ENGINEERING
REPORT

PRELIMINARY APPRAISAL
SEDIMENT TRANSPORT RELATIONS
UPPER HUDSON RIVER

for

New York State Department of
Environmental Conservation
Albany, New York

April 1976

INTERIM REPORT

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MONS 049359

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GLOSSARY

Terms which have specific usage in this report are:

- Sediment - soil particles with grain sizes greater than 0.001 mm.
- Suspended Sediment - Sediment suspended in the river water column.
- Suspended Materials - material other than sediment suspended in the river water column including:
  - Collodial Clay - soil particles with grain sizes less than 0.001 mm., and
  - Other Material - organic materials of natural and waste product origin. A special case in the Upper Hudson is wood debris from logging and sawmill operations.
- Bed Material - The mixture of sediment, collodial clay and other materials which comprise the river bed and banks.
- Bed Load - The mixture of sediment, collodial clay and other materials moving on or near (within 4 inches) of the river bed. Measured with a bed load sampler.
- Total Suspended Solids - The mixture of suspended sediment, collodial clay and other material suspended in the river water column.
- Total Suspended Solids Discharge - The weight of total suspended solids passing a given point during a period of time, usually day or year.
- Voltatile Solids - Determined by the volatilization of organic matter in the total suspended solids.
- Fixed Solids - Determined by subtracting volatile solids from total suspended solids.
- Sediment Transport - The capacity of the river to move suspended sediment and bed load. Expressed as a concentration, parts per million (ppm), or tons per day or year (T/d or T/yr). Does not include suspended materials (as defined).

1. This report has two primary purposes:
   a. A preliminary appraisal of river sediment transport phenomena and the movement of other suspended materials and the related movement of PCB in the Hudson River between Troy Dam and Bakers Falls at Hudson River N.Y.
   b. Preparation of a study plan for required field investigations, evaluation of alternative remedial measures and selection of a recommended program for further identification and ultimate resolution of PCB contamination in the study area.
2. Computations presented in this report are based in part upon readily available information. Important additional field measurements and laboratory analyses were performed for this study and related studies of PCB contamination by NY DEC, NY Department of Health, and USGS personnel. Complete field and laboratory data are not yet available at the time of preparation of this report.
3. The movement of river materials including: sediments and other materials present in the river bed or suspended in the river water column,, has been examined using a sediment transport equation and by observation of the movement of river materials.

4. The application of sediment transport theory to the Hudson River must consider several conditions:

   a. Relatively low values of sediment transport in the River (less than 100-200 ppm measured at 100 year flood discharges) caused by low natural sediment yields from the river basin and the trapping of sediment in the seven reservoirs on the river between Hadley, N.Y. and Bakers Falls, the Sacandaga Reservoir upstream of Hudson Falls and eight river pools formed by dams between Troy Dam and Bakers Falls.

   b. The presence of relatively large amounts of organic material in the river bed and river water column. Total suspended solids in the river with volatile solids contents of 40-percent and more have been measured at low and flood flows. In addition to the common organic materials of natural and waste product origins, the upper Hudson River contains sigificant amounts of wood debris. Wood particle levels as high as 70-percent have been measured in the pool deposits of the former Fort Edward Dam.

   c. River hydraulics and thus the sediment transporting capability of the river is controlled by the eight dams in the study reach.

5. Predicted sediment transport capability has been confirmed by measurement of total suspended solids and river bed load at three river discharges which were equal to the low-flow exceeded 55 percent of the time, a medium river flow which was about equal to the mean annual flood and a high flow equal to the estimated 100-year recurrence interval in the Fort Edward area and probably a somewhat lower frequency at Troy Dam.

6. The predicted mode of movement of sediment and other materials in the river is that under low flows and moderate flood flows there will be a tendency for sediments and suspended materials brought into the river pools from tributary streams and upstream sources to deposit in the pools. Heavier particles will settle out in the upper reaches of the pools. Lighter particles will tend to travel farther downstream because the river has a tendency to be deeper at the lower end and the lighter particles have a lower fall velocity therefore taking a longer time to reach the river bed. At flood flows the transport capacity of the river increases. Materials which could not be transported through the pool (i.e. carried over the dam) at low flows and low velocities will have a tendency to be resuspended and carried out of the pool.

7. The predicted mode of movement of sediment and other materials was confirmed by calculations and measurement in the Thompson Island pool. This is the one pool of the eight below Bakers Falls where computation of sediment transport is warranted at this time since detailed hydraulic computations are available for this reach.

8. Total suspended solids, volatile solids and bed load and associated PCB concentrations were measured through the study area at three river flows:

March 18, 1976	Q = 3,600 cfs,	flow equalled or exceeded 55% of time
March 29, 1976	Q = 17,000 cfs,	mean annual flood (approximate)
April 2, 1976	Q = 39,300 cfs,	100-year flood (approximate)

Additional relevant data on total suspended solids and PCB levels have also be utilized. Measured suspended sediment concentrations at the low flow of 3,600 cfs show essentially no sediment transport into or out of the Thompson Island pool. An estimated value of 1 ppm suspended sediment is presumed to reflect movement of very small particles not susceptible to settlement. Measurements at 39,300 cfs show an increase of 140 percent in suspended sediments through the pool. This value is consistent with the concept of scour of materials previously deposited at low and medium flows.

