THE TURBIDITY PROBLEM IN THE EASTERN RIVER, DRESDEN, MAINE

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The Turbidity Problem in the Eastern River, Dresden, Maine

By

James Connors
Allen Myers
Barry Timson

Earth Surface Research, Inc.

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THE TURBIDITY PROBLEM IN THE EASTERN RIVER, DRESDEN, MAINE

I. Introduction

With the increased awareness of the poor quality of Maine river waters, local concern of Dresden citizens has focused on the apparent high levels of suspended sediment (turbidity) in the tidal portions of the Eastern River. Whether or not the turbidity of the lower river represents a real water quality problem, simple observations along the lower stretches of the river "revealed" "muddy waters" compared to observations of the river's upper reaches or any of its tributaries (Gardiner Hunt, 1969).

Local residents feel that the turbidity problem has increased over the past 5 to 30 years. Speculation as to the causes of increased turbidity in the river has ranged from the muddying of the waters by carp populations to the introduction of additional sediment into the lower reaches by Kennebec River flow. Agricultural activity is not perceived to introduce significant amounts of soil material to river waters (Letter of D. Bruce Champeon, 1980).

In an attempt to quantify and determine the causes of turbidity within the Eastern River, the Dresden Planning Board sought to undertake a study of the problem. The Planning Board issued a Request for Proposals to conduct a sampling program and analysis of the turbidity phenomena in 1981 utilizing Coastal Zone Management funds distributed by the Maine State Planning Office.

Although scaled down from the original scope of the study intended by the Planning Board, this study is the result of the Planning Board's attempts to analyze the turbidity problem of the Eastern River and represents the first interdisciplinary analysis of the problem.

A. Objectives of the turbidity problem study.

This study is an in-depth analysis of the possible causes of turbidity in the lower portions of the Eastern River. The analysis was confined to investigating existing data on the problem, without undertaking an extensive monitoring program, although field trips were conducted along the river by canoe, foot, and vehicle to observe the existing situation. The study was designed to gather all existing written data on the Eastern River, analyze the data, and investigate areas of concern which would influence the levels of turbidity in the river.

Those areas of concern which were investigated are:

- Land use activity within the drainage basin which might increase soil erosion, including changes in land use patterns over the past twenty years which may cause an increase in the levels of soils delivered to the river.

- Geologic factors influencing sedimentation within the river basin and the amount and type of sediment delivered to the tidal portions of the river channel.

- Hydrologic factors of the drainage basin and tidal channel which determine the discharge to the river channel, flushing characteristics of the tidal portions of the river, and stability of the tidal flat surfaces in the river.

- Biological factors of the tidal riverine portions of the basin which influence the stability of sediment on flats and within the water column.

- Water quality criteria in order to relate the known turbidity levels within the river to known limiting values of turbidity in the environment.

The specific goals of this study were to:

1. evaluate the known turbidity values of the Eastern River as a water quality problem.

2. isolate probable causes for the perceived high turbidity levels in the Eastern River; and

3. recommend further monitoring tasks to determine the actual cause of heightened turbidity or mitigating actions which would prevent or lessen the turbidity levels.

II. Turbidity Levels in the Eastern River

The turbidity of a given water sample or water body is a measure of the extent to which the intensity of light passing through is reduced by the suspended matter. Turbidity and concentration of suspended sediment are not synonymous-- turbidity results from, and is one effect of, an increased concentration of suspended matter. Throughout this report, the distinction between these two terms will be maintained. The concentration of suspended matter (or sediment) in water is the measure of weight of the amount of matter within the water.

Excessive turbidity will affect the use of a water body as a domestic water supply and as a habitat for aquatic life forms. It also will affect aesthetic quality of the water body for recreation other than fishing.

More specifically, increased concentrations of suspended matter cause the following adverse impacts:

- reduction of light transmission through the water and thereby inhibit the growth of underwater plants that are the primary food source for aquatic life;

- interference with nursery grounds or other habitats of aquatic life;

- settlement of organic suspended solids to form oxygen-demanding sludge deposits;

- esthetic degradation; and

- a taste and odor problem for potable water supply.

Hunt (1969) found turbidity values of from 25 to 120 units in the tidal portion of the Eastern River. Turbidity units are defined in terms of the depth of water to which a candle flame can be clearly distinguished. For the purpose of comparison, most standards for drinking water stipulate that drinking water should not exceed 5 turbidity units and, in most instances, should average no more than 1 unit (EPA, 1977).

Hunt's turbidity values in the Eastern River are equivalent to about 35 to 350 milligrams per liter (mg/l) of suspended sediment (Section V of this report). These values can be compared to suspended sediment concentrations found in the Kennebec River at Richmond (3.5 to 9.5 mg/l) and off Abagadasset Point in Merrymeeting Bay (27.2 mg/l) in 1973 and 1974 (E. C. Jordan, 1975).

While these measured values represent only a few samples collected years apart, it appears that the Eastern River exhibits higher levels of suspended matter than the Kennebec River-- up to 100 times greater concentration.

III. Historical Land Use In The Eastern River Drainage Basin

The Eastern River encompasses portions of the town of Dresden and Pittston, Whitefield and Windsor (Figure 1).

Upland sources of silt are related, in part, to the variety of land use practices that occur in the river's watershed. Some land use practices can be a source of silt contributing to the perrenial coffee color of the Eastern River. An attempt to document the types and extent of land uses in the watershed over time, and to estimate the contribution ofsediments they could make to the river was undertaken utilizing photographic interpretation to delineate historical land uses.

Land erosion is created or accelerated as a result of human activities on the landscape. By utilizing the earth's surface and its resources for the production of goods and products it is, by necessity, disturbed as the result of transporting forest products, plowing and building activities, for example. These disturbances can sometimes interrupt the natural cycles of runoff and erosion of natural soils and surface sediments resulting in increased erosion and sedimentation.

Figure 1: Location of the Easter River Drainage Basin.

Scale: 1:250,000

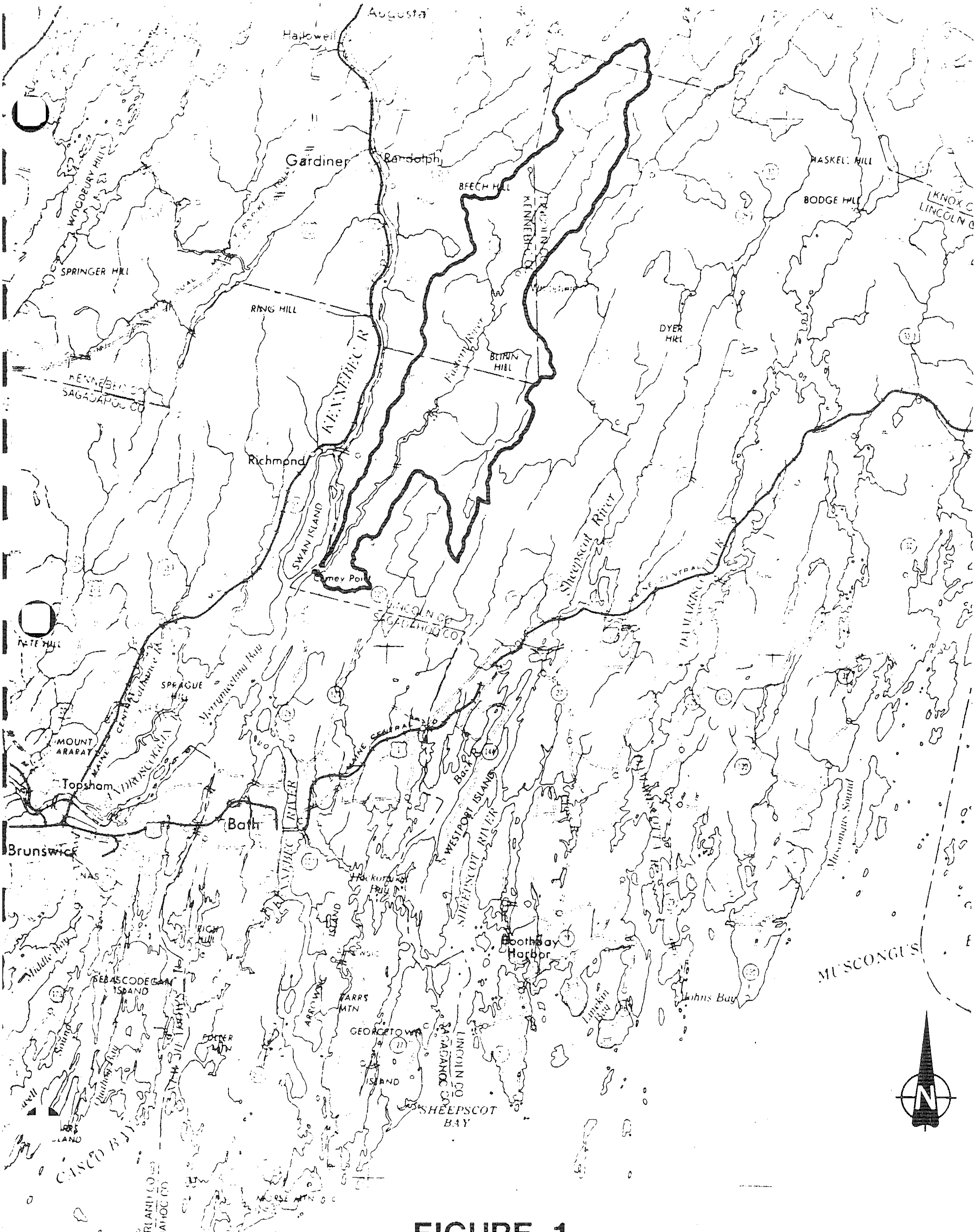

Augusta
Hallowell
Gardiner
Randolph
BEECH HILL
HASKELL HILL
BODGE HILL
KNOX CO
LINCOLN CO
WOODBURY HILLS
SPRINGER HILL
RING HILL
DYER HILL
BURN HILL
KENNEBEC CO
SAGADAHOC CO
KENNEBEC R
Richmond
SWAN ISLAND
Sheepscot River
LINCOLN CO
SAGADAHOC CO
SPRAGUE HILL
MOUNT ARARAT
Topsham
Bath
Brunswick
NAS
WESTPORT ISLAND
SHEEPSCOT RIVER
Boothbay Harbor
ARROWSIC
GEORGETOWN
ISLAND
SEBASCODEGAN ISLAND
SHEEPSCOT BAY
CASCO BAY
MUSCONGUS
Johns Bay
Muscongus Sound
N

FIGURE 1

Upland sources of silt are related to human uses of the landscape. For purposes of this study land uses are separated into several broad classes.

Forest land - woodlands subject to periodic cutting, including necessary skid and haul roads.

Farmland - agricultural land including tilled, pasture, blueberry and abandoned lands.

Urban/built-up - areas devoted to development, buildings, housing and the like.

Transportation - public road system, pipelines, and transmission lines.

Unfortunately, ther are no direct measurements of silt discharges into the Eastern River from upland sources. Estimates of sediment transport and discharge can be based on experiences elsewhere applied to the land uses taking place in the watershed. With the use of aerial photographs the extent of the various land use categories can be mapped at several points in time. By applying expected rates of erosion and adjusting for sediment delivery ratios, the amount of silt discharged into the river can be estimated for the past 15 years to see if this amount is enough to account for the muddy conditions observed in the river.

