SMWG REVIEW AND ANALYSIS OF SELECTED SEDIMENT DREDGING PROJECTS (REVISED)

Presented at:
The 2nd Meeting of the
National Research Council Committee on Dredging
Effectiveness at Superfund Megasites
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Irvine, California

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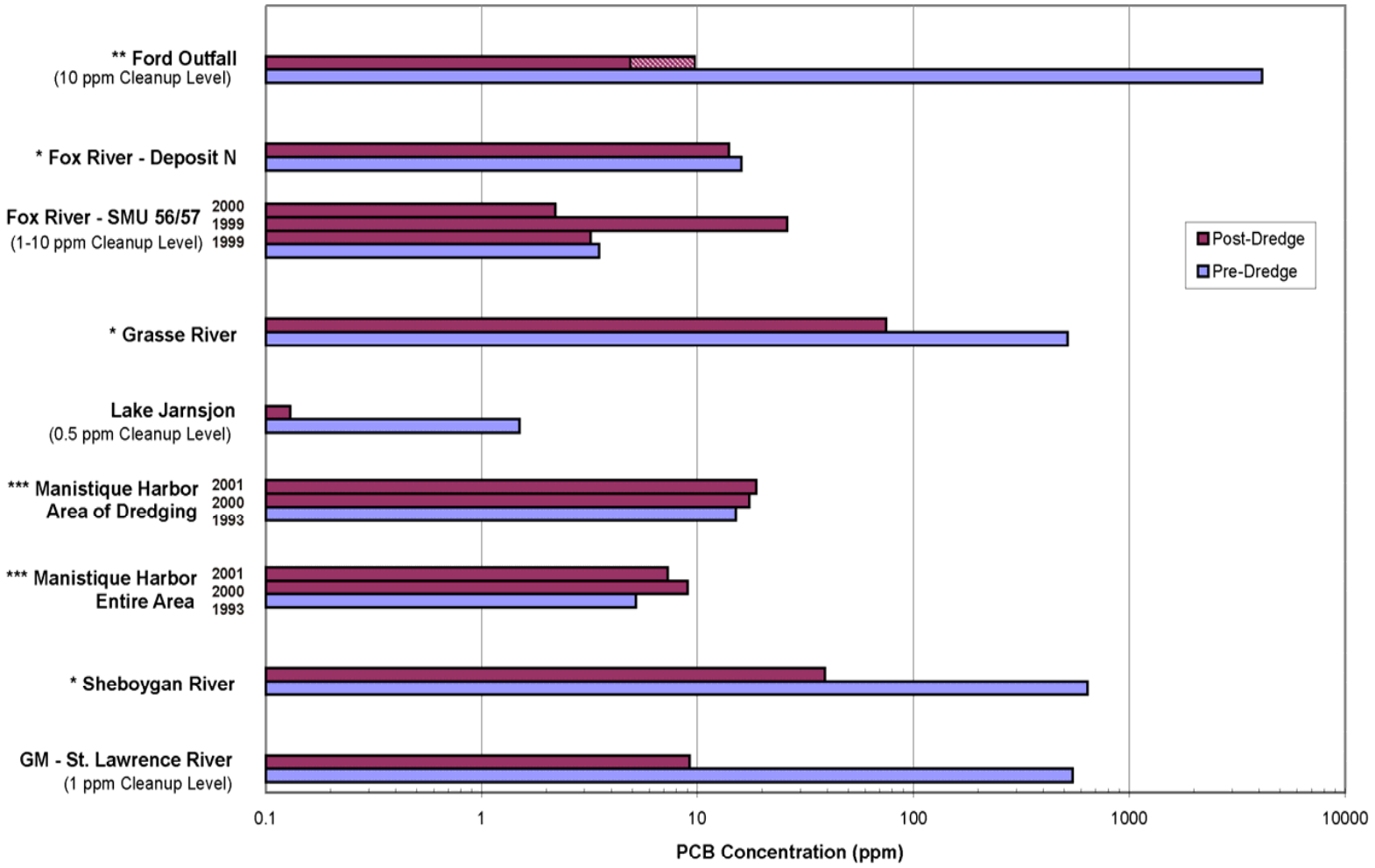
SITES TO BE REVIEWED

1. Grasse River (NTCRA), NY (1995)
2. Manistique Harbor, MI (1995-2000)
3. Fox River, WI
   - Deposit 56/57 (1999-2000)
   - Deposit N (1998-1999)
4. GM Massena – St. Lawrence River, NY (1995)
5. United Heckathorn, CA (1996-1997)
6. Cumberland Bay, NY (1999-2000)
7. Outboard Marine, Waukegon, WI (1991-1992)
8. Bayou Bonfouca, LA (1993-1995)
9. Marathon Battery, NY (1993-1995)

INTERPRETATION OF DREDGING EFFECTIVENESS

- Definition
  - The degree to which contaminated sediment removal via dredging achieves substantive reduction in risk to human health & the environment
- Concept
  - Should be evaluated in context of “Net Risk Reduction”
  - Inappropriate to equate “effectiveness” with quantity of contaminated sediment removed at all sites
  - Must be evaluated on a site-specific basis

AVERAGE SEDIMENT PCB DATA AT SELECT DREDGING SITES



Notes:

1. * Removal to the extent practical.
2. ** The post-dredge concentration for the Ford Outfall site is presented as 4.9 ppm (solid bar - calculated using zero for subcells with "no sediment") and 9.7 ppm (hatched bar - calculated excluding zero values).
3. *** Manistique Harbor data is for the 0 - 3 inch layer for 1993 (pre-dredging) and 0 - 12 inch layer for 2000 and 2001 (post-dredging).

GRASSE RIVER
NTCRA 1995 – MASSENA, NY

GRASSE RIVER
NTCRA 1995 – MASSENA, NY

- 3,000 cy sediment and debris with PCBs removed in 1995 (Alcoa)
- Mechanical debris removal and hydraulic dredging (horizontal auger)
- Sediment dewatered and disposed on site
- Goal: Removal of "all" sediment
- Heavily studied/monitored program
- Performed as NTCRA
- Project cost = $4.9 million ($1670/cy)

GRASSE RIVER
NTCRA 1995 – MASSENA, NY

- Pre and Post Conditions:

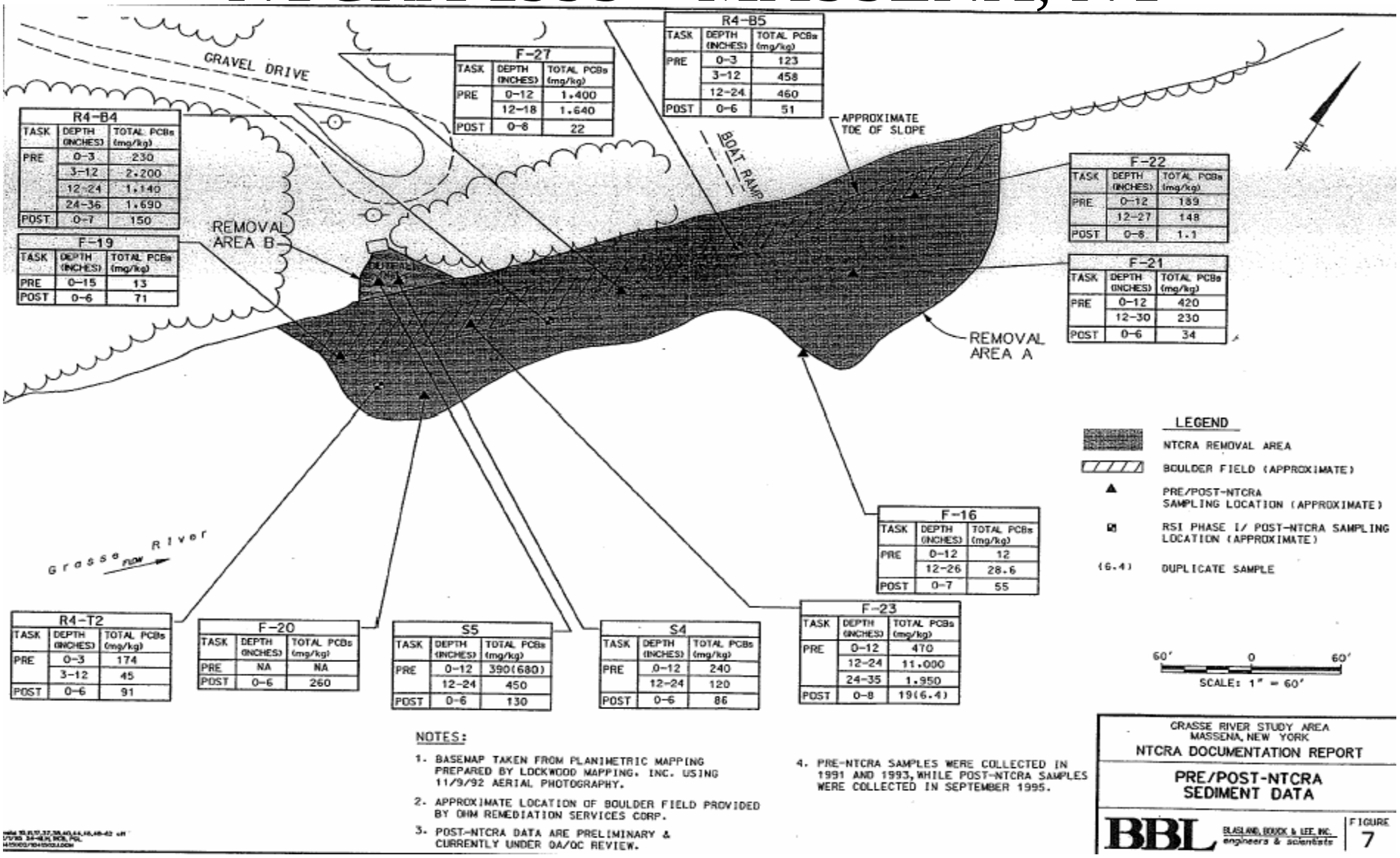
  Target: as much sediment as practical within 10 ppm isopleth

  - Pre-dredge prism: 1,108 mg/kg
  - Pre-dredge average surficial: 518 mg/kg
  - Post-dredge average surficial: 75 mg/kg

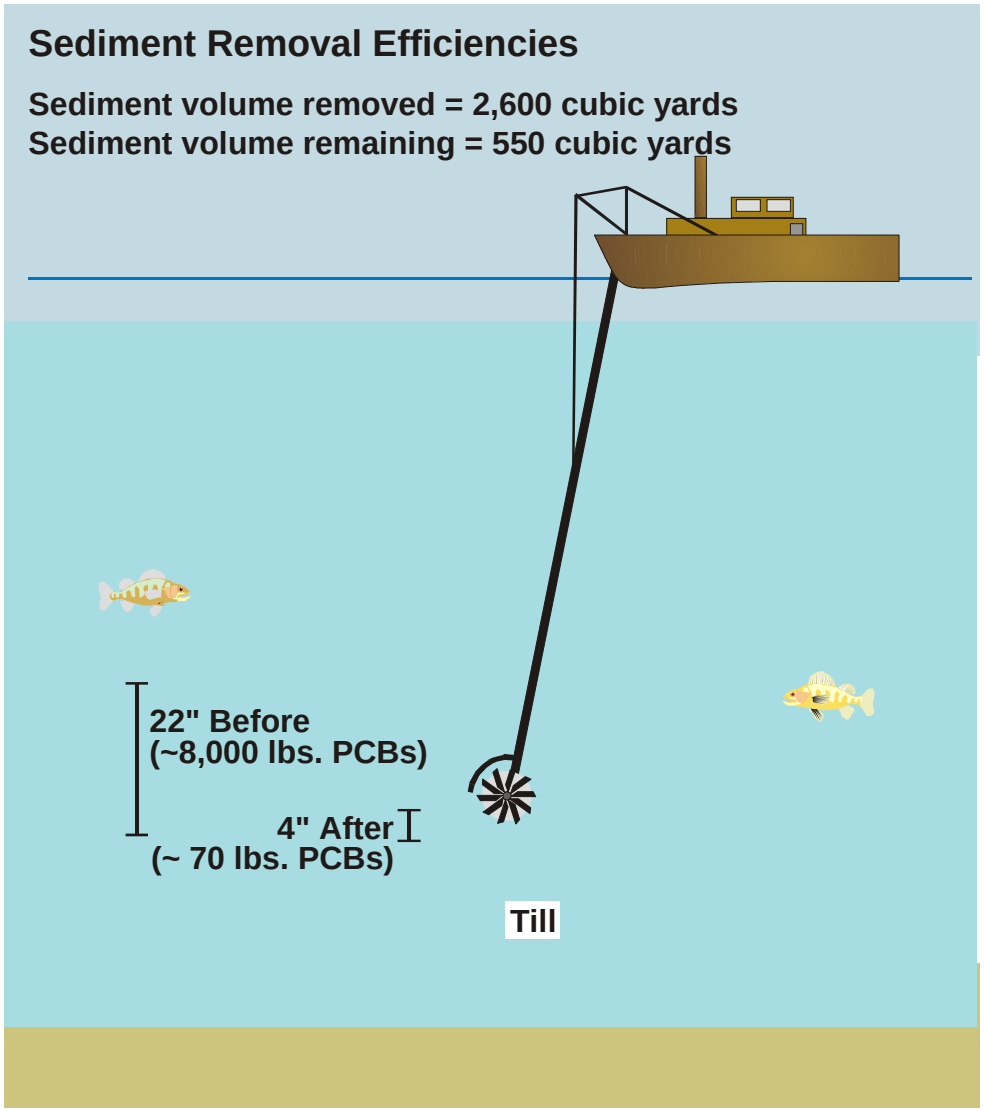
- Site-Specific Conditions:
  - River depth: 1ft. to 15 ft.
  - Dredging area: Approx. 1 acre
  - Equipment: Hydraulic 8 ft. horizontal auger
  - Passes: 1-2 avg., occasionally more

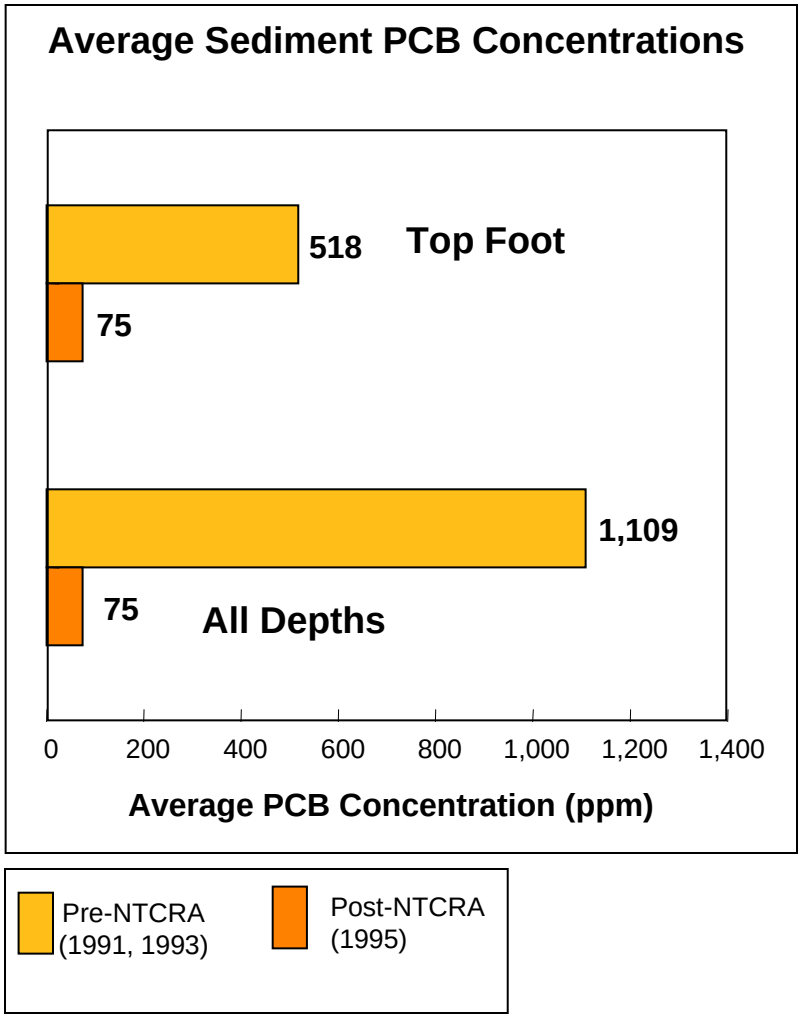
  Cobbles, boulders and occasional debris posed a difficult challenge

GRASSE RIVER
NTCRA 1995 – MASSENA, NY

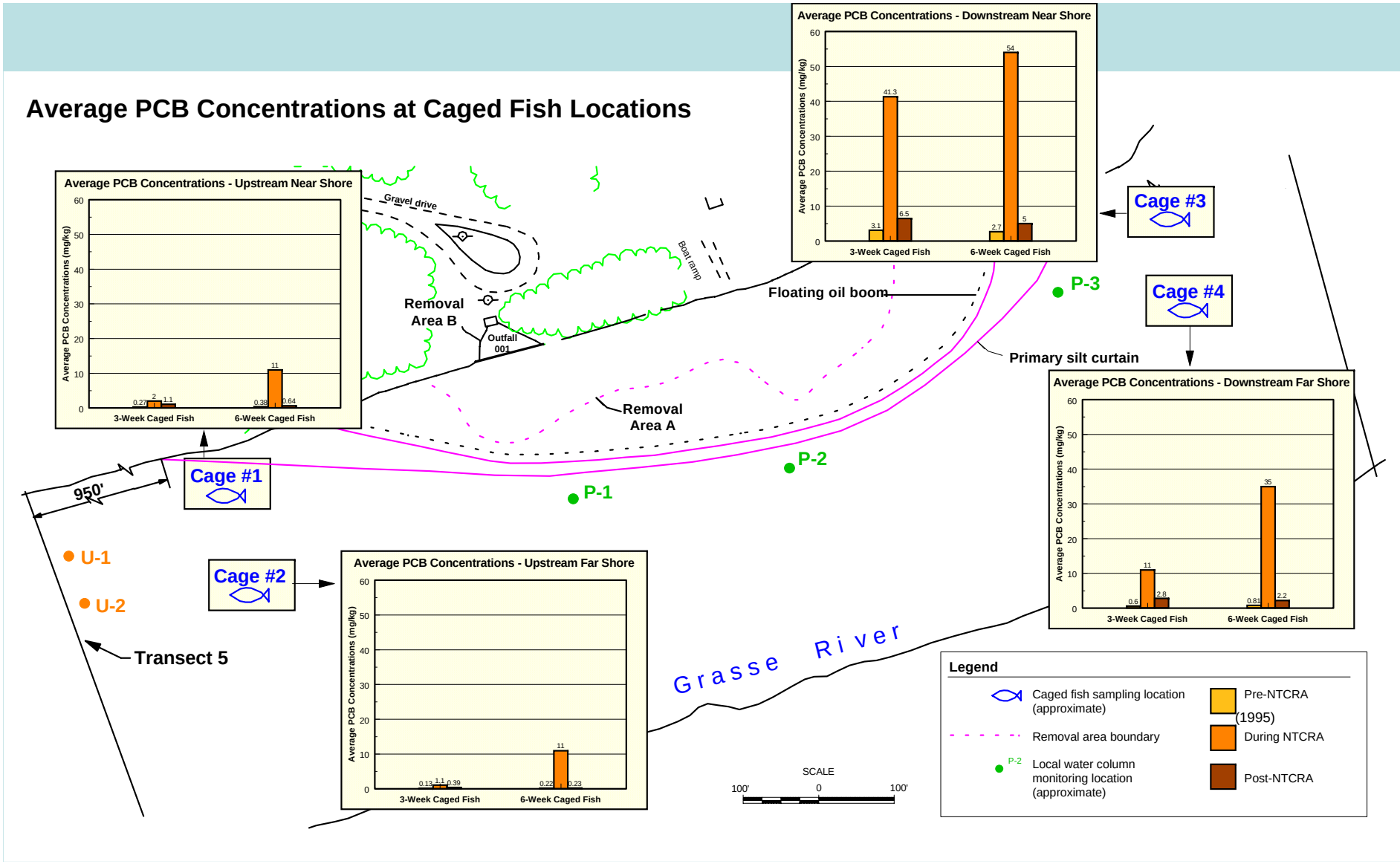


GRASSE RIVER
NTCRA 1995 – MASSENA, NY: Results





GRASSE RIVER
NTCRA 1995 – MASSENA, NY: Caged Fish



GRASSE RIVER
NTCRA 1995 – MASSENA, NY
AQUATIC SYSTEM RESPONSE
(Comparison to pre-dredging conditions)