Suspended materials show an increase with larger streamflow and a slight increase in concentration through the pool reach. This result is consistent with the suspension of organic materials as river velocities increase and the river's ability to carry them more or less independently of the transport forces present.

9. Theoretical analysis and measured total suspended solids, volatile solids and bed load demonstrate that sediment and other materials in the bed of the Hudson River will be transported throught the study area and into the Estuary and streamflows exceeded about 10 percent of the time during an average year.

10. PCB has been measured both in the river bed material and in the suspended sediment and the suspended material in the river water column. During periods of suspended sediment and suspended material movement PCB concentrations were measured at levels up to 9 ppb.

11. Based upon the foregoing measurements and neglecting transport of PCB at river flows less than those occuring 10 percent of the time, 5,000 to 10,000 pounds of PCB per year, on the average, are transported down the Hudson River at Waterford and into the Hudson River Estuary.

12. Assuming that there are currently no significant discharges of PCB to the Upper Hudson River; sources of the PCB being moved are principally the river pools behind each dam below Fort Edward and the remnant pool deposits at the former Fort Edward Dam.

13. An immediate program of field investigations and technical studies related to river dredging and other remedial measures is recommended in order to refine present understanding of the magnitude and extent of PCB contamination in the study area and to demonstrate the feasibility and cost of dredging.

The recommended program has four principal areas:

- o Field investigations
  - Control Surveys
  - Bed material sampling
  - River depth surveys
- o Engineering Studies
  - Evaluation of dredging techniques
  - Spoil site studies
  - Pilot dredging operation
  - Pilot treatment of dredge water
- o Alternative Evaluations
  - Dredge/Treatment/Spoil vs. PCB Removal
  - Alternate programs, cost estimates, schedules
  - Contract documents

o Environmental Assessment

14. A program of biological and water quality monitoring is recommended in addition to the above program in order to verify river conditions and to monitor the future progress in river restoration.

I. INTRODUCTION

Purpose

This evaluation has two primary purposes:

1. A preliminary appraisal of river sediment transport phenomena as it relates to the PCB contaminated sediments of the Hudson River between Troy Dam and Bakers Falls at Hudson Falls, N.Y.

2. Preparation of a study plan for required field investigations and the evaluation of alternative remedial measures for resolution of the PCB contamination.

This preliminary appraisal is part of the required response by DEC to the Interim Opinion and Order in the matter of Alleged Violations of Sections 17-0510, 17-0511 and 11-0503 of the Environmental Conservation Law of the State of New York by: General Electric Company, File No. 2333, dated February 9, 1976. Section III, Outstanding Remedial Issues (page 75) of the Interim Opinion and Order states, in part:

"Other issues include:

1. The extent to which GE should be ordered to rectify the effects of its prior discharges, including whether any practicable and environmentally safe method exists or can be devised to remove PCB's from the river bottom, and the expected duration and extent of PCB contamination if no remedial steps are taken;"

This appraisal will aid in that determination.

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Discussions have also been held with DEC personnel in order to characterize related considerations affecting the Hudson River PCB problem.

Study Area

The study area for this preliminary appraisal is the reach of the Hudson River from Troy Dam (mile 151.5) to Bakers Falls at Hudson Falls, New York (mile 197.1); a distance of approximately forty-six miles.

The river at the U.S. Geological Survey stream gage at Green Island, just above Troy Dam and just below the mouth of the Mohawk River, has a drainage area of 3,090 square miles. The Mohawk River drains 3,456 square miles at Conoes which gives a net upper Hudson drainage area of 4,634 square miles at Troy Dam. The drainage area of the Hudson River at the State Route 197 bridge three miles downstream of Hudson Falls, New York is 2,813 square miles.

Scope

This preliminary appraisal has been based upon:

1. A review of existing pertinent reports and data on river cross sections, river hydrology, physical characteristics of river sediments and river water quality data.
2. Additional field data acquired by: DEC personnel; Dr. Thomas Zimmie of Rensselaer Polytechnic Institute under contract to DEC; and U.S.

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Geological Survey (USGS) personnel of the Albany district office. Mr. Thomas Haddock, Jr., of the USGS National Center, Reston, Virginia has been consulted on the sedimentation engineering aspects of these evaluations. His services were made available through the NY State USGS cooperative agreement. Mr. Robert Forest, Chief Engineer, Hudson River-Black River Regulating District, provided valuable cooperation during field data collection periods.

Evaluation of sediment movement in the study reach has been based upon several factors:

- Sediment movement experienced with the Fort Edward Dam removal
- Tractive forces
- Sediment transport theory
- Sedimentation in river pools
- Past data on river total suspended solids
- Special river measurements

Computations of sediment transport have been focused on the river reach between Thompson Island Dam (also known as Crocker's Reef Dam), mile 185.5, and the State Route 197 bridge at Fort Edward, mile 194.1. There are several factors which warrant this approach:

- Detailed water surface computations are available for this reach (Reference 1).
- Present data indicate this to be the most highly PCB contaminated reach of the river.
- This pool is continuing to receive contaminated sediments from the former Fort Edward Dam pool area just upstream.

