Final Report

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A Study of the Measurement and Distribution of Costs and Benefits of Water Pollution Control

Marc J. Roberts, Ph.D., Principal Investigator

DISCLAIMER

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I. Background and Concepts

The purpose of this study is to advance our understanding of the way in which water pollution benefits and costs will accrue to different income and social groups. The very specification of the focus in this way acknowledges that economists and policy makers cannot be content simply with seeking economic efficiency. Instead it matters substantially whether net gains and losses occur to those who are better or worse off.

Taking this position means acknowledging that the mechanisms available for altering the distribution of welfare in the society are imperfect. That being so, the distributional outcomes from all the various particular economic and regulatory policies which are chosen will in turn have an impact on the final distributive situation. There is no way around this dilemma in an imperfect world.

We must recognize of course that benefits to upper income groups are still benefits. They surely are not without social value simply because they accrue to the well-to-do. But nonetheless we must bear their distributional meaning in mind when we go to reach an overall judgment on social policy questions.

In this initial section we discuss a variety of conceptual tools and issues in perparation for the actual analysis of benefits and costs. These latter tasks are carried out in Section II (benefits) and Sections III and IV (costs). We should make clear from the outset, however, that no highly quantified synthetic estimates are provided. We have not had the time or resources to reach such results. Instead we have made substantial progress toward such numerical magnitudes, and are able to offer what we believe to be some quite useful conclusions even at this stage.

I.1 Defining The Problem

To begin, note that an "externality/public good" is any output of any economic activity that matters simultaneously to more than one consumer.[1] Neither the physical nor the psychic effects have to be the same for everyone (nor even different from zero for most). The Strategic Air Command and a neighbor's obnoxious barking dog raise the same "problem"; namely, that the "correct" level of production can only be discovered by "adding up" the costs and benefits (at the margin) that accrue to all affected parties.[2] By "correct" in this context, economists usually mean that no mutually beneficial gains from trade remain unexhausted (i.e., that we are in a Pareto Optimal situation).[3] Production and consumption processes which have an environmental impact are clearly of this form.

But what "problem" do such externalities present? Should we worry that a market economy on its own might not arrive at "Pareto Optimality" when such goods are present? As Coase has argued, if all trades were "costless" and all participants "rational," all mutually beneficial transactions would occur.[4] <u>In a perfect frictionless world the economy must wind up in a Pareto Optimal situation, regardless of externalities</u>. For example, in such a world, if the harm caused by a smoking factory were greater than the cost of cleaning up, those harmed would organize to pay the factory to limit its emissions to the "correct" level.

I.1.1 Real World Difficulties

In the real world, there are two main reasons why such bargaining does not occur. First, the structure of the bargaining "game to which the externality gies rise to might include perverse incentives. In particular we may find ourselves faced with an n-person "prisoners' dilemma." That is, there might be "bargains" which would make everyone better off, but the players find it difficult to coordinate their behavior so as to realize such "trades." Second, transaction costs could be so high as to prevent what would otherwise be mutually beneficial trades from being negotiated. This latter possibility raises some problems in the definition of "optimality," to which we return below.

The "prisoners' dilemma" problem is also known in the public choice literature as the problem of "nonrevelation," the "logic of collective action" problem, or the "free rider" problem.[5] The argument depends upon four crucial, and often unstated, assumptions. (1) There are a large number of beneficiaries of the public good, all of whom assiduously seek their own self-interest. (2) The provider of the good cannot deprive any one person of benefits except by changing total output and hence depriving everyone else. (3) Cleanup is financed by voluntary contributions or taxes based on what is known about how much different individuals benefit and (4) No one consumer, by his own consumption choices, in any way alters the amount of benefits derived by other consumers.

In such situations each person might expect to gain by claiming to assign a low (or negative) value to abatement. If his fellow citizens provide cleanup anyway,- the understater gains and yet does not pay. If enough people behave this way, their calculations will turn out to be incorrect; the externality is not altered, and everyone winds up worse off. This is a classic "prisoners' dilemma" outcome. Large numbers are crucial. Otherwise, each individual will know that his expressed valuation both should and will affect the apparently optimal, and actual, level of externality control.

This analysis does have some power for explaining real world phenomena. For example, it helps to explain why it is so hard to organize private action to control widespread external effects like urban air pollution. The logic also operates when the beneficiaries of cleanup are also jointly the source of the difficulty--and each must bear the costs of cleaning up his own wastes. Littering and the use of polluting toilets on pleasure craft are in this category.

But the notion of perverse incentives has its limits as an explanation for the current situation. In practice, one or more of the assumptions noted above are often violated for environmental good. First, and most simply, people do not always behave on the basis of narrow calculations of self-interest. Cultural norms as to what is good, right, fair or just often intervene.[6] After all, many people do vote, help strangers, and respond to calls for the voluntary curtailment of electricity or water use in a shortage. All these actions are irrational from a selfish, game theory viewpoint, which only shows that the applicability of that formulation is not unlimited.

The explanation also breaks down because the second critical assumption is also often inaccurate in practice, namely that people who claim not to care cannot be deprived of the benefits "of a public good."

In Samuelson's classic formulation, each public good can be described by a single parameter--the level of expenditure/output.[7] Each level of output maps to a point in the space defined by individual utilities. (See Figure I.1) However, as Buchannan has argued, the distribution of benefits might be variable.[8] The government can spray more for mosquitos on my side of the lake and less on yours or visa versa. As a result, each level of expenditure maps to a frontier (not a point) in individual utility space (See Figure I.2).

Under such circumstances, an individual who understates the benefits he derives from a public good can expect to have less of it provided to him. A variety of circumstances influences the possibility of successful understatement. It clearly depends in part upon how many others must be affected in order to change any one person'e benefits, and on the resources that society saves by not giving him services. For some "environmental" issues, especially locational questions like the siting of power plants, roads, or new recreation facilities, the distribution of beneifts can often be varied significantly, and perhaps as a result citizen lobbying on such choices has often been very intense.

On the other hand, the distribution of many environmental benefits is sufficiently inflexible as to more closely approximate the classic public goods case. This is especially true of what we might call moral or ideological benefits that do not depend on the beneficiary having direct contact with the ecosystem. Many individuals care about the bald eagle population who have never and will never see such birds in the wild. It is hard to see how the

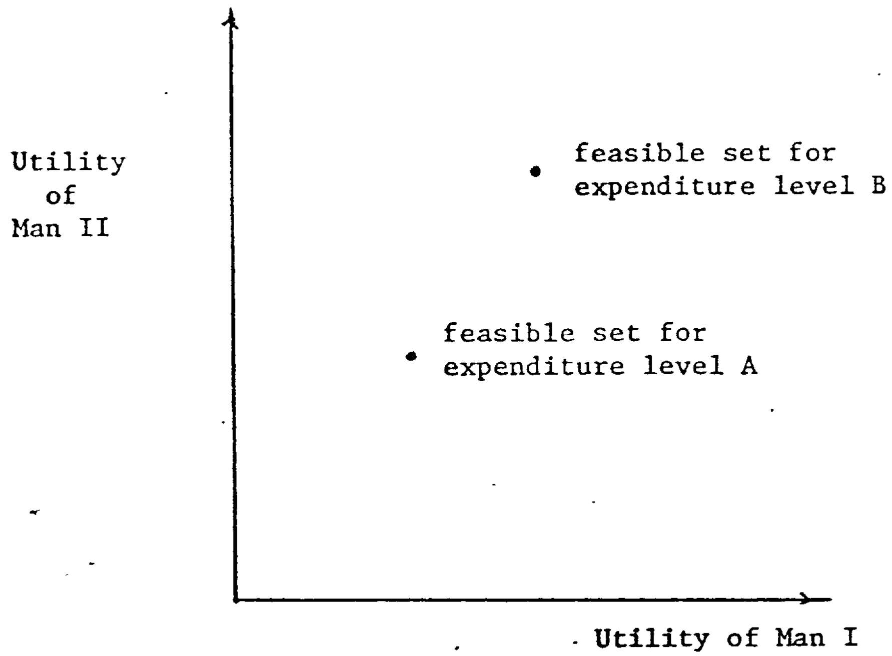


Figure I.2

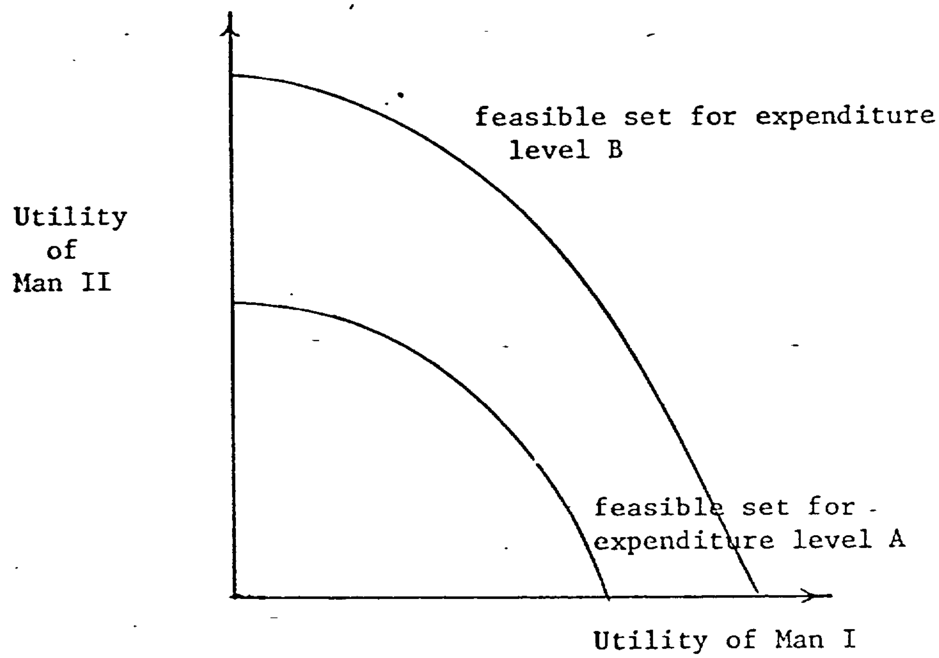


Figure I.2

distribution of such satisfactions can be varied like those from locating an oil refinery.

