APPENDICES

Appendix A

Correlating STP Performance and Operation to Boston Harbor Water Quality

One of the tasks en route to a cost-benefit analysis is to design and cost the technical options capable of modifying, maintaining, or raising the quality of the environment in question. The complement to this task is to collect data on the biological, physical, and chemical parameters of the current environment so that the changes to the environment made possible by the different technical options can be quantified. Neither of these tasks was performed by Meta Systems. Instead, technical and environmental data were collected from existing sources: no new information research (i.e., engineering analysis or environmental monitoring) was undertaken.

Correlating STP operations and performance with the water quality of the harbor is a complicated task. The problem is not so much that the necessary data does not exist at all but rather that the available information may not be collected in forms or manners suited to particular analysis goals. Water quality data shortcomings are the result of less than optimal sampling procedures such as:

- infrequent monitoring;
- parameter selections not consistent from one sampling to next;
- same locations not repeatedly sampled; and
- sampling not co-ordinated with seasonal, weather-related, tidal, STP, etc. events.

In the available reports the performance information presented for STP options differs from that presented for CSO options. The performance of the STPs under the various options is measured in terms of effluent constituent concentrations. CSO plans, on the other hand, estimate the water qualities achievable under various CSO designs as well as reduced loadings. In order to establish potential water qualities achievable under the different STP options it was necessary to describe the dispersion of STP effluents throughout the harbor.

A.1 Influent, Effluent, and Sludge Characteristics

Periodically, the MDC takes samples of STP influent and effluent and conducts tests to determine the composition of raw and treated municipal wastewaters. (See Table A-1.) Using the concentration information from this testing, along with values for total flow volume, the pollutant loadings to the harbor due to the Deer and Nut Islands' STP options, have been calculated. The combined loadings are presented in Section 2, Table 2-1. The knowledge of influent composition enables calculation of the loadings from raw sewage discharges due to STP bypasses.

To calculate annual loadings from influent and effluent concentrations and flow volume data:

1) milligrams per liter was converted to pounds per gallon using (8.4×10^{-6}) (mg/l) = 1bs/gal

2) the combined effluent discharge volume of Deer and Nut Islands was assumed equal to 500 million gallons per day (350 and 150 mgd, respectively)

3) concentrations for the individual STPs were weighted by volume of flow for a combined average concentration equal to (0.3) x (cont. at Nut Island) + (0.7) x (conc. at Deer Island)

4) annual loading: (365 days) x (500 mgd) x (combined average concentration)

Bypass loadings were calculated from:

1) influent (i.e., raw wastewater) composition: use of this data probably results in an overstatement of pollutant loadings

Table A-1.

MDC Treatment Facilities Current Pollutant

Removals for Wastewater Effluents

Pollutant	NUT ISLAND			DEER ISLAND		
	Influent (mg/l)	Effluent (mg/l)	Removal (Percent)	Influent (mg/l)	Effluent (mg/l)	Removal (Percent)
BOD_5	136.6	97.0	29.0	150.0	108.0	28.0
TSS	178.3	82.0	54.0	155.5	70.0	55.0
Cadmium	0.0176	0.0119	32.4	0.021	0.019	9.5
Chromium	0.051	0.041	19.6	0.147	0.108	26.5
Copper	0.618	0.292	52.8	0.246	0.357	-45.1 a/
Lead	0.104	0.074	28.8	0.157	0.131	16.6
Mercury	0.00199	0.00120	39.7	0.00124	0.0011	11.3
Nickel	0.889	0.291	67.3	0.115	0.131	-13.9 a/
Zinc	0.431	0.376	12.8	0.777	0.488	37.2

Source: The BOD_5 and TSS values are from Metcalf and Eddy, June 1982. The toxic metals data are from US EPA (1983) Table 3.2-6 and are for the period December 1975 through September 1977.

a/ The negative value of this removal percentage may be due to 1) random sampling error or 2) a propensity of the Deer Island's treatment process to concentrate this metal in the effluent rather than in the sludge.

since bypasses are often associated with storm events, thereby diluting the raw wastewater.

2) bypass volume estimates:

- for Nut Island:[a]

  Recorded untreated discharges to Boston Harbor January-August, 1982--2.1 billion gallons over 50 days (0.042 billion gallons/day);

  Spills of unknown amounts January-August, 1982--4 spills over 8 days estimated at 0.34 billion gallons (8.0 x 0.042);

  Total for January-August, 1982 = 2.44 billion gallons (0.305 billion gallons/month);

  Estimated annual loading = 3.66 billion gallons.

- for Deer Island:[a]

  Recorded untreated discharges to Boston Harbor January-October, 1982--2.2 billion gallons (0.22 billion gallons/month);

  No spills of unknown amounts:

  Estimated annual loading = 2.64 billion gallons.

- for Moon Island:[b]

  Estimated annual loading = .258 billion gallons.

Heavy metal loadings to the harbor from STP sludges were available from the draft report by Environmental Research and Technology (1978).

A.2 Pollutant Transport from STP Outfalls

To assess the impact of STP discharges in Boston Harbor, it is important to know how STP discharges are dispersed throughout the Harbor. Since discharges to the Harbor are subject to diverse and variable conditions, the water quality throughout the harbor is not uniform. Variations in quality

---

[a] Calculations based on bypass data from Dumanowski (1982).

[b] Moore (1980).

may be attributed to bottom topography, currents (directions and magnitudes), wind, and the location and means by which pollutants enter the Harbor. STP discharge dispersion is not easily correlated with the water quality of the Harbor. In order to understand the environmental consequences of STP discharges, information is needed about:

- transport of STP loadings via water movements (current speeds, volumes of flow, flow patterns, etc.);
- physical and chemical interactions of STP effluent and sludge with the Harbor's waters (decay rates, settling rates, chemical reactions which might neutralize toxics, chemical recombinations how pollutants get cycled through the aquatic environment, rates of stabilization).
- biological aspects of loadings (tolerance of aquatic organisms to loadings, pollutant uptake by aquatic organisms).

One form of water quality information available for Boston Harbor can be called "static data," which refers to measurements of ambient water quality at a specific time and location. Water quality information which describes changes in quality over time and the interactions between various elements of the harbor (physical, chemical, biological) contributes to a dynamic understanding of the Harbor's water quality. The problems with the static data available for Boston Harbor could be alleviated with more regular, extensive data collection and water quality measurement procedures. For dynamic information, however, the complexity of the harbor environment makes it extremely difficult to understand all interactions and interrelationships among its elements.

Static measurements ("grab samples") of pollutant parameters represent the contemporary environmental status of the harbor but do not clearly reflect the impacts of STP discharges in particular. Not all of the pollutant deposits in the Harbor are from the Deer and Nut Island's STPs.

Tests of harbor waters and sediments cannot distinguish among pollutants whose source is STP discharges, those deposited prior to STP operations, or those that were overflowed from a combined sewer. Not enough data has been collected to make definitive conclusions regarding discharges and their ultimate destinations. Such conclusions require a more rigorous sampling endeavor (periodic sampling, extensive coverage of harbor) and that water quality sampling be scheduled in conjunction with sampling of STP and CSO effluent to the harbor in order to correlate variations in discharges with variations in measured qualities throughout the Harbor.

Without historical information to demonstrate dispersion phenomenon of STP discharges within Boston Harbor, a predictive model of dispersion dynamics is of interest to this case study because it can help to describe what the future impacts of a number of STP options might be. Models of dispersion dynamics are perhaps the best means of determining what will happen to the effluent once it is discharged from an STP since available empirical information is insufficient for this task. A few models have been developed to quantitatively explain some aspect of the Harbor which, due to physical or economic constraints, cannot be adequately analyzed with static measurements. One model designed specifically to quantify the dispersion of STP discharges into Boston Harbor is the DISPER model, developed at MIT. It largely relies on water movement (currents) information to describe dispersion. DISPER itself is based on CAFE, another MIT-developed program which models these water movements. DISPER has several positive qualities which suggest that it be used as a reference. Most important is that it was designed specially for Boston Harbor. Its output also seems to correlate with the relative pollution concentrations measured throughout the Harbor. However, this may only mean that the developers of the model fit it to the existing situation, and thus it is descriptive but not necessarily predictive.

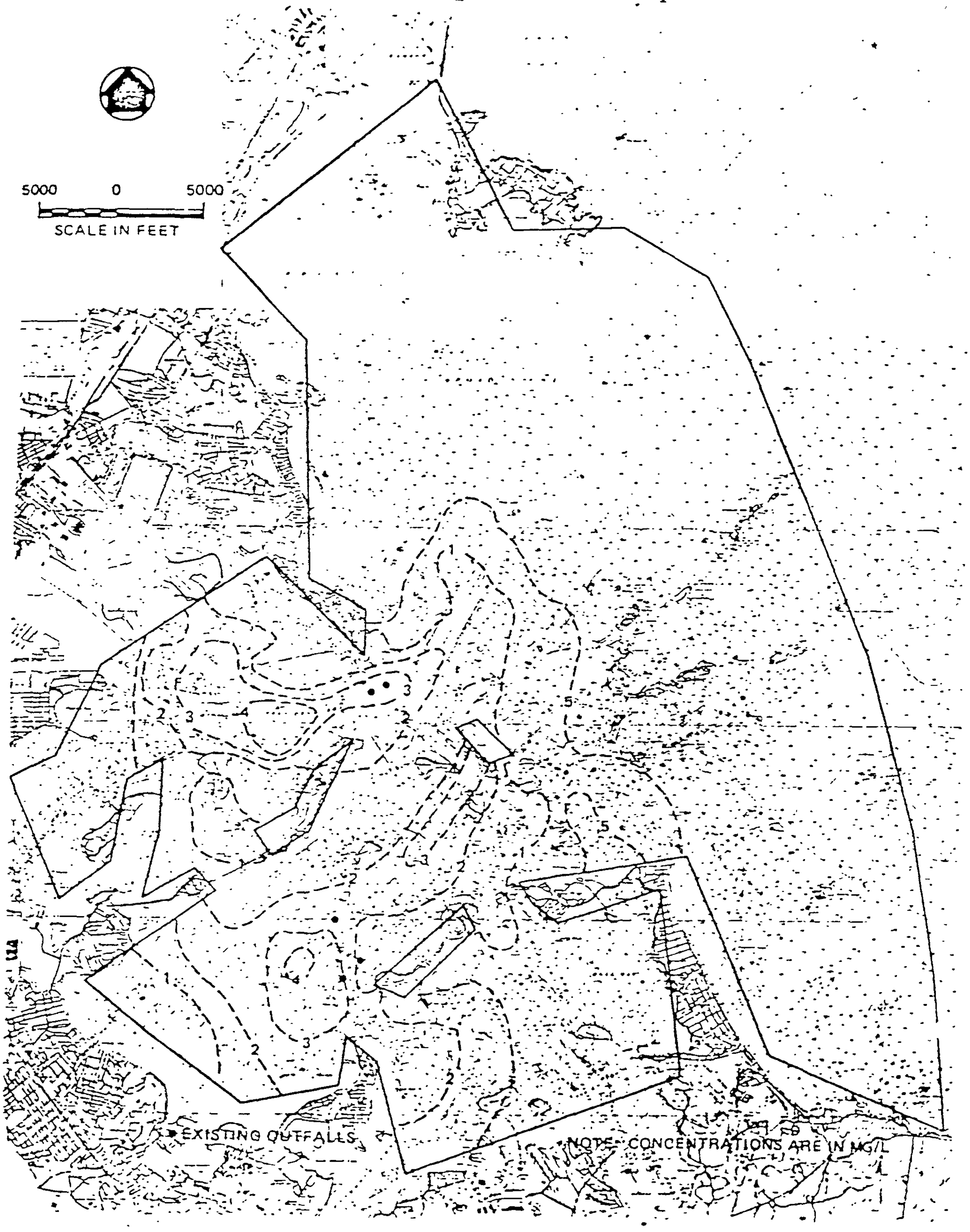
DISPER's greatest strength lies in its ability to predict volumetric inflows and outflows from the harbor area (across a specified, but imaginary, boundary). The model's next strongest capacity is its ability to predict water movement patterns (directions and magnitudes of flow). CAFE is largely responsible for these phases of the modeling effort. Bow STP effluent disperses through the harbor is the task addressed by DISPER. Whether pollutant loadings move exactly as does the water is unknown because settlement and decomposition in transport, propensities of marine organisms to assimilate was&es, etc., are not precisely understood.