- PCBs were mobilized and transported down river during dredging
  - At a location ~0.9 kilometers downstream of NTCRA, water column PCB congener concentrations increased ~5X
  - Adjacent to NTCRA, caged fish PCB levels increased ~50X
- For the immediate months following NTCRA dredging, disturbed bottom sediments continued to contribute to localized PCB levels
  - caged fish PCB levels increased ~6X

GRASSE RIVER
NTCRA 1995 – MASSENA, NY
Resuspension and Release/Lessons Learned

- Releases of PCBs to the water column occurred during dredging
- The TSS monitoring did not correlate to the PCB releases that were documented
- Caged fish results demonstrate the solubility potential (of PCBs)
- Substantial mass was successfully removed

GRASSE RIVER
NTCRA 1995 – MASSENA, NY
Resuspension and Release/Lessons Learned

- Silt curtains control TSS but not necessarily solubilized contaminants
- Debris can often cause multiple layers of problems, including equipment, delays, expense as well as significant impacts to residuals/dredging effectiveness
- Cost was high, $4.9 million / $1670 cy

MANISTIQUE RIVER & HARBOR, MANISTIQUE, MI

MANISTIQUE HARBOR, MI

- Site Background/Remedy Description:
  - River and Harbor Areas - 64 acres
  - River reach - 1.7 miles
  - Approximately 15 acres dredged
  - Dredging 1995 - 2000 (6 years)
  - Hydraulic dredging and substantial diver- assisted hand dredging

MANISTIQUE HARBOR, MI

- PCBs removed: 10,603 pounds or 5.292 tons
- Sediments removed: 187,500 cu. yards
- Total costs: $48,213,550 (based on unaudited POLREPS)
- Costs per pound of PCB removed averaged $4,547 and ranged from $2,630 to $59,542 per pound (Table 9)
- Cost ranged annually from $134 to $358 per cubic yard
- Average cost per cubic yard – total project: $276

MANISTIQUE HARBOR, MI

- Cleanup Goals
  - *Original Goal*: (1997) all sediment > than 10 ppm of PCBs anywhere in sediment column; residual sediments > 10 ppm to be capped if natural burial did not effectively reduce surface PCB concentrations
  - *Revised Goal*: (2001) 95% removal of PCB mass and an average concentration of 10 ppm throughout the entire sediment column

Note: Most regulators have concluded that a residual sediment concentration of 1 ppm of PCBs (or less) is necessary to achieve acceptable PCB levels in fish tissue.

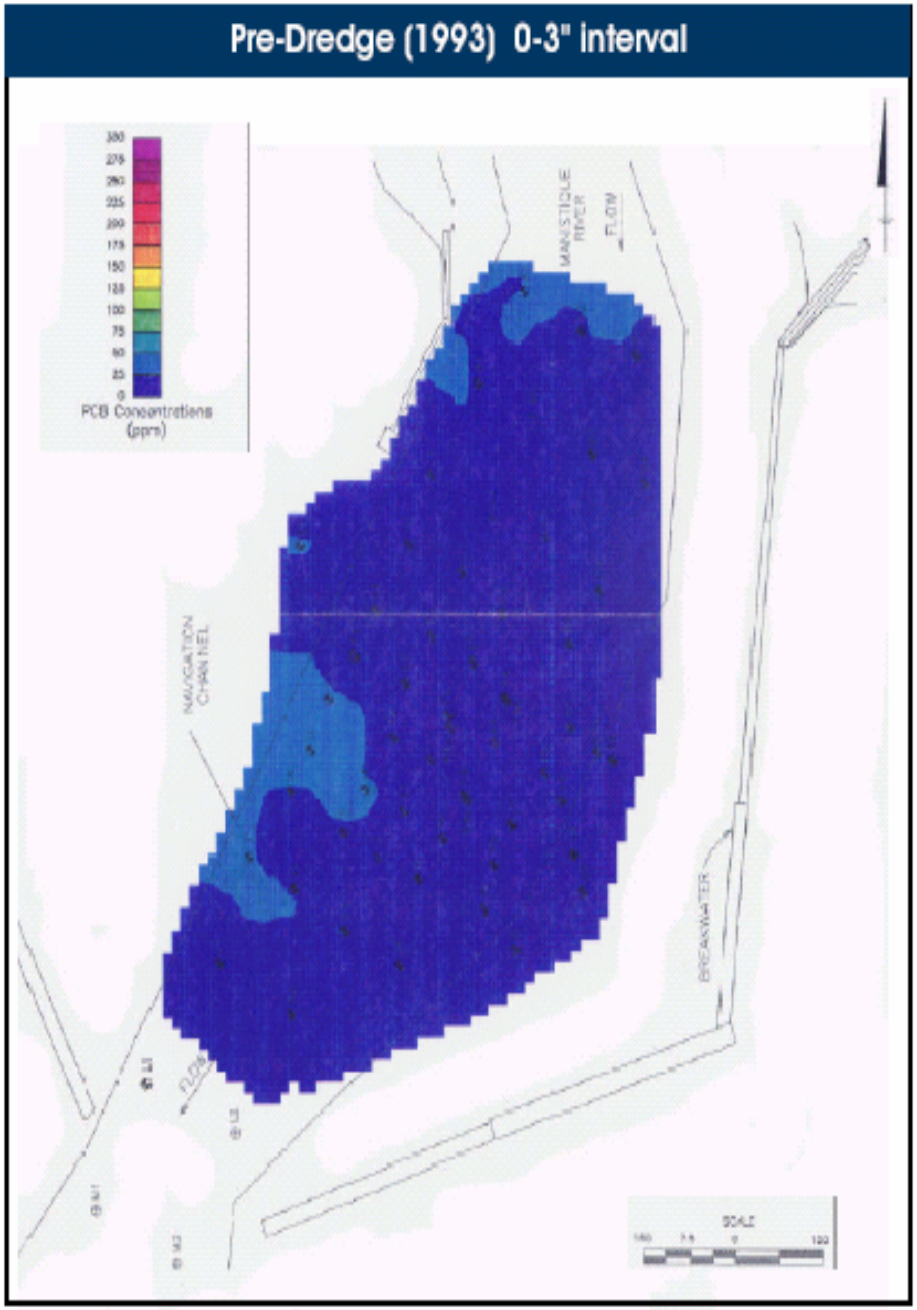
MANISTIQUE HARBOR, MI
Dredging Remedy Retrospective

- Cleanup Achieved:
  - Surface Samples (Representative examples of the top 10 highest surficial samples)

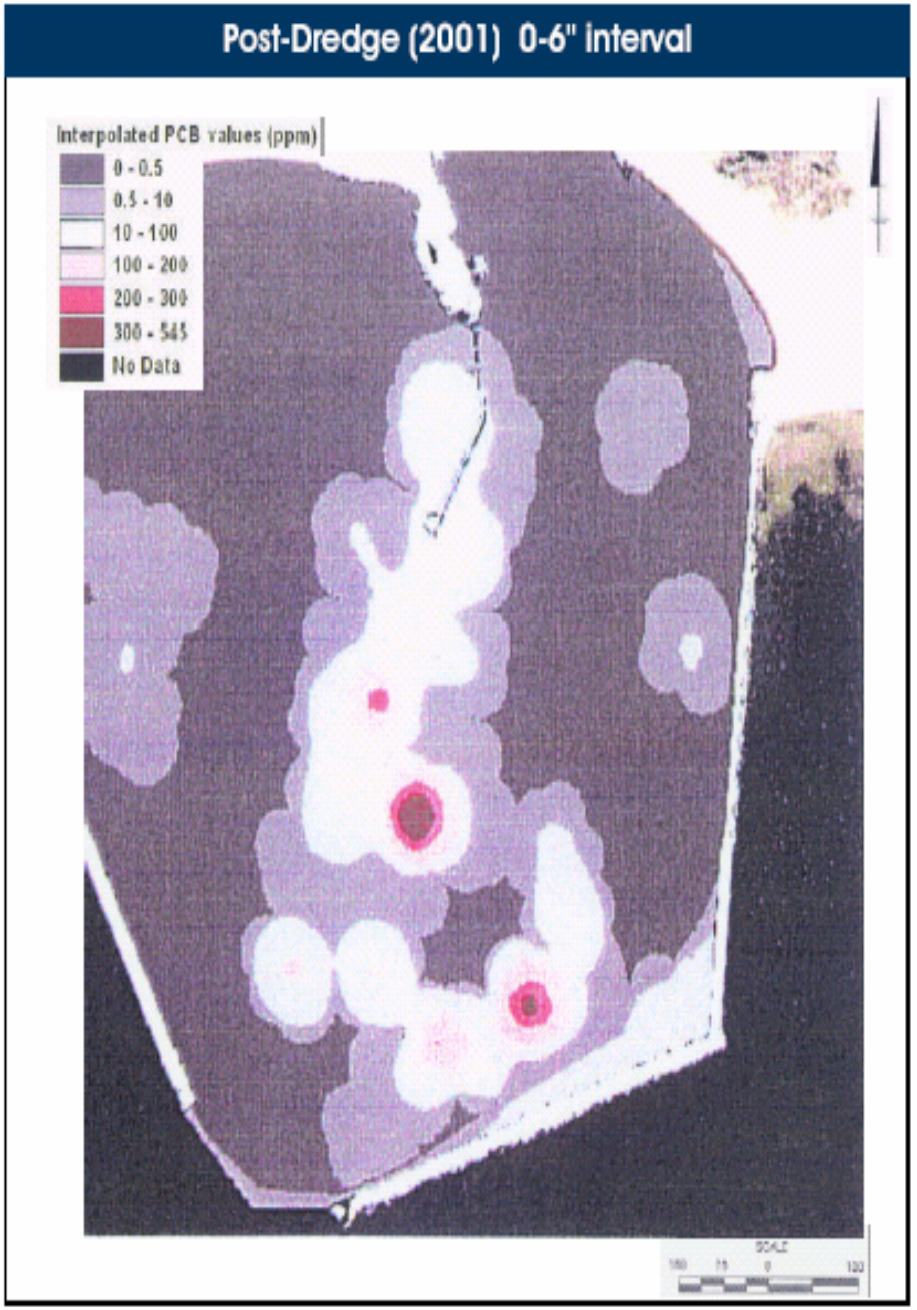
Sampling	ppm
2000 EOP Sampling:	35, 45, 60, 71, 75, 102, 128, 149, 186, 884
2001 FS Sampling:	32, 38, 68, 97, 116, 135, 214, 283, 392, 543
1993 Pre-dredging Sampling:	19, 19, 22, 28, 37, 50, 54, 70, 73, 120

