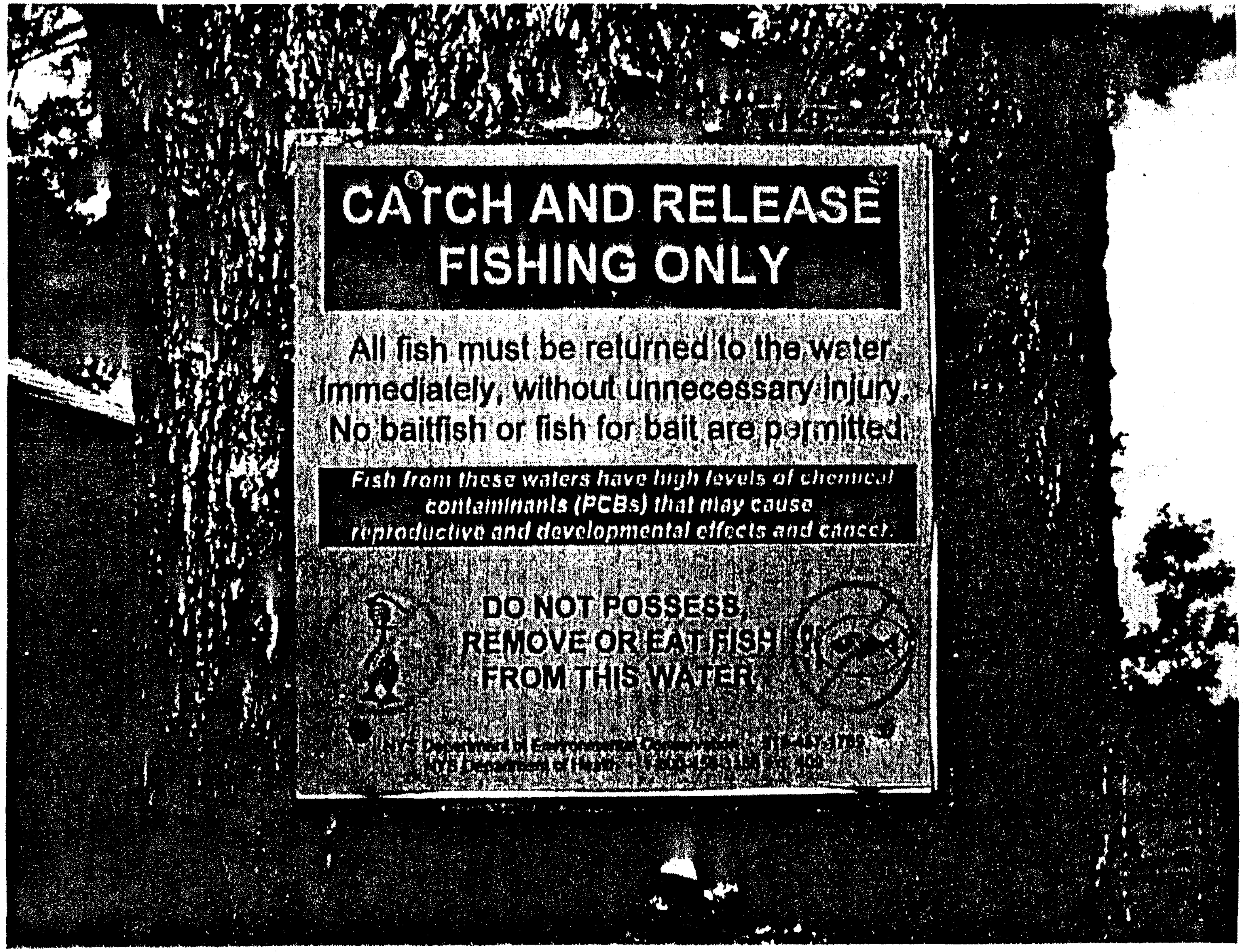


10.2379

10.2380

Upper Hudson River /Champlain Canal

Catch and Release Only on the Upper Hudson River



10.2381

10.2382

Hudson River PCBs Site Timeline

1947 -1976	GE used PCBs in manufacturing capacitors
1973	Ft. Edward Dam removed
1976	Fishing ban and consumption advisories
1980	Clean Water Act - Section 116
1983	Site proposed for Superfund NPL
1984	Record of Decision

Hudson River PCBs Site
<u>1984 Record of Decision</u>

- Cap Remnant Deposits
- Treatability Study for Waterford
- Interim "No-Action" for
  PCB-contaminated sediments

10.2383

Hudson River PCBs Site Timeline (cont'd)

1989	Decision to conduct the Reassessment
1990	Reassessment Scope of Work announced
1991	Remnant Deposit capping completed Event at GE Hudson Falls Plant Site
1992 - 1994	EPA Phase 2 sampling and analysis
1995	Data validation
1996 - 2000	Release of Phase 2 Reports

Decision to Conduct the Reassessment

- Re-opener in 1984 ROD
- Requested by NYSDEC
- EPA requirement for 5-Year Reviews

Reassessment Announced
December 1989

10.2385

Purpose of the Reassessment

To evaluate whether any action is required to address the PCB-contaminated sediments in the Upper Hudson River in order to be protective of human health and the environment.

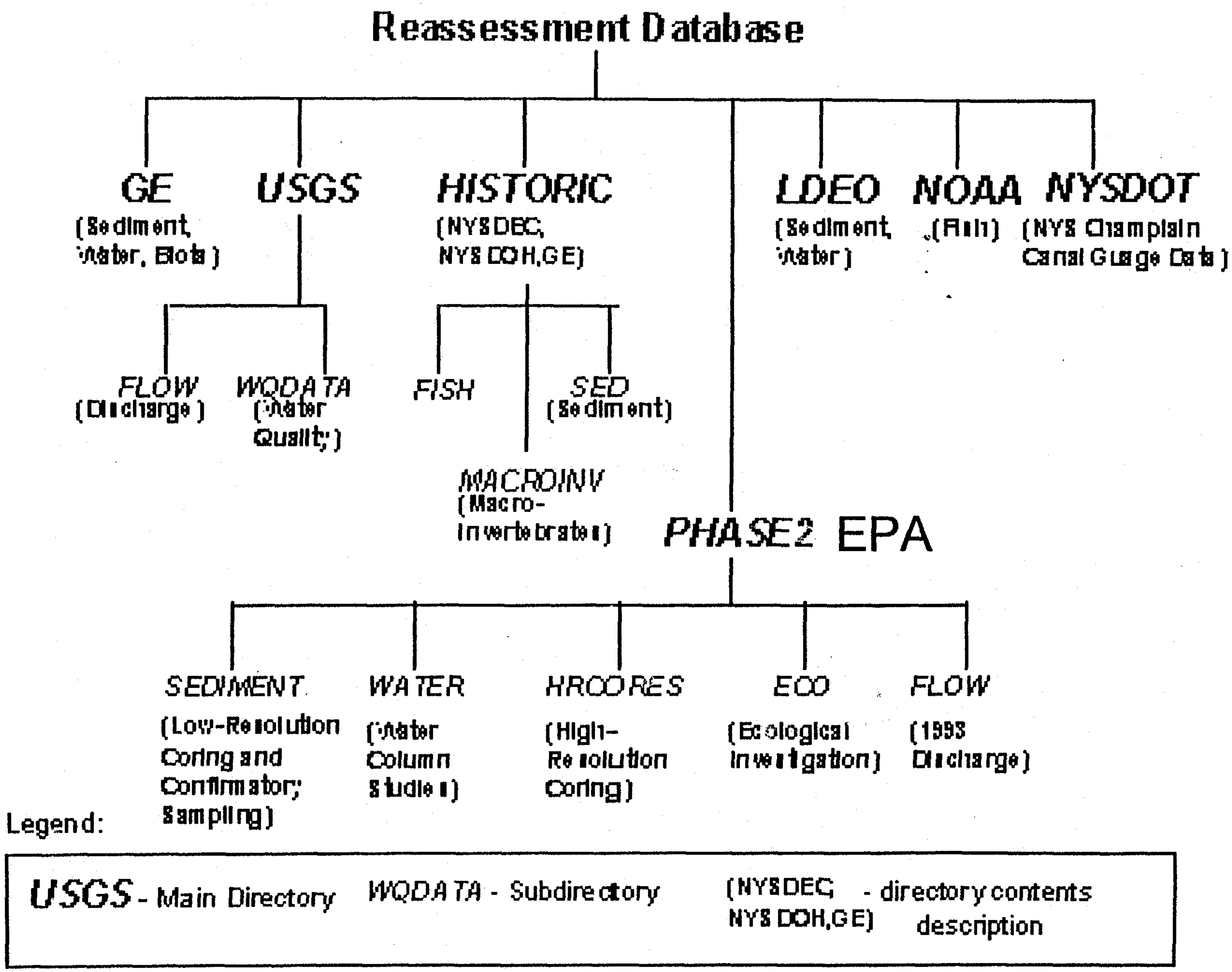
Principal Reassessment Questions

1. When will PCB levels in fish meet 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?

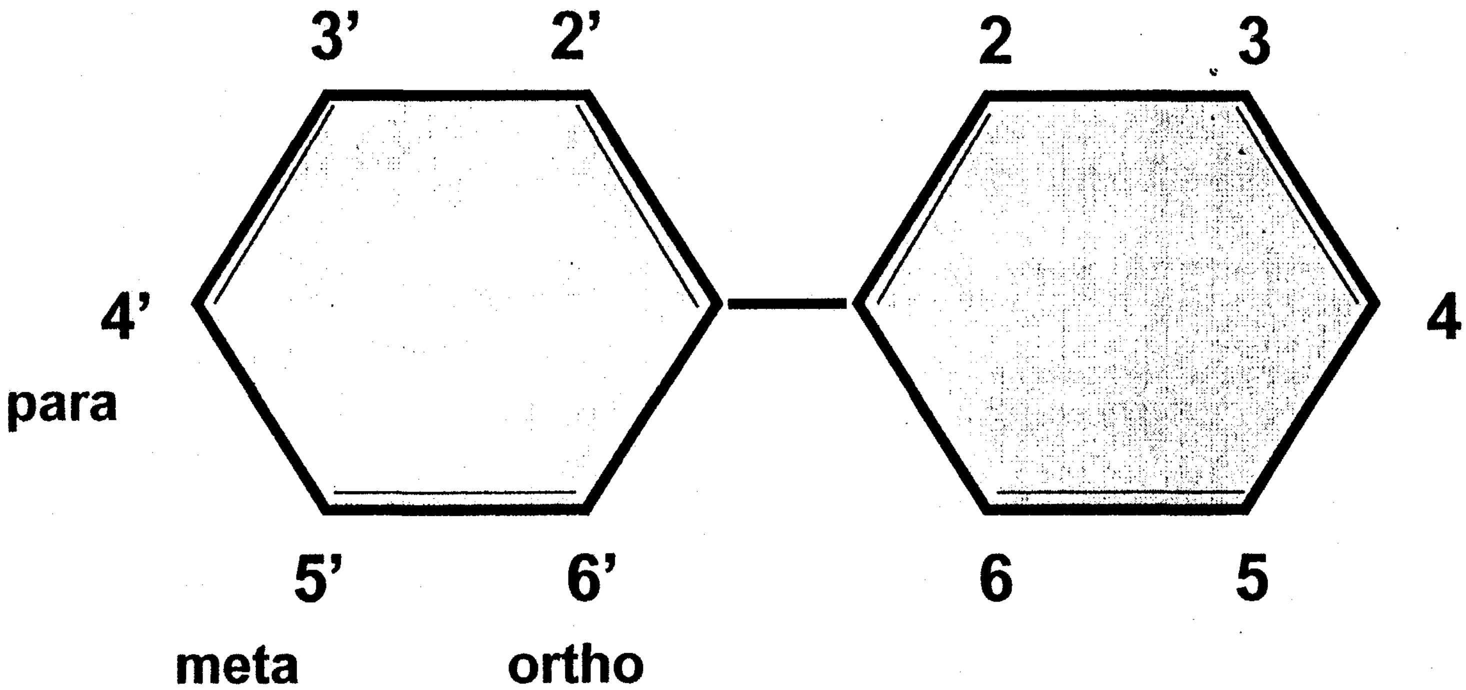
3. Could a flood scour sediments, exposing and redistributing buried contamination?

10.2388



Reassessment Database
GE
(Sediment, Water, Biota)
USGS
HISTORIC
(NYSDEC, NYSDOH, GE)
LDEO
(Sediment, Water)
NOAA
(Fish)
NYSDOT
(NYS Champlain Canal Guage Data)
FLOW
(Discharge)
WQDATA
(Water Quality)
FISH
SED
(Sediment)
MACROINV
(Macro-invertebrates)
PHASE2 EPA
SEDIMENT
(Low-Resolution Coring and Confirmatory Sampling)
WATER
(Water Column Studies)
HRCORES
(High-Resolution Coring)
ECO
(Ecological Investigation)
FLOW
(1993 Discharge)
Legend:
USGS - Main Directory
WQDATA - Subdirectory
(NYSDEC, NYSDOH, GE) - directory contents description

Polychlorinated Biphenyl



209 congeners

10.2389

PCB Analysis

- EPA Phase 2
  - Congener-specific (126 congeners)
- GE
  - Congener-specific on Aroclor standards
- USGS
  - Packed column through 1986
    - Didn't measure mono's and di's
  - Capillary column Aroclors post 1986
- NYSDEC
  - Packed column Aroclors

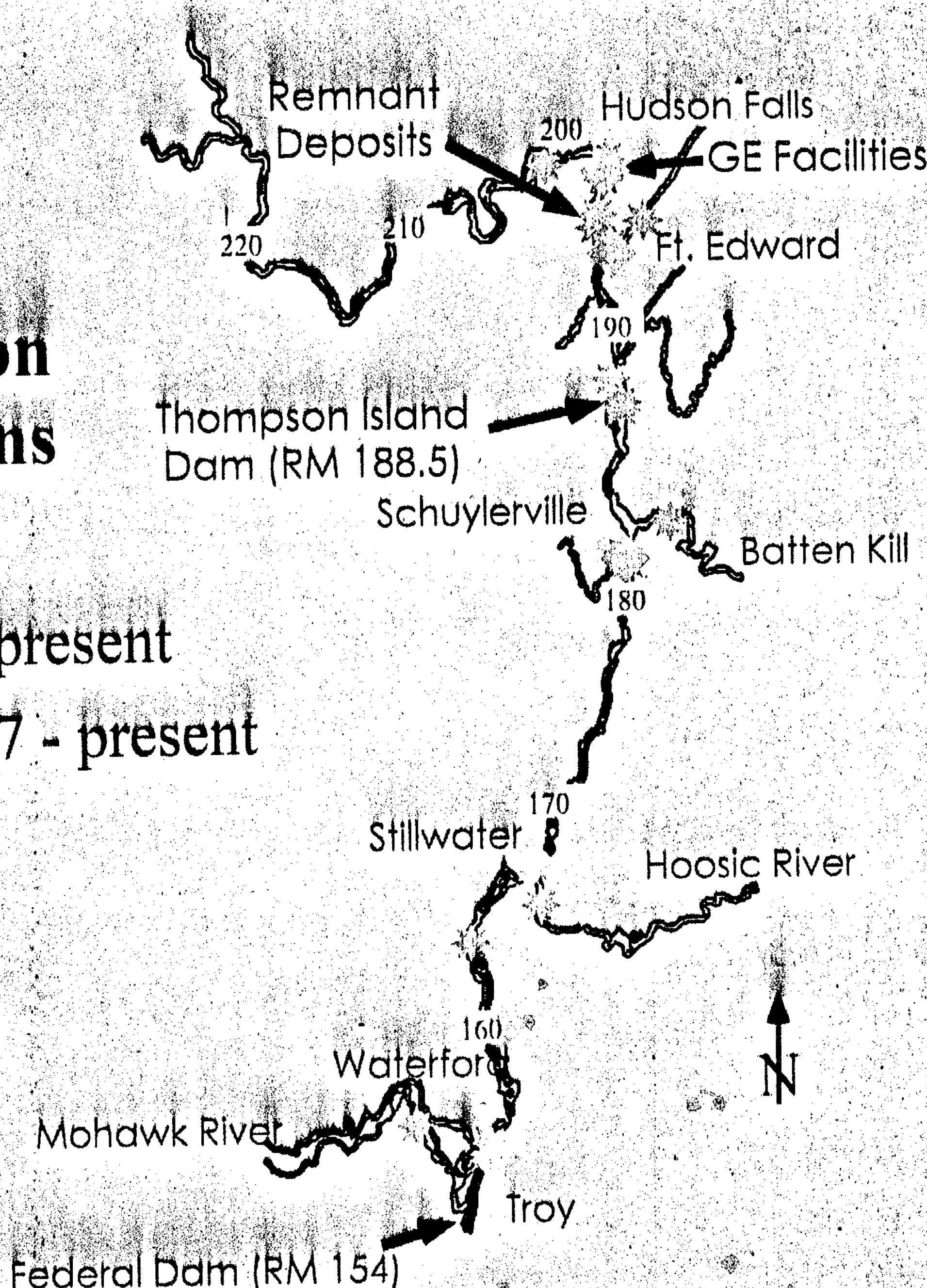
Tri+ PCBs

- Sum of congeners with three or more chlorines per molecule
- Provides a consistent basis for the comparison of various analytical techniques for the entire historic record

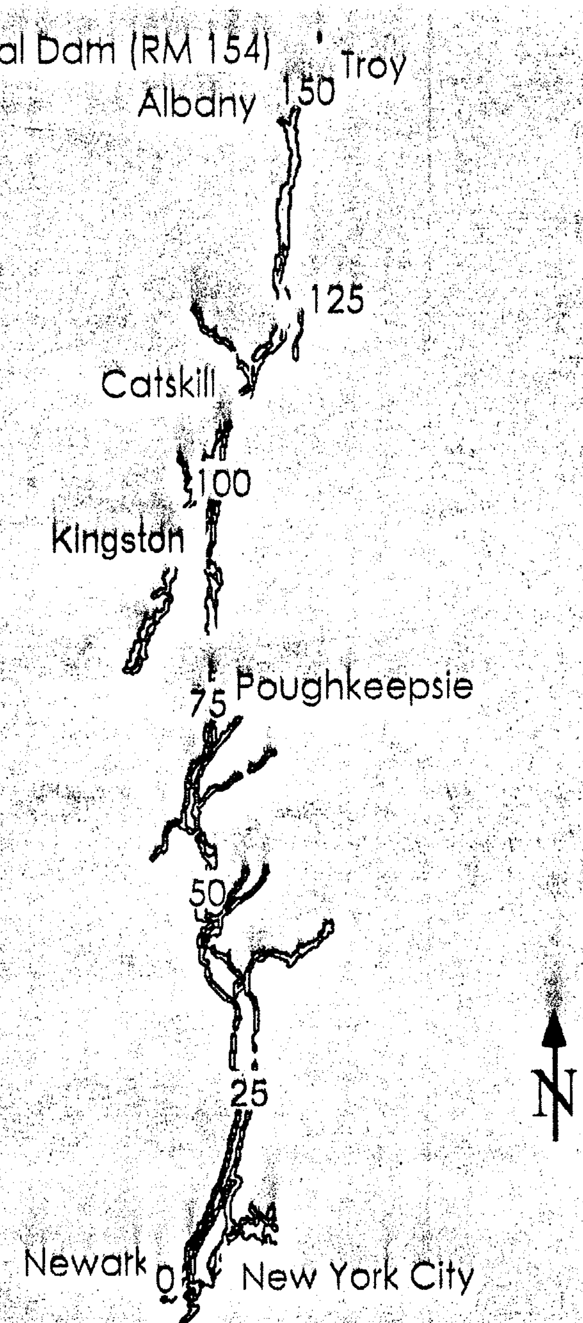
10.2391

Upper Hudson Water Stations

- EPA 1993
- GE 1991 - present
- USGS 1977 - present



Lower Hudson Water Stations EPA (1993)



10.2394

High Resolution Sediment Investigation

- High resolution sediment cores were obtained from 28 locations from the Upper and Lower Hudson

- Sediment cores were sliced into thin layers to examine historical PCB transport as recorded by the sediments

EPA Phase 2 Sampling Programs

- Water-Column Sampling
- Sediment Sampling
- Geophysical Investigation
- Ecological Investigations

10.2395

Water Column Sampling

- EPA Phase 2
  - Time-of-Travel (Transect) sampling (6)
  - Flow-Averaged sampling (6)
    (separated into suspended matter and dissolved fractions prior to PCB analysis)
  - Daily TSS monitoring (1994 High Flow)
- GE
- USGS

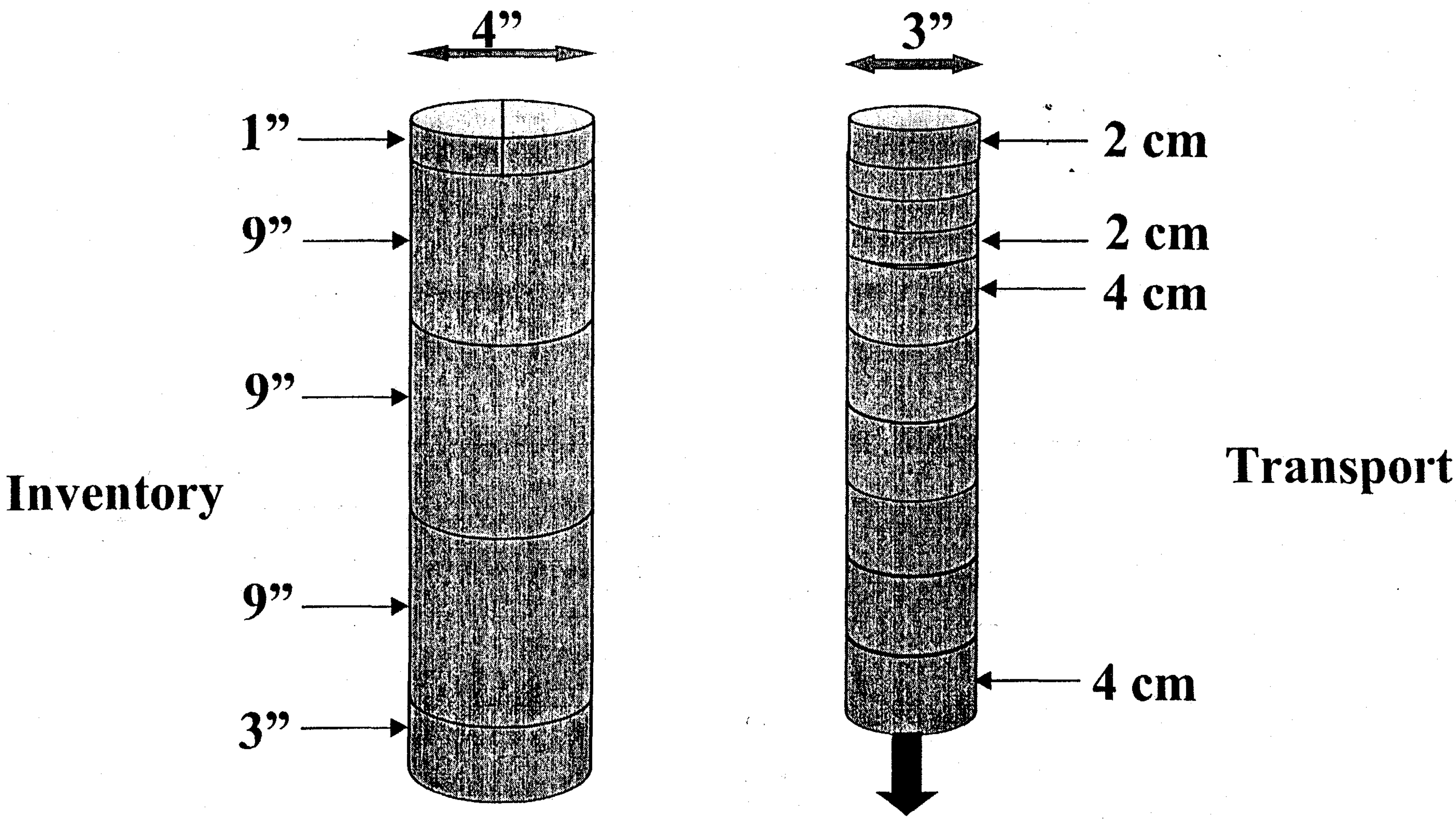
Low Resolution Sediment Coring Program

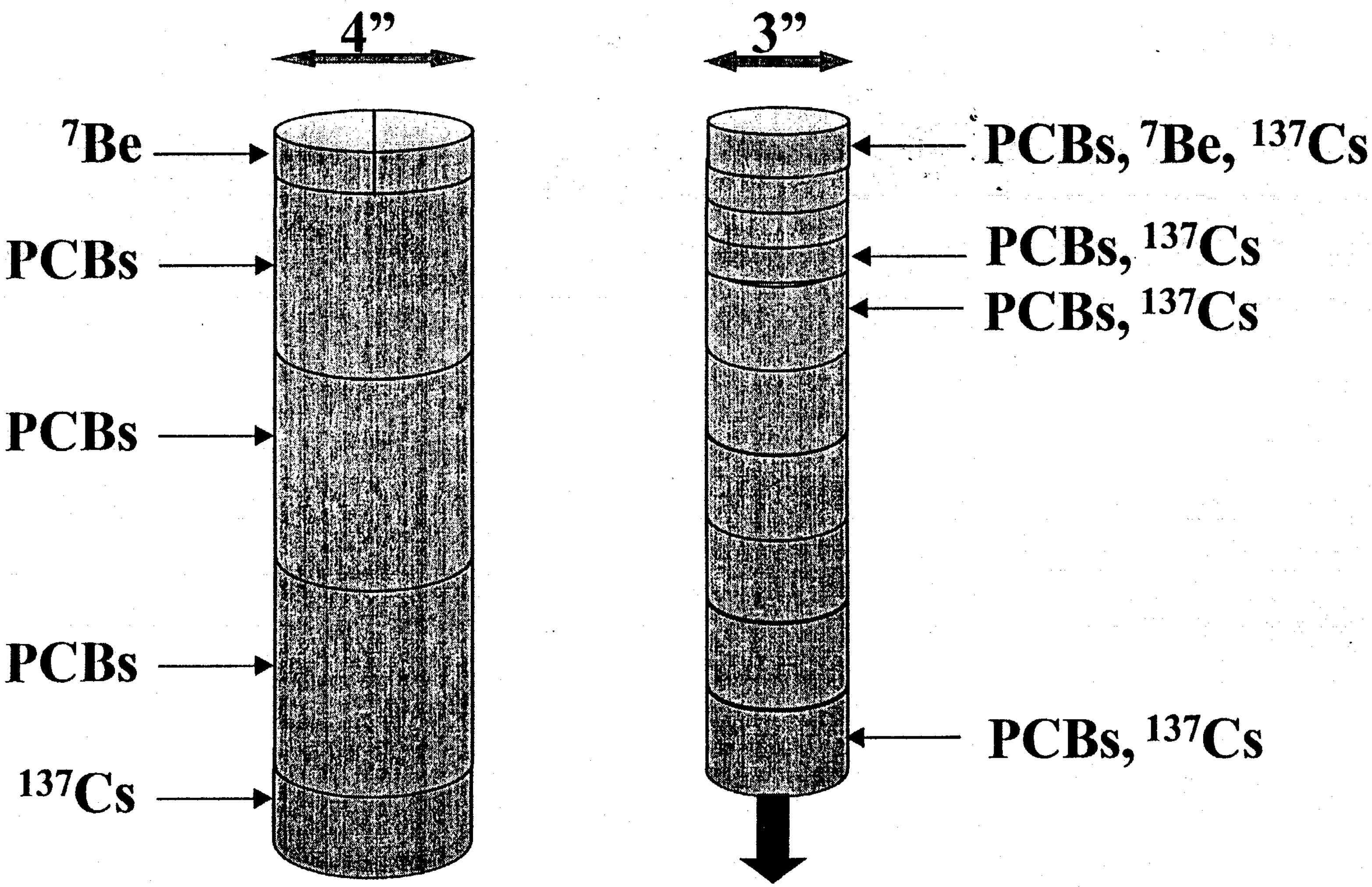
- Obtain new sediment PCB inventories to compare with 1984 estimates at selected locations in the TI Pool.

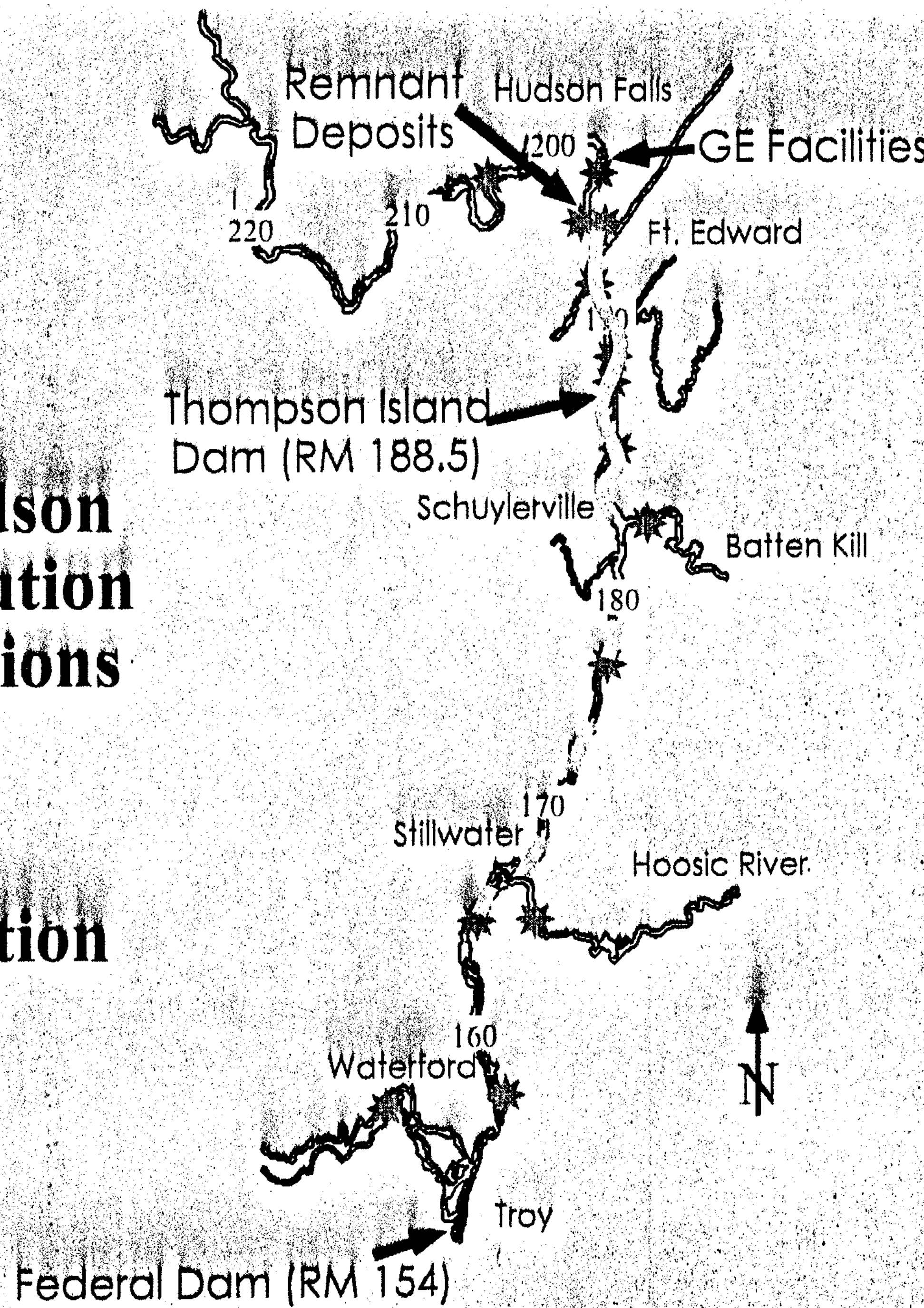
- Refine PCB mass estimates at selected hot spots below the TI Dam to compare with 1976 estimates.

10.2398

[redacted]



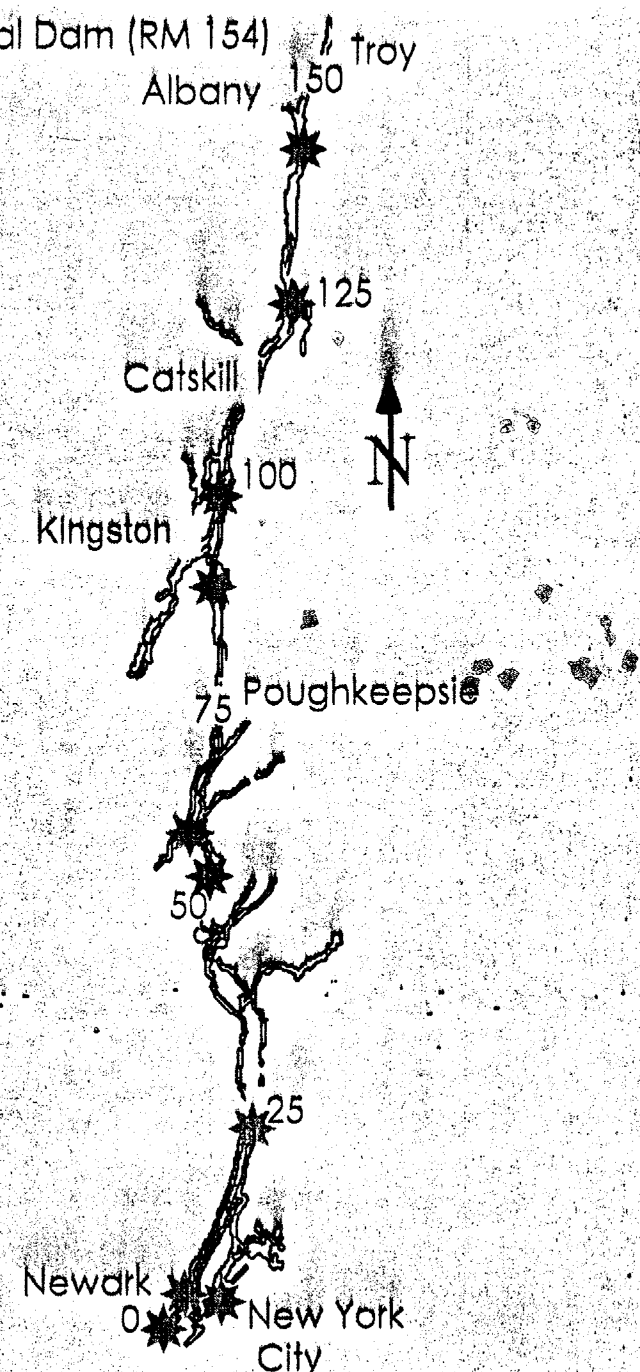

4”
3”
^{7}Be
PCBs
PCBs
PCBs
^{137}Cs
PCBs, ^{7}Be, ^{137}Cs
PCBs, ^{137}Cs
PCBs, ^{137}Cs
PCBs, ^{137}Cs



Upper Hudson High Resolution Core Locations ✱

Low Resolution Core Area

Lower Hudson High Resolution Core Locations

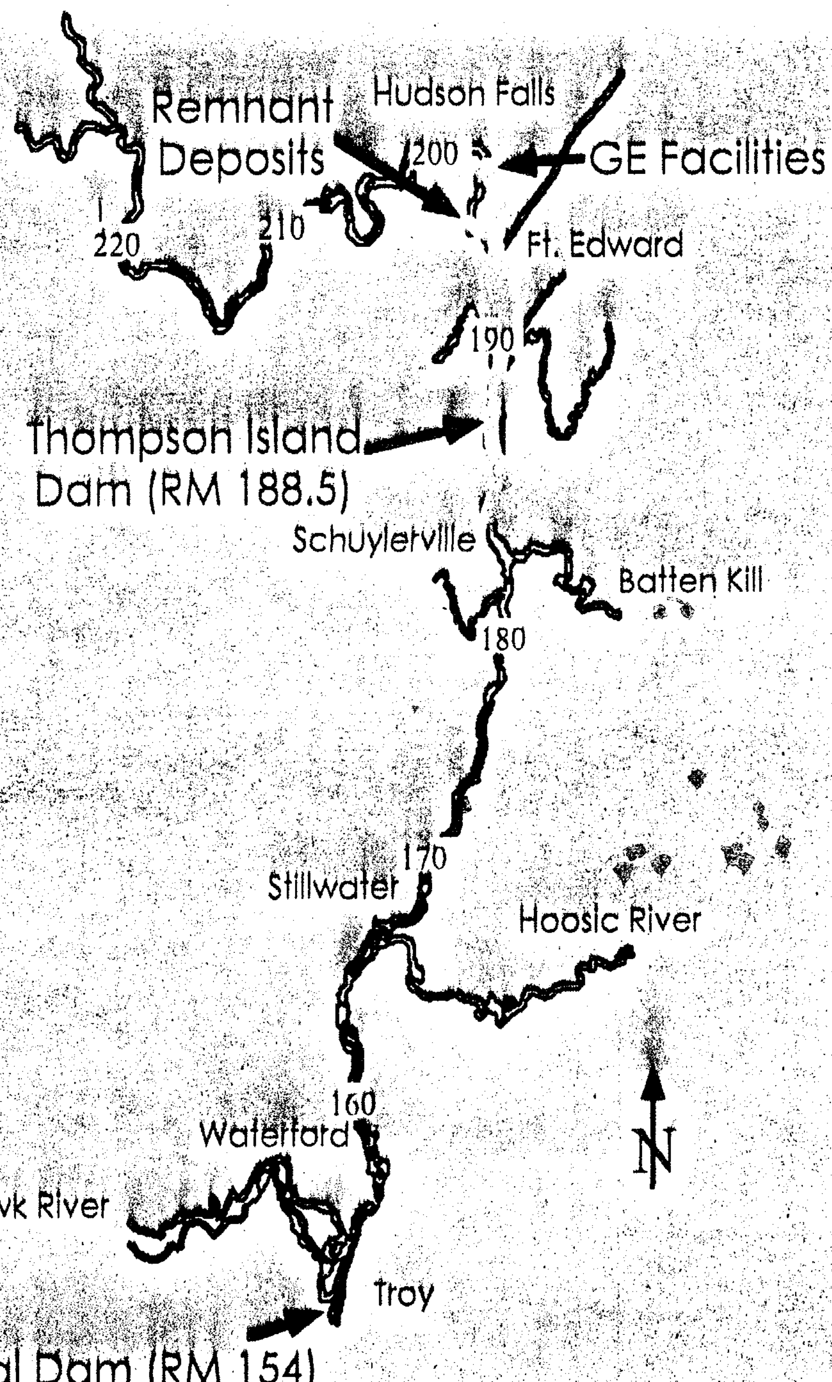


Geophysical Investigation

- Acoustic signals provide information on sediment texture, bathymetry and layering
  - Side-scan sonar images provide "photographs" of the river bottom

- Confirmatory samples provide confirmation of the sediment classes identified via acoustic signals

Geophysical Survey Area



Geophysical Survey Area

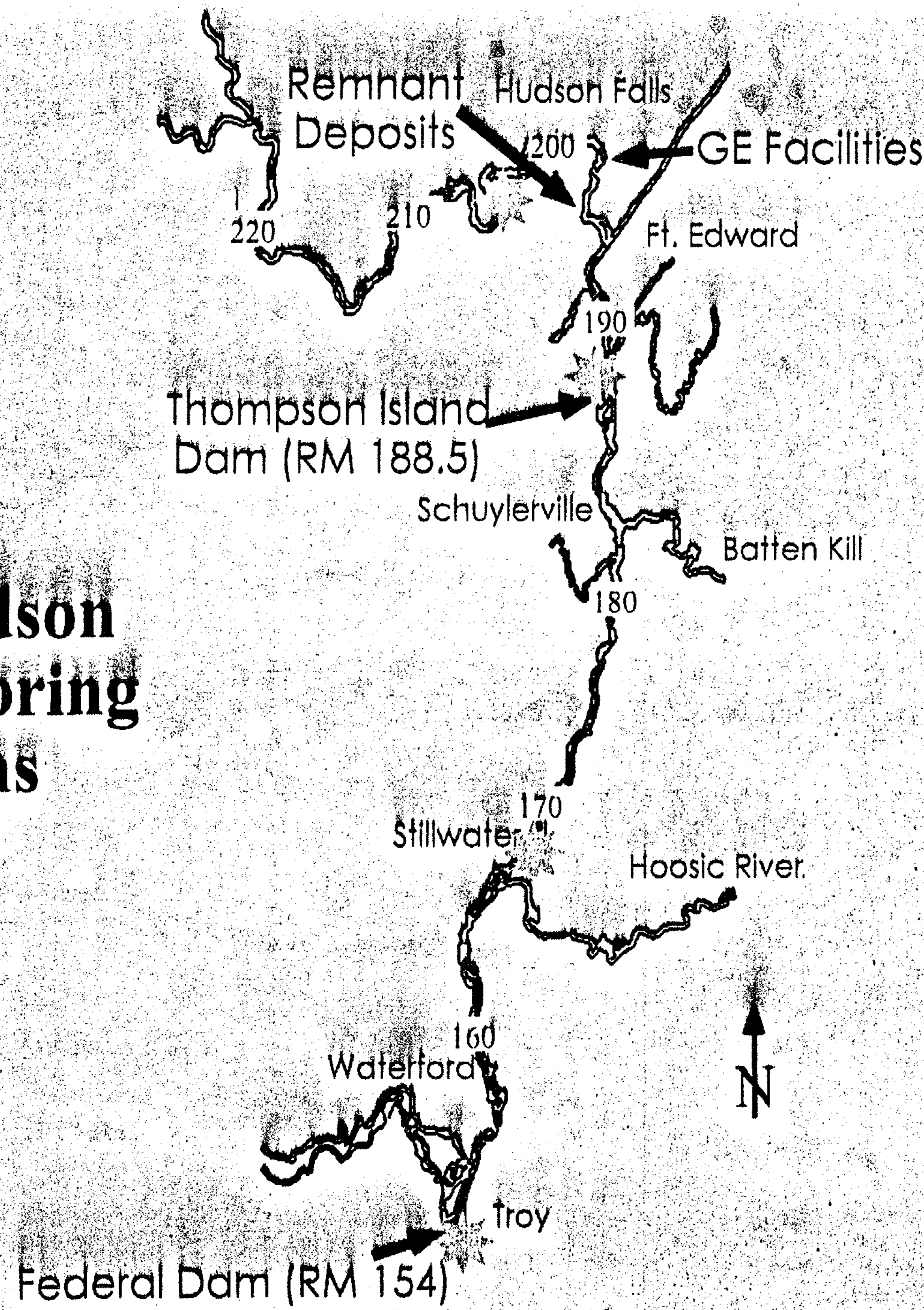
10.2403

10.2404

Ecological Investigations

- EPA Phase 2 (1993)
  - Sediment sampling
  - Benthic invertebrates
  - Fish
- NYSDEC Fish Monitoring
- NOAA/NYSDEC Fish (1993 and 1995)
- USF&W Tree Swallow Study
- NYSDOH Multiplate Sampling

Upper Hudson Fish Monitoring Locations



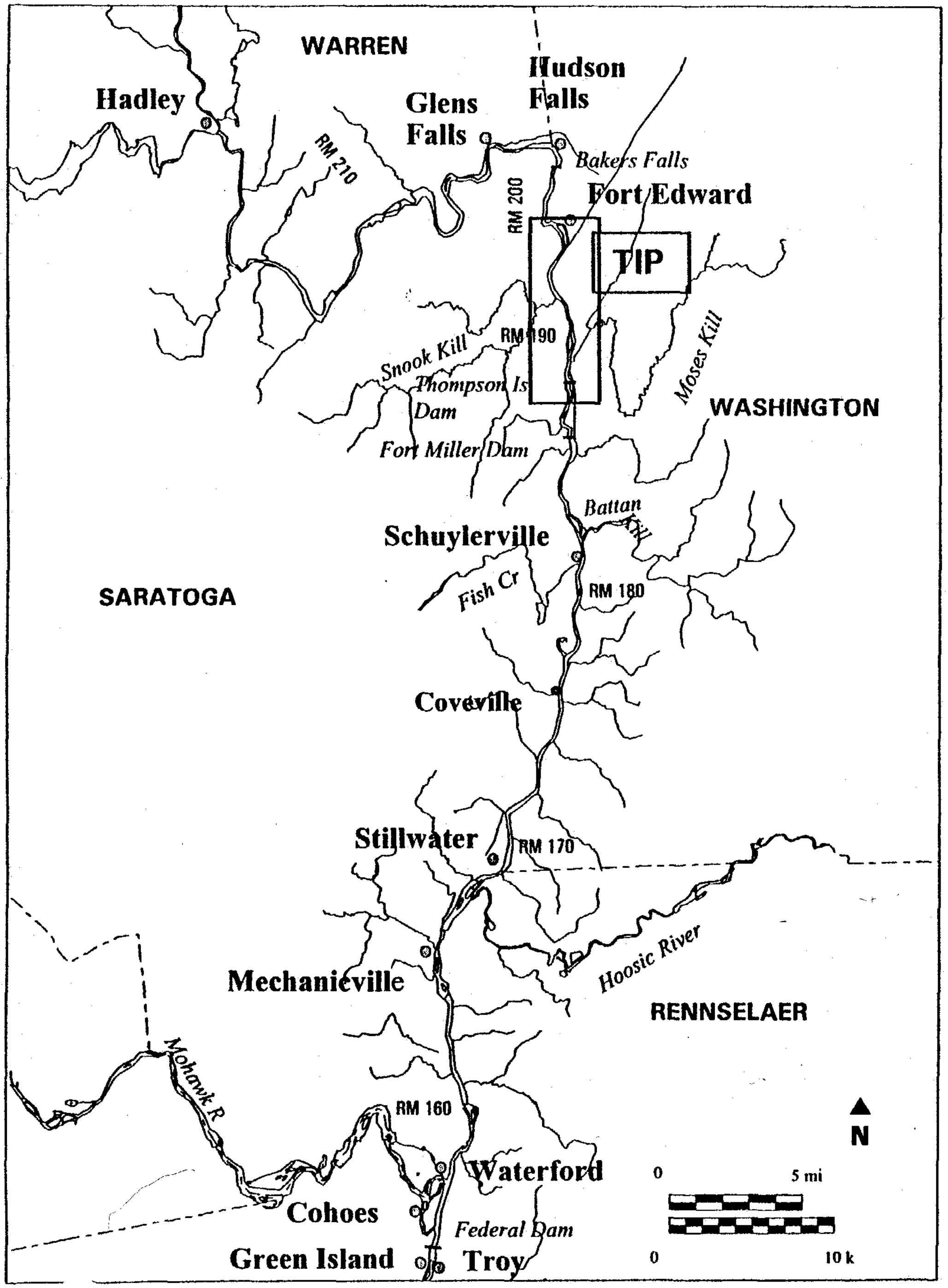
10.2405

Hudson River PCBs Reassessment Reports

Phase 1 Report	Aug 1991
Phase 2 Reports (Remedial Investigation)	
1. Database Report	Nov 1995
2. Preliminary Model Calibration Report	Oct 1996
3. Data Evaluation and Interpretation Report	Feb 1997
3A. Low Resolution Sediment Coring Report	July 1998
4. Baseline Modeling Report	May 1999
5. Ecological Risk Assessment	Aug 1999
6. Human Health Risk Assessment	Aug 1999
Phase 3 Report (Feasibility Study)	Dec 2000

Hudson River PCBs Reassessment

Phase 3 Report - Feasibility Study



Purpose of FS

Evaluate options to address the PCB-contaminated sediments in the Upper Hudson River to protect human health and the environment.