The impact of, for example, the ocean outfall diffuser is assessed using a conservative solute and BOD, a substance which decays at a first order rate. For the conservative substance, decay and settling rates and concentrations along the ocean boundary are assumed to be zero. The source loading is input continuously and steady-state concentrations are computed. No other sources or sinks are modeled. The results of this modeling effort included contour lines of constant dilution and concentrations of ultimate BOD as incremental additions from the treatment option being modeled.

Model results available to Meta Systems for review were run by Metcalf and Eddy. (A sample of Metcalf and Eddy's DISPER output is shown in Figure A-1). Metcalf and Eddy suggest that their assumptions tend to be conservative (i.e., decay rate = zero, settling rate = zero).

The predicted water quality impacts due to the various STP treatment options presented in Section 4 of the main report were made through comparisons of the following types of information, often in the form of mappings:

Figure A-1. Example of DISPER Output



CONCENTRATIONS OF ULTIMATE BOD FROM TREATMENT PLANT EFFLUENT EXISTING CONDITIONS

Source: Metcalf & Eddy (1982), Figure 3-17.

- effluent pollutant concentrations;
- dispersion model output (DISPER); and
- water quality at various receptors (beaches, recreational areas, shellfish beds).

The receptor site, Brewsters Islands, is provided as an example of the way the calculations of percentage pollution reduction in Tables 4-2 and 4-3 of the main report were done.

(1) Current Ambient Water Quality at Brewsters Islands

Fecal coliform (MPN/100 ml)	10
BOD_5 (mg/1)	1
TSS (mg/1)	10-20

Source: Maps from Region I, EPA, Boston Harbor Data Management System, December 1983.

(2) Existing Concentration of Effluent

	Deer Island	Nut Island
Fecal coliform	1500	1500
BOD_5	127.6	105
TSS	121	110

Source: See Table 4-1, Section 4 of main report

(3) Existing Outfall Dilution Ratio 500 500 (at Brewsters Island)

Source: See Table 4-1, Section 4 of main report

(4) Existing STP Incremental Contribution (Deer and Nut combined) at Brewster Islands

Fecal coliform	6
BOD_5	.47
TSS	.46

Source: Effluent concentrations (2) divided by dilution ratios (3) summed for both Deer and Nut Islands.

(5) Portion of Ambient Water Quality not Due to Existing STP

Fecal coliform	4
BOD_5	.53
TSS	9.5-19.5

Source: Current ambient water quality (1) minus STP contribution (4).

(6) Effluent concentrations

	Ocean Outfall	Secondary Treatment
Fecal coliform	1500	1500
BOD_5	115	30
TSS	86	30

Source: See Table 4-1, Section 4 of main report.

(7) Dilution Patio at Brewsters Islands

	200	500

Source: See Table 4-1, Section 4 of main report. Obtained from DISPER contour maps.

(8) Incremental Contribution from Treatment Option (at Brewsters Islands)

Fecal coliform	7.5	3
BOD_5	.57	.06
TSS	.43	.06

Source: Effluent concentration (6) divided by dilution ratio (7).

(9) Ambient Water Quality with Treatment Option (at Brewsters Islands)

Fecal coliform	11.5	7
BOD_5	1.11	.6
TSS	10-20	9.6-19.6

Source: Portion of ambient quality not due to existing STP (5) plus incremental contribution (8).

(10) Percentage Change in Water Quality (+ improvement/ - degradation)

Fecal coliform	-15	+30
BOD_5	-11	+40
TSS	0	+2 to +4

Source: Current ambient quality (1) minus ambient quality with treatment option (9) divided by (1).

References

Dumanowski, Diane, 1982. The Boston Globe, December 19, 20, and 21, Boston, MA.

EcolSciences, March 1979. Environmental Impact Statement: MDC Proposed Sludge Management Plan, Metropolitan District Commision Boston, MA, for Environmental Protection Agency, Region I, Boston, MA.

Environmental Research and Technology, 1978. Draft Report for the National Science Foundation, C-PRA77-15337.

Metcalf & Eddy, Inc., September 13, 1979. Application for Modification of Secondary Treatment Requirements for its Deer Island and Nut Island Effluent Discharges into Marine Waters, for Metropolitan District Commission, Boston, MA.

Metcalf & Eddy, Inc., June 1982. Nut Island Wastewater Treatment Plant Facilities Planning Project, Phase I, Site Options Study, for Metropolitan District Commission, Boston, MA.

Moore and Associates, Inc., H.E., September 1980. Wollaston Beach Exploration/Remedial Program Regarding Storm Water Contamination, Boston, MA.

Appendix B

Recreation Benefit Computations

B.1 Seasonal Swimming-Increased Participation

Increased participation in swimming due to pollution abatement control was calculated from current swimming participation and estimated unmmet demand. The example below is for one pollution control option (CSO controls) for the swimming beaches in the study area.

Beach	Increase in Participation from Pollution Control	=	(A) % Pollution Abatement (CSO)	x	(B) Increased Demand (User days)
Constitution	113,750		70		162,500
Dorchester	236,000		80		295,000
Wollaston	1,100,000		80		1,375,000
Quincy	63,560		80		79,450
Weymouth	0		0		52,910
Hingham	0		0		11,100
Hull	0		0		33,000

(A) Source: Section 4 of main report.

(B) Beach	Increase Demand (User days)	=	(1) Proportion of entire SMSA swimming usage supplied by beach	X	(2) Unmet Demand in User Days
Constitution	146,250-178,750 avg = 162,500		.034		4,258,801-5,199,090
Dorchester	265,500-324,500 avg = 295,000		.062		4,258,801-5,199,090
Wollaston	1,237,500-1,512,500 avg = 1,375,000		.291		4,253,801-5,199,090
Quincy	71,505-87,395 avg = 79,450		.017		4,253,801-5,199,090
Weymouth	47,619-58,201 avg = 52,910		.011		4,253,801-5,199,090
Hingham	9,990-12,210 avg = 11,100		.002		4,253,801-5,199,090
Hull	29,700-36,300 avg = 33,000		.007		4,253,801-5,199,090

(1) Calculation of Proportion of Entire SMSA Swimming Usage Supplied by Beach

Constitution Beach is used as an example. Figures for all other beaches calculated in identical fashion.

	Proportion of SMSA Swimming Use Supplied by Beach	=	(a) Beach Attendance	÷	(b) Total Seasonal SMSA Attendance
Constitution	.034	=	325,000		9,452,892

(a) Source: Metropolitan District Commission and municipalities.
(b) Source: See 2b below.

(2) Unmet Demand in User Days

Unmet user days	=	(a) Percent unmet demand for swimming in SMSA	x	(b) participation in swimming days per year
4,253,801-5,199,090		45-55		9,454,892

(a) Source: Department of Environmental, Management, Massachusetts Outdoors (SCORP), 1976 and discussions with cities and towns.

(b) Swimming Participants	=	(i) population SMSA	x	(ii) proportion participating in swimming	X	(iii) average # day trips
9,452,892		2,763,357		.32		10.69

(i) Source: 1980 Census

(ii) Source: Department of Interior, April 1984 (figure is for all U.S.).

(iii) Source: Abt Associates, New York-New England Study, 1979.

B.2 Seasonal Beach Capacity and Current Attendance

The calculations above, show estimated increased number of user days due to pollution control. It is necessary to compare the predicted increased use with the overall beach capacity so that the estimates doe not exceed the known capacity. The example beach capacity calculation is given for Constitution Beach. Table 6-1, Section 6 of the main report, presents the capacity figures for the beaches in the study area.

			(A)		(B)		(C)		(D)
	seasonal beach capacity	=	square feet of beach	÷	square feet of beach per person	x	persons per day turnover rate	x	peak days per season
Constitution Beach:	468,064		264,000		50		3		29.6

(A) Source: Metropolitan District Commission, Boston, MA.

(B), (C) Source: Department of Interior, Outdoor Recreation Standards, 1970.

(D) Source: Department of Environmental Management, Massachusetts Outdoors (SCORP) , 1976.

Capacities for all other beaches were calculated in a similar manner except for Wollaston Beach. The different assumptions used for Wollaston Beach were 40 square feet of beach per person and four persons per day turnover rate.

The predicted increased use is added to the current attendance figures before comparison with seasonal capacity. Table B-1 shows the current seasonal figures for the study area.

Table B-1.

Current Seasonal Attendance Figures

Beaches	MDC and Municipal Estimates 1982	MDC and Municipal Estimates 1974	Binkley/ Hanemann Estimate- Logit Model	Range	Best Guess
Constitution	150,000	500,000	1,258,571	150,000 - 1,258,571	325,00
Dorchester Bay					
Castle Island	15,000			15,000	15,00
Pleasure Bay	175,000			175,000	175,00
Carson	100,000			100,000	100,00
Malibu	150,000			150,000	150,000
Tenean	150,000			150,000	150,000
Wollaston	2,000,000 - 3,500,000	750,000	2,325,714	2,000,000 - 3,500,000	2,750,000
Quincy	140,194 - 177,600			140,194 - 177,600	158,82
Weymouth	103,600 - 108,040			103,600 - 108,040	105,82
Hingham	17,650 - 26,640			17,760 - 26,640	22,20
Hull	66,000			66,000	66,00

B.3 Lower Bound Estimate for Increased Participation

Not all the projected increased participation might occur because of relatively cold air temperatures at the beach, which might discourage increased beach visits even with improved water quality. The predicted increase in beach visits is reduced by a factor to take into account air temperature. It is derived as follows in order to obtain a lower bound estimates of increased participation.

(a) Each day of the summer season is categorized as
- poor (air temperature $\leq 75^{\circ}$ Farenheit)
- good (air temperature $> 75^{\circ}$ and $< 79^{\circ}$)
- excellent (air temperature $\geq 79^{\circ}$)

Air temperature data is available for sampled days during the months of June, July and August, 1982 and 1983.

Source: Approach suggested and data supplied by Dr. Richard Burns, Region 1, Environmental Protection Agency, Boston, MA Categories based on "Weather Conditions that Lure People to the Beach" by P. Rosenson and J. Havens in Maritimes, University of Rhode Island, Graduate School of Oceanography, August 1977. Air temperature for Boston Harbor area from NOAA, National Ocean Survey data file.

