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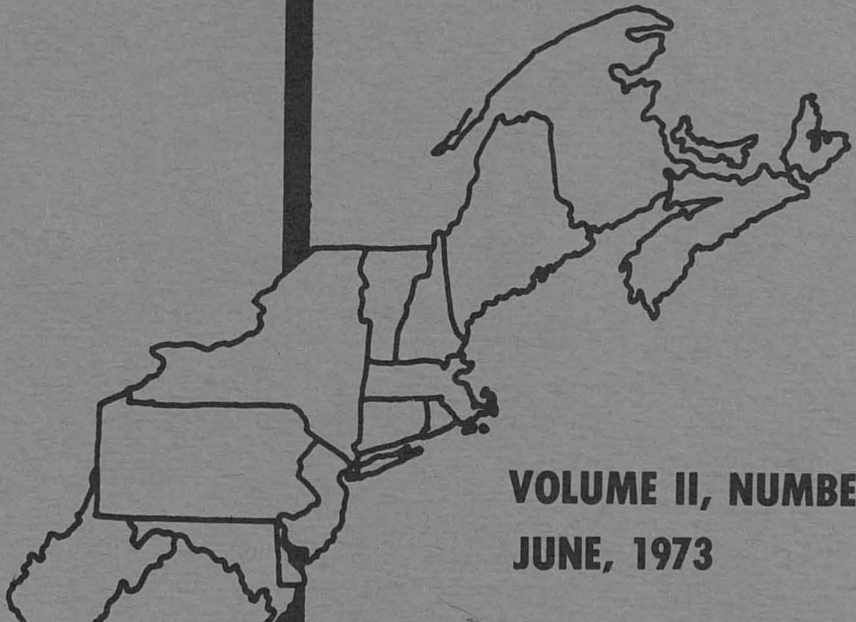

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AN INTERINDUSTRY MODEL FOR INDICATIVE, REGIONAL WATER RESOURCE PLANNING: SOME PRELIMINARY RESULTS*

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Introduction

Resource economists, planners, and local, state and regional officials have long been concerned with water quality and supply management issues within the New England area.[1] The primary responsibility for the planning and implementation of the majority of water resource programs within the region rests with local and state authorities. There are, however, efforts to approach many water supply and quality problems, particularly those which extend over a number of municipal and state jurisdictions, on a coordinated, regional basis, for example, through the various federal-state River Basins Commissions established throughout the United States.[2]

The ability to undertake a coordinated regional approach for dealing with future water resource problems, though, requires that planners be able to anticipate, if only approximately, what the particular problems are likely to be. Thus, there is a need for planning models which can assist regional as well as local and state officials in understanding the consequences of, say, expected economic and demographic developments on the region's water resources.[3]

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[1] For selected surveys of water resources research in New England, see Forste and Christensen [3, pp. G1-7] and Sokolosky [12]. An excellent, recent addition to the literature may be found in Russell, Areay, and Kates [9].

[2] In the northeast, the New England River Basins Commission is the federal-state authority coordinating regional water and related land resources planning. An example of a major reigonal planning effort may be found in [8].

[3] One could reverse the causality implied in the text to determine the consequences of water resource programs for measures of economic activity. In some cases, for example, for changes in environmental regulations or flood plain management schemes, this point of view is relevant. However, in this paper we adopt the viewpoint that economic developments are not essentially determined by water resource programs.

Our purpose in this paper is twofold. First, we wish to summarize the findings of an inter-industry study designed to reveal the interdependencies among industries and the linkages between the economy and the water resources of the Narragansett Bay area. Second, we wish to present some preliminary results of an attempt to apply the regional inter-industry model to the problem of forecasting the potential impact on the water supply and water quality of Southeastern New England. These forecasts will be based on predicted changes in the level and distribution of economic activity and population.