Manistique Harbor - Pre- and Post- Dredging Surficial Concentrations

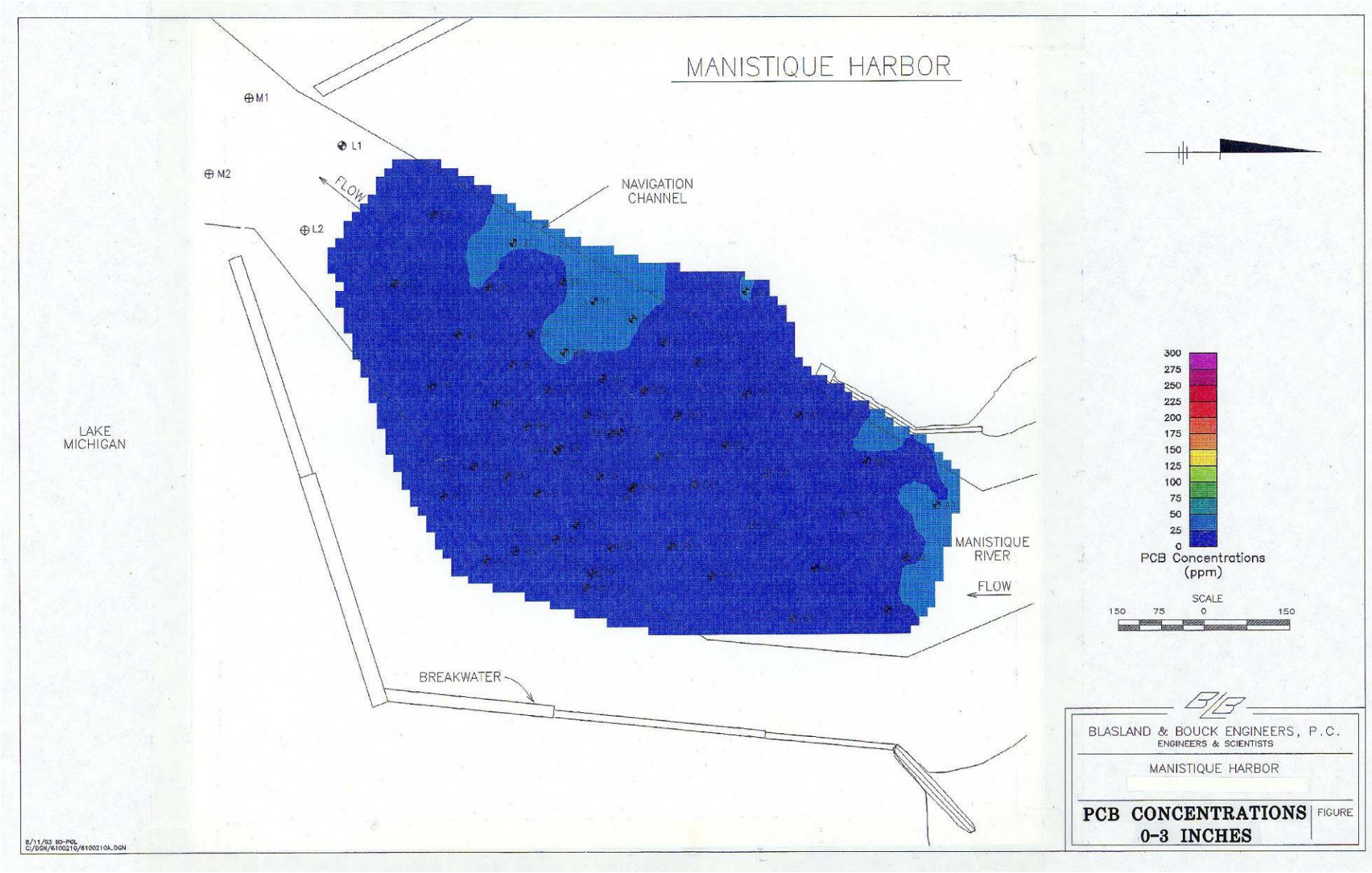
Pre-Dredge (1993) 0-3" interval



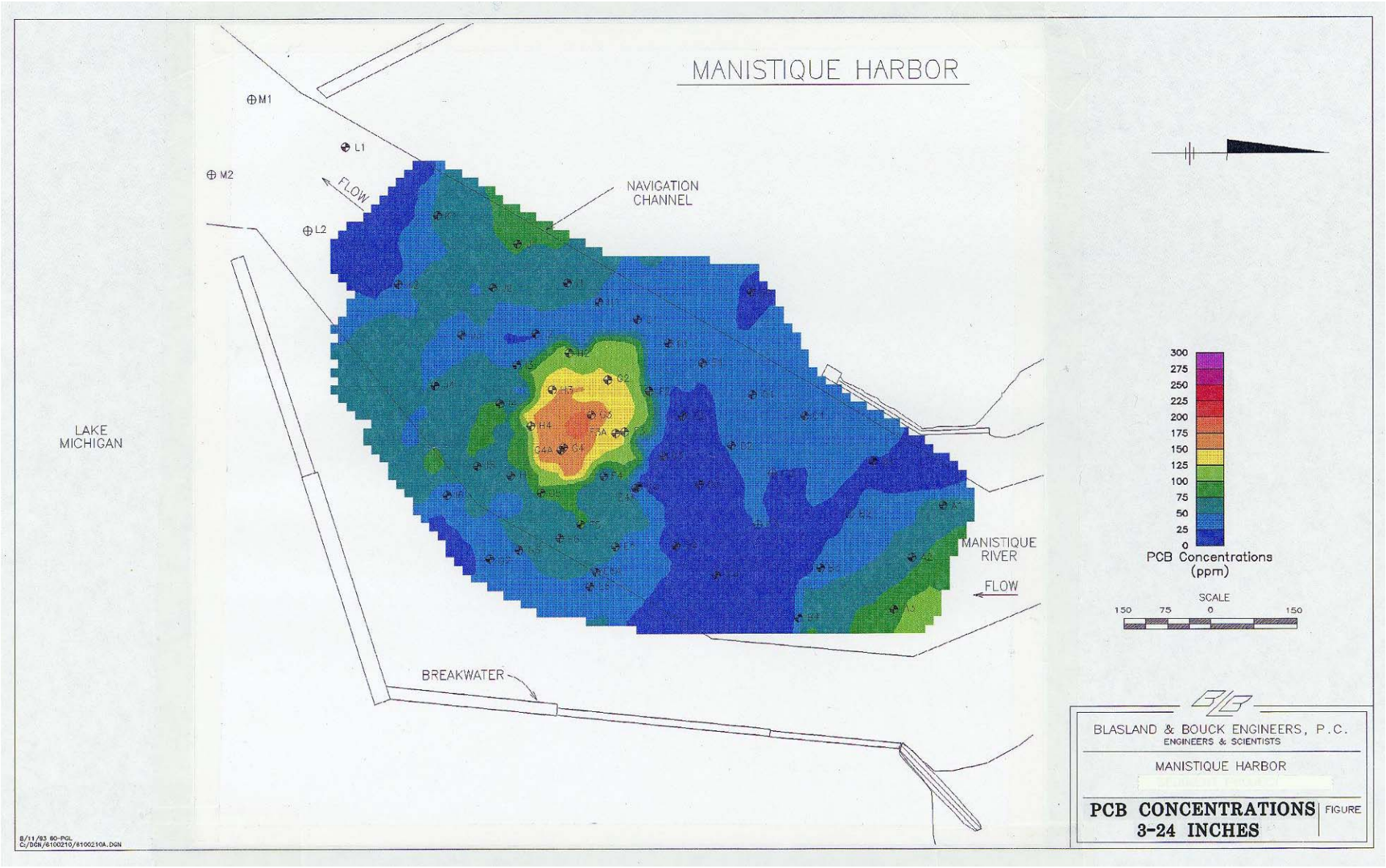
Post-Dredge (2001) 0-6" interval



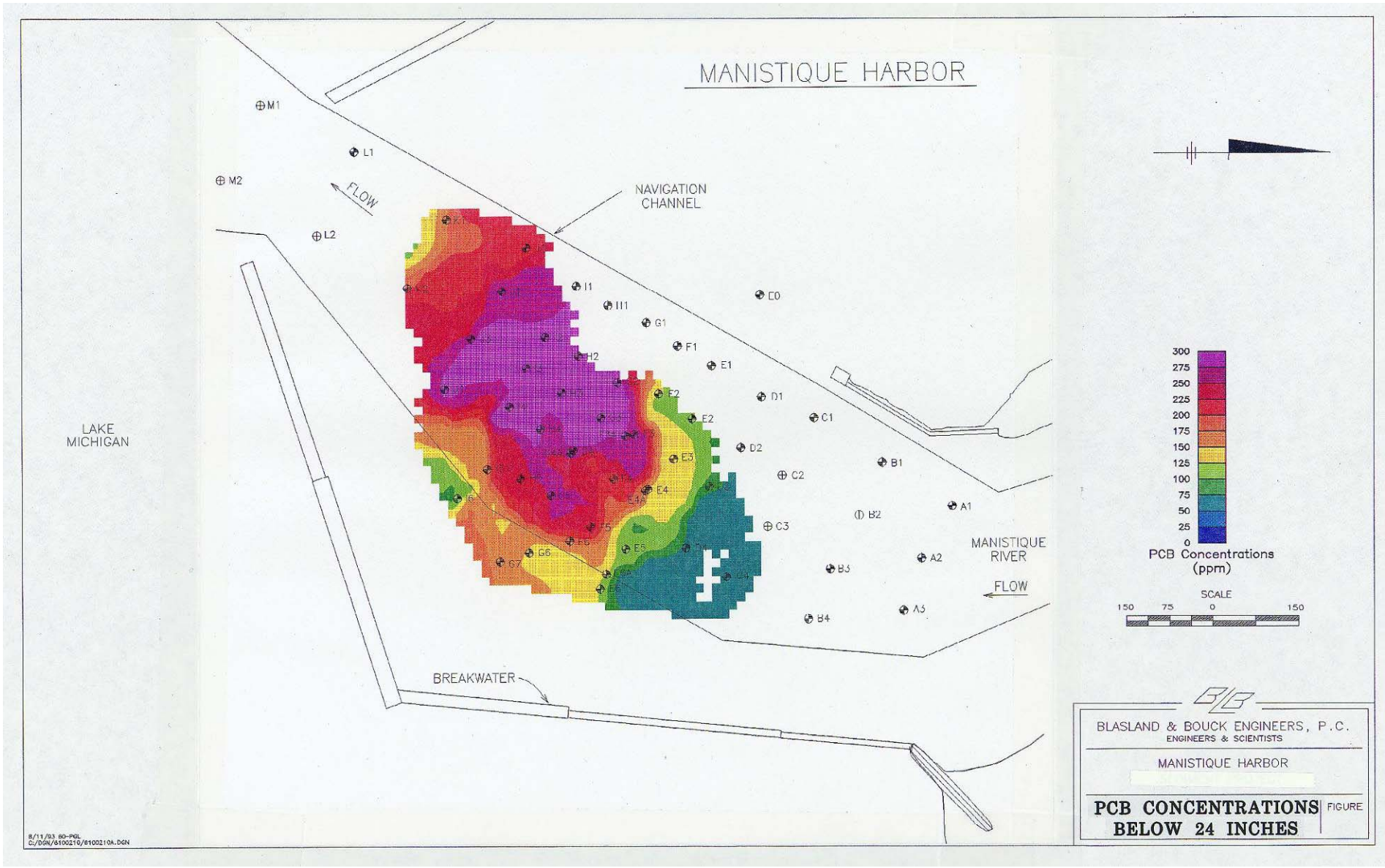
MANISTIQUE HARBOR, MI
Pre-Dredging PCB Concentrations - 0-3 Inches



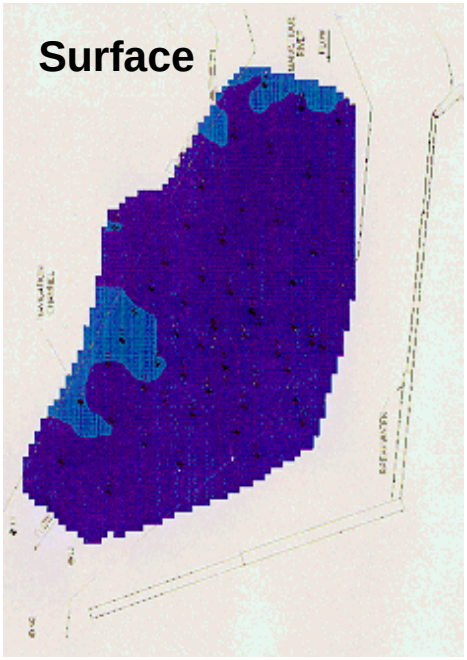
MANISTIQUE HARBOR, MI
Pre-Dredging PCB Concentrations 3-24 Inches

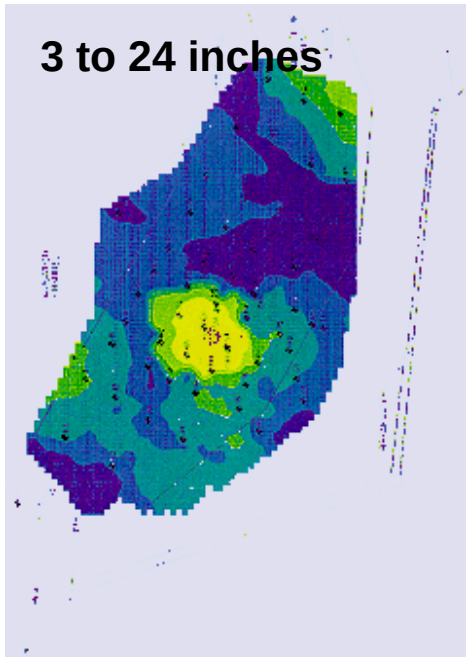


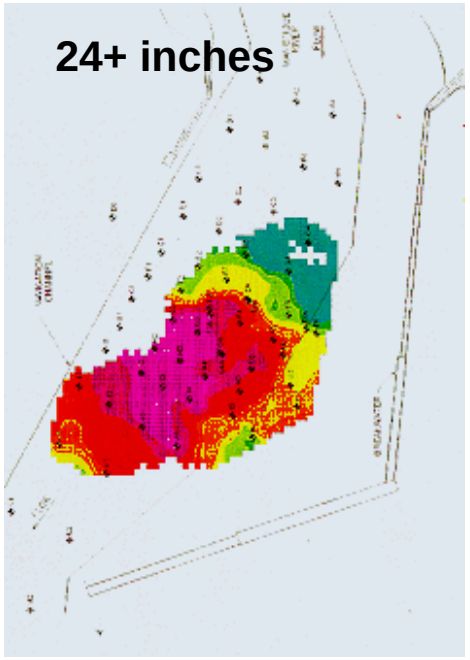
MANISTIQUE HARBOR, MI
Pre-Dredging PCB Concentrations Below 24 Inches



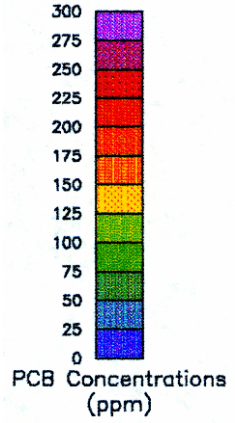
MANISTIQUE HARBOR, MI
PCB Distribution Before Dredging (1993)



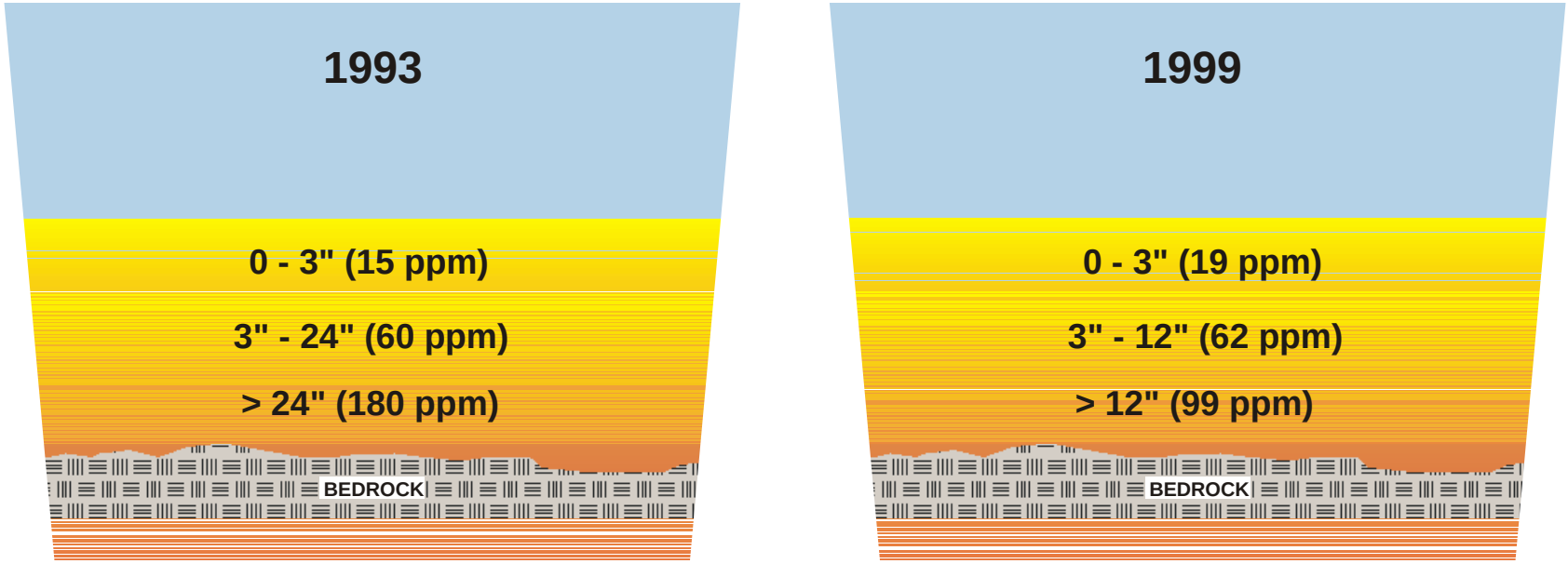




Highest PCB concentrations were found below sediments with lower PCB concentrations



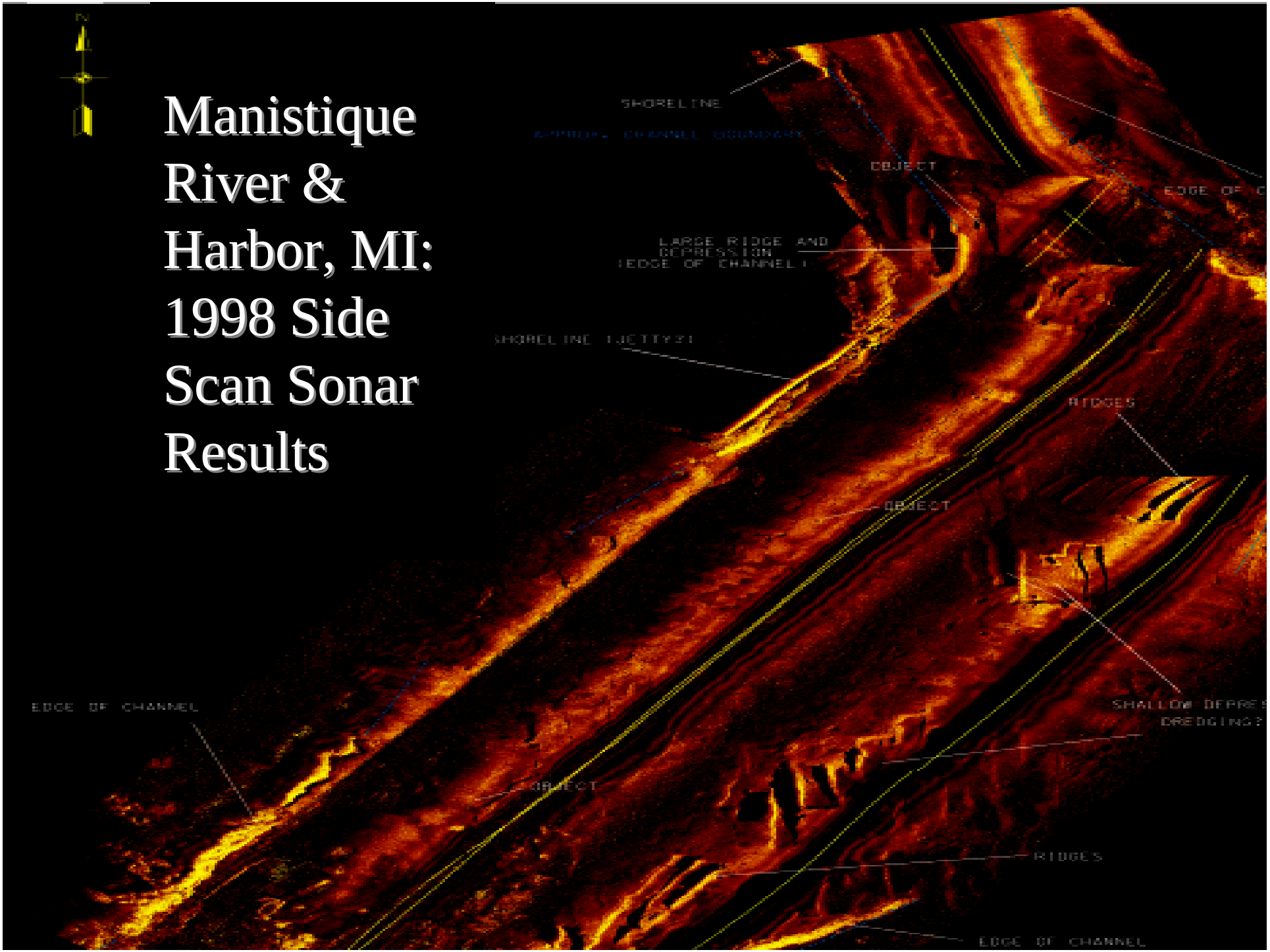
Manistique River & Harbor, MI: Area D -- Sediment Cross-Section



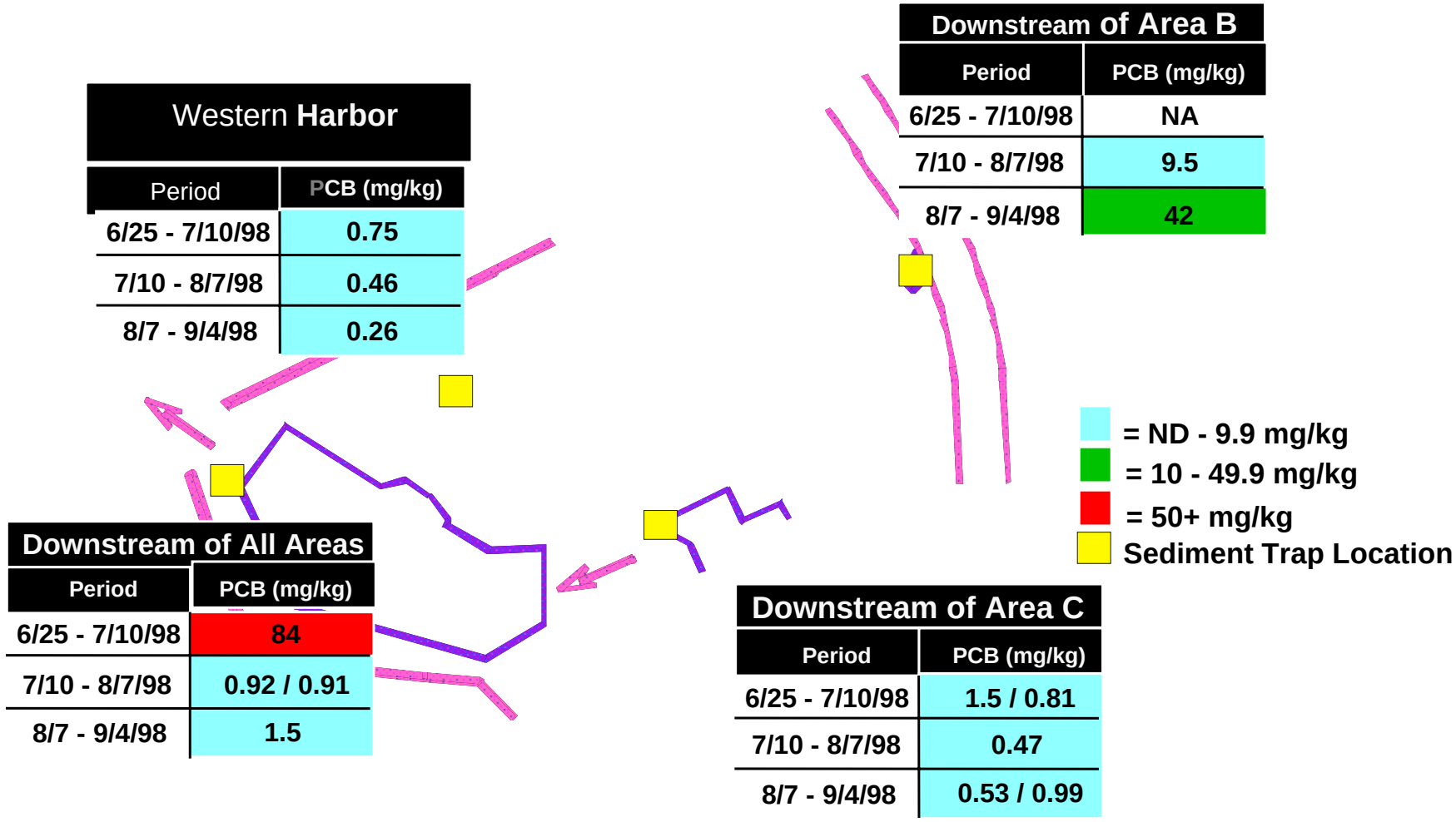
Based on BBL data.

Note: The 1999 cross-section is before the completion of dredging in 2000.