(b) The percentage of days in each category is calculated based on a total of 85 days sampled during the summers of 1982 and 1983.

(c) For each category of day a proportion of the predicted increased participation due to improved water quality is assumed to take place. For excellent days all the predicted increase is included. However, the assumption is made that on good and poor days only two-thirds and one-third (respectively) of the predicted increase is retained because the cooler air temperatures would tend to limit the increase predicted from improved water quality.

Source: Based on graph of attendance versus daytime temperature for a Rhode Island beach in "Weather Conditions that Lure People to the Beach" by P. Rosenson and J. Havens in Maritimes, University of Rhode Island, Graduate School of Oceanography, August 1977.

(d) Multiplying the proportion of days in each category (b) by the proportion of the predicted increased participation (c) gives the factor by which the upper bound estimate is reduced in order to obtain a lower bound estimate which takes into account air temperature.

The following table presents these calculations:

		Poor	Good	Excellent	Total
		$\leq 75^\circ$	$> 75^\circ$ and $< 79^\circ$	$\geq 79^\circ$	
(a)	No. of sampled days June, July, August, 1982 and 1983	36	12	37	8.5
(b)	Proportion of days in 1982 and 1983	.424	.141	.435	1.00
(c)	Proportion of projected increase in participation not limited by air temperature	.33	.67	1.00	--
(d)	"Reduction factor" for lower bound : (b) x (c)	.140	.094	. 4 3 5	.669

The total predicted increased participation is mulitiplied by the sum of the reduction factors to obtain the lower bound estimate of increased participation. For example, the upper bound predicted increase in participation for Constitution Beach is 113,750. The lower bound estimate is, therefore, .669 x 113,750 = 76,099.

B.4 The Conditional Multinomial Logit Model, in Brief

This section describes the conditional multinomial logit model of multiple site demand. The model works from the indirect utility function for an individual. The utility u_{ij} individual i receives from visiting beach j is

$$u_{ij} = f(d_{ij}, S_j, I_i) \tag{B.1}$$

where

d_{ij} = travel cost (perhaps time and distance) for individual i to reach beach j

S_j = characteristics of beach j (perhaps a vector of characteristics).

I_i = characteristics of individual i (perhaps a vector of characteristics).

Individual i will choose beach j if and only if

$$u_{ij} > u_{ik} \quad k \neq j \tag{B.2}$$

Suppose we recognize that the choice process is not perfect, either because the individual has imperfect information, makes "mistakes" in beach choice, or perhaps we do not recognize all the relevant factors in her utility function. Then we might model the indirect utility functions as

$$u_{ij} = v_{ij} + e_j \tag{B.3}$$

where e_j is an error term capturing the error in the choice process and v_{ij} represents the measurable, nonstochastic part of the indirect utility function.

Now the probability of individual i choosing beach j is

$$P_{ij} = \text{prob} \left\{ u_{ij} > u_{ik} \right\} = \text{prob} \left\{ v_{ij} + e_j > v_{ik} + e_k \right\}$$
$$= \text{prob} \left\{ v_{ij} - v_{ik} > e_j - e_k \right\} \quad k \neq j \tag{B.4}$$

McFadden (1973) proved that if e_j and e_k are independent with a Weibull distribution, then

$$P_{ij} = \exp(v_{ij}) / \sum_K \exp(v_{ik}) \tag{B.5}$$

If the nonstochastic part of the utility function, v, is specified to be linear in parameters then (B.5) can be estimated using maximum likelihood methods and hypotheses can be tested in that framework as well.

Our model predicts the total number of visits by individual i to site j, n_{ij}, as

$$n_{ij} = n_i P_{ij} \tag{B.6}$$

where n_i = the total number of visits by individual i.

In essence (B.6) factors a joint probability model into a conditional probability model. The underlying joint probability model predicts the probability of making a beach visit (instead of, say, going to a movie) and the probability of visiting a specific beach. Ben-Akiva (1973) showed the joint model can be factored with the inclusion of a particular term in the total visit model. The so-called "inclusive price" (IP) term reflects the service characteristics of the set of beaches:

$$IP_i = \sum_K \exp(v_{ik}) \tag{B.7}$$

Then the total visit model can be specified as

$$n_i = g(IP_i, I_i) . \tag{B.8}$$

Together (B.6), (B.5) and (B.8) permit one to model how changes in site characteristics S_j will effect the total quantity of visits and the split of visits among the various beaches. That is, we estimate the parameters of these equations by using the data described above. To simulate the effect of a change in the characteristic of one or more of the sites, use (B.8) to find the total number of visits, (B.5) to find the fraction of the visits which will be made to each site and (B.6) to determine the number of visits made to each site.

The benefits of the simulated change in water quality atone or more sites can be estimated using a modification of a procedure developed by Small and Rosen (1982) and adapted to this problem by Feenberg and Mills (1980). The outline of this procedure is as follows. Include the minimum level of expenditure necessary to achieve a given utility level in v. Differentiate v with respect to expenditures to obtain an expression for the change in expenditures as a function of a change in site characteristics. This is a compensated demand function for the site characteristic. Then integrate this expression over a change in site characteristics to obtain an estimate of the welfare change associated with the change in site characteristics. The following makes this argument more specific.

$$V_{ij} = v(d_{ij}, S_j, I_i, E_i) \qquad \text{(B.9)}$$

where E is the minimum expenditure for individual i to obtain utility level v given all the other parameters.

Then

$$\frac{E_i}{S_j} = - \frac{1}{\partial V/\partial E_i} \frac{\partial V}{\partial S_j} = - \frac{1}{\lambda} \frac{\partial V}{\partial E_j} \qquad \text{(B.10)}$$

where λ_i is the marginal utility of income.

From Roy's identity $\lambda_i = \frac{\partial v}{\partial d} \Big/ n_i$. Then, in expectation,

$$\frac{\partial E_i}{\partial S_j} = -\sum_j P_{ij} \quad n_i \frac{\partial V}{\partial S_j} \Bigg/ \frac{\partial V}{\partial d_{ij}} \qquad \text{(B.11)}$$

We know P_{ij} from (B.5). Further, specify (B.8) in power function form so that

$$n_i = \alpha_i \left[\sum_K \exp\,(V_{ik})\right]^{\alpha_2}$$

Substituting into (3.11) gives

$$\frac{E_i}{S_j} = -\sum_j \alpha_i \left(\sum_K \exp V_k\right)^{\alpha_2 - 1} \exp V_{ij} \Bigg/ \frac{\partial V}{\partial d} \qquad \text{(B.12)}$$

To find the welfare change associated with a change in site characteristics S_j^o to S_j^1 where the characteristics might change in more than one site we integrate this expression between those limits. That is:

$$EV_i = \oint_{-S_j^o}^{S_j^1} \sum_j \frac{\partial E_i}{\partial S_j} ds_j$$

$$= \frac{\alpha_i}{\frac{\partial V}{\partial d}} \quad \sum_j \left[\left(\sum_k \exp V_{ik}\right)^{\alpha_2}\right]_{S_j^o}^{S_j^1}$$

$$= \left(n_i(S_j^1) - n_i(S_j^0)\right) / \frac{\partial V}{\partial d} \cdot \alpha_2 \qquad \text{(B.13)}$$

Table B-2.

Sites Included in Logit Model [a/]

Site Number	Site Name/Location	Site Ownership
1.	Kings Beach (Swampscott)	MDC
2.	Lynn Beach (Lynn)	MDC
3.	Nahant Beach (Nahant)	MDC
4.	Revere Beach (Revere)	MDC
5.	Short Beach (Revere)	MDC
6.	Winthrop Beach (Winthrop)	MDC
7.	Constitution Beach/Orient Heights (Boston)	MDC
8.	Castle Island (Boston)	MDC
9.	Pleasure Bay (Boston)	MDC
10.	City Point (Boston)	MDC
11.	L & M Street Beaches (Boston)	Boston
12.	Carson Beach (Boston)	MDC
13.	Malibu Beach/Savin Hill (Boston)	MDC
14.	Tenean Beach (Boston)	MDC
15.	Wollaston Beach (Quincy)	MDC
16.	Nantasket Beach (Hull)	MDC
17.	Wingaersheek Beach (Gloucester)	Gloucester
18.	Crane's Beach (Ipswich)	Private
19.	Plum Island Newbury	Private
20.	Duxbury Beach (Duxbury)	Private
21.	White Horse Beach (Plymouth)	MDC
22.	Breakheart Reservation (Saugus)	MDC
23.	Sandy Beach/Upper Mystic Lake (Winchester)	MDC
24.	Houghton's Pond/Blue Hills Reservation (Milton)	MDC
25.	Wright's Pond (Medford)	DNR
26.	Walden Pond (Concord)	DNR
27.	Stearns Pond/Harold Parker State Forest (Andover)	DNR
28.	Cochituate State Park (Natick)	DNR
29.	Hopkinton State Park (Hopkinton)	DNR

[a/] Based on Data collected by Binkley and Hanemann, 1975.

B.5 Beach Closings

Beach closings were calculated using seasonal attendance and water quality data. They were calculated for water quality levels greater than 200 and 500 MPN/100 ml fecal coliform and, in certain cases, for 700 MPN/100 ml total coliform.

Tenean Beach, at water quality level > 500 MPN/100 ml and for the CSO control option is used as an example. Beach closings for all other affected beaches were similarly calculated.

Beach	Number of Beach Closings Averted (Visitor Days)	=	(1) Number of Beach Closings Under Present Conditions (Visitor Days)	x	(2) % Pollution Abatement From Control Options
Tenean	19,286	=	24,107		80

(1) Current Beach Closings

Number Beach Closings (Visitor Days)	=	(a) % of Season Water Quality > 500 MPN	X	(b) Seasonal Attendance
24,107	=	.1607		150,000

(a) Source: Meta Systems calculations based on data from Metropolitan District Commission and towns of Quincy, Weymouth, Hingham, and Hull.

(b) Source: See Table B-1 (above).

(2) Source: See Table 4-3, Section 4 of the main report.

B.6 User Day Values

Many of the recreation benefit estimation approaches calculate the value of benefits accruing from changes in the use of a resource by applying a specific dollar value to an incremental change in quantity of recreation. These user day values (also called unit day values) have been calculated using a variety of techniques including cost of travel and survey-derived estimates of willingness to pay. Generally an average figure is given which may not reflect the effects of incremental changes in environmental quality. They should be applied with care especially when user day values derived in one area of the country are applied to a different region. Table B-3 presents the (wide) range of values to be found in the literature and which are potentially applicable to this case study.