Even in these cases, however, nonrevelation is not usually a problem for public action because the third assumption of the argument is violated. <u>In practice, public activity, environmental and otherwise, is not financed either by voluntary contributions or on the basis of apparent benefits. Hence the non-relevation problem usually does not arise</u>. The members of the Sierra Club or Friends of the Earth do not face higher tax bills when they successfully lobby to keep the Colorado River wild or for a new national park. Why then not express, even overstate, one's preferences? Overstatement actually seems more characteristic of our public choice processes than nonrevelation. Indeed, members of environmental groups spend nontrivial resources to volunteer their views, in situations in which the collective action paradox would seem to imply a paralysis of all lobbying efforts!

The fourth assumption is also sometimes inaccurate. This says that consumption decisions are "non-rival" with respect to individual choices. For example, the quality of the air I breathe, or the satisfaction I derive from knowing the Colorado River is undammed, are independent of anyone else's enjoyment of these. While acceptable enough in some cases, it clearly does not apply to recreational use of the ecosystem where "congestion" effects are of major importance. Such rivalry complicates the public decision process greatly, as well as further diminishing the incentives everyone has to understate. (See Chapter II below)

Apart from the "game theory" problems, the second major reason why externalities are not "bargained" away by voluntary trading is because of the information and decision costs of arranging such transactions. Environmental externalities usually affect large numbers of individuals. This greatly increases the costs of reaching an agreement. The complexity of options, the multiple uncertainties-involved, and the typical pattern of costs and benefits also raise the costs of bargaining.[9] The benefits of environmental protection to any one individual are often (a) small, (b) difficult for the individual to quantify and evaluate and (c) uncertain, given our limited knowledge and the unpredictability of both man and nature. Accurately determining one's own "willingness to pay" under such conditions would require a significant investment in self-examination. Will such an investment seem justified given the expected returns and the other bargaining difficulties? If the answer is "no," then bargains are not struck which might be in everyone's interests--if only the transaction costs were lower. These costs together with the "prisoners' dilemma" seem to explain why the system fails to achieve Pareto optimality.

There is a theoretical difficulty, however. Once decision and information costs are considered, it is possible to argue (tautologically) that the world is always in a Pareto Optimal situation--from an expected utility viewpoint. Doesn't everyone always do the "best" he can, "all things considered"? For any unmade move, some participants must <u>perceive</u> transactions costs to be more than the probable gains. Otherwise the move would be made. Even obvious inefficiencies that result from decisions which are clearly mistaken *ex post* may not indicate non-optimality. At best such choices were made on the basis of optimally imperfect decisions rules and information, which inevitably lead to error some part of the time. This is quite apart from the "bad luck" of drawing an unfavorable outcome from a known stochastic process.[10] But perhaps these were errors whose expected utility costs *ex anti* were believed to be lower than the costs of avoiding them. How then can we call *any* outcome "inefficient"?

To understand the definitional problem more clearly, consider a group of men who (wrongly) choose to cease bargaining when there were still unachieved gains from trade. Perhaps they believed (mistakenly) that such gains were less than the costs of continuing, or that they had exhausted such gains. Suppose too that a little more investment in information gathering and decision making would have revealed the desirability of further negotiation. They did not undertake such an effort, however. Each of them had a "rule of thumb" which indicated that (1) in general such analysis of whether additional bargaining was beneficial would itself not be likely to "pay off" in the long run and (2) that it didn't pay to spend too much time worrying about possible exceptions to the previous generalization. If the general rules they all followed were reasonable--they too were chosen imperfectly on the basis of only partial analysis--in what sense is the outcome "Pareto Optimal" or not?

It is not clear that we can rescue a usefully operational concept of Pareto Optimality from this morass. At a minimum it must be defined in terms of a given information state, a given set of decision costs, and a given set of objectives for the participants. However this alone does not allow us to avoid the tautology of always justifying what occurs. Instead to make critical judgments, it would appear necessary to proceed from an evaluative position which in one or another of these respects differs from that of the actual participants. How can we only identify the "best guess" choices of others as "mistaken" unless we other. (1) know more than they, (2) can make better (cheaper) decisions, or (3) have different objectives?[11] In the real world, where information and decision making are costly, the true maximizing strategy, that is the "globally rational" strategy, in general is not to "maximize." Instead one should seek a "satisfactory" outcome where the definition of "satisfactory" varies with experience over time. The outcome of such "satisficing" processes are necessarily indeterminate. As discussed below, as a result, the "social opportunity set" is not clearly defined but is instead a region with a broad and fuzzy boundary.

Apart from these two problems, three other explanations of environmental market failure have been offered which I consider less important but wish to discuss briefly. First are our difficulties caused by our unwillingness to tolerate the short run, static inefficiency of setting prices which exclude people who could be served at zero cost, e.g., additional bathers on an uncrowded beach? The potential utility gains from such an activity are shown in Figure I.3. As long as we value individual increases in utility, we should always choose point B with no exclusion. When, as in Figure I.4, setting up a system of

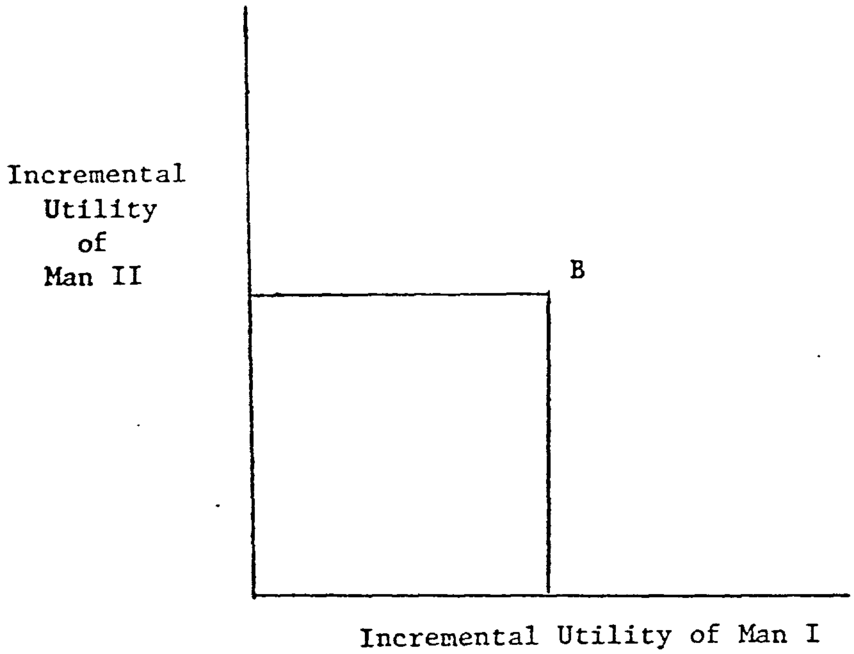


Figure I.3

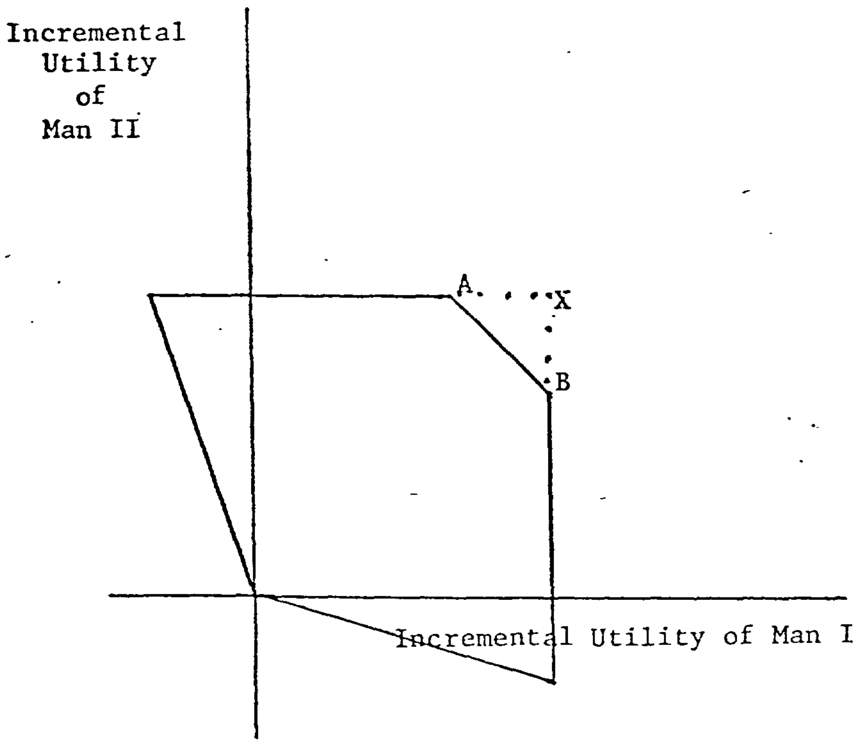


Figure I.4

exclusion requires a fixed amount of resources (AX = BX), we should, on the same assumptions, always choose some part along AB, where no exclusion actually takes place.

In practice this does not seem to be the source of our "problem" especially in the water pollution area. The society seems quite willing to let both public and private suppliers to levy charges in such circumstances. We have admission fees for uncrowded movie theaters and tolls on uncrowded turnpikes. This would appear to be because of the need to provide both funds to support these activities and information to guide the level of long-run capital investment.[12] Thus it is the difficulty of organizing markets for such outputs as clean rivers (not our fear that these arrangements might violate short-run optimality conditions) which has prevented the development of more of such schemes for providing environmental outputs.

Second, believers in the general efficacy of free markets have sometimes argued that the problem is that environmental "property rights" are not clearly enough defined.[13] How can the necessary transactions occur, they ask, when ownership is unclear? The state--which defines property rights--is thus at fault, not the market processes themselves. In my view, this contention is not well taken. Most environmental property rights are quite clear. As a result ambiguities in ownership just do not explain why more bargains have not been arranged. Firms and households have effectively "owned" the air, land, and water for disposal purposes. It was not any obscurity in the system of property rights which prevented the citizens of New York from banding together to pay Con Ed to emit less sulphur into the air.