Manistique River & Harbor, MI: 1998 Side Scan Sonar Results



MANISTIQUE HARBOR, MI
1998 PCB Results: Sediment Traps



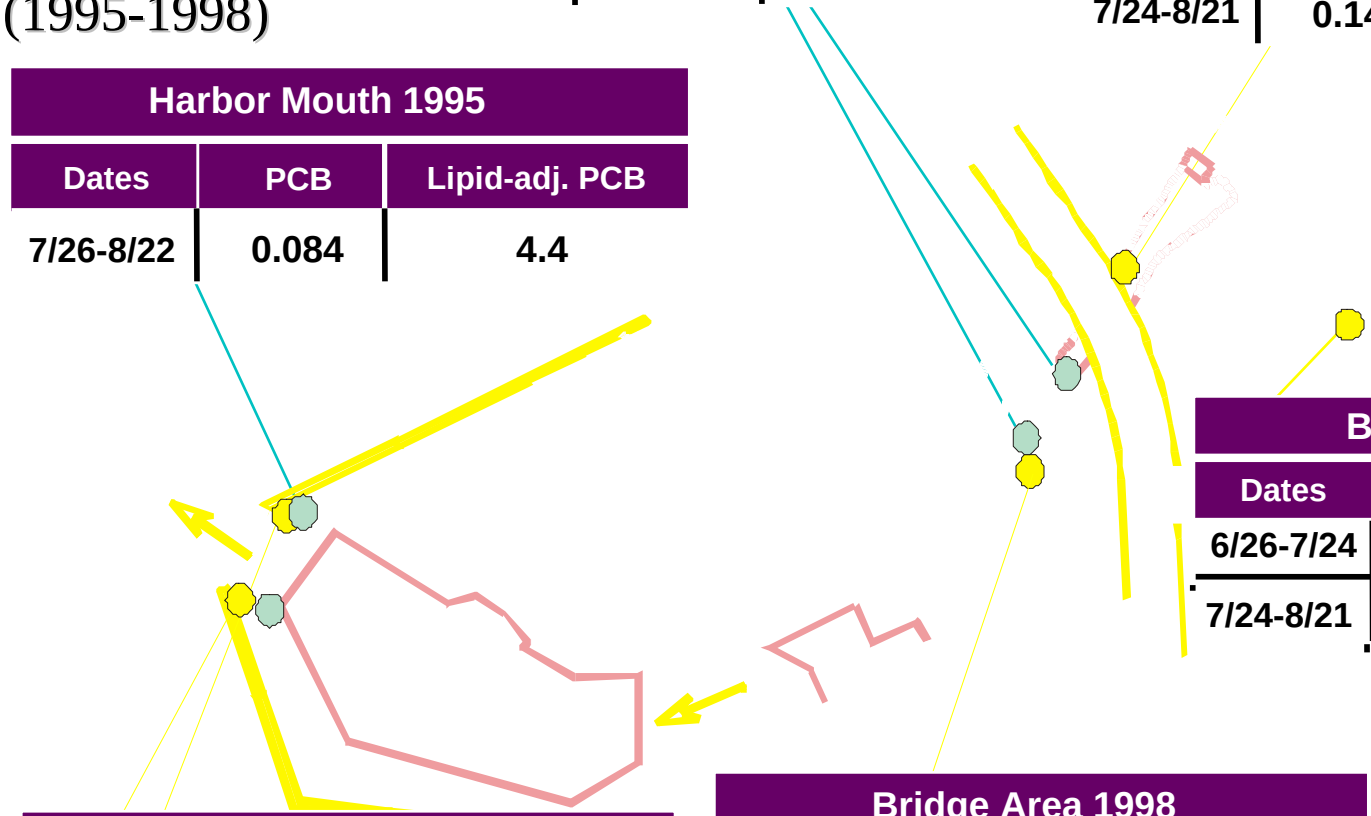
Caged Fish Location (1995-1998)

Bridge Area 1995		
Dates	PCB	Lipid-adj. PCB
7/26-8/22	0.16	8.6

North Bay 1998		
Dates	PCB	Lipid-adj. PCB
6/26-7/24	0.17	21
7/24-8/21	0.14	22

Harbor Mouth 1995		
Dates	PCB	Lipid-adj. PCB
7/26-8/22	0.084	4.4

Background 1998		
Dates	PCB	Lipid-adj. PCB
6/26-7/24	0.007	0.83
7/24-8/21	0.005	1.0



Caged Fish Location (1995)

Caged Fish Location (1998)

-Values are Means

-Units are mg/kg

Harbor Mouth 1998		
Dates	PCB	Lipid-adj. PCB
6/26-7/24	0.035	3.8
7/24-8/21	0.064	9.9

Bridge Area 1998		
Dates	PCB	Lipid-adj. PCB
6/26-7/24	0.024	3.0
7/24-8/21	0.035	3.8

MANISTIQUE HARBOR, MI

MANISTIQUE HARBOR, MI
POLREP Cost Summary

Year		
MOB	**$**	**1,636,332.00**
1995	**$**	**2,007,271.00**
1996	**$**	**4,060,850.00**
1997	**$**	**7,805,984.00**
1998	**$**	**10,005,488.00**
1999	**$**	**10,789,824.00**
2000	**$**	**10,696,007.00**
DEMOB	**$**	**1,211,794.00**
Total	**$**	**48,213,550.00**

MANISTIQUE HARBOR, MI
Cost Estimate Per Cubic Yard of Sediment Removed

	Total Costs*	In Situ Volume of Sediment Removed*	Cost per cubic yard of sediment removed
		Cubic Yards	
1995	$2,210,709	10,000	$221.07
1996	$4,549,100	15,000	$303.27
1997	$8,334,922	62,000	$134.43
1998	$10,575,113	29,535	$358.05
1999	$11,359,449	34,043	$333.68
2000	$11,184,257	36,936	$302.80
Total/Avg	$48,213,550	187,514	$276.00

***Based on unaudited PoLEREPS**

MANISTIQUE HARBOR, MI
Residual Sediment PCB Concentrations

Entire River and Harbor Area of Concern				
Sample	**Concentration**			
	1993 Pre-Dredging Data (56 acres)	**EOP Sampling (2000)**	**FS Sampling (2001)**	**FIELDS Calculation (64 acres)**
Total Column	**----**	**7.9 ppm**	**7.0 ppm**	
0-3 inches	**5.2 ppm**	**----**	**----**	**----**
0-6 inches	**----**	**----**	**----**	**7.7 ppm**
0-12 inches	**----**	**9.0 ppm**	**7.3 ppm**	**7.7 ppm**
12-24 inches	**----**	**5.4 ppm**	**7.2 ppm**	**6.6 ppm**
24-36 inches	**----**	**3.1 ppm**	**4.5 ppm**	**3.0 ppm**

MANISTIQUE HARBOR, MI
Residual Sediment PCB Concentrations

Dredged Area Only Pre and Post Dredging Sampling Results			
Sample	1993 Pre-Dredge data (15 acres)	EOP Sampling 2000 (15 acres)	FS Sampling (2001)
0-3 inches	15.1 ppm	----	----
0-12 inches	----	17.4 ppm	18.8 ppm

Special Notes:

(1) We have not reviewed any QA/QC data or report on the U.S. EPA data, so all data are taken at face value

(2) Since all of the averages computed for pre and post dredging rely on kriging and other extrapolations, and cover slightly different areas (56 vs. 64 acres, for example) the averages should be considered valid on a relative comparison basis, but should not be considered “absolutely” precise

MANISTIQUE HARBOR, MI
Resuspension and Release/Lessons Learned

- Sediment Data

  2002 Weston Sediment Data: 38.5 ppm (N.B. biased towards known previous elevated areas – post-dredging)

  2004 Weston Sediment Data: Average 0.88 ppm

  Confounding Factor: The favorable recovery of surficial sediment levels, since the average surficial concentrations when the project ended were virtually the same as the pre-dredging average surficial concentrations. This is a natural recovery success story!

MANISTIQUE HARBOR, MI
Resuspension and Release/Lessons Learned

- Fish Data: Modest pre-dredging fish data and more robust post-dredging fish data exist and will be provided shortly
- Confounding Factor: Because the average surficial sediment concentrations are within a couple parts per million pre and post-dredging, any change in fish tissue levels is more appropriately attributable to natural recovery than dredging

Manistique Harbor Recovery!

[Source: *Final Manistique Harbor and River Site Data Evaluation Report* (Weston, May 19, 2005]

- The mystery of the remarkable Manistique Harbor recovery has been solved:
- The Area of Interest (AOI) “received thousands of tons of introduced sand as cover” (p. 2-1)
- There also was a regular input of clean sediment from upstream sources, for the past four years (post-dredging) (p. 2-1)
- A portion of the upstream dam was removed, allowing “considerable” sediment to deposit in the River and Harbor (p. 2-1)

Manistique Harbor Recovery!

- A sand wedge has formed in the river channel and is spreading into the main harbor area (p. 2-5)
- THREE to SEVEN feet of sediment has been redeposited since the 1996 bathometric survey (p. 2-5)
- Conclusion: The Harbor is depositional and dredged areas are being covered with a substantial thickness of clean sediment (p. 5-1)

MANISTIQUE HARBOR, MI
Resuspension and Release/Lessons Learned

- Resuspension and Release Issues:
  - Very little or no data; however, caged fish and silt trap data collected by third parties showed measurable PCBs
  - Silt curtains only used for part of the project
- Lessons Learned:
  - The fractured bedrock bottom led to operational and residuals issues
  - Wood debris created issues
  - Post-dredging average surficial residuals were slightly higher than pre-dredging (15.1 ppm vs. 18.8 ppm)
  - Large mass successfully removed (187,000 cy)
  - High project cost - $48 million

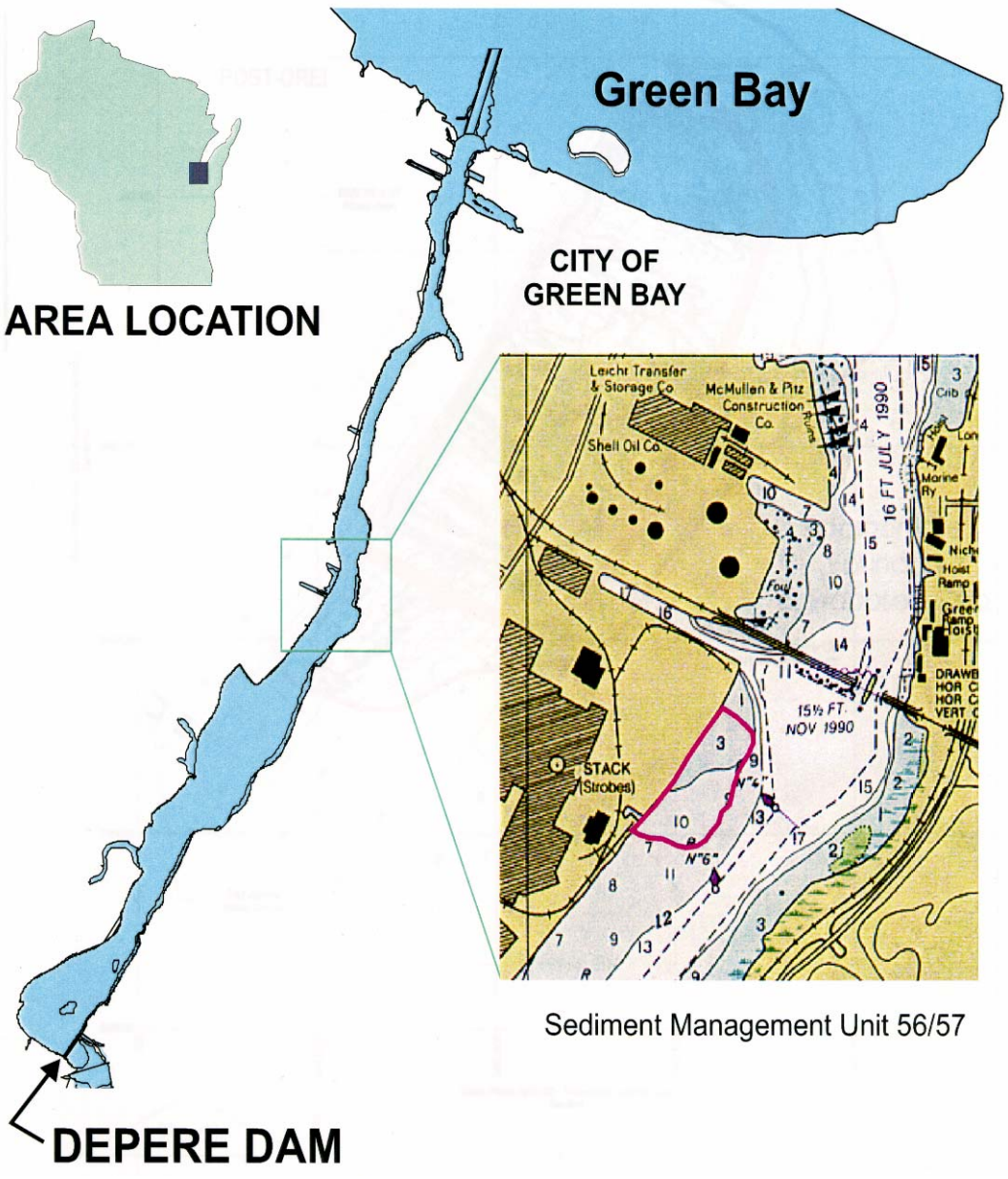
FOX RIVER, WI

- Deposit 56/57 (1999-2000)
- Deposit N (1998-1999)

FOX RIVER, WI: Deposit 56/57 - 1999

- Removal of 31,500 cy from 11 subunits (WDNR)
- Removed via horizontal auger dredge
- Containment system used was a perimeter silt curtain
- Sediment dewatered and disposed at a landfill operated by Fort James Corporation
- Goal→ To understand the implementability, effectiveness, and cost of a large-scale sediment removal project
- Project cost = estimated

  $7 million ($220/cy) - per State agreement
- Fort James completed project in 2000



FOX RIVER, WI: Deposit 56/57

- Site Background:
  - Pilot project with two distinct phases and results
  - COC: PCBs
  - 1999 WDNR Project-funded by PRP
  - 1999 Details
    - 31,000 cy
    - August – December
  - 2000 Details
    - 50,300 cy – some in original footprint and some additions
    - August - October

FOX RIVER, WI: Deposit 56/57

- Site-Specific Conditions:
  - Sloping, soft organic silt over stiff clay
  - Nearshore – significant debris and rip rap
  - Steel cable, wood debris, bricks
  - 1999 thickness removal – 6.7 feet (including overdredge)

FOX RIVER, WI: Deposit 56/57

- Pre and Post Sediment Data:
  - Pre-1999 dredge prism = 114 ppm
  - Pre-1999 avg. surficial = 4.4 ppm
  - Post-1999 avg. surficial = 73.0 ppm
  - Pre-2000 avg. surficial = 73.0 ppm
  - Post-2000 avg. surficial = 2.6 ppm
  - Overall project surficial = 4.4 (or 3.2 ppm) before comparison to 2.6 ppm after dredging

FOX RIVER, WI: Deposit 56/57

- Resuspension and Release Issues:
  - Resuspension did not appear to be an issue, yet
  - An USGS Study confirmed releases had occurred:
    - 14 kg (2.2%) of the 650 kg of PCBs dredged were released to the water column beyond the silt curtains
    - 20x increase downstream in dissolved PCBs

USGS MASS BALANCE STUDY - FOX RIVER DEPOSIT 56/57 ENVIRONMENTAL DREDGING DEMONSTRATION

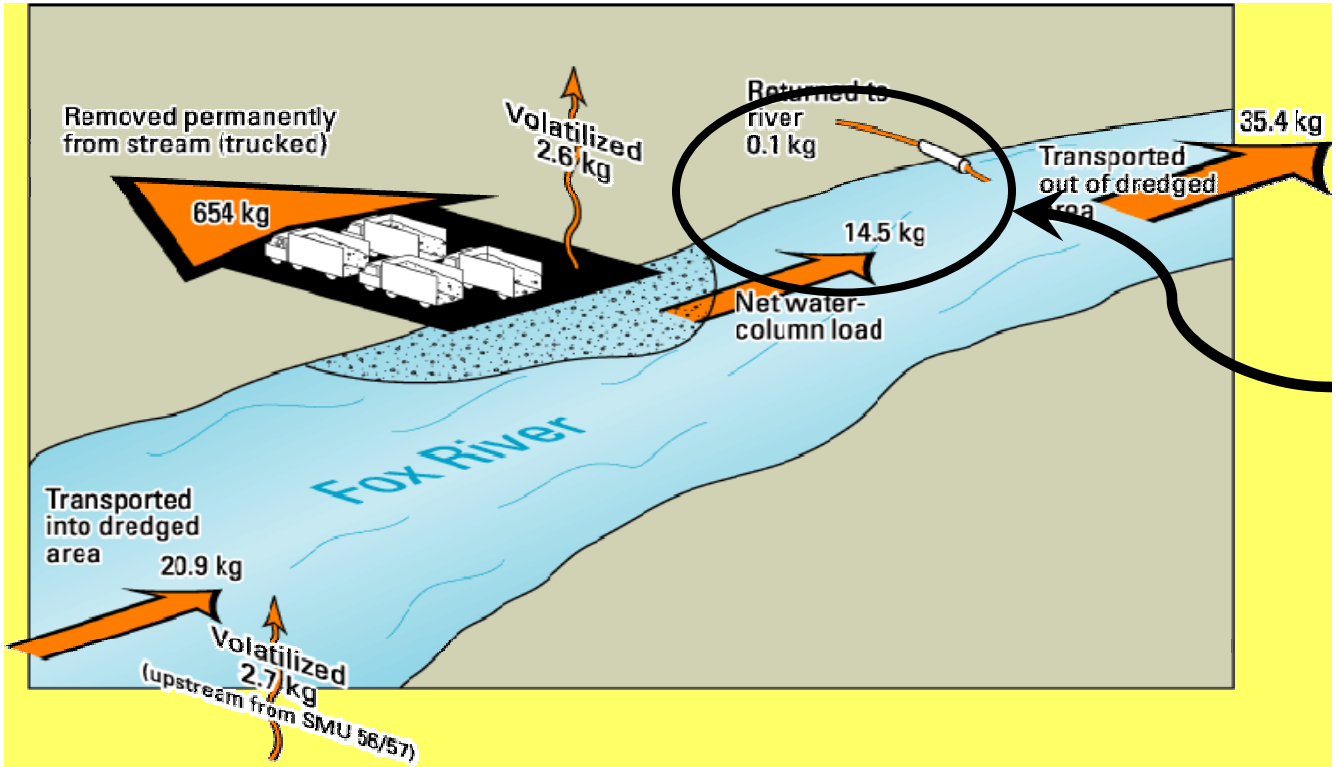


Figure1: Pathways of Polyclorinate Biphenyl (PCB) mass(Aroclor 1242) during the September 1- December 15, 1999 remediation at SMU 56/57. Amounts are in kilograms.