Table B-3. User Day Values

Source	User Day Value in Study	User Day Value[a] in 1982 $	Values Chosen for use in Boston Harbor Study
General Recreation or Swimming			
Heintz *et al.*	2.67 (1973$)	5.80	Harbor (moderate)
DPRA	2.54 (1975$)	4.56	
Binkley Logit Model[b]	5.65 (1974$)	11.06	Harbor (high)
Federal Register	1.60 to 4.80 (1982$)	1.60 to 4.80	Harbor (low)
Boating			
Heintz *et al.*	8.96 (1973$)	19.46	
DPRA	5.17 (1975$)	9.27	Charles River (low)
Charbonneau and Hay[c]	22.80 (1975$)	40.89	Harbor (high)
NPA	12.26 (1978$)	18.14	Charles River (high), Harbor (low)
Fishing			
Heintz *et al.*	8.74 (1973$)	18.98	
DPRA	5.15 (1975$)	9.24	
Charbonneau and Hay			
Trout	21.00 (1975$)	37.66	
Bass	19.00 (1975$)	34.08	Harbor (high)
Catfish	15.00 (1975$)	26.90	
Russell and Vaughan[d]			
Trout	11.10-24.10 (1979$)	14.76-32.05	
Bass	9.70-21.40 (1979$)	12.90-28.46	
Catfish	7.00-16.00 (1979$)	9.31-21.28	
Survey of Fishing	11.00 (1980$)	12.89	Harbor (low)
Federal Register			
General	2.30-4.80 (1982$)	2.30-4.80	
Specialized	11.20-19.00 (1982$)	11.20-19.00	

[a] Updated using Consumer Price Index, U.S. City Average, All Urban Consumers, average for 1982 (CPI-U=289.1).
[b] As presented in Appendix B.3 and Section 6 of main report.
[c] Assuming a ratio of boating to fishing (bass) of 1:2.
[d] Lower figure assumes fees reflect real resource costs and value of travel time is zero (net consumer surplus). Higher figure assumes fees are pure transfers and value of travel time is average wage rate (total willingness to pay).

References for Table B-3.

Charbonneau, J. and J. Hay, 1978, "Determinants and Economic Values of Hunting and Fishing," Paper presented at the 43rd North American Wildlife and Natural Resource Conference, Phoenix, Arizona.

Development Planning and Research Associates, Inc. (DPRA), 1976, National Benefits of Achieving the 1977, 1983 and 1985 Water Quality Goals, Environmental Protection Agency, Office of Research and Development, Washington, DC.

Federal Register, Volume 48, Number 48, March 10, 1983, "Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies", U.S. Water Resources Council, Washington, DC.

Heintz, H.T., A. Hershaft and G.C. Horak, 1976, National Damages of Air and Water Pollution, Environmental Protection Agency, Office of Research and Development, Washington, DC.

National Planning Association (NPA) , 1975, Water-Related Recreation Benefits Resulting from Public Law 92-500, National Commission on Water Quality, Washington, DC.

Russell, C.S. and W.T. Vaughan, 1982, "The National Fishing Benefits of Water Pollution Control," Journal of Environmental Economics and Management, 9:328-353.

U.S. Department of the Interior, 1982, 1980 Survey of Fishing, Hunting and Wildlife Associated Recreation, Fish and Wildlife Service and U.S. Department of Commerce, Bureau of the Census, Washington, DC.

B.7 Sources of Recreation Data

Information pertaining to recreation participation and the corresponding economic values were drawn from a number of existing reports. Not all of the information is specific to Boston Harbor, nor does each address exactly what is needed for the case study at hand. However, it is information that can be used to define ranges of values for both participation rates in and economic values derived from the water resources of Boston Harbor. In order to ascertain how the figures proposed by each source relates to this case study, the method of their derivation and the populations from which they were derived must be examined and compared to the objectives of this study and to the population using (or potentially using) Boston Harbor's water resources.

1. Abt Associates, 1979. New York-New England Recreational Demand Study, Vol. I and II. Cambridge, MA.

The focal point of this study was a survey designed to (1) quantify current recreational demands in the New York-New England region and, then, (2) to use that demand to develop a model of supply/demand interactions of recreational resource availability and needs of forecasting recreational demands.

The current demand figures from this study can be applied to the Boston Harbor case study because the statistical techniques used were thorough (including the breakdown of information by useful characteristics) and because the sample size was large. The forecasted recreational data is not applicable to Boston Harbor. One of the criticisms of the study is that demand forecasts are a dependent variable of supply. To accurately assess the particular effects of increasing the water quality of Boston Harbor, it would be preferable to use Boston Harbor-specific supply information in the model. The results forecasted by this study's model are based upon much larger geographic areas of recreational resources and thus do not directly help in pin-pointing the benefits accrued (real or potential) from improved harbor water quality.

2. U.S. Department of the Interior, November 1982. 1980 National Survey of Fishing, Hunting, and Wildlife Associated Recreation, Fish and Wildlife Service and U.S. Department of Commerce, Bureau of the Census, Washington, DC.

Every five years, since 1955, the Fish and Wildlife Service (in cooperation with the Bureau of Census) has conducted a nationwide survey of U.S. fishing and hunting activities. For the 1980 survey, questions about non-consumptive wildlife associated recreation (e.g., bird watching) were asked for the first time. Much of the information is of use to the Boston Harbor case study, including participation rates, level of participation intensity, and expenditures per activity. Unfortunately, there are no willingness to pay or latent demand analyses.

The survey's strongest recommendation is its large sample size, which lends confidence to statistical analyses derived from its data base. Over 116,000 households were sampled nationwide to determine participation rates in various wildlife-related activities. Of particular interest and application to the Boston Harbor case study are the statistics obtained for saltwater fishing. Fishing participants identified in the screening phase of the survey were re-interviewed, with attention to more details about:

- their intensities of participation (number of trips and days per year);
- location of activity (fresh or saltwater, in-state or out-of-state);
- mode of participation (boat, surf, shore, pier, etc.);

- expenditures for participating in the activity; and
- demographic characteristics of the participants.

For this second phase of data collection, "sample sizes were designed to provide statistically reliable results at the state level for fishing and hunting and at the Census geographic division level for non-consumptive activities".[a] In Massachusetts, 700 fishermen and women were interviewed. Of those interviewed, 272 participated in saltwater fishing only (39 percent of Massachusetts anglers), and 219 engaged in both fresh and saltwater fishing (31 percent).

Since the statistics above are for Massachusetts overall, it is necessary to consider how Boston area anglers differ from the "average" Massachusetts anglers. Given fishing as an activity of participation, participation rate differences between Massachusetts residents state-wide and Boston SMSA residents are considered. The proximity of saltwater resources to Boston suggests that the salt and freshwater fishing participation ratio might be even higher for the Boston area. Assuming that the greatest use of Boston Harbor is made by the local population, this is an important consideration and it suggests that the survey's results are a lower bound estimate of saltwater fishing participation. What might cause the survey's estimates to be overstatements for the Boston SMSA are the characteristics of Cape Cod and the shoreline communities to the north and south of Boston. These three areas are apt to have higher than average fishing participation rates assuming that individuals who like to engage is this activity are prone to reside in these areas. A statistically equivalent sampling of these areas could skew state-wide participation rates upward.

---

[a] Page viii of the survey.

The survey also presents participation rates by geographic area and place of residence. For New England, the saltwater fishing geographic/demographic distinctions are made for big cities, small cities and rural areas. Boston, however, is rather uniquely situated with respect to most other cities of New England because it is on the Atlantic Coast. Again, if proximity of the resource does have bearing on participation, then the study estimates are probably underestimates of Boston SMSA fishing rates. The days of participation figures generated by the survey are consistent with the same measure from other studies. A final recommendation of this survey is that it was completed quite recently (1980-1982).

3. McConnell, K.E., Smith, T.P., and Farrell, J.F., 1981. Marine Sportfishing in Rhode Island 1978. NOAA/Sea Grant, University of Rhode Island Technical Report 83, Narragansett, Rhode Island.

This study is recommended for a number of reasons, including:

- The data was collected recently, from February 1978 to January 1979;
- The sample size is large, implying statistical confidence (5,000 interviews were conducted at the sites of the fishing experiences and 9,000 phone interviews were conducted state-wide);
- The information collected pertains specifically to saltwater fishing:
- The geographic proximity of Rhode Island to Boston Harbor makes for similar fishing experiences in terms of the types of fish caught and the general environmental experience (weather, topography, vegetation, seasons); and
- The nearness of Rhode Island to the case study area captures similar population characteristics such as attitudes, lifestyles, economic activities, etc.

There are a few obvious differences between the two study areas. One difference is that the vast majority of fishing in Rhode Island does not take place near urbanized areas. Another is that public transportation is used less often in Rhode Island than in the Boston SMSA, suggesting that travel mode arguments are not identical for the areas. Travel time is comparable however, because of Rhode Island's small size. For instance, the travel time from Rhode Island's population centers in the northern part of the state (including Providence, the capitol) to the southern shores (popular fishing spots) is usually an hour or less by car; using Boston public transportation to visit a fishing site in and around the Harbor requires a comparable amount of time.

In addition to participation rate and intensity information, estimates of economic expenditures for participation are also available from this study. Average expenditures are based on "out-of-pocket" costs per trip which may or may not include some travel costs (for instance, if gas was bought on the trip, then it would partially account for travel costs). An examination of costs per trip and one-way mileage figures suggests that travel costs are not extensively covered by the "out-of-pocket" cost data; even at the conservative cost of $.10 per mile, the expenditure data barely accounts for travel costs.

By using the expenditure information available for the various modes of fishing (shore, fixed structure, boat) together with travel cost information specific to Boston Harbor, a range of plausible current trip expenditures for fishing in the Harbor can be calculated. Such a range represents demonstrated economic worth of the fishing resources but does not indicate consumer (participant) surplus of fishing activity.

The interview questionnaire used for this study did include willingness to pay questions, but that data has not yet been tabulated and analyzed. In the absence of willingness-to-pay measures, the demonstrated expenditures will be taken as lower bound estimates of the economic value of Boston Harbor's fishing resources.

4. Metcalf and Eddy, 1975. Eastern Massachusetts Metropolitan Area Study (EMMA). Technical Data (Volume 13B). Socio-Economic Impact Analysis.

The area of study for the EMMA series of reports roughly corresponds to the area of this case study, so the information presented is directly relevant to the case study at hand. The soci-economic impact analysis includes a section on recreation in the area. It examines actual and potential recreational activity there. Actual, or current, activity is defined as demand; potential activity, or un-met demand, is defined as need. (Need is translated as latent demand for application to this case study.)

Much of the information presented in EMMA regarding recreational opportunities is drawn from the Eastern Massachusetts supplement to the 1972 Massachusetts Outdoor Recreation Plan. Based on information drawn from the Outdoor Recreation and Open-Space Inventory and from census data, the supplement provides a data baseline on recreational opportunity in the area. Although the inventory and census were conducted in 1970, the recreational opportunity and activity calculations are still valid since the current population and recreational resources of the area are not much changed from that time, if recreational habits are also alike.

The assessments of demand and latent demand were performed according to population density groups within the MAPC area. The highest density groups. had the lowest ratios of recreation and open space acreage to population. It appears that the analyses for latent demand were performed within each density group; that is, if the recreational resources within a density group area were not sufficient to meet the total potential demand for the population within that group, the availability of such resources in other areas was not considered for satisfaction of those recreation needs. The high density areas exhibit latent demand of water-based recreational activities, even though the majority of municipal recreational sites is within the very dense and dense categories. Still, the extremely dense category has five percent of the recreational areas and 35 percent of the population within the study area.

The quality of the available recreational sites was not a factor in calculating recreational opportunity.

5. Metropolitan Area Planning Council, October, 1972. Boston Harbor Islands Comprehensive Plan, for Massachusetts Department of Natural Resources.

This report describes a plan for all phases and aspects of maintaining and developing the islands of Boston Harbor, which are considered a unique natural resource of significance to the New England Region. The islands are predominantly open, natural areas; some have historic sites or limited public facilities. The Plan contains descriptions of the islands and the current and planned activities for them. Many of the islands do not yet have the facilities or the water quality necessary for some of the activities: therefore, activity days figures most nearly reflect potential use of the Islands.