Environmental property rights often are nonexclusive rights, which is somewhat unusual. Others can also dump waste into the stream I use. But joint rights are still rights--as buyers and sellers of nonexclusive patent licenses and property with rights to the use of community facilities will attest. In many ecological systems large numbers of landowners have had pollution rights (which they may not be fully exercising). This does make bargaining more expensive--which reduces this argument to the transaction costs problem.

Third, Arrow has noted that when only a small number of individuals are involved in bargaining, the imperfect markets that result do not guarantee a Pareto Optimal outcome.[14] To what extent has this influenced our environmental policies? His point is that in such cases, participants might make strategic movies, such as threats or all-or-nothing offers, in order to capture most of the gains from trade for themselves. Threats mistakenly perceived as bluffs, and "called," may in fact be carried out. Participants in a good position might be unwilling to negotiate further when there are still gains from trade, fearful that social or cultural pressures--or a coalition of other participants--will force them to give up what they already have won. Noncontract curve (i.e., noncore) outcomes seem distinctly possible. This is especially so if the participants are playing an ongoing series of games, environmental and otherwise, so that their credibility in each depends on their behavior in others.

In reality, while breakdowns in environmental bargaining do occur, it is difficult to find many such instances. Environmental problems generally involve large numbers so that transaction costs and perverse incentives seem to be the more relevant difficulties in practice. However, when the many participants have been effectively aggregated into a small number of actors through political processes, bargaining problems can arise. For example, the relevant states could not agree on any Columbia River Basin Compact after twelve years of negotiation. Yet that was a situation in which almost undoubtedly there were some gains from trade that might have been realized.[15]

1.1.2 A Reformation

The argument thus far, as well as other considerations, implies that it is not very helpful to take the usual economists' tactic and depict social choices about the environment in terms of a convex, compact, static opportunity set. We have already noted that "satisficing" processes do not give rise to determinate outcomes. Such choices involve the use of arbitrary decision rules since it is <u>not</u> optimal in general to spend whatever it takes to determine the optimal strategy for discovering what is optimal, because require more resources than it is worth.[16] In addition, the notion of what is "technically possible" cannot be given unambiguous meaning. At what point in the development of a new technique does it enter our opportunity set?[17] Furthermore, as Samuelson noted long ago, social opportunities in fact depend upon what is achievable within the extant social, political and institutional setting. He suggested we use the notion of what is "politically feasible."[18] But surely political processes cannot be adequately characterized by the "feasible-unfeasible" distinction. For all these reasons, <u>the "boundary" of our opportunity set is a fuzzy and ambiguous region</u>. We cannot say in advance precisely what can and cannot be achieved with respect to environmental protection.

If we wish for a formal representation, and are willing to settle for a one-period concept, we might think of our opportunities as defined by a probability distribution over the set of outcomes. Some are impossible and have zero probability. The decision problem of any one political actor then can be posed by asking how that probability distribution alters, conditional on his expenditure of different amounts of the various resources he commands (time, money, etc.). More realistically, given the multi-period nature of real decisions, we might view policy choice as selecting a series of Markov matrices that indicate the transition probabilities among all possible outcomes between each pair of successive time periods. Yet even this is too simple. The probabilities in any future matrix in fact depend upon the intervening history. Information, opportunities, and attitudes will all be affected by experiences. Institutions, programs and policies are not fully reversible. Participants become invested in any set of arrangements--psychologically and financially. Any choice today changes the transaction costs of certain other future moves and the probabilities that they will occur.

<u>Our opportunities do depend upon the magnitude and distribution of the transaction costs and hence on the institutional arrangements and culture of the society</u>. Culture, tradition and socialization in particular play an often unnoticed role in limiting the kinds of claims, side payments and agreements which are considered socially legitimate. Coase noted that without transaction costs or constraints the optimal (and actual) outcome of bargaining over externalities is independent of how we assign the property rights.[19] <u>Given transaction costs, imperfect knowledge and limits on compensation possibilities--where the society both can and will wind up depends very much on where we start and on the process we sue to arrange transactions. The initial assignment of property rights in externality situations is thus very important</u>. If high transaction costs lead to the system being "stuck" at the status quo, it is

the initial distribution of rights that determines the outcome.

In our own society we have assigned disposal rights generally to the polluter. It is not that the relevant markets or property rights do not "exist." Rather the high transaction costs and game theory problems have made it impossible for those harmed to organize and to offer a bribe for cleanup. As a result, we have a zero "price" for the use of the environment for waste disposal. When the price paid for a resource is so low--even low value sues are encouraged. Waste has been disposed of th the environment even if it might have been cleaned up very cheaply, and where the damage that results is large.

It is not very interesting to ask if the current situation is or is not Pareto Optimal in an *ex ante* expected utility sense, given information available to the participant, their goals and so on. *The real question is not, "Are we at an optimal point," but simply, "Can we identify and devise a strategy for getting to a point that is discernibly more desirable than either the current situation or the outcome of other alternative moves*?

Admittedly, this is not a precise statement. How much better an outcome do we seek? What alternatives do we examine? These are not questions with general answers, but rather ones to be resolved on the basis of various strategic simplifications in any given context. Social choice itself, to be globally rational, is a "satisficing" process.

The "problem" is not simply that the environment is "dirty." In this the exposition differs somewhat from the viewpoint of some ecologists who insist that natural preservation should be an end in itself.[20] Instead, I have posed the question in terms of the traditional homeocentric viewpoint of economists which accepts individual satisfaction as basic to making judgments about alternative social states. From this perspective the "problem" is simply that existing institutional and cultural arrangements for allocating environmental resources prevent us from achieving situations which at least some individuals would prefer. This suggests a need to alter those arrangements so that changes both might be, and will be, made in the level and pattern of environmental outputs.

Furthermore, in my view, we should not only consider options where everybody in fact gains. Information and decision costs and social constraints do limit our choices. It may not be possible to make everyone better off as we improve environmental quality. Or we might choose not to do so for distributional reasons. In the real world, after all, few policies benefit everybody. Schematically, in Figure I.5, suppose we begin at point A, an individual utility space, with B and C unattainable. If a new policy now makes them possible, we might choose B, even though C is Pareto superior to A and B is not. The gains to one man might be large enough to make the losses to the other an acceptable price to pay. Note that putting it this way does not amount to reviving the old "compensation test" once urged by Kaldor, Hicks and so on although the incremented spirit is simpler.[21] Here we are comparing the social value of charges in individual well being, not the money payment each party would make to accomplish or avoid the proposed charge.

This statement of the problem does not lead to a policy of trying to fulfill, one by one, the "optimality conditions" of static social

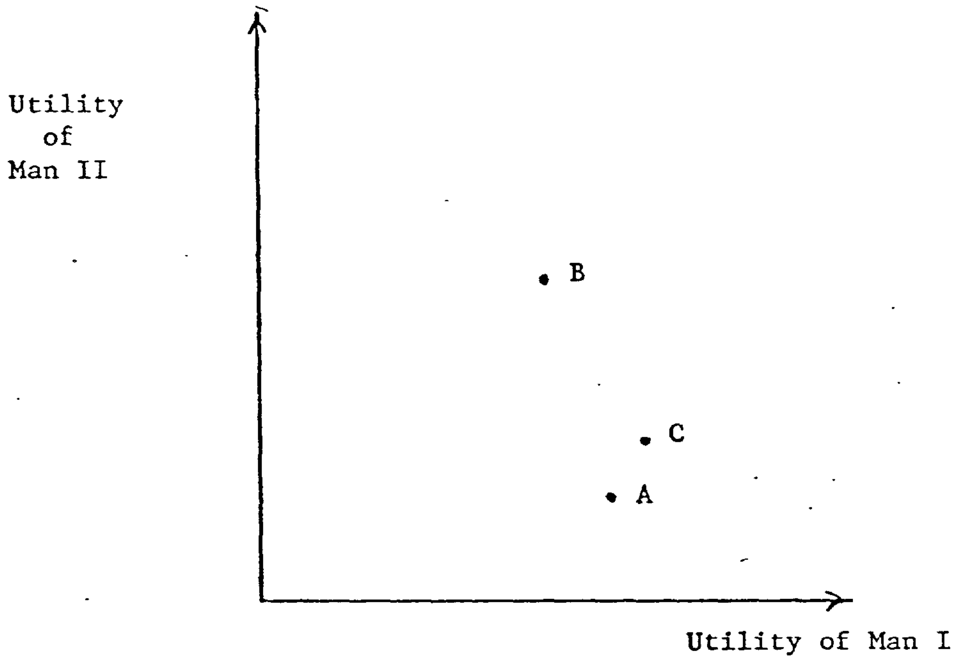


Figure I.5

welfare maximization. The reasons for this go beyond the well-known fact that in an imperfect world, such piecemeal optimization will not in general lead to desirable outcomes.[22] The conventional approach to that difficulty has been to try to define precisely the restrictions on the "second best" social opportunity set, and to derive appropriate maximizing conditions for the more-restricted situation.[23] Instead, the posture here is iterative and incremental. It involves recognizing that fuzzy regions do not have partial derivatives. In truth we face a sequential search process of great complexity. We have the most reliable knowledge about both our opportunities and preferences in those few situations we have actually observed. Only a limited number of alternatives policy can be developed and examined in light of both their short-run and long-run implications. A globally rational decision strategy will require us to use and construct appropriate simplifications, programs, and rules of thumb.

To devise such policy we need a better understanding of the substance of environmental problems. What is known about our opportunities and our preferences?

I.2 Environmental Opportunity Sets

If we consider waterways as ecosystems we realize that they are, stochastic, non-linear, nonseparable, and frequently in disequilibrium. Our information about them is imperfect and uncertain, and better data and analysis is very costly. A relevant discussion must deal with these characteristics even though the aesthetic sensibilities and training of eocnomists leads them to formalize the policy problem as a static choice under certainty with perfect information, where all resources are mobile, homogeneous, and divisible.