- **SOW 9/98**
- **Resp Sum 4/99**

Remedial Action Objectives

Developed as part of Feasibility Study

Specify:

- Contaminants (PCBs) and media of interest
- Exposure pathways (*e.g.*, consumption of fish)
- Preliminary remediation goals (*e.g.*, target conc. in fish)

Permits a range of alternatives to be developed

10.2409

General Response Actions

- No-action
- Monitored natural attenuation
- Containment (capping)
- *In-situ* treatment
- Dredging (+/- treatment) and disposal

NCP Nine Criteria

Threshold Factors
1) Overall Protection of Human Health and Environment
2) Compliance with Other Environmental Laws

Primary Balancing Factors
3) Long-term Effectiveness and Permanence
4) Reduction of Toxicity, Mobility or Volume
5) Short-term Effectiveness
6) Implementability
7) Cost

Modifying Criteria
8) State Acceptance
9) Community Acceptance

No-Action

- required by law
- provides basis for comparison of alternatives
- establishes baseline condition

No need for remediation
Monitoring is allowed

Monitored Natural Attenuation

- baseline condition presents risk or exceeds applicable standards
- expect to achieve remediation goals in reasonable time frame compared to active alternatives
- may include institutional controls
- may be used in conjunction with other alternatives

No active remediation
Monitoring is necessary

10.2413

10.2414

Proposed Plan - Record of Decision

- Proposed Plan identifies preferred alternative
  - Public comment (assess community acceptance)

- Record of Decision
  - Responsiveness Summary

Additional Background Information

www.epa.gov/hudson

2

Hudson River PCBs Site Reassessment

Peer Review of the Baseline Modeling Report

January 13, 2000

Douglas Tomchuk
USEPA - Region 2

Hudson River PCBs Site Reassessment

- Findings from Previous Reports

- Charge

Hudson River PCBs Reassessment Reports

Phase 1 Report	Aug 1991
Phase 2 Reports (Remedial Investigation)	
1. Database Report	Nov 1995
2. Preliminary Model Calibration Report	Oct 1996
3. Data Evaluation and Interpretation Report	Feb 1997
3A. Low Resolution Sediment Coring Report	July 1998
4. Baseline Modeling Report	May 1999
5. Ecological Risk Assessment	Aug 1999
6. Human Health Risk Assessment	Aug 1999
Phase 3 Report (Feasibility Study)	Dec 2000

10.2419

Principal Reassessment Questions

1. When will PCB levels in fish meet 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. Could a flood scour sediments, exposing and redistributing buried contamination?

Geochemistry

Data Evaluation and Interpretation Report (DEIR)
Low Resolution Sediment Coring Report (LRC)

- water-column transport
- dechlorination
- burial
- sediment inventory

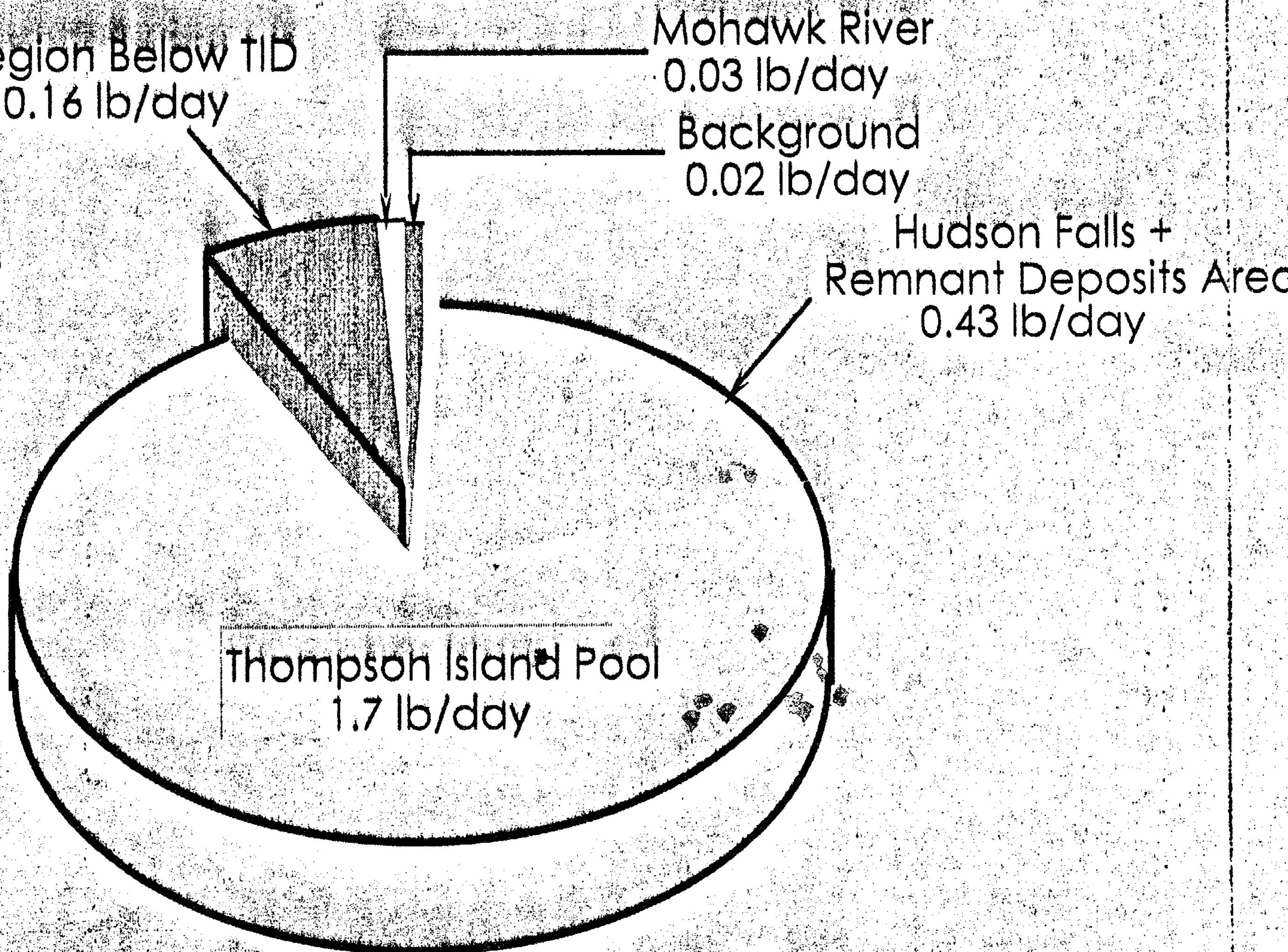
Peer Reviewed - acceptable with minor revision

Hudson River PCBs Reassessment

Data Evaluation and Interpretation Report

February 1997

Mean Summer Conditions 1993



The area of the site upstream of the Thompson Island Dam represents the primary source of PCBs to the freshwater Hudson.

10.2422

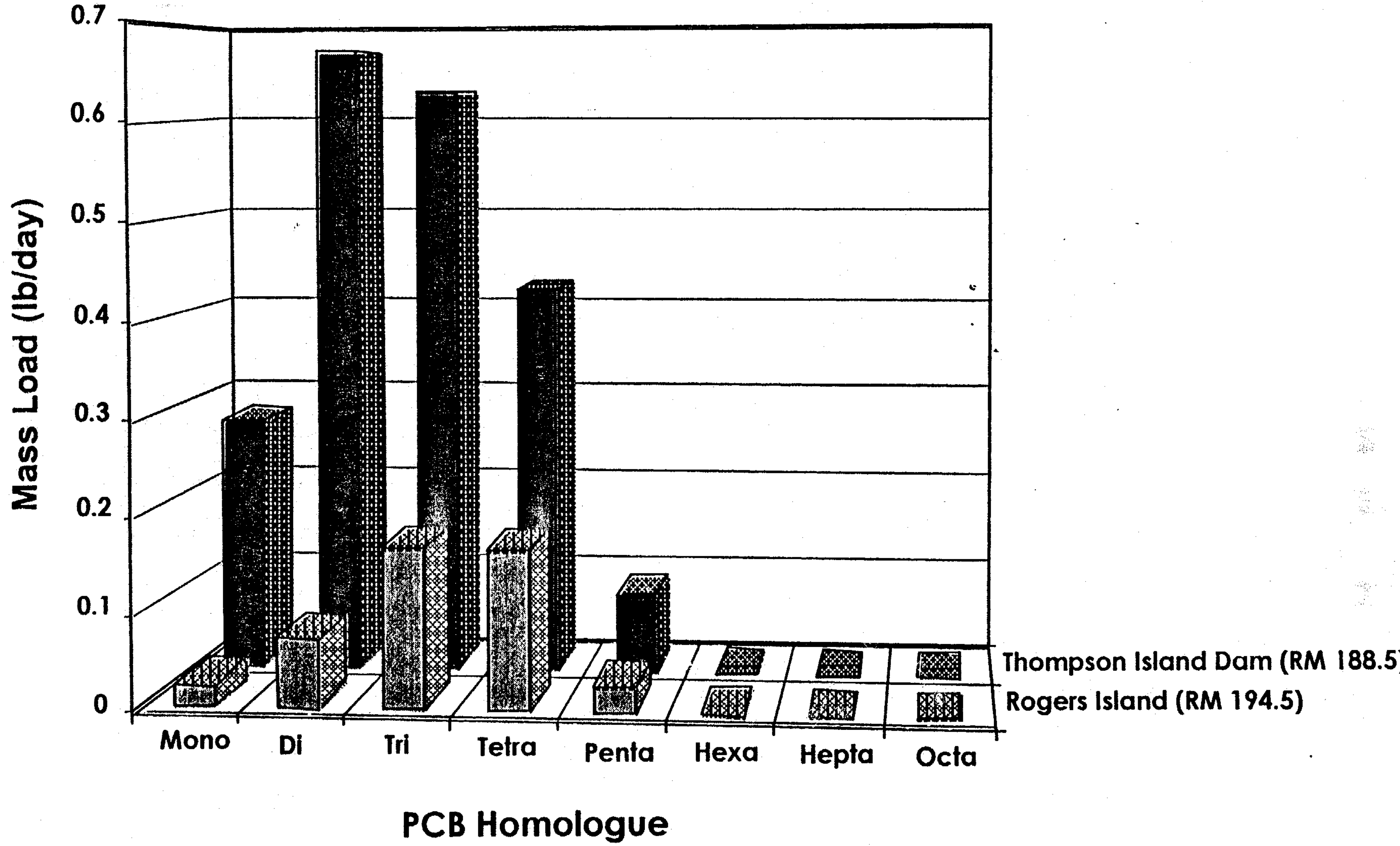
10.2423

Water-Column Transport

- The increased PCB load across the Thompson Island Pool (TIP) has a readily identifiable homologue pattern which originates from the sediments with the pool.

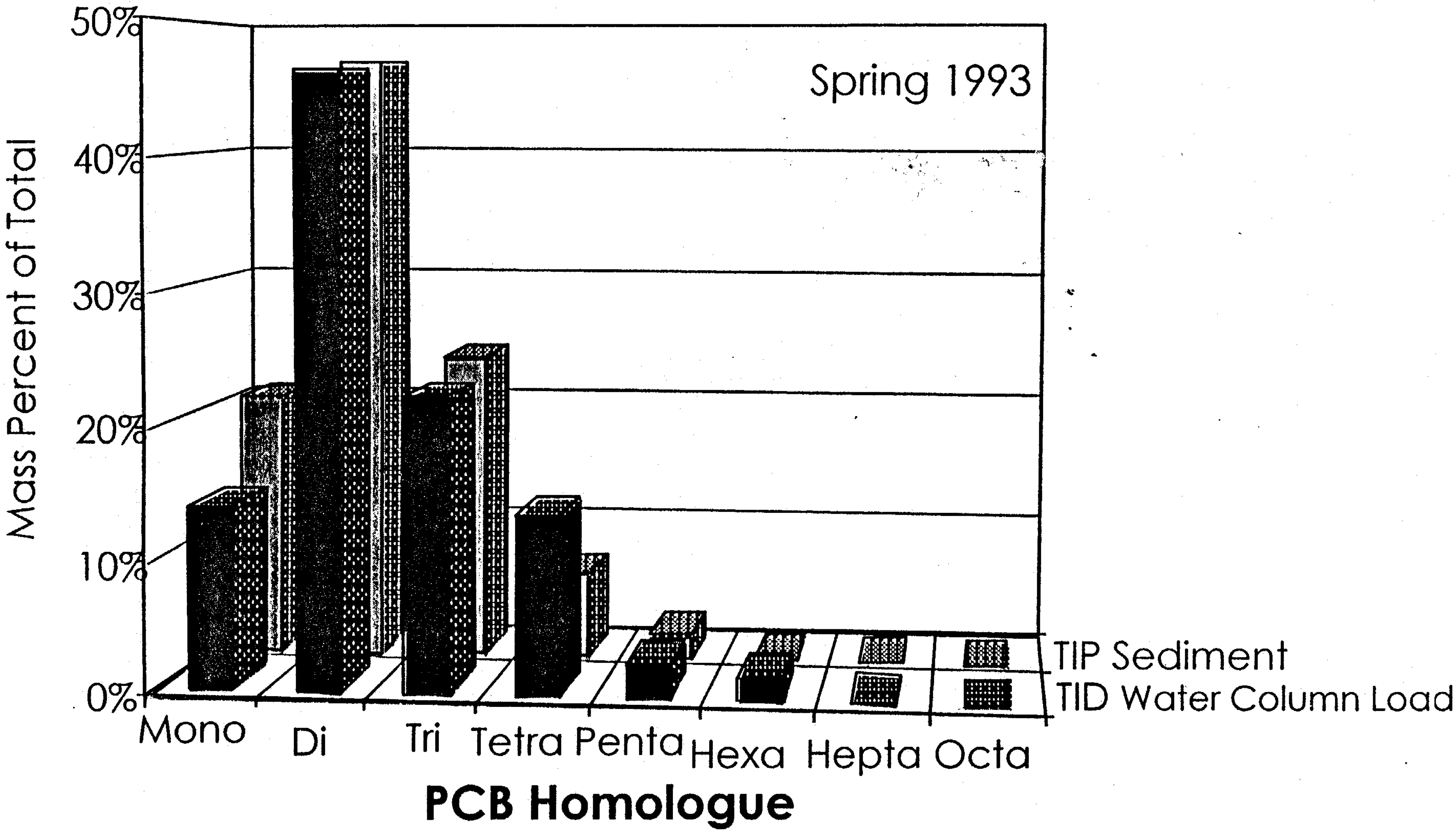
- The Thompson Island Pool load dominates the water-column load in the freshwater Hudson during low-flow conditions (10 months of the year).

The Thompson Island Pool sediments are a major source of PCBs to the freshwater Hudson.



Phase 2 Mean Summer Water Column PCB Loads (1993)

10.2424



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

Dechlorination

- The extent of dechlorination is limited in the sediments, resulting in probably less than 10 percent mass loss from the original concentrations.

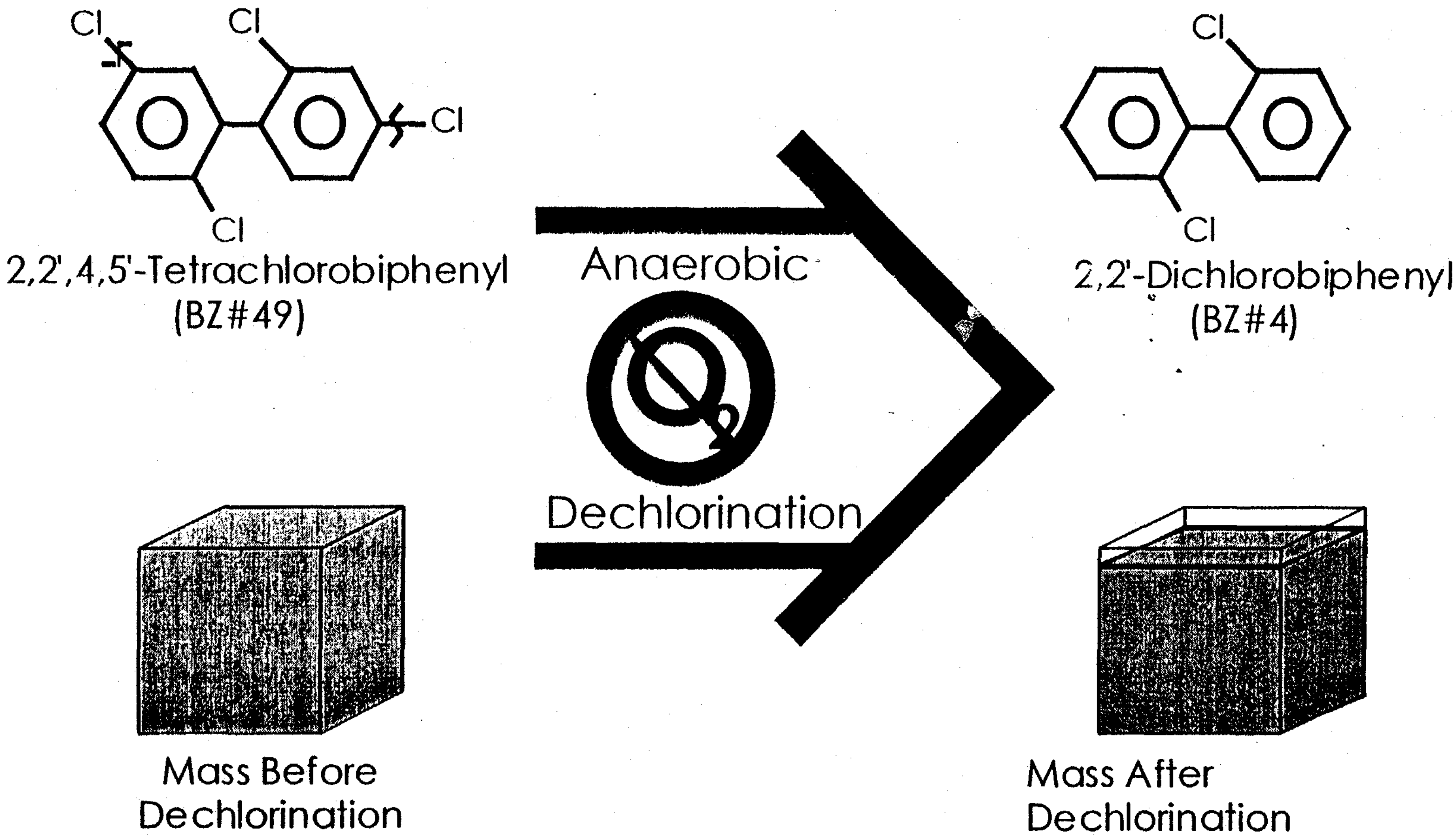
- Extent of dechlorination controlled by concentration, not time.

- Dechlorination occurs relatively quickly (several years), then rate becomes negligible.

- Even with “extensive” dechlorination, fish are still bioaccumulating Aroclor 1254-like PCBs (with 3, 4, 5 and 6 chlorine molecules).

Sediment inventories will not be naturally "remediated" via dechlorination.

10.2427



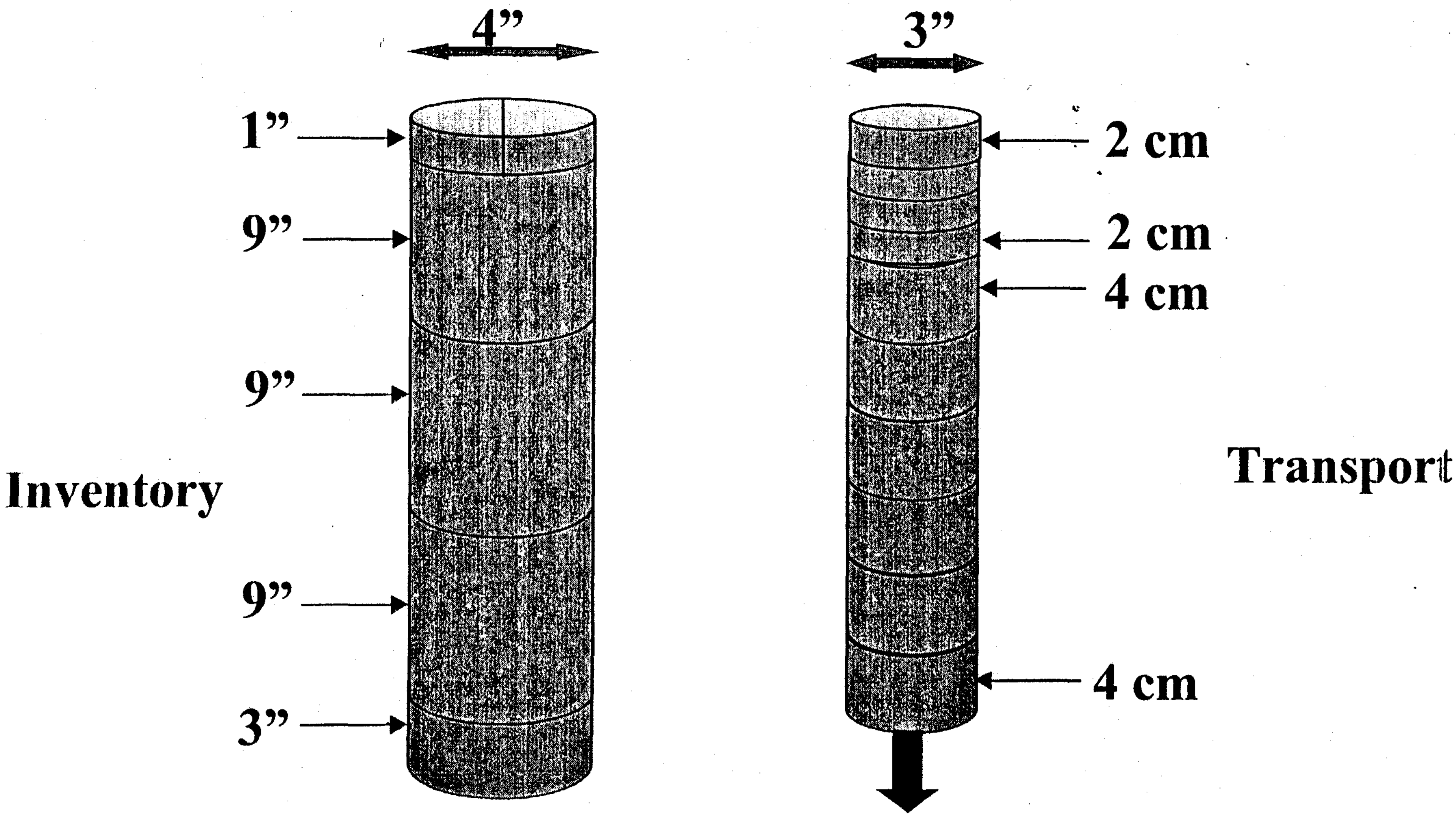
Cl
Cl
Cl
Cl
2,2',4,5'-Tetrachlorobiphenyl
(BZ#49)
Anaerobic
O_2
Dechlorination
Cl
Cl
2,2'-Dichlorobiphenyl
(BZ#4)
Mass Before
Dechlorination
Mass After
Dechlorination

Hudson River PCBs Reassessment

Low Resolution Sediment Coring Report

July 1998

Low Resolution v. High Resolution



Burial

• There was little evidence found of widespread burial of PCB-contaminated sediment by clean sediment in the Thompson Island Pool.

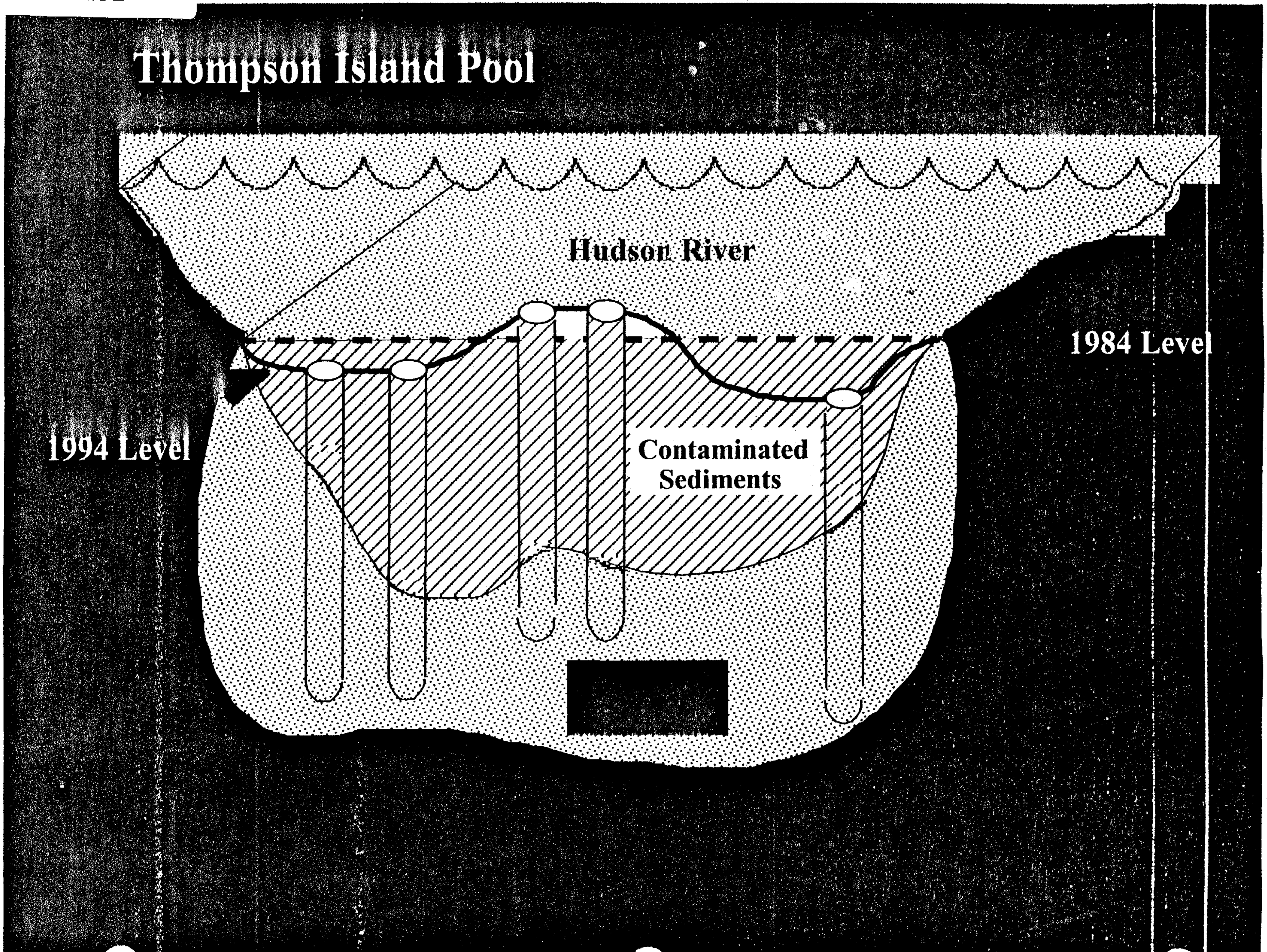
• In 60% of the cores the maximum PCB concentration was found within the top 9 inches.

• In most cores where contaminated material had been buried, the newly deposited sediments were also contaminated with PCBs.

• Burial is seen at some locations, but more core sites showed loss of PCB inventory than showed PCB gain or burial.

PCBs will continue to be released from Upper Hudson River sediment.

10.2431

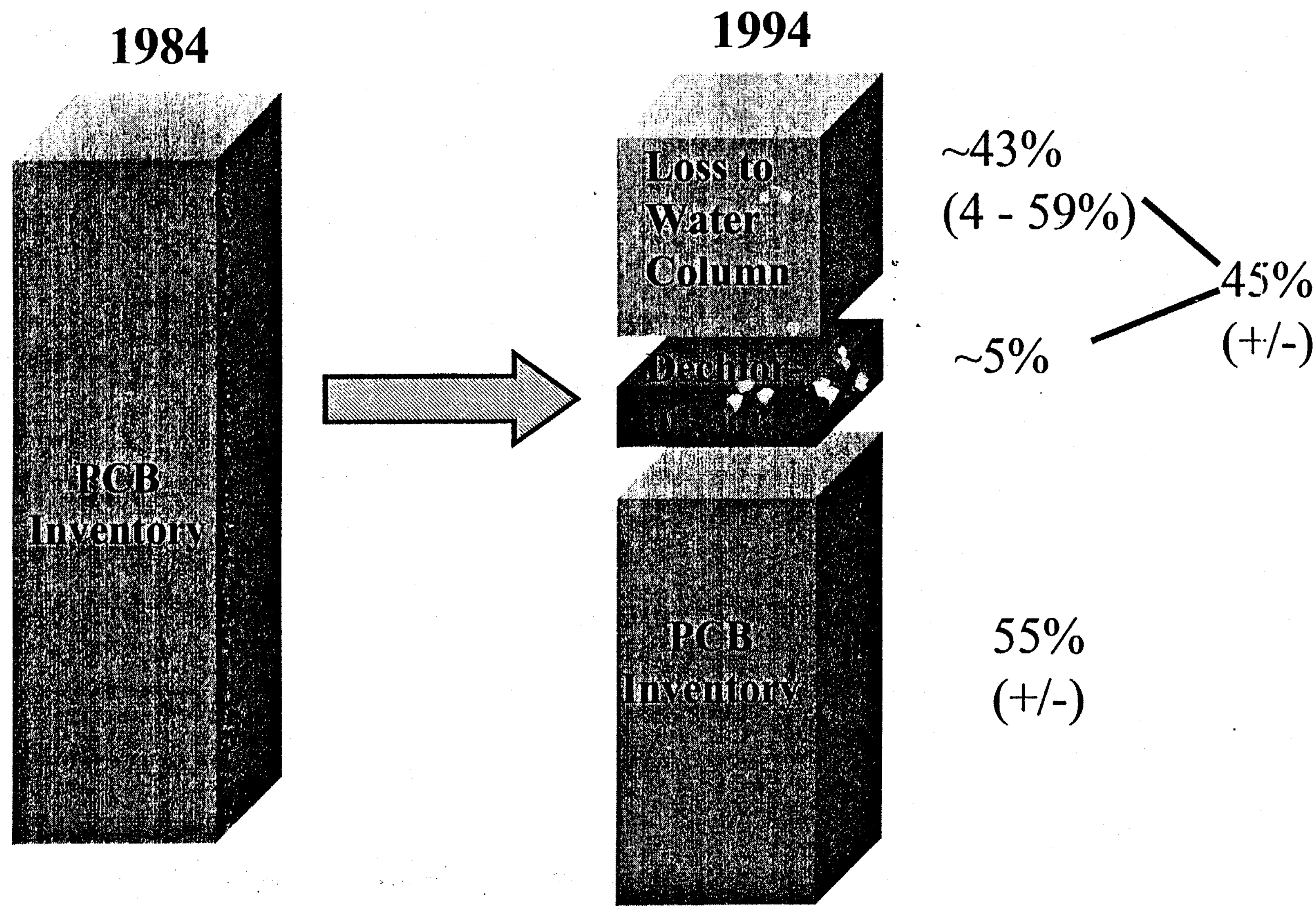

Thompson Island Pool
Hudson River
1984 Level
1994 Level
Contaminated
Sediments

Sediment Inventory

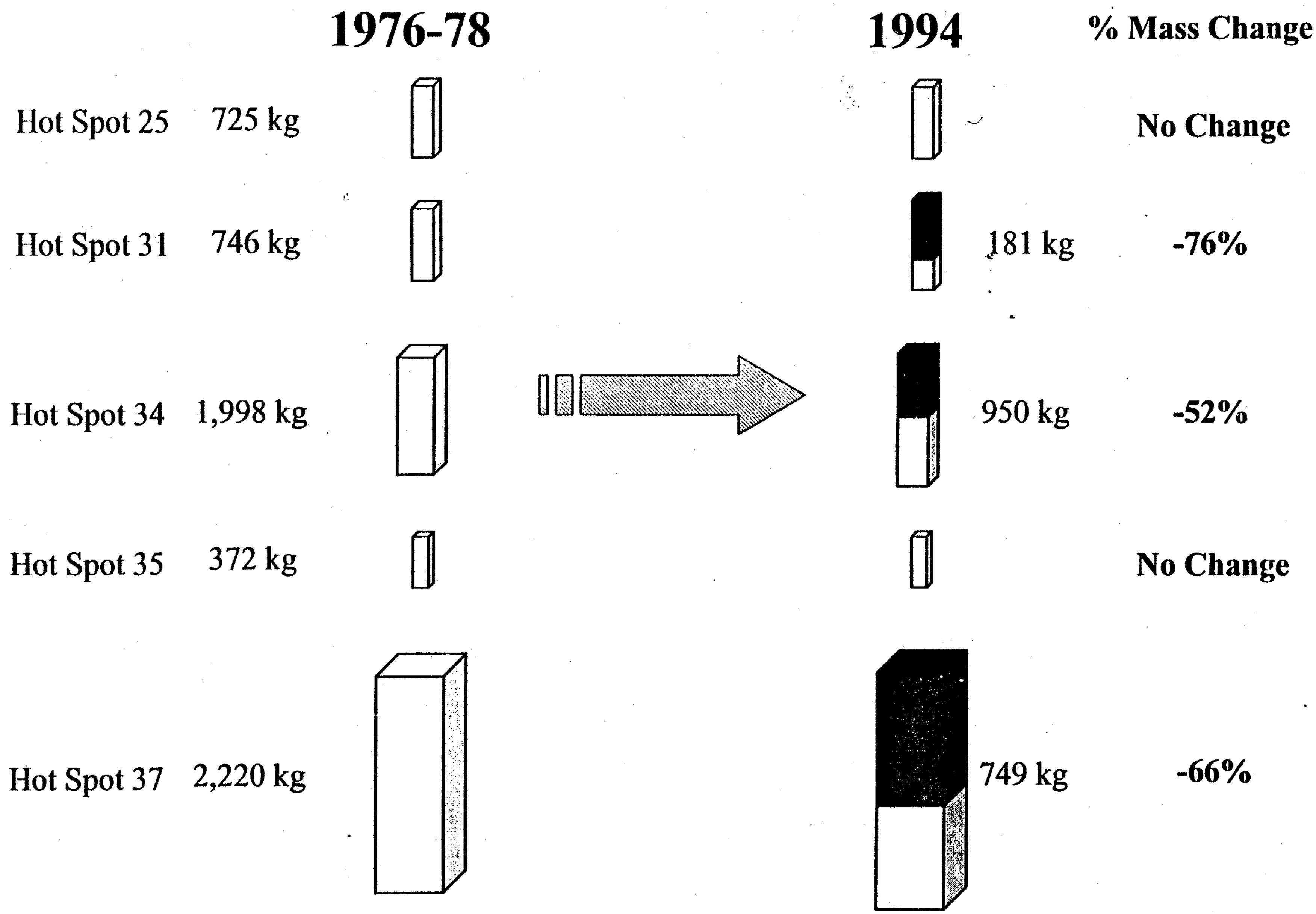
• From 1984 to 1994, there has been a statistically significant loss of PCB inventory (between 4 and 59 percent) from highly-contaminated sediments in the Thompson Island Pool (>10 g/m^2).

• From 1976 to 1994, there has been a net loss of PCB inventory in hot spot sediments between the TI Dam and the Federal Dam at Troy.

PCBs in the most highly contaminated areas are being redistributed within the river.


1984
PCB Inventory
1994
Loss to Water Column
Dechlor
PCB Inventory
~43%
(4 - 59%)
~5%
45%
(+/-)
55%
(+/-)

Hot Spot Inventories Below The TI Dam



Greater Inventory in Hot Spot 28

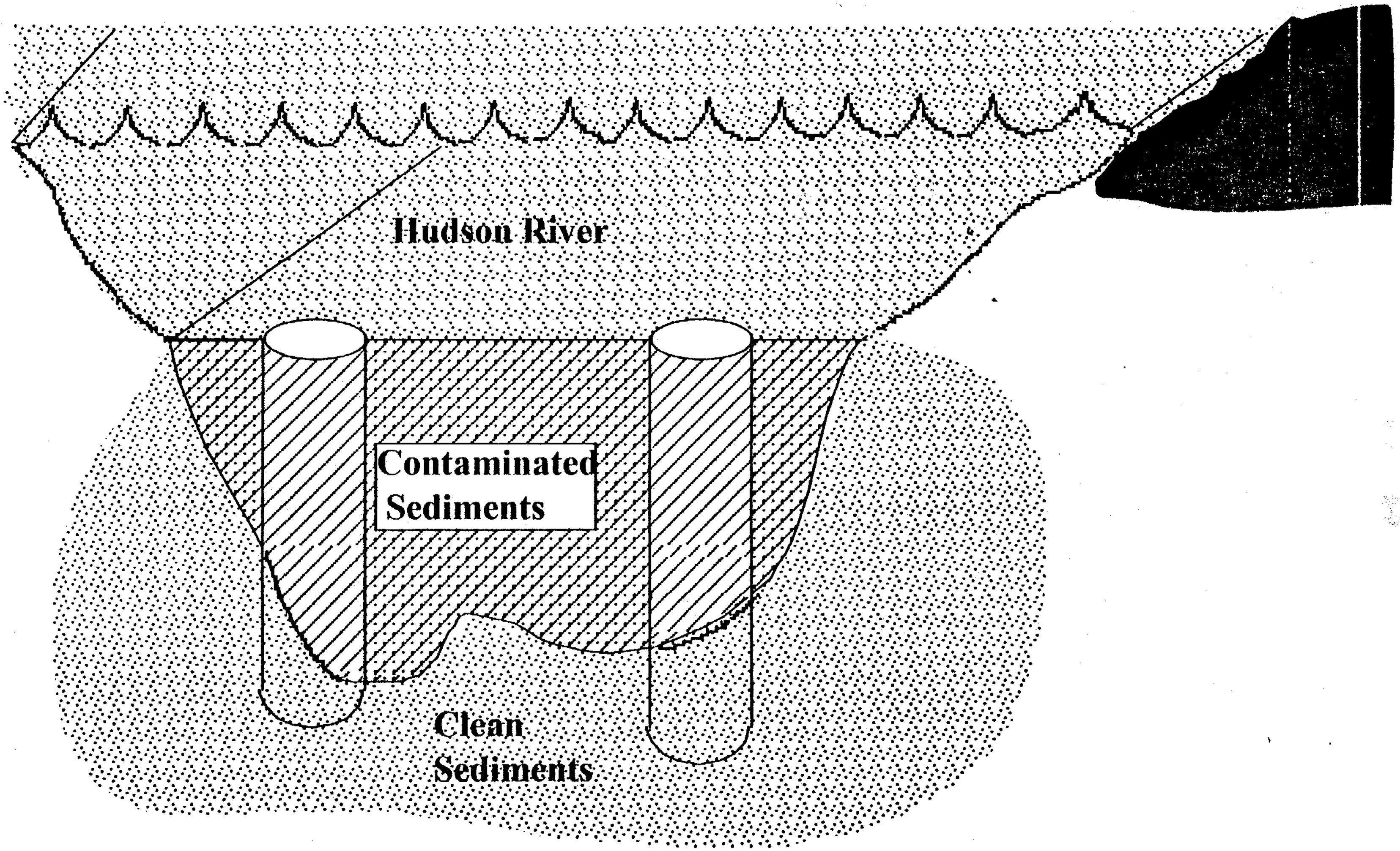
• The PCB inventory for Hot Spot 28 is considerably greater than previous estimates.

• The previous estimates were 2 to 7 metric tons. We now estimate 20 metric tons.

• This apparent "gain" in inventory is attributed to significant underestimates in previous studies rather than actual deposition of PCBs in Hot Spot 28.