There is no reason to believe, a priori, that the average value product of water or of the environment, when it is regarded as an input, are similar among economic activities. Indeed the findings of this study indicate that there are considerable differences in water and effluent intensities among industries. Thus, it is fundamental to the analysisin this paper that, given relative prices, regulatory measures, and technology, water demands and pollution discharges will depend importantly on changes in the level <u>and</u> the composition of economic activity as well as on population changes. In this connection it is evident that extrapolation techniques for forecasting water demand and effluent generation are prone to be highly misleading since there is no guarantee that the rate and mix of future economic changes will be the same as past or current trends. Similarly, more sophisticated econometric techniques can be of limited value for predictive purposes if the future level and composition of economic activities differ from the industries included in the cross section or time series data used to estimate the coefficients.

The paper is organized into three parts. Section I contains a statement of the properties, assumptions and limitations of the economic-environmental, inter-industry approach used in the study. In Section II data sources are discussed, and the results of the implementation of the model are summarized. This section also contains some preliminary results of an attempt to apply the model to the problem of forecasting regional water demands and effluent generation. A summary and concluding comments are presented in Section III.

I. The Model

The analysis undertaken in this study centers on an inter-industry or input-output model of regional economic activity. The model can be formally stated as follows:

$$X - \alpha X = Y \qquad (1)$$

$$(I - \alpha) X = Y \qquad (2)$$

$$X = (I - \alpha)^{-1} Y \qquad (3)$$

where

α represents an nxn matrix of technical coefficients

Y represents an nxl vector of final demand for the region's goods and services.

I represents an identity matrix .
X represents an nxl vector of total output required to produce Y.

The α matrix of technical coefficients reflects the direct structural inter-dependencies among industries within the region. Each element of this matrix measures the amount required from industry i in order for industry j to produce one dollar of output, where i and j refer, respectively, to the rows and columns of the α matrix. The $(I-\alpha)^{-1}$ matrix (the "Leontief inverse"), on the other hand, expresses the direct and indirect linkages among the industries of the region. A given element of $(I-\alpha)^{-1}$ is interpreted as the total requirements from industry i in order for industry j to meet a one dollar expansion in final demand.

Environmental-natural resource considerations can be linked to economic activity in the following manner. First, a matrix of direct environmental coefficients must be constructed each element of which measures effluent discharges into, or resource requirements from, the environment resulting from a one dollar expansion in each industry's economic output. The matrix is dimensioned such that each column corresponds to an economic sector of the input-output model and each row defines a specific environmental parameter. For example, row j could be BOD_5, while j+1 might be acidity. In practice, of course, the selection of the appropriate environmental parameters often is restricted by the problem of data availability; where possible, however, it is desirable to design the environmental matrix to include those waterborne effluents that are most significant in terms of the potential ecological consequences to the region.

The direct environmental matrix, when post multiplied by the $(I-\alpha)^{-1}$ matrix from (3), yields a matrix of direct and indirect environmental coefficients. Each element of this matrix depicts not only the environmental interactions each economic sector directly incurs, but it also indicates the less obvious, indirect environmental repercussions resulting from the structural inter-dependencies existing among the sectors of the regional economy. In symbols, this can be expressed as:

$$E = \varepsilon[I-\alpha]^{-1} \tag{4}$$

where

ε an mxn matrix of direct environmental linkages.
$[I-\alpha]^{-1}$ the inter-dependency coefficients from (2) and (3)
E an mxn matrix of direct and indirect environmental linkages.

Thus, for any of the n industries included in the transactions table of the input-output model, each of the corresponding m coefficients can be interpreted as the direct and indirect water resource consequences --in terms of the specified environmental parameters--of one dollar expansion in the final demand for the output of the nth industry.

It is worthwhile, at this point, to consider the shortcomings, and hence the limitations, of the model developed above. First, the economic model is subject to the many simplifying assumptions characteristic of input-output analysis [6, Ch. 8; 7]. In general this type of model tends to be demand oriented. Perhaps the most significant assumption, though, is that the relationship between inputs and output as reflected by the technical coefficients is constant throughout the production range. Thus, each sector's utilization of inputs is solely dependent upon its level of output, and this relationship is set as a fixed proportion. In addition, the average and marginal propensities to import into the region, by industry, are assumed to be equal and constant.