The limits on our information are especially important because they introduce substantial elements of subjective uncertainty into all forecasts and analyses. For example, we do not know nearly as much as we might like about many of the relevant biological and chemical processes. Exactly how will dissolved oxygen in a stream affect various species? When is water safe to drink and swim in? The scientific data on such matters are surprisingly skimpy.[24]

Similarly, very little is known about the human systems whose responses help to define the opportunity set for environmental policy. Who ultimately pays the corporation income tax? How will manufacturers respond to various pollution control regulations? How will local governments adjust taxes or services to pay for environmental programs?[25]

In particular our information about the benefits from environmental protection is really quite limited. Consider the five major categories of benefits of environmental improvement: (1) materials damage,

(2) health, (3) recreation, (4) direct aesthetic pleasure, and less usually considered what could be called (5) ideological benefits or the value of the unexperienced environment. Changes in materials damage are probably the easiest to measure, and the least important. Recreation benefits should conventionally be measured by consumer's willingness-to-pay for opportunities of various qualities. How well do consumers know that magnitude? The difficulties with such data have lead to the use of conceptually more ambiguous surrogates like the time and money devoted to recreation purposes.[26] Health benefits, from a consumer sovreignty viewpoint, should also be based on willingness-to-pay for avoiding ill health. The existing studies on the other hand employ the easier to measure magnitudes of treatment costs and expected income losses.[27] And they make no allowance for pain and suffering or attitudes toward risk and death. Aesthetics benefits are even more troublesome. What parameters of an ecosystem matter to individuals from an aesthetic point of view? Do potential beneficiaries know what determines how they feel about a clean river and can they place monetary values on these? The few existing studies suggest that citizens typically depend, as one would expect, on those parameters which are directly observable by the unaided senses: color, clarity, smell, etc.[28] Yet policy decisions are often made on the basis of quite different measurements.

The ideological benefits individuals derive from ecosystems they do not directly experience are still more difficult to measure. Many care about keeping the Colorado River wild or the Alaskan North Slope unsullied who do not come into direct contact with these environments. They enjoy simply knowing these systems are preserved. In part purity itself is valued. Also preservation gives pleasure to others who enjoy the system--which gives pleasure to the altruistic. Similarly preservation expands the options of future citizens, including one's own offspring.

The existence of such nonexperiential benefits greatly enlarges the set of individuals who must be considered when making choices about any one ecosystem. Asking those directly along a river what they are willing to pay for cleanup is not enough. In theory everyone who might care "should" be consulted. Yet does that mean everyone in the nation or everyone in the world?

Benefits (tastes) and costs (technology) are not simply difficult to discover--they also change in response to experience (and hence policy). Despite the fact that our models usually assume otherwise, in the real world, the values people place on environmental outputs depend in part on what they have experienced. What preferences then should we use as a source for policy evaluations?[29] The future technology of production and waste control also depends on the requirements we impose and the research we support in the interim. All these magnitudes and relationships are very imperfectly known, and even by investing a good deal more in forecasting offer only modest improvements in prediction can be achieved.

Ecosystems are also stochastic, that is objectively (as opposed to subjectively) uncertain. Rainfall and weather patterns vary from year to year. Some years the streams will be high, in others they will be low. Some years there will be few atmospheric inversions and others they will be more frequent. Changes in animal populations similarly are determined by uncertain reproductive processes. Even the behavior of business firms (and consumers) may well be more accurately represented by probabilistic as opposed to deterministic models.[30] In sum, we are subjectively uncertain about the shape of the objective probability distributions that generate our options.

The problem is also complicated because in the real world resources are not perfectly mobile, divisible, and homogeneous. Once a sewage treatment plant is in place, the concrete cannot be re-used for something else. Workers trained for a given job, or attached to a given area, can find it difficult, expensive, or even impossible to move occupationally or geographically. Once organizations are created and rules promulgated, patterns of self-interest become attached to the continuation of the system.

Natural systems too may be imperfectly reversible. The damage done by waste sometimes depends on the slowly decaying stock of pollution in the environment. This stock often cannot be diminished by later policy measures. Where we can modify these situations it is often possible to do so only slowly, imperfectly or at great cost. The bottom deposits in an estuary (which use up oxygen in the water) could only be removed by making very large expenditures for dredging. Some stripmined land might be reclaimed, again a costly process, and some seems quite immune from ameliorative action. More young redwood trees can be planted, but the stock of mature ones cannot be expanded in our lifetimes. And some would say that "purity," by definition, cannot be recaptured, that a restored system is never the same and always less valuable than one which has never been contaminated. On this view movements away from purity will never be fully reversible.

Such limitations on "reversibility" enhance the value of policies designed to preserve options and avoid risks.[31] If we guess wrong about the steady state population of eagles, the birds could become extinct. Unfortunately, the harm caused by a "stock" of environmental bads may not become apparent until the stock has grown (irreversibly) to dangerous levels. The biological and chemical processes that link

Many environmental systems also exhibit relevant nonlinearities and nonconvexities. Such systems often have a substantial capacity to absorb shocks of less-than-critical magnitude. How else can they survive normal variations in climatic conditions? But the ecosystem can also be pushed too far--past a threshold--which leads to large effects. For example, some decline in the dissolved oxygen in a stream due to the addition of organic wastes may have very little impact on the fish. To the fish it is just like a hot day in a dry summer. But if just a bit more waste is added, the dissolved oxygen level can then fall below a critical point, and many members of certain species will suddenly die.[32]

Such "thresholds" lead to nonlinear damage functions. Consider the certain, simple, full-knowledge case for expositional purposes. Suppose we have a number of ecosystems with the same linear damage functions (Figure I.6) (i.e., constant marginal damages). This means that the distribution of any given amount of pollution among the systems doesn't matter. Marginal damages are always the same everywhere. On the other hand, threshold effects imply some region of increasing marginal damages (Figure I.7). Here the marginal value of cleanup does depend on the final outcome. In this situation a given amount of pollution should be spread around as evenly as possible to minimize total damage. Alternatively, if additional waste loads don't matter very much beyond some point (an open sewer is an open sewer), marginal damages are decreasing (Figure I.8), and waste loads should be concentrated in one system. The Policy problems raised by such nonlinearities are considerable.

Since not all environmental systems are the same, real damage functions vary with the receiving medium, the geography, the particular waste products, the surrounding pattern of human activity, the ecology, and so on. Yet it is not unusual to find multiple thresholds with increasing marginal damages as we push past some environmental threshold, then decreasing marginal damages until we push through yet another critical area where marginal damages again increase (Figure I.9). In water pollution, for example, this might happen as we successively lose additional species and uses. Faced with such nonconvexities, a simple marginal decision criteria might not work because there might be more than one point at which marginal costs and benefits are equal. Consideration of total as well as marginal conditions is required. [33]

Of course, these diagrams are deceptive. In most relevant ecosystems a great number of parameters matter--and they interact. We cannot write down the damage function of one substance without knowing what is happening

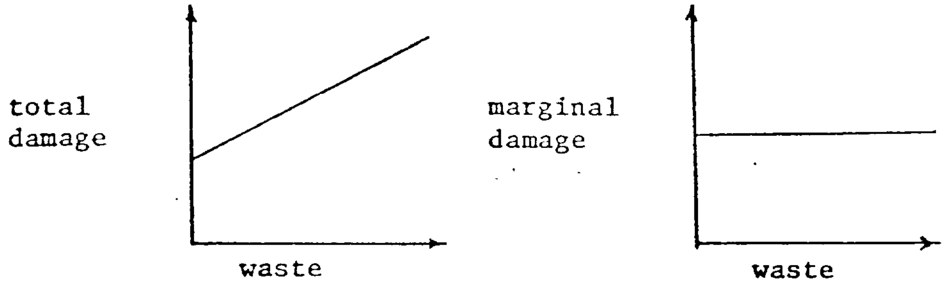


Figure I.6

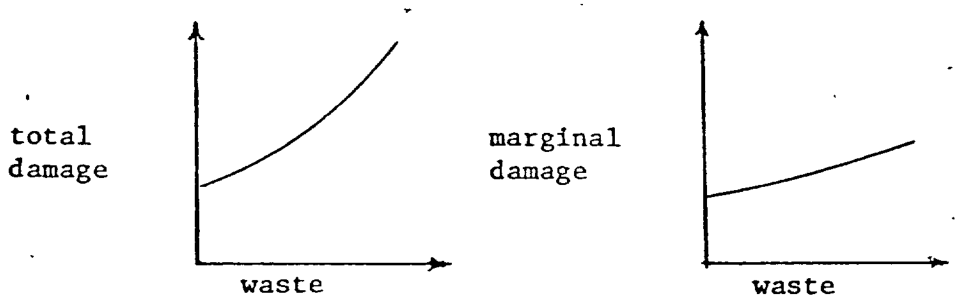


Figure I.7

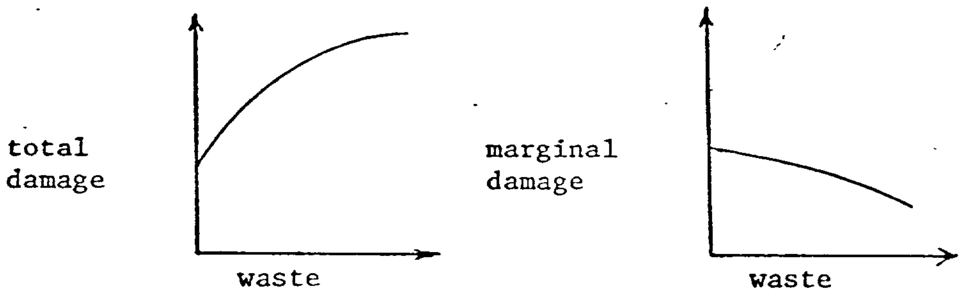


Figure I.8

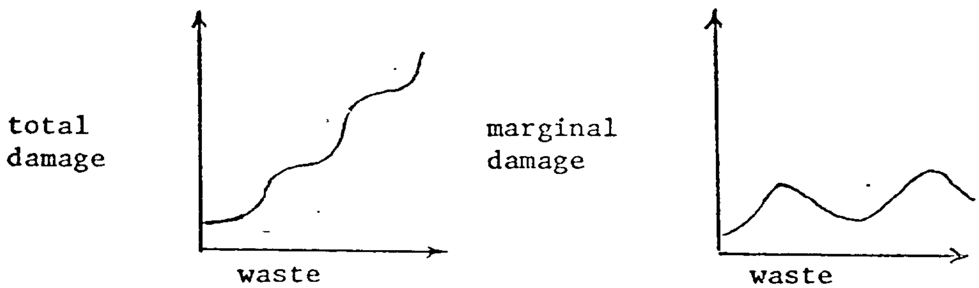


Figure I.9

to other substances. Damage functions usually are not "separable" (cross partial derivatives are not zero). Both particulate and sulphur oxide air pollution, for example, appear to make the effects of the other more severe.[34] Algae growth in lakes depends simultaneously on nutrient levels, oxygen and water clarity (here clear water creates problems!).[35] The diagrams also don't tell you that the particular shape and position of those damage functions depend in turn upon the stochastic natural processes noted earlier. For example, the effect of air pollution will depend on (uncertain) atmospheric conditions like wind directions, thermal layering, and so on. Obviously it would be desirable to have our policy measures responsive to such variations.