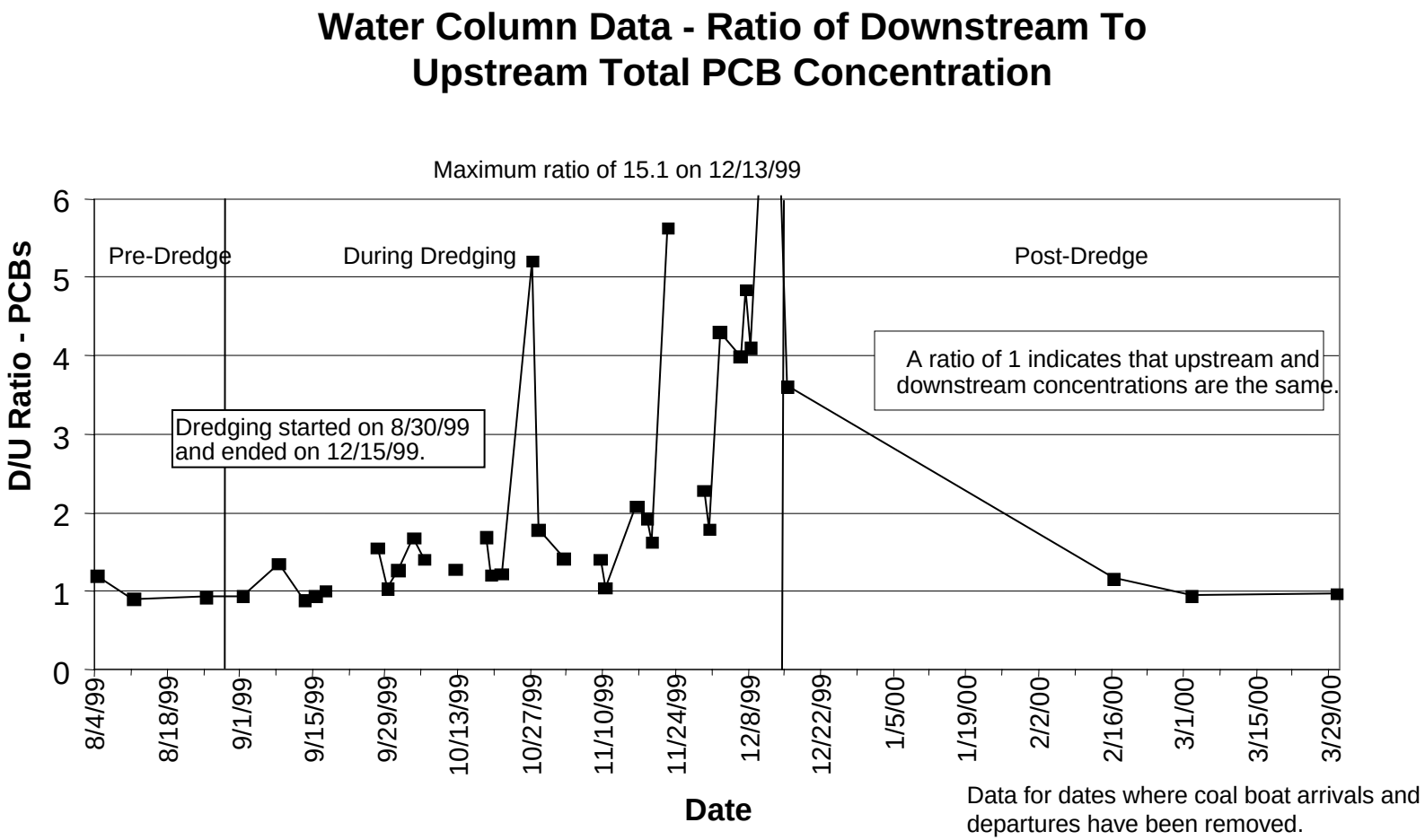
USGS Study shows that 2.2% of PCBs targeted for removal by environmental hydraulic dredging were mobilized to the water column and moved downstream

From:

US Geological Survey, 2000. *A Mass-Balance Approach for Assessing PCB Movement During Remediation of a PCB-Contaminated Deposit on the Fox River, Wisconsin.* (USGS Water Resources Investigations Report 00-4245). December 2000.

USGS science for a changing world

FOX RIVER, WI: Deposit 56/57



FOX RIVER, WI: Deposit 56/57

- Capping/Backfilling:
  - Due to the inability to achieve the 1 ppm level for PCBs, the area was backfilled with 6 inches of clean sand
  - During the succeeding 5 years, 4-5 feet of sediment filled in the depression

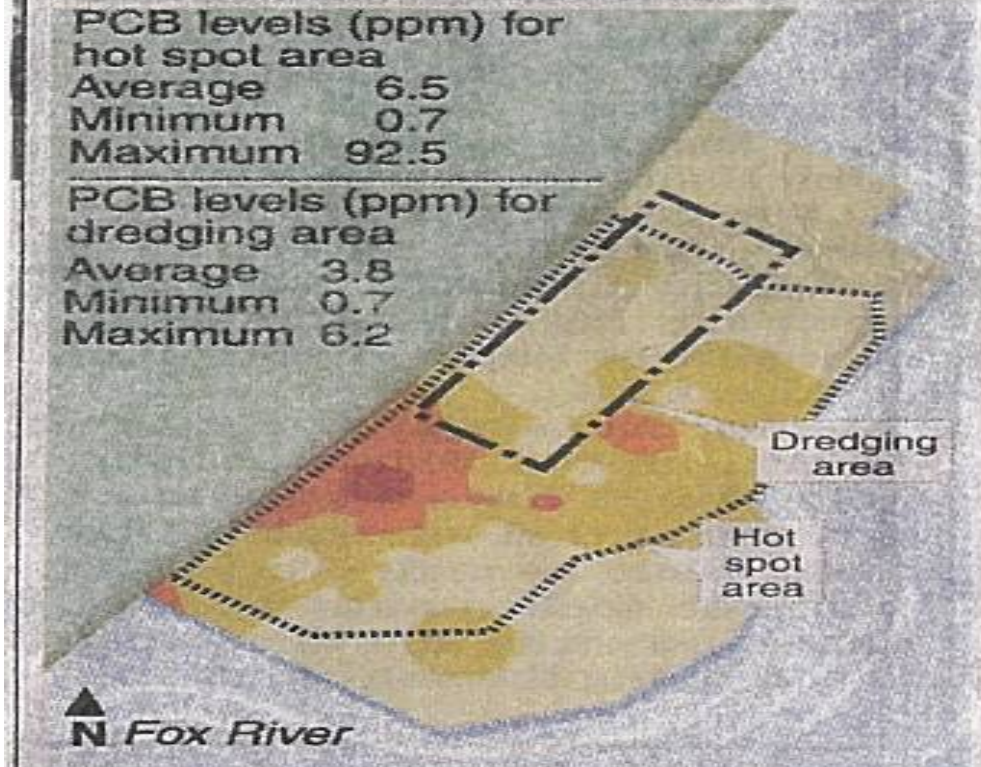
FOX RIVER, WI: Deposit 56/57

- Lessons Learned:
  - Hard pan clay and steep slopes contributed to the residuals
  - Although 90% of the mass was removed in 1999, the surficial concentrations were significantly elevated at the end of the first pilot (4.4 ppm to 73 ppm)
  - Roughly 6% of the PCB mass targeted in the 1999 removal remained as generated residuals
  - Approximately 2.2% of the PCB mass was released to the water column
  - Slopes (< 4 to 1) contributed to residuals

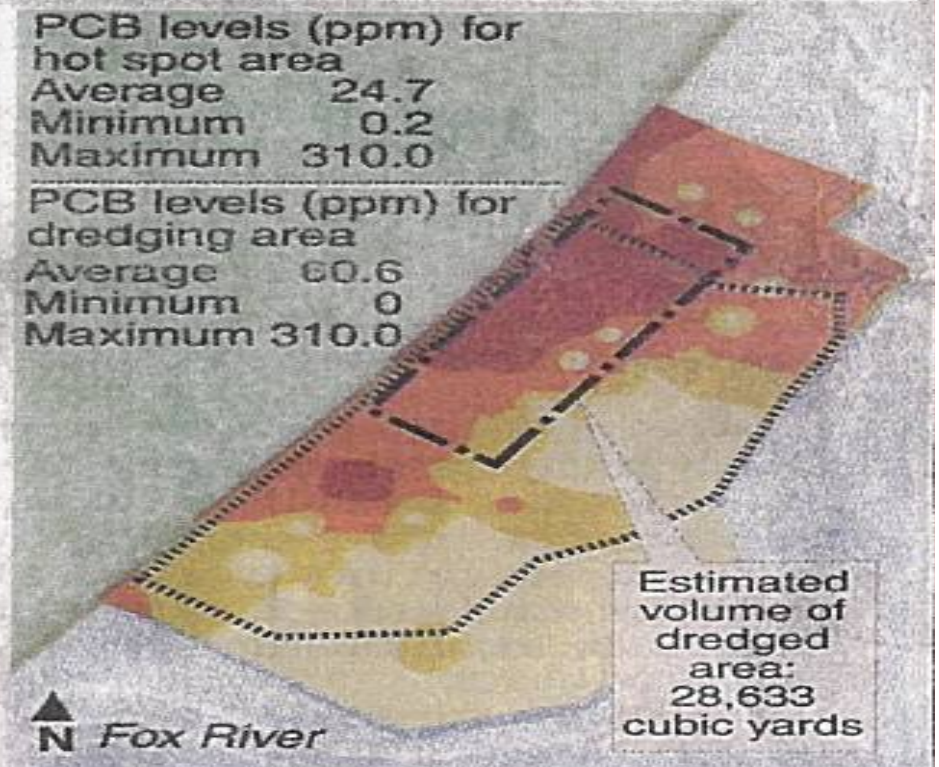
Unfinished business

A pilot dredging project outside Fort James Corp.'s West Mill ended in December with less than one-third of the removal goal met. The dredging exposed high levels of PCBs in the Fox River's worst hot spot.

Before dredging



After dredging



Source: U.S. Environmental Protection Agency

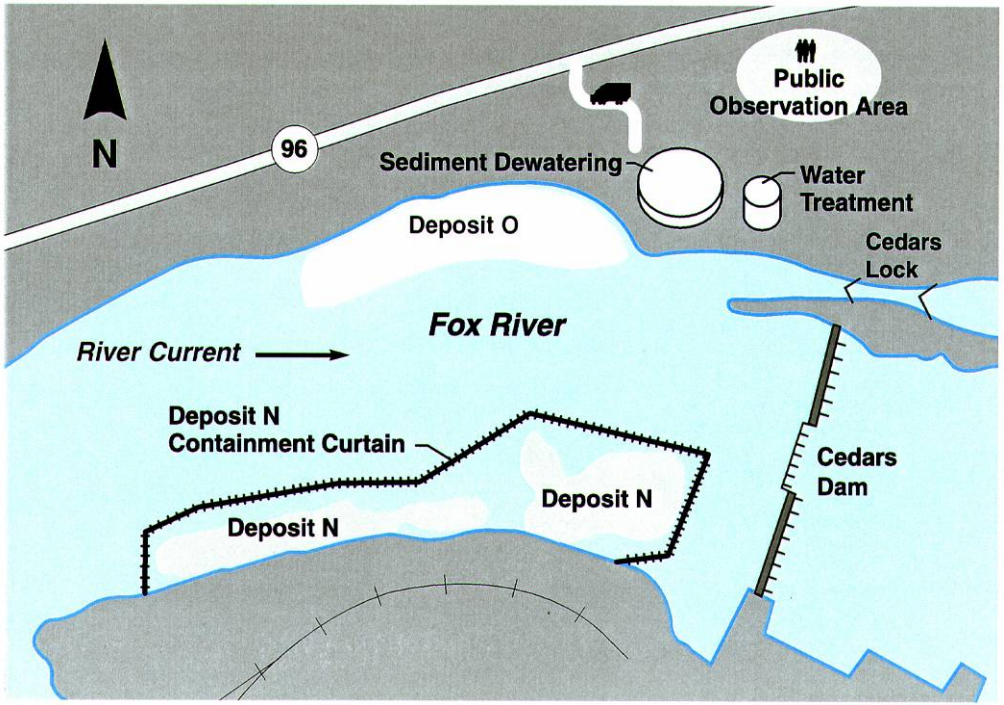
Press-Gazette

FOX RIVER PILOT

FOX RIVER, WI

FOX RIVER, WI: Deposit N

- 8,200 cy removed November to December 1998 and August to November 1999 (WDNR)
- Removed via hydraulic dredging (cutterhead)
- Silt containment included a perimeter turbidity barrier (80 mil HDPE) and two deflection barriers (80 mil HDPE and a silt curtain used primarily in 1998)

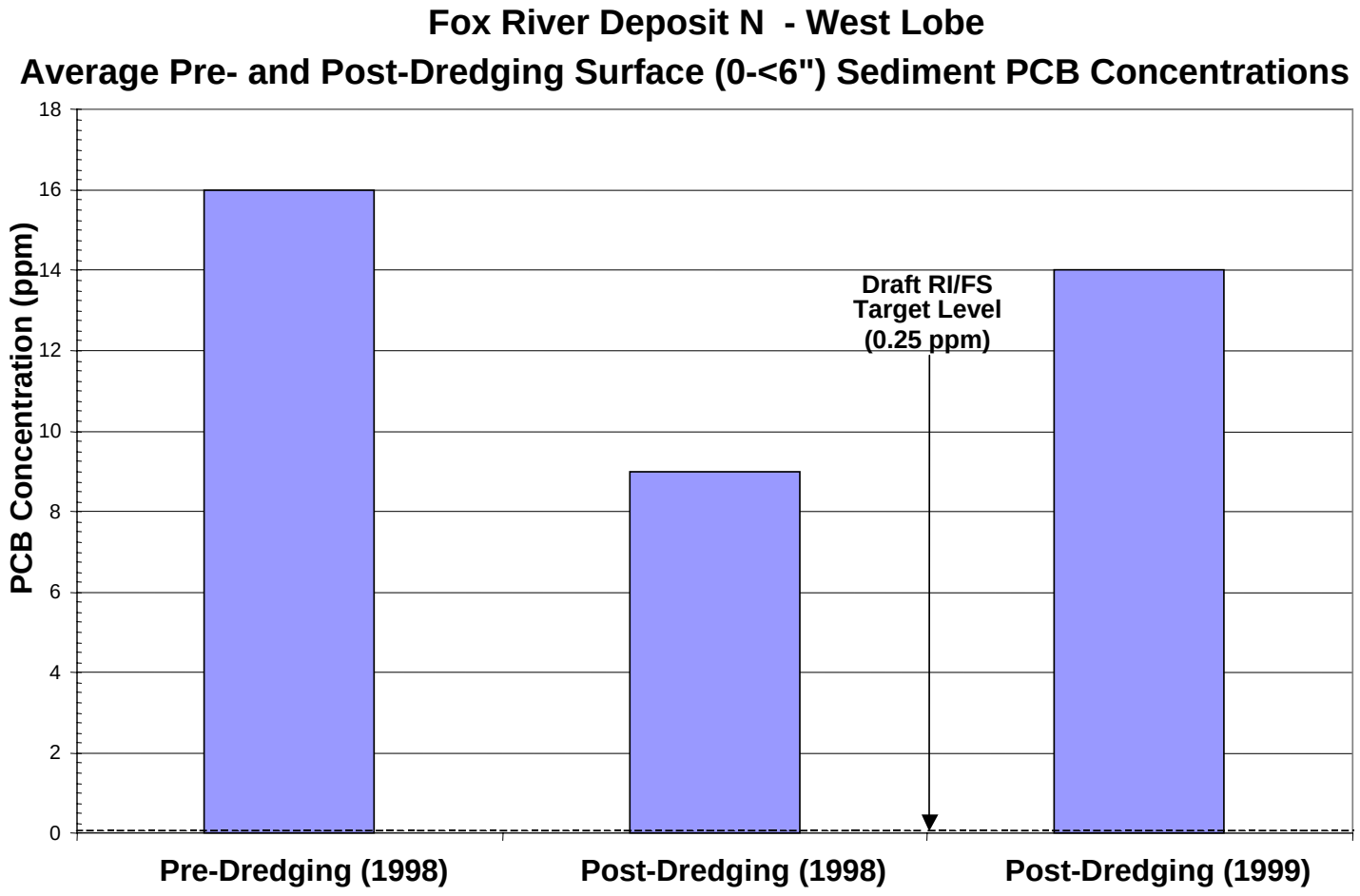


Sediment dewatered and disposed of off site

Goal→ Remove majority of contaminated sediment and leave thin residual layer (65% of volume targeted for removal due to bedrock conditions)

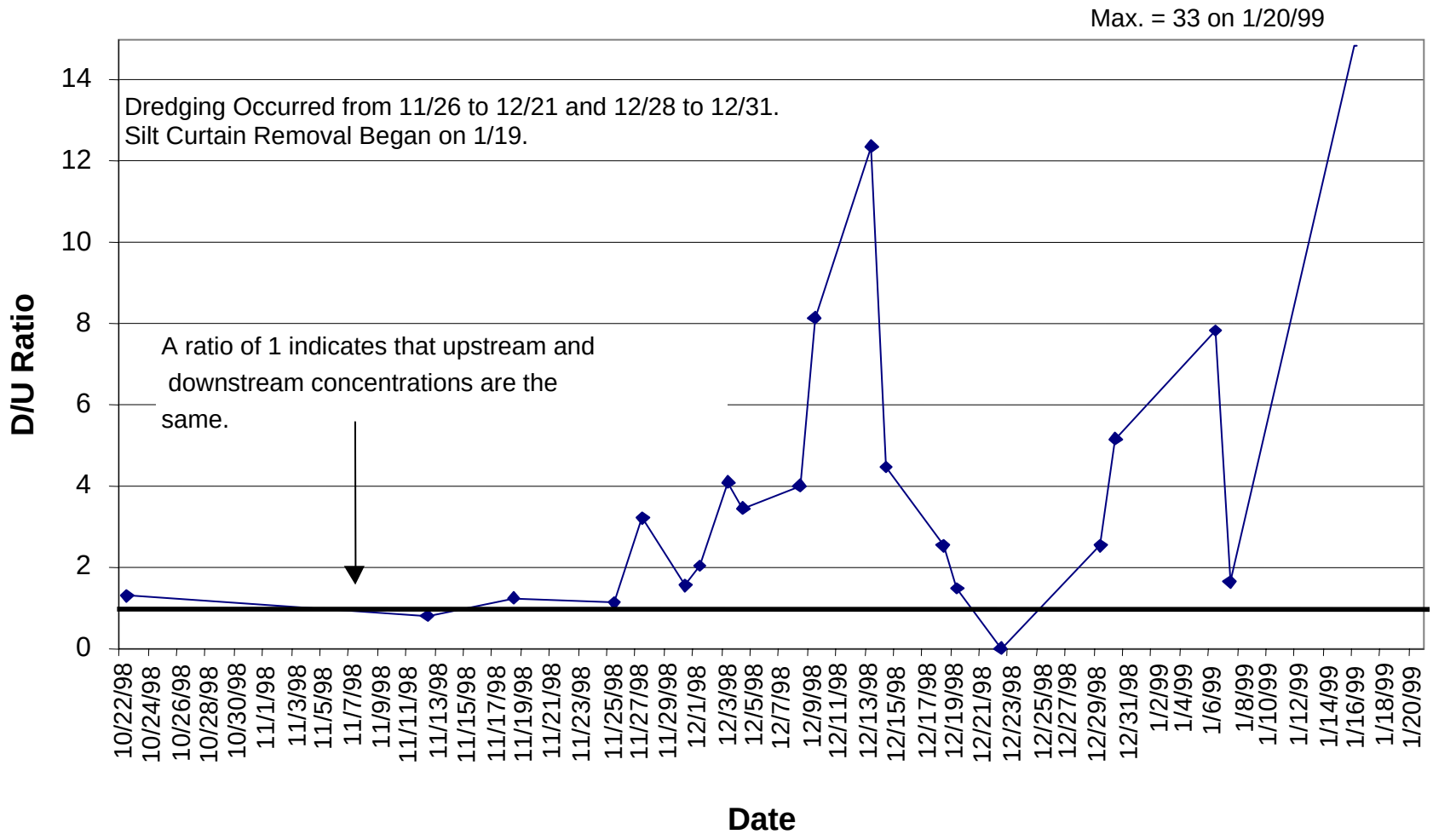
Project cost = $4.3 million ($525/cy)