For the purposes of this study the land use analysis will focus on those land uses most likely to disturb relatively large areas of the land surfce and thus be the largest contributors of silt into the river. The maps for 1966 and 1977 show the extent of cut over forest lands and tillable agricultural land (Plates 1 & 2). Both these categories of land use are known to be potential sources of silt.

Table 1 shows the amount of area classifed into the land use categories by year.

Table 1

Acreage of Land Uses by Time Period

	1966	1977
Forestland, cutover	776	890
Farmland, tillable	5599	4630

Within the eleven year period, the amount of agricultural land has significantly decreased while the amount of disturbed forest land has increased. Table 1 supports the general observation that total erosional products from agricultural land is probably decreasing, while potential erosion for forest lands is increasing due to more land being affected by cutting activities.

Table 2 presents the amounts of silt that can be expected to erode from the disturbed land areas. These values are calculated from actual measurement taken from other sections of the state and nation (Wischmeier et al, 1978). They are evaluated based on experience over time from other but similar situations.

Table 2
Expected Rates of Erosion from Selected Land Use Areas
in Tons/Ac/Yr

Forest land, disturbed	1.50
Farmland, Tillable	2.50
	Range 0 - 25

Using these figures as estimates, neither high nor low, with the average figures from Table 1 the total mount of soil moved can be calculated. The results are, for 1977, 1335 tons of soil from cutover forest land; and 11,575 tons from agricultural lands.

All of the soil moved from disturbed land areas does not end up in the river. A sediment delivery ratio for the Eastern River of 12% (Wischmeier et al, 1978) would result in approximately 3000 tons of silt discharged into the Eastern River each year from upland sources in the watershed.

The results of this analysis were incorporated into another soil loss model for the drainage basin and is presented in Section IV.

IV. Geologic Control of Sedimentation in the Eastern River

Geologic factors play a critical role in controlling sedimentation within any river basin. The composition, erodibility and distribution of bedrock lithologies within a river's drainage basin influence the size and quantity of sediment delivered to the river and its tributaries.

Of greater importance is the distribution of surficial sediments. Surficial deposits are unconsolidated and, therefore, easily eroded and transported to the river channel by overland flow processes.

Once sediment is delivered to the river channel, hydrologic processes within the channel control the transport and distribution of sediments. Hydrologic processes within the tidal river portion will be discussed in the following section.

Bedrock Geology of the Eastern River Drainage Basin

The drainage basin is underlain by three major bedrock units (Newburg, unpublished). A minor unit, a resistence amphibolite, occurs locally as ridges. From youngest to oldest, these bedrock units and their characteristics are:

SO_v : Vassalboro Formation: A thin-bedded calcareous quartzite

O_a : A massive horneblande amphilbolite

OC_{ce} : Cape Elizabeth Formation: A schist

OC_{cu} : Cushing Formation: A rusty schist

These bedrock units do not appear to have any control on sedimentation within the basin, other than their structural orientation. The strike of the rock, and the trend of folding, run parallel to the river channel. Moreover, Newburg (unpublished maps) has found two shear zones within the drainage basin. These two shear zones, evidence for faulting, run concidental with the lower part of the tidal river and the upper reaches of the western branch of the river. While most of the drainage basin rocks are covered by surficial deposits, these shear zones may be indicative of a major fault zone which runs parallel to the river. This fault zone, while inactive, would have influenced the orientation of the river when it originated. Hussey and Pankiwskyj (1975) have mapped a major high angle fault which coincides with the position of the Eastern River.

The major influence which the bedrock geology exerts on the Eastern River, then, is its probable structural control of the orientation of the river-- the river runs northeast to southwest. This is not a common trend of rivers in the Maine coastal region. Most rivers trend north-south or northwest-southeast. This orientation anomaly may play a very important role with respect to the hydrography of the tidal portions of the river. The river, at high tide, presents long reaches of fetch to southwesterly winds-- a prevailing wind direction in the coastal region. The influence of southwest winds on sedimentation will be addressed in the section on river hydrology.

Surficial Geology

The surficial deposits of the river basin play an important role relative to sedimentation within the river. The two major surficial units within the basin are lodgement till and glacial-marine deposits, collectively named the Presumpscot Formation (Thompson, 1975-1977; Smith, 1976) (Plate 3).

The Presumpscot Formation includes a blue clay unit consisting mostly of silt bound in a cohesive matrix of clay particles (Timson, unpublished data). The marine clay occurs in low-lying areas up to elevations of 290 feet. The lodgment till covers the higher elevations.

Occurring also within the drainage basin are minor topographic ridges, 2 to 3 feet in relief, distributed everywhere on top of the till. The Presumpscot may lap up onto, partially bury, or completely cover these ridges. These ridges, their axes oriented east-west or northwest-southeast in the region of the drainage basin, are end moraines (Smith, 1976) marking the successive positions of the retreating glacial terminus during the Wisconsin deglaciation (Thompson, 1978).

Glacial Deposits as Sources of Sediments to the Eastern River

These glacial-related deposits are the source for most of the sediment within and transported through the tidal portions of the Eastern River. Gravel, sand, silt and clay are eroded from the till and end moraines by weathering, mass wasting and overland flow processes, and delivered to the river channel by small tributary streams. Silt and clay are derived from the Presumpscot Formation, either by sheet runoff and overland flow and, more importantly, by direct erosion of the tidal river banks.

During a reconnaissance trip down the tidal portion of the river, the river banks were inspected for erosion. Along most of the reaches where unvegetated tidal flats were narrow and where the channel position was adjacent to a bank occurring in the surficial deposits, it was observed that the marine clay was being exposed and directly introduced into the upper tidal flats or channel banks. In all locations where this introduction of marine clay occurred, it was observed to be a natural process. The marine clay was covered by 1 to 2 feet of vegetated soil. The soil portion of the bank overhung the exposed marine clay by 1 to 1.5 feet. Retreat of the marine clay is occurring beneath the soil profile. Rates of retreat are unknown.

The process by which the blue clay is introduced onto the tidal flats or channel banks is one of gradual slumping. Continuous saturation of the bank-exposed clay by rising tidal waters, weakens the cohesiveness of the clayey silt. The blue clay is continually overcome by gravity forces, and fist-sized chunks or thin layers of the clayey silt slip onto the tidal banks.

At one location, the upper tidal bank was excavated by shovel to a depth of 1 foot. The sides of the excavation revealed discontinuous layers or chunks of the clayey silt interbedded with the tidal flat muds. The clayey silt still maintained its blue-grey color, while the tidal muds were brown in color. This is clear evidence of direct introduction of the marine clay unit into the river.

In a survey of former shad streams (U. S. Fish & Wildlife Service, date unkown) soundings in the channel of the Eastern River indicated the channel bottom was composed mostly of sand and gravel. The upper channel portions of the tidal river, however, were characterized by a mud bottom.

The sand and gravel is most probably derived either from past and present river erosion of till underneath the Presumpscot Formation, or from the end moraines mapped by Smith. Many of the end moraines consist of stratified sand and gravel derived from subaerial erosion of the sediment lying on the front margin of the wasting ice lobe.

Glacial deposits, then, are the most likely source of sediment now found in the tidal banks and channel bottom of the river.

What volumes of sediment are now being delivered to the tidal river basin from overland flow and tributory streams? Some understanding of this volume is necessary to determine if the drainage basin is contributing the increased amounts of sediment to the tidal river, or if some other source might be responsible for its presence.

Sediment Volumes Contributed to the Tidal Eastern River by Overland Flow and Tributary Streams.

When direct measures of sediment discharge into a river are not available, an estimate of the volume delivered can be obtained using the Universal Soil Loss Equation (U. S. D. A., 1978). The Universal Soil Loss Equation is:

$$A = R1TLSCP$$

where

A is the computed soil loss per unit area, expressed in the units selected for K and for the period selected for R. In practice, these are usually so selected that they compute A in tons per acre per year.

R, the rainfall and runoff factor, is the number of rainfall erosion index units, plus a factor for runoff from snowmelt or applied water where such runoff is significant.

K, the soil erodibility factor, is the soil loss rate per erosion index unit for a specified soil as measured on a unit plot, which is defined as a 72.6-ft. length of uniform 9-percent slope continuously in clean-tilled fallow.

L, the slope-length factor, is the ratio of soil loss from the field slope length to that from a 72.6-ft. length under identical conditions.

S, the slope-steepness factor, is the ratio of soil loss from the field slope gradient to that from a 9-percent slope under otherwise identical conditions.

C, the cover and management factor, is the ratio of soil loss from an area with specified cover and management to that from an identical area in tilled continuous fallow.

P, the support practice factor, is the ratio of soil loss with a support practice like contouring, stripcropping, or terracing to that with straight-row farming up and down the slope.

Initially, a general estimate of land use coverage was determined using 1956, 15' U.S.G.S. topographic coverage of the drainage basin. This map coverage includes color designation of forested and non-forested areas. Second, losses from agricultural lands were determined from the 1978 Soil Conservation Study of Non-point Agricultural Pollution in Maine.

The land cover types, acreages, and soil loss estimates using the Universal Soil Loss Equation are presented in Table 3.

Table 3
Land Use Types, Acreage and Estimated Soil Loss from the Eastern River Drainage Basin Annually: General Estimate

Land Use Types	% of Drainage Basin	Acreage	In Tons per Year Soil Loss /Acre	Total Soil Loss
Forest Land	64%	20,480	.04	819.2
Active Farmland	.3%	100	7	700
Open Pasture & Idle Land	30%	9,600	.03	288
Built-Up Land	.7%	224	--	--
Lakes, Ponds, Rivers	5%	1,600	--	--
Totals	100%	32,004		1807.2

Only 12% of the soil eroded from the land eventually ends up as discharge to the river (Wischmeier et al, 1978). Thus a general but low estimate of the amount of sediment delivered to the river on an annual basis is 216.8 tons.

As a result of the detailed land use category analysis presented in Section 1, an additional estimate of the amount of sediment delivered to the river was determined. The land use analysis more clearly identified land uses which would accelerate soil loss. Table 4 presents the revised land use types, areas and soil loss estimates based on this more detailed analysis of land use using 1977 aerial photography.

The new estimates yield a sediment discharge annually to the river of 1,700.6 tons.

Using two estimates of the Universal Soil Loss Equation, from 200 to 1,700 tons of sediment are delivered to the river each year. This range of sediment discharge tonnage will be examined further in the Section on Hydrology to determine if this volume of sediment can account for the turbidity values found in the tidal portion of the Eastern River.

V. Hydrology of the Eastern River

The Eastern River, at its mouth or confluence with the Kennebec River, drains 50 square miles (32,000 acres). (U.S. Geological Survey, 1980). There have been no direct measures of discharge made along the river. To estimate the discharge of the river, - a necessary step to arrive at an average concentration of suspended sediment in the river and the determination of a flushing rate for the tidal portion of the river - a method adopted by the Water Resources Branch in Maine of the U.S. Geological Survey (USGS) was utilized (Hayes and Morrill, 1970). This method utilized compiled data from Maine on precipitation, drainage basin area, snow index, slope of the river, forest cover, storage, mean basin elevation and precipitation intensity in a regression analysis to calculate the mean annual and monthly discharges of a given river. The method has a standard error of 5% when comparing the calculated discharge to observed discharge in rivers where 25 years of direct measurement are available.