The fixed proportions rule also is assumed for the interactions between economic output and environmental linkages, as evidenced by the constant environmental coefficients. It is, in addition, important to emphasize that effluent generation, per se, need not be identical to the problem of technological external diseconomies. Technically, the results of this study are only a part of the overall problem of relating economic activity to regional ecological impacts. Regional ecological effects are not endogenousto the model developed in this paper; such effects, as determined by natural scientists, must be estimated independent of the model and then related back to economic factors. This approach differs substantially from that of Isard et al [5]. In their model, economic interactions with the ecologic system are assumed to take place on a constant coefficient basis [5, Ch. 3, Sec. 5]. The Isard model, then, is theoretically more complete than the one presented here, but it is open to question whether the additional set of biological interactions approaches a linear relationship.

II. Application of the Model

The regional model used to derive the results in this paper is based primarily on the work by Feld [2]. The model is a static, partially closed (the household sector is treated endogenously) inter-industry model, which encompasses economic activity within the Narragansett Bay Drainage Basin. This region covers some 742 square miles and is inhabited by approximately 990 thousand people residing in both Rhode Island and Southeastern Massachusetts. In the Rhode Island portion, over 90 percent of the State's population and economic activity are within the study area. In Massachusetts the area covered includes portions of Norfolk County, Worcester County and Bristol County as well as the city of Attleboro.

The inter-industry model has 59 endogenous economic sectors and four final demand sectors, and the environmental matrix contains information on 35 effluents andon water demand, i.e., the ε and E matrices in (4) are of the order 36 x 59. However, since the water demand and effluent discharge forecasts in this paper are based on the economic forecasts of the Bureau of Economic Analysis (BEA), Department of Commerce, it is necessary to aggregate the regional economic sectors to make them comparable with the BEA industry breakdown.

The development of the technical coefficients is discussed in detail in Feld [2, Ch. 3]. With regard to the environmental matrix, initially it was felt that environmental coefficients for the ε matrix would be available from secondary sources [1, 4, 9]. However, this data proved exceptionallysketchy and in most instances could not be applied to the model because of differences in sector definitions. Fortunately, a relatively new data source became available. Corps of Engineers' permit applications for discharges into navigable waters are now public record and contain information which can be translated into relevant coefficients [14]. The permit applications proved useful in developing coefficients for over one-third of the economic sectors delineated in the model. Even more important, the activities covered are recognized as those critical industries in terms of waterborne wastes generated. In addition, the level of detail far exceeds what is available from other sources with as many as 28 specific parameters quantified for individual sectors. The final matrix of environmental coefficients utilized in this study containsa more disaggregated compilation by sector than any similar tabulation encountered in the literature. However, the water demand information, at this point, draws on the findings of others [1, 4, 9, 15].

II.A Regional Water Coefficients

In Table 1 the direct, and the direct and indirect, water demand and effluent generation coefficients, by BEA industry category, are summarized. These coefficients correspond, respectively, to ε and E in the text (see (4)); however, for convenience all the effluent discharge information has been aggregated to a single environmental flow for this paper. It should be noted, however, that for particular applications total pounds of waste is not an ideal index of pollution as the damages caused by waste production in an aquatic environment depend on the specific composition of the waste and on the nature of the ecological system.

Each of the four coefficients in Table 1 is classified in one of five categories ranging from LL, "low-low", to HH, "high-high", and in addition each industry is ranked for each coefficient.[4/]

Several aspects of Table 1 merit emphasis. First, as noted earlier there are considerable differences among industries for each of the direct coefficients. Second, it is apparent from differences between the direct coefficients and the direct and indirect coefficients that the indirect water resource consequences of an expansion in the final output of many sectors can be important for the region. For example, consider the waterdemand coefficients of the apparel and other textiles sector. The direct coefficient has the lowest classification, LL, but when the indirect economic effects and the associated derived water demands are taken into account, the coefficient shifts up two classes to M. In fact, it is interesting that there are sectors for which no direct water demand data were available--operationally, this means the sectors

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[4/] The five classifications are, in ascending order, LL, L, M, H, HH. The equivalent numerical scale for each classification accompanies Table 1.