Hot Spot 28

1994: 20 metric tons
1976: 2 to 7 metric tons



1994 Phase 2 cores penetrate the depth of contamination better characterizing the Hot Spot inventory

Hudson River PCBs Reassessment

Baseline Modeling Report - May 1999

To be Superceded by the

Revised Baseline Modeling Report - January 2000

Hudson River PCBs Reassessment

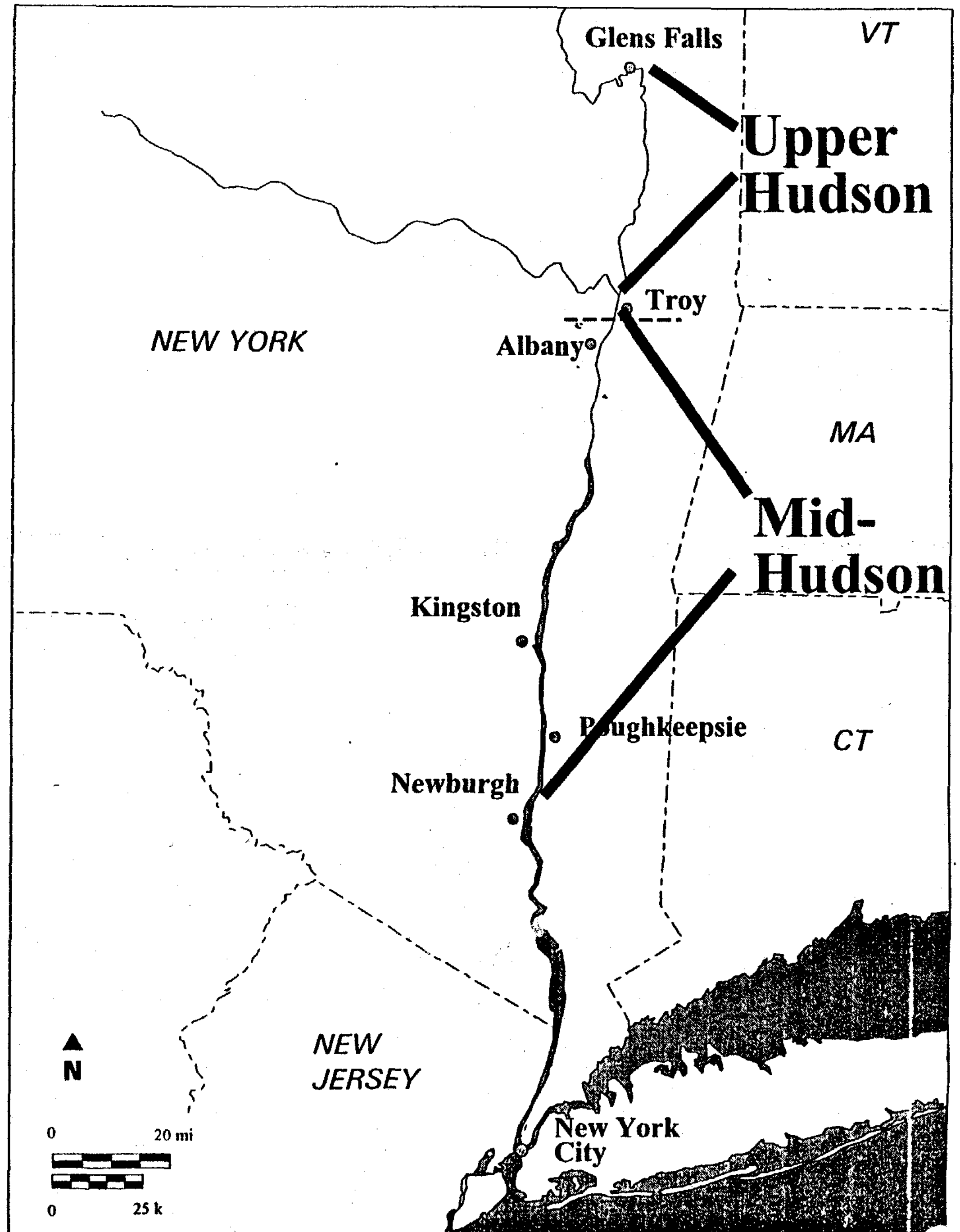
Human Health Risk Assessment

Upper Hudson - August 1999

Mid-Hudson - December 1999

10.2439

Areal Coverage of the Human Health Risk Assessments



Risk Assessment - Basic Components

Risk is a function of:

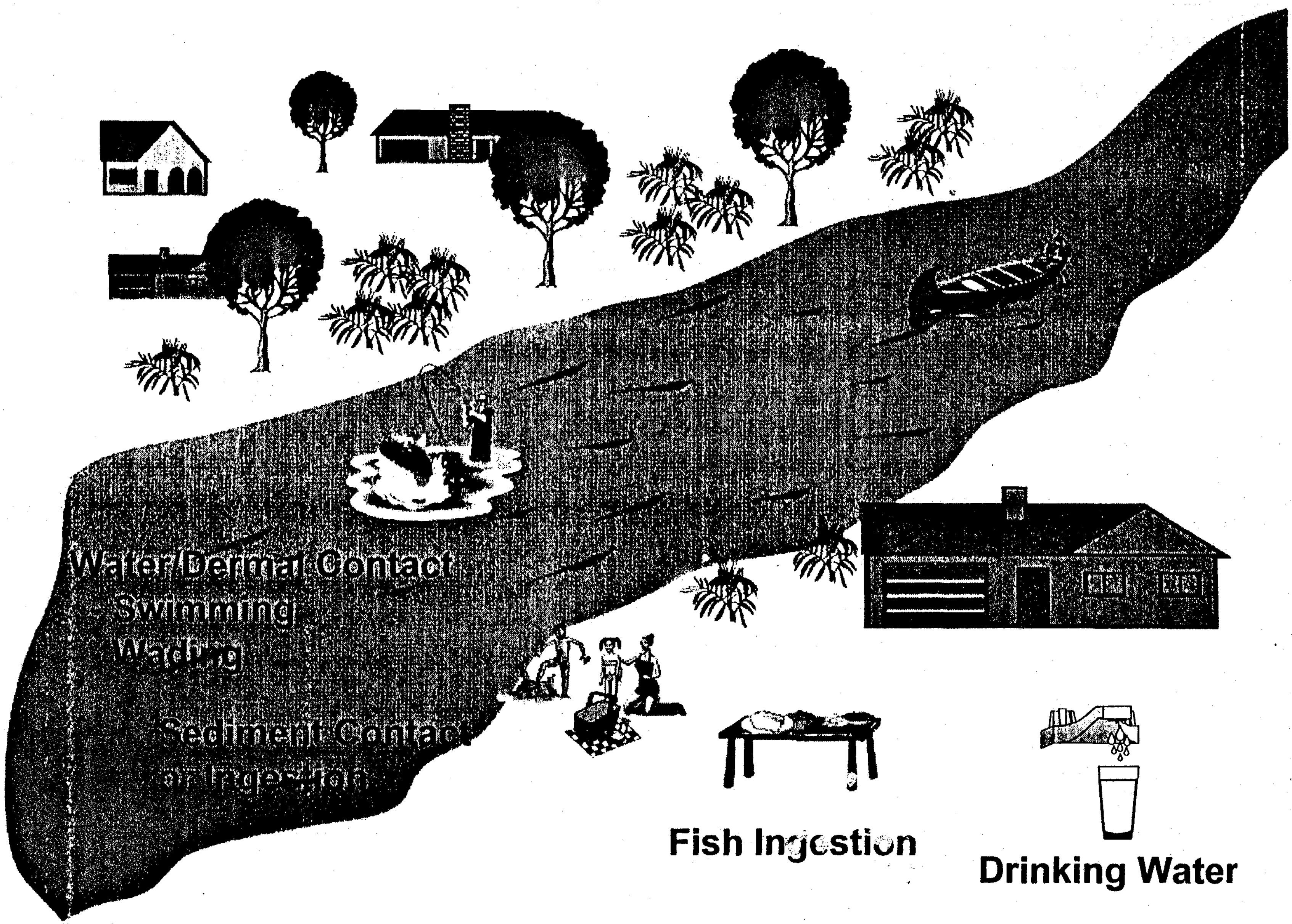
The ability of a chemical to cause adverse effects

Exposure

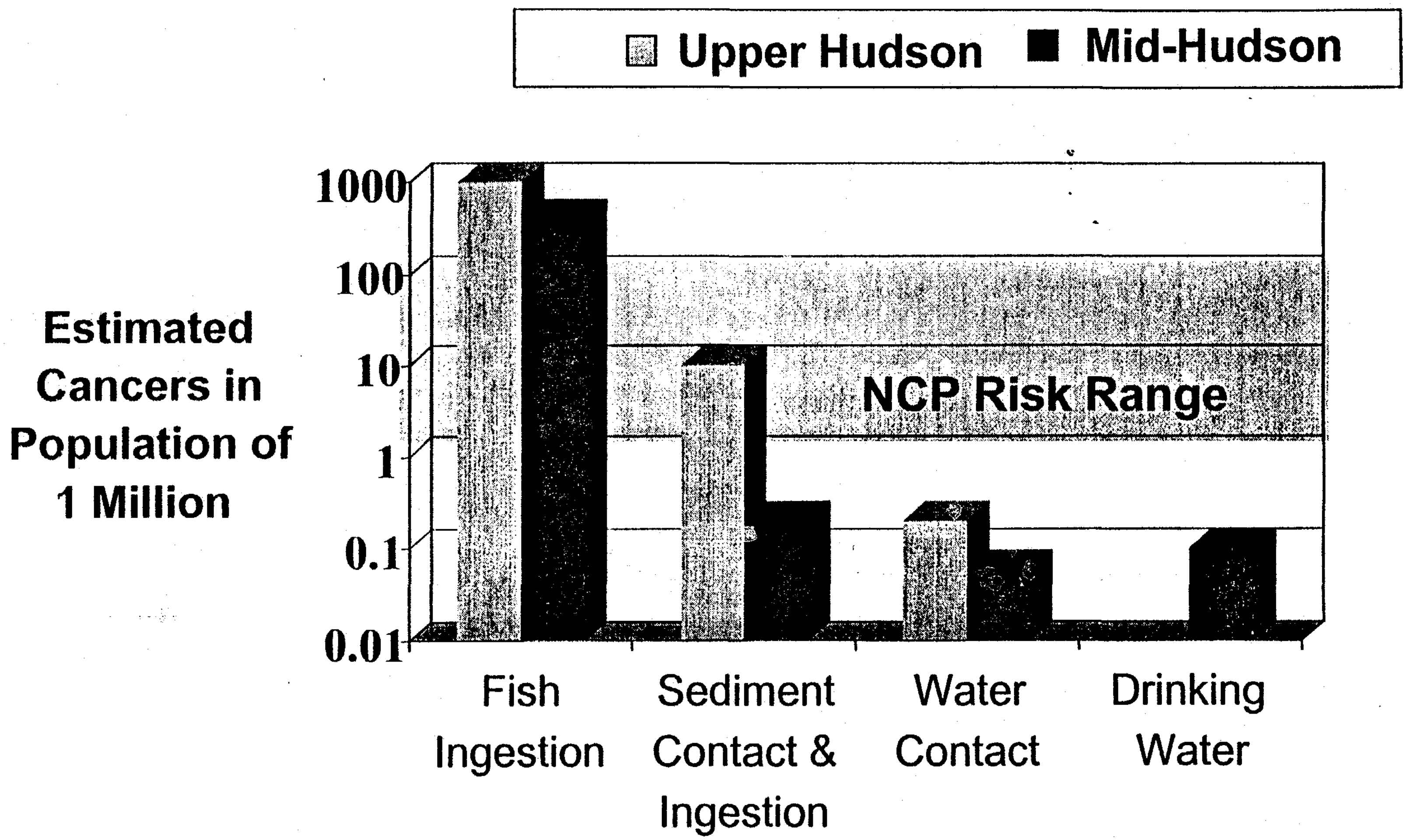
Toxicity

Chemicals in food, sediment, water, air and their contact with humans and ecological receptors

Exposure Pathways to PCBs

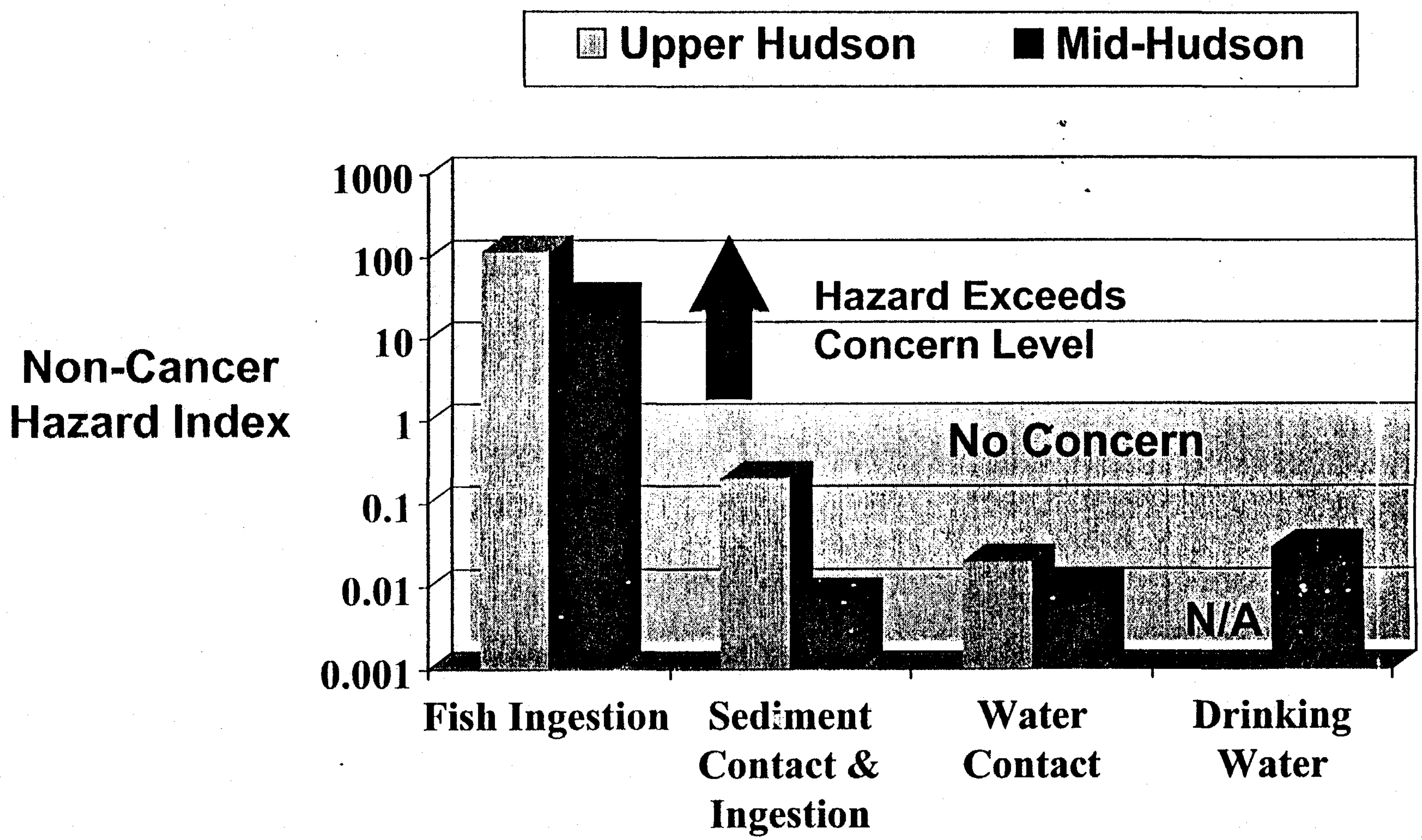


Cancer: Reasonable Maximum Estimate

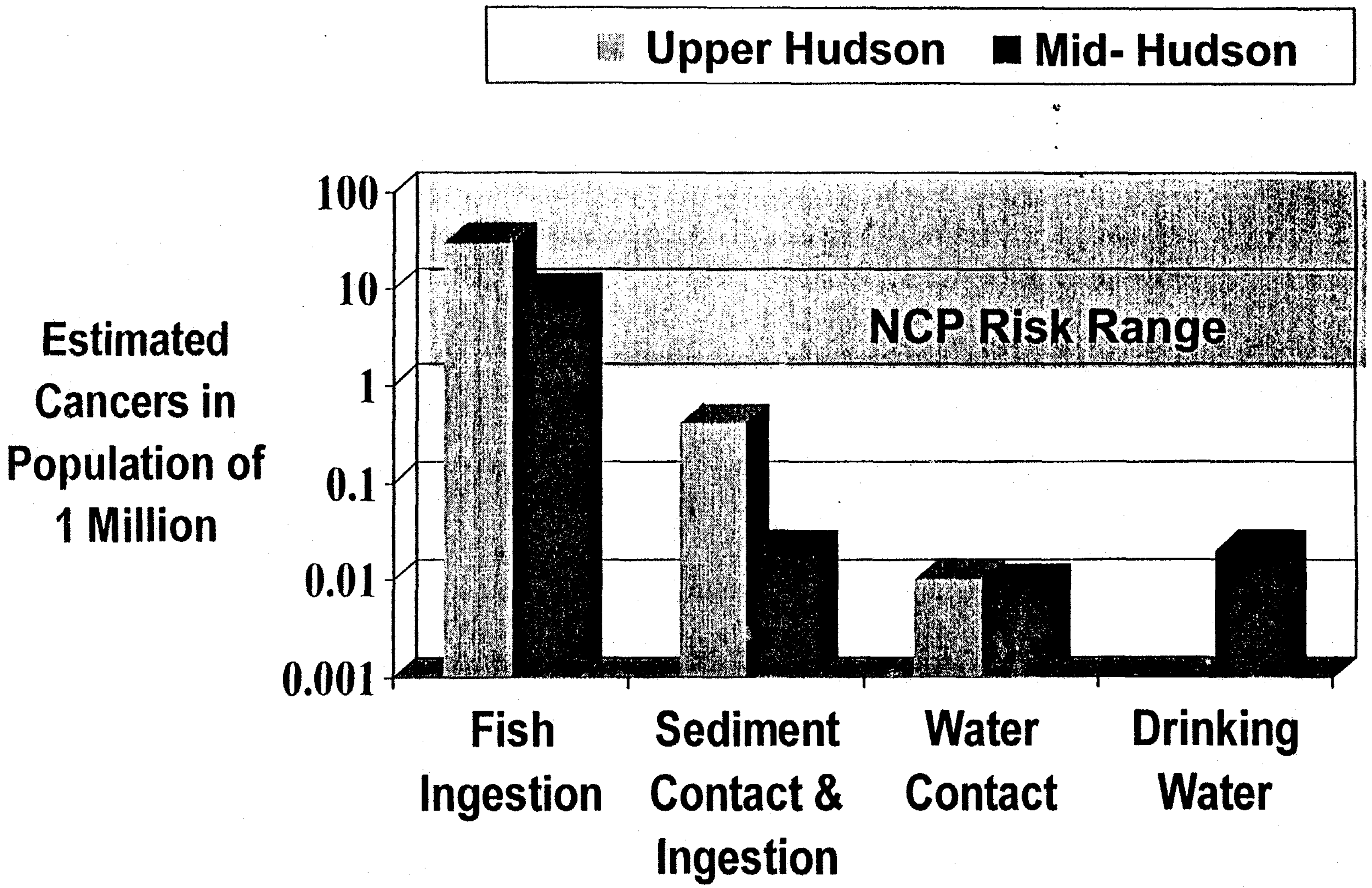


10.2442

Non-Cancer: Reasonable Maximum Estimate



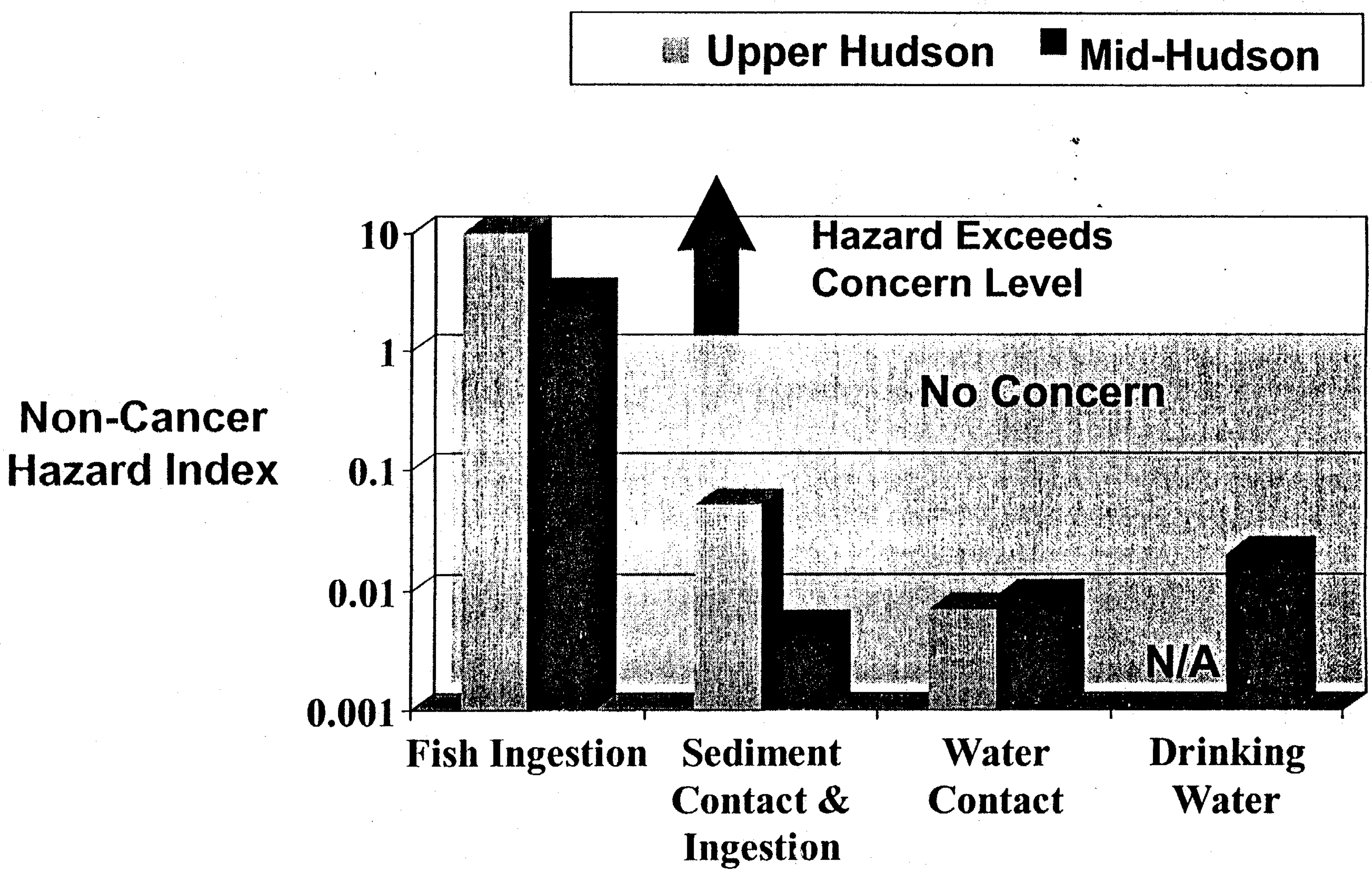
Cancer Central Estimate (Average)



10.2444

10.2445

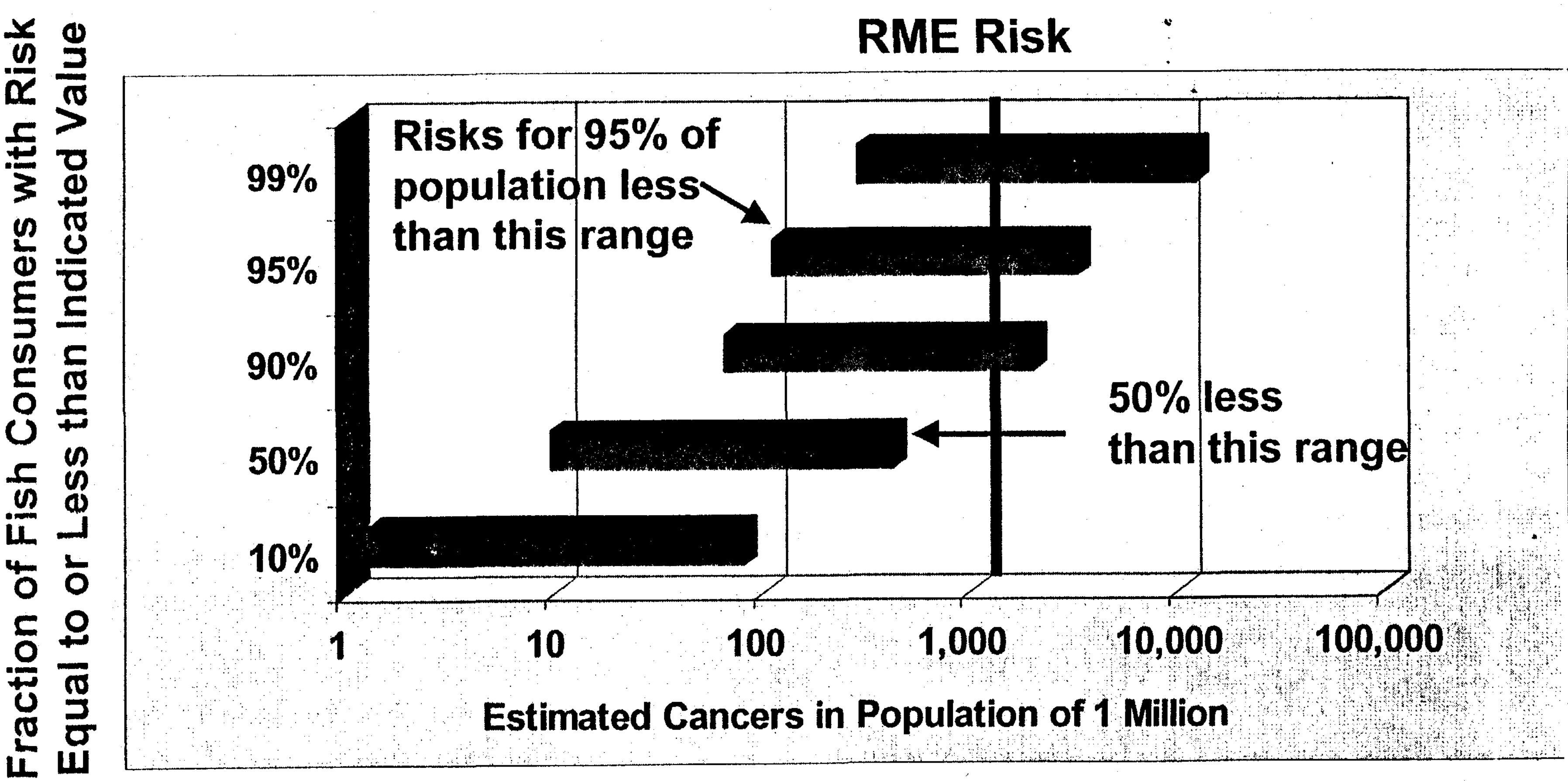
Non-Cancer Central Estimate (Average)



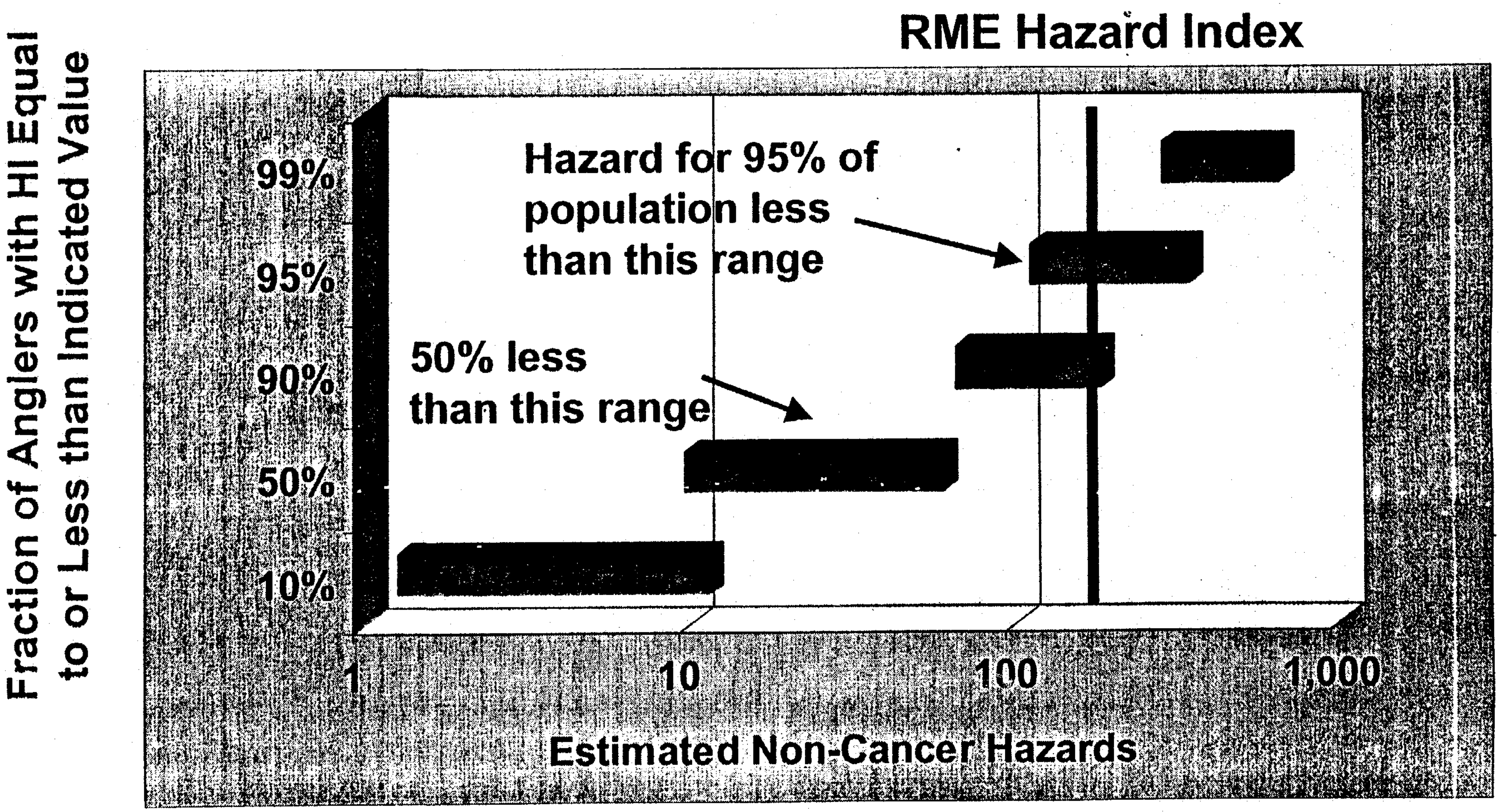
Monte Carlo Analyses (Upper Hudson)
(72 Combinations)

Exposure Factor	Base Case	Sensitivity Analysis
Fish Consumption	1991 NY Angler Survey	Maine Survey Michigan Survey L. Ontario Survey
Exposure Duration	Minimum of Fishing and Residence Duration	Residence Duration only
PCBs Lost in Cooking	20% (midpoint)	0% high end 40% low end
Fishing Location (concentration)	Average Thompson Is. Pool, Stillwater, Troy/Albany	Thompson Is. Pool (high) Troy/Albany (low)

Range of Cancer Risk Estimates for Fish Ingestion (Upper Hudson)



Range of Non-Cancer Hazard Index Estimates for Fish Ingestion (Upper Hudson)



10.2448

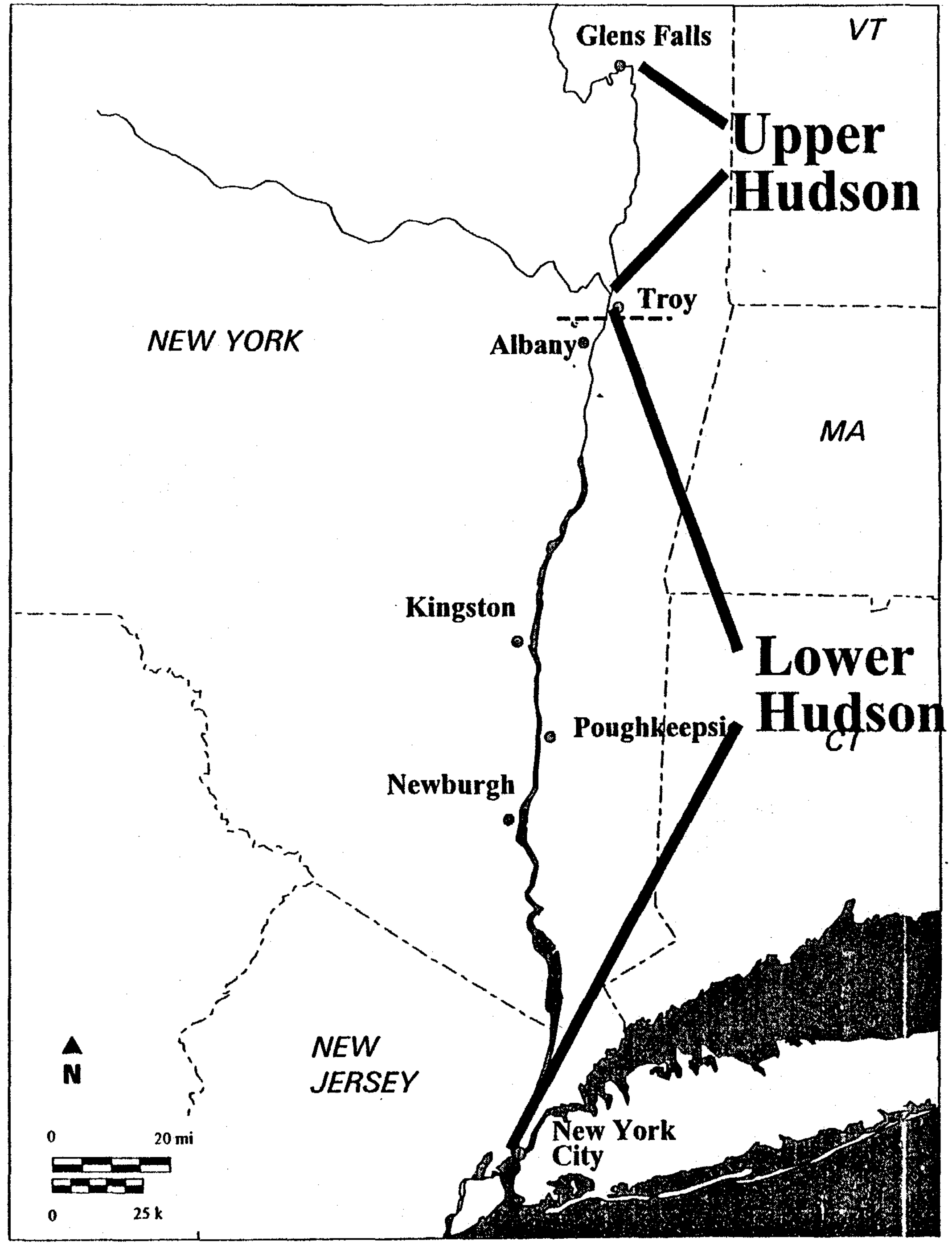
Hudson River PCBs Reassessment

Ecological Risk Assessment

Upper Hudson - August 1999

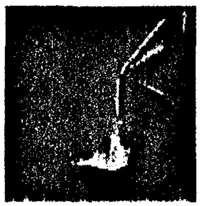
Lower Hudson Future - December 1999

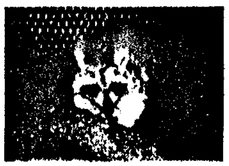
Areal Coverage of the Ecological Risk Assessment



10.2450

Ecological Receptors of Potential Concern in the Lower Hudson River


Little Brown Bat


Raccoon


Mink


River Otter

Birds


Tree Swallow


Mallard


Belted Kingfisher


Great Blue Heron


Bald Eagle


Spottail Shiner


Pumpkinseed

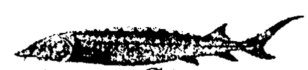

Brown Bullhead

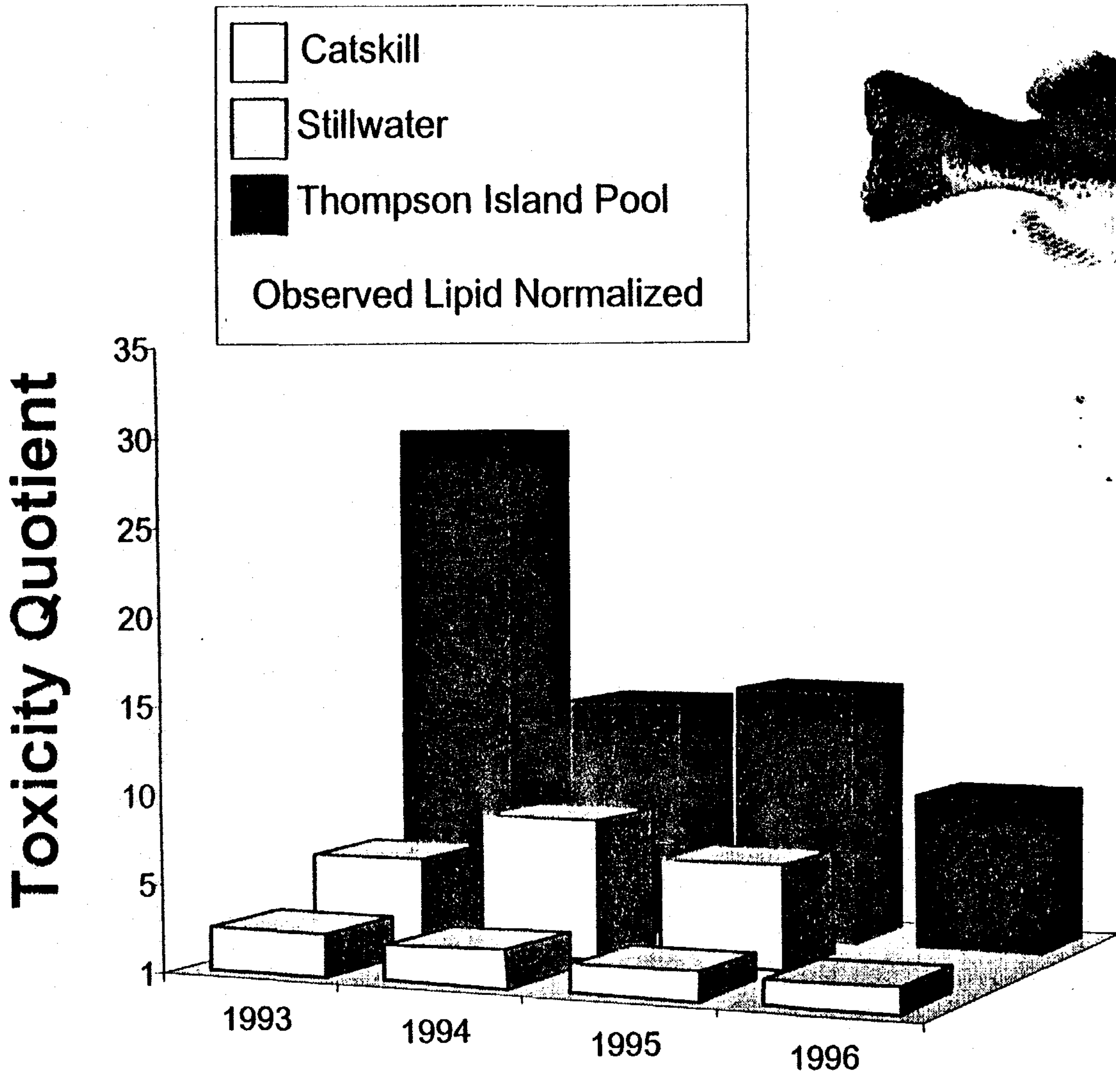

White Perch


Yellow Perch


Largemouth Bass


Striped Bass

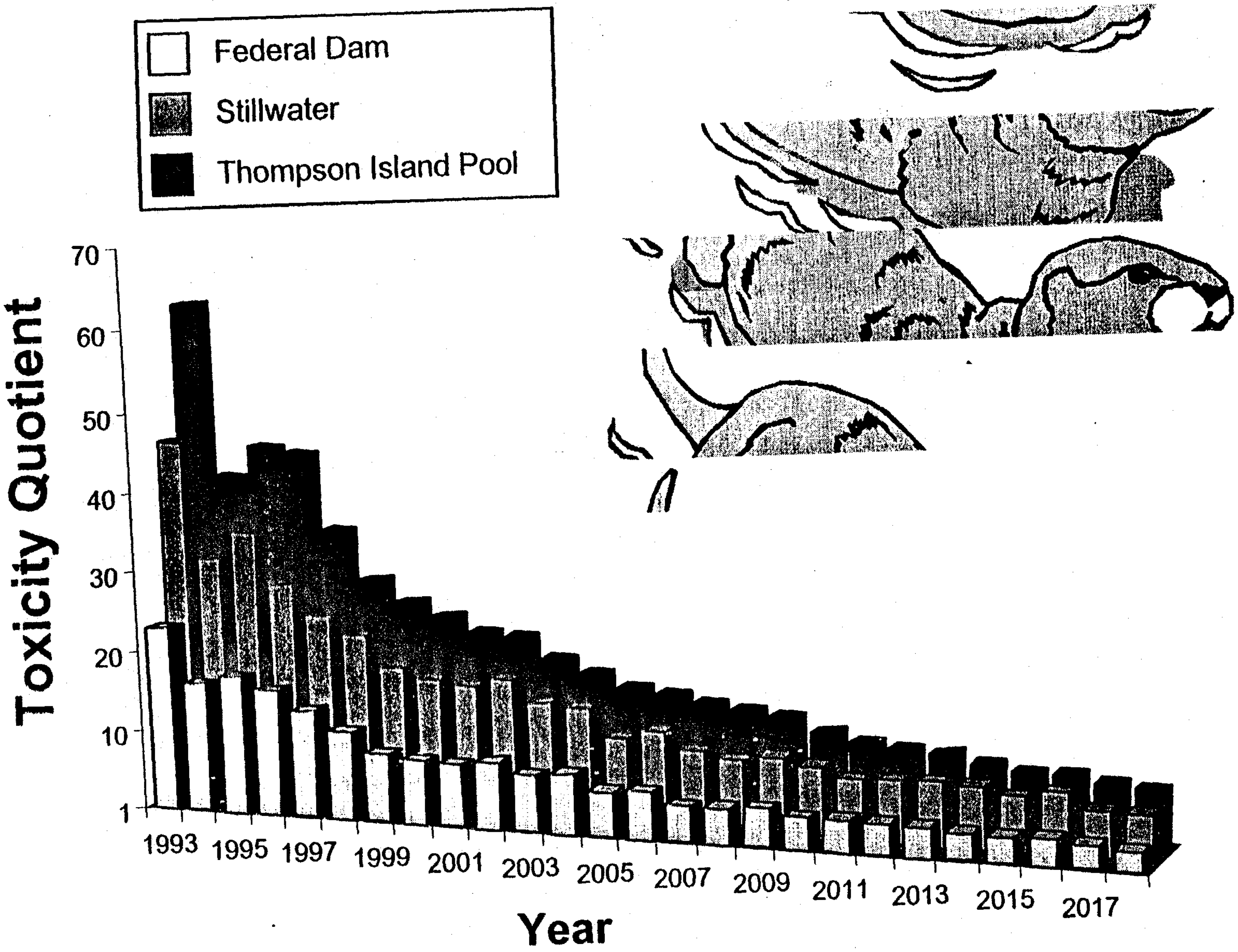

Shortnose Sturgeon



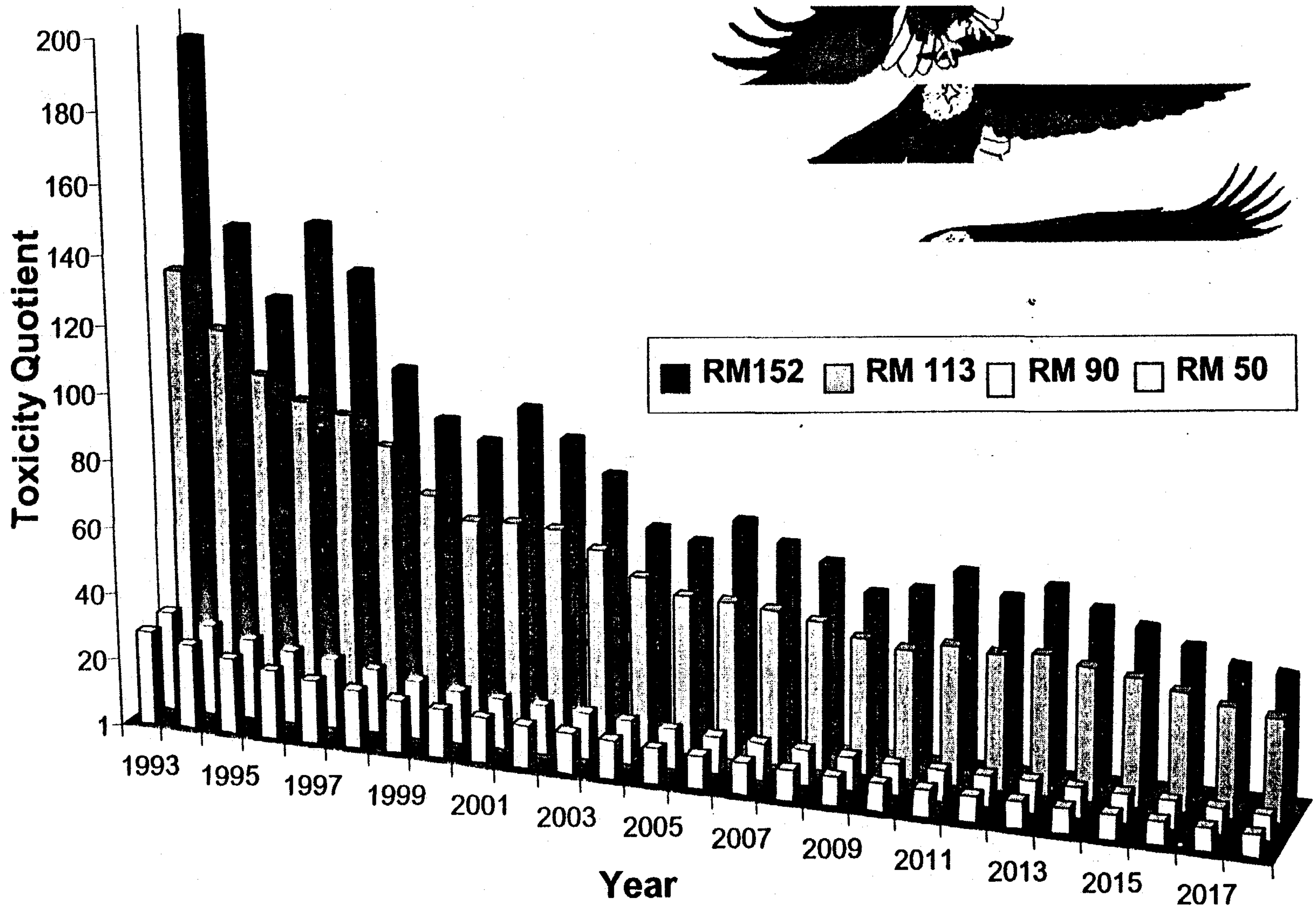
Largemouth Bass Risk Based on TEQs

10.2452

10.2453



River Otter Risk Based on Tri+ Congeners



Risk to Bald Eagle in Lower Hudson River

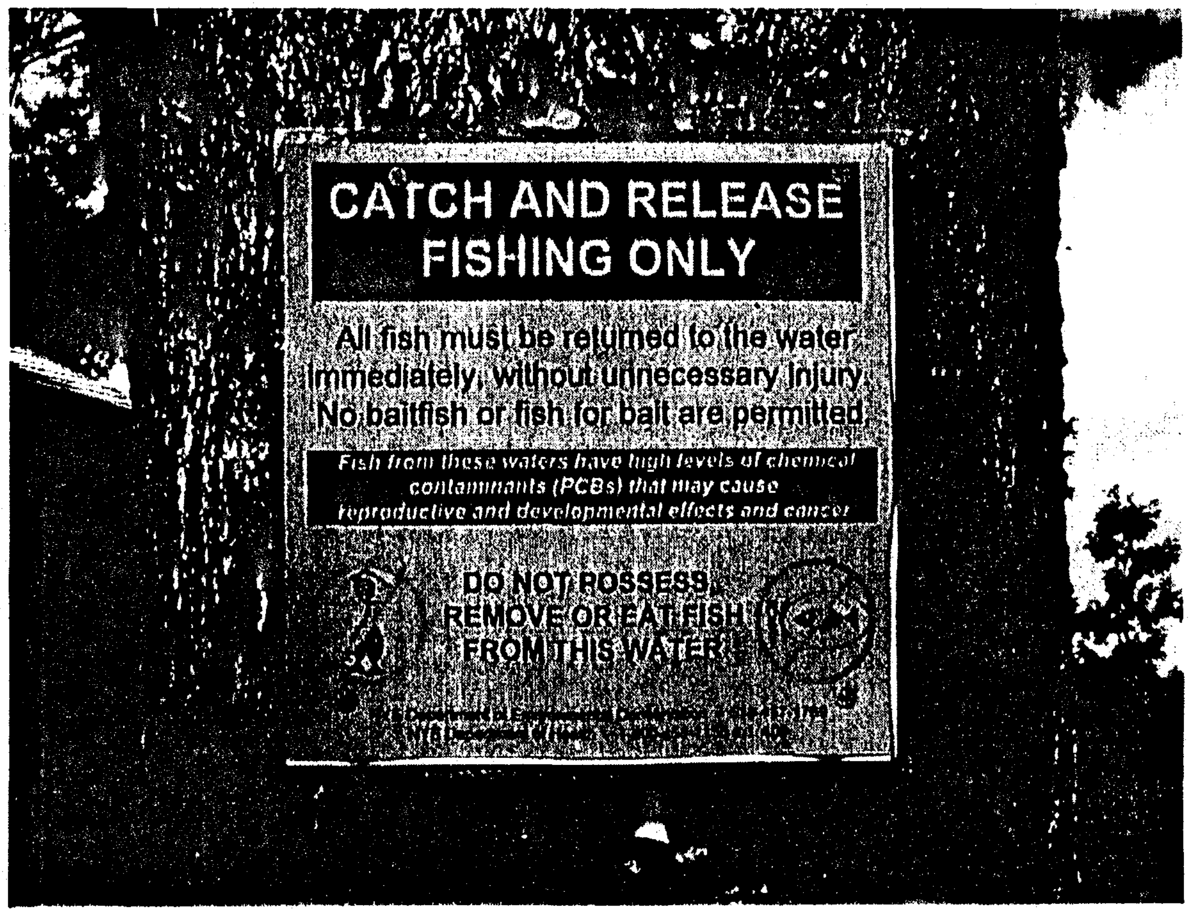
TQ Based on NOAEL-Diet Tri+ PCBs

10.2454

Summary

- TIP sediment is the major source of PCBs to water column
- Dechlorination is not sufficient
- Burial does not isolate PCBs in sediment
- Risks and hazards exceed levels of concern (primarily for consumption of fish)
- Risks to ecological receptors

Hudson River PCBs Reassessment



www.epa.gov/hudson

3

Revised Baseline Modeling Report

PCB Transport and Fate Model

Hudson River PCBs
Site Reassessment RI/FS

Limno-Tech, Inc.

Menzie Cura and Associates, Inc.

Tetra-Tech, Inc.

Hudson River Peer Review 3
January 13, 2000

Outline

- Reassessment Questions
- Site Characteristics
- Modeling Approach
- Historical Calibration
- Validation
- Forecast Simulations
- Conclusions

Reassessment Questions

- When will PCB levels in fish meet human health and ecological risk criteria under continued No Action?
- Can remedies other than No Action significantly shorten the time required to achieve acceptable risk levels?
- Could a flood scour sediments, exposing and redistributing buried contamination?