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Some physical data are available on the seven pools below Thompson Island Dam. Assumptions required to evaluate sediment transport capabilities and tractive forces in these pools are such that these computations are not warranted at this time. Past and recent sediment observations in the seven pools provide a reasonable basis for present evaluations.

II. RIVER HYDROLOGY AND HYDRAULICS

Hudson River low flow and flood flow characteristics in the vicinity of Fort Edward, N.Y. were developed for the report on the "Investigation of Conditions Associated with the Removal of Fort Edward Dam, Fort Edward, N.Y., February 1975", (Reference 1). Streamflow relations used in this study have been based upon this report with adjustment for increases in the river drainage area between Fort Edward and Troy Dam.

Water surface profiles (river levels) were developed in the above report for the reach of river from a point approximately 3,000 feet upstream of Thompson Island Dam (Crocker's Reef Dam in report) to the foot of Bakers Falls. Profiles were computed for the river low flow equaled or exceeded 90 percent of the time (2,500 cubic feet per second, cfs), the mean annual flood (20,600 cfs), five-year and 100-year recurrence interval floods (25,000 and 41,400 cfs) and the May 4, 1972 flood (35,800 cfs, estimated 30-year recurrence interval). River cross section data and computed energy gradients and velocities for the above river discharges are presented in the report.

Characteristics of the river downstream of Thompson Island Dam were developed from DEC data on river cross sections (Reference 2). Data on river pools are summarized in Table 1.

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TABLE 1

CHARACTERISTICS OF RIVER POOLS

Pool	River Mile at Dam	Pool Length miles	Area acres	Average Width, feet	Average Depth, feet	Volume acre-ft	Volume mil gal	Drainage Area, sq mi
Troy Dam	153.9	5.4	530	700	14	7,400	2,400	8,090
Lock 1	159.3	4.1	390	850	10	4,000	1,300	4,600
Lock 2	163.4	2.4	250	800	9	2,400	780	4,500
Lock 3	165.8	1.7	350	1100	9	3,300	1,100	4,400
Lock 4	168.0	15.2	1,160	600	12	14,100	4,600	3,700
Lock 5	183.2	2.9	225	650	13	2,900	940	2,900
Lock 6	186.1	2.3	100	600	9	940	305	2,930
Thompson Island	188.4	5.2	380	550	12	4,400	1,400	2,920

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III. RIVER SEDIMENTS

Development of the Hudson River for water power and navigation in the early 1800's converted all but approximately 4 miles of the relatively steep stream reaches and waterfalls in the study area into a series of eight pools behind dams between Troy Dam and Fort Edward, a distance of about 40 miles. These pools have typical depths of 10 to 20 feet and typical widths of 600 to 1,000 feet. From Fort Edward to Hadley, N.Y. seven additional dams varying in height from about 10 to 80 feet create additional Hudson River Pools. Sacandaga Reservoir is a large reservoir near the mouth of a principal tributary of the Hudson near Hadley.

The average annual sediment discharge passing Bakers Falls is on the order of 40,000 to 50,000 tons per year based upon DEC water quality observations of total suspended solids at Fenimore Bridge, Hudson Falls (2,800 sq mi).(1) This is equivalent to 15 to 20 tons per square mile per year (T/sq mi/yr).

(1) Estimate is based upon observed relation between fixed suspended solids and stream flow. Fixed suspended solids = Total suspended solids - volatile suspended solids. Volatile suspended solids approximate the natural and waste product organic materials in the river.

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As a comparison, the Delaware River at Trenton, New Jersey (6,780 sq mi) has a measured suspended load of 150 T/sq mi/yr.(1)

Sediment transport through the study area, therefore, has a relatively low value. This results from the low values of natural sediment yield from the river basin and the tendency for the river pools above Fort Edward to trap sediments.

Fort Edward Pool Deposits

A striking example of the limited sediment carrying capacity of the Thompson Island Pool below Fort Edward was observed subsequent to the removal of the Fort Edward Dam in the summer of 1973. As reported in the previously referenced study (Reference 1), approximately 850,000 cubic yards of deposits were scoured from the former pool during July 1973 - July 1974. 775,000 cubic yards of this material was deposited between the dam site and the Champlain Canal below Fort Edward. This deposited material was removed and deposited in spoil areas on the west bank of the river. The difference in scoured material and in deposited material is due in part to transport of sediment and other suspended material down the river.

(1) as reported in Reference 5, page 76.

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Anotner interesting feature of tne pool deposits is tne large volume of wood debris present. Tests indicated that tne amount of wood varied from 9 to 72 percent based on dry weight of boring samples. The wood debris consists of logs, wood slats and chips and sawdust; all waste products of tne once flourishing Adirondack lumbering industry. The relevance to the present concern over PCB transport is the fact that much of the material subject to movement from tne former Fort Edward pool to the Thompson Island Pool, and in other portions of the river, have transport and settling characteristcs different from natural sediments.