The equation for determining the mean annual discharge for any river is:

$$QA = .00189A^{1.00}\ St^{-0.06}\ E^{-0.15}\ I^{0.29}\ P^{1.25}\ Sn^{0.43}\ F^{0.25}$$

The applicable exponents for calculating the mean monthly discharges are given in Table 5.

Table 4
Land Use Types, Acreage and Estimated Soil Loss from the Eastern River Drainage Basin Annually using 1977 Aerial Photography to Detmine Land Use

Land Use Types	% of Drainage Basin	Acreage	In Tons Per Year Soil Loss /Acre	Total Soil Loss
Undisturbed Forest	61%	19,590	.04	783.6
Disturbed Forest (cutover)	3%	890	1.5	1,335
Active Farmland	.3%	100	7	700
Tillable Farmland	14%	4,480	2.5	11,200
Open Pasture and Idle Land	16%	5,120	.03	153.6
Built-Up Land	.7%	224	--	--
Lakes, Ponds, Rivers	5%	1,600	--	--
	100%	32,004		14,172.2

Table 5 --Summary of regression results (From Hayes & Morrill, 1970)

(Model is $Y = aA^{b1}, S^{b2}, L^{b3}, St^{b4}, E^{b5}, I^{b6}, P^{b7}, Sn^{b8}, F^{b9}$

	Flow characteristic (Y)	Regression constant, a: Number	Regression constant, a: Power of 10	Exponent of basin characteristic: Drainage area (A)	Main channel slope (S)	Stream length (L)	Surface storage (St)	Mean basin elev. (E)	Precipitation intensity (I)	Mean annual precip. (P)	Snow Index (Sn)	Forest cover (F)	Stand. error of estimate (percent)
	Qa	1.89	-03	1.00	----	----	-0.06	-0.15	0.29	1.25	0.43	0.25	5.1
	SDa	3.56	-01	1.00	0.08	----	- .05	- .15	----	----	----	----	8.1
Jan.	Q1	1.62	-05	.97	----	----	.09	- .42	.84	2.74	----	----	12.0
Feb.	Q2	1.76	-01	.97	----	----	.08	----	1.18	1.37	-1.24	- .55	13.6
Mar.	Q3	7.01	-03	.95	----	----	----	- .20	2.02	2.95	----	-1.64	19.4
Apr.	Q4	8.71	-01	.99	----	----	- .14	----	1.18	----	.50	----	10.6
May	Q5	5.59	-05	1.04	----	----	----	----	- .55	1.17	.65	1.33	9.5
June	Q6	1.06	-04	1.09	----	----	----	----	----	1.20	----	1.02	17.1
July	Q7	1.18	-04	1.07	----	----	----	----	----	----	----	1.85	20.8
Aug.	Q8	1.06	-04	1.01	----	----	----	----	- .70	----	----	2.03	24.9
Sept.	Q9	3.66	-03	1.03	----	----	- .16	----	----	----	----	1.15	18.5
Oct.	Q10	6.49	-04	1.02	----	----	- .16	----	.78	----	.65	1.22	18.2
Nov.	Q11	1.73	-01	.99	.10	----	- .16	- .20	.99	----	.93	----	11.6
Dec.	Q12	8.40	-02	.95	----	----	----	- .21	.85	----	----	.52	10.4

Values chosen for the constants are:

(A)	Drainage Basin Area:	50 square inches
(St)	Surface Storage Area:	2 (percent of drainage area + 1)
(E)	Mean Basin Elevation:	.187 in thousandths of feet
(I)	Precipitation Intensity:	3.1 inches (U.S. Weather Bur., 1959)
(P)	Mean Annual Precipitation:	43 inches (U.S.G.S. Hydrologic Atlas - 7)
(Sn)	Snow Index:	3.2 inches (U.S.G.S. Hydrologic Atlas - 7)
(F)	Forest Cover:	64 (percent of drainage basin + 1)

Results of the analysis are given in Table 6.

Table 6
Mean Annual and Monthly Discharges for the Eastern River at its Confluence with the Kennebec River in Cubic Feet Per Second (CFS)

Q Annual = 83.11

Q Jan. = 119.92	Q July = 17.03
Q Feb. = 130.46	Q Aug. = 11.58
Q Mar. = 284.78	Q Sep. = 21.99
Q Apr. = 258.37	Q Oct. = 27.12
Q May = 76.88	Q Nov. = 94.13
Q June = 47.82	Q Dec. = 111.71

VI. Sediment Loads Delivered to the Tidal Portions of the Eastern River

The mean discharge figures can be utilized to determine the average annual concentration of suspended sediment which is delivered to the tidal portion of the river. Consideration of the ditribution of suspended sediment within the tidal portion of the river can then be determined in light of flushing rate calculations.

Under average annual conditions from 200 to 1,700 tons of sediment are delivered to the tidal river under discharge conditions ranging from 11.5 cfs. to 284.7 cfs.

The mean annual flow of the river is 83.1 cfs. with a sediment load of 950 tons. This average discharge and load figure represents a concentration of suspended sediment delivered to the tidal basin of 11.5 mg/liter. But, conditions may be such that a whole range of sediment concentrations may occur coincident with the load range of 200 to 1,700 tons on an annual basis. The range of concentrations on an average annual basis would be from 2.4 mg/liter to 20.6 mg/liter.

A comparison of these sediment concentration levels to those found by Hunt (1969) indicates that sediment loads being delivered to the tidal portions of the river from natural and human-induced erosion sources on the upland cannot account for the increased levels of turbidity. The range of sediment load concentration calculated as entering the lower river area appear compatible with those concentrations found in neighboring rivers and Merrymeeting Bay.

A look at the lower and tidal reaches of the Eastern River is necessary to investigate the possible causes of excess turbidity.

VII. Hydrologic Processes in the Lower Eastern River

Thirteen kilometers of channel of the lower Eastern River are tidal. The river level experiences the rise, and fall of the combination of lunar and solar tides - two low tides and two high tides each twenty-four hour day. While the lower river is tidal, it is not estuarine. No ocean water intrudes into the river on a flooding tide. Moreover, water from the Kennebec River flows into the lower Eastern River during flood tides.

The distribution and accumulation of any material suspended in the water column of the tidal portion of a river requires some knowledge of the flushing or exchange rate between the water that is flowing into the tidal segment from its head and that which flows into it from the mouth.

Ketchum (1951) determined the flushing rate of an estuary by computing in exchange ratio for a series of segments of the estuary. Each segment of the estuary is defined as the segment length which a particle of water travels in a single tide. This methodology may be applied to tidal rivers as well as estuaries, as long as one knows the length of one tidal excursion, the rate of influx of fresh water (river discharge), the low tide volume of each tidal segment, and the tidal prism of each segment, or the amount of water in each segment that moves into the river from its mouth.

A longitudinal model of the tidal portion of the Eastern River was constructed (Figure 2) to determine the flushing rate of the tidal river. The model assumed:

1. One tidal excursion equals 4.4 kilometers, an excursion distance determined by Hunt in 1967.

2. A channel bottom profile which approximates that of a general river profile from a head just above the Kelly Road Bridge in East Pittston at elevation + 4.75 feet above mean low water (NOAA, 1982) to its mouth at a depth of -20 feet (MLW).

3. Complete mixing is achieved between the river discharge and the tidal prism of each segment.

The required tidal volumes were then completed for each of the segments which numbered three from the mouth to the head of the tidal river.

The tidal volumes were calculated using the channel depths assumed by the model (no bathymetric data exist for the upper ten kilometers of the tidal river) and the acreages of tidal flat and channel determined from the U. S. Fish and Wildlife Ecological Characterization of the Maine Coast (1981). It was assumed that the tidal flats sloped evenly from the mean high water elevation to the channel edge at the mean low water elevation.

An exchange ratio for each segment was then calculated using Ketchum's formula:

$$rn = \frac{Pn}{Pn \; \& \; Vn}$$

where, rn = exchange ratio of segment n

Pn = volume of the tidal prism of segment n

Vn = low water volume of segment n

Table 7 reports the results of these determinations.

An exchange ratio of 0.174 for the 3rd segment, therefore, means that only 17.4% of the water which resided in the segment at high water was removed during the next successive ebb tide.

Figure 2: Water volumes, tidal segments, and flushing characteristics of the lower Eastern River.

LOWER EASTERN RIVER FLUSHING CHARACTERISTICS

SEGMENT III

Flat Volume = 1,383,786 M^3
Channel Vol = 6,572,328 M^3
Total Vol = 7,956,114 M^3
Flushing Rates: 7.4 Tidal Cycles

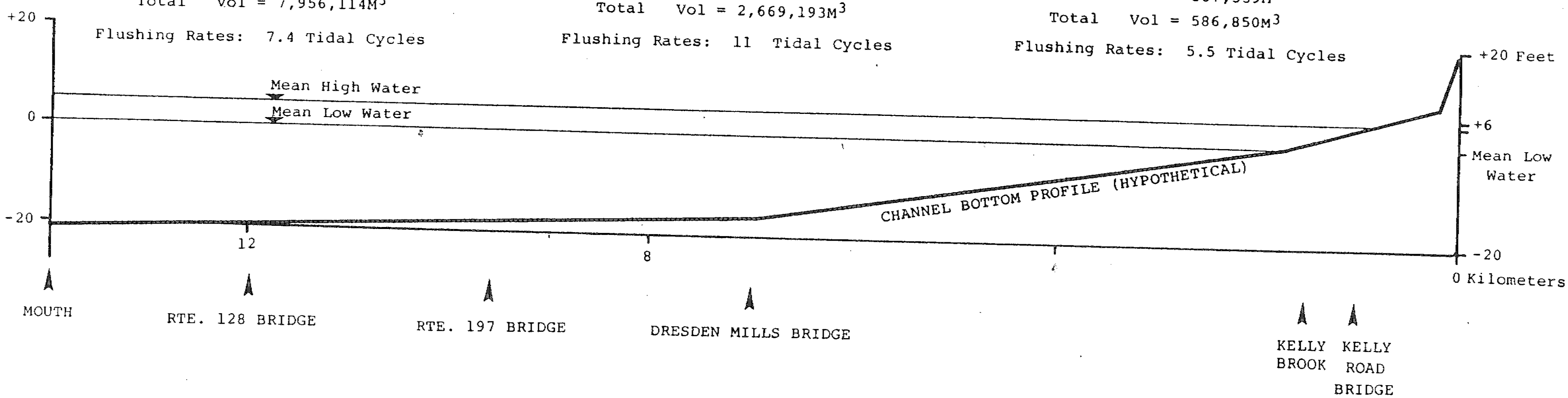
SEGMENT II

Flat Volume = 323,625 M^3
Channel Vol = 2,345,568 M^3
Total Vol = 2,669,193 M^3
Flushing Rates: 11 Tidal Cycles

SEGMENT I

Flat Volume = 199,511 M^3
Channel Vol = 387,339 M^3
Total Vol = 586,850 M^3
Flushing Rates: 5.5 Tidal Cycles

WEST BRANCH
EAST BRANCH
KELLY BROOK
36,578 M^3 /Tidal Cycle



TOTAL VOLUME = CHANNEL VOLUME + FLAT VOLUME or TIDAL PRISM

$11,212,157 M^3 = 9,305,235 M^3 + 1,906,922 M^3$

Total Flushing Rate: 24 Tidal Cycles

FIGURE 2

Table 7
Low Water Volumes, Tidal Prisms, and Exchange Ratios for the Lower Eastern River Segments

Segment #	Low Water Volume Vn (M^3)	Tidal Prism Pn (in M^3)	Exchange Ratio rn
3 North to Route 197 Bridge	6,572,328	1,383,786	0.174
2 Route 197 Bridge to 6.8 km. above Route 27 Bridge	2,345,568	323,625	0.21
1 1.8 km. above Route 27 Bridge to .1 km. above Kelly Road Bridge	387,339	199,511	0.235

A particle of sediment which entered the river segment during a flood tide, either from the head or the mouth, would not necessarily be removed from the segment during the next ebb tide. Therefore, unless the exchange ratio were 1, suspended sediment can accumulate within a tidal segment to a point where the concentration can exceed the concentration input from the river or from the water entering the mouth of the tidal segment.