FOX RIVER, WI: Deposit N - West Lobe

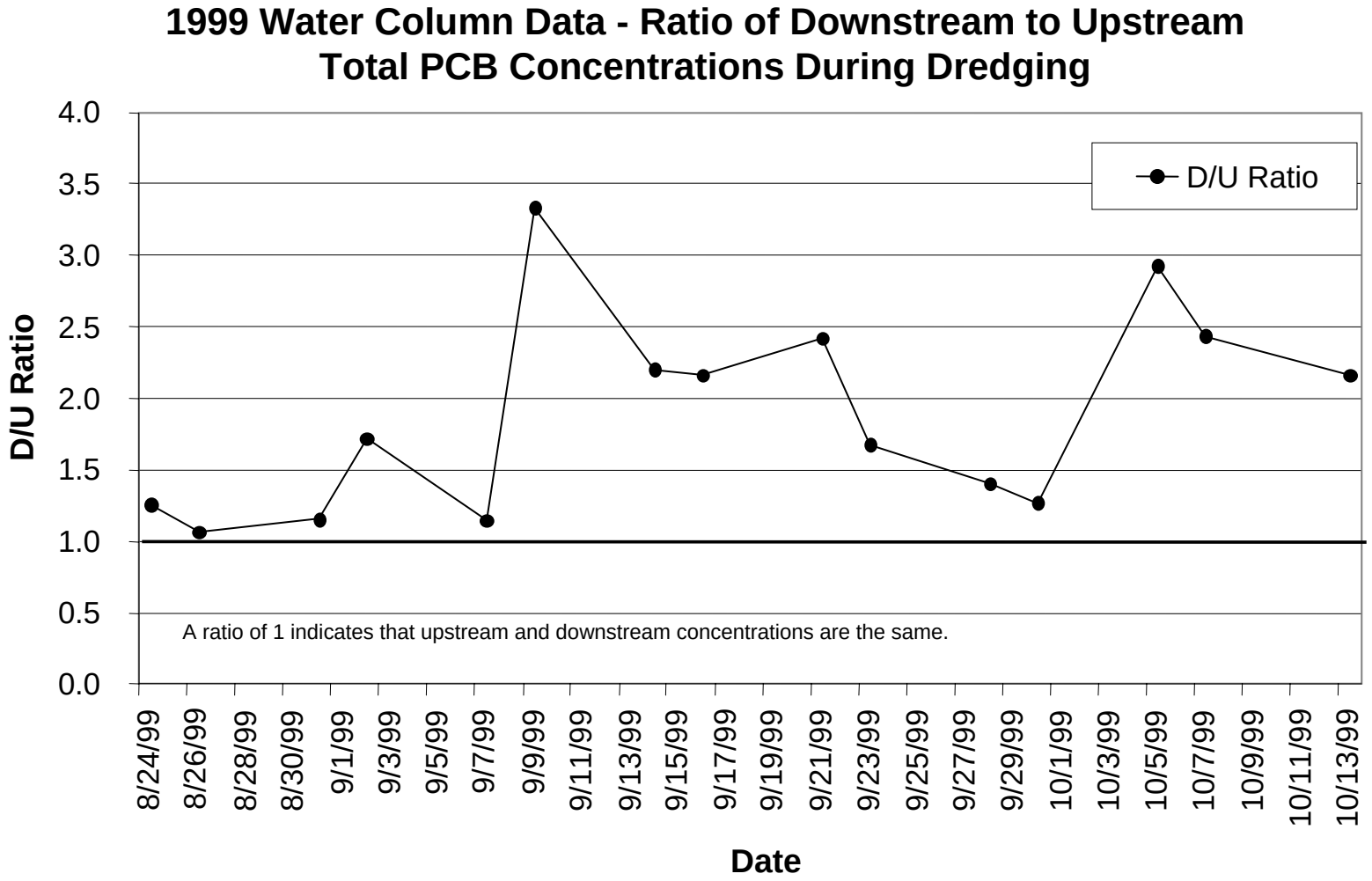


NOTE: Data are from Foth & Van Dyke. BBL calculations show post-dredging PCBs at 21 ppm.

FOX RIVER, WI: Deposit N



FOX RIVER, WI: Deposit N



FOX RIVER, WI: Deposit N

- Lessons Learned:
  - Pre-dredge average surficial = 11 ppm; post-dredge 14 ppm (Foth), 21 ppm (BB&L)
  - Fractured bedrock prevented overdredging and led to difficulties with residuals
  - Dredging removed 78% mass, but resulted in post-dredge surface concentrations similar to pre-dredge levels
  - Roughly 8% of the PCB mass targeted for removal remained as residuals

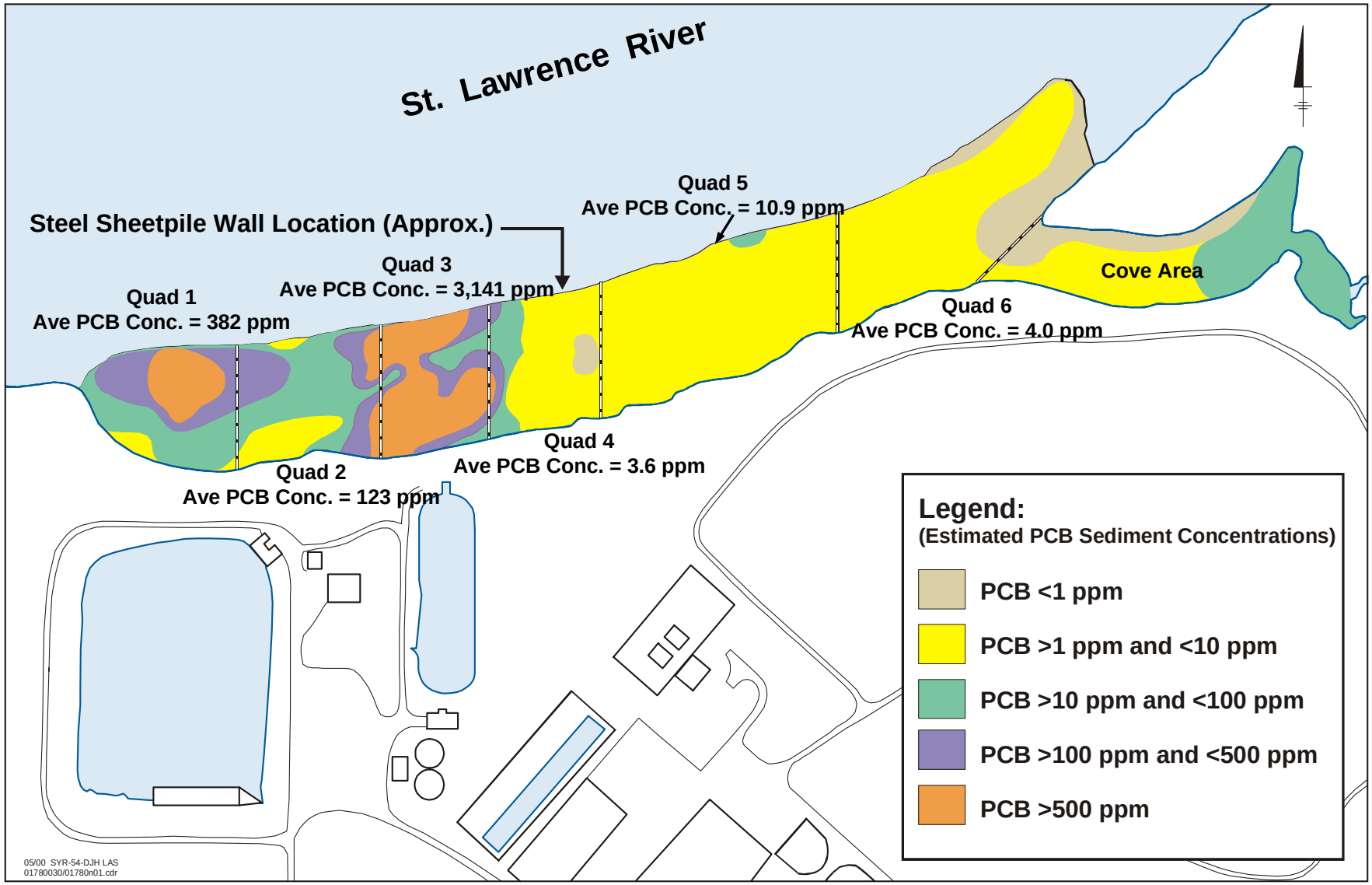
ST. LAWRENCE RIVER - GM MASSENA: HYDRAULIC DREDGING

- 11-acre area of nearshore sediments dredged in 1995
- Goal 1 ppm PCB (sediment)
- Mechanical debris removal and hydraulic dredging (horizontal auger)
- Projected cost = $11.5 million ($870/cy)
- 1 ppm cleanup goal unachievable (up to 30 passes)
- Average surficial PCBs >9.2 ppm
- One area capped after removal
- Silt containment—steel sheeting

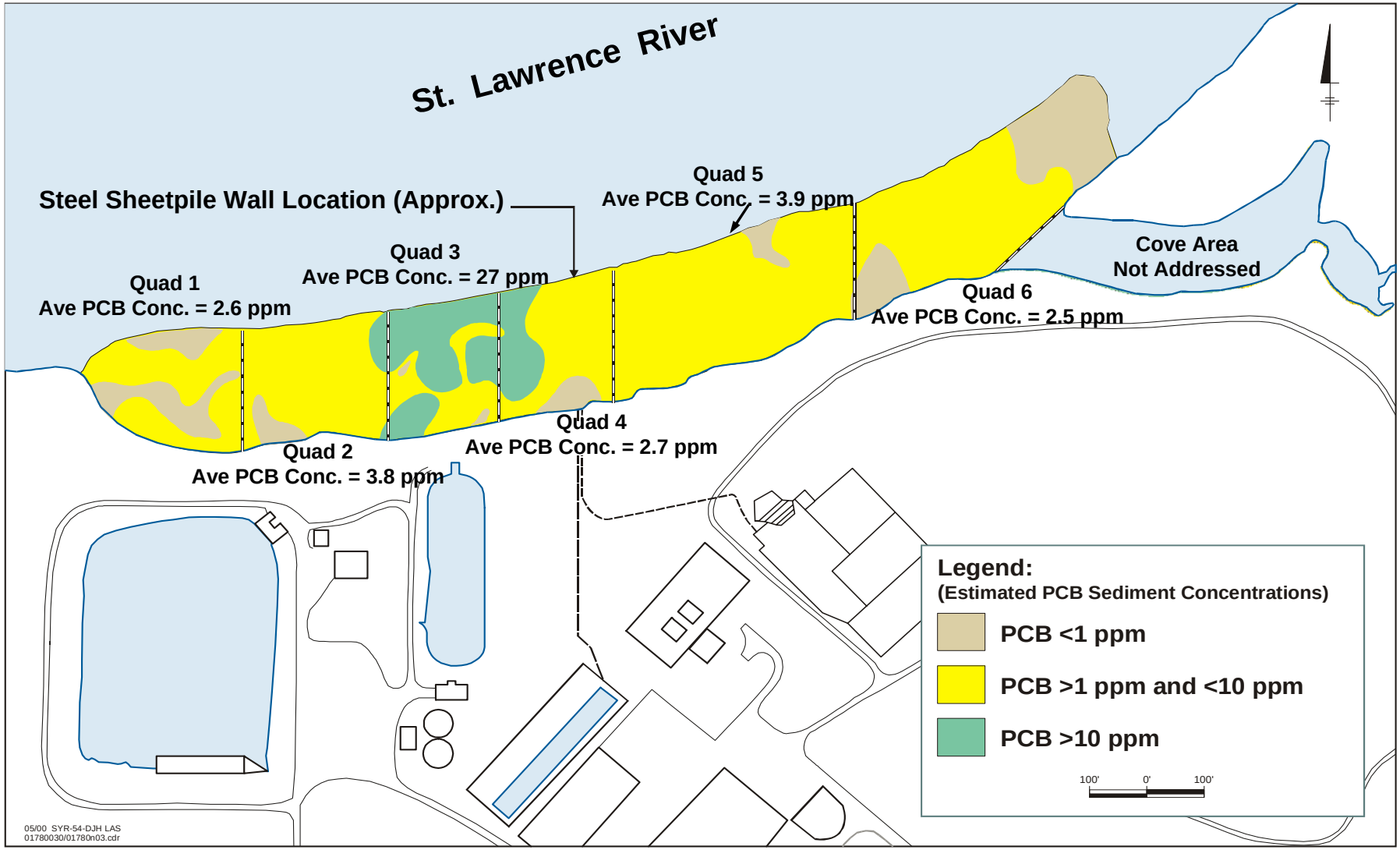
1 ppm PCB cleanup goal for sediment was unachievable, even with significant effort

ST. LAWRENCE RIVER - GM MASSENA:

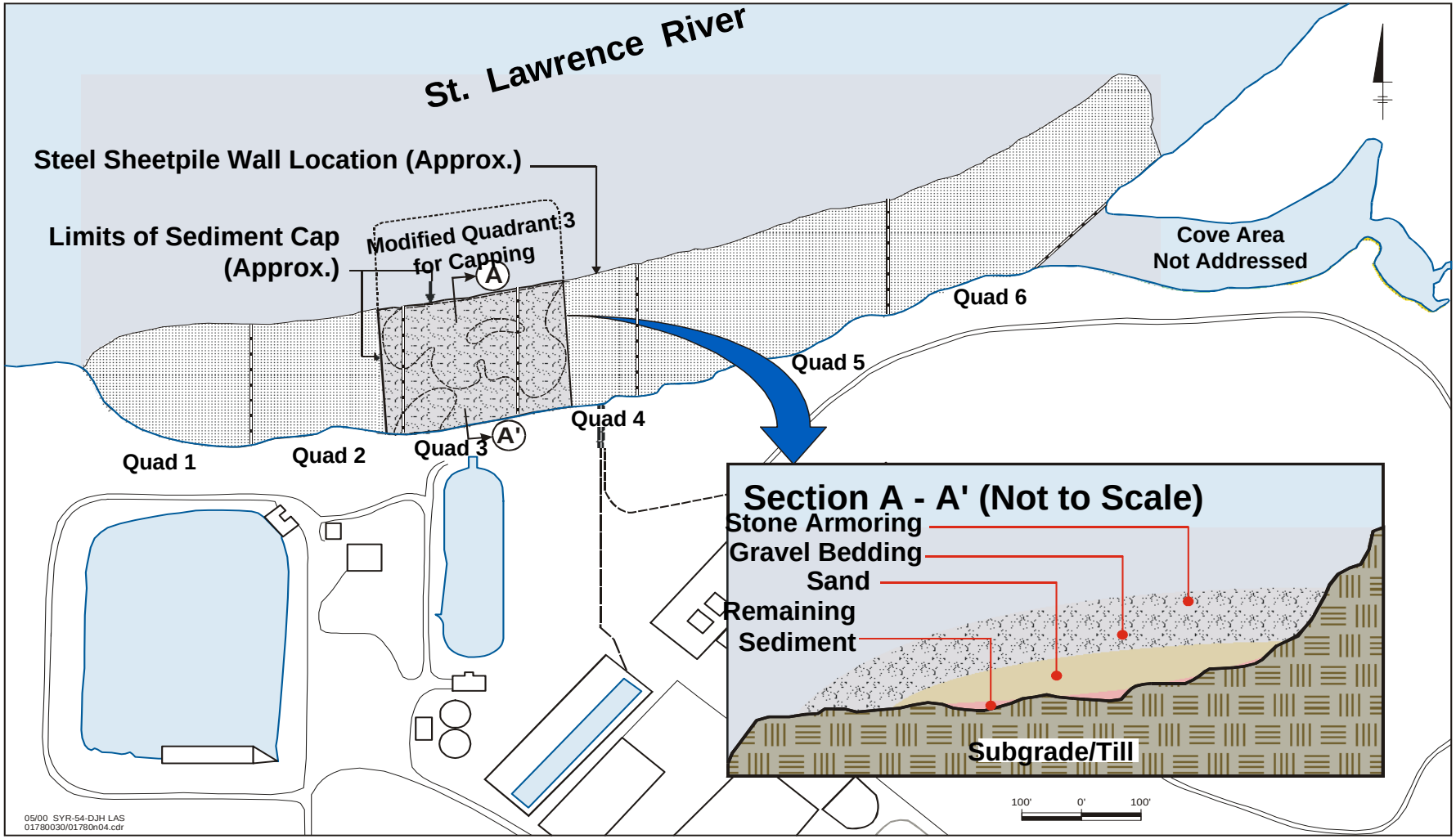
Pre-Dredging PCB Concentrations (Surface)



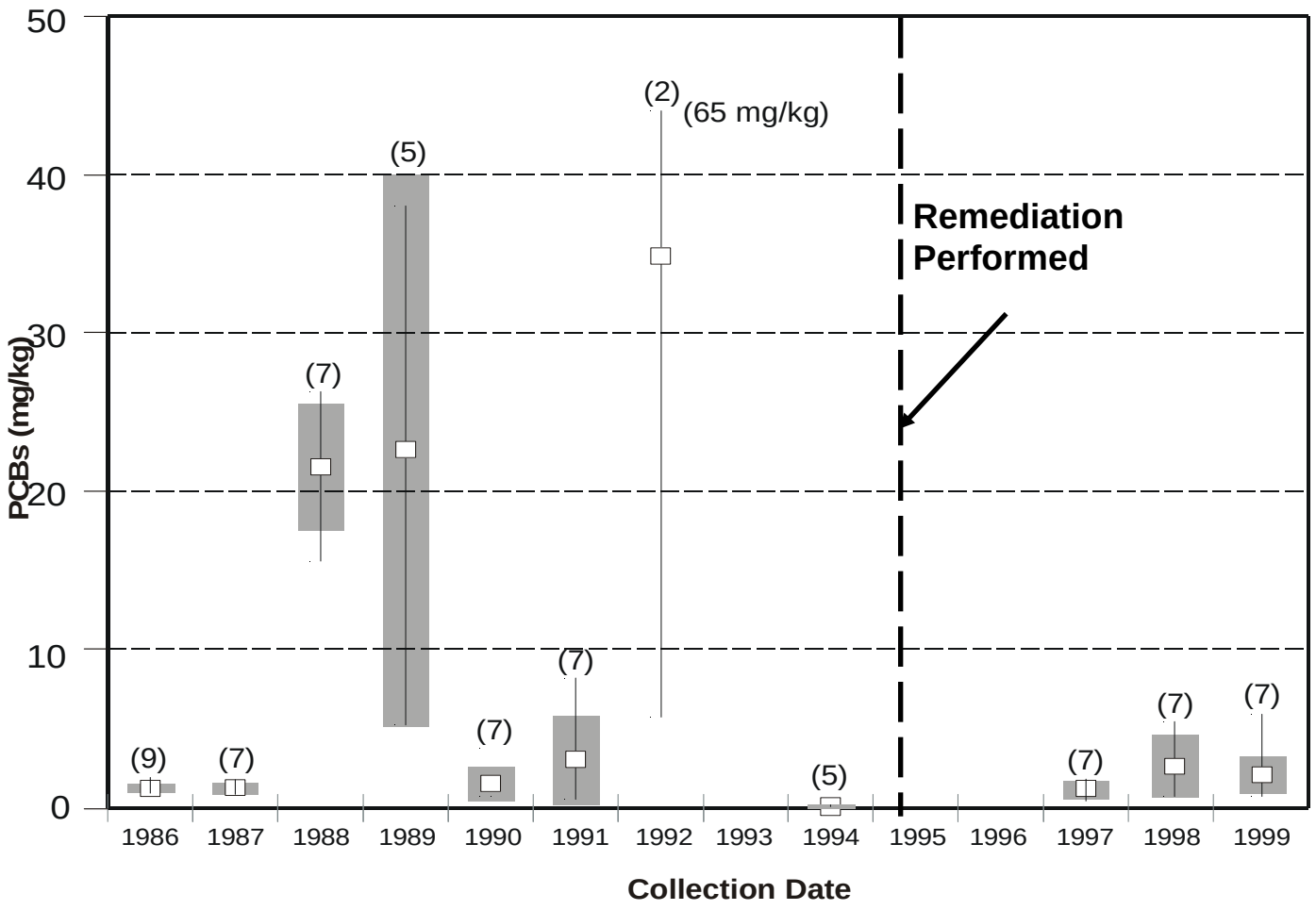
ST. LAWRENCE RIVER - GM MASSENA:
Post-Dredging PCB Concentrations (Surface)