Study Goal

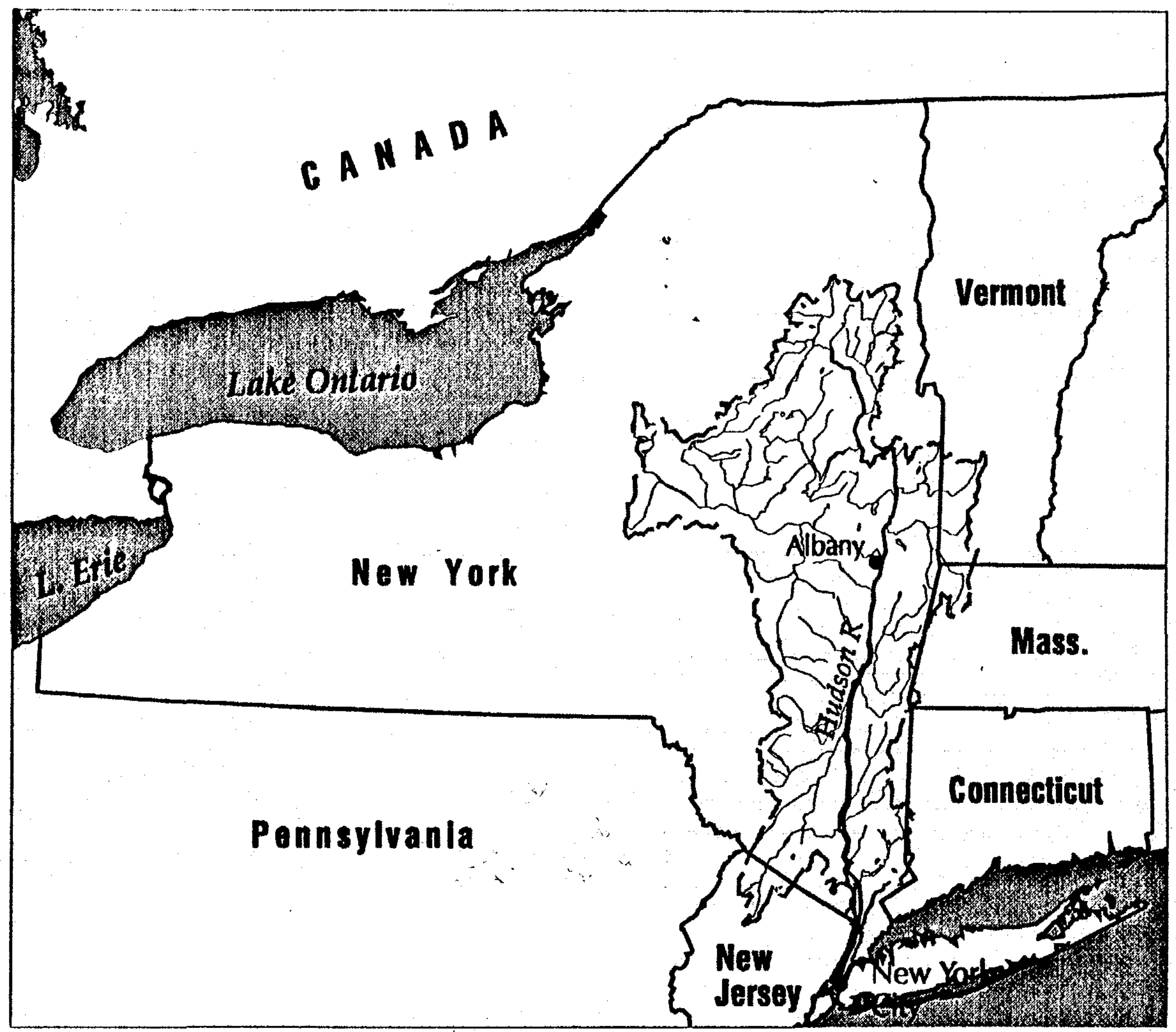
- Develop useful and scientifically credible models to forecast PCB concentrations in the water column, sediments and fish for use in:
  - Human Health Risk Assessment
  - Ecological Risk Assessment
  - Feasibility Study
    - Determination of Acceptable Risk-Based Levels
    - Comparison of Remedial Alternatives

Site Characteristics

Background

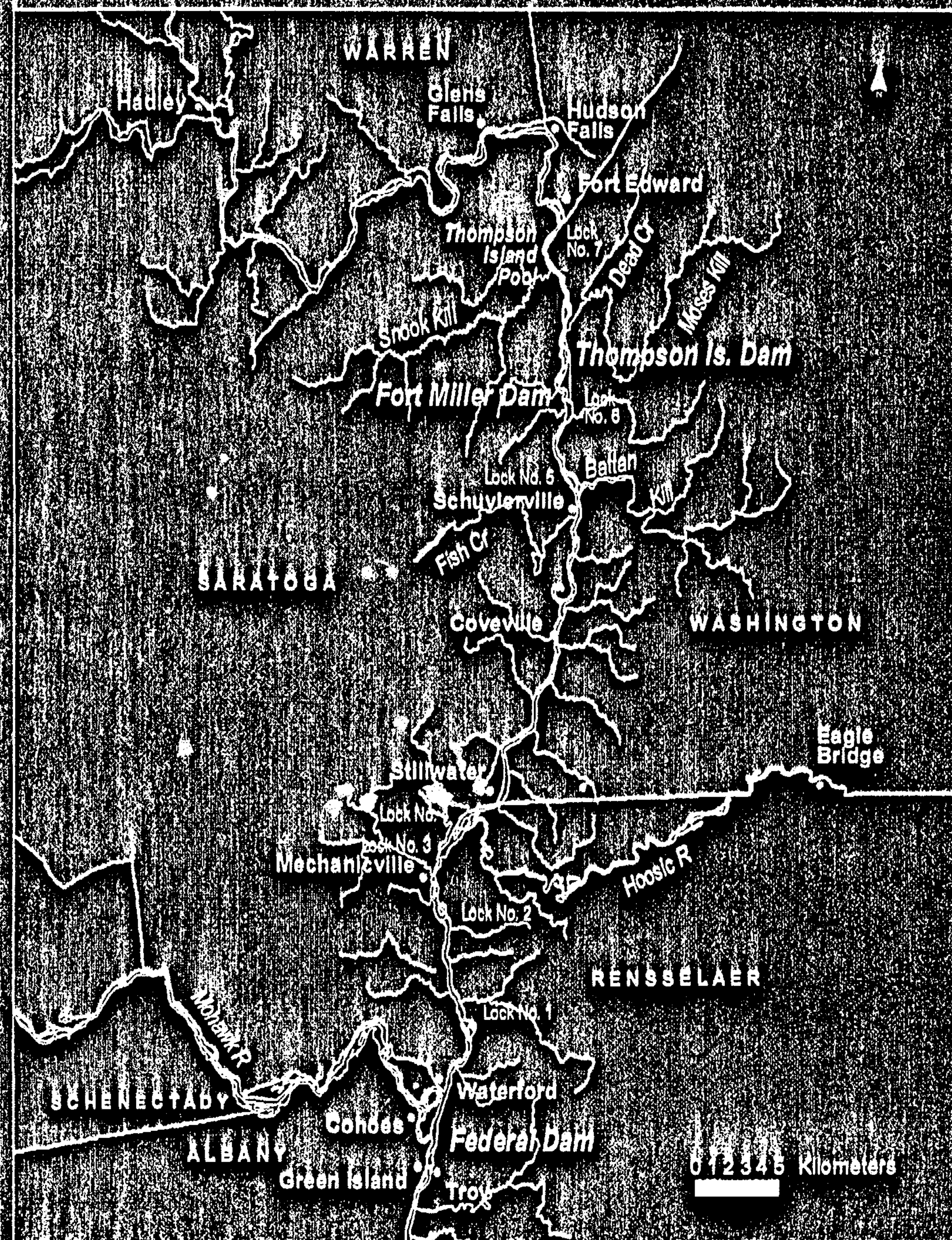
- Contamination began in 1940s
- Downstream load enhanced by dam removal in 1973
- PCB use discontinued in 1977
- USGS monitoring since 1976-1977
- GE monitoring since 1991
- EPA Reassessment RI/FS monitoring in 1992-1994
- Long-term declines in water and sediment PCB concentrations

Hudson River Watershed

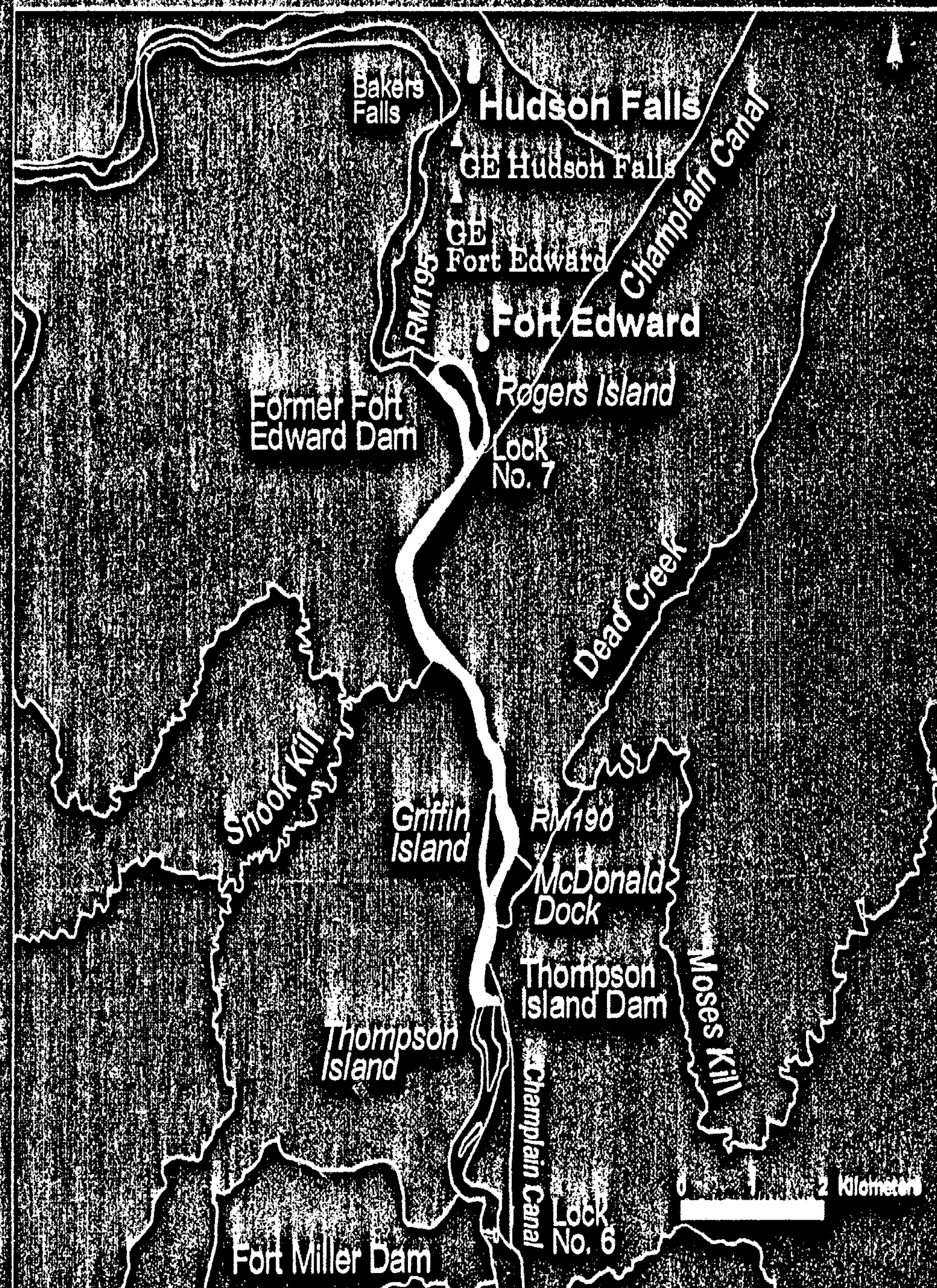


10.2463

Upper Hudson River Watershed



Thompson Island Pool



Upper Hudson River

Thompson Island Pool

- Upper 6 miles
- 1 dam
- 40% of PCB mass
- Higher sediment concentrations
- Relatively data rich

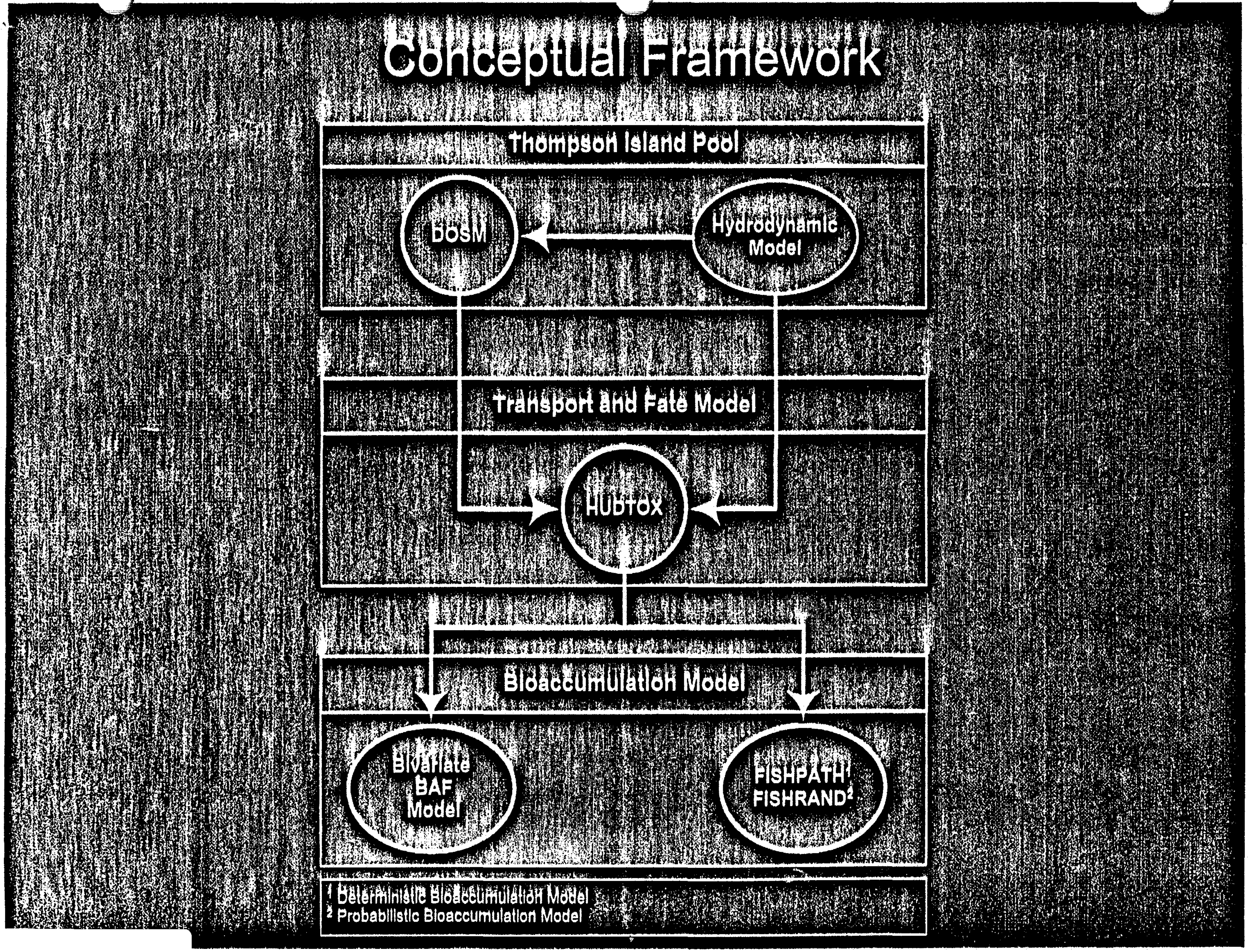
Downstream Reaches

- Lower 34 miles
- 7 dams
- 60% of PCB mass
- Lower sediment concentrations
- Relatively data poor

Modeling Approach

Approach

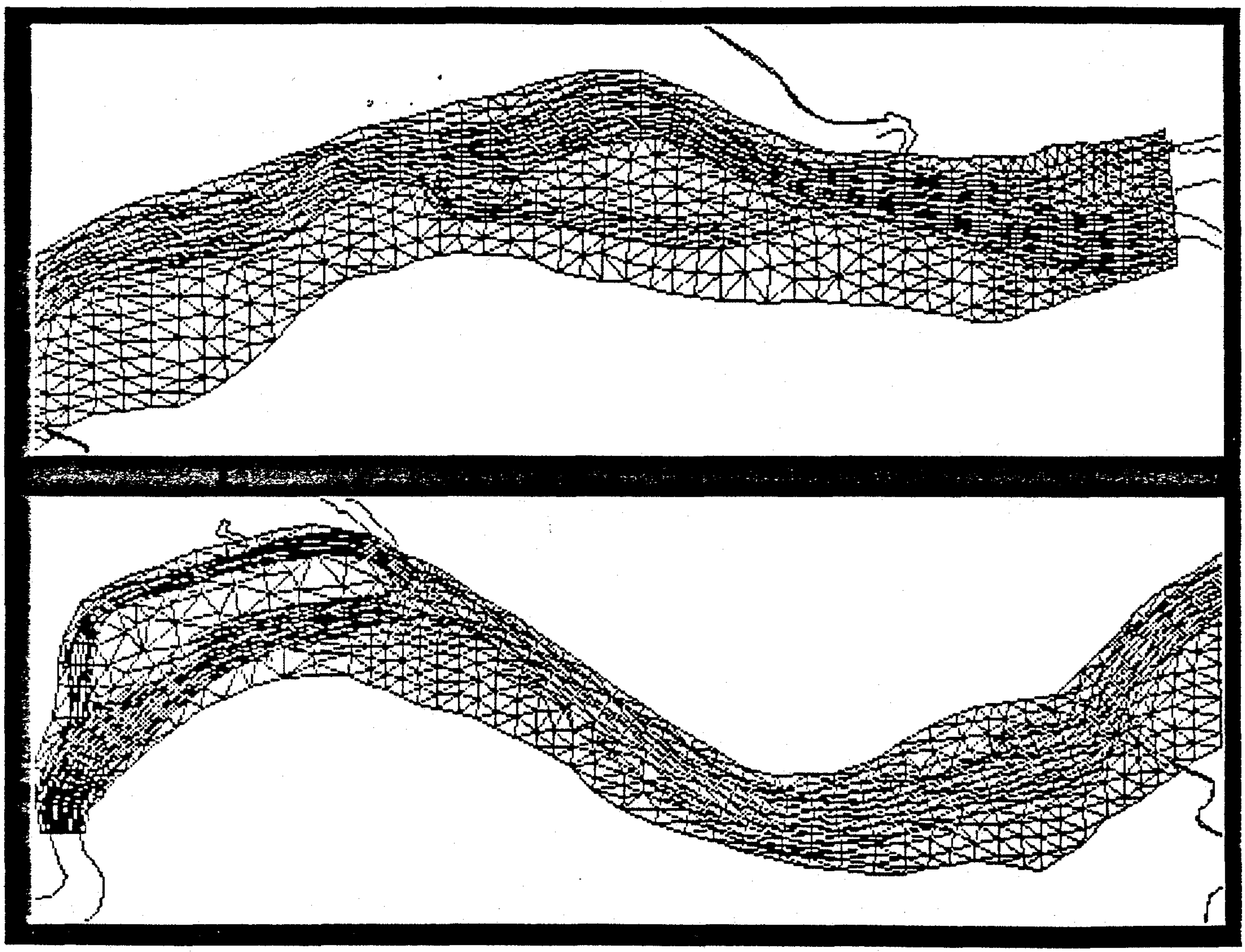
- Assess and process site-specific data
- Develop mass balance model
- Long-term historical calibration 1977-1997
- Short-term hindcast applications 1991-1997
- Validation to 1998 data
- Forecast simulations
  - Continued No Action
  - 100-year peak flow
- Sensitivity analyses


Conceptual Framework
Thompson Island Pool
DOSM
Hydrodynamic Model
Transport and Fate Model
HUDTOX
Bioaccumulation Model
Bivariate BAF Model
FISHPATH¹
FISHRAND²
¹ Deterministic Bioaccumulation Model
² Probabilistic Bioaccumulation Model

10.2469

RMA-2V Hydrodynamic Model

- Applied to Thompson Island Pool
- Time-dependent, 2D, vertically-averaged
- Explicit representation of flood plain
- Water depth, velocity and flow routing for HUDTOX mass balance model
- Applied shear stresses at sediment-water interface for HUDTOX and Depth of Scour Model (DOSM)



Depth of Scour Model

- Applied to Thompson Island Pool
- Spatially-refined information on sediment erodibility in response to flow events
- 2D, GIS-based
- Estimates of depth of sediment bed scour and masses of solids and PCBs eroded for 100-year peak flow
- Resuspension-flow relationships for cohesive sediment areas in HUDTOX mass balance model

HUDTOX Mass Balance Model

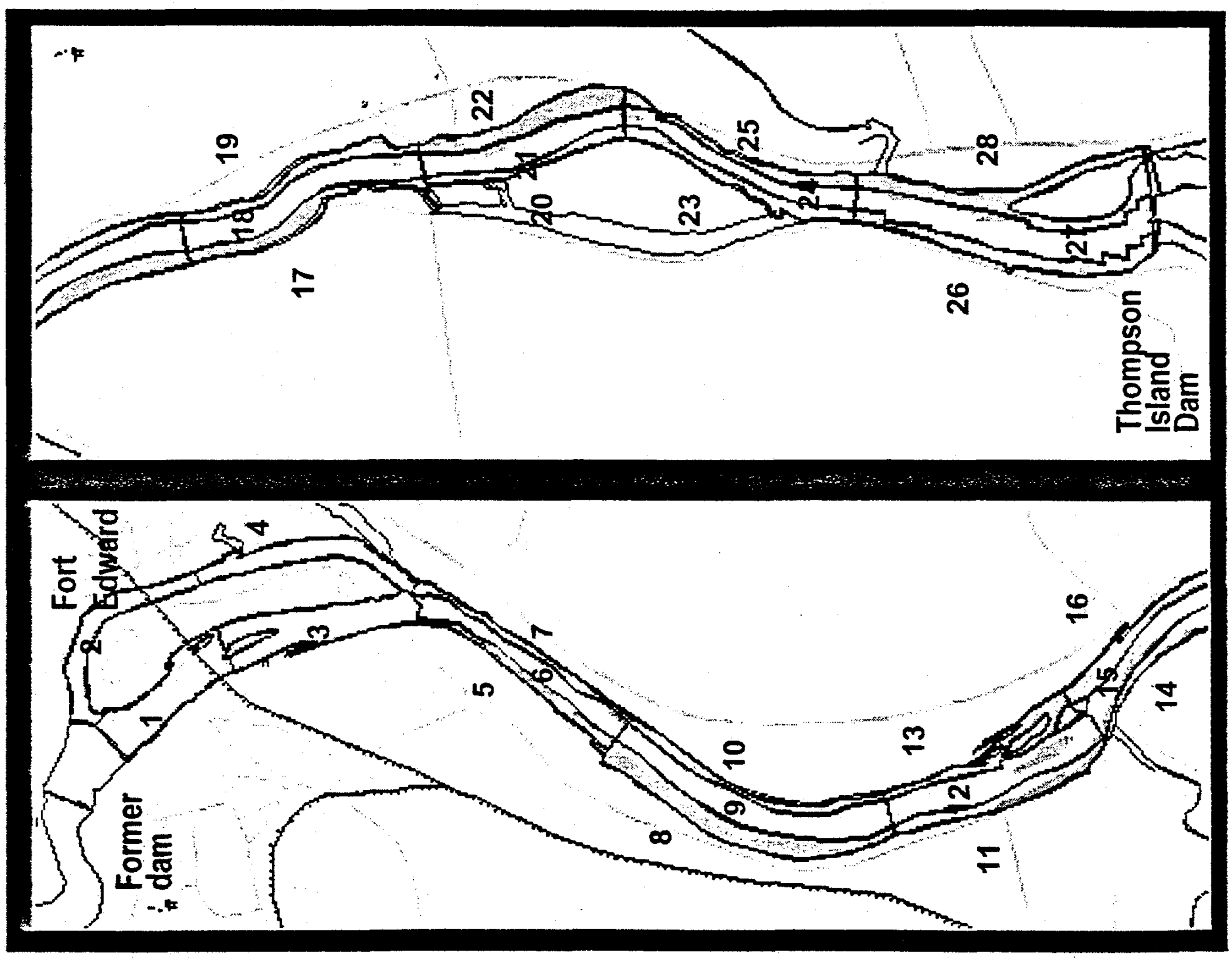
- Mass balances for flows, solids and PCBs
- Spatial scale
  - 2D in water column in Thompson Island Pool
  - 1D in water column between TIP and Federal Dam
  - 3D in sediments
- Time-dependent
- Represents cohesive and non-cohesive sediment areas
- Three-phase partitioning for PCBs

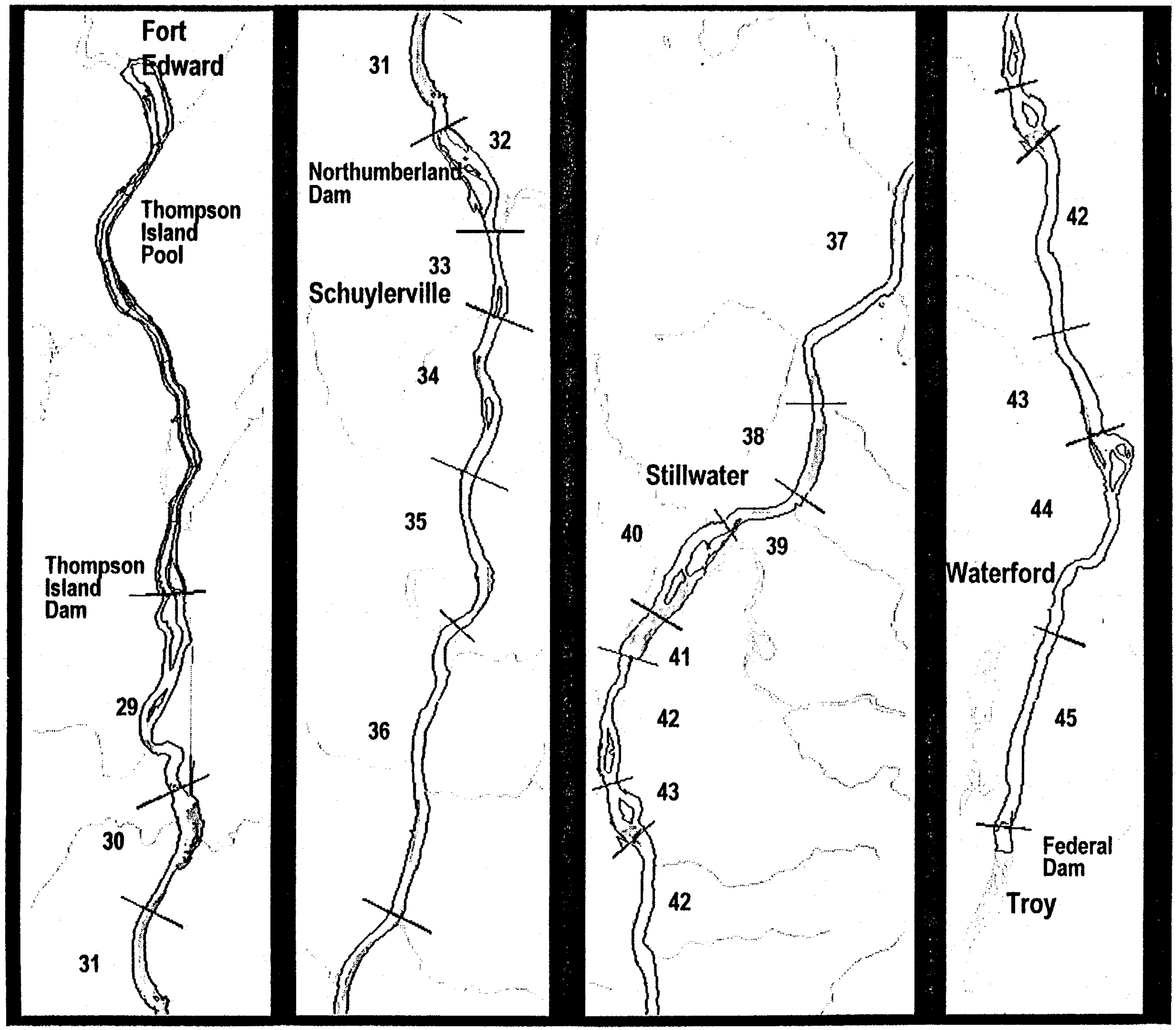
HUDTOX State Variables

- Total suspended solids
- Tri+ (sum of trichloro and higher congeners)
- Total PCBs
- Congeners
  - BZ#4 (dichloro)
  - BZ#28 (trichloro)
  - BZ#52 (tetrachloro)
  - BZ#[90+101] (pentachloro)
  - BZ#138 (hexachloro)

HUDTOX Spatial Scales

- Thompson Island Pool (upper 6 miles)
  - 28 water column segments (2D)
  - 42 surface sediment segments (2D)
  - 13 vertical layers (2-cm each)
- TIP to Federal Dam (lower 34 miles)
  - 19 water column segments (1D)
  - 28 surface sediment segments (1D)
  - 13 vertical layers (2-cm each)
- 1035 total spatial segments


Fort Edward
Former dam
Thompson Island Dam
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28


Fort Edward
Thompson Island Pool
Thompson Island Dam
29
30
31
31
32
Northumberland Dam
33
Schuylerville
34
35
36
37
38
Stillwater
39
40
41
42
43
42
42
43
44
Waterford
45
Federal Dam
Troy

10.2477

10.2478

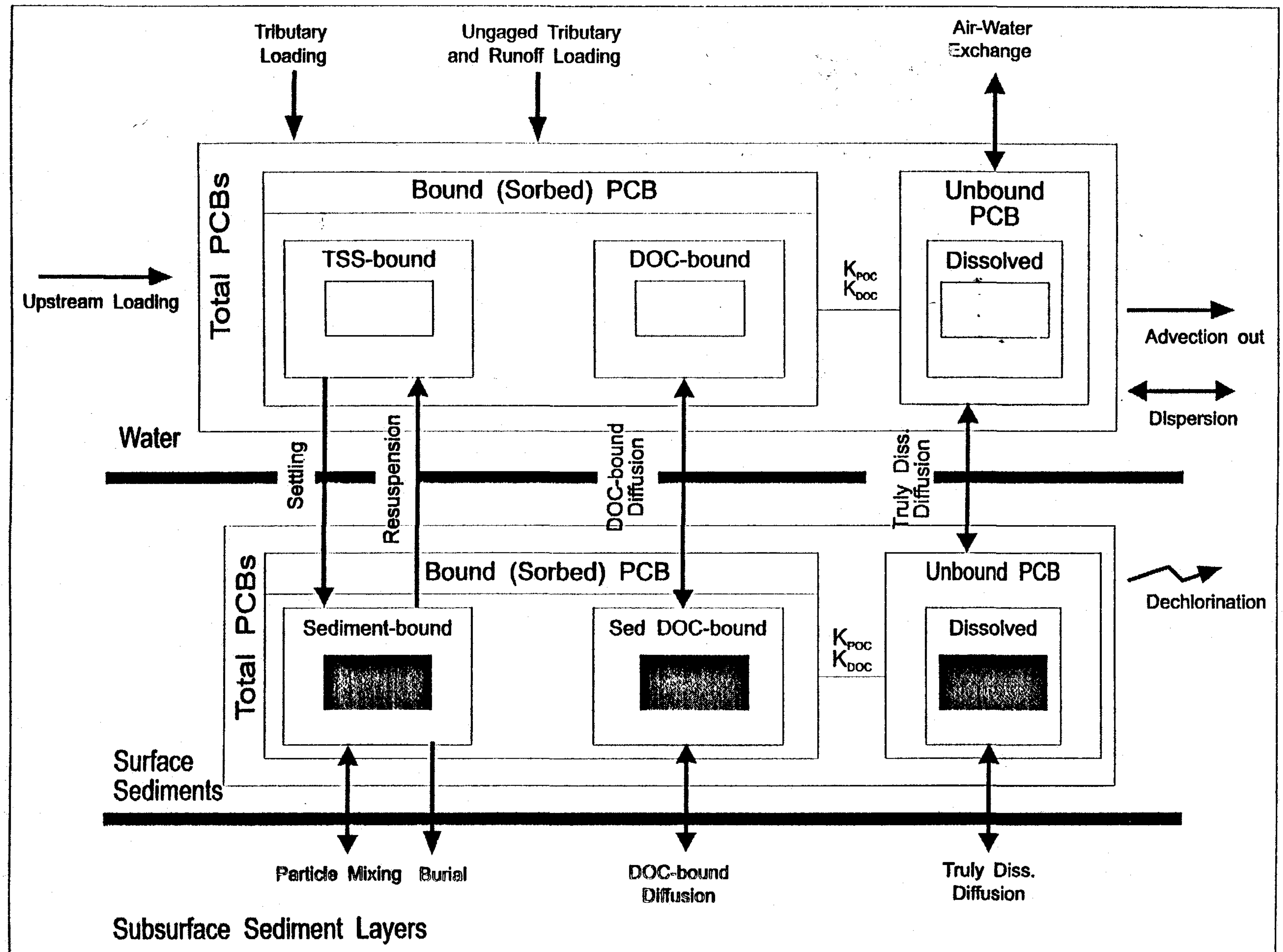
HUDTOX Time Scales

- Historical calibration (21 years)
  - 1977 to 1997
  - Solids and Tri+
- Hindcast applications (7 years)
  - 1991 to 1997
  - Solids, Total PCBs and congeners
- Validation (1998)
- Forecast period (70 years)
  - 1998 to 2067

Process Mechanisms

- Solids
  - Gross settling
  - Flow-dependent resuspension
  - Burial
- PCBs
  - Equilibrium phase partitioning
  - Water-air transfer
  - Sediment-water transfer
    - Flow-dependent
    - Non-flow-dependent

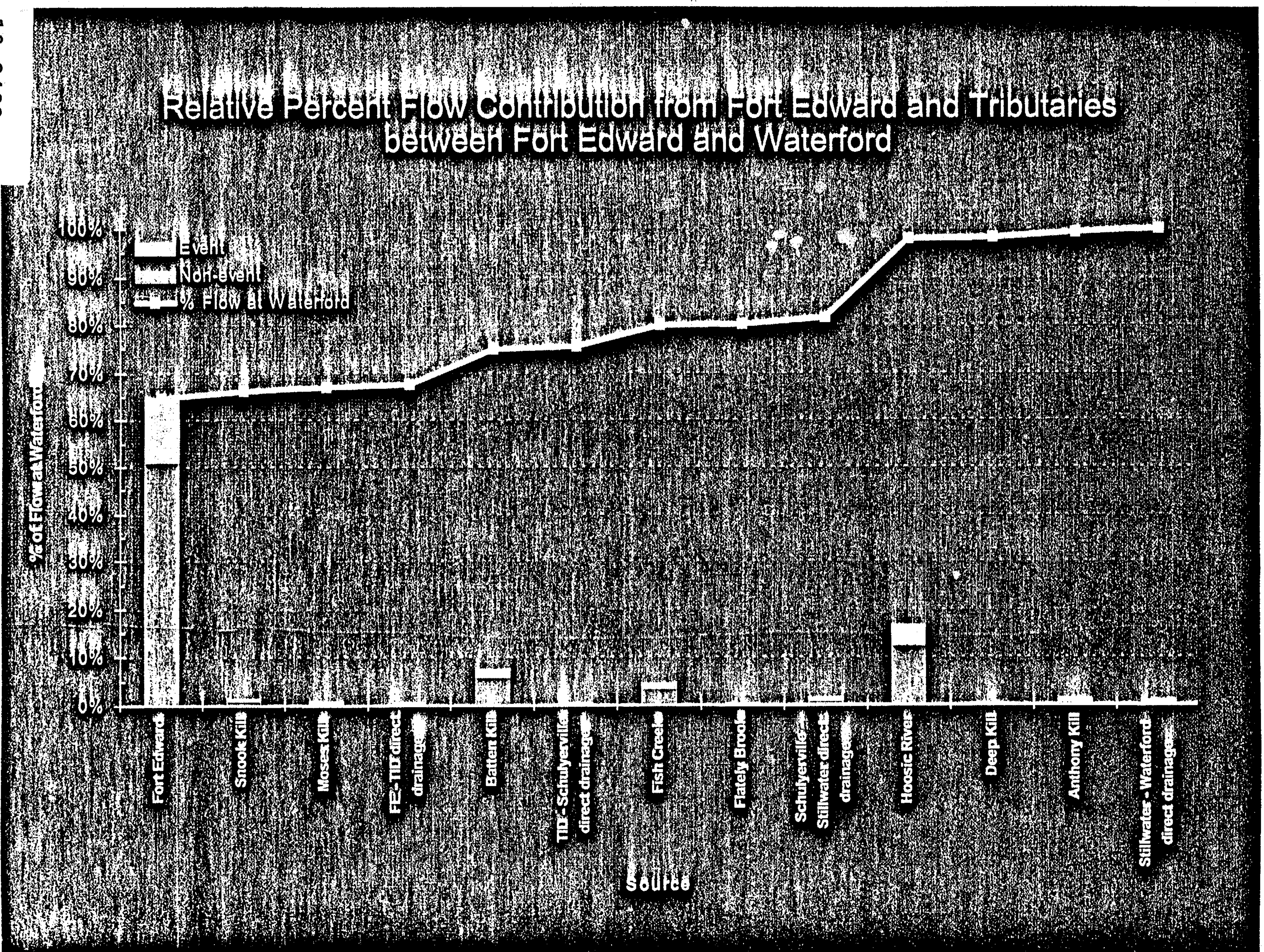
10.2480



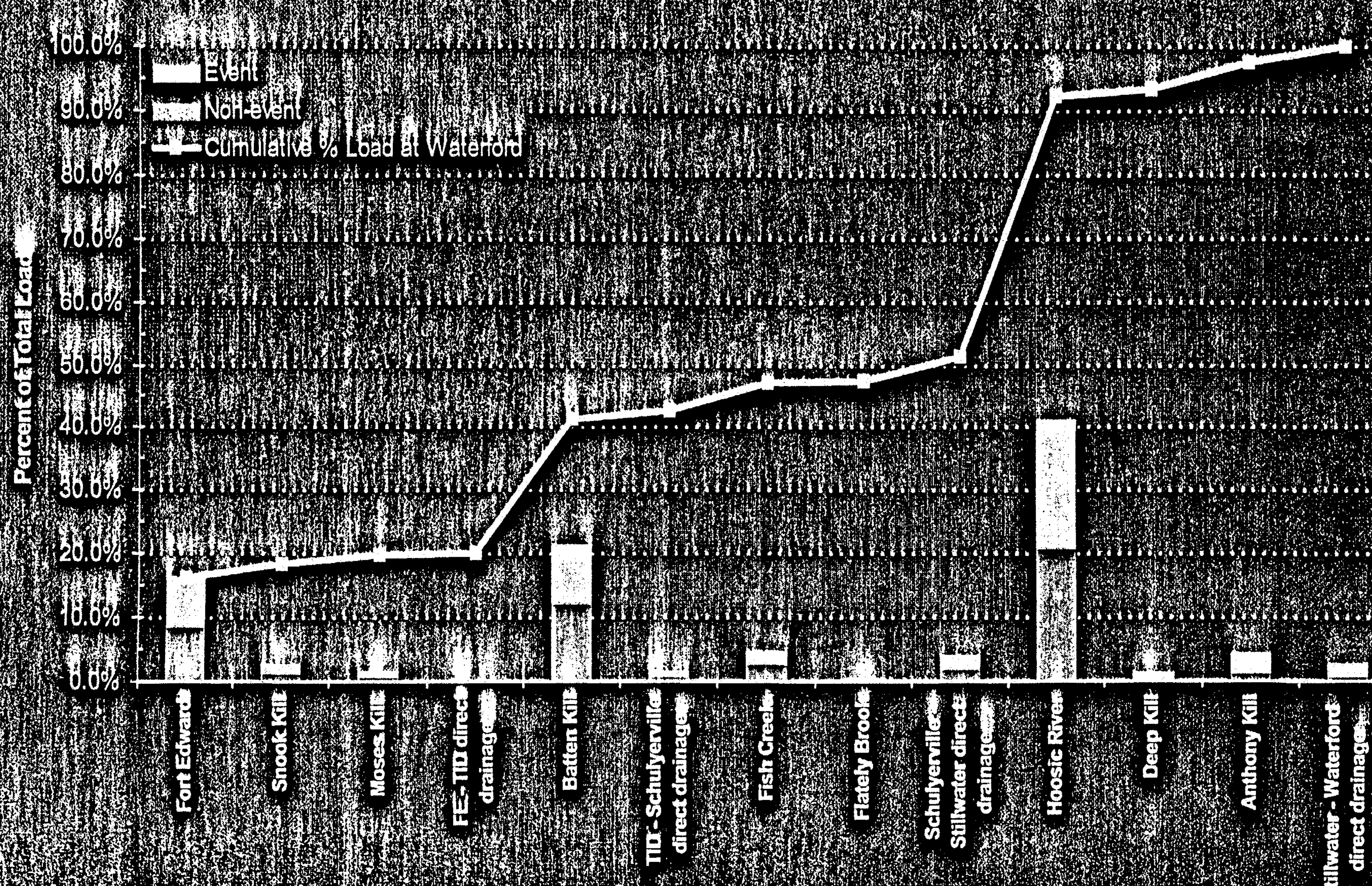
Limno Tech, Inc.