A better measure of the accumulation of water or suspended matter within a tidal segment is that of a flushing rate - the length of time in days in which it takes a particle entering the head of the tidal river to travel to the mouth of the river.

A very simple flushing rate can be calculated using the formula.

$$T = \frac{V+P}{P}$$

Where t = flushing rate in tidal period,

V = low water volumn of the tidal river,

P = tidal prism of the tidal river.

When calculated, the flushing rate for the lower Eastern River equals about 5.9 tidal cycles, or three days.

This is the very simplest of determinations, and assumes complete mixing of th waters in the tidal portion of the river. It also does not account for the volume of river water entering the head of the tidal river.

A more accurate computation of the flushing rate involves an analysis of the river water which has accumulated within each tidal segment based upon the segments exchange ratio. It is assumed that for any given river discharge input, the tidal segment of the river reaches a steady state such that the amount which enters the head of the tidal reach is removed at the mouth.

In this analysis, it was assumed that, under average conditions, 36,578 M^3 would be the discharge into the head of the tidal portion of the river during a tidal cycle. This figure is that portion of the computed discharge which can be attributed to the West Branch and East Branch of the Eastern River as well as that of Kelly Brook.

36,578 m^3 of river water would enter segment 1 during 1 tidal cycle. Since the exchange ratio of segment 1 is 0.235, only 8,595.8 m^3 of the original river water would be removed in one tidal cycle. If we assumed no more input, then another 6,575.8 m^3 of original water would be removed during the second tidal cycle. If we continue this series of computations, it would take 5.5 tidal cycles to reach a point where the amount removed during the first tidal cycle equaled the amount remaining within the segment. A steady state is then reached.

If similar computations are done for segments 2 and 3, we have the following flushing rates for the tidal river:

Segment 1	5.5 tidal cycles
Segment 2	11 tidal cycles
Segment 3	7.4 tidal cycles

Under average flow and tidal conditions it takes a particle of suspended sediment 24 tidal cycles or twelve days to be transported from the Kelly Road Bridge to the mouth of the Eastern River.

For comparison purposes, McAlice (1969) calculated the flushing rate of the Damariscotta River estuary to be 24 $\pm$ 7.4 days. Timson and Look (1980) report a flushing rate of the upper Sheepscot River (12 km) of from 8.5 to 11 days from Garside (unpublished data).

Although many simplifications to the Eastern River flushing "model" were necessary because of a lack of field data, the determined flushing time appears comparable to other neighboring estuaries. The determination of a real flushing rate would be extremely difficult, as most estuaries flushing rates based on field data are determined from known parameters ofthe tidal prism (sea water) and fresh water. With respect to the Eastern River, a situation arises where two fresh water masses are mixing with one another.

If we assume that our calculations of the flushing rate for the lower Eastern River approach reality, then our known average discharge concentration of suspended sediment would increase within the tidal stretch from the Kelly Road Bridge to the mouth.

If our average discharge concentration is 11.5 mg./liter, per day, then mixing in the lower portions of the river could increase the concentration to 12 x 11.5, or 138 mg./liter. If we also assume that the average concentration of suspended sediment delivered to the lower Eastern River from the Kennebec River (6.5 mg./l) per day, then another 78 mg./liter might accumulate. Together, these concentrations equal about 216 mg./liter -- about one-third less the maximum concentration of suspended sediment of 350 mg./liter reported by Hunt (1969).

It does not appear that the excessive turbidity reported from the lower Eastern River can be attributed to the amount of sediment delivered to the tidal river from the upland, or its concentration due to the flushing characteristics of the tidal portions of the river.

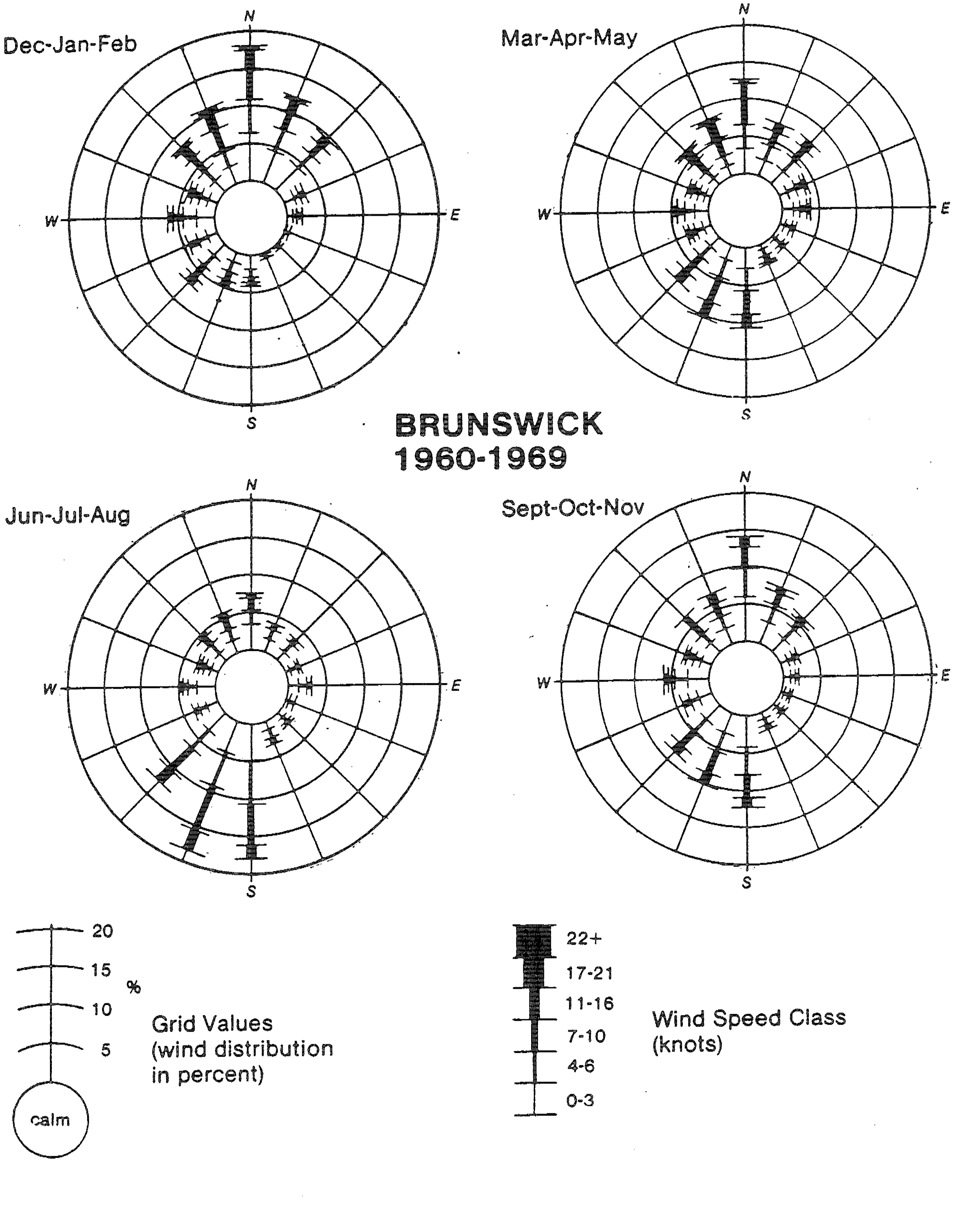
Other Hydrologic Considerations

The orientation of the lower tidal river basin of the Eastern River may contribute to the apparent excessive turbidity. The basin, as mentioned in an earlier section, is aligned with the regional bedrock structure trend. This alignment is approximately S35^{o}W--N 35^{o}E. This orientation is parallel to the direction of prevailing surface winds for six months of the year as recorded at the Brunswick Naval Air Station (Figure 3).

The spring and summer months (March through August) for the Merrymeeting Bay Region witness, regularly, southerly winds of up to 16 knots coming from the direction of S 0° W through S 45° W.

These seasonal winds funnel up through the Eastern River basin with a significant fetch to create surface waves at high water within the tidal basin. These waves are very capable of resuspending fine-grained sediment from the tidal flats, especially in the portions of the river above Dresden Mills.

Figure 3: Seasonal wind directions and speeds at Brunswick, Maine.



BRUNSWICK
1960-1969
Dec-Jan-Feb
Mar-Apr-May
Jun-Jul-Aug
Sept-Oct-Nov
N
S
E
W
20
15
10
5
%
calm
Grid Values
(wind distribution
in percent)
22+
17-21
11-16
7-10
4-6
0-3
Wind Speed Class
(knots)

FIGURE 3

VIII. Biological Causes of Turbidity in the Eastern River

The distribution of plants and the life activities of many of the animals in the Eastern River affect the level of turbidity in the river. The survey of Eastern River wildlife, both plant and animal, which follows reveals that fact. While not enough is known to establish the causes of excessive turbidity in the river as exclusively biological, living organisms clearly exacerbate the problem.

Vegetation

Distribution patterns of vegetation were examined by: (1) determining the areas of various wetlands classes mapped on 1:24,000 aerial photographs in the Ecological Characterization of Coastal Maine (henceforth ECCM) (Table 8); (2) determining the areas of various geological sub-environments mapped in the ECCM (Table 10); (3) examining unpublished surveys of vegetation composition and distribution (Maine Department of Inland Fisheries and Wildlife; Table 12); and (4) making field checks from both the river banks and canoe of the conclusions reached using the data from the first three sources.

Distributional patterns of different species of plants may be used to define wetlands environments. A systematic classification scheme for wetlands has been worked out by Cowardin, Carter, Golet, and LaRoe (1979) for uniform application to any wetland in the United States. This classification system was applied to the Eastern River in the ECCM.

TABLE 8. Areas of various Wetland classes (as designated in ECCM) within, connected to, or immediately adjacent to the Eastern River, in hectares (1 Ha = 2.47 acres). Figures in parentheses are percent of the total wetland type which occurs within each river segment. Data derived by planimetry from 1:24,000 inventory sheets of the ECCM.