Tractive Forces

Water flowing over the stream bed exerts a shearing stress or tractive force. The ability of tne stream bed to resist tne tractive force depends upon the grain size distribution of tne bed sediments and tne cohesive forces which may exist due to tne presence of silt or clay particles.

Tractive forces experienced in the Thompson Island Pool have been computed for three flow conditions. Results of tne analysis are presented in Table 2.

Median grain sizes for river bed sediments vary from 0.2 to 0.7 mm as measured at five pool locations from Bakers Falls to Waterford. The tractive force which would cause

TABLE 2

TRACTIVE FORCE

Station(1)	River Mile	90% duration low flow Q=2,500 cfs		Mean Annual Flood Q=20,800 cfs		100-year Flood Q=41,400 cfs	
		V	T	V	T	V	T
15300	183.9	0.23	0.0007	1.5	0.01	2.3	0.02
19250		0.46	0.0008	2.9	0.04	4.4	0.08
36650		0.63	0.0025	3.0	0.05	4.6	0.08
39920		0.47	0.001	2.8	0.035	4.3	0.08

(1) Stations for river cross sections from Reference 1

V = mean channel velocity, ft/sec

T = tractive force computed at each section from average channel depth, velocity and energy gradient given in Reference 1., lb/sq ft.

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movement of conesionless sediments with these sizes is approximately 0.004 to 0.008 lb/sq.ft (1). Ref. Critical mean water velocities for these grain sizes (sufficient to move the bed sediments) are 0.6 to 0.7 ft/sec.

This tractive force analysis, although approximate and based upon limited information, shows that river forces are sufficient to move observed bed materials at flows exceeding low flows. This finding is consistent with subsequent analysis.

Sediment Transport

Sediment transport capabilities of the Thompson Island Pool have been estimated by use of the Maddock sediment transport function (Reference 4). Values were computed for the upper pool section at the State Route 197 Bridge (Station 43920) and at the lower pool section near the Thompson Island Dam (Station 15300). Channel hydraulic characteristics for these sections were taken from Reference 1.

Computed values for sediment transport are given in Table 3. These values can be used to estimate the movement of sediment into and out of the Thompson Island Pool.

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(1) Reference 3, p. 4-9.

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TABLE 3

SEDIMENT TRANSPORT
THOMPSON ISLAND POOL

Location	River Flow, cfs	Predicted Sediment Concentration for a Median Grain Size of: d_{50}, ppm				River Flow, cfs	Measured Suspended[2][3] Sediment Concentration, ppm	Measured Volatile Solids Concentration (organic materials) ppm	Total Suspended Solids ppm
		0.001	0.01	0.1	0.2				
0.5 mile above dam (mile 108.9) lower end of pool	2,500	-	-	-	-	3,600	1	4	5
	20,600	-	-	-	-	17,000	10[4]	10	20
	41,400	*	40			39,300	80	45	125
Route 197 - East Channel (mile 194.1) upper end of pool	2,500	-	-	-	-	3,600	1	3	4
	20,600	*	2,530*	35	10	13,500	X	X	20[5]
	41,400	*	4,345*	70	30	39,300	35	40	75

(1) Expected total sediment concentration (suspended and bed load) of the sediment mixture with a median grain size as indicated. Computed by Haddock relation (Reference)

(2) Inorganic fraction of total measured suspended sediments determined by subtracting volitle solids from total suspended solids. Median grain sizes of collected simple not yet available.

(3) Grab samples collected by DLC personnel at these and other river locations (except as noted) are supported by suspended sediment measurements by USGS which results are not yet available. Values shown are rounded to reflect probable accuracy.

(4) Median grain size of this concentrations expected to be less than 0.001 mm but no determination of grain size made on this sample.

(5) Average of 2 USGS suspended sediment measurements.

(-) Indicates no transport capacity for sediment mixtures with median grain size indicated.

(*) Indicates sediment mixtures with this median grain size are not anticipated.

(X) Indicates not measured.

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Field measurements - The validity of the estimates of sediment transport capability has been confirmed by several sets of field observations of river sediment concentrations. A comparison of computed and measured sediment transport is given in Table 3.

Selected results of observed total suspended solids and volatile solids through the study area are shown in Table 4. All values in Table 4 are "grab samples" collected by DEC personnel. USGS measurements at comparable river discharges have been made but results are not yet available.

As indicated in Table 4, measured sediment concentrations (as estimated by fixed solids) at the low flow of 3,600 cfs show essentially no sediment transport into or out of the Thompson Island pool. The value of 1 ppm suspended sediment is presumed to reflect movement of very fine particles not susceptible to settlement. Measurements at 39,000 cfs shown an increase of 140 percent in suspended sediments through the pool. This value is consistent with the scour of materials previously deposited at low and medium flows. Suspended materials (as estimated by volatile solids) show an increase with larger streamflow and a slight increase in concentration through the pool reach. This result is consistent with the suspension of organic materials as river velocities increase.