Principal Controlling Factors

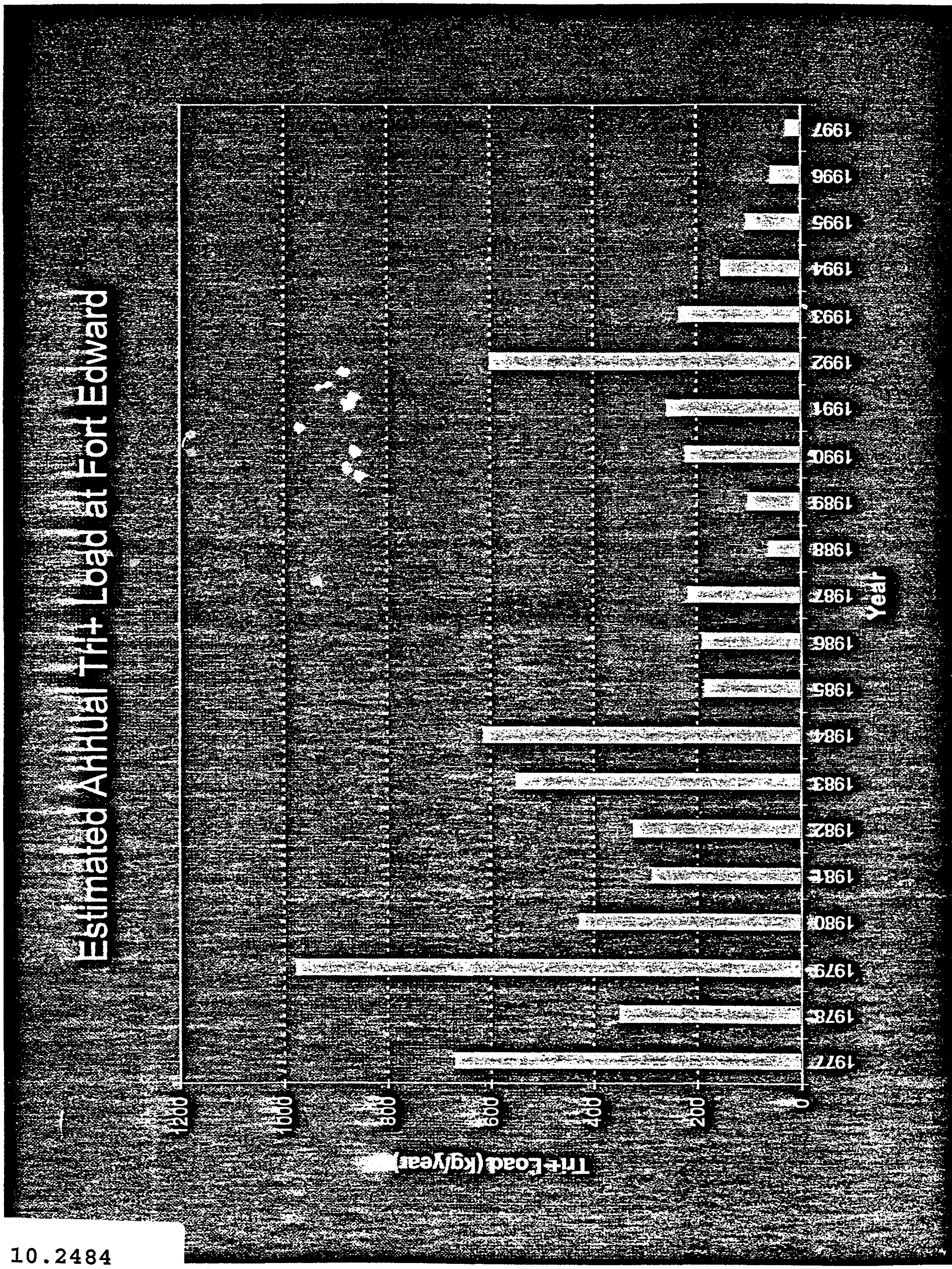
- Hydrology
- Solids loadings
- Tri+ loadings
- Tri+ partitioning
- Tri+ sediment-water mass transfer under non-scouring flow conditions
- Solids burial rates
- Particle mixing depth in the sediments


Relative Percent Flow Contribution from Fort Edward and Tributaries between Fort Edward and Waterford
Event
Non-event
% Flow at Waterford
% of Flow at Waterford
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Fort Edward
Snook Kill
Moses Kill
FE - TID direct drainage
Batten Kill
TID - Schuylerville direct drainage
Fish Creek
Fately Brook
Schuylerville - Stillwater direct drainage
Hoosic River
Deep Kill
Anthony Kill
Stillwater - Waterford direct drainage
Source

Relative Percent Solids Contribution from Fort Edward and Tributaries between Fort Edward and Waterford



10.2483

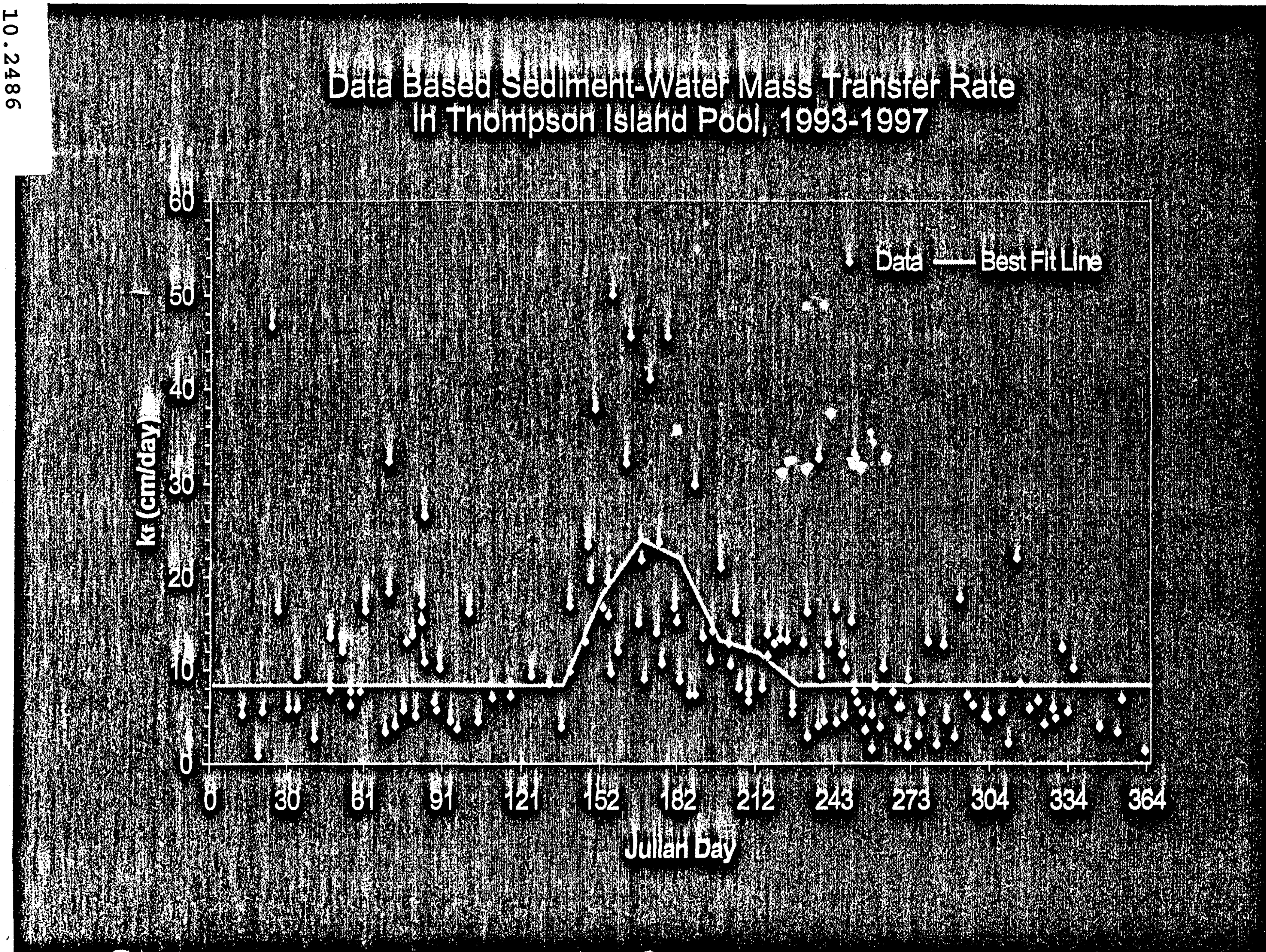

Estimated Annual Tri+ Load at Fort Edward
Tri+ Load (kg/year)
0
200
400
600
800
1000
1200
Year
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997

10.2484

Principal Controlling Factors

- Hydrology
- Solids loadings
- Tri+ loadings
- Tri+ partitioning
- Tri+ sediment-water mass transfer under non-scouring flow conditions
- Solids burial rates
- Particle mixing depth in the sediments

10.2486


Data Based Sediment-Water Mass Transfer Rate
in Thompson Island Pool, 1993-1997
Data
Best Fit Line
kf (cm/day)
0
10
20
30
40
50
60
0
30
61
91
121
152
182
212
243
273
304
334
364
Julian Day

Principal Controlling Factors

- Hydrology
- Solids loadings
- Tri+ loadings
- Tri+ partitioning
- Tri+ sediment-water mass transfer under non-scouring flow conditions
- Solids burial rates
- Particle mixing depth in the sediments

10.2487

Historical Calibration

Calibration Approach

- Long-term annual average behavior
- Tri+ surface sediment concentrations
- Mean solids and Tri+ mass transport at high and low flows
- Water column solids and Tri+ concentrations

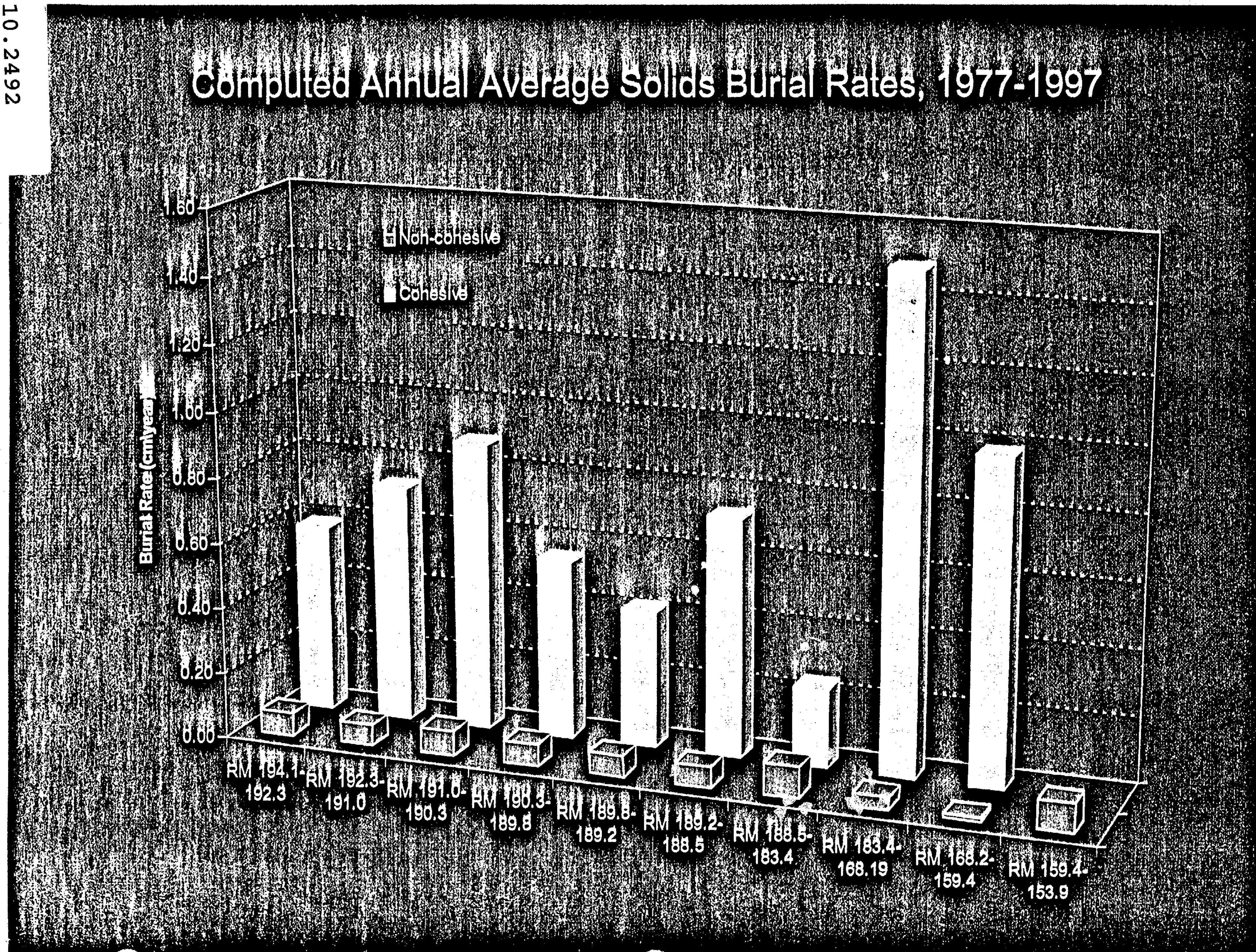
10.2489

HUDTOX Calibration Parameters

- Gross settling velocities into cohesive and non-cohesive sediment areas
- Resuspension rates from non-cohesive sediment areas
- Depth and rate of particle mixing in the sediments

Constraints on Solids Burial Rates

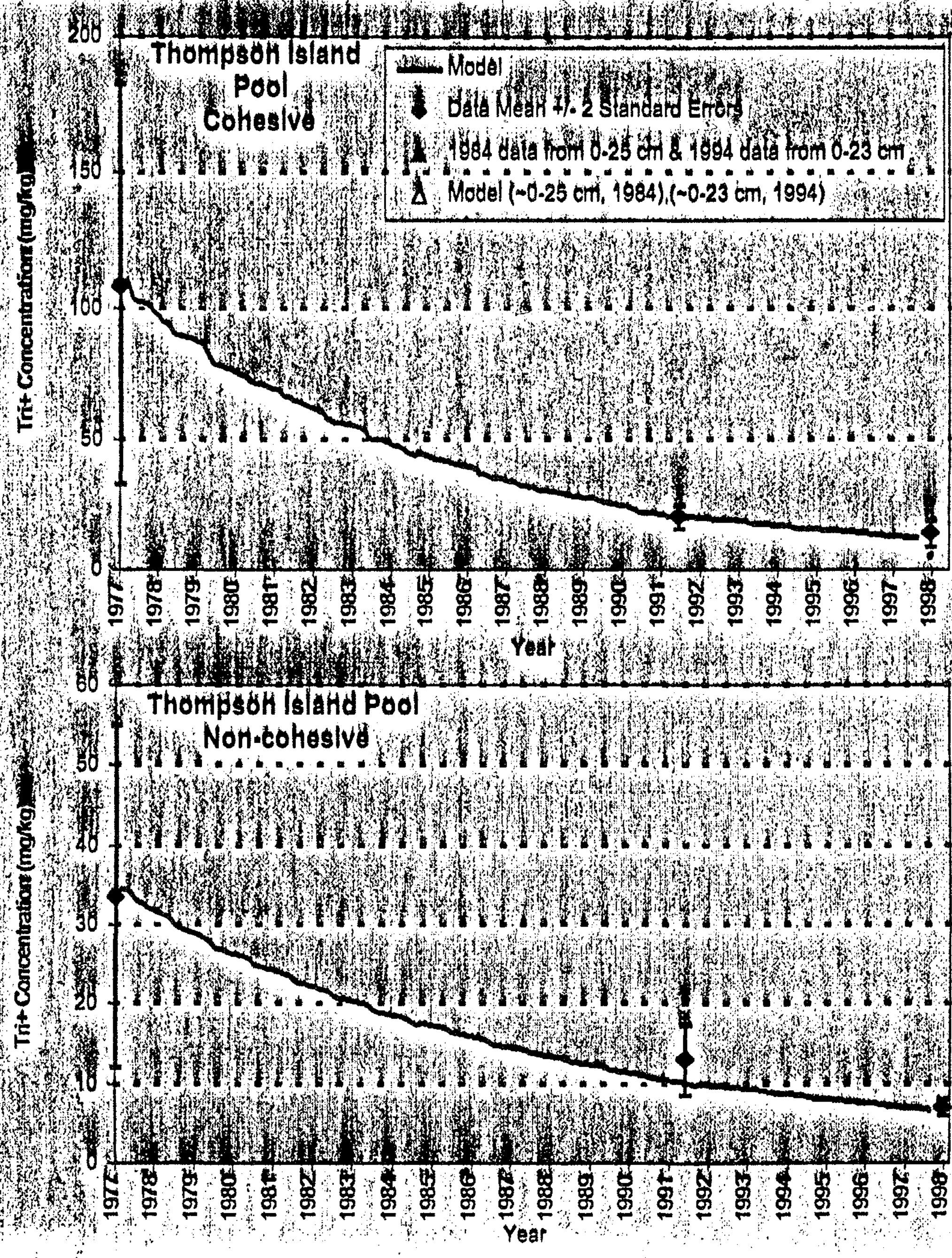
- Measured burial rates from dated sediment cores
- Computed burial rates from a sediment transport model
- Tri+ surface sediment trajectories
- In-river solids and Tri+ mass transport at high and low flows



Computed Annual Average Solids Burial Rates, 1977-1997
Non-cohesive
Cohesive
Burial Rate (cm/year)
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
RM 194.1-192.3
RM 192.3-191.0
RM 191.0-190.3
RM 190.3-189.8
RM 189.8-189.2
RM 189.2-188.5
RM 188.5-183.4
RM 183.4-168.19
RM 168.2-159.4
RM 159.4-153.9

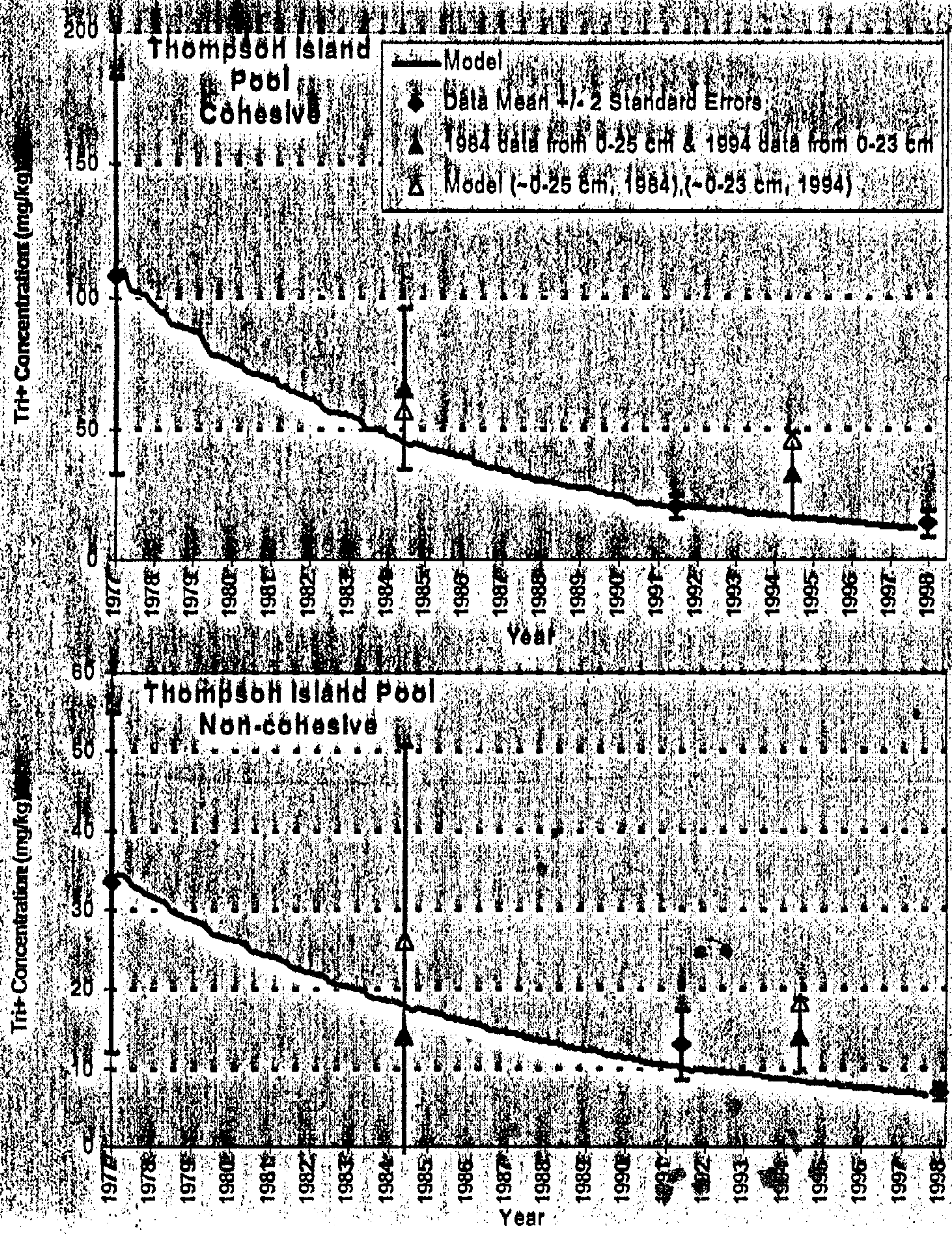
10.2492

Comparison Between Computed and Observed Surface Sediment Tri+ Concentrations in Thompson Island Pool



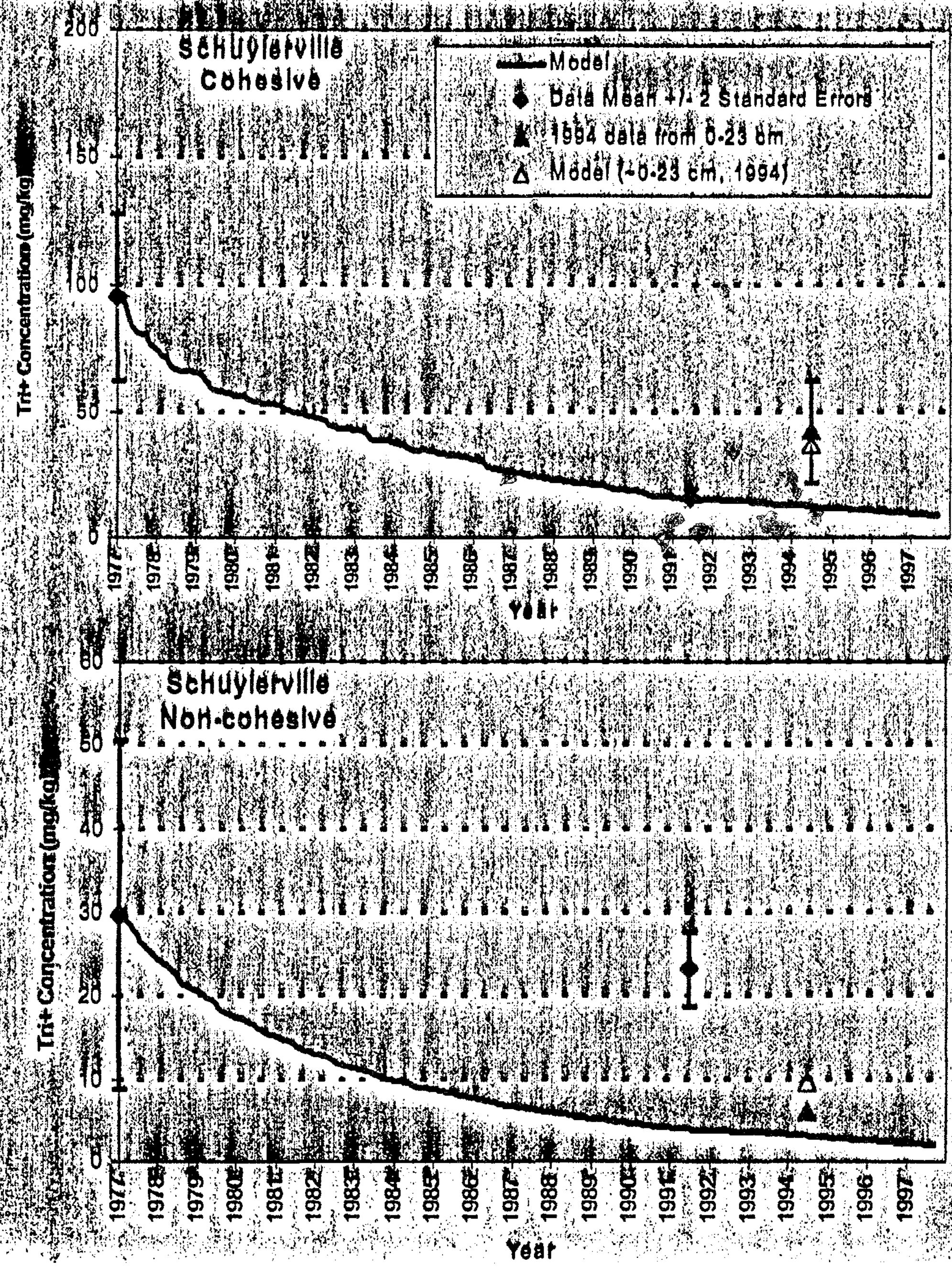
10.2493

Comparison Between Computed and Observed Surface Sediment Tri+ Concentrations in Thompson Island Pool



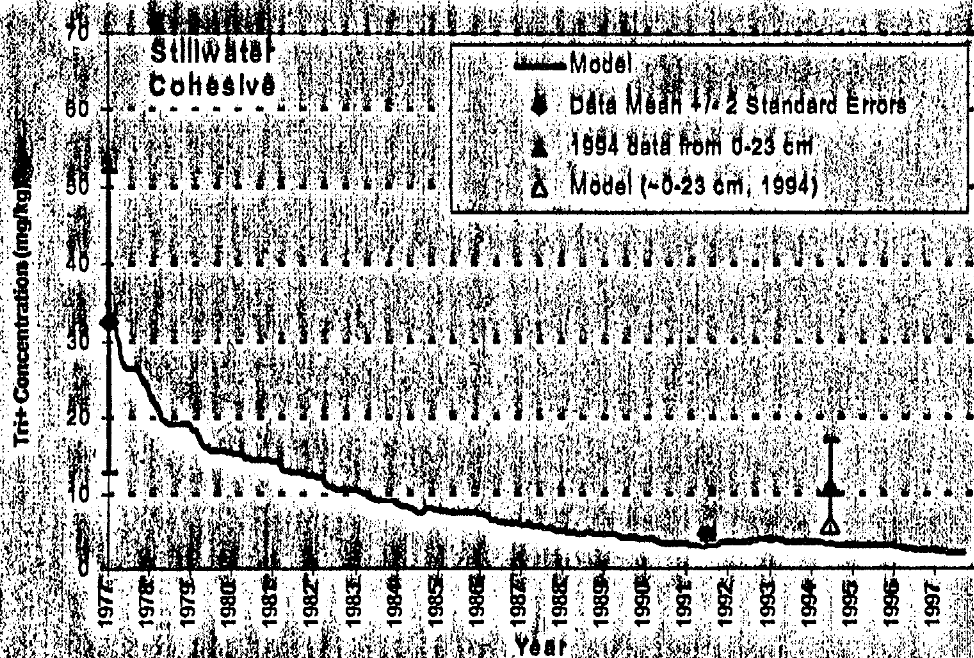
10.2494

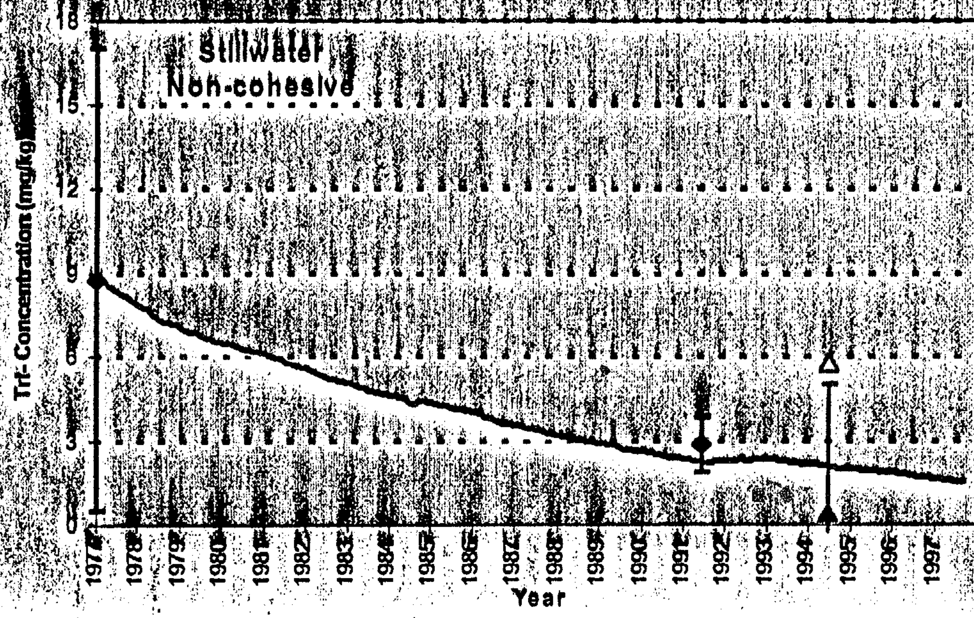
Comparison between Computed and Observed Surface Sediment Tri+ Concentrations for Schuylerville Reach



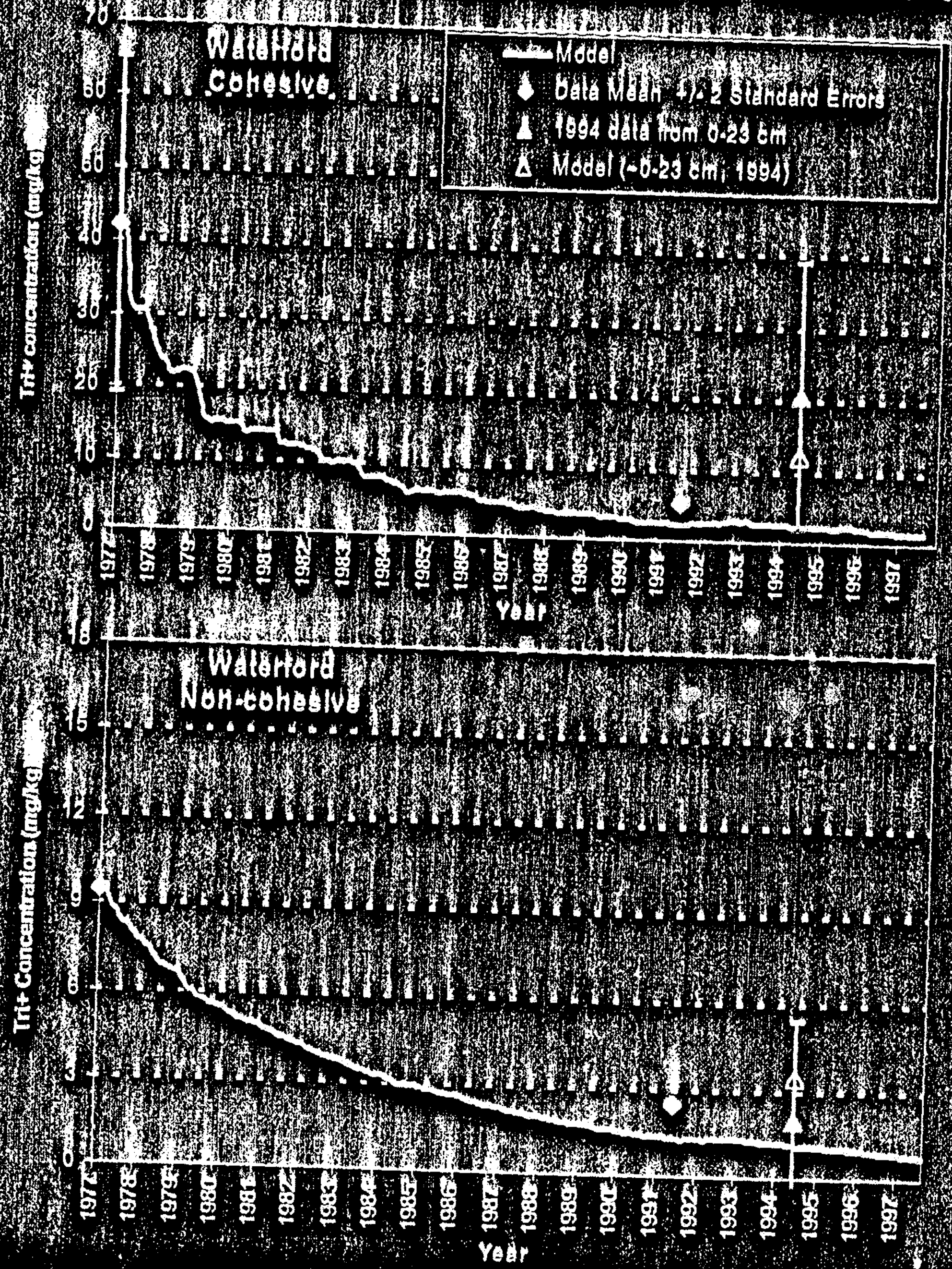
10.2495

Comparison Between Computed and Observed Surface Sediment Tri+ Concentrations for Stillwater Reach.

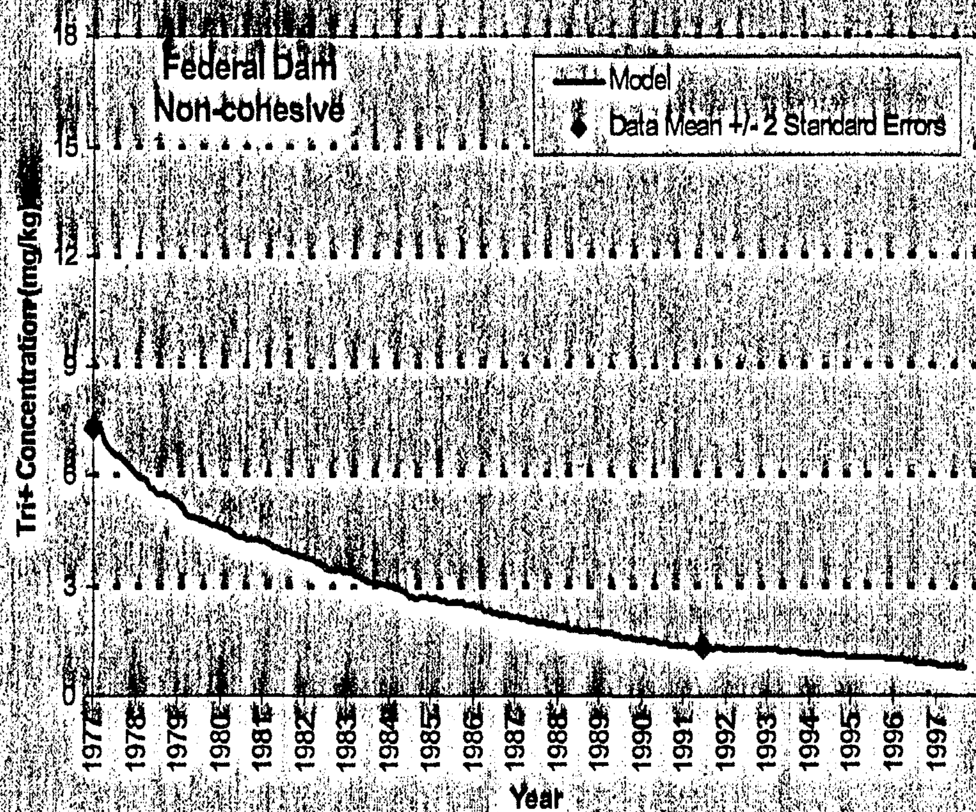




Comparison Between Computed and Observed Surface Sediment Tri+ Concentrations for Waterford Reach.



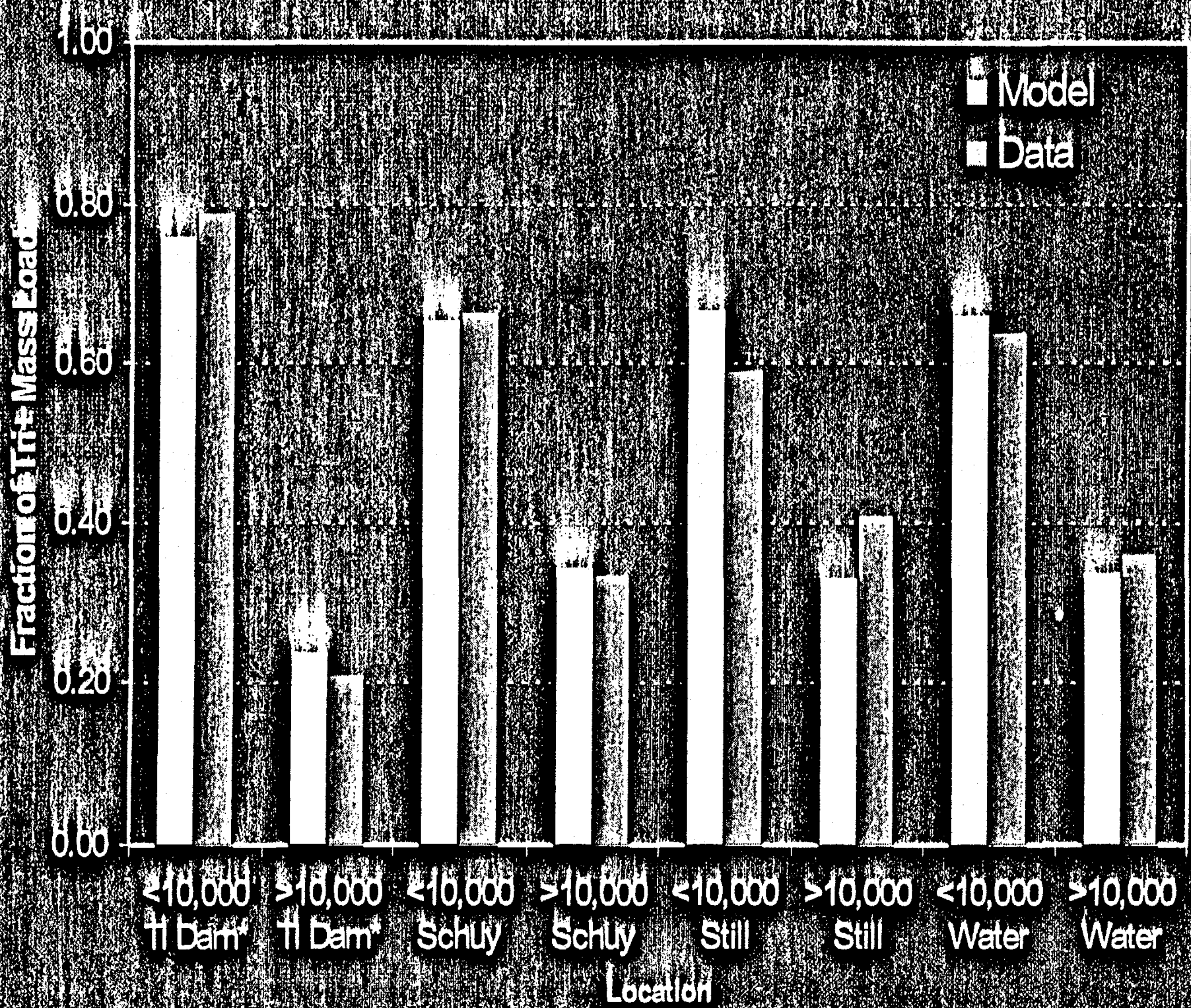
Comparison between Computed and Observed Surface Sediment Tri+ Concentrations for Federal Dam Reach.

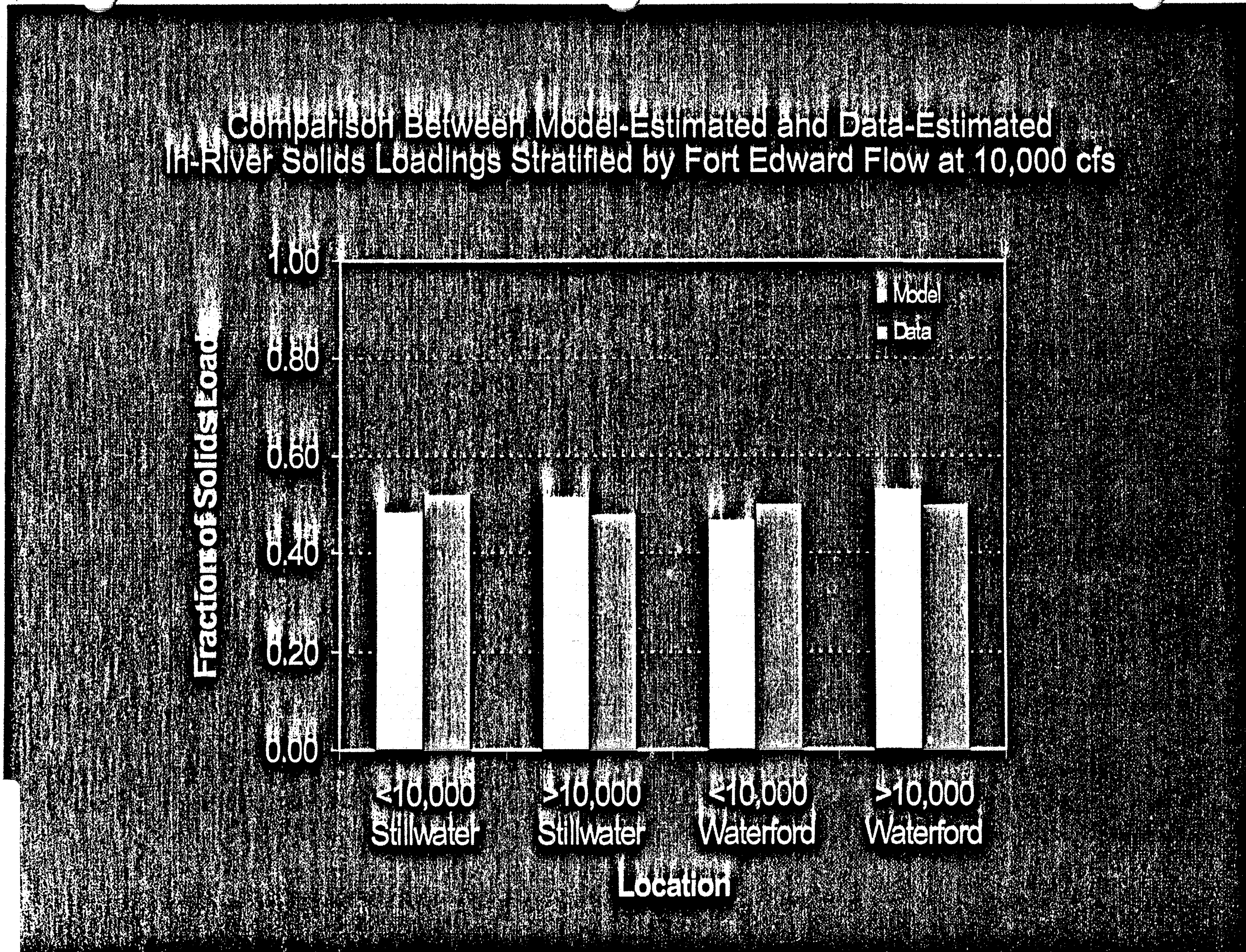


Constraints on Solids Burial Rates

- Measured burial rates from dated sediment cores
- Computed burial rates from a sediment transport model
- Tri+ surface sediment trajectories
- In-river solids and Tri+ mass transport at high and low flows

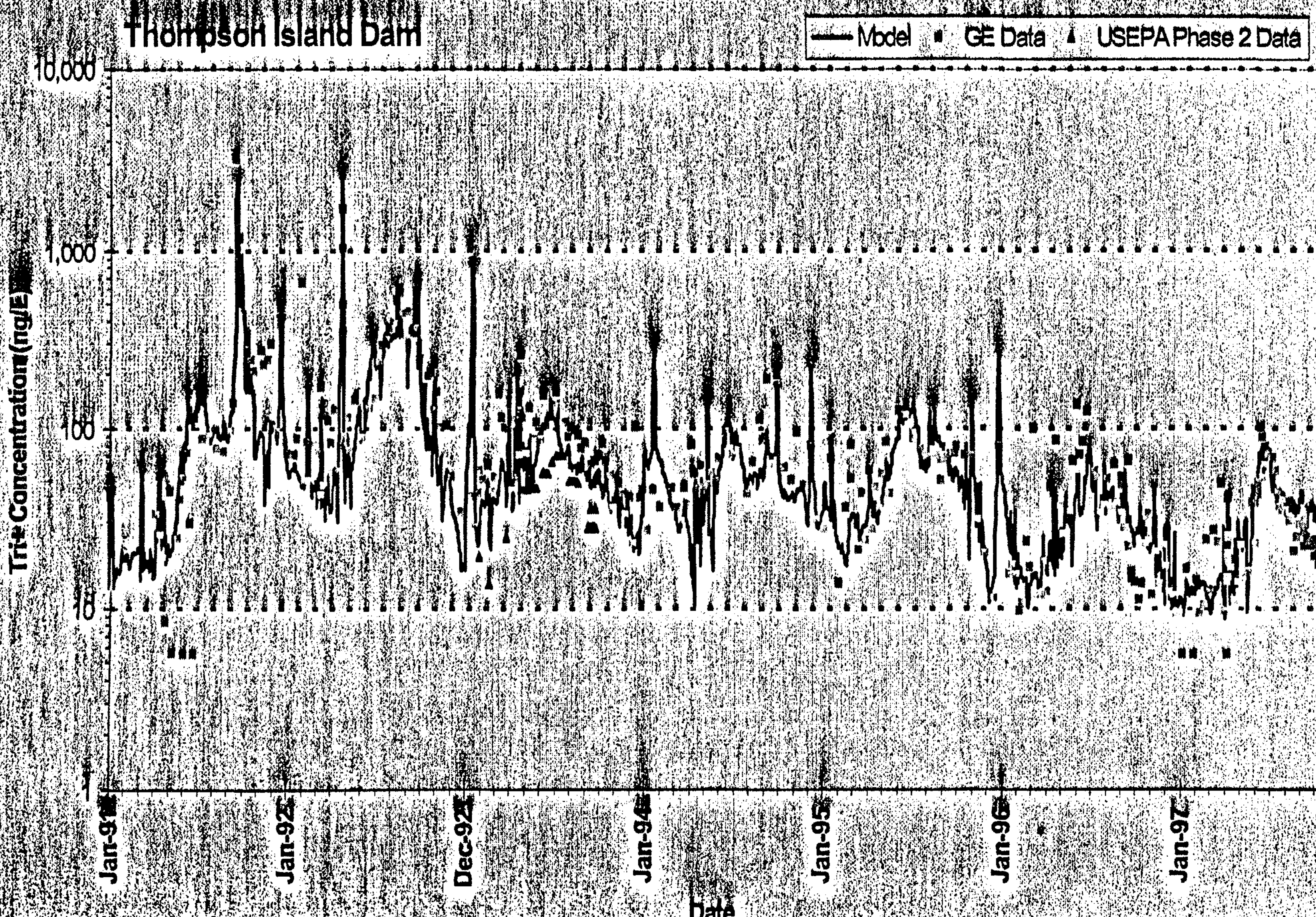
Comparisons Between Model-Estimated and Data-Estimated In-River Tri+ Loadings Stratified by Fort Edward Flow at 10,000 cfs

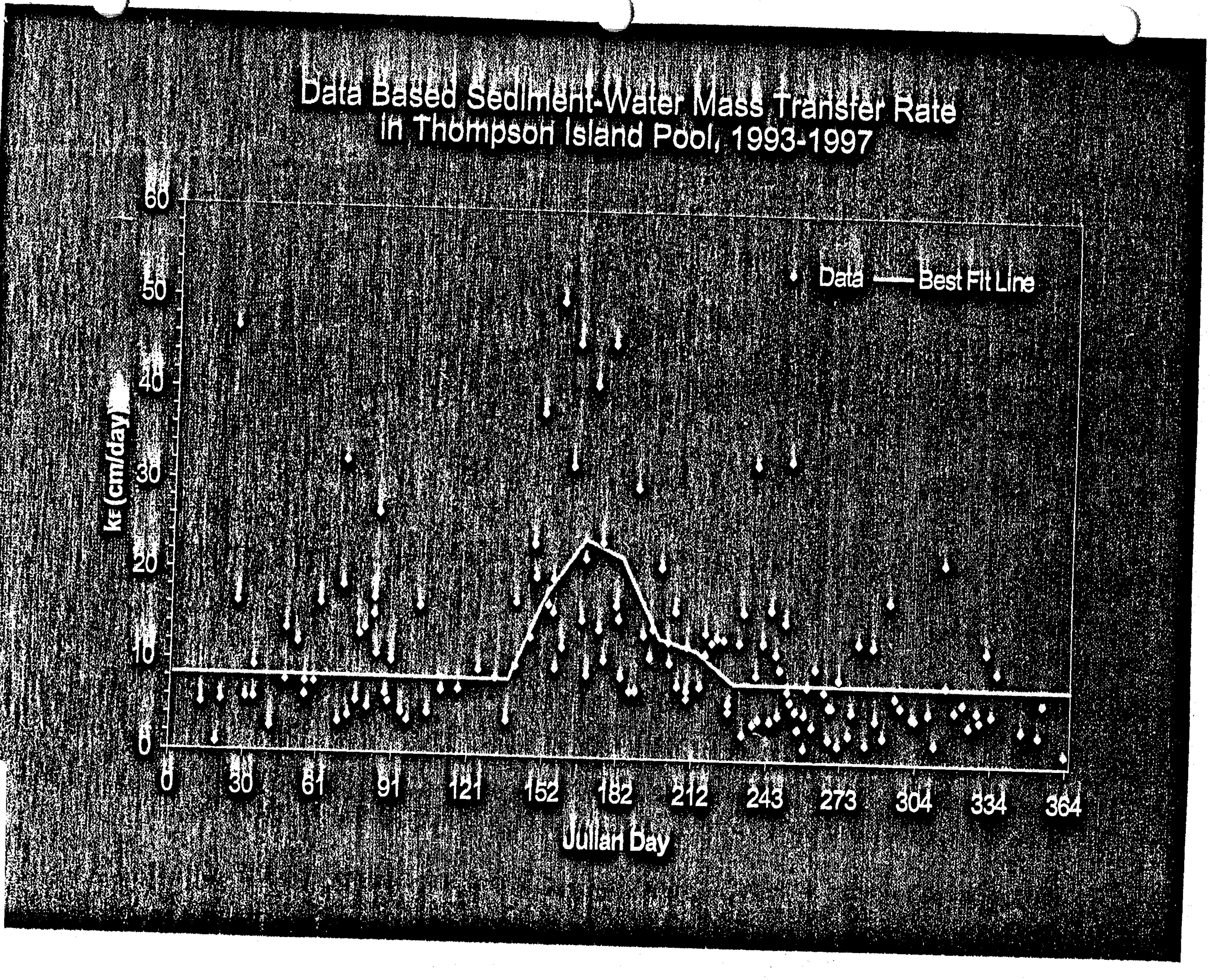


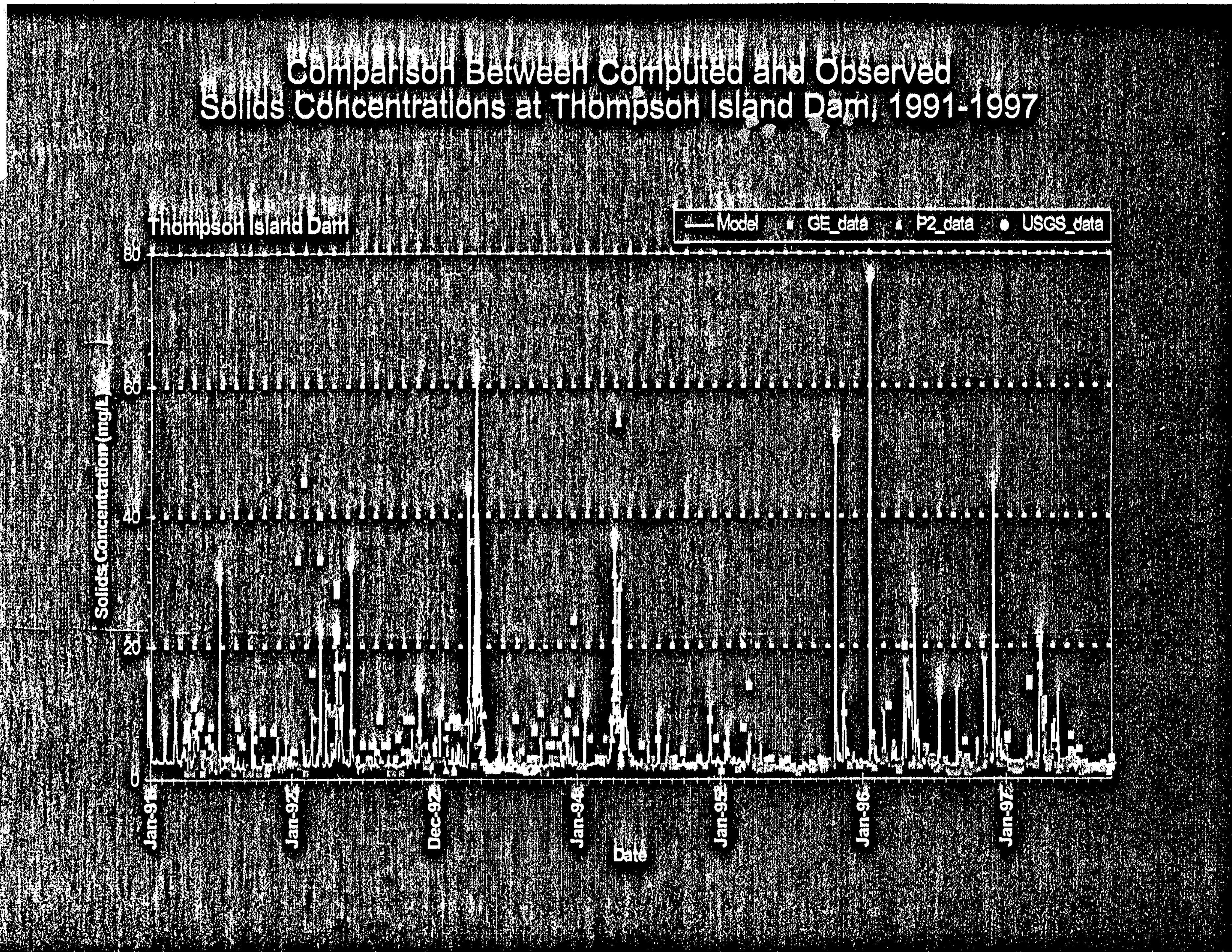

Comparison Between Model-Estimated and Data-Estimated
In-River Solids Loadings Stratified by Fort Edward Flow at 10,000 cfs
Fraction of Solids Load
1.00
0.80
0.60
0.40
0.20
0.00
Model
Data
<10,000 Stillwater
>10,000 Stillwater
<10,000 Waterford
>10,000 Waterford
Location