The available analytical techniques for dealing with such complex systems leave many fundamental issues incompletely resolved. There is surely no agreement about how we should make choices about changing our own tastes and values or about how we should "count" the satisfactions of citizens yet unborn.[36] Similarly, there is no consensus on how to place a social value on the various objective and subjective "risks" which we would then use as a basis for policy choice.[37] Many economists--to their and our peril--rather self-confidently suggest that they know how to "solve" the environmental system for "optimal" outcomes.[38] In fact, neither the data nor the theory support such an optimistic position. We face a complex system which we do not understand very well and which posses choice problems we have not yet learned to resolve very adequately.

At every step we should ask if more complex policies and an additional investment in making choices is worth the cost. Institutional flexibility, and policies which have learning potential are especially valuable. The dimensionality of the vector needed to describe our options would be a very large number indeed

Is it really surprising that we have had so little private bargaining about the environment? Benefits are complex and hard to measure. Many people are in each "game." Most are in many such games. The values each places on the outcome of any one bargaining process depends on what happens in other situations. (The value of preserving clean air in a smog-free desert today will depend on whether there are ten or zero other unspoiled areas.) Logically, many apparently distinguishable environmental bargaining games should be considered part of one (or a few) enormously complex sets of interrelated negotiations. No wonder so few "offers" have been made to pollutors.

FOOTNOTES

1. Samuelson, P.A. "Pure Theory of Public Expenditure and Taxation" in Margolis (ed). Public Economics. St. Martins Press, 1969.

2. A recent survey of externality theory is E.J. Mishan, "The Postwar Literature on Externalities: An Interpretive Essay," Journal of Economic Literature, March 1971, pp. 1-28.

3. Samuelson, P.A. The Foundations of Economic Analysis. Harvard Press, 1948, Chapter X.

4. Coase, R.H. "The Problem of Social Cost," Journal of Law and Economics, October 1960.

5. "Non-revelation" is Samuelson's term. For the other characterizations see Olsen, M. The Logic of Collective Action. Harvard Press, 1965, and Buchanan, J.M. The Demand and Supply of Public Goods. Rand-McNally 1968.

6. Arrow, K. "Social Responsibility and Economic Efficiency," Public Policy. Summer 1973, pp. 303-18.

7. Samuelson, P.A. "Diagramatic Exposition of a Theory of Public Expenditures," Review of Economics and Statistics, 1958, pp. 350-6.

8. Buchanan, op. cit., Chapter 4.

9. Roberts, M.J., "Comment.," American Economic Review. May 1971, pp. 174-77.

10. That is, even if you believe (correctly) that the dice will only come up "two" one chance in 36, that contingency will occasionally occur. On the other hand, if the process generating various outcomes is complex, the optimally imperfect decision maker will occasionally operate on the belief that a probability is say .1 when it is .15--but he believed it would have cost too much to get better data.

11. This argument raises serious problems with Liebenstein's exposition in "Allocative Efficiency vs. 'X-Efficiency'," American Economic Review, June 1966.

12. This can be rationalized, however, by claiming that the average cost of the marginal unit is the correct cost to use in an expanding industry. See Boiteux, M. "Marginal Cost Pricing," and Dessus, G., "The General Principles of Rate-Fixing in Public Utilities," both in Nelson, J.R. Marginal Cost Pricing in Practice. Prentice Hall, 1964.

13. Demsetz, H., "Some Aspects of Property Rights," and "The Exchange and Enforcement of Property Rights," in Journal of Law and Economics. October 1964 and October 1966 respectively.

14. Arrow, K.J. "The Organization of Economic Activity," Haveman and Margolis (eds). Public Expenditures and Policy Analysis. Marhkam, 1970.

15. The issue that ultimately divided the state legislators was whether public or private interests would be allowed to develop the power along the river.

16. Baumol, W. and Quandt, R. "Rules of Thumb and Optimally Imperfect Decisions" American Economic Review, May 1964.

17. Griliches, Z. "Comment" on The Rate and Direction of Inventive Activity, National Bureau of Economic Research, 1962, pp. 346-53.

18. Samuelson, P.A. "The Evaluation of Real National Income," Oxford Economic Papers, 1956, pp. 1-29.

19. Coase, op. cit.

20. Commoner, B. The Closing Circle. Alfred Knopf, 1971.

21. Mishan, E.J., "A Survey of Welfare Economics, 1939-1959," Economic Journal, 1960, pp. 197-256. See also Samuelson, "The Evaluation..." op. cit.

22. Baumol, W.J. "On Taxation and the Control of Externalities," American Economic Review. June 1972.

23. Rees, R. "Second Best Rules for Public Enterprise Pricing," Economica, August 1968; also Baumol, W.J. and Bradford, D.F., "Optimal Departures from Marginal Cost Pricing," American Economic Review, June 1970.

24. See Water Quality Criteria, Report of the National Technical Advisory Committee, Federal Water Pollution Control Administration, U.S. Dept. of Interior, 1968.

25. See the discussion in Section III below.

26. Clawson, M. and Knetch, J. Outdoor Recreation. Published for Resources for the Future by Johns Hopkins Press.

27. Lave, L. "Air Pollution Damage: Some Difficulties in Estimating the Value of Abatement," in Kneese, A.V. and Bower, B.I. Environmental Quality Analysis. Published for Resources for the Future by Johns Hopkins Press, 1972.

28. Ackerman, B. and Sawyer, J. "Uncertain Search for Environmental Policy," University of Pennsylvania Law Review, January, 1972.

29. Harsanyi, J. "The Welfare Economics of Variable Tastes," Review of Economic Studies, 1953-54, pp. 204-213. C.C. Von Weizsacker, "Notes on Endogenous Change of Tastes," Journal of Economic Theory, December, 1971, pp. 345-72.

30. Georgescu-Rogen, N. "Threshold in Choice and the Theory of Demand," Econometrica, 1958, pp. 157-68. Luce, R.D. "Semi-Orders and a Theory of Utility Discrimination," Econometrica, 1956, pp. 178-91.

31. Of course not every "insurance policy" of additional protection is necessarily worth whatever it costs. But the "risk" aspects can assume major importance, as in the debate over the S.S.T., for example.

32. Jones. Fish and River Pollution. Buttersworth.

33. Baumol, W.J. "On Taxation..." op. cit.

34. Lave, L., op. cit.

35. This is because the algae need sunlight in order to grow and clear water allows more light to be transmitted.

36. See references in footnote 29 above. By and large economists ignore this problem by assuming that preferences are determined outside of the system being analyzed.

37. Fleming, J.M. "A Cardinal Concept of Welfare," Quarterly Journal of Economics, 1952, pp. 368-84. Harsanyi, J. "Cardinal Welfare, Individualistic Ethics and Interpersonal Comparisons of Utility," Journal of Political Economy, Aug. 1955, pp. 309-21. Roberts, M.J. "Alternative Social Choice Criteria," Harvard Institute of Economic Research No. 223, 1971.

38. Freeman, A.M. III, et. al. The Economics of Environmental Policy. Wiley, 1973, Chapter 5.

I.2 Conceptualizing Environmental Outcomes

Some substantial thought has been given as part of this project to the issue of exactly how to define environmental outcomes from the distributive point of view. We also examined in some detail the problem of what measure of welfare should be used for comparative purposes (see section I of the interim report). Rather than reproduce those arguments in any detail, here we propose only to summarize them and to mention the conclusions which are important for the studies that follow.

I.2.1 Indexes of Relative Well-Offedness

There seems little question that the economists' favorite theoretical measure of relative position is of little or no value for realistic policy analysis. That measure is the subjective welfare of each individual, i.e., the level of "utility" he experiences. The difficulties with this formulation are manifold.

1) It is not psychologically sophisticated. Most of the work on understanding human mental processes for the past century has accepted the possibility of complexity, tension and internal disequilibrium (or at best dynamic equilibrium) within the personality. The utility model assumes that every man always knows exactly what he wants, never feeling ambivalent or subject to apparently irreconcilable desires.

2) It assumes an unrealistic computational capacity on the part of individuals. There is little reason to believe that most individuals can in fact "maximize their utility" when faced with moderately complicated options. Indeed there is no reason to believe that in fact it would be optimal for them even to do so. Instead they both do, and should, search sequentially for a "satisfactory" outcome according to "optimally imperfect" decision rules and strategies. These they revise only in the case

of "unsatisfactory" performance.

3) It is not obviously ethically attractive. The problem with utilitarianism is that is assumes that we are happy with giving individuals who have a taste for luxury a larger share of the society's goods and services. This may not be in fact an acceptable conclusion. The case against such attitudes is made even stronger when we consider that individuals are not fully responsible for their current preferences and that their current experiences will effect both their own later, and their offsprings preferences.