River Segment	R1OW Riverine open Water	R1FL Riverine flat	Wetlands Class: R1EM Riverine emergent	Wetlands Class: PFO Palustrine forested	PSS Palustrine scrub-shrub	P SS/EM	PEM Palustrine emergent
Middle Ground to Rt. 128	68.3 (38%)	7.1 (8%)	135.2 (88%)	2.6 (4%)	7.5 (12%)	---	---
Rt. 128 to Rt. 197	40.0 (22%)	12.2 (14%)	15.6 (10%)	14.2 (25%)	29.2 (48%)	---	---
Rt. 197 to Rt. 27	35.0 (19%)	27.7 (32%)	---	5.4 (9%)	1.1 (2%)	---	---
Rt. 27 to E. Pittston	37.7 (21%)	38.8 (45%)	3.6 (2%)	35.5 (62%)	23.4 (38%)	68.3 (100%)	30.5 (100%)
TOTAL	181.0 (100%)	85.8 (100%)	154.4 (100%)	57.7 (100%)	61.2 (100%)	68.3 (100%)	30.5 (100%)

TABLE 9 Percent of area covered by each wetland class within each River segment. Figures in parentheses are percent area covered disregarding Palustrine classes.

	Wetlands Class						
	R1OW	R1FL	R1EM	PFO	PSS	P SS/EM	PEM
Middle Ground to Rt. 128 220.7	30.9 (32.4)	3.2 (3.4)	61.2 (64.2)	1.2 --	3.4 --	--	--
Rt. 128 to Rt. 197 111.2	36.0 (59)	11.0 (18)	14.0 (23)	12.8 --	26.2 --	-- --	-- --
Rt. 197 to Rt. 27 69.2	50.6 (55.8)	40.0 (44.2)	--	7.8	1.6	--	--
Rt. 27 to E. Pittston 237.8	15.8 (47.1)	16.3 (48.4)	1.5 (4.5)	14.9	9.8	28.7	12.8

TABLE 10. Areas of geological sub-environments within the Eastern River, in hectares (1 Ha = 2.47 acres). Figures in parentheses are percents of the total sub-environment which occur within each river segment. Data derived by planimeter from 1:24,000 inventory sheets of the ECCM.

	Geological sub-environment			
River segment	C_f (channel)	F (flats)	S_r (fluvial marsh)	S_m (fresh-brackish marsh)
Middle Ground to Rt. 128	56.6 (37%)	26.5 (24%)	116.2 (87%)	---
Rt. 128 to Rt. 197	33.3 (22%)	17.5 (16%)	11.5 (9%)	2.0 (100%)
Rt. 197 to Rt. 27	31.1 (20%)	25.3 (23%)	1.7 (1%)	---
Rt. 27 to E. Pittston	31.1 (20%)	41.7 (38%)	3.9 (3%)	---
TOTAL	152.1 (100%)	111.0 (100%)	133.3 (100%)	2.0 (100%)

TABLE 11. Percent of area covered by each geological sub-environment within each river segment. Marsh types combined.

River segment	Geological sub-environment		
	C_f (channel)	F (flats)	S_r (fluvial marsh) + S_m (fresh-brackish marsh)
Middle Ground to Rt. 128	28.4	13.3	58.3
Rt. 128 to Rt. 197	51.8	27.2	21.0
Rt. 197 to Rt. 27	53.5	43.5	2.9
Rt. 27 to E. Pittston	40.5	54.4	5.1

TABLE 12. Percentages of areas in and along the Eastern River covered by various wetland classes and geological sub-environments. Derived from Tables I and III.

Wetlands Class	% Area covered	Adjusted % (see text)	Equivalent Geological sub-environment	% Area covered
R1OW riverine open water	28.3	43.0	C_f channel	38.2
R1FL riverine flat	13.4	20.0	F flat	27.8
R1EM riverine emergent	24.2	37.0	S_r fluvial marsh	33.5
		100.0%	S_m fresh-brackish marsh	0.5
PFO palustrine forested	9.0			100.0%
PSS palustrine scrub-shrub	9.6			
$P\frac{SS}{EM}$	10.7			
PEM palustrine emergent	4.8			
	100.0%			

NOTE: Palustrine environments make up 34.1% of the total wetlands.

TABLE 13. Areal coverage, as percentages of the littoral zone, by major plant species in rivers of the Merrymeeting Bay region. (Table 5 of Spencer, 1958).

Species	Muddy/Cathance Rivers	Androscoggin River	Abagadasset River	Middle Bay[2]	Eastern River[1]
	Percent Coverage — Locality				
Wild rice	14.9	11.2	16.3	13.1	39.3
Mixed emergents	10.1	18.3	10.2	5.8	23.8
Sub-aquatics	5.2	4.5	16.6	61.6	14.8
Sweet flag	0.1	0.1	0.2	0.5	0.6
Softstem bullrush	7.2	8.1	16.9	2.3	7.6
River bullrush	1.9	1.9	0.2	0.4	0.4
Pickerelweed	4.3	0.4	1.9	0.5	0.8
Yellow water lily	36.9	6.4	2.1	2.1	3.5
Unvegetated: Sand	1.9	32.9	14.2	1.2	0.2
Silt	14.8	13.2	16.9	5.8	7.0

NOTE: 1. Data for the Eastern River were developed only for Middle Ground.

2. Part of Merrymeeting Bay.

Two major classes of wetlands are found in the Eastern River basin: (1) the riverine -- those environments directly in contact with, formed by, and influenced by the river itself; and (2) the palustrine -- all other wetlands not directly affected by the river. Eastern River riverine wetlands include the river channel proper, tidal flats and bars, and river-margin marshes. Eastern River palustrine wetlands include all the other areas popularly designated as swamps, bogs, upland marshes, and small ponds. Such wetlands are classified on the basis of the dominant vegetation -- forested, scrub/shrub, emergent vegetation, or a mixture (see Table 8).

For the purposes of this report, the Eastern River was divided into four sections, each delineated by a numbered highway crossing: from the mouth of the river (designated Middle Ground in the tables) to Route 128; from the Route 128 bridge to the Route 197 bridge; from the Route 197 bridge to the Route 27 bridge; and from the Route 27 bridge to East Pittston. These sections are not equal in length. The Middle Ground section is the shortest; the two middle sections are roughly the same length; and the Route 27 - Pittston section is approximately twice as long as either of the middle sections. Nonetheless, the divisions allow the delineation of trends in the river.

The data in Tables 8 - 11 support the following observations:

(a) Except at the mouth (which is very wide), the river channel (R1OW) makes up nearly half the riverine environment.

(b) Riverine flat (R1FL), which is unvegetated tidal flat, increases markedly with respect to the area of channel upstream (Tables 9 and 11). Except for the segment between routes 197 and 27, more flats are found on the eastern side of the river.

(c) Riverine emergent (R1EM), consisting of flats covered with vegetation, the leaves and flowers of which mostly stand up out of the water, is found primarily on Middle Ground. In the mouth segment 98% of the emergent vegetation is found below the Route 197 bridge.

(d) Palustrine wetlands are concentrated in the section between Route 27 and E. Pittston -- a broad, flat area where marshes and bogs have become well-established, possibly as a successional stage to an earlier riverine emergent environment. Palustrine forest and scrub-shrub wetlands are also well-represented in the segment between Routes 128 and 197. In general, the areas of palustrine wetlands along the river reflect the topography of the adjacent land and increase when the topography becomes flatter or hummocky.

For comparison and as a check on the precision of the environmental classification on the wetlands inventory, the areas of geological sub-environments were also determined. These were worked out on the same data base but by different personnel from those doing the wetlands inventory and from a different point of view. These areas are tabulated in Table 10 . The river has been divided up into segments the same way, and the same cautions apply. The observations on riverine wetlands all appear to apply equally well to the geological sub-environments. Since the geological mapping did not include any palustrine environments, the percentages of the three riverine wetland classes were recalculated without reference to the palustrine wetlands, shown as "Adjusted %" in Table 12, along with aggregate percentages of all the wetland and geological sub-environment classes. The fact that the adjusted percentages of the riverine wetland classes agree with those of the geological sub-environments (within 8%) increases confidence in the photo interpretations.

Palustrine wetlands, accounting for 34% of the total wetlands in the Eastern River basin, are probably not major sources of suspended sediments because they are usually densely vegetated. Water moves through them slowly during most of the year. Therefore suspended sediment entering such wetlands will probably settle out there, with the possible exception of spring run-off when increased melt-water flow flushes some sediment into the river (this subject is treated in another section of this report). Streams, the areas of which were too small to measure, constitute a very small portion of palustrine wetlands. Those field-checked had gravel or coarse sand channel bottoms and were not turbid. Hunt (1969) made the same observation. Since these palustrine environments do not seem to be major sources of suspended sediment contributing to the Eastern River turbidity problem, they will not be considered further here, and attention will focus on the riverine environment itself.

Unvegetated areas of the river account for 63-66% of its area (river channel and riverine flats). Of the remaining 34-37% of the area, which is vegetated, most is found at or near the Eastern River mouth on Middle Ground (see Table 8). Spencer surveyed this area in 1958 using both field checks and aerial photos as part of the Maine Department of Inland Fisheries and Wildlife Merrymeeting Bay studies. The results of his survey, expressed as percents of the littoral zone covered by each species of plant, are tabulated in Table VI. Compared with other rivers in the Merrymeeting Bay region and with the Middle Bay itself, the Middle Ground of Eastern River contains proportionately the greatest stands of wild rice (*Zizania aquatica*) and mixed emergent vegetation. Sub-aquatics, (those plants which have both leaves and flowers under water), the third category in the table, covered a significant area of Middle Ground (14.8%) though field checks in 1981 in other parts of the Eastern River indicated that submerged vegetation was relatively rare. Field checks for the present report showed that wild rice is still the dominant emergent plant on Middle Ground. Spencer analyzed plant coverage in the study area again in 1961, at which time he found no substantial changes compared with his previous study, although there were changes in *minor* constituents of up to 300%. Such fluctuations among minor constituents are to be expected, since the presence or absence of a few plants will make a large difference in the percentages. Unvegetated flats make up a rather small proportion of Middle Ground in Spencer's 1958 survey -- only 7.2%, one of the smallest relative areas in the table. Data from the ECCM indicate that only 5% of Middle Ground was unvegetated at the time of the aerial photographs in 1974. In other words, there was no substantial change in vegetational cover on Middle Ground in the sixteen intervening years.

As a bar deposited at the confluence of the Eastern and Kennebec Rivers, Middle Ground has very likely existed in one form or another for over 100 years. Its current form was very likely stabilized by the building of the Green Point Breakwater about 1896, and the vegetation covering it has probably been dominated by emergent species, particularly wild rice.

Unfortunately, there are no historical data bearing on vegetation cover farther up the Eastern River than Middle Ground.

To summarize the distribution of vegetation: the Eastern River is characterized for most of its length above Route 128 by unvegetated channel and flanking unvegetated tidal flats; flats covered by emergent vegetation are found primarily at Middle Ground; the areal coverage by plants (both emergent and sub-aquatic) of Middle Ground has been stable for at least 16 years, and probably much longer; there are no comparable data for the upper parts of the river.