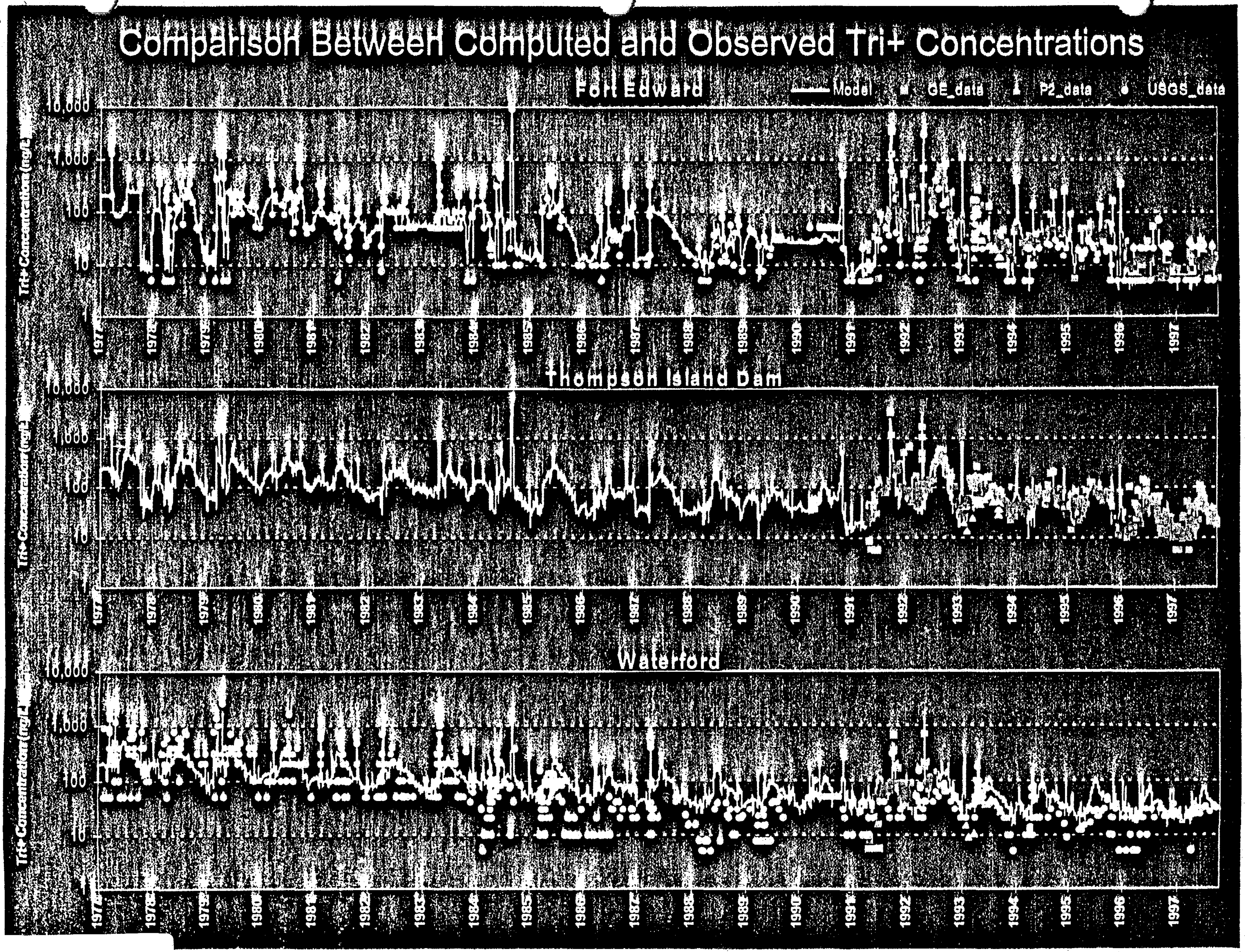
10.2502

Comparison Between Computed and Observed Tri+ Concentrations at Thompson Island Dam, 1991-1997




Data Based Sediment-Water Mass Transfer Rate
in Thompson Island Pool, 1993-1997
Data
Best Fit Line
kf (cm/day)
0
10
20
30
40
50
60
0
30
61
91
121
152
182
212
243
273
304
334
364
Julian Day


Comparison Between Computed and Observed
Solids Concentrations at Thompson Island Dam, 1991-1997
Thompson Island Dam
Model
GE_data
P2_data
USGS_data
Solids Concentration (mg/L)
0
20
40
60
80
Jan-91
Jan-92
Dec-92
Jan-94
Jan-95
Jan-96
Jan-97
Date


Comparison Between Computed and Observed Tri+ Concentrations
Fort Edward
Model
GE_data
P2_data
USGS_data
Thompson Island Dam
Waterford
Tri+ Concentrations (ng/L)
10,000
1,000
100
10
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997

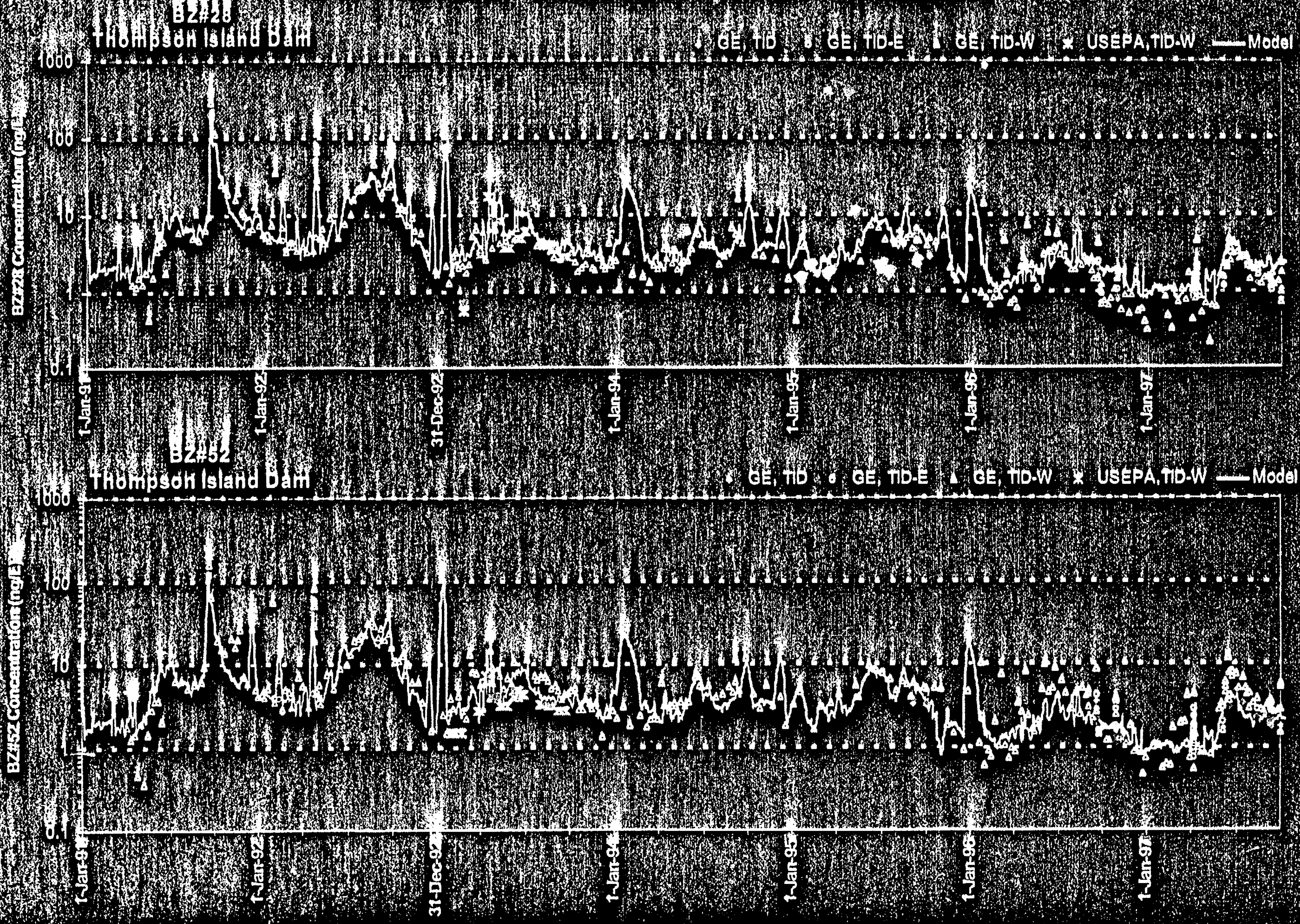
10.2506

Comparison Between Computed and Observed Solids Concentrations
Fort Edward
Model
GE_data
P2_data
USGS_data
Solids Concentration (mg/L)
100
10
1
0.1
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
Note: Fort Edward Solids Concentrations Displayed are Daily Averages Using All Available Data Sources.
Thompson Island Dam
Solids Concentration (mg/L)
100
10
1
Waterford
Solids Concentration (mg/L)
1000
100
10
1
Year

Hindcast Application

10.2507

Concentration Times Series for BZ#28 and BZ#52 With Historical Calibration Model Parameters



Computed Percent Gross Inputs to Water Column

Source	Solids	Tri+
External Loadings	80	25
Gross Resuspension (Flow-Driven)	20	25
Sediment-Water Transfer (Not Flow-Driven)	N/A	50

10.2509

Computed Net Load Gains to Water Column

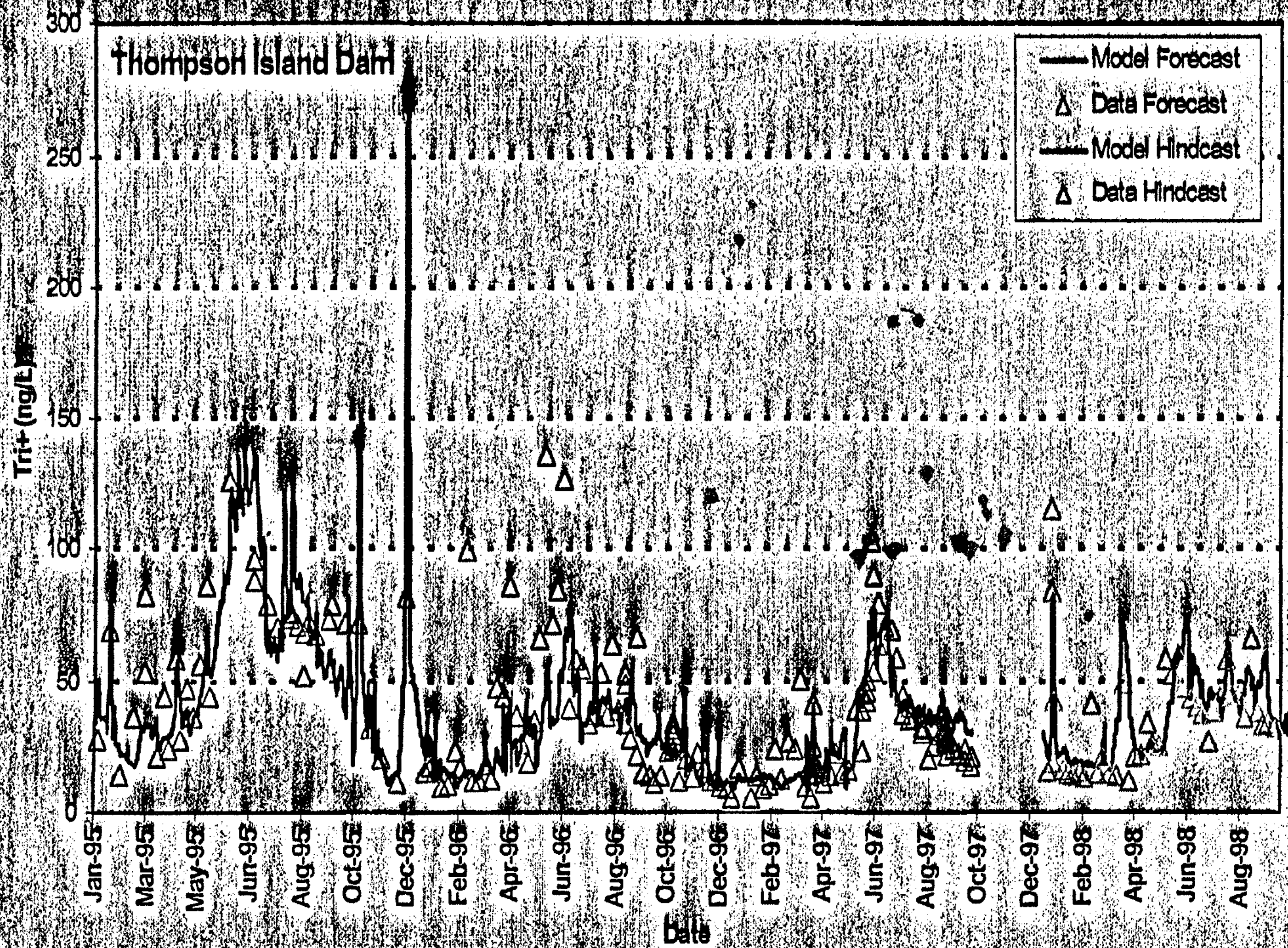
Reach	Solids (MT)	Tri+ (Kg)
Thompson Island Pool	81,000	4,049
Schuylerville	13,000	2,736
Stillwater	1,000,000	275
Waterford	1,949,000	2,081

10.2510

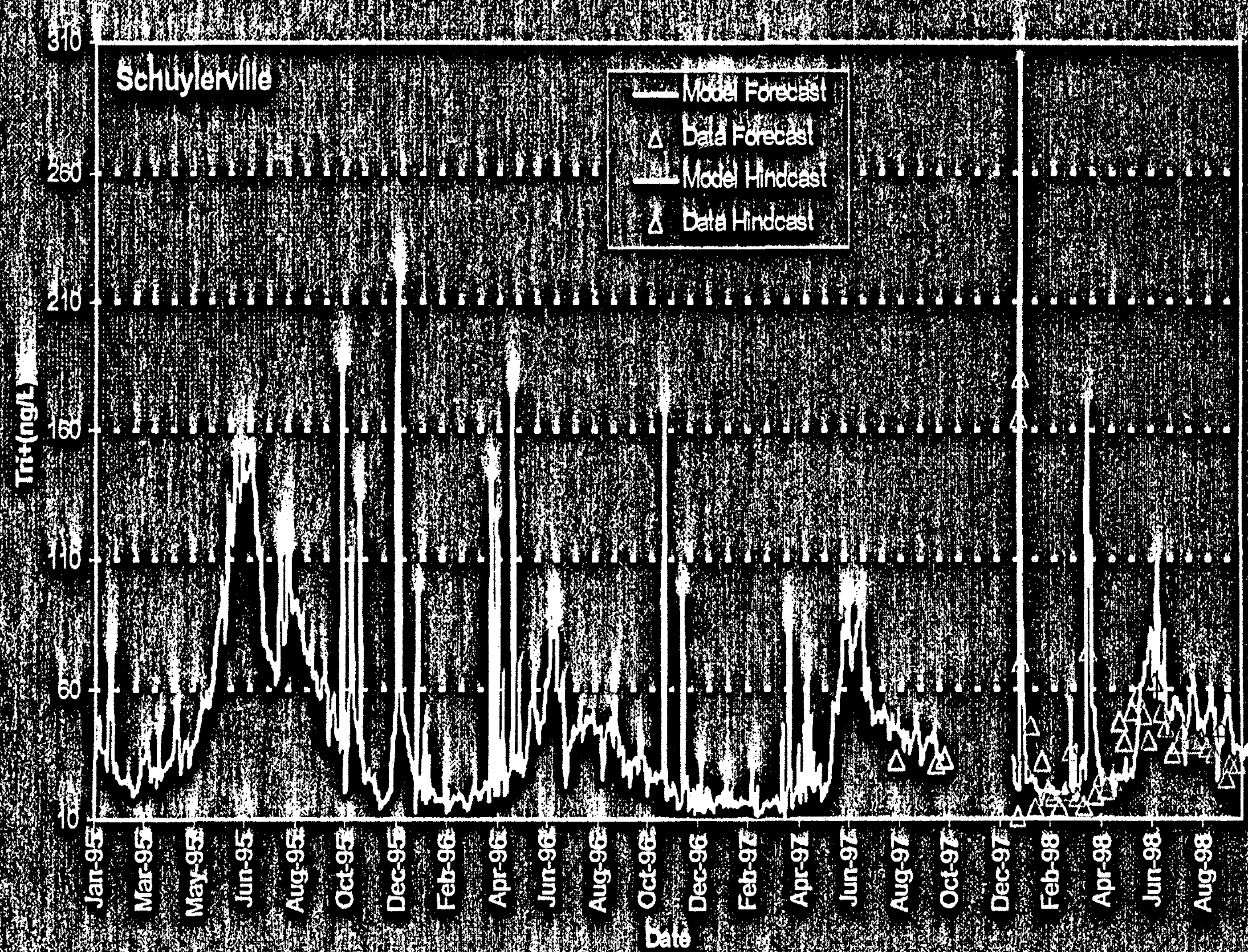
Validation

10.2512

Validation Results - Comparison of Predicted and Observed Tri+ Concentrations at Thompson Island Dam



Validation Results - Comparison of Predicted and Observed Tri+ Concentrations at Schuylerville



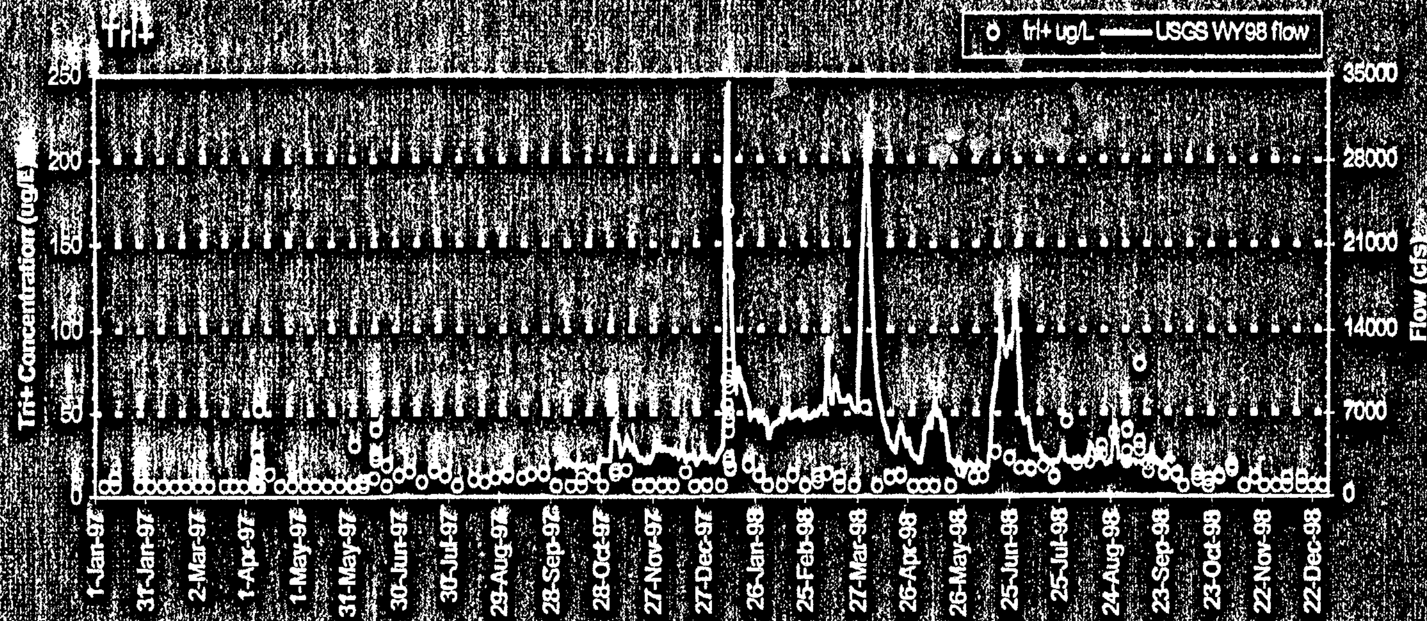
10.2514

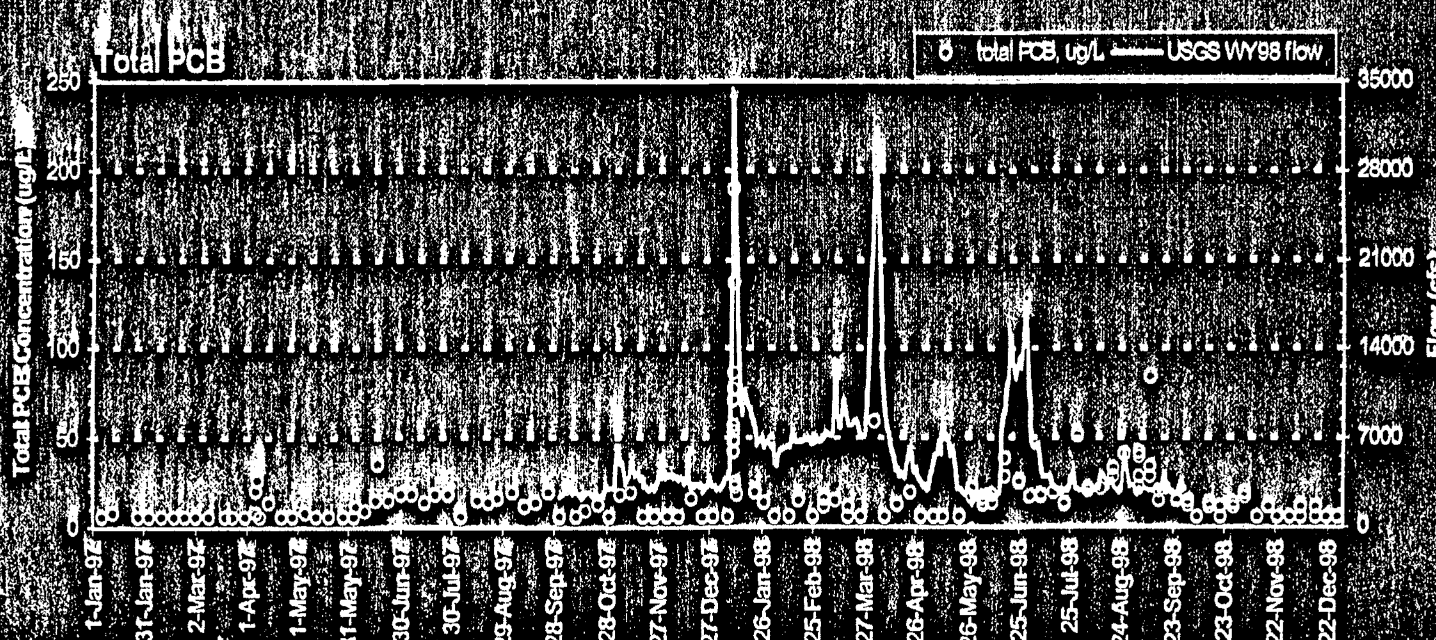
Forecast Simulations

Forecast Assumptions

- Forecast period of 70 years (1998 -2067)
- Initialize to 1991 sediment data
- Annual hydrographs selected randomly from 1977-1997 historical calibration period
- Solids loadings
  - Fort Edward: rating curve from 1991-1997
  - Tributaries: rating curves from historical calibration
- Upstream Tri+ concentrations at Fort Edward
  - 0, 10, 30 ng/L
- No Action and 100-year peak flow simulations

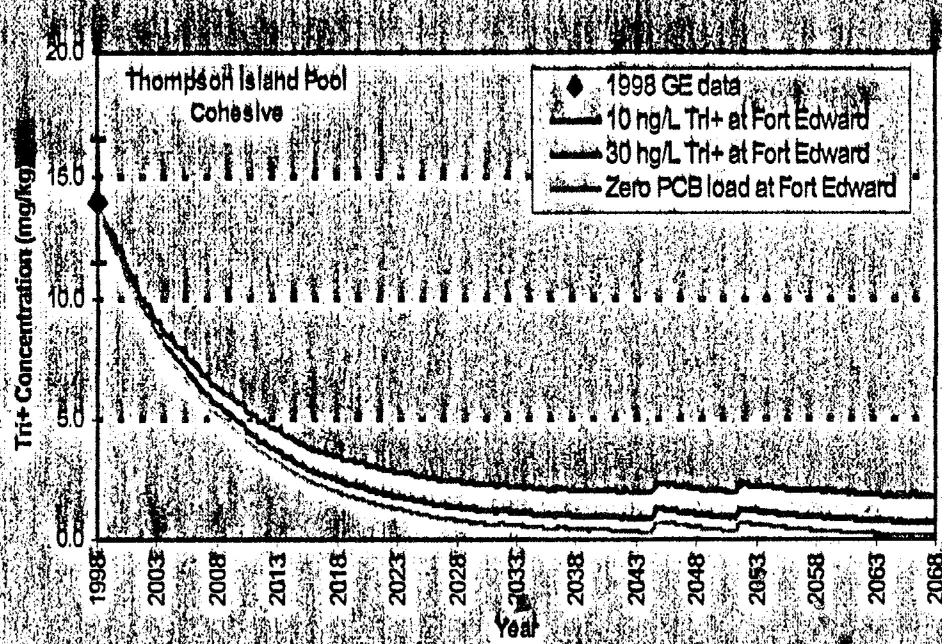
Observed Total PCB and Tri+ Concentrations at Fort Edward during 1997 and 1998

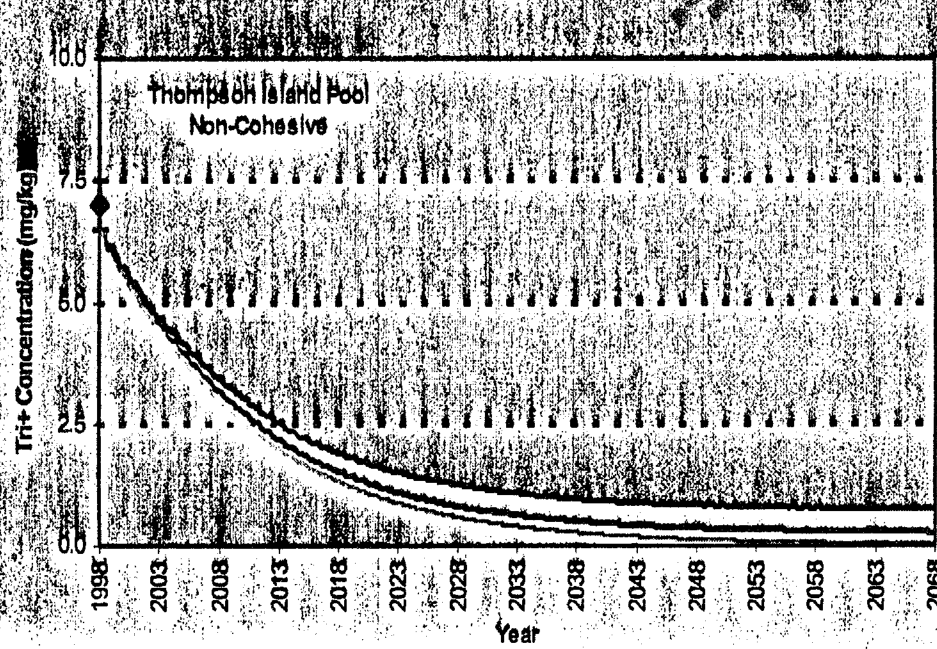




10.2516

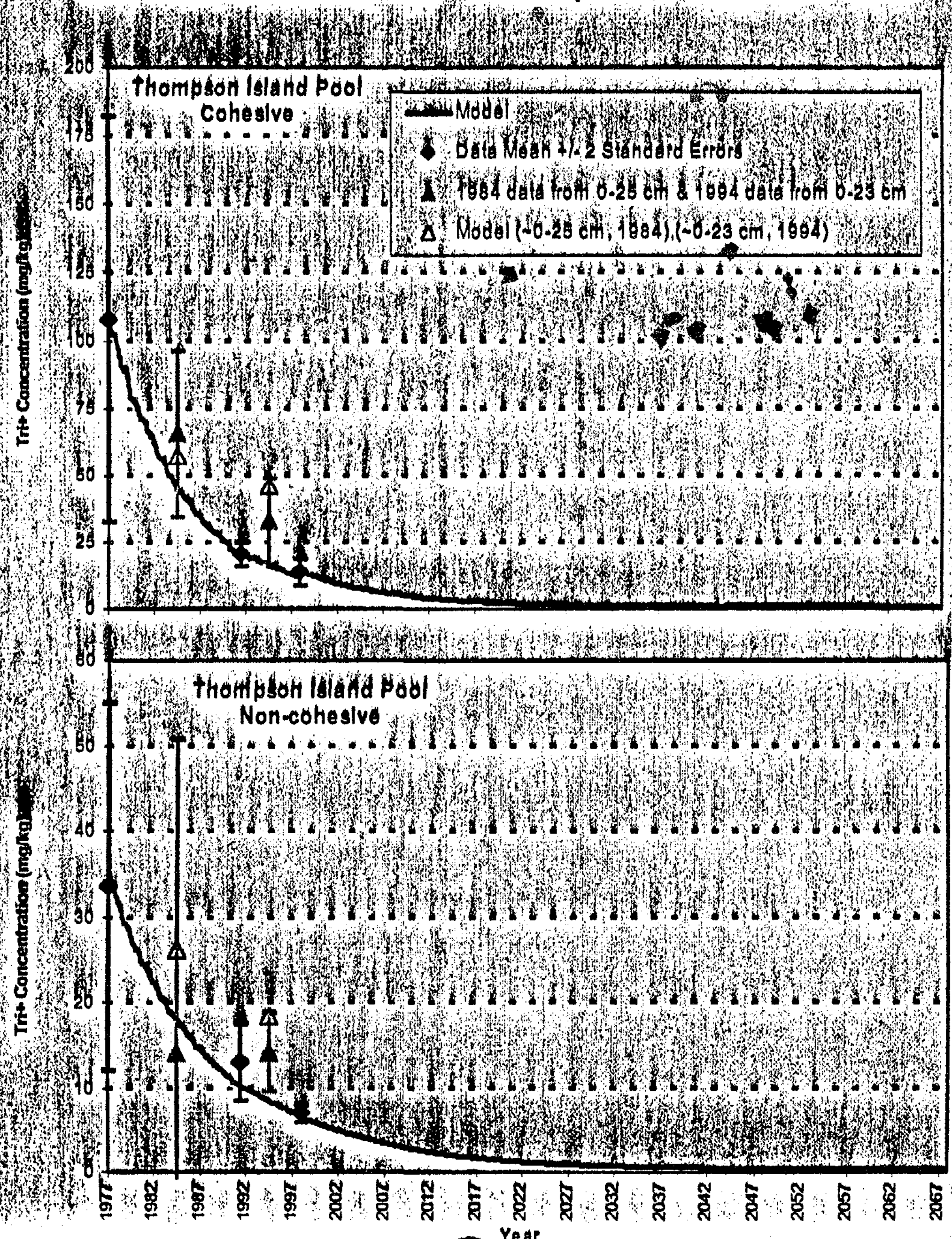
Forecast Surface Sediment Tri+ Concentrations for Thompson Island Pool





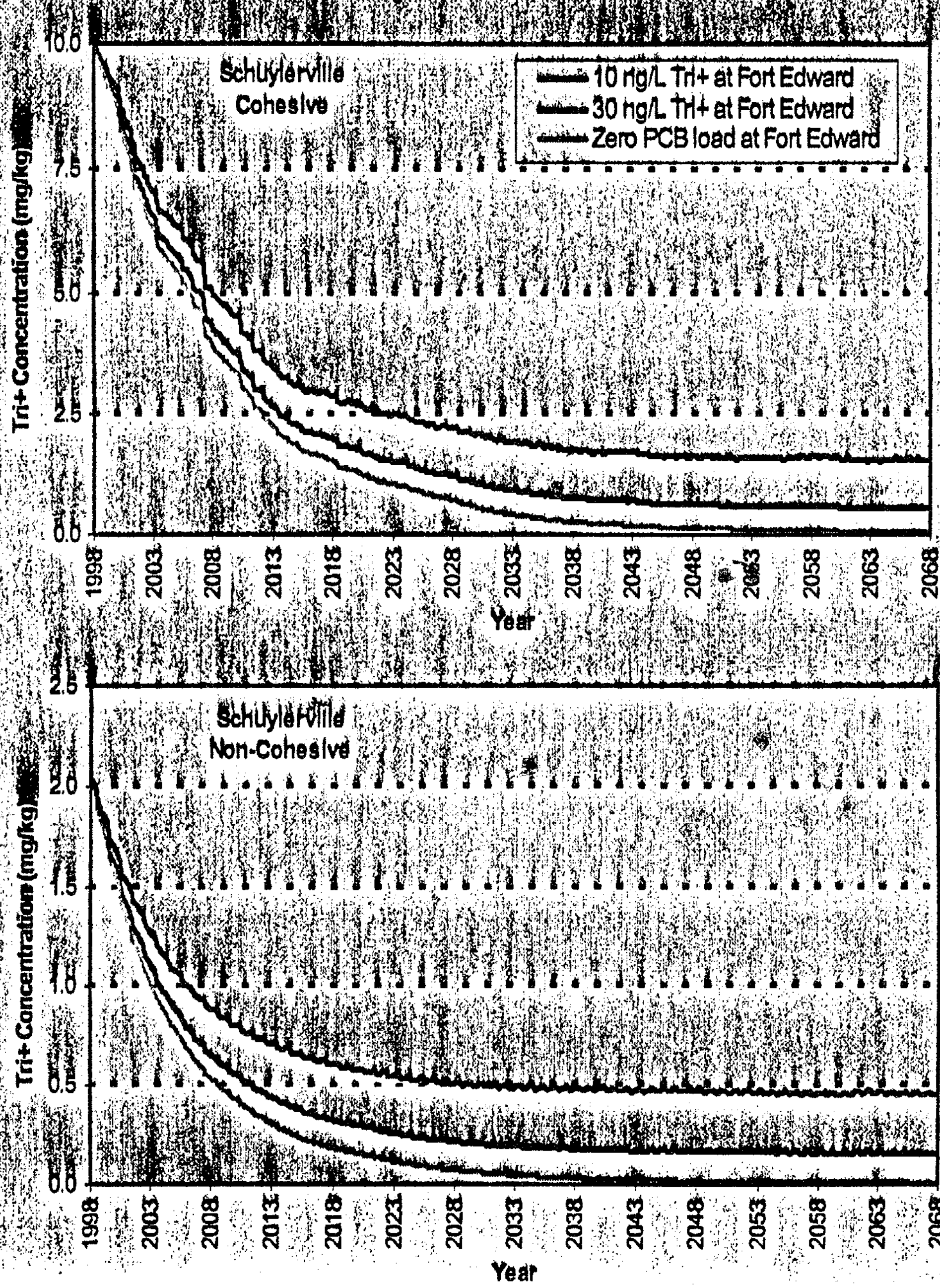
10.2517

Historical and Forecast Surface Sediment Tri+ Concentrations for Thompson Island Pool



10.2518

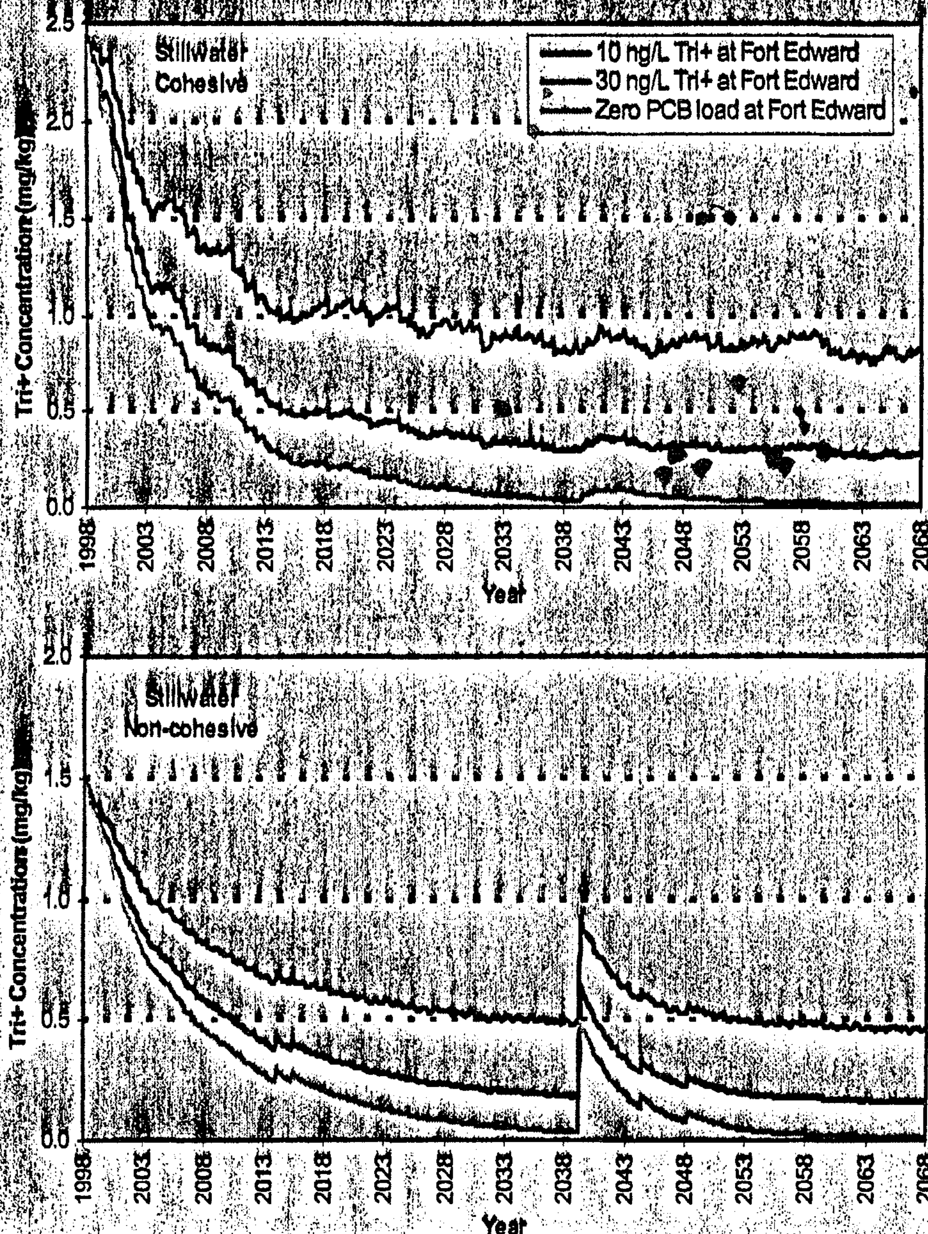
Forecast Surface Sediment Tri+ Concentrations for Schuylerville Reach



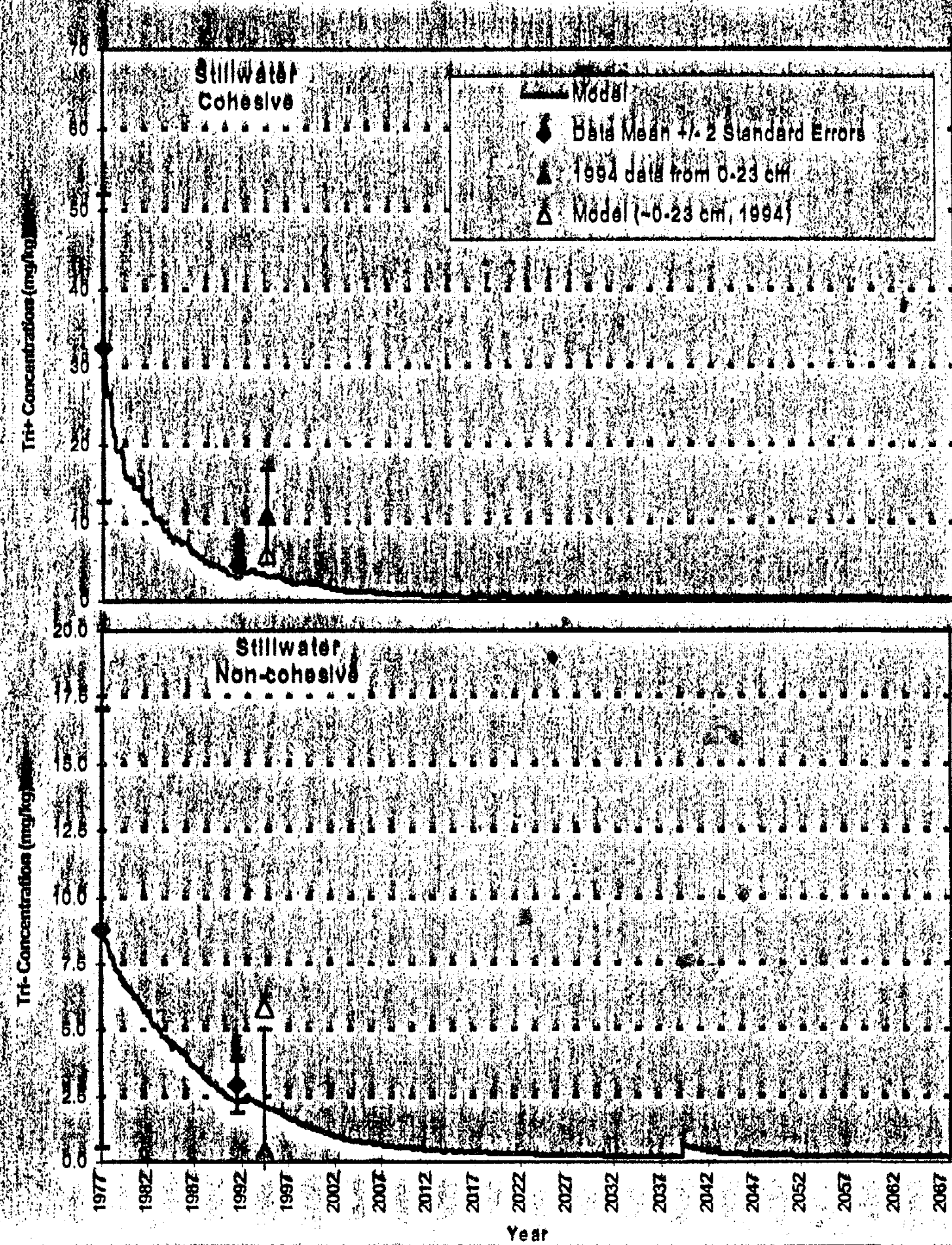
10.2519

10.2520

Forecast Surface Sediment Tri+ Concentrations for Stillwater Reach



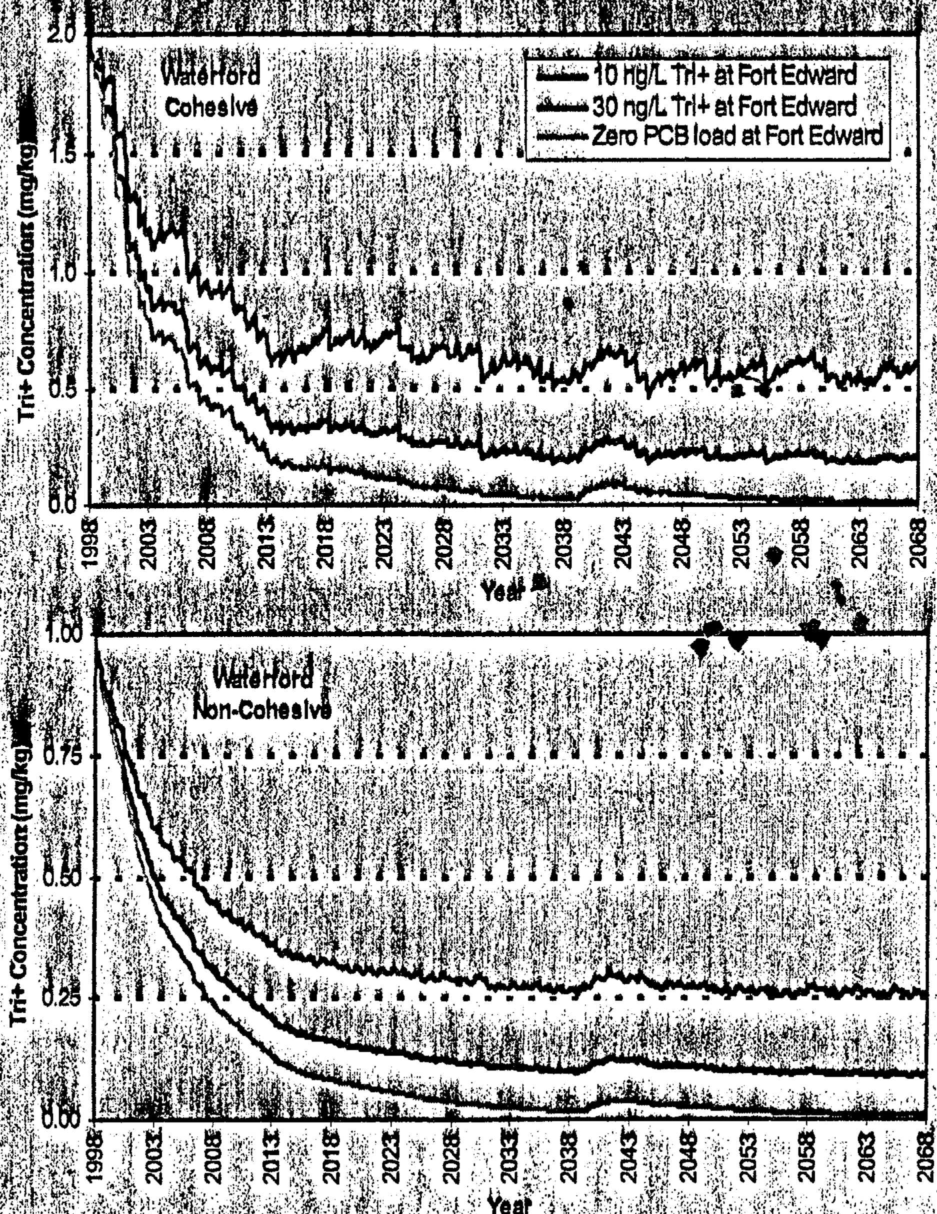
Historical and Forecast Surface Sediment Tri+ Concentrations for Stillwater Reach