4) It is not operationally usable. This may be the most telling objection of all, from a practical point of view. Whether one views these limits as unavoidable or merely due to the poor state of neurophysiology is beside the point in the short-to-medium run. The problem is that there is no inexpensive way to take into account differences in subjective experience. Indeed if one accepted the advice of some economists -- that such interpersonal comparisons are impossible on principle -- then utilitarianism is utterly indefensible as an ethical position for policy purposes.

Given these objections, what do we use as the basis of our comparisons? Here we have followed the now traditional procedure and used income. There are many difficulties with this notion -- which can best be rationalized as an attempt to measure external, objective opportunities as opposed to internal, subjective experience. Fortunately some of them are not applicable in our sample, but some of them are.

First, one would want to correct for inter-regional variations in both the price level and in the physical goods needed to provide similar standards of living (one does not need as much for heating, cooling and clothing in San Francisco or Raleigh as one does in Chicago or Boston.) Within one metropolitan area of course such problems do not arise. It is possible that such minor corrections might have been made in our Boston-Seattle comparisons, but these seem likely to be of small magnitude given the other inaccuracies in the data.

Second, one should perhaps make some allowance for the differential availability of public services in different communities, as well as for differences in family size. We have not done this for practical reasons. In addition there are arguments which suggest that such corrections are not always warranted. To an extent individuals choose both their location and their family size. They then pay for public services and the costs of childrearing through higher taxes and expenditures. One thus can argue that these are just differences in tastes for the consumption of different types of goods, and not an aspect of external opportunities.

Third, one might want to correct for differences in other aspects of life, notably the effort or satisfaction derived from work and the nature of general environmental conditions. Again we have not made such corrections -- although the implications of doing so for our sample are clear. Since upper-income individuals live in nicer areas and in general have more interesting jobs, the distribution of well-being is more unequal than the numbers we use suggest.

In summary then we are driven back to using good old family income as our index of relative position. Do note that in doing so we have shifted the relevant basis of our analysis from the individual to the family. Indeed, although we did ask only one member of the family for his opinions in the recreation survey,since family members were often-grouped together, we not infrequently got joint or multi-individual responses.

I-2.2. Measuring Benefits

As noted previously (Section I.1) the traditional economists' measure of benefits has been "willingness-to-pay." Indeed we have used that measure ourselves in the telephone survey. We do not wish to give the impression that such data can be relied upon for any hard quantitative estimates however. People probably do not spend the time and attention required to produce an informed estimate of their own actual willingness-to-pay. Instead such numbers should be viewed only as indicative of attitudes and preferences.

There is a problem with willingness-to-pay data however. Clearly since higher income people have more money, even with identical "tastes" they may well be willing to pay significantly more than lower income individuals. Indeed, since individuals tend to have spending priorities, upper income individuals could well be willing to spend not only <u>more</u> money, but also a higher <u>proportion</u> of their income on such luxuries as the environment, once necessities like food and shelter have been provided for. We found some evidence for such patterns of expressed preferences as Section II.3 below reveals. In such cases it is necessary to try to "weight" the different 'willingnesses" of different income groups differently. Unfortunately there is no obvious or "objective" way to do this.

An alternative is to try to look at actual use and accessibility patterns. We have undertaken a bit of analysis along these lines in Section II.4. That is, we have not attempted to determine what different income groups would be willing to pay for water-based recreation. Instead we have concentrated on trying to see which groups tended to use which sites.

Asking willingness-to-pay questions about the use of particular sites is very difficult. After all, the respondent can just use another area. Thus his "willingness-to-pay" is for this site in a context of available alternatives. However, if a given facility were to be closed, other areas may in fact turn out to be more crowded than those answering the question foresaw. This could lead to mistaken estimates of their differential valuation of the area in question.

Similarly, we have not tried to estimate willingness-to-pay on the basis of distance traveled. This is because we cannot assume in areas like the ones studied that the person's option is to stay home. Thus we would need to know his incremental travel time or distance compared to what the alternative sites would require of him. This is a very difficult data gathering problem, one that could not be resolved within the context of this modest survey,

I.2.3 A Definitional Point

In what follows, where we use distance, we mean *straight line* distance and not road distance. We conputed this measure by locating those interviewed on a map and measuring the distance to the site in question.

II. Water Quality Benefits in the Boston Metropolitan Area

Given the definition of the problem, and the conceptual tools discussed in the previous chapter, we can now turn more directly to the problem of the distribution of benefits. In order to present the results we need some preliminary background. This is presented in sections II.1 and II.2 where current quality levels and the existing institutional arrangements for providing water quality in Boston are examined. To get to the heart of the matter, in sections II.3 and II.4 we present the results of both a telephone survey and a survey of recreation users. These are intended to tell us something about water quality benefits in the Boston area. In section II.5 we discuss some possible innovative methodologies that might be used for water quality benefit assessment and the virtues and difficulties of these techniques, as derived from our exploratory studies. This chapter closes with a summary and a review of conclusions in section II.6.

II.1 Water Quality Management in Boston

The municipal water supply and sewage collection systems of Boston and other inner cities of the metropolitan areas are among the oldest in the nation. In the last two decades of the nineteenth century they were reorganized and enlarged and they ranked among the most sophisticated systems of the time. To a large extent they are still in use today. Between 1889 and 1895, a parks agency and wholesale water supply and sewage collection agencies were established to serve the larger metropolitan area. Soon after they were combined into the Metropolitan District Commission, a multi-purpose metropolitan water resources management agency. This agency is the key to water quality management in the area.

II.1.1. The Cast of Characters

The M.D.C. is a creature of the State Government.[1] A full commissioner and four part-time Associate Commissioners are all appointed by the Governor. There are separate divisions for Water, Sewer, Parks, and Construction. The first three are wholesale suppliers to distinct sets of communities. The service areas do not fully coincide. Each town pays and initial entrance fee and an annual assessment. These fees and all bond issues, budgets and so on, are controlled in varying degrees by the State Legislature. Altogether, 53 communities in the metropolitan area are members of the M.D.C. for one or another function. The Construction Division, in contrast, supplies construction and, to some extent, planning services for the other divisions of the M.D.C.

The M.D.C.'s sewer activities are undertaken through the metropolitan sewer district. In fact, two separate districts were set up in 1889, when the district was created.[2] The communities north of the Charles River and the Mystic River Valley were formed into a North Metropolitan Sewerage District, with trunk interceptors discharging untreated sewage into Boston Outer Harbor at the south tip of Deer Island. Communities on the south bank of the Charles and on the north bank in the lower Charles Valley were formed into a South Metropolitan Sewerage District; its interceptors were connected with the city of Boston's Main Drainage System (BMDS), which had been constructed between 1876 and 1885 and which discharged untreated sewage into the Outer Harbor off Moon Island. The North and the South Districts were combined into a single Metropolitan Sewerage District in 1959; but since 1889 they had been jointly managed by the Sewerage Division of the M.D.C.

Originally, there were 13 members in the North District and 4 members in the South District; in addition, the city of Boston was a member of both districts. Currently, there are 42 member communities. The original membership was confined to communities in the watershed of the Charles River and the Mystic-Chelsea Rivers. As it grew, the Sewerage District spread not only to the Neponset watershed, but also to the Ipswich and Merrimack watersheds in the north and the Suasco watershed in the west. The reasons for this pattern of expansion seem to have been political rather than technical.

In 1945 the M.D.C. started planning fundamental changes in the structure of its sewerage system, which had been preserved intact for almost 60 years.

In the South District a primary treatment plant was constructed at Nut Island, on the east side of Quincy Bay, away from the beaches of South Boston. A major interceptor was installed to divert to it the sewage of all member communities, except Boston. The plant came into operation in 1952; the Boston Main Drainage System continued, nevertheless, to discharge raw sewage off Moon Island. In the North District, it was planned to build a primary treatment plant at Deer Island; this project, first conceived in 1945, was completed in 1968, many years behind schedule and at three times the planned cost. Also in 1968, the BMDS was partially connected with trunk interceptors leading to Deer Island.[3]

The Main recreation agency of the M.D.C.'s the Metropolitan Parks District. Established in 1893, it inherited over 10,000 acres of municipal parkland and open space in the watersheds of the Mystic River, the Charles River, and the Neponset River. It has not substantially enlarged its land holdings since then, but it has branched into new activities--it now operates gold courses, skating rinks, and swimming pools throughout the metropolitan area. In addition, it owns 10 beaches in the harbor, including most of the important beaches in Boston, and several islands.

By virtue of its land holdings, the District has become a major highway authority in the area: some of the highways crossing its land, for example, the highways along the banks of the Charles River, have become major traffic arteries leading into the city of Boston. Along with these highways, the District has also acquired a highway police force.

Beyond the M.D.C. the most relevant branch of the state government is the <u>Department of Natural Resources</u> (DNR). This has several divisions, of which the most important, notably the <u>Division of Water Pollution Control</u> (WPC), and the <u>Division of Water Resources</u> (WR).

If the proposed reorganization of the state government is carried out, all existing state agencies will be regrouped into nine functional areas under a cabinet system. One of these, an Office of Environmental Affairs, is supposed to incorporate both the DNR and the M.D.C. The details of this reorganization, however, have not yet been worked out. At present the M.D.C. is not subordinate to the divisions of the DNR, although it cooperates with them. Instead, it reports directly to the State Legislature.

Two other agencies are relevant. <u>The Metropolitan Area Planning Council</u> (MAPC) was established in 1964, and now has a membership of 99 cities and towns in the metropolitan area. Its membership includes, but is somewhat larger than, the memebership of the M.D.C.[4] The MAPC is empowered by the Demonstration Cities Acto of 1960 to review all projects to funded by federal money in member communities to determine compatibility with the overall regional plan. It is financed partly by annual grants from the federal Department of Housing and Urban Development.

There is also <u>The New England River Basins Commission</u> (NERBC). established in 1967 under the provisions of the Water Resources Planning Act of 1965.[5] The Commission's area of jurisdiction is the six New England states plus the Housatonic River Basin in New York. Its job is to coordinate water resource and related land use planning in the region of its jurisdiction. It is financed by annual payments from the seven member states and by a matching grant from the Water Resources Council.