Tidal marshes are well-documented traps for sediment (Smith, Bridges, and Anderson, 1981 for example). The mechanism of trapping is a reduction in water current velocity among the stems and leaves of marsh vegetation. As the water current slows down, much of its suspended load is allowed to settle out. Studies in sediment mechanics have demonstrated that fine-grained sediments (silts and clays) are more difficult to lift off the bottom by water currents than to be carried in the water column once entrained (Inman, 1963). This fact, together with the development of algal mats among the marsh plants and the binding of sediments by the roots of marsh vegetation, leads to the retention of sediment within marshes. Tidal marshes typically begin as isolated clumps of emergent vegetation on intertidal flats. These clumps coalesce and then gradually grow upward until they reach highest tide level. They evolve subsequently into palustrine forested wetlands when upland vegetation encroaches over the marsh surface. Such marshes are common flanking the Eastern River between Route 27 and E. Pittston. The large amount of unvegetated riverine environment (63-66% of the total) indicates that a large surface area is available from which sediment may be mobilized, without the stabilizing effects of vegetation. Middle Ground may be considered to be in an early successional stage of the marsh-building process. Given enough time, Middle Ground could become a marshy island. Historical data have not been found which would indicate whether the relative amounts of marsh and unvegetated flats have remained the same over time. The fact that the river banks are not vegetated suggests that for some reason the river bank material is inhospitable to plant seedlings, whether because of properties inherent in the glacial sediments in which the river channel is cut, or because of other physical factors.

Animals

Field trips along the Eastern River revealed at least one otter and a number of shorebirds. In addition, there was abundant evidence of raccoons. Turtles are said to be common in the river (Robert Fessler, personal communication). Fresh-water clams (sub-family Anodontinae, genus either Strophitus or Anodonta) appeared to be common in the upper reaches of the river. Field work was conducted too late in the year to find much evidence of other invertebrates, particularly insects, but there can be little doubt that they are present.

Otters, turtles and raccoons stir up sediment in digging burrows or searching for food. Clams filter suspended food and sediment from the water column, and bind it into pellets which settle out on the river bottom, there to become food for other invertebrates. Almost all aquatic insect larvae spend at least part of their lives burrowing in sediment, loosening particles from the river bed and thus rendering them more easily suspended. The size of the contribution by invertebrates to river turbidity is exceedingly difficult to estimate, even relative to that caused by other animal groups. The bottom-dwelling (both burrowing and sediment surface--dwelling) invertebrates are the major link in the food chain between microscopic life (bacteria, fungi, algae) and the vertebrates (ducks, fish, amphibians, mammals). In addition to their direct effects in loosening and "fluffing" sediment through their life activities, these bottom-dwelling invertebrates-- as the major food organisms for vertebrates living on or in the river-- attract the vertebrates and, in effect, determine those vertebrate feeding habits which stir up large quantities of bottom sediment.

The ECCM identifies black ducks, ring-neck ducks, wood ducks, and blue-winged teal as the major species of breeding waterfowl inhabiting Merrymeeting Bay and adjacent areas, including the Eastern River. Since wild rice is a major food of many species of ducks in this area, most ducks will be expected to be found at Middle Ground, although the upper reaches of the river should be ideal wood duck habitat. Under "Wetlands important to waterfowl" in the ECCM, Middle Ground is identified as especially important for a large population (1000 - 2500) of the semipalmated sandpiper. All common waterfowl in this area feed largely on invertebrates-- insects and insect larvae, amphipod crustaceans, and worms of various kinds-- found on or in the river-bottom sediment. In the course of these feeding activities, sediment is resuspended and, in the presence of water currents, can be carried into the river channel. Birds are particularly significant in stirring up sediment in marshy areas, where, as has been noted previously, fine-grained sediment is trapped. Thus the feeding activities of large numbers of birds can prevent the settlement of suspended sediment in vegetated areas, also preventing this sediment from becoming bound into the marsh root-mat, and therefore slowing the upward growth of the marsh. Such a process may be important in Middle Ground, where the abundant wild rice attracts large numbers of waterfowl.

Fish make up the third major group of animals occupying the Eastern River. They are more numerous than all other vertebrates together. Species regularly found in the Eastern River are listed along with their population characteristics in Table 14 . There are sizable resident populations of many species as well as large quantities of fish which visit the Eastern River seasonally-- the rainbow smelt is an abundant example.

Feeding is the most important characteristic for fish on a day-to-day basis. Feeding characteristics are summarized in Table 15 and are discussed here as they relate to turbidity in the Eastern River.

Bottom feeders are fish which actively stir up the river bottom in their search for food. Such fish generally have highly sensitive lips and accessory sensory organs (barbels) which help them find food organisms primarily by touch and "taste" rather than by sight. In the Eastern River, four species fall into this feeding type: two species of sturgeo~ the carp, and the white sucker. Sturgeon are very rare fish in these waters, and, while their large size means that they can stir up considerable sediment in their feeding, the small number living in the Eastern River probably do not make a major contribution to turbidity. Carp and white suckers, however, both occur in the Eastern River in abundance. The extent of that abundance is not known, since neither of these species has ever been subjected to a quantitative survey in the Eastern River. White suckers and carp have the same feeding habit, which probably is a major cause of sediment suspension. (In the U.S. carp are reputed to increase turbidity and will be considered separately later on in this report.) The presence of two common bottom feeding fish species in the Eastern River is testimony to a considerable productivity of invertebrates in the bottom sediments. Carp are relative newcomers to the Eastern River, but white suckers have presumably existed there throughout post-glacial time. Sturgeon too have been considerably more abundant in the past. These facts indicate that the Eastern River has conditions of bottom sediment and invertebrate productivity which will support this feeding habit.

Water column feeders are those fish which obtain their food directly from the water column-- by filtering plankton (e.g. American shad) or by catching swimming invertebrate prey such as insects and crustaceans (Brook trout). Ten species from the Eastern River list are included in this group. They are significant because turbidity (as suspended sediment) may be deleterious to filter-feeding fish by clogging their gills, and because catching prey in the water column frequently demands visual contact, which is difficult if the water is turbid. Smelt, shad, and herring are all seasonal visitors-- smelt in the cold seasons, herring and what few shad are left in the summer (as juveniles, primarily). Except for the Pumpkinseed sunfish, the remaining species in this feeding group are relatively small and might frequent marginal palustrine wetlands where the water is less turbid. Nothing is known of the detailed distribution of these fish in the river.

TABLE 14 Fish regularly found in the Eastern River. List of species and characteristics supplied by Lewis N. Flagg and Tom Squiers, Research Division, Maine Department of Marine Resources. # = year 'round resident population.

COMMON NAME	TAXONOMIC NAME	POPULATION CHARACTERISTIC
Lampreys		
Sea Lamprey	Petromyzon marinus	spring migrant
Sturgeons		
Atlantic Sturgeon	Acipenser oxyrhynchus	rare
Short-nosed Sturgeon	Acipenser brevirostrum	rare
Herrings		
Alewife	Alosa pseudoharengus	common; juveniles abundant in summer
American Shad	Alosa sapidissima	uncommon
Blueback Herring	Alosa aestivalis	common; juveniles abundant in summer
Salmonids		
Atlantic Salmon	Salmo salar	few
Brook Trout	Salvelinus fontinalis	mostly confined to streams
Smelt		
Rainbow Smelt	Osmerus mordax	very abundant
Suckers		
White Sucker	Catastomus commersoni	#; common
Minnows		
Carp	Cyprinus carpio	#; common
Golden Shiner	Notemigonus crysoleucas	#
Common Shiner	Notropis cornutus	#
Spottail Shiner	Notropis hudsonius	#
Killifish		
Banded Killifish	Fundulus diaphanus	#
Mummichog	Fundulus heteroclitus	#
Sticklebacks		
Ninespine Stickleback	Pungitius pungitius	#
Threespine Stickleback	Gasterosteus aculeatus	#
Cod		
Tomcod	Microgadus tomcod	few; visitor, late fall, late spring
Sea Bass		
White Perch	Morone americanus	#
Striped Bass	Roccus saxatilis	transients, in summer only
Sunfish		
Smallmouth Bass	Micropterus dolomieui	#; low numbers
Pumpkinseed Sunfish	Lepomis gibbosus	#
Perch		
Yellow Perch	Perca flavescens	#
Eels		
American Eel	Anguilla rostrata	#

Water column and epibenthic feeders combine the feeding characteristics of the previous two groups by feeding normally both from the water column and from the surface of the bottom (*i.e.*, they do not rummage around in the bottom sediment like the bottom-feeding species). This feeding group includes nine Eastern River species, all fair-sized fish, plus three species from the water column group which sometimes assume an epibenthic feeding habit. Epibenthic feeders often browse on hard (gravelly or rocky) bottoms. In the Eastern River, such bottoms are found in the tributary streams, as well as along the sides of the river itself in many places. Epibenthic feeding displaces little sediment directly, but such fish swimming close to the bottom while searching for prey undoubtedly stir up sediment by their motions. Again, the epibenthic feeding habit assumes that the benthic productivity is fairly high. It also assumes some dependence on vision.

Piscivorous (fish-eating) fish comprise the final group in Table 15, including nine species found in the Eastern River. All of these species occur on other lists in the Table, so eating other fish is only a part of their feeding strategy. These fish prey on other fish at different times of their life cycles, and often prey on the young of other fish. This feeding habit is very strongly dependent on visual cues and would be ineffective in highly turbid water. The difficulty here is in knowing what levels of turbidity affect fish feeding habits. It is possible that very few fish are able to assume the piscivorous habit in the main part of the Eastern River except at brief periods of better-than-normal visibility. In the upper reaches of the river, and in tributary streams and marginal wetlands, there may be more piscivory.

Larval stages of sea lampreys, called ammocetes, burrow into river bottoms and live there for several years, feeding on invertebrates living in the sediments and detritus which settles there, and finally metamorphosing into adults which return to the sea, where they are parasites on other large fish (Migdalski and Fichter, 1976).

This survey of fish feeding habits was gathered from all the fresh-water fish sources listed in the Literature section. In the course of gathering the information, it became clear that a given species of fish will feed on a diverse menu, depending on where it finds itself and what is available, limited only by the size of the fish and its feeding equipment. (For example, filter-feeding fish have to have special filtering apparatus on their gills, which does not, however, prevent them from preying on other fish or eating invertebrates, etc.) Those species in Table VII designated as "resident populations" breed, grow, and die in the Eastern River, and their feeding habits will be closely adjusted to the conditions they encounter there throughout their life cycles. Their feeding habits may be quite different from fish of the same species living in a different kind of river in the Kennebec system. However, the existence of a healthy variety of feeding types represented among Eastern River resident fish species suggests that, whether or not these species cause the turbidity in the

TABLE 15. Feeding characteristics of fish regularly found in the Eastern River. Information gleaned from multiple sources.

Bottom Feeders

Short-nosed Sturgeon
Atlantic Sturgeon
Carp
White Sucker

Water Column Feeders

Rainbow Smelt
American Shad
Blueback Herring
Golden Shiner
Spottail Shiner
Banded Killifish
Mummichog
Ninespine Stickleback
Threespine Stickleback
Pumpkinseed Sunfish

Water Column and Epibenthic Feeders

Atlantic Salmon
Brook Trout
Alewife
American Eel
Common Shiner
White Perch
Yellow Perch
Smallmouth Bass
Tomcod

also, sometimes: Pumpkinseed Sunfish
Golden Shiner
Mummichog

Piscivorous Fish (eat other fish)

Atlantic Salmon
Brook Trout
Rainbow Smelt
American Eel
White Perch
Yellow Perch
Smallmouth Bass
Striped Bass
Tomcod

river, this turbidity does not have a very drastic adverse affect on them.