The islands offer a range of activities: swimming, boating, fishing, hiking, picnicking, group and primitive camping, play, and historic fort visitation. Only the first three activities mentioned are of concern to this case study because they are most directly affected by water quality. (However, water quality can affect the experiences of other activities such as camping and hiking.) This report is particularly useful because it provides data on the recreational potential (activity days) of the Harbor Islands.

The economic values per day for each Boston Harbor Island activity day were based upon the Federal Water Resources Council's "Standards for Planning Water and Land Resources" (July 1970). These values are nationwide estimates. Because the values in the Harbor Plan are in 1970 dollars it was necessary to inflate them to 1980 dollars using the Consumer Price Index for urban consumers. Furthermore, the round trip ferry fee to George's Island of $3.00 has been added to the value in order to account for a portion of the travel costs incurred in visiting the islands. The Department of Environmental Management provides a free taxi service to reach other islands from George's Island. The travel costs incurred by private boaters to the islands are probably at least $3.00 considering the costs of gas and/or costs of upkeep.

6. Bureau of Outdoor Recreation, September, 1977. National Urban Recreation Study: Boston/Lowell/Lawrence/Haverhill, Northeast Regional Office: National Park Service and Forest Service.

This particular study offers qualitative insights into and justifications for recreational resource preservation in its study area. (Some of the ideas are presented here.) A basic premise of the study is that open space which is close to home is desirable. At present, Boston has only 5.4 acres of open space per thousand population, whereas the recommended minimum by the National Recreation and Park Association and the Urban Land Institute is 10 acres per thousand population. Most of Boston's land is already developed. Once it has been developed, it is economically and physically difficult to reclaim as open space. Of the open spaces that do remain, there is considerable competition for their use.

Only about one-sixth of New England's coastline is accessible to the general public. The recreational potential that Boston Harbor offers is substantial by comparison since approximately 40 percent of the harbor shoreline remains relatively undeveloped; portions of this undeveloped area are used for recreational activities. In addition, the islands are within a 25 mile radius of 2.7 million people. The 1977 Coastal Zone Management Plan lists three types of recreational facilities as being in greatest demand for Boston Harbor. They are: (1) large scale beaches and waterfront parks; (2) smaller scale beaches and parks for local use; (3) walkways. Certainly, water quality is critical to swimming activity and can enhance the enjoyment of parks and walkways.

Whereas the waterfront was once largely an area of warehousing and industrial activity, new development and redevelopment styles are leading to different interactions with the Harbor, particularly in the downtown areas along the Inner Harbor. More people are living, shopping, and staying in hotels near the water--their relationship to the Harbor is becoming more intimate so the aesthetic quality and sense of open space it can offer is becoming more important. Furthermore, as more white-collar businesses move into the waterfront commercial spaces, perceptions and expectations of the working environment change (visits by clientele, visual appearances of surroundings, etc.).

7. Massachusetts Department of Environmental Management, December 1976. Massachusetts Outdoors: Statewide Comprehensive Outdoor Recreation Plan (SCDRP).

The information on recreation participation rates and latent demand in this report is of interest to the Boston Harbor case study. However, the methodology employed to obtain that information has a number of limitations. The primary problem is the sample size of the data collection effort.

A telephone survey was conducted of 400 households/persons throughout Massachusetts and this survey is the data source for all subsequent analyses. The Boston SMSA is contained within a region extending west to Worcester, north to the state border, and south to Bridgewater. This region is one of seven equally sampled areas within the state, meaning that the Boston SMSA recreational demand is calculated from only 57 (or fewer) interviews.

Some of the results of the data analysis are counter-intuitive. One such result suggests that power boating participation rates are more strongly associated with low income groups than with higher income groups, although power boat operation and maintenance can be quite expensive. Information from the "Boston Marinas and Live-Aboards Study" indicates a high proportion of large boats in the Boston area, thus countering the explanation that the power boat population is dominated by small boats with outboard motors (i.e., less expensive power boats, affordable to low income groups).

The results of the SCORP study are more meaningful if they are interpreted qualitatively, rather than quantitatively. The shortcomings of the empirical findings are often mentioned by the authors throughout the study, suggesting that SCORP results should be applied with caution.

8. Department of Interior, April 1984. The 1982-1983 Nationwide Recreation Survey, National Park Service, Washington, DC.

The most recent nationwide survey of recreation activities was designed for comparability with certain portions of the national recreation surveys conducted in 1960 and 1965. It includes data on participation rates, expenditures, reasons for recreating, and reasons for constraints on recreating. At the time of this report only nationwide figures were available. Regional (but not as detailed as the SMSA level) figures are expected to be published later.

References

Abt Associates, 1979. New York-New England Recreational Demand Study, Volumes I and II, Cambridge, MA.

Ben-Akiva, J., 1973. The Structure of Passenger Travel Demand, Ph.D. dissertation, Massachusetts Institute of Technology, Department of Civil Engineering, Cambridge, MA.

Binkley, Clark S. and W. Michael Hanemann, 1975. The Recreation Benefits of Water Quality Improvement, NTIS PB257719, for the U.S. Environmental Protection Agency, Washington, DC.

Department of Interior, March 1970. Outdoor Recreation Standards, Bureau of Outdoor Recreation, Washington, DC.

Department of Interior, September 1977. National Urban Recreation Study: Boston/Lowell/Lawrence/Haverhill, Northeast Regional Office, Bureau. of Outdoor Recreation, National Park Service and Forest Service, Boston, MA.

Department of Interior, November 1982. 1980 National Survey of Fishing, Hunting and Wildlife Association Recreation, Fish and Wildlife Service and U.S. Department of Commerce, Bureau of the Census, Washington, DC.

Department of Interior, April 1984. The 1982-1983 Nationwide Recreation Survey: Summary of Selected Findings, National Park Service, Washington, DC

Feenberg, Daniel and Edwin Mills, 1980. Measuring the Benefits of Water Pollution Abatement, Academic Press, New York, NY.

Massachusetts Department of Environmental Management, December 1976. Massachusetts Outdoors: Statewide Commprehensive Outdoor Recreation Plan (SCORP), Boston, MA.

McConnell, K.E., Smith, T.P. and Farrell, J.F., 1981. Marine Sportfishing in Rhode Island 1978, NOAA/Sea Grant, University of Rhode Island Technical Report 83, Narragansett, RI.

Metcalf and Eddy, 1975. Eastern Massachusetts Metropolitan Area Study (EMMA), Boston, MA.

Metropolitan Area Planning Council, October 1982. Boston Harbor Islands Comprehensive Plan, for Massachusetts Department of Natural Resources, Boston, MA.

Small, K and H. Rosen, 1981. Applied Welfare Economics with Discrete Choice Models, Econometrica 40: 105-130.

Appendix C

Swimming Health Benefit Calculations

Health benefits for recreational swimming are derived using dose-response functions and beach attendance data. The distribution of water quality levels throughout the swimming season for each beach was used as the basis for estimating the exposure of the swimming population. The first section of this appendix shows how the number of highly credible gastroenteritis cases was calculated for each water quality level at each beach. Tenean beach, at water quality level 7 (60 MPN fecal coliforms per 100 ml), is used as a representative example. The second section of this appendix shows the calculations of reduced number of cases of illnesses for each treatment option for each beach.

C.1 Number of Cases of Gastrointestinal Illness
(Tenean Beach, water quality level 7)

Number of Cases of Highly Credible Gastroenteritis At Water Quality Level 7	=	(A) Number of Cases of HC gastroenteritis per 1000	x	(B) Population at Risk, up to Water Quality Level 7	÷	1000
190	=	18.09		10,500		

(A) Number of cases per 1000 = 0.2 + 12.2 log Enterococci (1) $R^2 = 0.75$

18.09 = 0.2 + 12.2 x 1.47

Source: Cabelli *et. al*, 1982.

(1) Lag $\underline{\text{Enterococci}}$ = 0.825 log $\underline{\text{Fecal coliform}}^{(a)}$ R^2 = 0.82

1.47 = 0.825 x log(60)

Source: Meta derived statistical relationship using averaged MDC and other municipal water quality data, 1974-1982.

(a) When total coliform concentrations were measured instead of fecal coliform concentrations, total coliform concentrations were substituted using the following relationship:

log $\underline{\text{Fecal coliform}}$ = 0.65 log $\underline{\text{total coliform}}$ R^2 = 0.89

Source: Meta derived function, based on averaged MDC and municipal water quality data, 1974-1982.

(B)

Population at Risk at Water Quality Level 7	=	Seasonal Beach Attendance (1)	x	Percentage of Season Water Quality At Level 7 (2)
10,500	=	150,000		.07

(1) Source: MDC, Towns of Quincy, Weymouth, Hingham and Hull.

(2) The frequency, per season, of thirteen water quality levels was measured for fecal coliform concentrations, MPN per 100 ml (see Table C-1).

C.2 Reduced Cases of Gastrointestinal Illness

The above calculations are done for each water quality level to establish the base case for each beach. This gives the estimated number of cases of illness occurring under current conditions. Similarly, the calculations can be carried out assuming a certain percentage of pollution reduction. This is done by reducing the average fecal coliform count for the water quality level by the percentage pollutant reduction. For example, in the base case water quality level 7 has a fecal coliform count of 60 MPN/100 ml.

Table C-1 Water Quality Fecal Coliform Levels

Level	Water Quality Range Fecal Coliform	Median Value Fecal Coliform Used	% During Season for Tenean Beach
1	0	0	0
2	1-5	3	10
3	6-10	8	13
4	11-20	15	9
5	21-30	25	1
6	31-50	40	12
7	51-70	60	7
8	71-130	100	9
9	131-170	150	7
10	171-330	250	9
11	331-470	400	6
12	471-730	600	9
13	≥ 731	731	10

Under the CSO control option with 80 percent reduction the same water quality level 7 would be assigned a fecal coliform count of 12 MPN/100 ml. Then, the string of calculations listed in Section C.1 above are repeated to estimate the number of cases of illness under these new water quality conditions. The number of cases for each of the water quality levels are summed to give a total incidence of illness at that beach. revels for which the fecal coliform counts exceed 500 MPN/100 ml, however, are not included because we assume the beach is closed to swimming at counts above 500 MPN/100 ml. These calculations are shown for Tenean Beach in Table C-2.

C.3 Population at Risk

The studies of swimmers and related health effects divide the population of visitors to a. beach into swimmers and non-swimmers. Two available studies have this information for Boston area beaches. Their results are shown below.