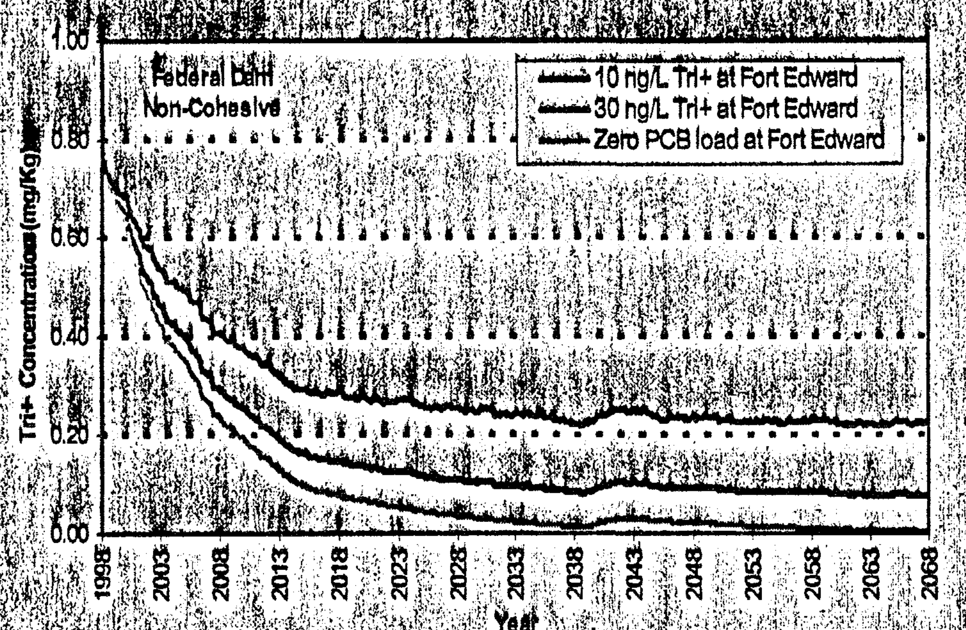
10.2521

10.2522

Forecast Surface Sediment Tri+ Concentrations for Waterford Reach



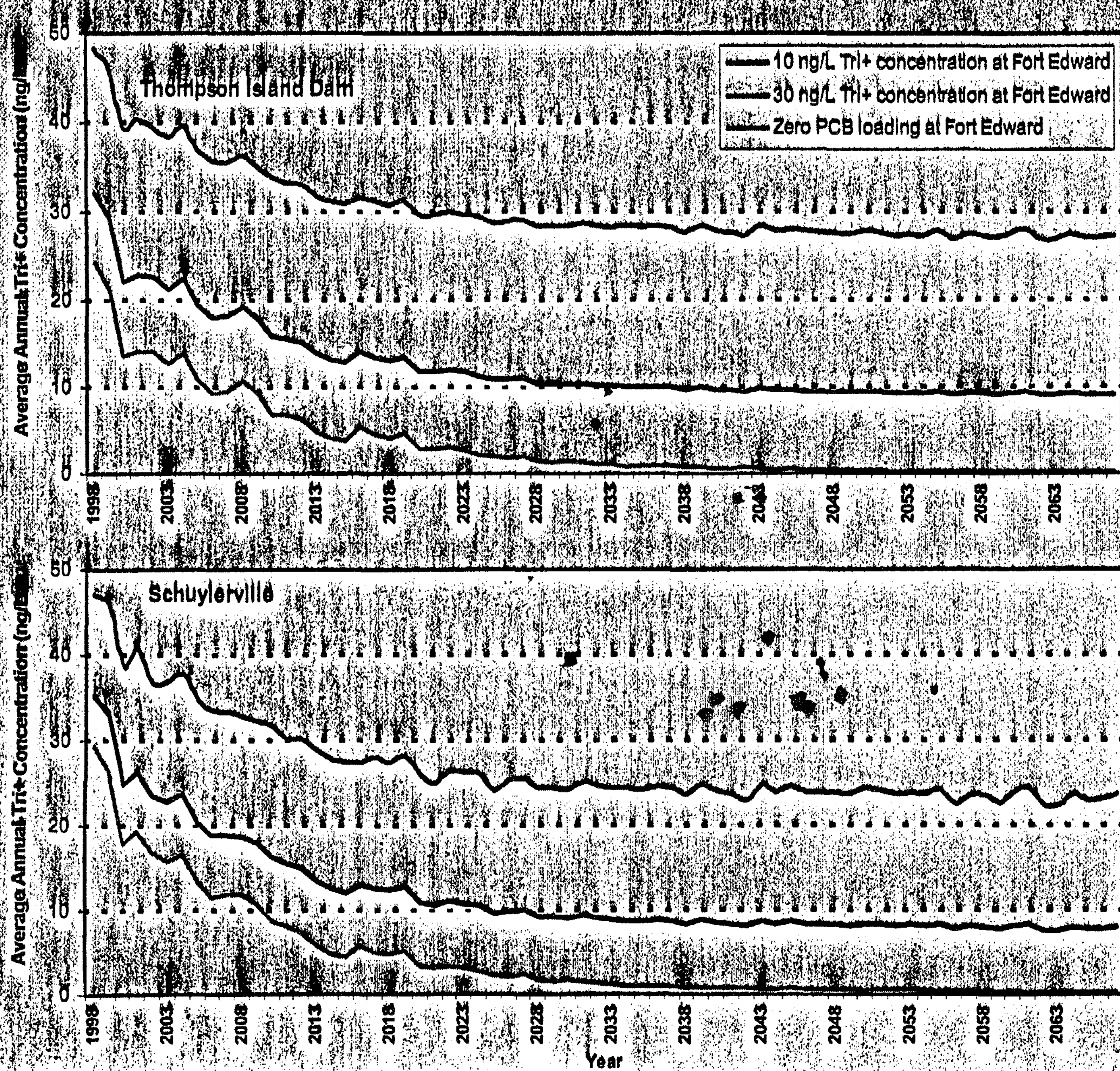
Forecast Surface Sediment Tri+ Concentrations for Federal Dam Reach



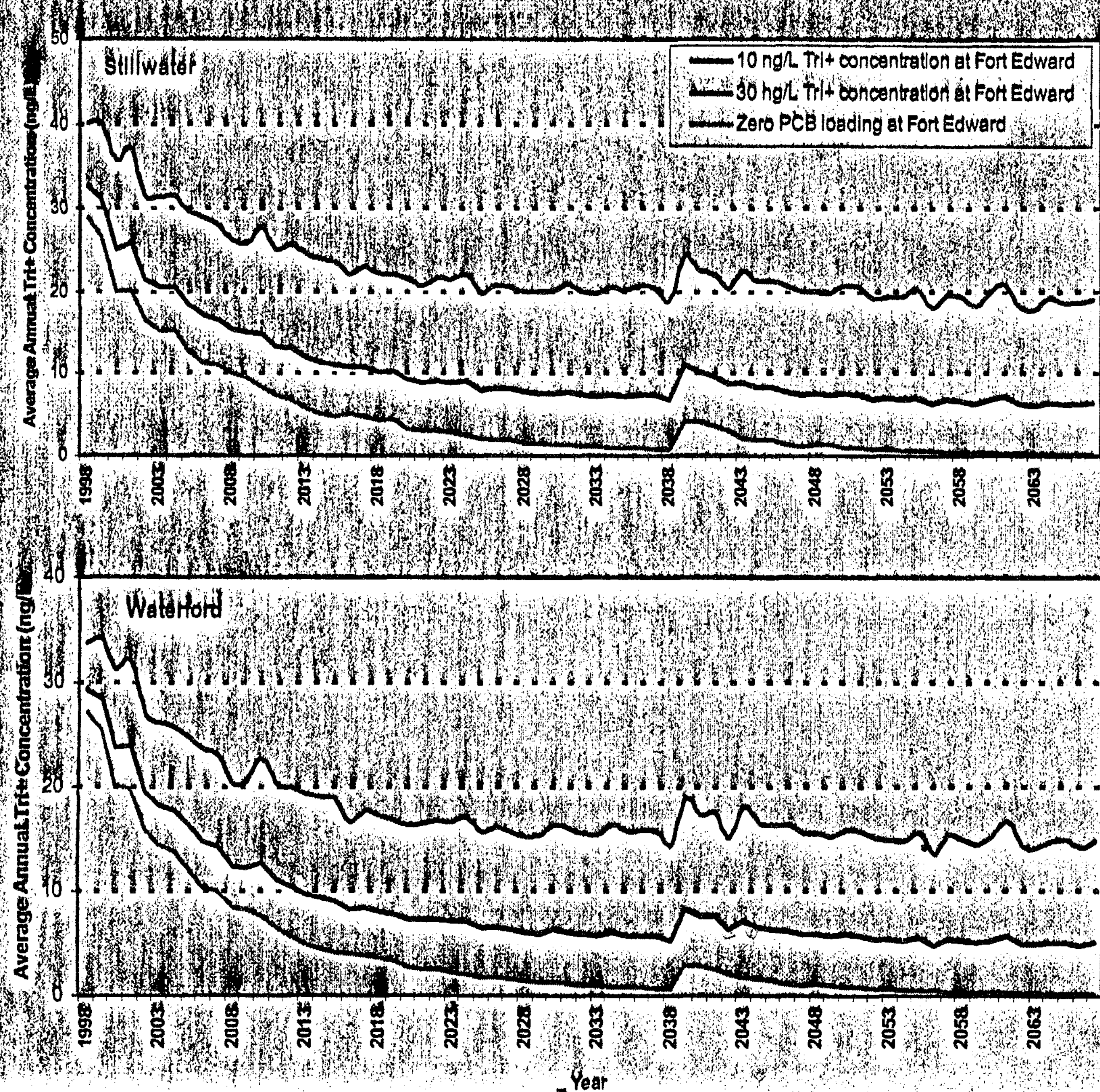
10.2523

10.2524

Forecast Annual Average Tri+ Concentrations at Thompson Island Dam and Schuylerville

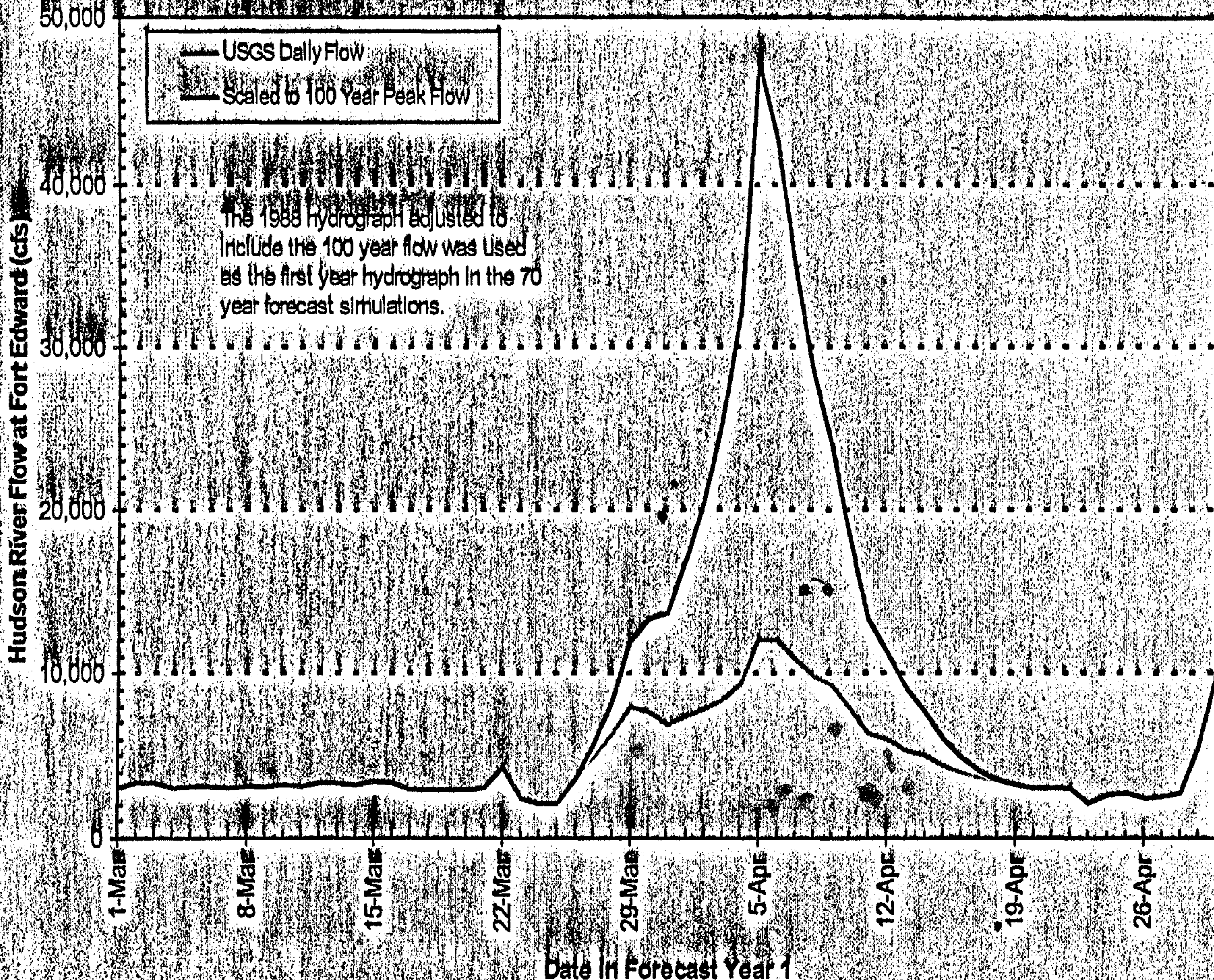


Forecast Annual Average Tri+ Concentrations at Stillwater and Waterford

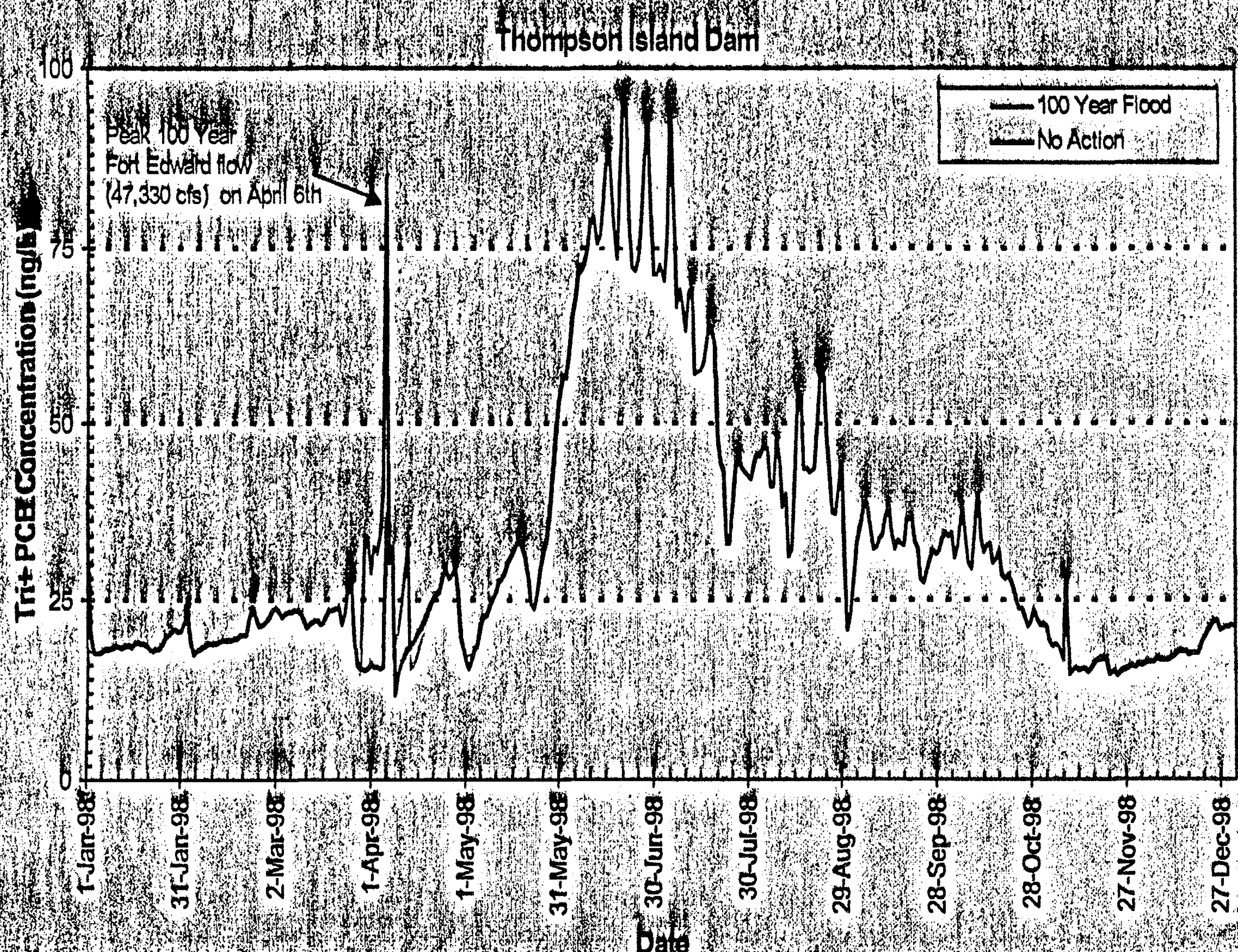


10.2525

Adjustment of Fort Edward Hydrograph to Include the 100-Year Peak Flow



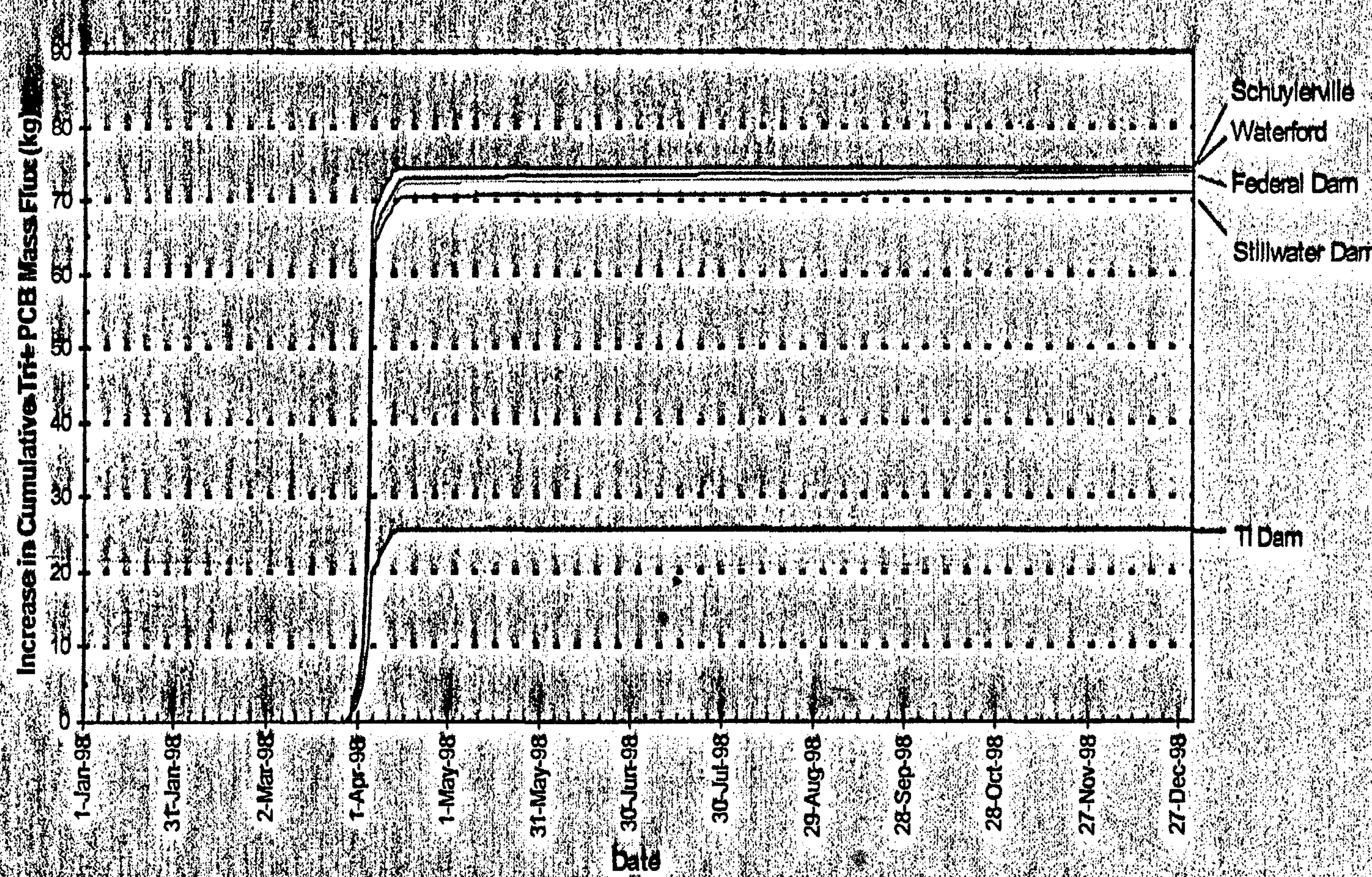
Predicted Impact of 100-Year Flow on Tri+ Concentrations at Thompson Island Dam



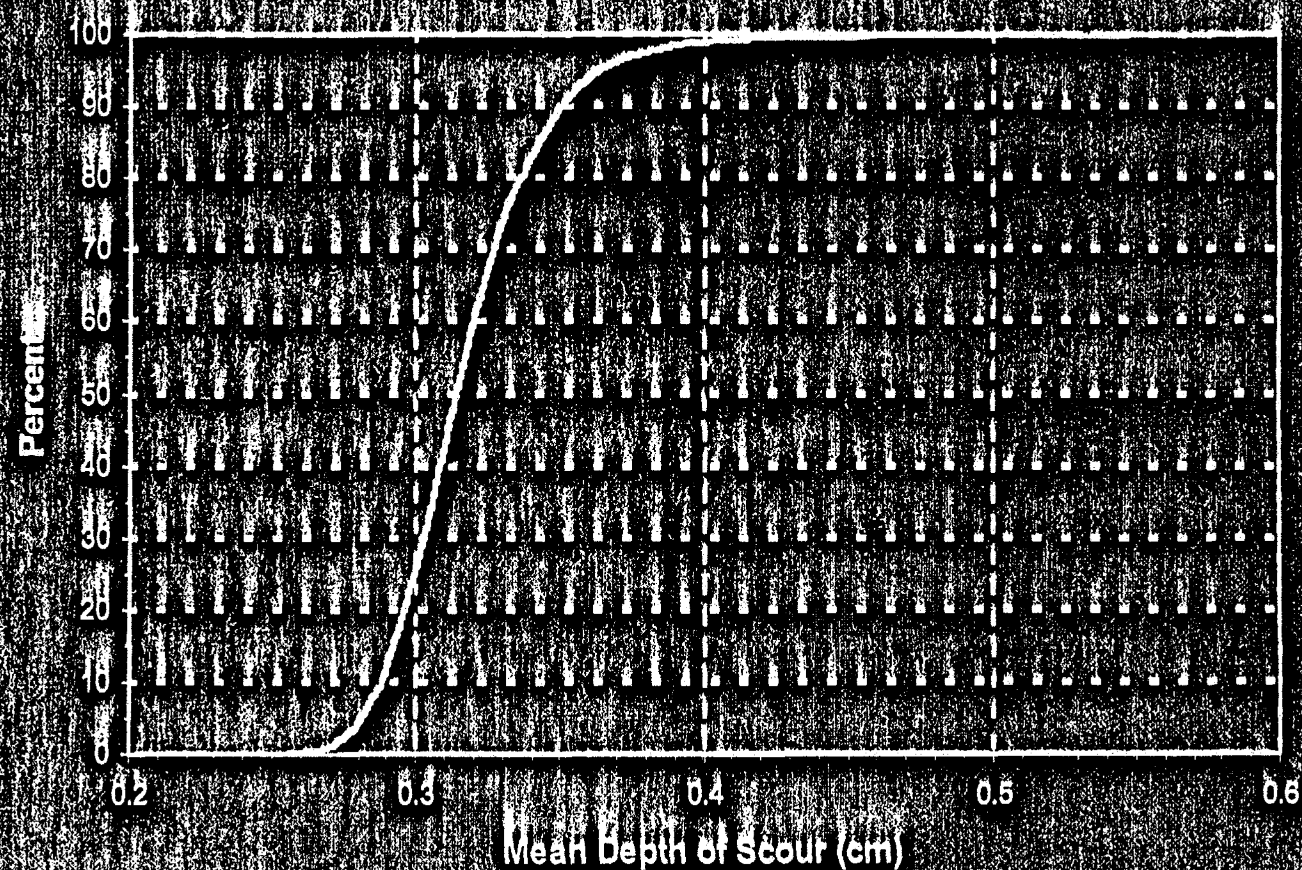
10.2527

10.2528

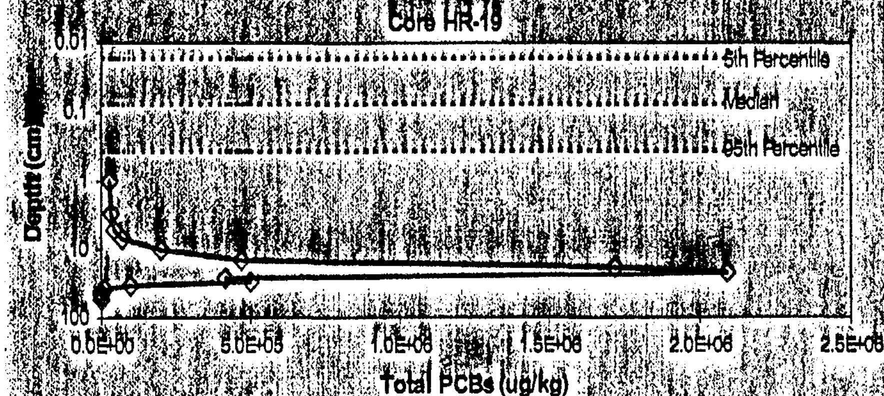
Cumulative Net Increase in Tri+ Mass Loading Due to 100-Year Peak Flow, Relative to No Action

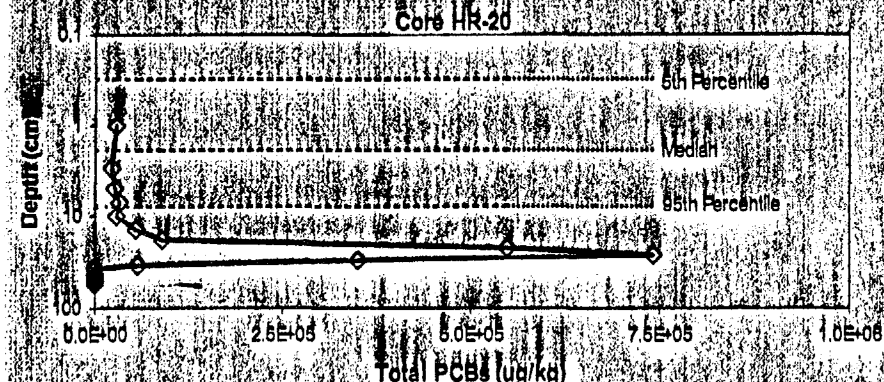


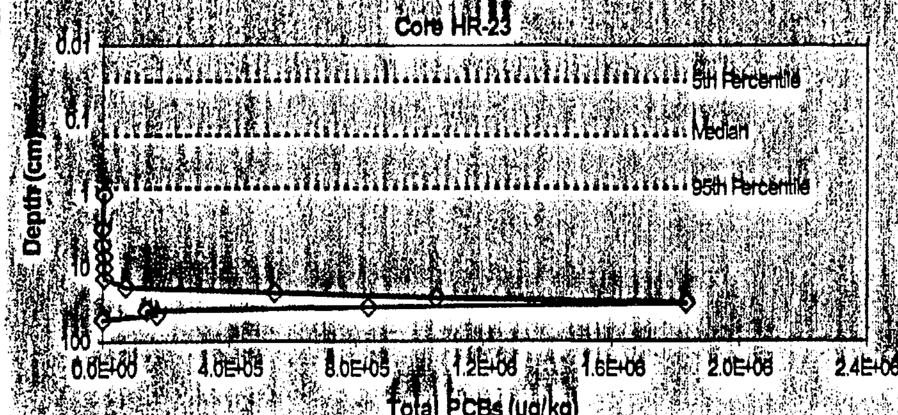
Cumulative Percent Versus Mean Depth of Scour for Cohesive Sediments in Thompson Island Pool

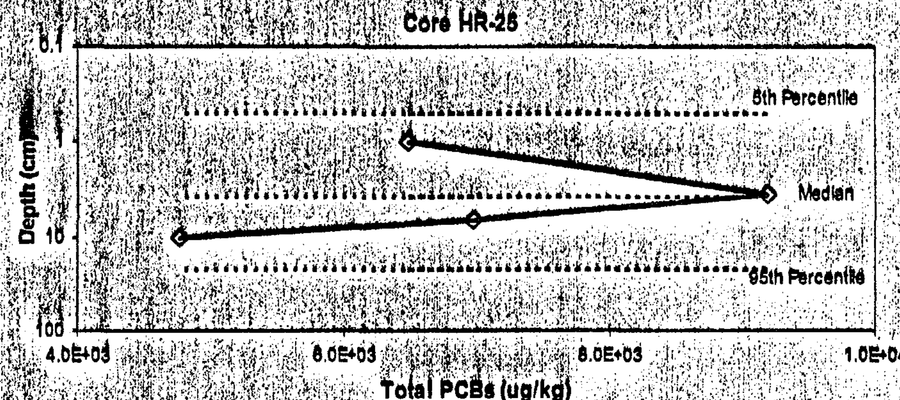


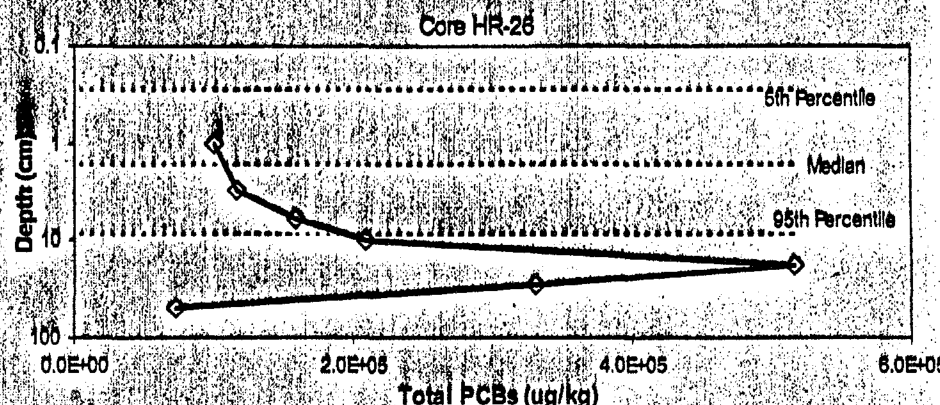
Likelihood of PCB Scour for Selected Phase 2 High Resolution Sediment Cores in Thompson Island Pool











Other HUDTOX Results

- Calibration sensitivity analyses
- Forecast sensitivity analyses
- Quantitative model-data comparisons for water column solids and Tri+ concentrations
- Component mass balances for solids and Tri+

10.2532

Conclusions

- Transport and fate model is scientifically and technically sound
- Model is appropriate and useful for addressing the principal Reassessment questions
- Invite the Peer Review Panel to assess the model within the context of the Reassessment questions, the available database, and the peer review charge

4

Hudson River Bioaccumulation Models

Presentation to the Baseline Modeling
Report Peer Review Committee

January 13, 2000

Menzie-Cura & Associates, Inc.

Katherine von Stackelberg

Outline

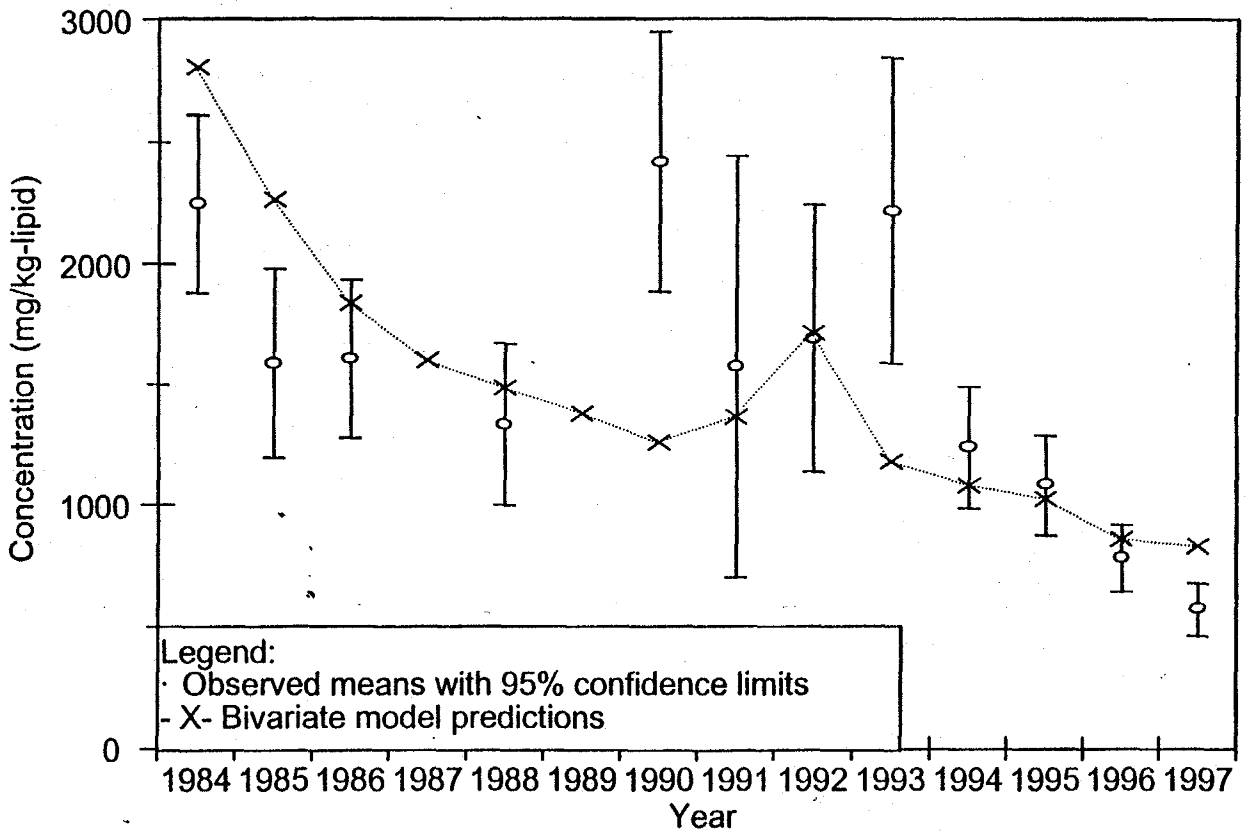
- Modeling approach
- Historical calibration
- Validation
- Forecasts

Bioaccumulation Models

- Bivariate Statistical Model
  - Direct sediment and water influence
  - Central tendency
- Empirical Probabilistic Model
  - Distributions
  - Incorporates feeding preferences
- FISHRAND
  - Mechanistic, time-varying
  - Predictive power

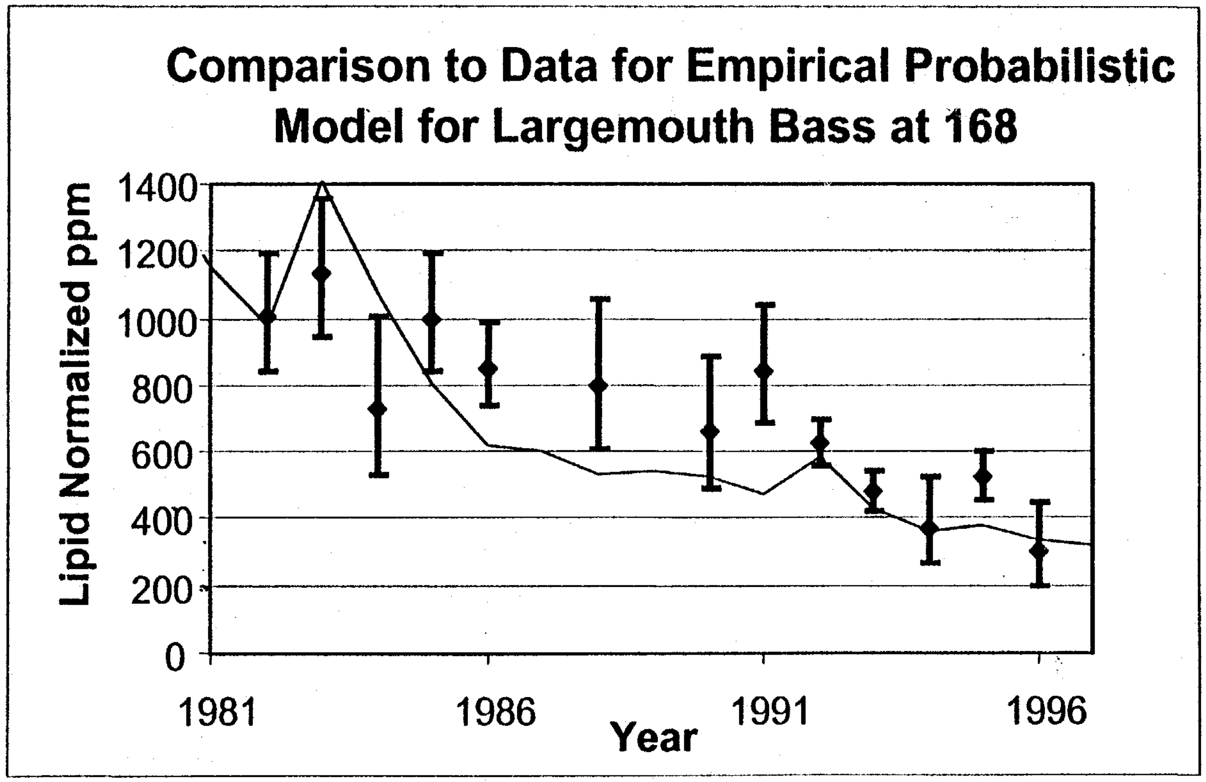
10.2536

Results for Largemouth Bass: Bivariate Statistical Model at 189



Largemouth Bass

Results for Largemouth Bass: Empirical Probabilistic Model at 168



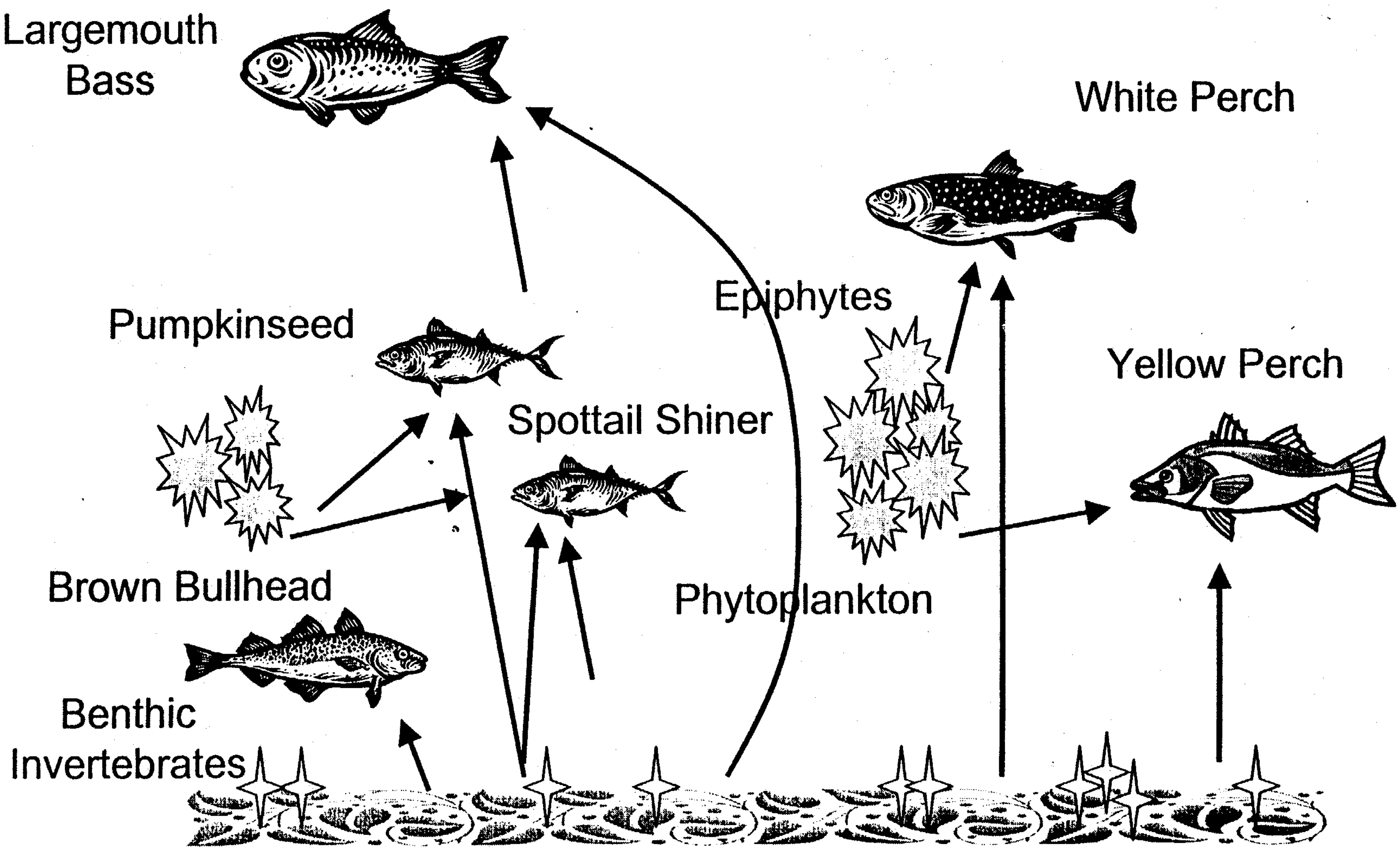
Largemouth Bass

10.2537

The Approach Taken in FISHRAND

- Based on approach of Gobas (1993; 1995)
- Availability and use of site-specific data
- Distributions for input parameters
- Bayesian updating as calibration procedure
- Calculates population distribution of PCB body burden
- Explicit consideration of uncertainty / variability

Conceptual Model of Food Web



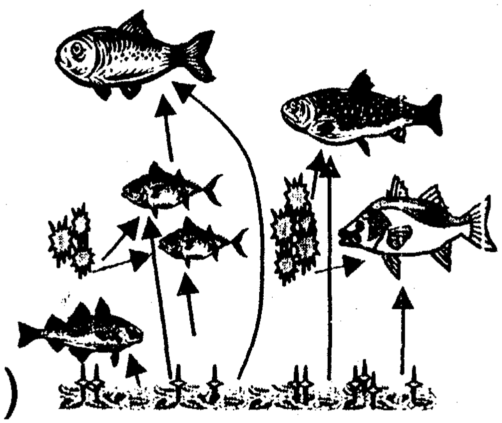
10.2539

Mathematical Basis of the Model

$$\frac{dC_f}{dt} = k_1 * C_{wd} + k_d * C_{diet} - (k_2 + k_e + k_m + k_g) * C_{fish}$$

where:

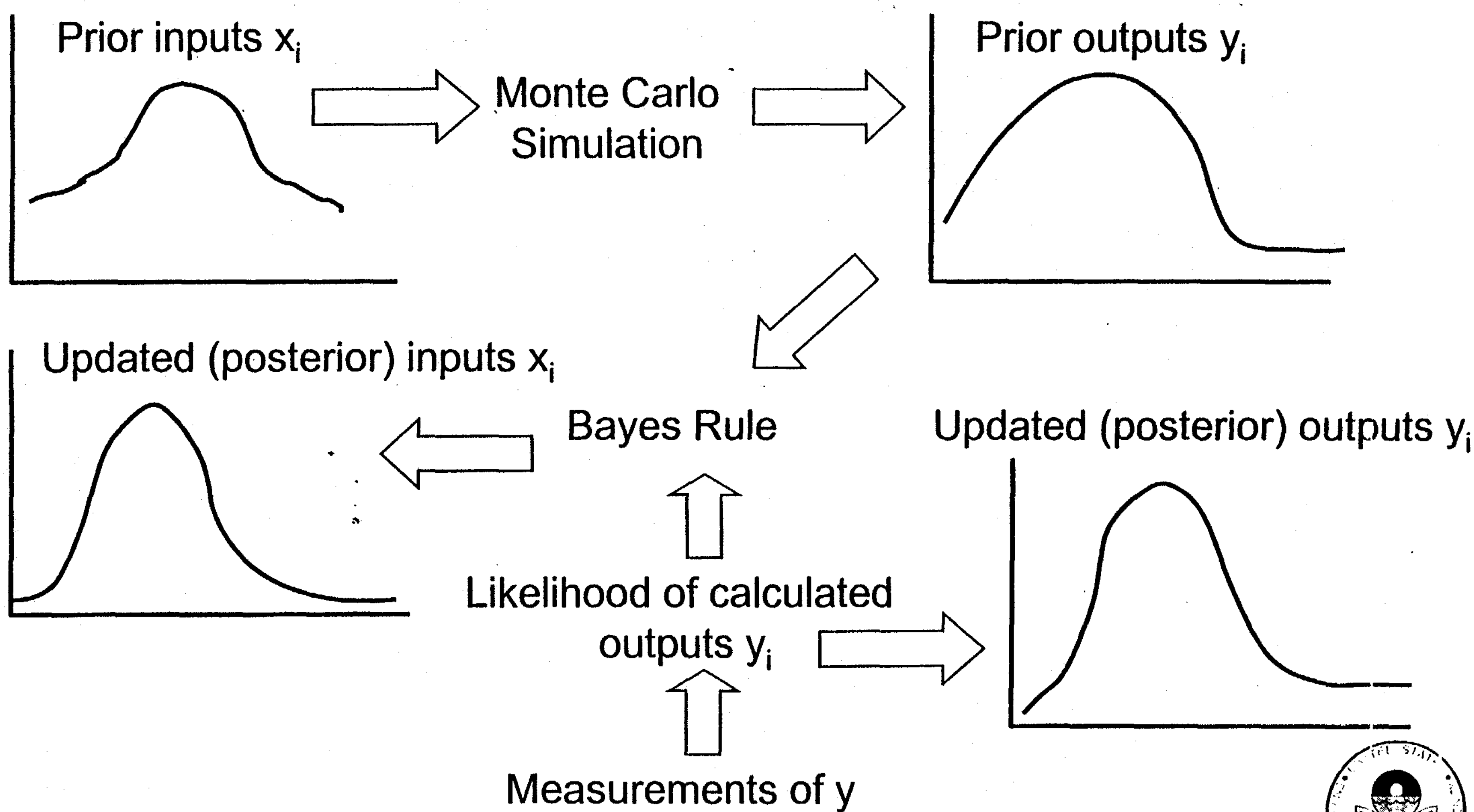
k_1	=	gill uptake rate (L/Kg/d)
C_{wd}	=	truly dissolved concentration in water
k_d	=	dietary uptake rate (d^{-1})
C_{diet}	=	concentration in the diet (g/g)
k_2	=	gill elimination rate (d^{-1})
k_e	=	fecal egestion rate (d^{-1})
k_m	=	metabolic rate (d^{-1}) (assumed to be zero)
k_g	=	growth rate (d^{-1})
C_{fish}	=	concentration in fish