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TABLE 4

OBSERVED SUSPENDED SOLIDS CONCENTRATIONS
ppm

Location	Mile	March 18, 1976 Q = 3,600 cfs 55% Duration Tot.	Vol.	Fix.	March 29, 1976 Q = 17,000 cfs Mean Annual Flood (approx) Tot.	Vol.	Fix.	April 2, 1976 Q = 39,300 cfs 100-year Flood (approx) Tot.	Vol.	Fix.
Troy Dam	153.9	12	4	8	66	15	51	185	30	155
Mohawk River		13	3	10	76	16	60	206	33	173
Rt. 4 Br., Waterford	156.5									
Lock 1, Dam	159.3	5	4	1	61	15	46	171	46	125
Lock 2, Dam	163.4	7	4	3				210	48	162
Br., Mechanicville										
Lock 3, Dam	165.8	2	1	1				175	38	137
Lock 4, Dam	168.0	11	4	7				171	43	128
Rt. 67 Br., Stillwater	168.1									
Rt. 29 Br., Schuyerville										
Lock 5, Dam	183.2	7	5	2	34	12	22	125	33	92
Rt. 4 Br., Northcumberland	183.5							104	39	65
Lock 6, Dam	186.1	6	4	2				133	53	80
Thompson Is. Dam	188.4	5	4	1	22	11	11	123	44	79
Rt. 197 Br., Ft. Edward	194.1	4	3	1				75	42	33
Fenimore Bridge	197.1							60	25	35

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Note: Grab samples by DEC.

Tot. = Total Suspended Solids
Vol. = Volatile Solids
Fix. = Fixed solids

DEC Monitor Stations - Total suspended solids and volatile solids measured at DEC water quality monitoring stations are also available. Data from the following stations have been examined:

Sampling Period?

Mile 197.1 - Hudson Falls
Mile 194.1 - Fort Edward, East Channel
Mile 183.5 - Route 4 Bridge, Northumberland
Mile 168.1 - Route 67 Bridge, Stillwater
Mile 156.5 - Route 4 Bridge, Waterford

Bed Load Measurements - Bed load measurements at the three river flows identified in Table 4 have been made by Dr. Thomas Zimmie under contract to DEC. Preliminary results indicate that bed load movement is measurable, especially at the 100-year flood discharge. Total weight of bed load material moved, however, is small compared to the total suspended load based upon preliminary estimates of Dr. Zimmie.

Total Suspended Solids Discharge - The total suspended solids moving through the Thompson Island pool has been estimated for the 9-day flood period March 31 - April 8, 1976; approximately a 100-year flood event. Total suspended solids concentration variation with river flow is based upon observed values. Total inflow computed at Fort Edward is 36,000 tons. Total pool outflow is estimated at 45,000 tons, a net increase in total suspended solids, or a pool scour, of 9,000 tons is indicated. If it is assumed that this scour took place in the lower one-third of the pool,

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where finer materials would be located, an average bed lowering of 0.05 ft or 0.6 inches is indicated.

On an annual average basis approximately 70,000 tons of total suspended solids enter the Thompson Island pool. About 60 percent of this transport will occur at river flows equaled or exceeded about 10 percent of the time. Currently available data indicate that approximately 80,000 tons of suspended solids will leave the pool on an annual average basis. This increase of about 10% is subject to confirmation and may not be meaningful.

Sedimentation in River Pools

Sediment transport estimates in the Thompson Island Pool reach (Table 3) shows that sediment deposition takes place in the pool at low and medium stream flows. This prediction can be confirmed for the Thompson Island Pool and extended to the remaining pools in the study area through application of sedimentation theory.

Sedimentation tanks are commonly characterized by overflow rates. Overflow rates for the Hudson River pools below Bakers Falls at three river discharges are shown in Table 5. These rates are generally within the range of tank design.

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TABLE 5

RIVER POOL OVERFLOW RATES

Pool	River Mile At Dawn	Pool Area Acres	Pool Volume mi/gal	Overflow Rate - gal/day/sq ft At Q 90	Q 2.3	Q 100
Troy Dam	153.9	530	2,900	-	-	-
Lock 1	159.3	390	1,300	100	1,400	2,300
Lock 2	163.4	390	780	150	2,100	3,500
Lock 3	165.8	350	1,100	100	1,500	2,500
Lock 4	168.0	1160	4,600	30	300	700
Lock 5	183.2	225	940	200	1,400	2,700
Lock 6	186.1	100	305	500	3,100	6,100
Thompson Island		380	1,400	100	800	1,600

Q 90 = Flow equaled or exceeded 90% at the time = 2,500 cfs at Ft. Edward

Q 2.3 = Mean annual flood = 20,600 cfs at Fort Edward

Q 100 = 100-year recurence interval flood = 41,400 cfs at Fort Edward

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The preliminary evaluation of percentage of suspended particles removed in the river pools for inorganic particles (specific gravity = 2.3) and sawdust particles (specific gravity = 1.05) are as follows:

	SG=2.3		SG=1.05	
gal/d/sq ft	0.1 mm	0.01 mm	0.1 mm	0.01 mm
100	100	55	75	4
1000	100	10	25	0
2000	85	5	10	0

Comparison of the river pool overflow rates contained in Table 5 with the corresponding range of removals for various particles shown above, indicates that a marked difference in settling of inorganic particles (suspended sediments) and sawdust particles exists. At high river flows (i.e., high overflow rates) essentially all sawdust particles and related suspended materials will pass through the river pools. Under high flows much of the suspended sediments greater than about 0.1 mm in size will be trapped in the river pools.