Table 1

Water Demand and Effluent Generation Characteristics, Per Dollar of Earnings, by Industry, for the Narragansett Bay Drainage Basin a/

	Water Demand		Effluent Generation	
	Scale and (Rank)		Scale and (Rank)	
INDUSTRY	Direct b/	Direct and Indirect c/	Direct b/	Direct and Indirect c/
Agriculture, Forestry, Fisheries	n.a.	L (25)	LL (29)	M (18)
Mining & Construction	LL (19)	L (29)	L (15)	M (19)
Manufacturing				
Food & Kindred Products	L (8)	L (17)	H (9)	H (9)
Textile Mill Products	M (6)	H (7)	H (10)	H (10)
Apparel & Other Textiles	LL (9)	M (14)	HH (3)	HH (4)
Printing & Publishing	LL (15)	L (26)	LL (28)	M (28)
Chemicals & Allied Prod.	HH (4)	HH (4)	HH (2)	HH (2)
Lumber & Furniture	LL (18)	L (21)	HH (5)	HH (7)
Machinery, excl. Elec.	LL (17)	L (24)	LL (31)	M (25)
Electrical Equipment	LL (16)	L (27)	L (13)	M (17)
Motor Vehicles	LL (14)	M (15)	L (21)	M (14)
Other Trans. Equip.	LL (13)	L (18)	L (18)	M (12)
Paper & Allied Products	HH (3)	HH (3)	HH (1)	HH (1)
Petroleum Refining	H (5)	HH (5)	HH (4)	HH (5)
Primary Metals	LL (11)	M (12)	H (7)	HH (3)
Fabricated Metals	LL (10)	M (16)	L (16)	M (16)
Misc. Manufacturing	LL (20)	LL (32)	L (17)	M (21)
Transportation, Communications, Public Utilities	HH (2)	HH (2)	M (11)	H (11)
Transportation & Warehousing	n.a.	H (31)	LL (30)	M (27)
Communications	n.a.	L (28)	LL (32)	M (29)
Utilities	HH (1)	HH (1)	H (8)	H (8)
Wholesale & Retail Trade	n.a.	M (8)	L (22)	M (26)
Finance, Insurance, Real Estate	n.a.	L (30)	LL (27)	M (20)
Services	LL (12)	M (10)	M (12)	M (13)
Lodging & Personal Serv.	M (7)	H (6)	HH (6)	HH (6)
Business & Repair Serv.	n.a.	M (9)	LL (26)	M (15)
Amusements, Recreation Service	n.a.	L (20)	L (20)	M (22)
Private Household Serv.	n.a.	LL (33)	LL (33)	M (33)
Professional Services	n.a.	M (11)	L (19)	M (24)

(continued)

	Water Demand Scale and (Rank)		Effluent Generation Scale and (Rank)	
INDUSTRY	Direct[b/]	Direct and Indirect[c/]	Direct[b/]	Direct and Indirect[c/]
Civilian Government	n.a.	L (19)	LL (24)	M (31)
Federal Government	n.a.	M (13)	L (23)	M (23)
State & Local Government	n.a.	L (23)	LL (25)	M (32)
Armed Forces	n.a.	L (22)	M (14)	M (30)

Scales:

A. Effluent Generation, lbs. per $1. of earnings

LL - less than .01
L - .01 - .1
M - .1 - 1.0
H -1.0 - 3.0
HH -over 3.0

B. Water Use, gals. per $1. earnings

LL - less than 20
L - 20 - 50
M - 50 -100
H -100 -200
HH -over 200

Rankings

The industry ranks are in a descending order of magnitude.