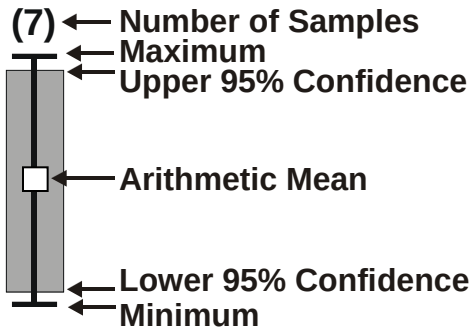
ST. LAWRENCE RIVER - GM MASSENA:
Post-Dredging Sediment Cap



ST. LAWRENCE RIVER - GM MASSENA: Fish Data



Historical Spottail Shiner PCB Concentrations



Reference: BBLES, 1999

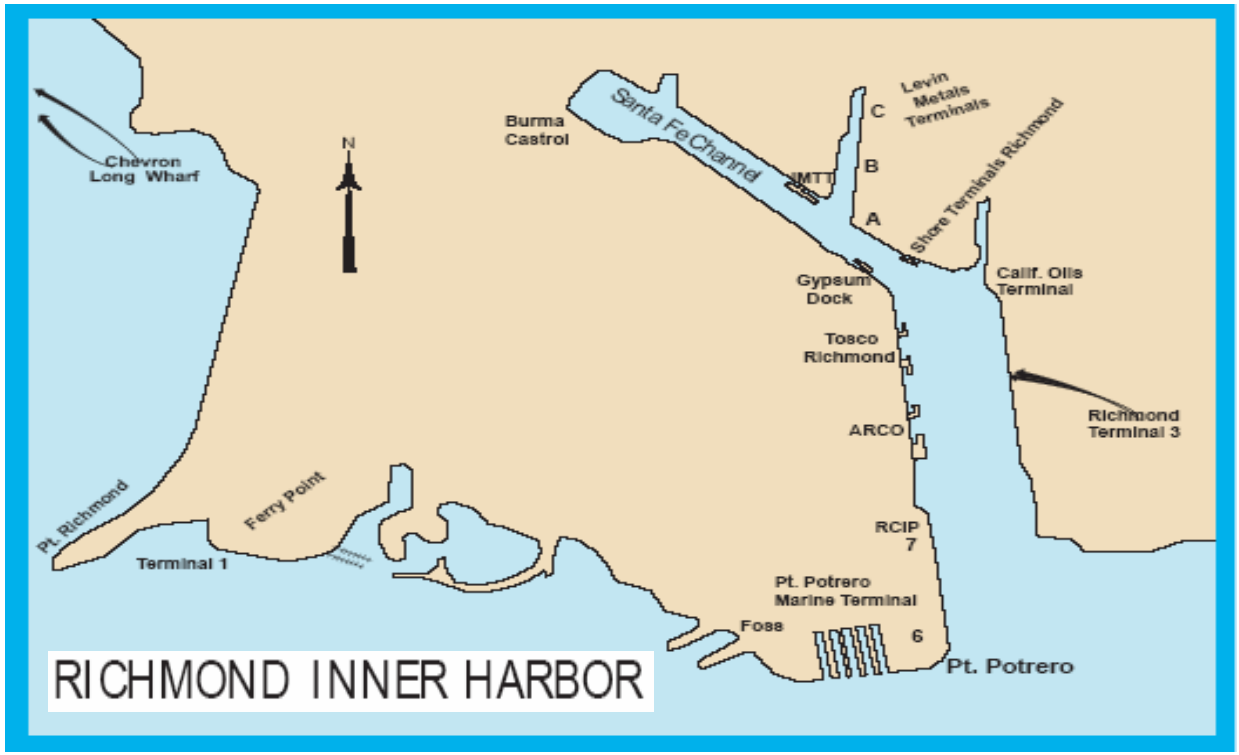
ST. LAWRENCE RIVER - GM MASSENA

- Supplemental Information:
  - Average pre-dredge surficial = 548 ppm of PCB
  - Sediment bottom included soft sands, silts, clay and rocks
  - 2500 ft of sheet pile installed

ST. LAWRENCE RIVER - GM MASSENA

- Lessons Learned:
  - Inherent limitations of dredging revealed during this project under certain conditions – such as high rock or debris content
  - Traditional backhoe technique to address rock/debris did not work well
  - Repeated dredge passes often do not solve these challenges
  - Silt curtains typically will not be effective in currents over 1 ft/sec
  - Sheet pile can be effective, but is very costly
  - Limited pre-dredging biota samples make it difficult to evaluate the effectiveness of the remedy

UNITED HECKATHORN NPL SITE



UNITED HECKATHORN NPL SITE
San Francisco, CA

- Waterbody/Location:
  - Lauritzen Channel and Parr Canal, Inner Richmond Harbor, San Francisco Bay, CA
- Waterbody characteristics:
  - Intertidal - The Lauritzen Channel and Parr Canal are dead-ended channels branching from the larger Santa Fe Channel
  - The Lauritzen Channel varies in depth from 10 feet at the northern end to 40 feet at its mouth
- Contaminants of concern:
  - DDT and dieldrin

UNITED HECKATHORN NPL SITE
San Francisco, CA

- Project dates:
  - Lauritzen Channel: Sep. 13, 1996 to Apr. 16, 1997; Parr Canal: Aug. 7-30, 1996 and Apr. 10-16, 1997.
- Dredge type/size/number:
  - Lauritzen Channel – One 12 cy Cable Arm environmental clamshell bucket for soft sediments and one 7 cy conventional clamshell bucket for harder sediments.
  - Parr Canal – two long-stick excavators.
- Dredged volume (projected/actual):
  - 65,000 cy/108,000 cy

UNITED HECKATHORN NPL SITE
San Francisco, CA

- Type of sediment bottom:
  - "Younger" bay mud, classified as fine to very fine silt to clay, depth of one to five feet, was targeted for removal
- Debris factors:
  - Prior to dredging, two sunken barges, a used storage tank, caissons, cables and other large debris were removed
  - The young bay mud contained extensive amounts of metal debris, rail road spikes, metal cable, rope and miscellaneous rubble. The debris "field" extended throughout the channel.

UNITED HECKATHORN NPL SITE
San Francisco, CA

- As each scow was unloaded, the debris had to be separated from the sediment prior to processing in the dewatering area
- Each segregation process required two hours to pull debris from the sediment prior to mixing
- Debris caused at least two distinct problems: (1) dredging efficiency and effectiveness and (2) significant water treatment breakdowns and cost impacts

UNITED HECKATHORN NPL SITE
San Francisco, CA

- Targets of Key COCs:
  - 590 ppb DDT
- Pre-dredge concentration:
  - Pesticide concentrations were highest in the Lauritzen Channel, and decreased with increasing distance from the former United Heckathorn Site
  - The maximum measured total DDT concentration was 633 ppm

UNITED HECKATHORN NPL SITE
San Francisco, CA

- Pesticide concentrations of greater than 100 ppm were detected in sediment from the northern and western portions of the channel
- The median total DDT concentration was approximately 47 ppm at the head of the Lauritzen Channel
- The maximum and median total DDT concentrations measured in Parr Canal sediment were 4 ppm and 0.8 ppm, respectively

UNITED HECKATHORN NPL SITE
San Francisco, CA

- Post-dredge cover
  - Post-dredging, a 6-18 inch layer of clean sand was hydraulically placed, not as a cap, or backfill, but as a habitat enhancement. (None was placed under the piers due to the steep slopes.)
- Post-dredge surficial concentration:
  - Initially, the verification sampling prior to sand placement showed that both the average and median DDT concentrations in the Lauritzen Channel were below the clean-up level of 590 ppb
    - Average DDT concentration of 263 ppb
    - Median DDT concentration of 44 ppb
    - Maximum DDT concentration of 1.3 ppm

UNITED HECKATHORN NPL SITE
San Francisco, CA

- Three samples were collected from the Parr Canal cores which showed
  - Average DDT concentration of 200 ppb
  - Median DDT concentration of 200 ppb
  - Maximum DDT concentration of 1.5 ppm
- The Year 2 post-remedial (and post-sand placement) monitoring, however, showed that concentrations of DDT had risen to the levels that existed before remediation
- DDT range 2700 ppb – 130,000 ppb

UNITED HECKATHORN NPL SITE
San Francisco, CA

- Biological Information:
  - In samples taken pre-dredging, in October 1991 and February 1992, fish contained approximately 10 ppm DDT in the Lauritzen Channel
  - 1 ppm in the Santa Fe Channel
  - 0.1 ppm in the Richmond Inner Harbor Channel
  - A 2002 University of California Berkeley study, which sampled one month (8/96) before dredging and then four (7/97) and sixteen months (7/98) after dredging, found that dredging increased the concentrations of DDT in fish
    - Anchovy body burdens increased 76-fold
    - Speckled sanddab increased 32-fold
    - Staghorn sculpin increased 16-fold

UNITED HECKATHORN NPL SITE
San Francisco, CA

- Confounding Factor: The University of California Berkeley study noted that there were errors in the reports of the DDT concentrations in mussels in the early reports (cited below). [1] [2] A calculation error resulted in a reported apparent 77% decrease in mussel DDT residues rather than the actual 108% increase.

•[1] Anderson BS, Hunt JW, *et al*. 2000. Ecotoxicologic change at a remediated Superfund site in San Francisco, California, USA. *Environ. Toxicol. Chem*. 19: 879-887.

•[2] Antrim LD and NP Kohn. 2000. Post-remediation biomonitoring of pesticides in marine waters near the United Heckathorn Superfund site, Richmond, CA. PNNL-11911, Rev. 1. Battelle Pacific Northwest National Laboratory, Richland, WA, USA.

UNITED HECKATHORN NPL SITE
San Francisco, CA

- Resuspension and Release Issues:
  - Silt curtains were deployed across the mouth of the water bodies during dredging activities
  - Curtain was damaged by ship traffic and storm-related tides and currents and repaired on numerous occasions throughout the project

UNITED HECKATHORN NPL SITE
San Francisco, CA

- Recontamination:
  - Two years of post-remediation monitoring showed that elevated concentrations of DDT (2.7 - 130 ppm) and dieldrin (0.05 - 3.3 ppm) remained in the top 10 inches of sediments, and water concentrations of DDT and dieldrin were still about 100 times greater than the remedial goal
  - US EPA completed a Five-Year Review in September 2001. The Five-Year Review concluded that the dredging remedy has not kept the Lauritzen Channel from being recontaminated with unacceptable levels of pesticides.

UNITED HECKATHORN NPL SITE
San Francisco, CA

- Possible sources of recontamination:
  - The margins of the channel could not be dredged due to the presence of pilings and docks
  - In 2002, EPA found a buried outfall only visible at low tide that discharged water with high levels of DDT

- <u>Site-Specific Complicating Factors</u>:
  - Rail operations proved difficult
    - Problems with scheduling, consistency and reliability

UNITED HECKATHORN NPL SITE
San Francisco, CA

- Changing disposal sites was expected to improve rail service, but the opposite occurred
- After debris management, use of rail for transport caused the most significant overall project impacts and problems
- Public controversy over suitable disposal site
  - Greenpeace and local residents protested the shipments of Heckathorn sediments and attracted substantial media attention
  - EPA asked the Contractor to stop shipping to Arizona, and begin using the only feasible alternate site, the East Carbon Development Corp. (ECDC) facility in Utah

UNITED HECKATHORN NPL SITE
San Francisco, CA

- Lessons Learned:
  - The importance of understanding the potential impact (recontamination in this case) of residual or inaccessible contaminated sediment prior to remedy selection implementation
  - The need to fully characterize rocks, vegetation, and debris prior to dredging
  - The influence of disposal operations on dredging, e.g. delays and protests at commercial disposal facilities; logistical delays with rail cars; disposal site load refusals
  - Debris impact on water treatment system operation and cost

CUMBERLAND BAY NPL SITE
Plattsburgh, NY

CUMBERLAND BAY NPL SITE
Plattsburgh, NY

- Location:
  - Cumberland Bay, Lake Champlain, Plattsburgh, NY
- Contaminants of concern:
  - PCBs
- Dredged volume (projected/actual):
  - 93,000 cy/195,000 cy
- Project dates:
  - April – December, 1999; April – October, 2000

CUMBERLAND BAY NPL SITE
Plattsburgh, NY

- Dredge type/size/number:
  - Two hydraulic dredges, each attached with an 8-foot wide, 8-inch diameter auger head; one using a 10-inch discharge line and one using a 12-inch discharge line
- Type of sediment bottom:
  - The sludge bed comprised varying mixtures of sediment, paper-making residuals, wood chips, and sawdust overlying lake sand

CUMBERLAND BAY NPL SITE
Plattsburgh, NY

- Targets of Key COCs:
  - The target was complete removal of the sludge bed down to the underlying sand layer
- The maximum pre-dredge PCB concentration in the Mudflats and Breakwater areas was 33 ppm, while the average concentration in the Dock area was 431 ppm
- Pre-dredge data for sludge bed samples from 0 to 10 inches in depth ranged from <0.00125 to 1,850 ppm total PCBs

CUMBERLAND BAY NPL SITE
Plattsburgh, NY

- During the dredging operation, a four-phased rigorous sampling program was implemented to evaluate the bottom of the dredged bay area in 1999 and 2000
- Phase I sampling proved not to be representative of the remaining sludge, as it was discovered that the sampling tool used did not retain all of the sludge present during retrieval

CUMBERLAND BAY NPL SITE
Plattsburgh, NY

- In Phase II, more areas were identified that still contained sludge
- The Breakwater sludge area, originally believed to have been dredged to a hard bottom since the sampling device encountered refusal, turned out to be an area of hard crust underlain by up to 4 feet of sludge with PCBs at concentrations up to 54 ppm

CUMBERLAND BAY NPL SITE
Plattsburgh, NY

- In Phase III, the consolidated sludge was also found in depressions scattered along the bottom of the lake
  - Since the hydraulic auger dredge was bridging these depressions, hand-held dredging was used to remove sludge from those areas
- In Phase IV, the results of the core sampling and inspection by divers indicated that a few areas still needed to be dredged
  - Those areas were then dredged by divers using hand-held hydraulic dredge lines

CUMBERLAND BAY NPL SITE
Plattsburgh, NY

- After dredging, 115 confirmation cores were collected
  - 42 cores yielded 51 samples that were analyzed for PCBs
  - The results ranged from 0.04 mg/kg to 18.0 mg/kg, and averaged 5.87 mg/kg

CUMBERLAND BAY NPL SITE
Plattsburgh, NY

- Dredging Effectiveness – Biological Information:
  - Robert Edwards of NYSDEC indicates that a five-year review of ongoing fish monitoring data is being compiled and will be presented in a report form in the Fall of 2006

CUMBERLAND BAY NPL SITE
Plattsburgh, NY

- Resuspension and Release Issues:
  - As no good correlation existed between TSS and turbidity, turbidity was used only as an indicator and not in association with an action level
  - Sludge resuspension was observed in association with dredging activities and elevated TSS results were detected outside the work zones
  - 1,000 linear feet of sheetpiling and 2,200 linear feet of silt curtains were installed to isolate the sludge bed during dredging operations

CUMBERLAND BAY NPL SITE
Plattsburgh, NY

- Site-Specific Complicating Factors:
  - The layers of paper sludge were light and fluffy. The dredge head tended to "blow it away" rather than "suck it up"
  - Sludge in this area contained pockets of gas that when exposed would lift the sludge to the surface which resulted in repeated dredge passes in an attempt to capture the resuspended material
  - Lots of wood chips were present, as well as logs

CUMBERLAND BAY NPL SITE
Plattsburgh, NY

- Substantial debris and some large rocks were encountered
  - Embedded debris and large embedded rocks were left in place and work continued around the obstructions
- The bottom surface in the Bay is not flat
  - Peaks and valleys (up to 5’) were present with peaks of hard sand which were more difficult to dredge than paper sludge
- The capacity of the wastewater treatment facility limited dredging

CUMBERLAND BAY NPL SITE
Plattsburgh, NY

- Lessons Learned:
  - A correlation between TSS and turbidity could not be developed based on site-specific conditions, which, therefore, prevented real-time monitoring of resuspension
  - Dredging with horizontal auger caused resuspension of fine sediments
  - Residuals posed a significant problem as evidenced by the four phases of sampling and new discoveries of pockets of residuals or undredged inventory

OUTBOARD MARINE NPL SITE
Waukegan Harbor, IL

OUTBOARD MARINE
Waukegan, IL

- Location:
  - Waukegan Harbor, Lake Michigan, Waukegan, IL
- Contaminants of concern:
  - PCBs (1242 and 1248)
- Dredged volume (projected/actual):
  - 46,600 cy/38,300 cy
- Project dates:
  - Overall, June 1991 to November 1994
  - Includes 2.5 years for the settling of sediment within Slip #3, the sediment disposal location
  - Dredging itself was concluded in early 1992

OUTBOARD MARINE
Waukegan, IL

- Dredge type/size/number:
  - For Upper Harbor, a ten-inch hydraulic cutterhead dredge; for Slip #3, an eight-inch hydraulic cutterhead dredge
- Waterbody type/water depths:
  - Harbor and boat slip/ water depths in the harbor generally vary from 14 to 25 feet with some shallower depths in Slip #3
- Type of sediment bottom:
  - The harbor sediments consist of 1 to 7 feet of very soft organic silt overlying typically 4 feet of medium dense, fine to coarse sand

OUTBOARD MARINE
Waukegan, IL

- Debris factors:
  - Sediments were “raked” daily for stones and debris prior to dredging.
- Targets of Key COCs:
  - 50 ppm PCBs

OUTBOARD MARINE
Waukegan, IL

- June 1976, four surface sediment samples
  - PCBs ranging from 74 to 301 ppm
  - Two surface samples from Slip #3 exhibited PCBs of 3,900 and 10,300 ppm
- May 1976, six surface sediment samples were collected in the 27-acre Lower Harbor
  - One sample was 216 ppm PCBs
  - Five other samples ranged from 1.8 to 36 ppm PCBs

OUTBOARD MARINE
Waukegan, IL

- July 1977, surface sediment samples
  - Slip #3 exhibited PCBs ranging from 350 ppm to 3,600 ppm
  - Five samples from the 10-acre Upper Harbor exhibited PCBs ranging from 36 to 460 ppm (median 140 ppm)
  - Lower Harbor exhibited PCBs ranging from 0.8 ppm to 26 ppm (median 10 ppm)

OUTBOARD MARINE
Waukegan, IL

- No verification samples were collected for PCBs in the Upper Harbor
- A pre-defined volume of sediment was removed to an underlying sand layer, which was expected to achieve less than 50 ppm PCBs in the Upper Harbor
- US EPA estimated that approximately 900 kg of PCBs remained in the harbor sediments following the cleanup. It is now thought that these residual sediments are potentially being resuspended by navigational activity.