II-1.2 Systems Development

As noted above the sewer service area has spread beyond the natural drainage area of the harbor along the South Shore, in the north and the west. Various explanations account for these moves. For example, the communities in the west were allowed to join because they lost their customary disposal basin with the development of Quabbin reservoir by the M.D.C. Such choices however have had an unfavorable effect on the sewerage system: wastes travelling from thirty miles inland to Deer Island do turn septic inside the pipes.

Until recently there was little demand from non-member communities to join the Sewerage District. This changed when the State Division of Water Pollution Control (WPC) began to enforce water quality standards in the metropolitan area. In the last two years 10 or 11 communities on the fringes of the District, which were under pressure from the WPC because they had inadequate treatment facilities or no public sewerage at all, have sought to join. The M.D.C. is discouraging these applications, for several reasons. One reason is that these would involve the transfer of more water out of local river basins which suffer from low-flow problems even now. Also most of the applicants are some distance from the Sewer Divisions trunk interceptors and the Division is fearful of everextending and overloading its system.

Indeed parts of the system will soon be reaching full capacity. The flow of sewage from members of the district has risen steadily. At Nut Island there is little that can be done, except to enlarge the plant. At

Deer Island the sewage contains a substantial amount of salt water -- perhaps 80 mgd--which enters through leaking tide gates in the city of Boston's sewage system. If these gates are repaired, the capacity of Deer Island should be adequate well into the 1980's.[6]

It is also doubtful whether any substantial new sewerage districts will be established in the metropolitan area. A recent study of the small rural communities in the Upper Charles Valley found that large regional schemes would be uneconomical. The communities were so scattered that the costs of trunk interceptors were high and the waste load would be too small to achieve significant economics of scale in treatment.[7]

The Sewer Division is financed by an annual assessment on members of the district set so as to cover the total cost of operations and maintenance and debt service.[8] The attention of maintenance operating costs is based on the population in each community. The cost of debt service is divided according to the capacity of each member's connections with the district's trunk interceptors as a proportion of the aggregate capacity of <u>all</u> connections. It works out that members pay, for example, $1,500 for a six-inch connection.

Of the local sewer systems, that of the city of Boston is most relevant. Quite simply, the system is old and works badly in parts because it has been neglected. The city's maintenance and renovation programs are not really adequate.

Furthermore, system planning is poor. For the last 50 years there has been a policy of sewer separation in new construction. Currently, of the 20,500 acres of sewered land in the city only 7,000 acres are served by combined sewers. However, because appropriate interceptors have not been constructed much of the land with separate sewers drain into the combined sewer system.[9] The main obstacles to a better system are lack of money, lack of manpower, and lack of coherent strategy.

FOOTNOTES

1. Boston Harbor Islands Commission, The Boston Lower Harbor, M.I.T. Harbor Summer Study Group, 1968.
   Boston Redevelopment Authority. Progress Report. 1968-1969.

2. Massachusetts Department of Natural Resources, Richard I. Furbush, Office of the Secretary. Origin, Development and Activities of the Metropolitan District Commission. November 1964.

3. Camp, Dresser & McKee, Inventory of Water and Sewer Facilities, Eastern Massachusetts Regional Planning Project, for the Metropolitan Area Planning Council, Department of Commerce and Development, May 1967.

4. Massachusetts League of Women Voters. Massachusetts State Government. Harvard University Press, Second Edition. 1970.

5. New England River Basins Commission. Water, Land and Change. Annual Report for Fiscal Year 1968.
   New England River Basins Commission. Water, Land and Change. Annual Report for Fiscal Year 1969.
   New England River Basins Commission. Technical Report No. 1, Safety Control of Private Dams. January 1969.

6. Camp, Dresser & McKee. Projected Needs and Current Proposals for Water and Sewer Facilities for MAPC. July 1969.

7. Metropolitan District Commission. Report of Director of Sewerage Division and Chief Sewerage Engineer for the Fiscal Year Ending June 30, 1969.

8. Charles A. Maguire & Associates. Boston Water Distribution System with Recommendations for Improvement. September 1967.
   Metropolitan District Commission, Sewerage Division. Annual Report for the Fiscal Year Ending June 30, 1968.

9. Volumes I and II (Camp, Dresser & McKee). Report on Improvements to the Boston Main Drainage System. September, 1967.

II.2. Water Quality in Boston

Figure 2.1 shows the major rivers within the metropolitan area, as defined by the Metropolitan Area Planning Council. In 1970 that included 100 cities and towns with a population of 3 million and an area of 1400 square miles.[1] As is clear, there are three major watersheds from north to south: The Mystic, The Charles and the Neponset. All of these in turn empty into Boston Harbor. Each of these four areas is reviewed separately below.

II.2.1. The Mystic River

Massachusetts' Water Resources Commission has classified the greater part of the Mystic River Basin as B (that is, to be improved to swimmable quality). (See Figure 2.2) All reaches of the river upstream of and including the Lower Mystic Lake--the Aberjona River, Horn Pond, Upper Mustic Lake, and the major tributaries of Sweetwater Brook and Mill Brook--have been so classified. Further downstream, Alewife Brook, the Malden River, and the main stem of the Mystic River have been deemed C (suitable for noncontact water recreation), while the tidal estuary is classified SC (see map).

With the exception of Mill Brook, most of the upstream reaches of the river are within striking distance of the coliform standard that both meets the Class B standard and would allow swimming under the state sanitary code (less than 1000 per 100 ml.). Some, in fact, are presently used for swimming--Horn Pond, Leonard Pool, and Sandy Beach on the Upper Mystic Lake. Other ambient parameters are less encouraging Ammonia-nitrogen and phosphate levels are clearly above required levels (although some would attribute the failure to meet the phosphates requirements to unattainable high standards). BOD_5, dissolved oxygen, and pH are unacceptable in particular reaches of the river, with many of the problems confined to small stretches.

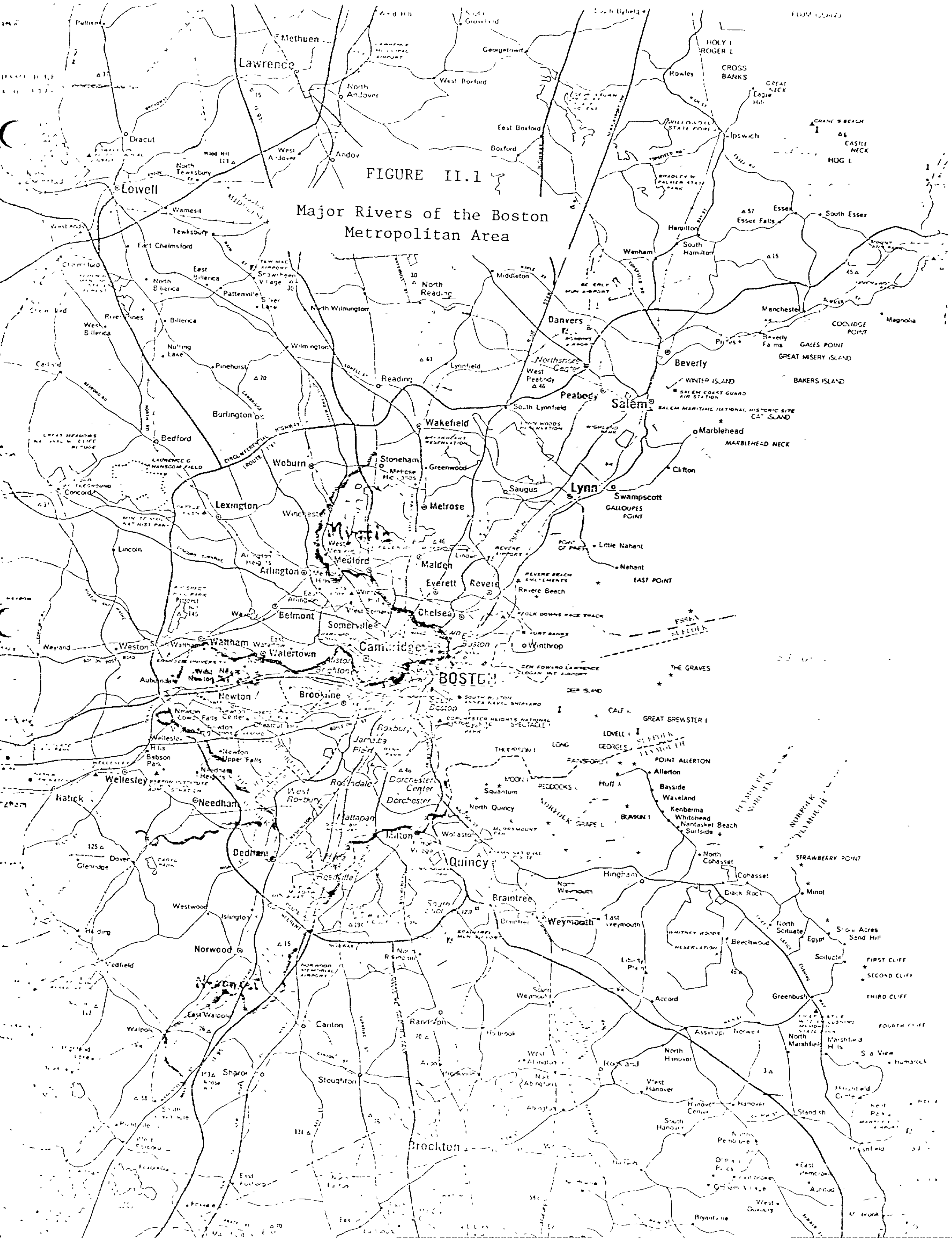
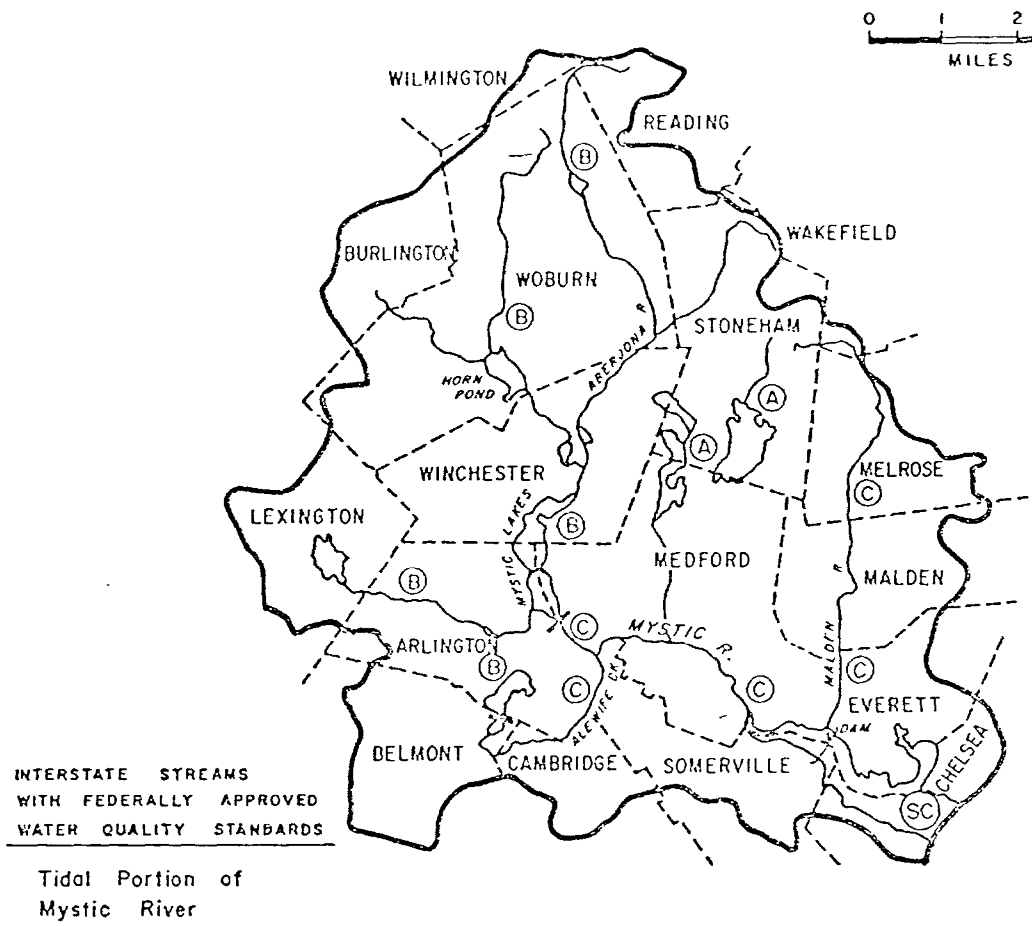