Model Segments and PCB Forms

- Three reaches
  - Thompson Island Pool (river mile 189)
  - Stillwater (river mile 168)
  - Waterford - Federal Dam (river mile 154)
- Tri+ PCBs
  - Annual average dry weight surface sediment
    - 75% cohesive, 25% noncohesive (0 - 5 cm)
  - Monthly average dissolved water

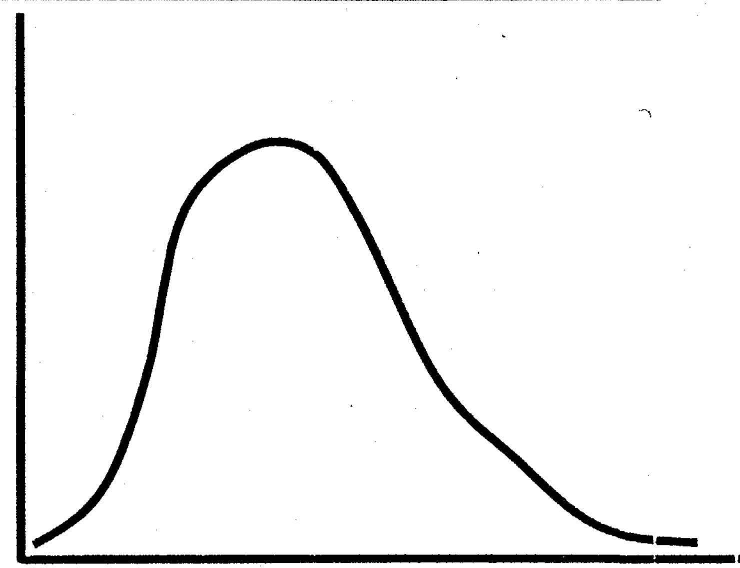
Bayesian Calibration Procedure



Parameterizing Distributions: Overview

Species-specific information:

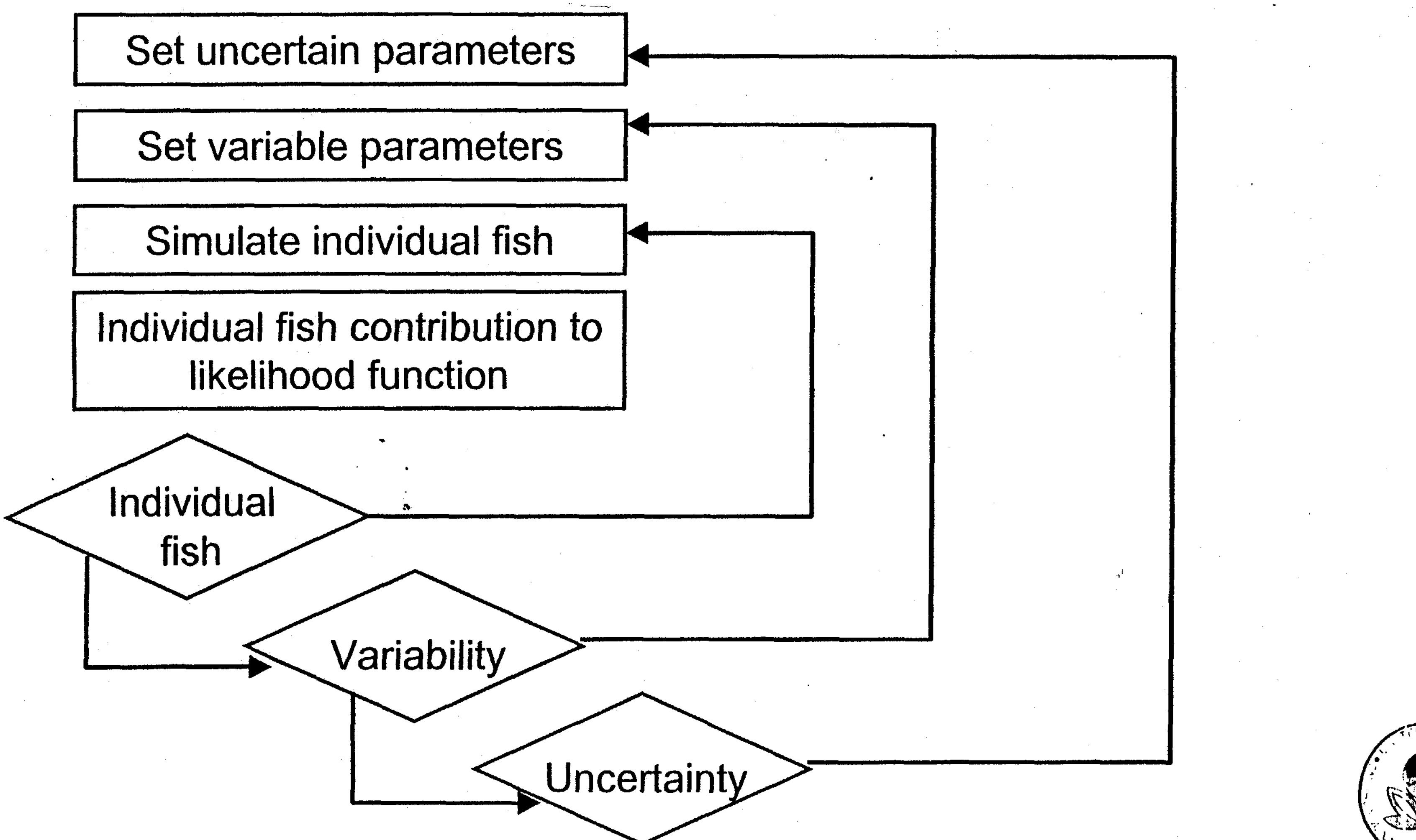
- Lipid content
- Weight
- Dietary composition



Environmental information:

- Total organic carbon
- Log octanol-water partition coefficient (K_{ow})
- Annual sediment concentrations
- Monthly water concentrations

Simulation Procedure



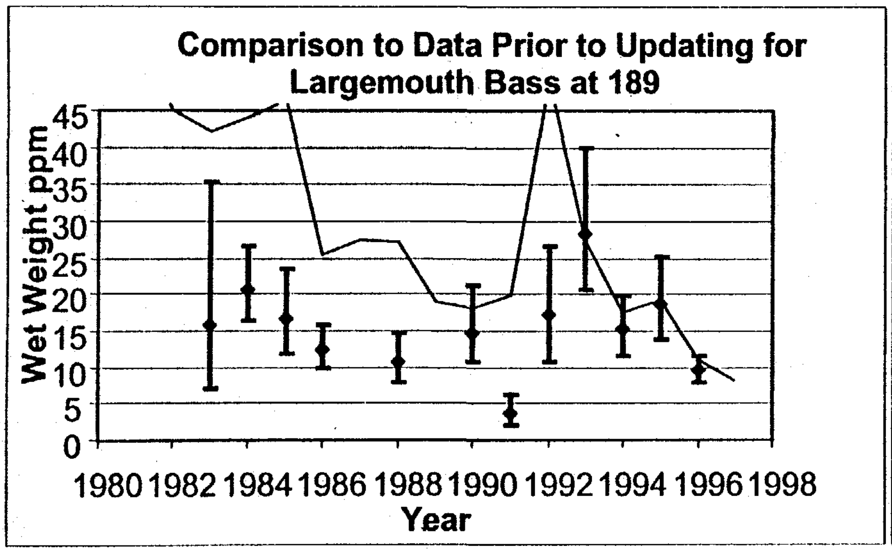
Parameterizing Distributions: Methods

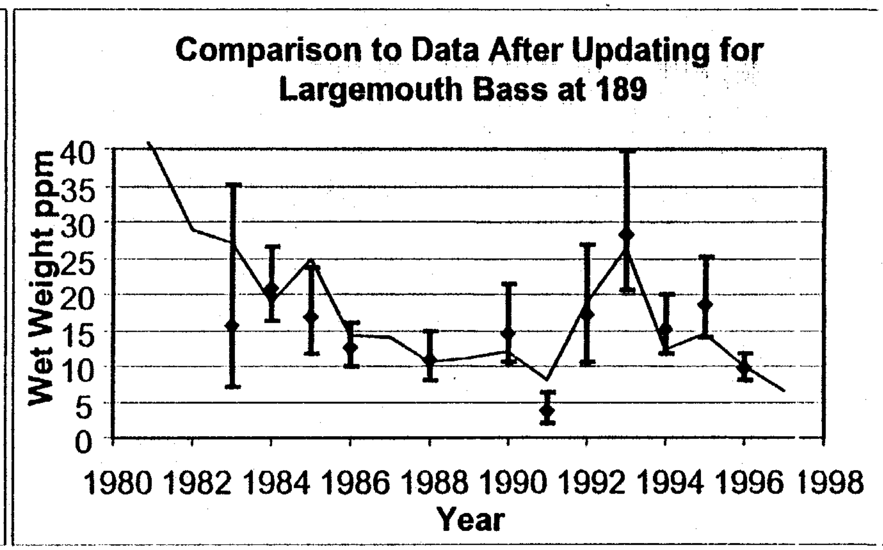
- Interested in particular age-class in population
- Evaluate three locations in the Upper Hudson
- Compile data -- Evaluate differences between locations and years
- Plot combinations of parameters to identify correlations, relationships
- Plot histograms, CDFs and construct empirical distributions (typically triangular)

Selection Process for Bayesian Calibration

- Rate constants in model
  - Plot elasticities over time
  - Growth rate coefficient
- User-specified input parameters
  - Sensitivity analysis using rank correlation techniques
  - TOC
  - K_{ow}
  - Lipid in fish
- Likelihood profile

Results for Largemouth Bass: Comparison to Observations





Largemouth Bass at River Mile 189 (Thompson Island Pool)

Line: FISHRAND median results

Bars: Median data and 95% confidence interval

10.2547

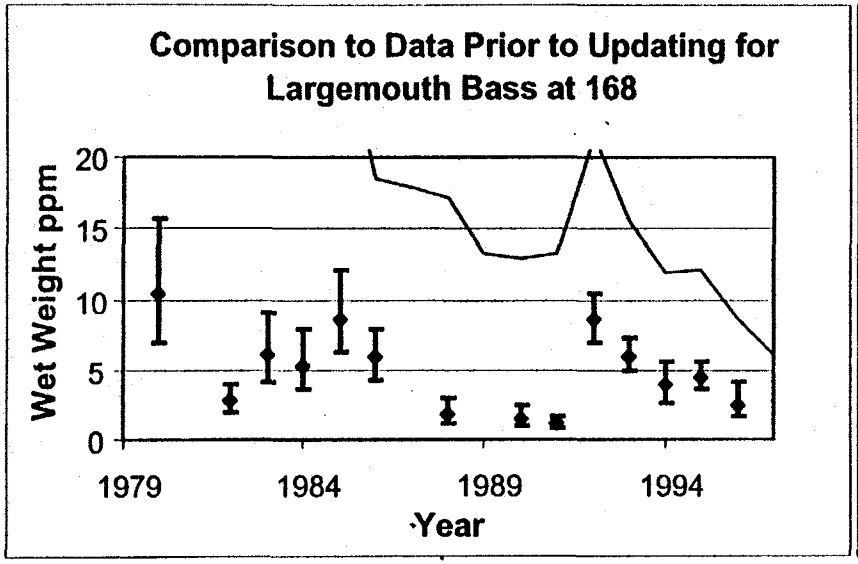
10.2548

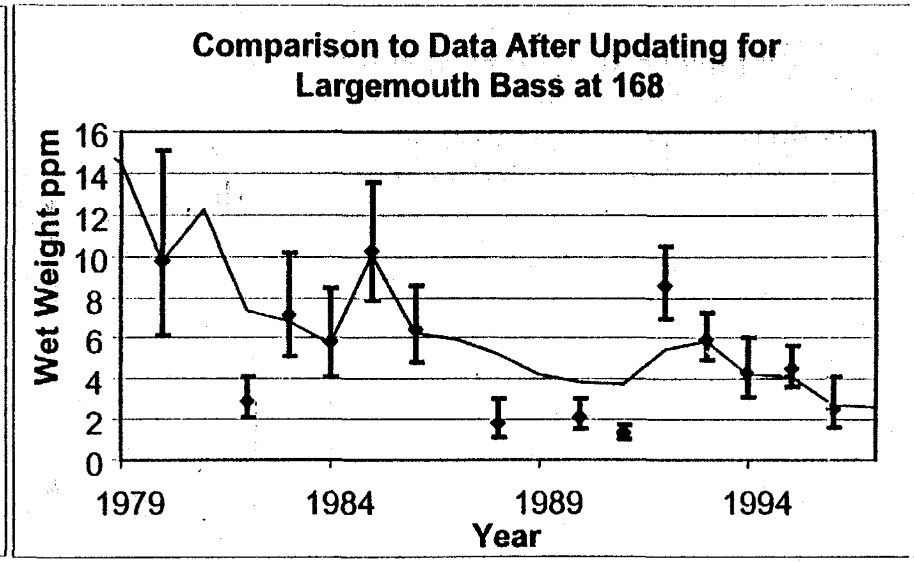
Results for Largemouth Bass: Relative Percent Difference at RM189

1983	34%	1991	100%
1984	1%	1992	4%
1985	48%	1993	-8%
1986	13%	1994	-16%
1988	36%	1995	-16%
1990	12%	1996	3%

(predicted - observed) / observed

Results for Largemouth Bass: Comparison to Observations





Largemouth Bass at River Mile 168 (Stillwater)

Line: FISHRAND median results

Bars: Median data and 95% confidence interval

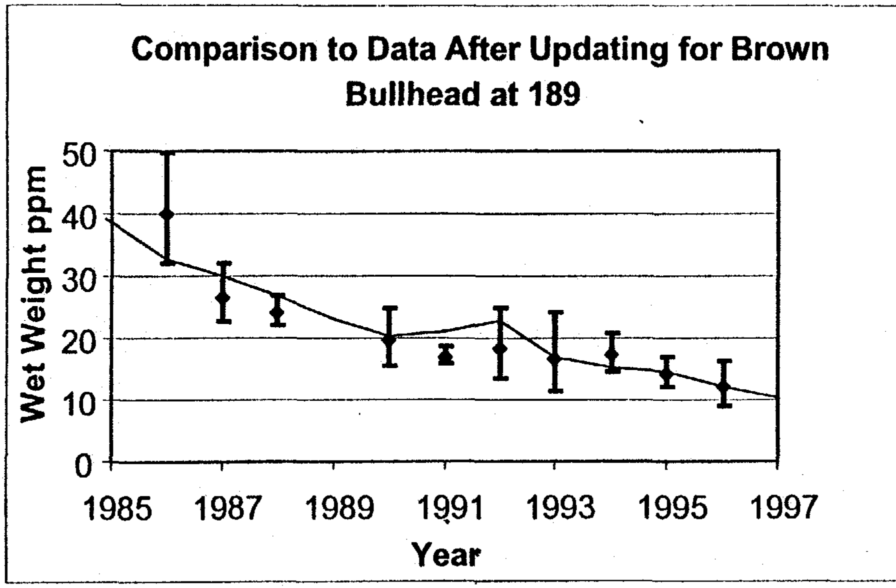
10.2549

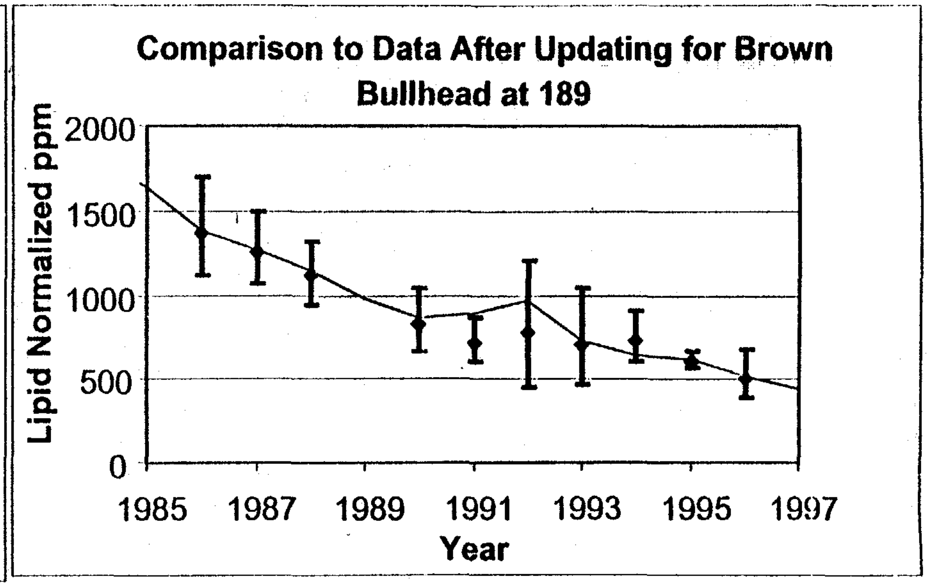
Results for Largemouth Bass: Relative Percent Difference at RM168

1977	-55%	1990	26%
1978	-82%	1991	90%
1980	0%	1992	-36%
1983	-5%	1993	-3%
1984	-2%	1994	-2%
1985	-2%	1995	-8%
1986	-2%	1996	3%
1988	100%		

(predicted - observed) / observed

Results for Brown Bullhead: Comparison to Observations



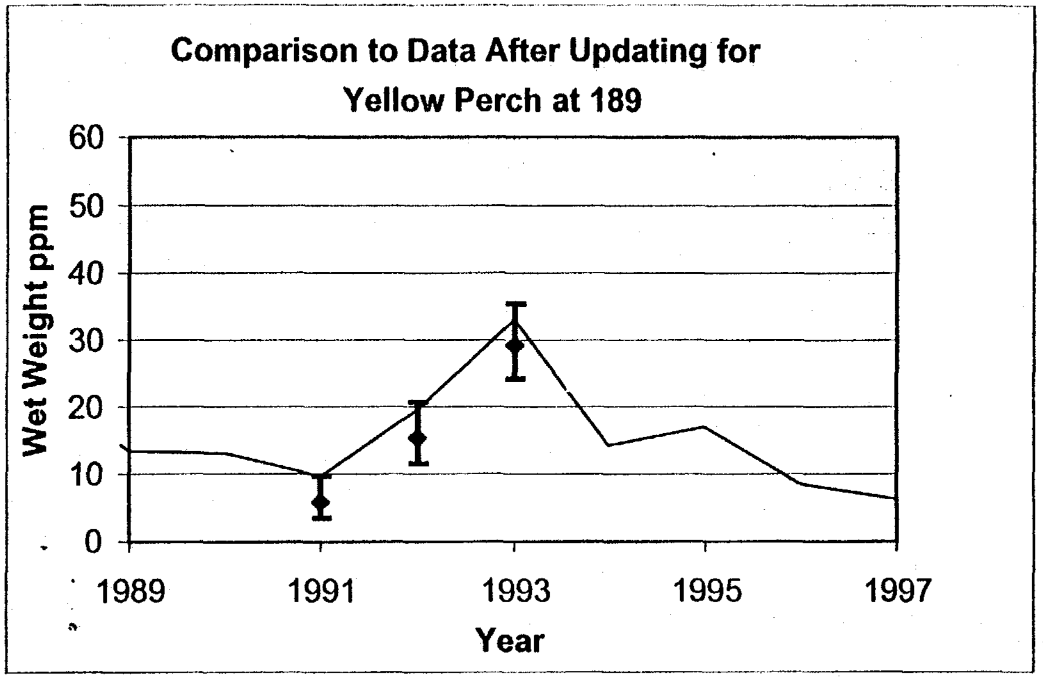


Line: FISHRAND median results

Bars: Median data and 95% confidence interval

10.2551

Results for Yellow Perch: Comparison to Observations



Line: FISHRAND median results

Bars: Median data and 95% confidence interval

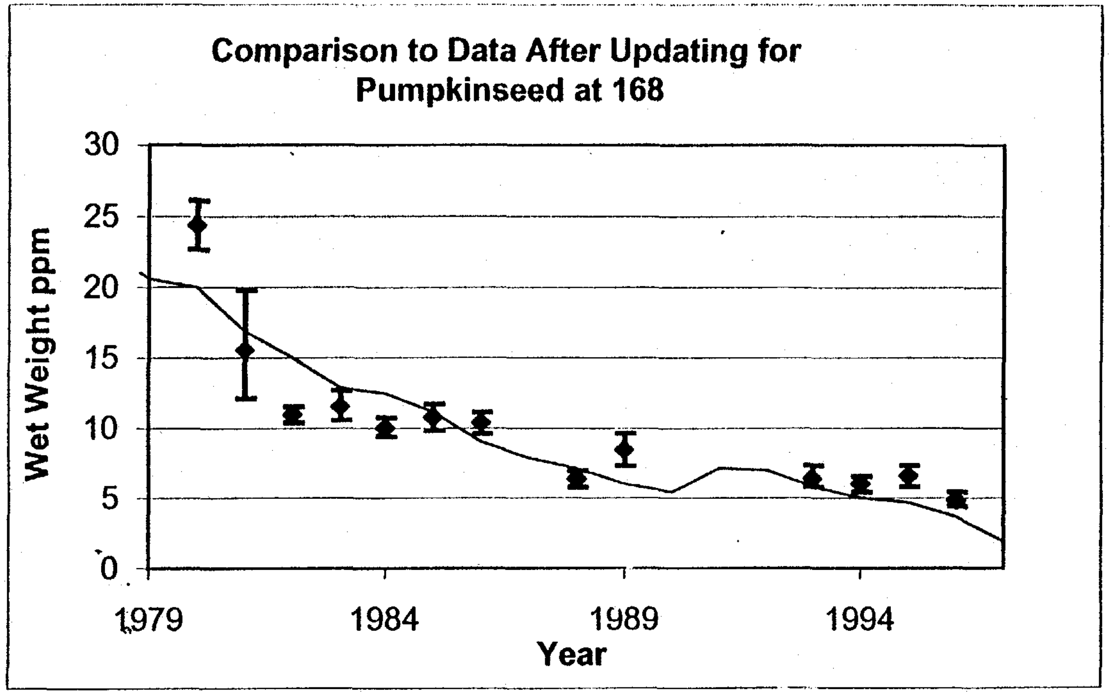
Results for Yellow Perch: Relative Percent Difference at RM 189

1991	53%
1992	27%
1993	13%

(predicted - observed) / observed

10.2553

Results for Pumpkinseed: Comparison to Observations



Line: FISHRAND median results

Bars: Median data and 95% confidence interval

Results for Pumpkinseed: Relative Percent Difference at RM 168

1980	-1%
1981	-3%
1982	36%
1983	12%
1984	19%
1985	18%
1986	14%
1988	3%
1989	-18%
1993	26%
1994	-18%
1995	-22%
1996	-8%

Comparison to Data

Benthic invertebrates at river mile 189 (1993):

observed - 13.0 ppm
predicted - 11.0 ppm

All concentrations are median, wet weight, ppm

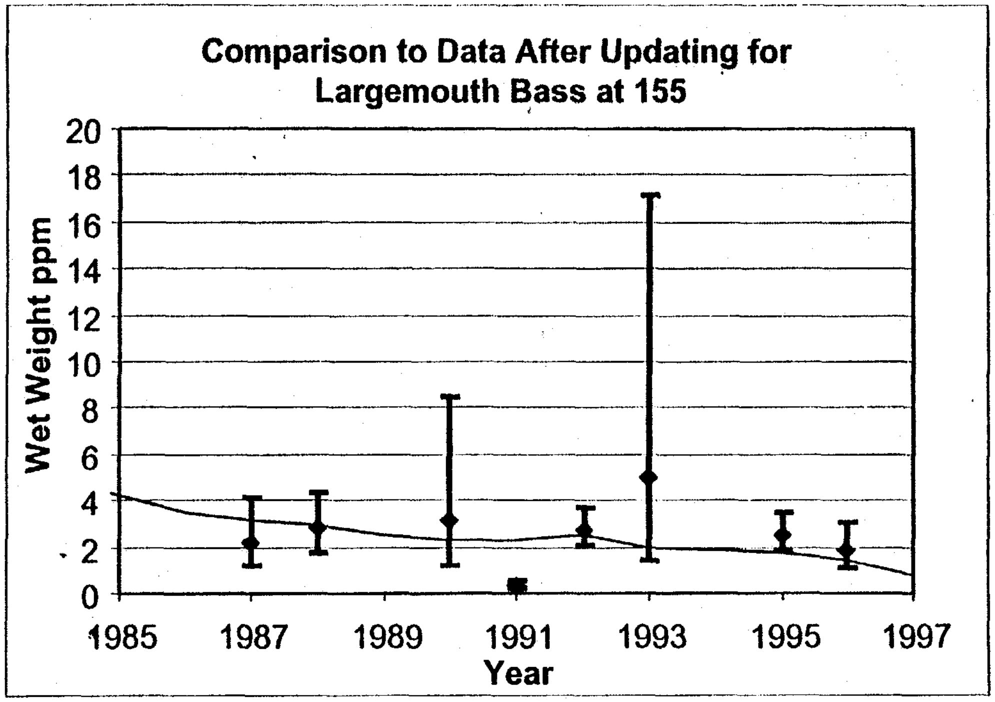
Spottail shiner:

	189	168	154
predicted	12.8	1.9	1.2
observed	13.8	1.7	1.6

White perch median concentration at river mile 154:

underprediction: -32%
overprediction: 1%

Results for Largemouth Bass: Comparison to Observations



Largemouth Bass at River Mile 155 (Waterford)

Line: FISHRAND median results

Bars: Median data and 95% confidence interval

Results for Largemouth Bass: Relative Percent Difference at RM 154

1979	31%
1987	-8%
1988	4%
1990	-28%
1991	100%
1992	-10%
1993	-49%
1995	-23%
1996	-3%

(predicted - observed) / observed

Summary of Results for Historical Calibration

- On a median basis:
  - within a factor of two or less for most years
  - within uncertainty of median for most years and locations
- Within-year variability approximately factor of two

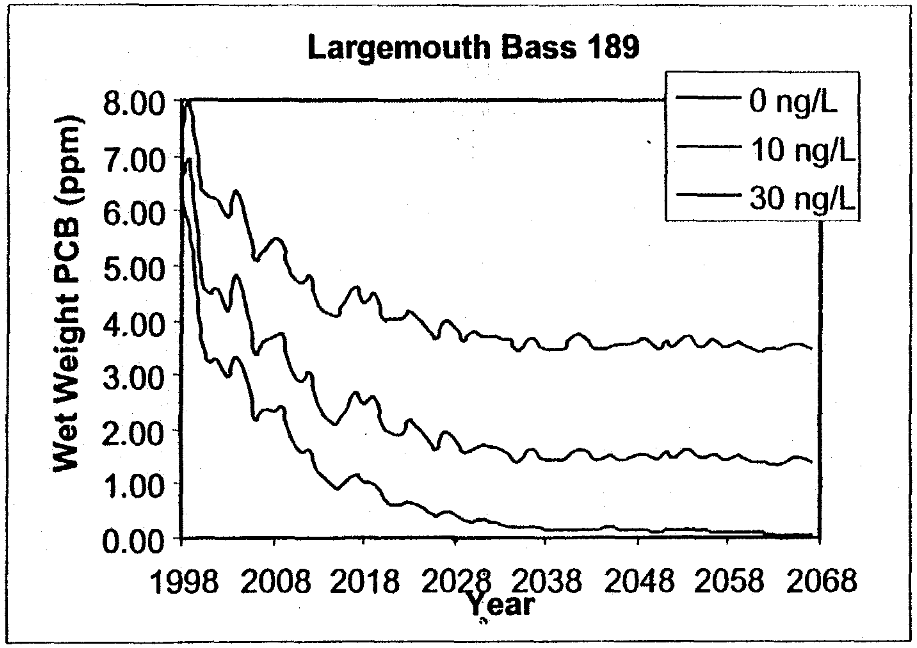
10.2560

Relative Importance of Sediment vs. Water

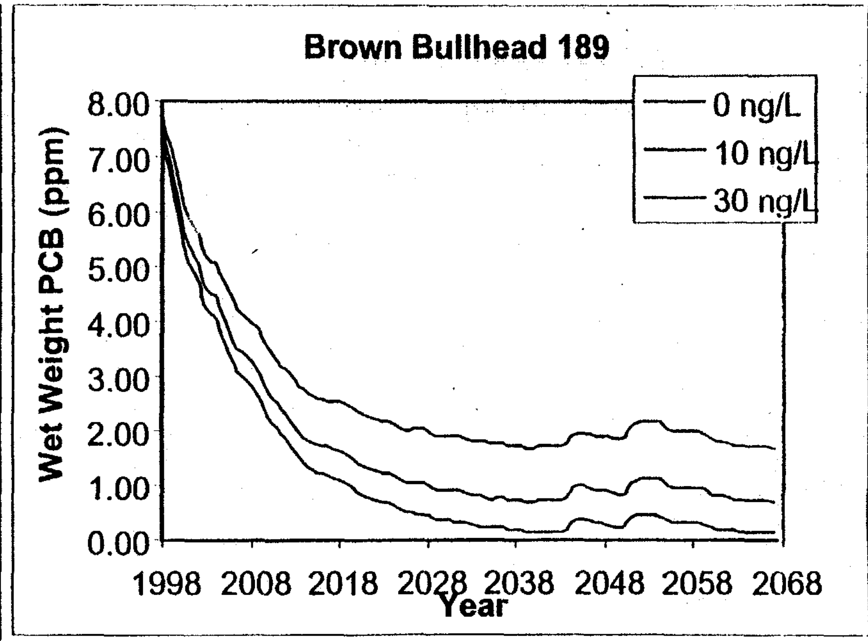
	Brown Bullhead	Largemouth Bass	Pumpkinseed
Elasticities			
Dissolved Water (ng/l)	0.05	0.27	0.77
Sediment (mg/kg)	0.95	0.73	0.23

Coefficients obtained using average-based steady-state model results in linear regression

FISHRAND Forecasts 1998 - 2067 for River Mile 189



Largemouth Bass Median



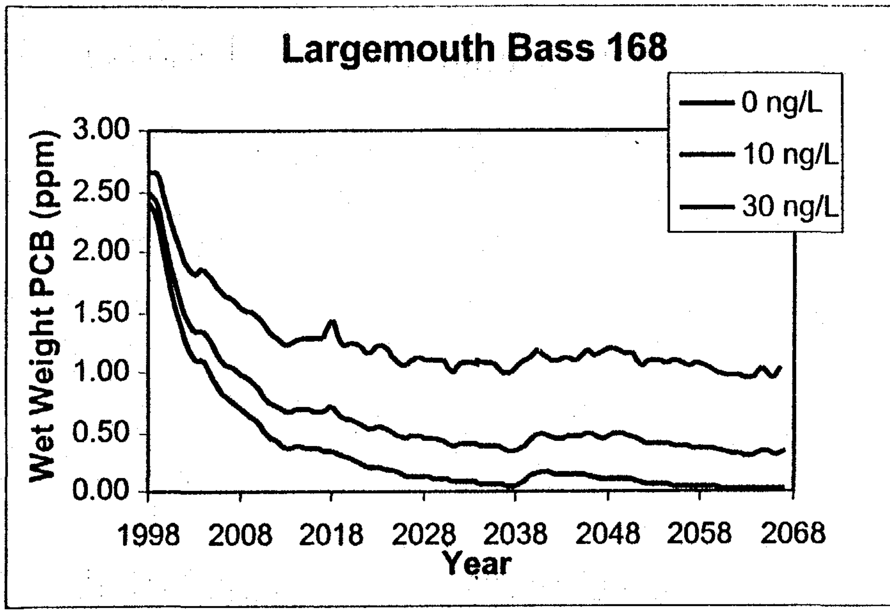
Brown Bullhead Median

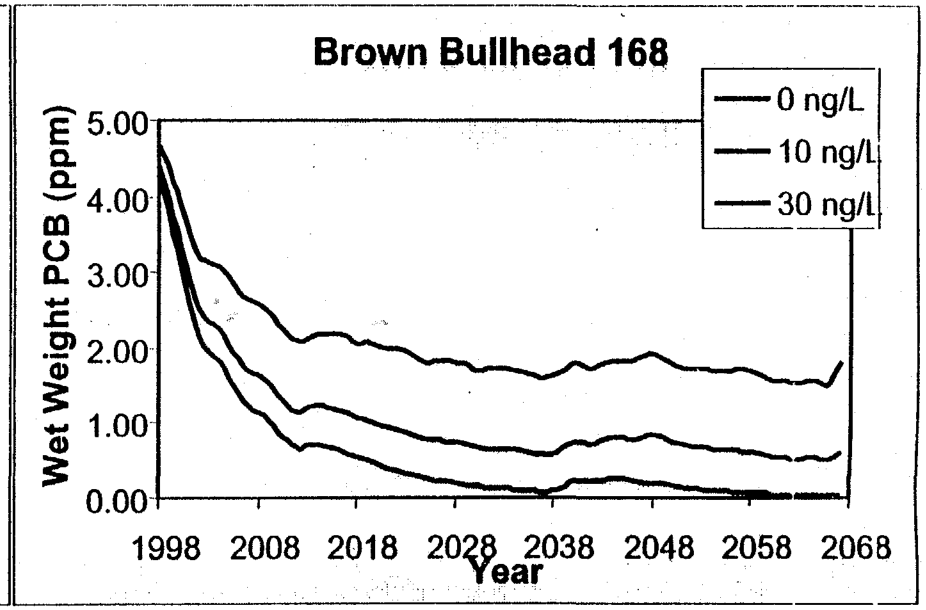
0 ng/L, 10 ng/L and 30 ng/L refer to upstream boundary assumption

10.2561

10.2562

FISHRAND Forecasts 1998 - 2067 for River Mile 168



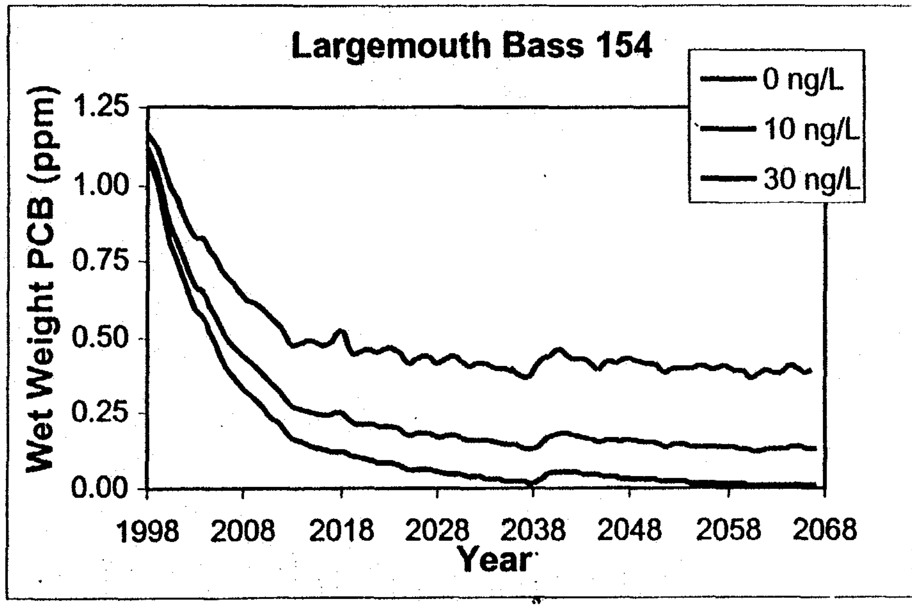


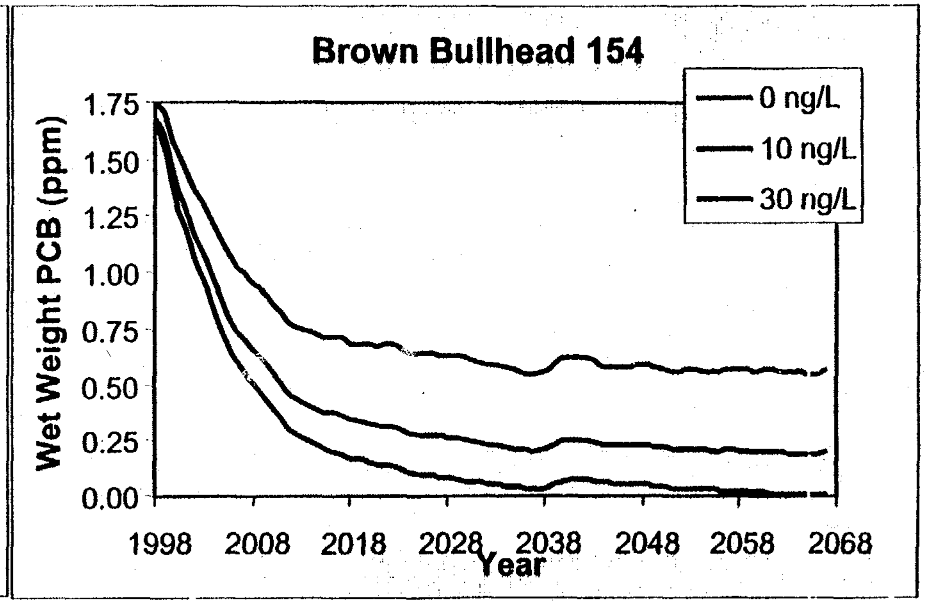
Largemouth Bass Median

Brown Bullhead Median

0 ng/L, 10 ng/L and 30 ng/L refer to upstream boundary assumption

FISHRAND Forecasts 1998 - 2067 for River Mile 154





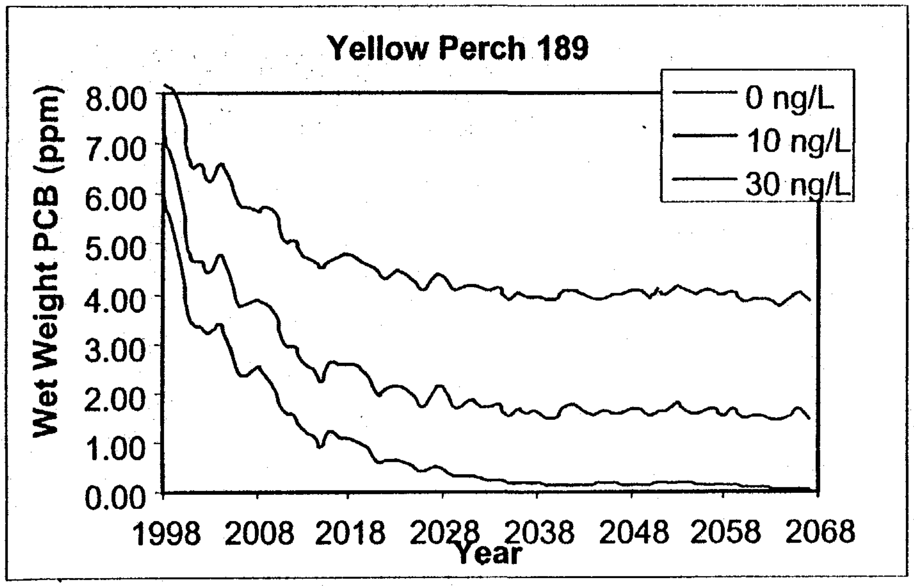
Largemouth Bass Median

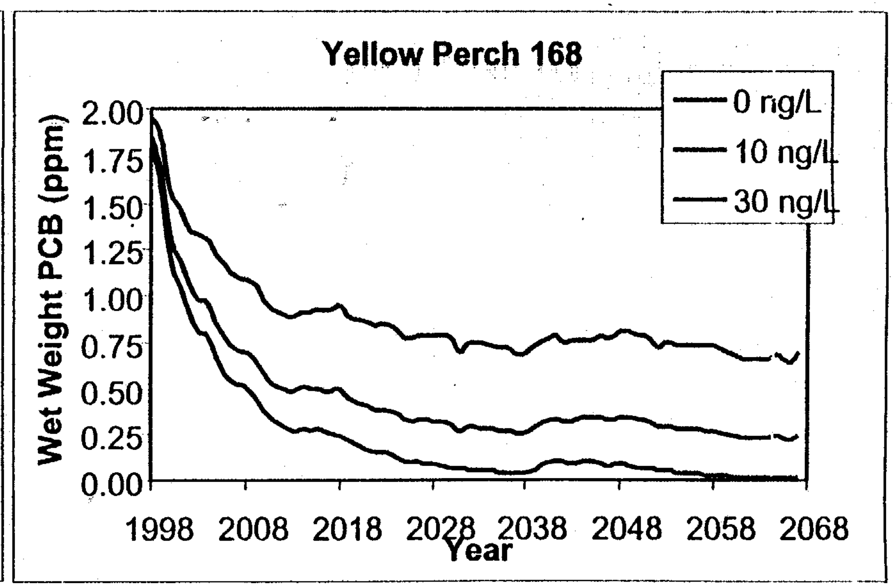
Brown Bullhead Median

0 ng/L, 10 ng/L and 30 ng/L refer to upstream boundary assumption

10.2564

FISHRAND Forecasts 1998 - 2067





Yellow Perch Median

Yellow Perch Median

0 ng/L, 10 ng/L and 30 ng/L refer to upstream boundary assumption

FISHRAND Forecasts for River Mile 189

Largemouth Bass	Median		95th percentile	
0 ng/L	0.05	(0.03 - 0.08)	0.1	(0.05 - 0.2)
10 ng/L	1.5	(0.8 - 2.3)	3.4	(1.7 - 5.1)
30 ng/L	3.5	(1.8 - 5.3)	8.1	(4.1 - 12.2)

Brown Bullhead	Median		95th percentile	
0 ng/L	0.1	(0.06 - 0.12)	0.2	(0.1 - 0.24)
10 ng/L	0.7	(0.4 - 0.8)	1.1	(0.6 - 1.3)
30 ng/L	1.8	(1.0 - 2.2)	2.6	(1.4 - 3.1)

Concentrations are wet weight ppm

FISHRAND Forecasts for River Mile 189

Yellow Perch	Median		95th percentile	
0 ng/L	0.05	(0.03 - 0.06)	0.1	(0.05 - 0.11)
10 ng/L	1.4	(0.7 - 1.5)	3.5	(1.8 - 3.9)
30 ng/L	3.8	(1.9 - 4.2)	6.1	(3.1 - 6.7)

Concentrations are wet weight ppm

FISHRAND Forecasts for River Mile 168

Largemouth Bass	Median		95th percentile	
0 ng/L	0.02	(0.005 - 0.06)	0.03	(0.008 - 0.09)
10 ng/L	0.3	(0.08 - 0.9)	0.4	(0.1 - 1.2)
30 ng/L	1.0	(0.3 - 3)	2.3	(0.6 - 7)

Brown Bullhead	Median		95th percentile	
0 ng/L	0.02	(0.01 - 0.04)	0.03	(0.015 - 0.06)
10 ng/L	0.6	(0.3 - 1.2)	0.9	(0.5 - 1.8)
30 ng/L	1.5	(0.8 - 3.0)	0.7	(0.4 - 1.4)

Concentrations are wet weight ppm

FISHRAND Forecasts for River Mile 168

Yellow Perch	Median		95th percentile	
0 ng/L	0.01	(0.005 - 0.02)	0.02	(0.01 - 0.04)
10 ng/L	0.2	(0.1 - 0.4)	0.3	(0.15 - 0.6)
30 ng/L	0.7	(0.4 - 1.4)	1.5	(0.8 - 3.0)

Concentrations are wet weight ppm

FISHRAND Forecasts for River Mile 154

Largemouth Bass	Median		95th percentile	
0 ng/L	0.01	(0.007 - 0.02)	0.01	(0.007 - 0.02)
10 ng/L	0.1	(0.07 - 0.2)	0.2	(0.1 - 0.4)
30 ng/L	0.4	(0.3 - 0.8)	0.5	(0.3 - 1.0)

Brown Bullhead	Median		95th percentile	
0 ng/L	0.01	(0.005 - 0.02)	0.02	(0.01 - 0.04)
10 ng/L	0.2	(0.1 - 0.4)	0.3	(0.15 - 0.6)
30 ng/L	0.6	(0.3 - 1.2)	0.9	(0.5 - 1.8)

Concentrations are wet weight ppm

FISHRAND Forecasts for River Mile 154

Yellow Perch	Median		95th percentile	
0 ng/L	0.01	(0.005 - 0.02)	0.02	(0.01 - 0.04)
10 ng/L	0.1	(0.1 - 0.2)	0.2	(0.1 - 0.4)
30 ng/L	0.3	(0.3 - 1.2)	0.5	(0.6 - 2.4)

White Perch	Median		95th percentile	
0 ng/L	0.01	(0.005 - 0.02)	0.02	(0.01 - 0.04)
10 ng/L	0.2	(0.1 - 0.4)	0.4	(0.2 - 0.8)
30 ng/L	0.6	(0.3 - 1.2)	1.2	(0.6 - 2.4)

Concentrations are wet weight ppm

Summary of Forecast Results

- Fish concentrations approach asymptotic value according to upstream boundary condition
  - 0 ng/L
  - 10 ng/L
  - 30 ng/l
- Dilution effect moving down river

Summary of Forecast Results

- Fish concentrations approach asymptotic value according to upstream boundary condition
  - 0 ng/L
  - 10 ng/L
  - 30 ng/l
- Dilution effect moving down river