IV. RIVER SUSPENDED MATERIALS

For the purpose of the study, suspended materials being transported by the river are defined as colloidal clay particles with grain sizes less than 0.001 mm and other materials consisting of organic materials of natural and waste product origin. Other suspended materials include algae, microorganisms and wood deoris.

These materials are significant in the Upper Hudson for two reasons:

1. Because of the low sediment transport of the river organic suspended materials may makeup as much as 50 to 75 percent of the total suspended solids being transported by the river during low stream flow. Observed total suspended solids must be corrected, therefore, to give a better indication of suspended sediments. The test for volatile solids has been used as a measure of organic material.

2. Colloidal clay particles and organic materials have very low or zero settling rates. These particles are not likely to settle out in the river pools even under the most favorable conditions for settling. At streamflows experienced most of the time, therefore, observed river total suspended solids will consist largely

of colloidal clay and organic materials. Flocculation of suspended materials may take place in the river and result in increased settling rates.

Suspended materials do not follow the ordinary sediment transport relations applied in Section III. The measured values of organic material as indicated by volatile solids at the sampled streamflows (Table 4) have been used in suspended material estimates.

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V. - PCB CONCENTRATION

The amount of PCB associated with river bed material and in the river water column have been determined in several groups of DEC and USGS samples.

Variations in PCB levels in river bed material have been reported in a DEC report[1] and in recent DEC data from surveys conducted during the period February 24 - March 9, 1976. These data show a marked reduction in PCB levels from the Thompson Island Pool to below Lock 1 and into the Lower Hudson River.

River Water Column - River water column levels of PCB are available for a number of points in the study area. Observed PCB levels at Fort Edward (Route 197 Bridge), Thompson Island Dam and near Northumberland, are plotted vs. the mean daily flow at Spier Falls in Figure 1. The following observations plotted in Figure 1 were made subsequent to September 1975.

(1) PCB Monitoring in the Upper Hudson River Basin, NY DEC, October 1975.

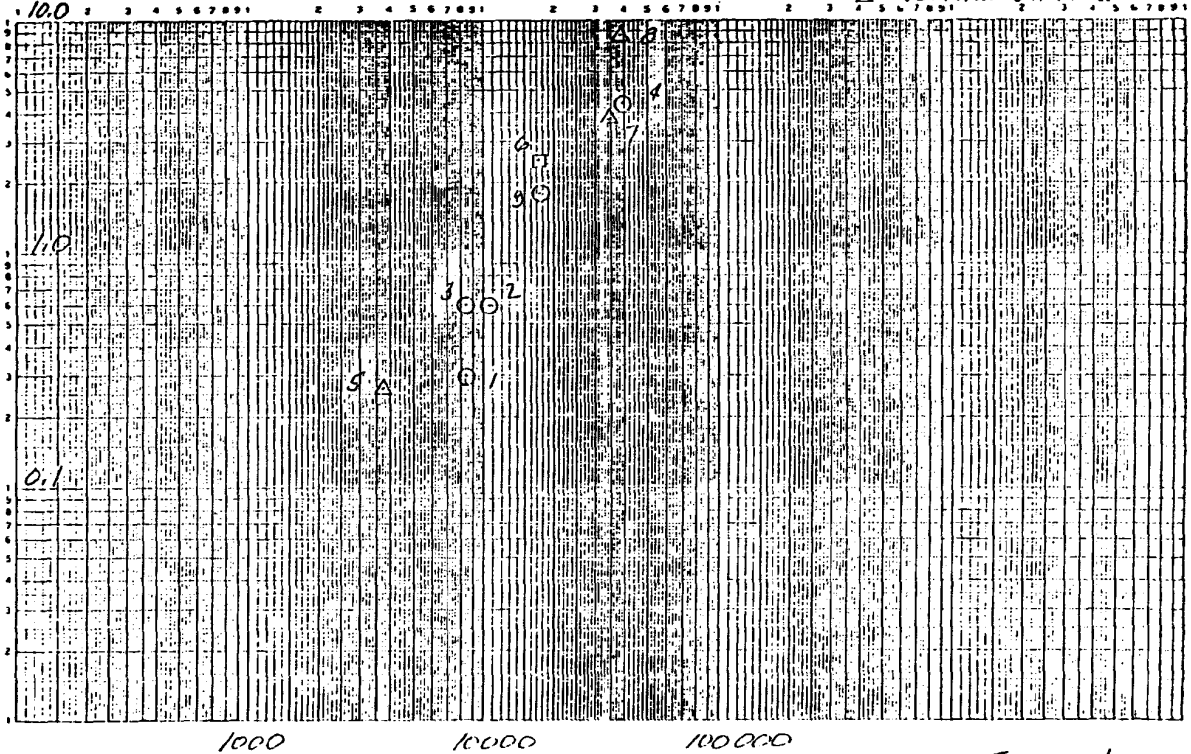

Figure 1

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Point on Figure 1	Date	PCB ppb	Spier Falls Discharge, cfs	Location
1	10/28/75	0.3	8840	Ft. Edward
2	11/18/75	0.6	10440	Ft. Edward
3	12/16/75	0.6	8340	Ft. Edward
4	4/2/76	4.4	39310	Ft. Edward
5	3/29/76	0.27	3600	Northumberland below Lock 5
6	3/29/76	2.5	17250	Thompson Is. Dam
7	4/3/76	3.8(1)	33360	Northumberland Route 4
8	4/2/76	8.7(2)	39310	Northumberland Route 4
9	3/29/76	1.8(3)	17250	Ft. Edward