Study	Total $ of Visitors	% of Swimmers who go swimming
43 Boston area beaches (Hanemann, 1978)	2507	32 %
2 Boston area beaches (Cabelli *et al.*, 1980)	4153	49 8
6 Coastal beaches in U.S. (Cabelli *et al.*, 1980)	16182	63 %

In this study we use the figure of 4:6 for a lower bound estimate of the population at risk. In addition, a reduction factor tied to the distribution of air and water temperature during the summer season is used. This factor is calculated by first categorizing the summer days as follows:

Table C-2. Calculation of Number of Highly Credible Gastroenteritis Cases for Tenean Beach

Level	Fecal Coliform Count (average)[a]	% of Season Water Quality at Given Level[a]	# of Base Cases[b]	With 10% Reduction f.c. Count[c]	With 10% Reduction # of Cases[b]	With 80% Reduction f.c. Count[c]	With 80% Reduction # of Cases[b]	With 90% Reduction f.c. Count[c]	With 90% Reduction # of Cases[b]
1	0	0	0	0	0	0	0	0	0
2	3	10	73	2.7	66	0.6	0	0.3	0
3	8	13	181	7.2	172	1.6	41	0.8	0
4	15	9	163	13.5	157	3	66	1.5	24
5	25	1	22	22.5	21	5	11	2.5	6
6	40	12	296	36	288	8	167	4	111
7	60	7	192	54	187	12	116	6	84
8	100	9	277	90	271	20	180	10	137
9	150	7	235	135	230	30	159	15	127
10	250	9	332	225	326	50	235	25	194
11	400	6	240	360	236	80	176	40	148
12	600	9	385	540	379	120	288	60	246
13	731	10	441	657.9	434	146.2	333	73.1	287
Total Cases			2837		2767		1772		1364
Total Cases below 500 MPN/100 ml			2011 (a)		1954 (b)		1772 (c)		1364 (d)

Calculations for Each Treatment Option

Treatment Option	% Pollution Reduction	Number of Reduced Cases of Illness	Calculation Method
CSO only	80	239	(a) - (c)
Ocean Outfall	10	57	(a) - (b)
Secondary Treatment	10	57	(a) - (b)
CSO and Ocean Outfall	90	647	(a) - (d)
CSO and Secondary Treatment	90	647	(a) - (d)

a/ From Table C-1.

b/ Calculated using Cabelli et al. (1982) equation.

- Poor (air temperature $\leq 75^{\circ}$ Fahrenheit and/or water temperature $< 65^{\circ}$ Fahrenheit)
- good (air temperature $> 75^{\circ}$ and $< 79^{\circ}$ and water temperature $\geq 65^{\circ}$)
- excellent (air temperature $\geq 79^{\circ}$ and water temperature $\geq 65^{\circ}$)

Then, the distribution of days in each category is estimated from data on air and surface water temperature for the months of June, July and August for the years 1982 and 1983. For "poor" days it is assumed that only one-third of the predicted increased population at risk will actually go swimming. For "good" days it is assumed that two-thirds of the predicted increase due to improved water quality will go swimming but not all of the predicted increase because of the relatively lower air and water temperatures. For "excellent" days, all of the predicted increased population at risk is assumed to go swimming.

Thus, the lower bound estimate of increased population at risk is 49% of the predicted increased beach visitors times the reduction factor (.551) for the air and water temperature constraints. We used 100% of beach visitors as an upper bound estimate because the question in the studies is often phrased "what is your primary beach activity" rather than "did you go swimming". Thus, visitors may go swimming even for a limited amount of time where their primary beach activity was something else.

The following table presents the calculations for the lower bound "reduction factor": a/

	Poor Air ≲ 75° and/or Water < 65°	Good Air > 75° and < 79° and water ≥ 65°	Excellent Air ≥ 79° and Water ≥ 65°	Total
(a) No. of sampled days June, July and August, 1982 and 1983	55	4	26	85
(b) Proportion of days in 1982 and 1983	.647	.047	.306	1.00
(c) Proportion of predicted increase in population at risk not limited by air and water temperatures	.33	.67	1.00	--
(d) "Reduction factor" for lower bound estimate: (b) x (c)	.214	.031	.306	.551

a/ Approach suggested and data supplied by Dr. Richard Burns, Region 1, Environmental Protection Agency, Boston, MA. Categories and proportions used in (c) based on "Weather Conditions that Lure People to the Beach" by P. Rosenson and J. Havens in Maritimes, University of Rhode Island, Graduate School of Oceanography, August 1977, and "Adapted Aquatics" by The American National Red Cross, 1977, Washington, DC. Air and surface water temperature for Boston Harbor Area from NOAA, National Ocean Survey data file.

References

Cabelli, Victor J., et al., 1980. Health Effects Quality Criteria for Marine Recreational Waters, Environmental Protection Agency, EPA-600/1-80-031.

Cabelli, V.J., A.P. Dufour, L.J. McCabe, and M.A. Levin, 1982. Swimming Associated Gastroenteritis and Water Quality. American Journal of Epidemiology, 115:606-616.

Hanemann, W.M., 1978. A Methodological and Empirical Study of the Recreation Benefits from Water Quality Improvement. PhD dissertation, Harvard University, Cambridge, MA.

Appendix D

Commercial Fisheries Benefit Computations

D.1 Demand Function Estimation

Other than the one in the study done in Maryland to predict future fisheries' supply,[a] which was discussed in the main body of the report, no other soft shelled clam demand functions were found in the literature. At present, research is being conducted at the University of Rhode Island Department of Resource Economics on developing such information about various fisheries based on National Marine Fisheries Service data. Dr. Stephen Crutchfield ran some regressions using this data to produce a range of soft shelled clam demand functions for us.[b] One of these will be described below for illustrative purposes. Because of the lack of information available to calibrate these functions properly for Massachusetts, and because these functions do not represent consumer demand in a particular market area (as discussed in the main report concerning the Maryland demand function), it was not possible to use them to compute the impacts of pollution abatement in Boston Harbor. However, since this information may be useful to others, one of these demand functions will be presented here.

The best six variable logarithmic linear model, as indicated by the maximum improvement in the R-squared statistic, found using the stepwise regression technique is as follows:

$$P = 1.876 - .076Q + .450W + .117C + .751I + .087S + .029F$$
$$(R^2 = .96)$$

---

[a] Marasco, 1975.

[b] Crutchfield, 1983.

where,

dependent variable: P = exvessel soft shelled clam prices (Maryland)

independent variables: Q = soft shelled clam landings (Maine)

W = wholesale prices of soft shelled clams (New York)

C = exvessel prices of quahogs (Rhode Island)

I = per capita income

S,F = seasonal dummy variables, summer and fall.

The stepwise regressions were run using monthly data from 1960 through 1982, where available. The regressions were set up so that Q was always included as an independent variable. Price data from Maryland and landings (harvest) data from Maine had to be used because of insufficient time series data elsewhere; extensive price and landings data were not available for Massachusetts nor did the data base used have both price and landings data for the same state. The wholesale price in New York was included as a demand shifter since New York is a large market for soft shelled clams. Quahog prices were added to represent demand for a competitive product. Per capita income is used to reflect derived demand. Seasonal dummy variables were included to account for the wide seasonal variations in demand caused by the summer tourist season. This equation produces extremely high price and income elasticities of demand. For this and the reasons mentioned above and in the main report, it was not used to compute pollution abatement benefits.

D.2 Demand Function Computations

Computations to determine the constants for the demand functions for alternative price elasticities were carried out as shown below. The following demand function was used:

$$Q = A \times P^{\alpha}$$

where, Q = consumption (bu.)
A = constant
P = price ($)
α = price elasticity

and transformed to log form:

$$\log Q = \log A + \alpha \times \log P.$$

For the Boston market for 1981, Q was set at 625,000 bu. and P at $28.45. Alternative price elasticities were selected: -.5, -1, -2 and -3. Using -1 as an example the calculations were done as follows:

$$625{,}000 = A \times (28.45)^{-1}$$

$$\log (625{,}000) = \log A - 1 \times \log (28.45)$$

$$5.7959 = \log A - 1 \times 1.4541$$

$$5.7959 = \log A - 1.4541$$

$$7.2500 = \log A.$$

To compute the new price for each price elasticity assumed and for each pollution abatement option, log A, calculated as shown above, was substituted into the demand function along with $Q + \Delta Q$, as shown below. For instance, for ΔQ = 29,603 bu., associated with the STP pollution abatement option, the computations to determine the new price were as follows (price elasticity assumed to be -1):

$$\log (Q + \Delta Q) = \log A - 1 \times \log (P - \Delta P)$$

$$5.8160 = 7.2500 - 1 \times \log (P - \Delta P)$$

$$1 \times \log (P - \Delta P) = 1.4340$$

$\log (P - \Delta P) = 1.4340$

$P - \Delta P = 27.16$

$P - 27.16 = \Delta P$

$\Delta P = 28.45 - 27.16 = 1.29.$

Total benefits for each abatement option were calculated as shown below. The change in consumer surplus is equal to the following:[a]

$$\Delta CS = \Delta P \cdot Q + 1/2 (\Delta P \times \Delta Q)$$

where, ΔCS = change in consumer surplus ($)
ΔP = change in price ($)
Q = initial consumption (bu.)
ΔQ = change in consumption (bu.).

Referring back to Figure 7-2 in the main body of the report, it can be seen that $\Delta P \times Q$ computes the area B + C and $1/2(\Delta P \times \Delta Q)$, the area E, and that their sum in the above equation represents ΔCS equal to area B + C + E.

As an example, using the ΔP and ΔQ associated with the STP option from the above calculations, and using 16,000 bu. as a reasonable estimate of the initial consumption from Boston Harbor shellfish areas, total benefits (equal to change in consumer surplus) were estimated as follows:

$$\Delta CS = \Delta P \times Q + 1/2(\Delta P \times \Delta Q)$$

$$= (1.29)(16,000) + 1/2[(1.29)(29,603)]$$

$$= (20,640) + 1/2(38,188)$$

$$= (20,640) + (19,094)$$

$$= \$39,734.$$

[a] Note that simple geometric calculations are used here rather than integration under the curve. Even though the latter method is more accurate and correctly assumes a non-straight-line demand curve, the former is simpler, and given the magnitude of the possible error in the assumptions already made, will not adversely affect the outcome.

D.3 Supply Cost Data and Computations and Producer Surplus Computation Example

No estimates concerning producer surplus changes due to pollution abatement in Boston Harbor could be made due to lack of data. Attempts were made to develop a supply curve but were unsuccessful; these will be described below. As mentioned in the main body of the report, it is likely that change in producer surplus due to pollution abatement would be zero because the fishery is unregulated and there are no limits to prevent new firms from eventually entering and bidding away any short-run excess profits: i.e., the supply curve is probably flat in the area of interest. Despite an extensive search, no supply curves for the fishery were found in the literature. There is general agreement that is would be very hard to produce such a curve due to the extreme difficulty of modeling the biological processes affecting shellfish supply. Thus, supply for a fishery like the soft shelled clam industry is usually held to be exogenously determined.[a/] This approach was taken here.

As discussed in the main report, the Boston area market for clams is supplied by Maine and Maryland as well as Massachusetts fisheries. Harvesting cost data is available for Maine (Townsend and Briggs, 1980). Costs for the typical Massachusetts digger are very similar to those for Maine.[b/] Costs to diggers in restricted areas in Massachusetts, however, are higher than to others because of the special licensing requirements, depuration costs and additional transportation necessary to get the clams to

---

[a/] From discussions with individuals at the Maryland Department of Natural Resources, the Maine Department of Marine Resources, and the Universities of Maine, Maryland and Rhode Island.

[b/] Massachusetts Division of Fisheries and Wildlife estimates.

the purification plant. Prices to Maine diggers are lower than prices to Massachusetts diggers.[a] From this information, it was assumed that the supply curve for the Boston area soft shelled clam market could be represented by the curve displayed in Figure D-1. This is a stepwise supply curve in which the quantity Q_1, and price P_1, represent the quantity supplied by Maine diggers at their lower cost level. Similarly, the quantity from Q_1 to Q_2 represents the amount supplied by Massachusetts diggers from unrestricted areas and from Q_2 to Q_3 that supplied from Boston Harbor restricted areas at a higher cost. The dashed line at Q_4 and P_4 shows the decreased costs and increased quantity to the diggers that operate in Boston Harbor as a result of pollution abatement. Maryland quantities and costs are not included because the fishery there is highly mechanized and has a totally different cost structure.