OUTBOARD MARINE
Waukegan, IL

- Resuspension and Release Issues:
  - Turbidity measurements were recorded daily during raking (of stones and debris) and dredging activities from depths of 10 and 20 feet on either side of the silt curtain and 500 feet south of the silt curtain
  - The turbidity readings outside of the silt curtain were reportedly less than 17 NTUs, which was well below the 50 NTUs action level

OUTBOARD MARINE
Waukegan, IL

- Biota:
  - Reassessment fish sampling was performed annually from 1993 to 1996 and a fish consumption ban was partially lifted in January 1997, leaving only a no-consumption advisory for common carp taken from the harbor
  - The maximum fish PCB concentrations recorded in 1999 and 2000, 83.8 ppm and 40 ppm (not reflected on the table below), respectively, were considerably elevated when compared to results from previous years and to fish of similar size. As of April 2002, Illinois EPA reportedly believed that these results were anomalies

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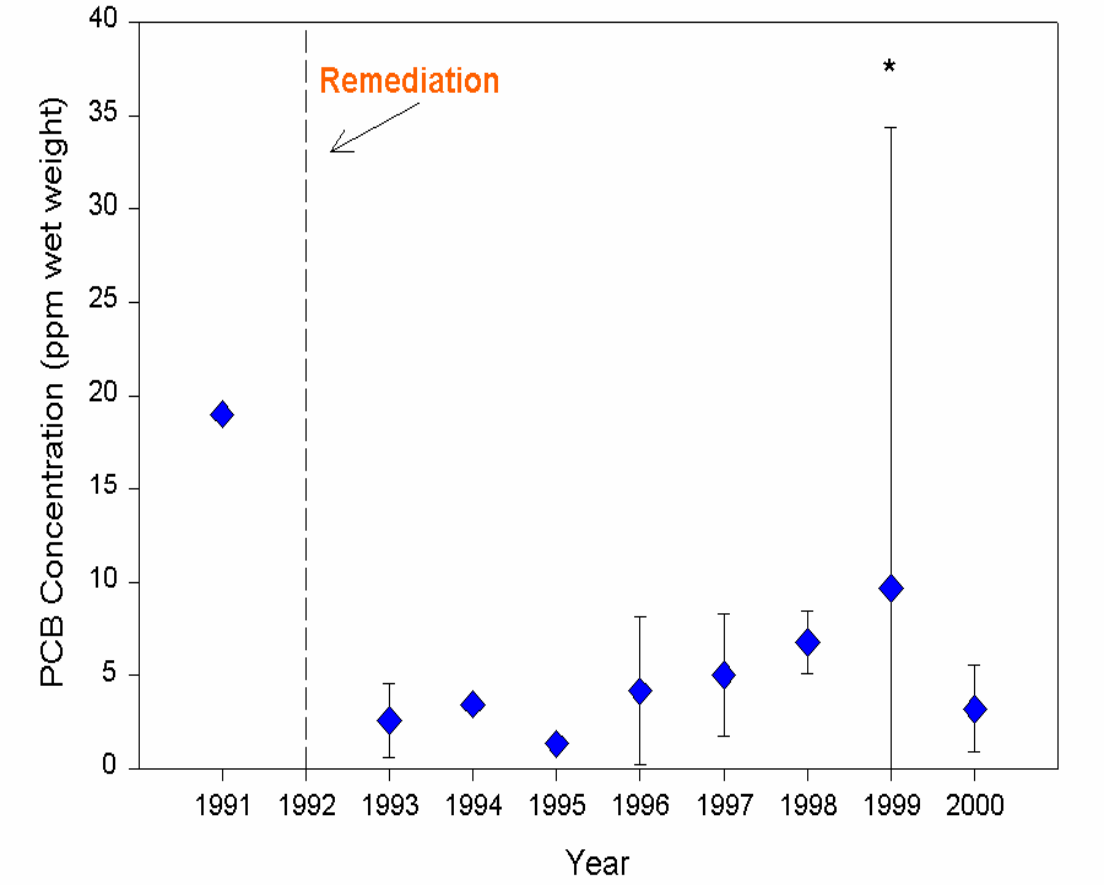
engineers & scientists

PCB Levels In Carp From Waukegan Harbor
Station QZ001 - North Harbor



The inappropriateness of relying on a single data point in 1991 to evaluate the effectiveness of dredging was underscored in 1999, when one sample result out of several taken had 83.8 ppm of PCB. If that fish had been caught in 1993 as the only data point, one would have concluded that dredging caused a 63.8 ppm increase in PCBs in fish in the first post-dredging year!

***83.8 ppm reported in a single carp fillet in 1999.**

OUTBOARD MARINE
Waukegan, IL

- Miscellaneous:
  - A silt curtain (anchored to bottom) was deployed at lower part of Upper Harbor and at entrance to operating Slip #4
  - After completion of the Upper Harbor dredging and water treatment, the harbor water was sprayed with Nalcolyte, a potable coagulant, to aid in the settling of suspended particulate

OUTBOARD MARINE
Waukegan, IL

- Site-Specific Complicating Factors:
  - Silt curtain failures due to wind and wind-driven currents
  - Material deposited into Slip #3 was temporarily capped with clean sand, but took about 2.5 years to settle sufficiently to allow capping to be completed
  - Upper Harbor dredging was prohibited during boating season

OUTBOARD MARINE
Waukegan, IL

- Lessons Learned:
  - The lack of timely pre-dredge sediment data and post-dredge verification samples make it difficult to evaluate the effectiveness of environmental dredging for removing the target sediment and to verify the final sediment residual levels for guiding future work at the site. Pre-dredge data were from 1976 to 1977, 15 years prior to dredging. Sediments were removed to a target depth representing 50 ppm PCBs, but did not require the collection of post-dredge verification samples.

BAYOU BONFOUCA NPL SITE
Slidell, St. Tammany Parish, LA

Bayou Bonfouca NPL Site
Slidell, LA

- Contaminants of concern:
  - PAHs (creosote)
- Dredged volume (projected/actual):
  - 46,500 cy/170,000 cy
- Project dates:
  - November 1993 - July 1995
- Dredge type/size/number:
  - Single excavator on barge w/ 5.2 cy bucket

Bayou Bonfouca NPL Site
Slidell, LA

- Waterbody type/water depths:
  - Bayou Bonfouca, a drainage channel w/ nominal 10 foot water depth
- Debris factors:
  - Rocks, construction debris and logs
- Apparently, one of the driving forces behind the need for cleanup was the constant odor complained about by the local residents before the dredging project

Bayou Bonfouca NPL Site
Slidell, LA

- Targets of Key COCs:
  - PAHs (creosote) – dredged to specified depth
- Pre-dredge concentration:
  - 1987 ROD indicates maximum sediment total PAH concentration of 13,450 ppm
- Post-dredge surficial avg. concentration:
  - Post-dredge sediment sampling was not performed for PAHs; only analyzed were PCBs (3 samples) and semi-volatiles (10 samples)
- Anomalies/confounding factors/notes:
  - No PAH post-dredging sediment sampling occurred even though this constituent was driving the remedy

Bayou Bonfouca NPL Site
Slidell, LA

- Pre-dredge species:
  - During 1981, the biota sampled had total PAH concentrations of 210 parts per million (ug/g) in plankton; 170 ug/g in crabs; and up to 0.6 ug of benzo (a) pyrene per gram of wet tissue in the clams
- Post-dredge species:
  - Post-monitoring sampling performed September 16, 1997 maximum concentrations were as follows:

Largemouth bass	-	arsenic 0.1 ppm
Largemouth bass	-	lead 0.06 ppm
White bass	-	PCBs 86.4 ppb
Unspecified Fish	-	semi-VOCs 203.6 ppm dry weight

Bayou Bonfouca NPL Site
Slidell, LA

- Capping/Backfilling:
  - Following dredging, the area was backfilled with about one foot each of sand and then gravel
- Complicating Factors:
  - Rocks, construction debris, and logs; constant oil slick on water during dredging; dredging limited to normal daylight work hours, five days per week due to proximity of residences

Bayou Bonfouca NPL Site
Slidell, LA

- Lessons Learned:
  - No pre-dredging and post-dredging average surficial sediment data are available to permit a conclusion to be reached on the effectiveness of the dredging based on exposure to sediment

MARATHON BATTERY NPL SITE
Village of Cold Spring, New York

MARATHON BATTERY

- Location:

  The site is divided into three areas, two of which are aquatic. Area II is the actual battery plant and surrounding grounds.

  AREA I

  East Foundry Cove Marsh: 12 acres of cattail marsh

  Constitution Marsh: 281 acres (Audubon Society Sanctuary)

  AREA III

  East Foundry Cove: 36 acres of tidal flat and cove

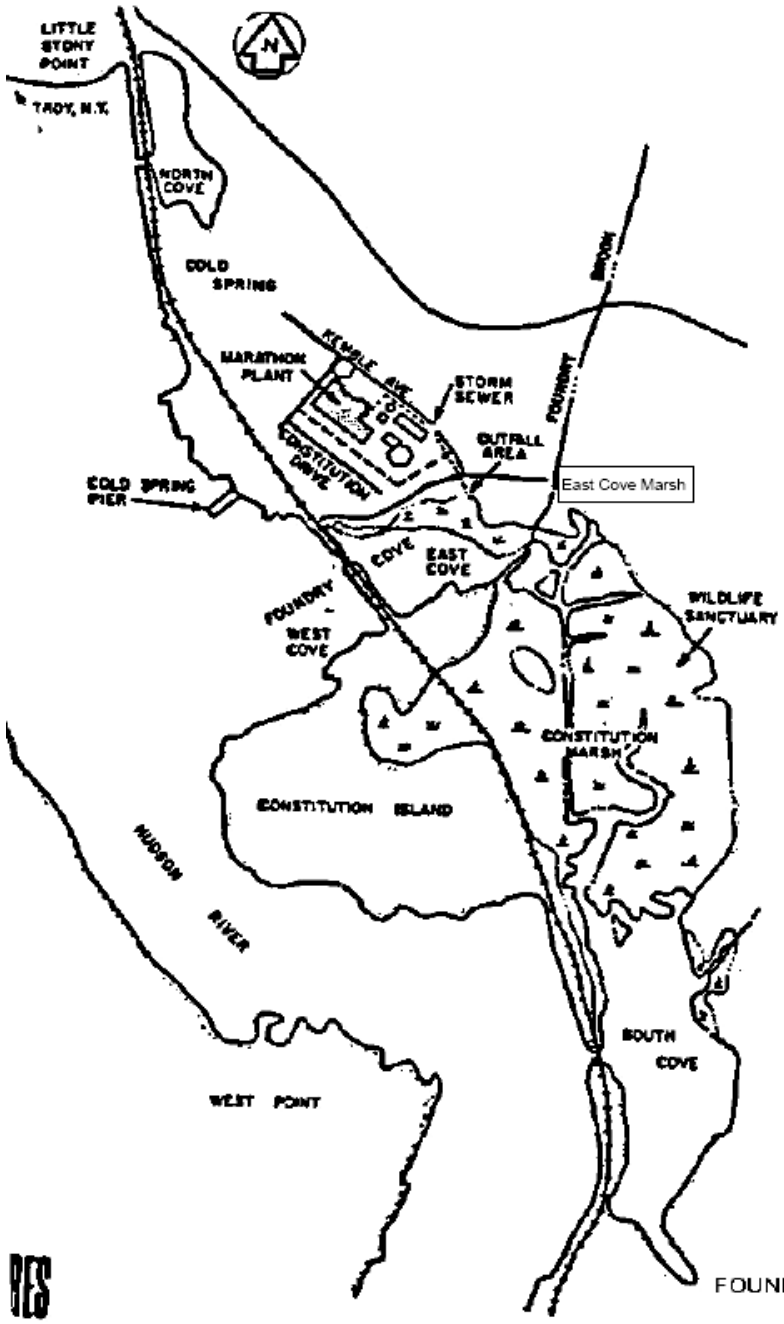
  East Foundry Cove Pond: 6 acre tidal estuary

  West Foundry Cove: slow-flow eddy area

  Cold Spring Pier area: 361 ft slow-flow eddy area

MARATHON BATTERY

Locations of Areas within the Site



FOUNDRY COVE AND VICINITY
Figure 2

MARATHON BATTERY

- Contaminants of Concern:
  - Contaminants of concern: Metals, primarily cadmium, also nickel and cobalt
- Targets of Key COCs:
  - East Foundry Cove Marsh: 100 ppm Cd for ecological protection
  - East Foundry Cove: 220 ppm Cd for human protection, 10 ppm for ecological protection
  - East Foundry Cove Pond: 220 ppm Cd for human protection, 10 ppm for ecological protection
  - Cold Spring Pier Area: 220 ppm Cd for human protection, 10 ppm for ecological protection

MARATHON BATTERY

- No numerical cleanup level. Removal was done to a depth of 1 ft because most of the mass of contaminants was located within 1 ft.

MARATHON BATTERY

- Remedy Selected & Equipment:

  Area I
  - East Foundry Cove Marsh: Dry excavation followed by capping
  - Constitution Marsh: Monitored natural recovery

  Area III
  - East Foundry Cove: Dredging
  - East Foundry Cove Pond: Dredging
  - West Foundry Cove: Monitored natural recovery
  - Cold Spring Pier Area: Dredging and excavation

MARATHON BATTERY

- Equipment:
  - For dredging: One horizontal auger dredge
  - For excavation of Cold Spring Pier: Barge-mounted clamshell
  - For dry excavation: Low ground pressure tracked excavators

MARATHON BATTERY

- Amount of Sediment Removed:
  - Amount Removed (As estimated in ROD/Actual)
    - East Foundry Cove Marsh: 30,000/23,000 cy
    - East Foundry Cove/Pond: 60,200/67,600 cy
    - Cold Spring Pier Area: 13,200/9,600 cy

- Remediation Dates (Active construction start – finish): August 1993 to April 1995.

MARATHON BATTERY

- Site-Specific Conditions:
  - The bottom consisted of silt and clay with rocks and extensive vegetation
  - Failures of the water-filled containment structures on East Foundry Cove Marsh due to material defects and to a storm. Later replaced with an earthen berm.
  - Replaced the initial dewatering system to improve performance

MARATHON BATTERY

- Site-Specific Conditions:
  - Original approach of feeding dredge slurry directly to in-line screens and centrifuges for dewatering was abandoned in favor of settling basins, due to highly variable feed quality which continuously clogged the screens
  - Dredging operations were routinely interrupted by tidal cycles
  - Restoring vegetation in the East Foundry Cove Marsh

MARATHON BATTERY

Pre- and Post-Dredging Sediment Concentrations

Sediment Cadmium Concentrations (pre-/post- remediation (2000), mg/kg)

	Area III						*Area I*			
	East Foundry Cove (Dredging)		*West Foundry Cove (MNR)*		*Cold Spring Pier Area (Dredging)*		*East Foundry Cove Marsh (Excavation)*		*Constitution Marsh (MNR)*	
Minimum	*0.29*	*0.74*	*1.1*		*1.2*	*2.5*	*70*	*0.38*	*4*	
Maximum	*2,700*	*81.2*	*569*		*1,030*	*35.7*	*116,100*	*90.0*	*940*	
Median	*5.6*		*4.2*		*3.9*		*2,800*		*170*	
Mean	*179.3*	*10.9*	*43.9*		*12.6*	*15.0*	*27,799*	*11.8*	*178*	

MARATHON BATTERY

- Capping:
  - The East Foundry Cove Marsh was capped and revegetated
- Resuspension and Release Issues:
  - A containment dike was constructed around East Foundry Cove Marsh to hydraulically isolate the marsh from the Cove and the Hudson River.

MARATHON BATTERY

- Biota:
  - East Foundry Cove Marsh & Constitution Marsh
    - Decreased Cd concentrations in livers and kidneys of swallows and marsh wrens following excavation of East Foundry Cove Marsh
  - The trends in Canada goose and wood duck are less clear
  - Few individuals were sampled (~5)
  - All these species are mobile and can inhabit both the excavated area, East Foundry Cove Marsh, and the monitored natural recovery area, Constitution Marsh, which complicates analysis of any trends

MARATHON BATTERY

- Lessons Learned:
  - Cleanup target was were achieved
  - The statistical validity of the biological data should be carefully examined

SUMMARY AND CONCLUSIONS

- Dredging is one of three primary viable remedies for addressing contaminated sediment
- However, there is NO perfect remedy to address contaminated sediment
- Dredging had been *presumed* to reduce risk for many years
- More careful scrutiny of dredging and evaluation of its effectiveness in prior and even more recent projects has raised awareness that there are significant issues with dredging effectiveness and dredging's ability to effectively reduce risk

SUMMARY AND CONCLUSIONS

- Dredging will always have a role (currently it is a significant one) when it is necessary to remove sediment because either the contaminants are bioavailable or the sediment is unstable
- Dredging has several important deficiencies in terms of achieving effective risk reduction, including:
  - Dredging almost always leaves **RESIDUALS**
    - Sometimes the residuals result in an increase in the post-dredging average surficial concentrations
    - Sometimes the post-dredging residual average surficial concentrations are lower
    - Sometimes the residual concentrations are lower, BUT do not achieve the very low levels typically considered necessary to achieve risk reduction (i.e., 1 ppm or less for PCBs)

SUMMARY AND CONCLUSIONS

- A second issue with dredging is RESUSPENSION
- Resuspension of solids with contaminants can cause increased risk, both short term and long term
- Resuspension often does not correlate well with releases to the water column
- A third issue with dredging is RELEASES, where the COC solubilizes, enters the water column, and often is transported some distance from the dredged area (such as what occurs with PCBs)

SUMMARY AND CONCLUSIONS

- With the concept of “net risk reduction,” which is recognized in U.S. EPA’s recently issued comprehensive Contaminated Sediment Guidance (December 2005), the positive and negative attributes of each remedial alternative must be evaluated, quantified and compared
- Therefore, dredging’s effectiveness at a particular site, for some or all of the remedial needs, must be realistically evaluated and compared to the projected risk reduction potential of the other alternatives of in-situ capping and monitored natural recovery, and the issues of RESIDUALS, RESUSPENSION AND RELEASE should be taken into account

SUMMARY AND CONCLUSIONS

- This Committee can serve an important role in advancing a better understanding and acceptance of the science on this important topic, by evaluating dredging effectiveness at “megasites” (and others), and thereby accelerating the realistic evaluation of dredging’s strengths and weaknesses (just as the other remedies must be equally scrutinized)
- Although there are many data gaps which preclude drawing complete and thorough conclusions at many of the completed dredging projects, there is enough information available collectively and “lessons learned” to evaluate and reach conclusions on many aspects of the effectiveness and limitations of dredging

THE SEDIMENT MANAGEMENT WORK GROUP

FOR FURTHER INFORMATION …

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