Three commercial species are caught or were formerly caught in the Eastern River: the American shad, alewives (including blueback herring), and smelt. Shad runs declined steadily after 1898, due primarily to dams, which blocked off spawning grounds, and pollution in the Kennebec (Foye, Ritzi, AuClair, 1969). Those few shad which return annually to spawn in what is left of the spawning grounds are hardy indeed. Alewife landings in the Eastern River have declined from 4000 pounds in 1979 to 2400 pounds in 1981 (data from Lewis Flagg, Dept. of Marine Resources). Such a trend may be due to deteriorating environment, but is more likely to reflect fishing effort and perhaps natural cycles in alewife abundance. Smelt too show some fairly large fluctuations in abundance (reported catches only) over the last eight years-- although this is too small a sample of time to allow any conclusions about long-term population changes. Over the last 100 years, all species of anadromous fish in the Kennebec and its tributaries have declined due to dam-building and pollution.

The carp deserves special attention in this report for at least two reasons: it is the "cause" most frequently cited for the turbidity in the Eastern River, and it has an unsavory reputation among fisheries biologists throughout the United States for destroying habitats of favored game fish.

Carp were imported from Europe late in the last century for culture as a food fish in farm ponds. Sigler (1958) notes: "Carp are probably more abundant than any other fresh-water fish in the United States." That is to say, carp have been extraordinarily successful in adapting to a large variety of habitats, where until the last century they had been absent. Foye and Mairs (1965) cite evidence that carp escaped from farm ponds near Augusta into the Kennebec River system between 1880 and 1896. The course of their growth as a breeding population and their expansion into the Kennebec tributaries was not charted. The Maine Department of Inland Fisheries and Wildlife fished systematically for carp in two locations in the 1950's and found that the carp population was well-established, containing fish of all ages (L. H. Bond, personal communication). A Maine Inland Fisheries and Wildlife Department informal report for 28 June 1964 noted that nine carp were gill-netted nine miles up the Eastern River: the fish varied from 9.7 - 12.3 inches in length, and from 10 ounces to 1 pound-2 ounces in weight-- all considered year I fish. Sigler (1958) notes wryly that carp learn net and baited line avoidance early-- within the first year-- and can be line-caught usually only during the breeding season.

Carp are known to be tolerant of a wide variety of industrial pollutants (Rept. State Comm.- Australia), are extremely fecund (up to 2 million eggs for a 15-pound female-- Foye and Mairs, 1965), and have a high survival rate of young, compared to other fish (Sigler, 1958). In the Kennebec River system, these qualities of the carp undoubtedly gave the species a competitive edge over other species during the years of industrial pollution and the reduction of habitat caused by dam construction.

According to Sigler (1958), carp prefer quiet waters. They move inshore during the early morning and at twilight. They will live in 3-4' of water if there is cover (emergent vegetation), and during spawning they prefer such areas. Young carp hatch and live in 3-4 inches of water during their first two months. Carp enter shallow water as long as the level is rising, but retreat rapidly to deep water at the slightest drop in level. Carp cease feeding and become inactive at water temperatures of 35 - 37°F. They can survive without feeding for considerable periods and spend such periods preferably in deep water.

In specific reference to carp in the Eastern River, these characteristics suggest that:

- Adult carp do not inhabit the upper reaches of the river or the tributary streams.

- Carp move onto the flats (both vegetated and unvegetated) with rising tide (given enough water) and move out into the river channel when the tide starts to ebb.

- Adult carp will spawn in the water-covered shallows, which will be primarily on Middle Ground-- although there are other appropriate areas in the river-- and young carp will preferentially occupy the marginal shallows for their first two months.

- During the winter, carp will be found (if in the river at all) in the deepest parts of the channel, relatively inactive, doing relatively little if any feeding.

It should be noted that fish become acclimated to the temperature range of the environment in which they are living, and carp may in fact be active in the Eastern River at lower temperatures than those reported in the literature. For instance, research in the Soviet Union revealed that, although carp become torpid and die at water temperatures below 34°F, they can survive ice-covered water if under the ice the water is flowing and well-oxygenated (Rept. State Comm.- Australia).

Carp are frequently reported to produce in enclosed waters (lakes and ponds) levels of turbidity which are detrimental to other species of fish, particularly game fish. Carlander (1977) cites studies reporting that carp-caused turbidity markedly decreased the success of smallmouth bass breeding nests, and that largemouth bass numbers decreased in the presence of abundant carp. Walden (1964) reports that spawning success of both smallmouth bass and yellow perch are adversely affected by carp-caused turbidity.

More specifically, it is the eggs of many fish species which are most vulnerable to damage by excessive turbidity caused by carp. At least part of such damage can be attributed to the physical activity of the carp themselves during their own spawning process which takes place, as noted, school, so that all the depressions in one area were made at the same time. Not all the depressions observed during the field trip were equally fresh. Some "wallow fields" had been clearly modified by the river current. Evidently, the fish forming these wallows do not feed everywhere in the river during every tidal cycle. Although no carp were observed feeding, carp are the logical candidates for the species forming these extensive "wallow fields," though white suckers should not be exempted from consideration. Robert Gleason (personal communication) reported seeing from an aircraft what he took to be abundant carp in shallow depressions along the margins of Middle Ground.

To summarize, in view of long-standing pollution of the Kennebec and of declines in anadromous fish populations, these carp, introduced accidentally 100 years ago, have proven admirably suited to life in the tidewaters of the Kennebec River system. It is likely that, because of its high reproductive potential and its tolerance for adverse conditions, the carp population became well-established very quickly in the Kennebec. What few data there are suggest that the carp population has not had a drastically deleterious affect on river vegetation. In view of its life habits, carp could be a major contributor to excessive turbidity in the Eastern River. But it is clearly not the only contributor, as this survey of wildlife, particularly other fish species and ducks, should make clear. As pollution is abated in the Kennebec River system, gamefish, especially predatory species, will increase in number. There is ample evidence from around the world that carp can co-exist with other species-- including those more popular with sport fishermen-- and that carp are not necessarily always associated with highly turbid waters. The carp population should be expected to assume its place in the balance of wildlife species generally. There seems to be scant potential for the carp population to take over the Eastern River and thus assume sole responsibility for its turbidity.

Turbidity

There are very few data on turbidity in the Eastern River. Hunt (1969) gives measurements on six samples taken from various points along the river. Only four of these showed measurable turbidity, ranging from 25-120 Jackson Turbidity Units (JTU). JTU may be considered roughly equivalent to NTU (Nephelometric Turbidity Units). On that basis, Hunt's (1969) measurements in the Eastern River can be compared to measurements by E. C. Jordan (1975) at Abagadasset Point in the Kennebec River (5 NTU) and at Richmond Bridge (3-8.4 NTU); and measurements by the Maine DEP in the Muddy River (0.7-1.5 NTU), the Androscoggin River at the Brunswick-Topsham Bridge (2.2-12.0 NTU, avg. 5.3), and the Kennebec River just above the Augusta dam (0.5-12.0 NTU, avg. 2.4). By these standards, the Eastern River is very turbid.

Hunt (1969) also reports a volume of suspended matter found in 300 ml samples allowed to settle 24 hours (Imhoff test). In two samples, he found 0.2 ml of sediment; in a third, only a trace (this latter sample was taken from a tributary brook near East Pittston). Table 17 gives a size analysis for bottom sediment in several Merrymeeting-region rivers reported by

TABLE 17. Size characteristics and organic matter content of sediments from rivers in the Merrymeeting Bay Region, expressed as percents. Taken from Spencer, 1958.

	River				
Size Class	Androscoggin	Abagadasset	Cathance	Muddy	Eastern[1]
Sand	85.7	46.4	34.1	49.5	43.8
Silt	8.1	38.7	49.6	32.6	34.1
Clay	6.8	14.8	16.2	17.9	20.1
Organic matter from all classes, as a % of total	1.1	5.7	4.3	4.2	3.7

NOTES: 1. Data for the Eastern River were derived from samples taken on Middle Ground only.

2. _Only_ values from the Androscoggin River are significantly different from the other values, based on statistical tests performed by Spencer.

in shallow waters, and is characterized by jumping and splashing. In Table 16, the breeding seasons of the various species of fish inhabiting or frequenting the Eastern River have been plotted in a bar diagram. The breeding seasons of all but six species overlap with that of the carp. Some species may avoid conflicts with the carp by breeding in tributary streams and marginal palustrine areas not frequented by carp, while others may not be particularly sensitive to turbidity. Thus, the presence of a large number of species with breeding seasons overlapping that of the carp suggests that fish in the Eastern River have accomodated to conditions there-- both to the carp and to the turbidity.

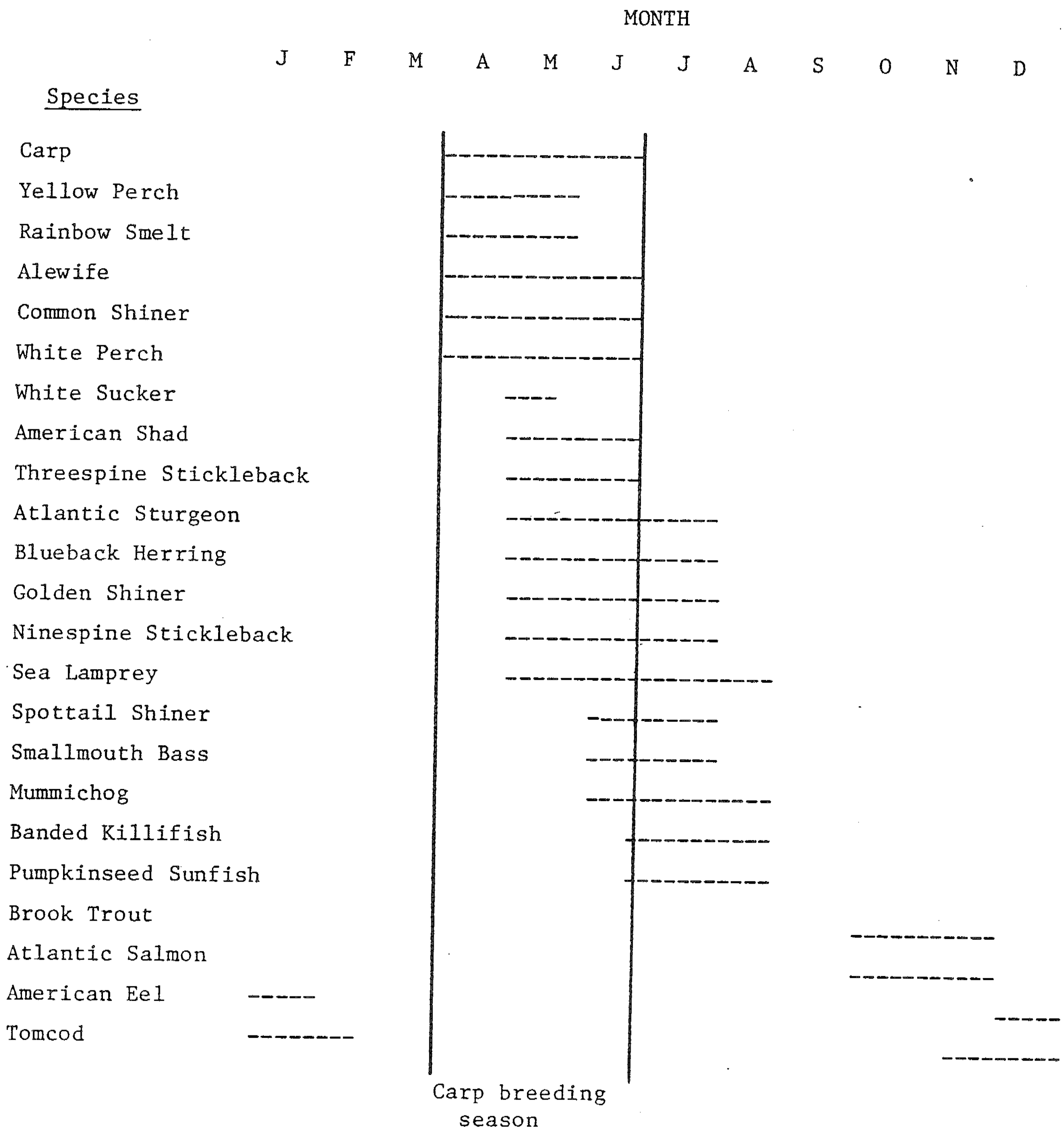
At least some of the fish-eating species, as well as waterfowl working over the weedy shallows, are major predators upon carp fry and young fish. 80% - 98% of the newly-hatched fry and 60%-70% of those surviving to young fish may be eaten by predators (Rept. State Comm.- Australia). High reproductive potential accounts for the carp's success in the face of such losses (which, however, are probably less than losses suffered by other fish).