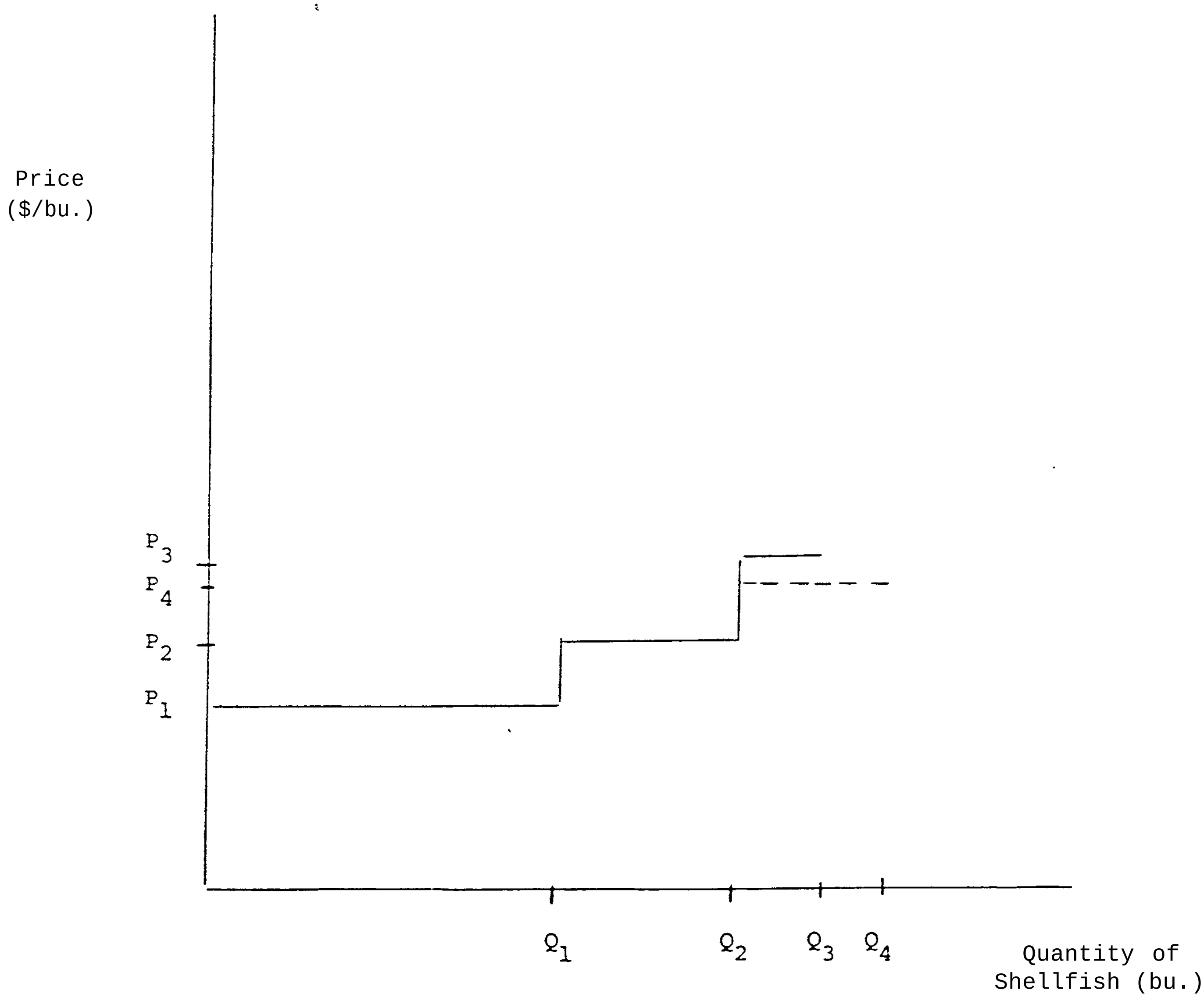
Initially, it was thought that, given the available Maine cost data, costs for Massachusetts firms could be developed for both restricted and unrestricted areas. However, with the limits on time and resources and the lack of data, it was not possible to solve two main problems. The first was to account for the fact that the firms that operate in the restricted areas are composed of a master digger and subordinate diggers unlike typical other Massachusetts and Maine firms which are single-person operations. Information was not readily available on wages and numbers of employees. The second problem, the really major one, was to determine what impact pollution abatement and the potential increased supply available in Boston Harbor would have on the harvest costs. Reasonable assumptions could be made concerning non-labor costs such as assuming decreased per unit transportation costs

---

[a] Maine Department of Natural Resources and Massachusetts Division of Fisheries and Wildlife data.

Figure D-1.

Assumed Shape of Supply Curve for
Boston Area Soft Shelled Clam Market.



since more clams could be hauled per daily trip to the purification plant. However, it was very difficult to estimate the impacts on return to the master digger or on numbers of subordinates that would be hired. Therefore, it was not possible to complete this representation of the supply curve for the Boston Harbor market so that it could be combined with the previously estimated demand curves to compute changes in producer surplus. It was thought, however, that the preliminary computations that were completed might be useful to others and should be presented in an appendix. The following tables and discussion show the data used and computations that were made in order to estimate soft shelled clam harvest costs for both unrestricted areas in Maine and restricted and unrestricted areas in Massachusetts.

Table D-1 shows annual 1978 costs for a typical Maine clam digging firm, a one-person operation, developed by Townsend and Briggs (1980). In Table D-2, these costs are updated to 1980 dollars for Massachusetts diggers who operate in unrestricted areas, Updated costs for Maine firms are also shown at the bottom of this table.

Tables D-3 through D-6 show the computation of nonlabor costs for Massachusetts shellfishing firms operating in Boston Harbor restricted areas. Because it was not possible to develop costs for a typical firm operating in Boston Harbor restricted areas due to the lack of information regarding numbers of subordinate diggers employed and their wage rates, it was decided that costs should be developed on a per bushel basis. Table D-3 shows per bushel costs divided into four categories for computation purposes. Nonspecialized items are those for restricted firms that correspond to the items included in the single-person unrestricted firms shown in Table D-2. Specialized items are those that are required by either

Table D-1. Cost Data for a Typical Maine Clam Digging Firm, 1978 $

Capital Costs:

Items	1978 Cost	Life	Annual Depreciation
Car (1/2 cost of new car)	2500	4	625
Boat	1200	10	120
Trailer	600	10	60
Outboard Motor	1000	4	250
SUBTOTAL:			1055

Direct Expenses:

Items	1978 Unit Cost	No. of Units	Annual Cost
Fuel, Car	.80/gal	55.6	44
Fuel, Boat	.80/gal	7.5	6
Auto Maintenance			200
Boat Maintenance			200
License			10
Insurance			100
Boots & Gloves			28
Hods	12	2	24
Clam Hoe		1	15
SUBTOTAL:			627
TOTAL:			1682
Owner Operator Income:			2234

Source: Townsend and Briggs, 1980.

Notes:

Volumes: 210 bushels/year @ $18.65.

Gross Revenue: $3916.50.

Employment: one.

Operates: 5 months per year.

Table D-2. Costs for a Typical Massachusetts Shellfishing Firm Operating in Unrestricted Areas, 1980$

Capital Costs:

-Items	1978 Cost	Adjustment Factor[a]	1980 Cost	Life	Annual Depreciation[b]
Vehicle (1/2 cost of new car; 50% devoted to clamming)	2500	1.31	3275	4	818.75
Boat	1200	1.31	1572	10	157.2
Trailer	600	1.31	786	10	78.6
Outboard Motor	1000	1.31	1310	4	327.5
SUBTOTAL:					1382.05

Direct Expenses:

Items	1978 Price	Adjustment Factor[a]	1980 Price	Quantity	Total
Fuel, Car	.80/gal	1.31	1.05	55.6 (1,000 mi/yr @ 18 mi/gal)	58.4
Fuel, Boat	.80/gal	1.31	1.05	7.5 (300 mi/yr @ 40 mi/gal)	7.9
Auto Maint.	200	1.31	262	1	262
Boat Maint.	200	1.31	262	1	262
License			30	1	30
Insurance	100	1.31	131	1	131
Boots & Cloves	28	1.31	36.68	1	36.68
Hods	12	1.31	15.72	2	31.44
Clam Hoe	15	1.31	19.65	1	19.65
SUBTOTAL:					839.07
ANNUAL CAPITAL COSTS PLUS DIRECT EXPENSES:					2221.12

[Similarly Updated Annual Costs for Maine Firms (1980 $) = 2203.05]

Source: Meta Systems estimates based on Townsend and Briggs, 1980 and Williams, (no date).

a/ CPI Boston.

b/ Assumes straight-line depreciation.

Notes:

210 bushels/yr.; average harvest.

Operates 5 mo./yr.; 100 days/yr.; 5 days/wk.

120 tides per year; 1.75 bu./tide/digger.

Table D-3. Per Bushel Nonlabor Harvest Costs for Boston Harbor Restricted Areas

Cost Categories	Cost/Bushel 1980 $
Nonspecialized Items	5.01
Specialized Items - Subordinate Diggers	3.47
Specialized Items - Master Diggers	6.18
Depuration Costs	2.00
TOTAL:	16.66

Notes:

Depuration Costs: $1.00/rack; 2 rack/bu.; $2/bu.

Table D-4. Per Bushel Costs for Nonspecialized Items[a]

Capital Costs:

Items	1978 Cost	Adjustment Factor[b]	1980 Cost	Life	Annual Depreciation[c]
Boat	1200	1.31	1572	10	157.2
Trailer	600	1.31	786	10	78.6
Outboard Motor	1000	1.31	1310	4	327.5
TOTAL:					563.3

Direct Expenses:

Items	1978 Price	Adjustment Factor[b]	1980 Price	Quantity	Total
Fuel, Boat	.80/gal	1.31	1.05	7.5 (300 mi/yr @ 40 mi/gal)	7.9
Boat Maint.	200	1.31	262	1	262
Insurance	100	1.31	131	1	131
Boots & Gloves	28	1.31	36.68	1	36.68
Hods	12	1.31	15.72	2	31.44
Clam Hoe	15	1.31	19.65	1	19.65
TOTAL:					488.67
ANNUAL CAPITAL COSTS PLUS DIRECT EXPENSES:					1051.97

= $5.01/bu. @ 210 bu./yr. (from Maine cost data)

[a] Based on costs estimated for Maine diggers for 1978, Townsend and Briggs, 1980.

[b] CPI Boston.

[c] Straight-line depreciation assumed.

Table D-5. Per Bushel Specialized Costs for Subordinate Diggers

Capital Costs:					
Items	1978 Cost	Adjustment Factor[a]	1980 Cost	Life	Annual Depreciation
Car (50%)	2500	1.31	3275	4	818.75
Direct Expenses:					
Items	1978 Price	Adjustment Factor[a]	1980 Price	Quantity	Total
Fuel, Car	.80/gal	1.31	1.05	55.6	58.4
Auto Maint.	200	1.31	262	1	262
License	--	--	30	1	30
TOTAL:					350.4
ANNUAL CAPITAL COSTS PLUS DIRECT EXPENSES:					1169.15

= \$1169.15/subordinate digger x 49 diggers[b] ÷ 16,500 bu. = \$3.47/bu.