a/ Note: Composite figures for effluent used in the table unavoidably contain some elements of double counting, and in addition some of the items are not strictly additive. The classifications in the table were derived under a specific set of assumptions which are explained in the text and other table notes. Source: Adapted from: Sidney Feld, An Economic-Waste Generation Model of Narragansett Bay, Rhode Island (unpublished doctoral dissertation, Department of Resource Economics, University of Rhode Island, 1973).

b/ The direct coefficients specifically relate to the industry breakdown for the Narragansett Bay area, in Feld, Ibid.

c/ The direct and indirect coefficients are adapted from Feld, Ibid. and they can be applied to sub-areas outside the Narragansett Bay drainage area (see the text) only insofar as the economic structure of these areas and the environmental and water demand coefficients can be regarded as at least approximately similar to that of the Narragansett Bay area.

were assigned a zero direct coefficient--yet they have direct and indirect water demand coefficients ranging from LL to H in one case. Overall, there are only six sectors where the direct and indirect water demand coefficient is in the same classification as the direct coefficient.

Clearly, one implication of the results in Table 1 is that, for regional water resource planning purposes, it can be short-sighted to examine only the direct water demands from an expected increase in the final output level of particular sectors. For many activities, the indirect water demands may be quite important. This is another way of stating the more technical point that, although the α matrix and the ε matrix for a region will have a good many zero elements, the $(I-\alpha)^{-1}$ and the E matrices will contain relatively few zero elements. The inter-industry approach, in this regard, is ideally suited for obtaining measures of the disaggregated, indirect economic and environmental effects of changes in the final demand for regional outputs.

Similar observations apply to the effluent generation coefficients contained in Table 1. The direct coefficients vary considerably across sectors, and the direct and indirect coefficients in most cases are in higher classifications than the corresponding direct coefficients. Again, the total environmental consequences of an increase in a sector's activity level will depend upon the linkages within the regional economy. For example, consider the primary metals sector, which, directly, is a "dirty" industry in our classification system, i.e., its direct coefficient is H, and it has a rank of 7. An examination of the α matrix (not included in the paper) reveals that the most important direct regional inputs into this sector are, in descending order, from itself and from the chemicals and utilities sectors. In Table 1 these sectors, respectively, have direct effluent discharge coefficients of H, HH, and H. It is understandable, then, how the direct and indirect effluent generation coefficient for the primary metals sector can be HH and move up in rank to 3.

II.B Preliminary Forecasts of Water Demands and Effluent Discharges

In addition to its use in revealing the structure of the Narragansett Bay regional economy and the linkages between the regional economy and the derived demands for water and environmental services, the model can be used for forecasting purposes.

Our aim, it should be stressed at the outset, is not to attempt to obtain precise forecasts of water demand and effluent generation. This would imply, for one thing, excessive faith in a single set of economic forecasts (discussed below). Also, the water demand and effluent generation data are at present, incomplete and are continually being improved. In addition there is the question of whether an inter-industry approach, or for that matter any single approach, can be expected to provide reliable forecasts in this area.

Thus our purpose in making these forecasts is only to provide some indicative measures of what autonomously forecasted changes in the level and composition of economic activity and the level and distribution of population could mean to the Southern New England area, given the specific assumptions of the approach.

The approach taken is as follows. First, an adjusted Bureau of Economic Analysis' forecast of population and of earnings, by industry, for water resource areas is employed.[5/] This information is available [13] for the following Southeastern New England areas for 1980 and 1990.[6/]

1. Greater Boston
2. Worcester-Fitchburg-Leominster
3. Fall River-New Bedford
4. Coastal Massachusetts (essentially, Cape Cod)
5. Providence-Pawtucket-Warwick
6. Coastal Rhode Island

The earnings data by area and by industry are then multiplied by the coefficients underlying the construction of Table 1 for 1969, 1980 and 1990. To these figures we add a (preliminary) per capita water demand of 25,000 gallons a year estimated by Siegel [11] times the population in each area for each period.[7/] The resulting 1980 and 1990 totals for water demand and effluent generation, when divided by the corresponding figures for 1969, indicate an index of future water demands and waste discharges, by area, relative to the base period, 1969.[8/]