Several sources noted that carp uproot vegetation in the course of feeding and may destroy vegetation cover important to other species. In the Eastern River, this could be important because the plant favored as duck food, wild rice, is very shallow-rooted and quite easily dislodged. It is significant, therefore, that, according to Spencer's surveys in the late 1950's, the area of Middle Ground covered by wild rice did not change appreciably over a three-year period. Neither did the survey of vegetation coverage for this report reveal any significant change in the areal extent of vegetation on Middle Ground compared with Spencer's surveys of 16 years earlier.

The deleterious effects of carp on other species of fish are especially pronounced in enclosed bodies of water such as ponds and lakes, and therefore most attention has been focused there. The effects are much less pronounced in rivers except where the river is particularly slow-flowing. According to Sigler (1958), evenly-distributed populations of carp probably have relatively modest effects on their environment, while local concentrations of some 500 fish per acre were considered extremely harmful to vegetation. Such concentrations of carp could occur at spawning season. For carp in the Eastern River, such concentrations might be reached during the breeding season. But understanding the behavior and distribution of carp in the river is greatly complicated by the fact that the Eastern River is an open-ended system, and carp are free to journey to other undammed tributaries of the Kennebec.

Evidence of fish wallows-- shallow, dish-shaped depressions in soft sediment-- were found beginning about one mile below the entrance into the Eastern River of Kelly Brook. They became plentiful within the next one-half mile and were abundant wherever tidal flat was exposed below that. In fact, at one site the entire flat was covered with shallow depressions, like a huge waffle, suggesting that the fish were bottom-feeding in a

TABLE 16. Breeding seasons of fish regularly found in the Eastern River. Information gleaned from multiple sources.



Spencer (1958). Sediments on Middle Ground in the Eastern River do not differ statistically from those of the Abagadasset, Cathance, or Muddy Rivers; all have appreciable proportions of silt and clay, and much of the suspended sediment will consist of the latter (smallest) sediment size. It is expected that such small particles settling to the bottom of a settling tube will include a sizable proportion of water. Thus, unless it was centrifuged, the volume of sediment reported by Hunt (1969) included a substantial amount of water. The water content of naturally-occurring sediments of this size typically is 80-98%. Assuming these values and a mean specific gravity for the sediment particles of 2.65 (the specific gravity of quartz), Hunt's sediment volumes calculate out to a suspended sediment load of between 35 and 350 mg per liter. These estimates may be compared with the E. C. Jordan results from Abagadasset Point (27.2 mg/l) and Richmond Bridge (3.5-9.5 mg/l), and the DEP report for the Muddy River (0.4-4.0 mg/l). The Eastern River is clearly muddier than other rivers in the Merrymeeting Bay region, even though their sediments have a similar composition. A recent review by Saila (1980) summarizes much existing data on the effects of turbidity on juvenile and adult fish behavior and survival. There is virtually no reported effect on these aspects of animal life at the estimated turbidity levels in the Eastern River. Such a finding is consistent with the observations made previously that fish species common to the Eastern River exhibit a complete variety of feeding habits and must somehow have accomodated to the turbidity regime there.

Turbidity affects vegetation by cutting down the amount of light which penetrates water and is available for photosynthesis. It is significant that on the field checks of the Eastern River submerged aquatic plants were rarely seen. A few such plants observed in Kelly Brook were dusted with fine sediment-- certainly a hindrance to photosynthesis and healthy growth. In contrast, Spencer's (1958) survey of Middle Ground showed a sizable area (14.8%) covered with submerged aquatics. The problem of submerged aquatics in the Eastern River is important because of the large area of unvegetated flats there. These flats are a major source of suspendable sediments. The question is whether they are unvegetated because turbidity prevents the establishment and healthy growth of plants (submerged aquatics as well as emergent species), or because bottom-feeding fish (carp and suckers) constantly work over the sediment, ingesting, burying, or uprooting new seedlings. Yet another question is whether fish maintain the unvegetated flats by their activities, or are merely taking advantage (for feeding on bottom-dwelling invertebrates) of areas which cannot support vegetation for other reasons. In either case, fish are implicated-- along with ducks, especially on Middle Ground-- in contributing to turbidity levels in the Eastern River.

It has not been possible to establish from the data the historical picture of turbidity in the Eastern River. There is a sometimes vague, sometimes quite distinct "general memory" that the river was once much clearer than it is now. If the present level of turbidity is attributable primarily to carp, then a "pristinely clear" Eastern River would have begun to turn muddy shortly after the turn of the century, when the carp population began to expand into ecological niches vacated by declining anadromous fish stocks and by other fish adversely affected by pollution in the Kennebec River. From direct observation, it is clear that wind-generated waves and tidal currents are sufficient-- without any help from wildlife-- to stir up sediments in the Eastern River. If the present distribution of unvegetated flats existed 100 years ago before the advent of carp, these flats should have been the source of significant turbidity in the river. If, on the other hand, the flats were vegetated 100 years ago, waves and currents would not have been as effective in stirring up sediment, and the river might have been considerably clearer. The growth of the carp population in this latter case could possibly have created sufficient turbidity to make light for submerged aquatics a problem, leading to the devegetation of the flats.

IX. Water Quality in the Eastern River

The Eastern River is classified as Class C, the tidal portions are classified as Class SC. This classification is supposed to be of such quality as to be satisfactory for recreational boating, fishing and other similar uses except primary water contact (MRSA Title 38, Chapter 3).

The turbidity values recorded by Hunt (1969) indicate that the turbidity in the lower river exceeds the minimum recommended values for safe drinking water. There are no standards, apparently, for minimum turbidity values recommended for contact recreation. EPA standards recommend that the minimum turbidity levels for protection and propagation of fish and wildlife in cold waters should be less than 10 Jackson Turbidity Units (EPA, 1968).

While the excess turbidity (25 to 120 JTU) found in the Eastern River does not inhibit non-contact recreational use of the river, it would be desirable to decrease the turbidity to levels which would more closely reflect recommended levels for the propagation of fish and wildlife. A reduction in turbidity level would also increase the aesthetic desirability of the river.

X. Conclusions

Analysis of the turbidity levels found in the tidal portions of the Eastern River indicate that they exceed levels found in surrounding rivers and tidal basins, and exceed recommended levels for the optimal propagation of fish and wildlife in cold waters.

There are limited existing data to determine the causes of the excess turbidity, but analysis of the available data leads to the following conclusions:

- The excess turbidity is not caused by land based activity within the Eastern River drainage basin. Land based activities such as forest harvesting and active crop propagation may increase soil erosion above natural erosion levels, but not to an extent which can be considered significant.

- The excess turbidity is not caused by natural erosion of the surficial deposits or bedrock units of the upland.

- The major source of fine-grained material within the river originates from the slumping and mass-wasting of marine clay (the Presumpscot Formation) deposits along the river banks in the upper reaches of the tidal portions of the river. The marine clay is directly introduced into the upper tidal flats and the margins of the main river channel.

- Comparison of turbidity levels found in the Kennebec River, Merrymeeting Bay and other tidal rivers which enter Merrymeeting Bay indicate that the turbidity is indigenous to the Eastern River tidal basin and primarily in its upper reaches. The Kennebec River is not a major contributor of suspended sediment to the Eastern River.

- The flushing rate of the tidal portion of the Eastern River is found to be, on a preliminary basis, about twelve days. While flushing rates of this magnitude would lead to a concentration of suspended matter within the tidal basin, the rate, alone, is not the cause for elevated turbidity levels in the water column of the tidal waters.

- The primary causes of turbidity in the Eastern River appear to be (1) fish populations which, because of their feeding habits, contribute directly to the suspended sediment concentration found in the waters; and decrease the surface stability of the intertidal mud flats; and (2) wave resuspension of the surface sediment on intertidal mudflats. Wave resuspension of mudflat sediment is enhanced over what would normally be expected because the river basin is oriented parallel to the prevailing wind direction for at least six months of every year and fish feeding habits continuously loosen mudflat surface sediment. The muds are more capable of being eroded by surface wave activity.

XI. Recommendations

Excess turbidity in the lower Eastern River results from fish feeding and foraging habits which directly introduce sediment into the water column and increase the susceptibility of mudflat sediment resuspension by waves caused by southwest winds. Much of this sediment was originally derived from erosion of the upland river banks by normal bank erosion processes.

While much of the analyses performed during this study were based on limited data and based on simplified assumptions and models which result in conditions departing from actual conditions, it nonetheless appears that further water monitoring investigation would be inadvisable and too costly to justify on the basis that the actual impacts of the excess turbidity levels in the river are not hazardous to human health.

There are no cost effective steps which can be taken to prevent the introduction of the marine clay into the intertidal flats, directly reduce the carp population, or reduce the wave activity which resuspend tidal flat sediment into the water column.

With the increase in water quality of the Kennebec and Androscoggin Rivers, fish species other than the carp should become more populous in the Merrymeeting Bay area, including the Eastern River. Hopefully, in time, this would lead to a reduction in the carp population by increased competition for habitat space.

The state of Utah and several other mid-western states have developed a sport fishery for carp (Sigher, 1958). Reduction in the carp population could be affected in this manner.

An alternative approach to reducing the amount of suspended sediment being introduced into the river water column would be to establish aquatic vegetation on the unvegetated tidal flats. The U.S. Army Corps of Engineers has conducted studies of vegetating intertidal dredge spoil sites for the stabilization of sediment and propagation of wildlife, but the present cost ($1000-$3000, 1975 dollars) may be too prohibitive for application in the Eastern River.

Further studies of the aquatic vegetation in the tidal river basin and their present ability to colonize unvegetated mudflat surfaces is recommended if the Town of Dresden feels that such studies might lead to an eventual program of increasing the vegetation on the tidal flats.

Otherwise the only approach available is to realize that the present ecology of the Eastern River is such that excessive turbidity is to be expected. Unless increased competition from more desirable fish species is eventually accomplished in the coming years, excess turbidity of the river water is to be expected.

XII. Acknowledgements

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