[a] CPI Boston

[b] Estimated average annual number of subordinate diggers = 16,500 bu./yr. total harvest ÷ 210 bu./digger/yr. = 79 diggers ÷ 30 master diggers = 49 subordinate diggers. This number may be an overestimate because restricted flats may tend to have more clams/acre and therefore the harvest may be greater per person than indicated in the Maine data. However, personnel must be used to transport clams to the purification plant which would increase the employee/bushel ratio.

Table D-6. Per Bushel Specialized Costs for Master Diggers

Capital Costs:

Items	1978 Cost	Adjustment Factor	1980 Cost	Life	Annual Depreciation
Truck	5500	1.31	7205	4	1801.25
Packs			$10 x 33 = 330	3	110
Surety Bond			500	20	93.5[a]
SUBTOTAL:					2004.75

Direct Expenses:

Items	1978 Price	Adjustment Factor	1980 Price	Quantity	Total
Fuel, Truck	.80/gal	1.31	1.05	611.2[b]	641.76
Truck Maint.	500	1.31	655	1	655
License			100	1	100
SUBTOTAL:					1396.76
ANNUAL CAPITAL COSTS PLUS DIRECT EXPENSES:					3401.51

= $3401.51/master digger x 30 master diggers ÷ 16,500 bu. = $6.18/bu.

a/ Used capital recovery factor = ,187 (20 yr. life, 8% interest).

b/ 611.2 = 55.6 (1000 mi/yr @ 18 mi/gal) + 555.6(10,000 mi/yr @ 18 mi/gal).

NOTES:

Operates 5 mo./yr.; 5 days/week; 100 days/yr.

Approximately 16,500 bu./yr. depurated from Boston Harbor; 30 master diggers operate in Boston Harbor; 550 bushels/master digger/yr.; 5.5 bushels/day/ master digger.

2 racks/bushel; 11 racks/day x 3 days = 33 racks/master digger.

Approximately 50 mi. from harvest area to depuration plant; 100 mi./day x 100 days/yr. = 10,000 mi./yr. to depuration plant.

the master or subordinate digger because they operate in restricted areas. Depuration costs are the per bushel costs for the clams to be handled by the purification plant. The development of nonspecialized costs is shown in Table D-4. Specialized costs are computed for subordinate diggers in Table D-5 and for master diggers in Table D-6. These computations assume that the annual harvest from Boston Harbor restricted areas is 16,500 bushels,[a/] that there are 30 master diggers[a/] operating in the harbor and that each digger harvests approximately 210 bushels annually.[b/]

Changes in per bushel costs due to pollution abatement are shown in Table D-7. It is assumed, for illustration purposes, that the fishery is restricted and therefore no additional firms (master diggers) can enter. More subordinate diggers would be hired, however. The additional yield from the restricted areas was a preliminary figure later changed in the main body of the report (see Table 7-2). To compute total number of diggers, the same annual harvest rate was assumed as for Table D-3. The main impact of the pollution abatement was assumed to be an increased annual harvest which would allow master diggers to transport approximately four times as many bushels per daily trip to the purification plant as without abatement. The purification plant is currently undergoing expansion which will allow it to handle larger numbers of shellfish per day.

Table D-8 compares available price data with the nonlabor cost data computed for Maine and Massachusetts. Theoretically, the difference between the price and the nonlabor cost should reflect the income to the firm owner

---

[a/] Division of Marine Fisheries estimates. The 16,500 was later revised to 16,000 in the main report.

[b/] Townsend and Briggs, 1980.

Table D-7. Changes in Per Bushel Nonlabor Costs for Boston Harbor Restricted Areas Due to Pollution Abatement

	Cost Per Bushel, 1980 $	
Cost Categories	Without Abatement	With Abatement
Nonspecialized Items	5.01	5.01
Specialized Items - Subordinate Diggers	3.47	5.03
- Master Diggers	6.18	1.69
Depuration Costs	2.00	2.00
TOTALS :	16.66	13.73
Change in Per Bushel Cost	-2.93	

Notes:

Annual yield: 16,500 + 49,928 [a/] = 66,428 bu./yr.

66,428 bu./yr. ÷ 30 master diggers [b/] = 2,214 bu./master digger/yr.; 22.1 bu./day (4 times as many as before abatement)

66,428 bu./yr. ÷ 210 bu./digger [c/] = 316 diggers

÷ 30 master diggers = 286 subordinate diggers

Costs for nonspecialized items - no change.

Specialized costs - subordinate diggers:

$1169.15/subordinate digger x 286 diggers ÷ 66,428 bu. = $5.03/bu.

Specialized costs - master diggers:

Racks: 2 racks/bu.; 44.2 racks/day x 3 days = 132.6 racks/master digger;

132.6 racks x $10 = $1326 ÷ 3 yr. life = $442.

Cost per master digger = $3733.51 x 30 master diggers ÷ 66,428 bu. = 1.69/bu.

Depuration costs - no change.

---

a/ Assuming additional yield of 49,928 bu./yr., revised in main report.

b/ Assuming restricted fishery - no change in number of master diggers.

c/ Townsend and Briggs, 1980.

Table D-8. Comparison of Nonlabor Costs and Prices

Location and Year	Nonlabor Cost/Bu.	Inflated Price/Bu.[a]	Price/Bu.
Maine, 1978 $	8.01[b]	n.a.	18.65[b]
Maine, 1980 $	10.49	24.43	22.65[c]
Massachusetts, 1980 $			
Unrestricted Areas	10.57	24.43	28.00[d]
Restricted Areas			
Before Abatement	16.66	n.a.	28.00[d]
After Abatement	13.73	n.a.	28.00[d]

[a] CPI used to inflate 1978 Maine price to 1980 $.
[b] Townsend and Briggs, 1980.
[c] Maine Department of Marine Resources, Clam Production and Value, 1887-1982.
[d] Resources for Cape Ann, 1982.

n.a. = Not applicable.

and employees. However, there is not enough cost and price information available to address this question adequately.

If the cost computations discussed above formed a reasonable basis on which to estimate shifts in the supply curve, then they could be used to calculate change in producer surplus due to pollution abatement. This is simply not the case because of data inadequacies. For illustration purposes, however, we could assume that they are acceptable and that the change in per bushel cost shown in Table D-7 is a reasonable estimate of per unit supply cost changes due Co pollution abatement. Change in producer surplus would then be computed as follows:

$$\Delta PS = Profits_1 - Profits_0$$

$$= (P_1Q_1 - C_1Q_1) - (P_0Q_0 - C_0Q_0)$$

$$= Q_1 (P_1 - C_1) - Q_0 (P_0 - C_0)$$

where,

$Profits_0$ = initialprofits = $P_0Q_0 - C_0Q_0$
$Profits_1$ = new profits = $P_1Q_1 - C_1Q_1$
ΔPS = change in producer surplus ($)
P_0 = initial price ($)
P_1 = new price ($)
Q_0 = initial quantity harvested (bu.)
Q_1 = new quantity harvested (bu.)
C_0 = initial cost ($)
C_1 = new cost ($)

As an example, if the preliminary change in yield and initial quantity harvested (later revised) used in Table D-7 and the initial price of $28.00/bu. (also revised) and cost of $16.66/bu. used in Table D-8 were assumed and if a price change of -$1.99 was also assumed (this is also a preliminary estimate that was made using the preliminary change in yield and one of the initial demand functions considered, later revised in the main report), then the change in producer surplus would be computed as follows:

$$\Delta PS = \text{Profits}_1 - \text{Profits}_0$$

$$= Q_1 (P_1 - C_1) - Q_0 (P_0 - C_0)$$

$$= (66{,}428)\ (26.01 - 13.73) - (16{,}500)\ (28.00 - 16.66)$$

$$= (66{,}428)\ (12.28) - (16{,}500)\ (11.34)$$

$$= 815{,}736 - 187{,}110$$

$$= \$628{,}626.$$

It should be emphasized that this number is only hypothetical. As discussed earlier, it was thought best to omit computation of producer surplus changes in the main report because of lack of information to specify supply curve shifts and because of the likelihood that these changes would be zero due to the lack of regulation of the fishery.

References

Crutchfield, Stephen R., February 1983. "Soft Clam Exvessel Demand Functions and Clam Fishery Data," unpublished data, Department of Resource Economics, University of Rhode Island, Kingston, RI.

Marasco, Richard J., May 1975. An Analysis of Future Demands, Supplies, Prices and Needs for Fishery Resources of the Chesapeake Bay, MP 868, Agricultural Experiment Station, University of Maryland, College Park, Maryland.

Resources for Cape Ann, April 1982. The Costs of Pollution: The Shellfish Industry and the Effects of Coastal Water Pollution, Massachusetts Audubon Society.

Townsend, Ralph and Hugh Briggs, September 1980. Some Estimates of Harvesting and Processing Costs for Maine's Marine Industries, technical report, Department of Economics, University of Maine.

Williams, Doug, (no date). "Data and Procedures Used to Estimate Technical Coefficients for the Clam/Worm Sector," unpublished paper, Department of Agricultural and Resource Economics, University of Maine.

Appendix E

Charles River Boating Benefits

Additional Boating Days per Year on the Charles River

Boating Days	=	ΔBP (1)	x	Current Boating Days (2)
52,810	=	0.03142		1,680,800 High
5,750	=	0.03142		183,000 Low

(1) $\Delta BP = 0.38485\,(\Delta W)^{(a)} + 0.03142\,(\Delta FPS)^{(b)}$

$0.03142 = (0.3845)\,(0) + 0.03142\,(1)$

Source: Davidson P., G. Warns and J. Seneca, 1966. The Social Value of Water Recreational Facilities from an Improvement in Water Quality: the Delaware Estuary. Water Research, Allen Kneese and Stephen C. Smith, eds. Baltimore: Johns Hopkins University Press for Resources for the Future.

(a) ΔW = acreage of recreational water available per capita.

= 0, because currently all 675 acres of the Charles River in the Basin planning area are boatable.

(b) ΔFPS = change in recreational facility rating.

= 1 (assumed).

(2) Current Boating Days

Boating Days	=	Portion of Population Boating on Charles (a)	x	No. days per Boater (b)	x	Boating Population (c)
High = 1,680,800	=	.40		5.5		764,000

(a), (b) Source: Recreation studies (see Appendix B).

(c) Boating population equals population of towns bordering or very near to the Charles River in the planning area.

Cambridge	95,000
Watertown	34,000
Newton	83,000
Brookline	55,000
3/4 Boston	420,000
Somerville	77,000
Total	764,000

Source: 1980 U.S. Census.

				(i)		(ii)
Low	=	Boating Days	=	Family visitor days per season	x	Family number
Low	=	183,000	=	68,000	x	2.69

(i) Source: Calculations based on information in Binkley and Hanemann, 1975, <u>The Recreation Benefits of Water Quality Improvement</u>, prepared for Environmental Protection Agency, Washington, DC. 5.6 percent of all reported 850 visits for the summer season were boating-related activities, Sample was statistically representative of 0.07 percent of the SMSA population.

Therefore 850 = 1,214,286 family visits, of which 5.6 percent, or 68,000 are family visitor days.

(ii) Source: 1980 U.S. Census.