(1) average of 2 values
(2) values for araclor 1221 and 1254 only
(3) estimated from value for laboratory filter

A similar plot for PCB levels at Waterford is shown in Figure 2. This figure is based upon the following observations made subsequent to September 1975:

Point on Figure 2	Date	PCB ppb	Waterford Discharge, cfs
1	10/10/75	0.3	7170
2	10/20/75	0.9	30240
3	11/7/75	*	5320
4	10/10/75	*	5320
5	11/20/75	*	9270
6	12/5/75	*	6910
7	12/18/75	*	6670
8	12/22/75	*	5165
9	1/6/76	*	2640
10	1/28/76	3.6	13000 ice condition(1)
11	1/29/76	*	15000(1)
12	3/15/76	0.1(2)	5300(1)
13	3/23/76	0.11	15000(1)
14	3/31/76	2.1	33000(1)
15	3/18/76	0.18	4100(1)

* less than 0.1
(1) Discharge estimated from relation with Spier Falls.
(2) Estimated from value for laboratory filter.

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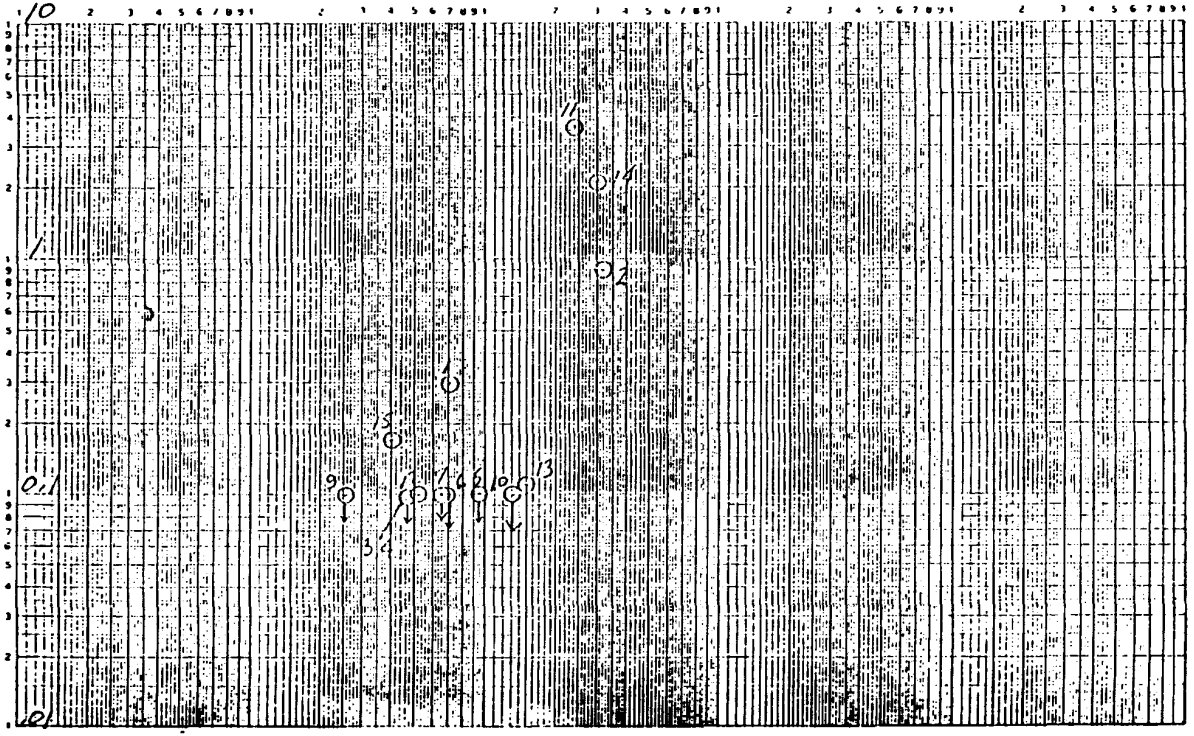

Figure 2

The average annual transport of PCB to the Lower Hudson River has been estimated using the relation for Waterford presented in Figure 2. For flows equaled or exceeded 10 percent of the time (16,000 cfs at Waterford) the PCB transported will total 5,000 to 10,000 pounds per year. A range of transport is given to allow for the scatter shown in the data in Figure 2. PCB transport at flows which occur 90 percent of the time have been neglected in this estimate.