[5/] The BEA of the Department of Commerce makes forecasts for each of the water resource areas throughout the United States. Essentially, the methodology employed is a shift-share approach modified by certain historical trends for each area, by technological factors, and by changes in population and the labor-participation rate over time. The BEA forecasts for Southeastern New England may be found in [13]. However, the BEA forecasts in [13] are probably on the high side primarily because they are based on an assumed rate of population growth, the so-called series C projections, which appears to be too high in light of recent trends. Consequently, the economic and population forecasts used to derive Table 2 were arbitrarily decreased by ten percent. We are indebted to Niels Rorholm for discussion on this point.

[6/] Forecasts have been made out to 2020 [13]. However, forecasts over such an extended period are not likely to be reliable, and these figures are not used in this study.

[7/] The per capita figure in the text is not adjusted for seasonal factors; consequently, peak load considerations have to be regarded as outside the results of this paper.

[8/] To the extent both numerator and denominator are off by the same multiplicative factor, any error would be self canceling.

The results are summarized in Table 2. The adjusted BEA forecasts, used in conjunction with the coefficients underlying Table 1, indicate that water demand in 1980 could be as much as 1.52 times that of 1969 for the total Southeastern New England region. For 1990, the index could be 2.17 for the region as a whole.

Table 2

Future Water Demands and Effluent Generation in Southeastern New England Relative to 1969 a/

AREA	Water Demand 1980	1990	Effluent Generation 1980	1990
Greater Boston	1.52	2.17	1.51	2.13
Worcester-Fitchburg-Leominster	1.52	2.16	1.46	2.02
Fall River-New Bedford	1.53	2.20	1.45	1.96
Coastal Massachusetts	1.80	2.89	1.85	3.03
Providence-Pawtucket-Warwick	1.46	2.03	1.48	2.06
Coastal Rhode Island	1.87	2.96	1.69	2.54
TOTAL-Southeast New England	1.52	2.17	1.50	2.11

a/ Note: The assumptions and limitations underlying the results in Table 2 are explained in the text.

SOURCES: Feld [2], Siegel [11], and the adjusted B.E.A. forecasts in [13].

On the other hand, waterborne effluents discharged into the environment in 1980 and 1990 could be 1.5 and 2.11 times as large as the 1969 figure for the region, other things held equal. The highest water demand and effluent generation ratios, not surprisingly, are for Coastal Massachusetts and Coastal Rhode Island, the two areas which are expected to grow at the most rapid rate.

It is essential that the assumptions used to construct Table 2 be made explicit. First, constant technical and environmental coefficients are assumed. Changes in relative factor prices and environmental regulations, and advances and changes in water treatment and water using technologies could be expected to alter the coefficients. In general, the farther out one forecasts, the less valid is the assumption of constant coefficients. (Of course, the coefficients can be improved and brought up to date in the light of new knowledge.) Second, the results in Table 2 assume that the technical and environmental coefficients of the Narragansett Bay region can be regarded as approximately representative of the other sections of Southeastern New England. Third it is assumed that the adjusted BEA forecasts used for the water demand and effluent discharge projections are reasonably reliable indicators of future economic developments. And finally, it is assumed that the highly aggregated economic sectors employed in this study will continue to reflect the relative composition of industries found to exist in the base year.

III. Summary and Conclusions

In this paper we have presented some results of an inter-industry study designed to provide an understanding of the structure of the Narragansett Bay regional economy and the linkages between the economy and the derived demand for water and environmental services. In addition, some preliminary, indicative forecasts of future water demands and effluent discharges, relative to a base period, were made for the Southeastern New England Area, under a specified set of simplifying assumptions.

We have argued that the inter-industry framework outlined in this paper can provide important insights into the inter-dependencies between economic activity and the use of the region's water resources. This model, perhaps when used in conjunction with complementary information on elasticities and technological trends, can be of value for water resources planning at the regional level.

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