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VI. RELATED CONSIDERATIONS

In addition to potential PCB transport by river sediments and suspended materials, three additional transport mechanisms are identified:

- o floating materials
- o dissolved phase resulting from direct discharge and/or release of PCB from contaminated river bed materials
- o food web.

A complete appraisal of PCB transport and its environmental consequencies requires consideration of the above mechanisms. Such considerations are being carried out or coodinated through DEC.

VII IMPLICATIONS OF PRELIMINARY APPRAISAL

The estimates of sediment and suspended materials movement and deposition through the eight river pools between Bakers Falls and Troy Dam have been confirmed by measurements at low, medium and high flood flows. The computed and measured data demonstrate that the Hudson River is a relatively low sediment yielding stream which is significantly affected by the characteristics of the river pools in the study reach. Even at high flood flows (approximately 100-year recurrence interval) a relatively low volume of sediment and other suspended materials is moved.

However, PCB contaminated sediments and suspended materials are continuing to move over the Troy Dam. Calculations of PCB transport based upon currently available measurements show that a 0.1 ppb PCB threshold at Waterford will be exceed about 10 percent of the time with PCB concentrations up to of 9 ppb.

Contaminated materials originate primarily in the former Fort Edward and the Thompson Island pools with the assumption that there are currently no significant discharges of PCB to the Upper Hudson River. These pool areas contain the highest measured levels of contamination and are also subject to low inflows of uncontaminated materials which might cover existing contaminated deposits.

VIII NECESSARY DETAILED STUDIES

Although significant conclusions can be drawn from this preliminary appraisal, detailed field investigations and technical studies are warranted in a problem of the magnitude and complexity of the PCB contamination of the Hudson River. Refined data and detailed analysis of sediment and suspended material movement in the river and associated elements of the PCB problem are justified for three reason:

1. Reduction of present uncertainties related to technical aspects of the problem, such as, dredging techniques, treatment of dredged materials and alternative methods of reducing the PCB contamination to an acceptable level,

2. Determination of the location and characteristics of PCB contamination in the pools of the study area in detail adequate to optimize the cost-effectiveness aspects of alternative remedial programs, and

3. Preparation of an environmental assessment of alternative remedial programs.

Performance of adequate and reliable evaluations of alternative courses of action in resolving the PCB problem is necessary in order to assure the public and many interested groups and agencies that a proper solution has been implemented.

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The detailed studies necessary involve four categories:

1. Field Investigations
2. Engineering Studies
3. Evaluation of Alternatives
4. Environmental Assessment

A brief statement of the purpose and scope of these categories, as they relate to engineering solutions, is given in the following paragraphs.

Because of the critical nature of the PCB problem these studies should be initiated at the earliest opportunity.

Field Investigations - Field investigations will involve three principal work areas:

- o Survey of baseline for control of field measurements and possible future remedial dredging.
- o River depth measurement at selected cross sections.
- o Collection and analysis of bed sediments.

It is anticipated that the survey baseline and river depth measurements will be limited to the pool areas that would require remedial dredging. Bed sediment samples and a limited number of flood plain samples will be collected and analyzed for PCB on a reconnaisance basis in all of the pools in the study reach. Approximately three to five samples will be collected in each pool. This data will

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confirm that remedial measures can be limited to specific pool reaches. More detailed sampling will be carried out in the critical reaches. Detailed sampling will likely consist of three samples across the river at 2000 to 3000 foot intervals along the river. River depths will be determined at each sample section. The detailed sampling and depth measurement will be controlled by the survey baseline.

Engineering Studies - Engineering studies will emphasize the technical and economic aspects of river dredging programs. There are five study areas:

- Dredging Evaluation: Evaluate the performance and cost of alternative dredging techniques and their impacts on loss of fine materials at the dredge head, interference with river navigation, ability to control depth of cut and work in shallow river areas.
- Spoil Sites: Identify and analyze potential spoil sites including their storage capacity, acquisition cost, wetland and ground water impacts, present and subsequent land use potentials and their compatibility with dredging program needs.

- o Water Treatment Pilot Plant: Conduct laboratory and field pilot scale studies of alternative treatment techniques in order to develop performance - cost functions for treatment of dredge return water flow.

- o Demonstration Dredging: Conduct demonstration of dredging techniques to confirm performance with Hudson River conditions.

- o Model of River Sediment Movement: Modify, as necessary, existing computer models and apply to analysis of river hydraulics and sediment and other materials movement through the river pools. This analysis will aid in refining evaluations of necessary dredging areas.(1)

Alternate Evaluations - Evaluate performance - cost relations for alternative remedial programs including dredging of critically contaminated areas and other viable programs that may be developed. Work areas include; description of the relations between PCB removal from the environment and the dredging/treatment/spoil system, program cost estimates and schedules and contract documents for the recommended program.

(1) An example of such a program is: Scour and Deposition in Rivers and Reservoirs, U.S. Corps of Engineers,, Hydrologic Engineering Center; September 1975.

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Environmental Assessment - An environmental assessment will be prepared based upon:

- o Necessary baseline data,
- o Participation in the field surveys and investigations undertaken,
- o Review engineering studies and alternative evaluations.

IX REFERENCES

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