FIGURE II.1

Major Rivers of the Boston Metropolitan Area



WATER QUALITY STANDARDS
ADOPTED BY
COMMONWEALTH OF MASSACHUSETTS
WATER RESOURCES COMMISSION

MYSTIC RIVER BASIN

CLASSIFICATION

WATER QUALITY STANDARDS - A B C D SC

Figure II.2. The Mystic River Basin

Downstream, in the Mystic River proper, the problem is primarily that of excessive coliform, with the inflow from Alewife Brook as the worst offender. Heavy storm runoff only compounds the problem.[2] In the Aberjona River domestic sewage is a relatively minor problem. All the communities adjoining the river are tied into the MDC sewer system (see section II.1) with a high percentage of homes served by separated sewers. However, the town of Stoneham is operating an antiquated sewer system, installed in the early 1900's, which occasionally results in combined sewer overflows into the river. The Division of Water Pollution Control estimates that 60 manholes are in need of replacement; each to cost $10,000. This replacement program is only in the planning stage. Once completed it should eliminate Stoneham's combined sewer overflows into Sweetwater Brook. Those homes adjoining the Mystic Lakes which are an occasional problem have septic tanks with overflow pipes connected directly into the river. However, the coliform they generate apparently is minimal.

The major industrial polluters of the Aberjona are supposed to be cleaning up to state standards on the basis of agreed upon implementation schedules. At the moment, however, they remain a source of pollution. Leaching from the holding lagoons of National Polychemical Corporation (Wilmington), according to studies conducted by the Mystic River Watershed Association, Inc., is largely responsible for the high ammonia-nitrogen concentrations upstream.[3] MRWA also points to the Woburn dump and the firms in the Woburn industrial park as point-source polluters. Drainage ditches also continue to carry polluted water long after implementation plans have been completed. In addition, contaminated water continues to leach into the river from the soil, long after the offenders have ceased operations (the now defunct piggeries are an excellent example). Thus, chemical and other industrial pollution will remain serious problems for the Aberjona.

These problems are compounded by the Aberjona's low flow, especially noticeable during the late summer and early fall.[4] According to Dr. Bruce Haines, chairman of the Aberjona River Watershed Committee, this is the river's most serious problem. The naturally low flow is exacerbated by two factors: the draw-down effects of wells near the river and the vast accumulations of trash and debris which line the Aberjona and its tributaries. As Table 2.1 shows, over 11 million gallons are daily removed from the groundwater by local wells. Only the water drawn out by Parkview Apartments is returned to the river.

Low flow augmentation proposals have come from several sources. Reservoirs do not seem feasible given the high cost of the relevant land. Another proposal, to use wells as a source of augmentation, is more promising, although no action has yet been taken (part of the problem being that federal and state grants are not available for the construction of such facilities).[5]

Phosphates remain a problem. In part, their high levels may be attributed to storm runoff (e.g., fertilizer used on lawns, on cemetaries and on the Woburn golf course). Intensive use of phosphate-containing detergents may also be a contributing factor. However, the high levels may be natural, caused by runoff through marshes and swamps (wetlands) which predominate along the upper Aberjona.

Table 2.1

Well Operators in the Mystic River Basin

Operator	Location	Av. Daily Use (MGD)
Along Aberjona River		
General Foods, Inc.	Montvale Avenue, Woburn	4.41
Parkview Apartments	Swanton Street, Winchester	1.20 *
City of Woburn	Salem Street, Woburn	1.00 *
Swift Chemical Company	Cross Street, Winchester	0.36
J. J. Riley Leather Company	Salem Street, Woburn	0.30 *
City of Woburn	Horn Pond, Woburn	4.30 *
	Total	11.57

Note: Other wells were present but were determined to be of insignificant capacity and/or too far removed from the areas in question.

*These well data were taken from the 1967 study by Camp, Dresser & Mckee, Aberjona River Watershed Committee Report.

The lower part of the basin comprises Alewife Brook, the Malden River, and the Mystic River. These flow through very heavily urbanized areas, unlike the suburbs of the Aberjona and its tributaries. However, point source industrial pollution is relatively insignificant. As a result of intensive enforcement processes, literally dozens of firms have been placed on implementation schedules, most of which have already been met.

Domestic sewage is the problem of major proportions in this part of the basin, even though all adjacent communities belong to the MDC system. While Melrose, Malden, and Everett have separated sewers and apparently no overflows directly into the streams, the remaining communities do have combined sewer problems. Alewife Brook suffers from enormously high coliform counts, attributable to two overflows from Somerville and several from Cambridge. Cambridge is in the process of completing a five-year, $15 million program to separate its sewers; when completed, its overflows should be eliminated. Somerville has engaged Camp, Dresser, and McKee to undertake a comprehensive water and sewer study; ultimately, proposals will be forthcoming for controlling the sewer overflows (including two additional overflows into the Mystic River). The Somerville Pretreatment Facility and Marginal Conduit (capital cost of $1,662,000) should soon be operational; it will deal wihh the overflow near Wellington Bridge. Both screening and chlorination will take place there, with the solids to be pumped into the MDC sewers and the remaining chlorinated effluent to flow out <u>below</u> the Amelia Earhardt Dam.

Despite these problems there is an alewife population which annually run up the river as far upstream as the Mystic lakes. According to the Fisheries and Game Division of the Massachusetts Department of Natural Resources, cleaning up the Mystic River will have little or no impact on these fish. Because of limited access to spawning grounds water pollution control would, however, have a significant impact on other fish populations. The state discontinued stocking the Upper Mystic Lake with trout three years ago because of pollution problems. Recent studies show that dissolved oxygen levels remain too low to support the fish. In addition, heavy metals (primarily zinc) plague the lake. Resolution of these problems would allow the Division to reinstitute its stocking program.

II.2.2. The Charles River

As of the last major survey, in 1967, while the upper reaches of the Charles River meet their ambient quality goals under the state's water pollution control plan, the lower reaches generally do not.[6] (See Table 2.2 and Figure 2.3) The results of a new sampling program just being completed are not yet available. Some additional evidence is available from a private consulting group which has been undertaking studies in the Charles River Basin. Their results suggest distinct stratification and a lack of the expected thermal mining.[7]

The water quality problems of the Upper Charles are due to both municipal and industrial sewers. Some of the low density, residential communities do not have municipal sewer systems--notably Holliston, Bellingham, Dover, Norfolk and Sherborn. however, the waste loads in these areas seems low enough to make this situation acceptable.

TABLE 2.2

Charles River Watershed Classification

Boundary	River Miles	Present Use	Anticipated Future Use	Present Condition	Classification
The Charles River from its source to Dilla Street, Milford	80.1-76.5	Water Supply	Water supply	A	A
The Charles River from Dilla Street, Milford to Main Street, Milford	76.5-75.2	Bathing Fish & wildlife propagation	Same	B	B
The Charles River from Main Street, Milford to Bridge Street, Dover	75.2-44.7	Recreational boating Fish & wildlife propagation Fishing Assimilation	Same	D & C	C
The Charles River from Bridge Street, Dover to Watertown Dam, Watertown	44.7-9.8	Recreational boating Fish & wildlife propagation Fishing Assimilation	Same and bathing	D & C	B
The Charles River from Watertown Dam, Watertown to the Charles River Basin Dam in Boston	9.8-1.2	Recreational boating Fish & wildlife propagation Fishing Assimilation	Same	D & C	C
Farm Pond, Sherborn	---	Recreation	Recreation	B	B
All other streams in the Charles River Watershed unless denoted above	---	---	---	-	B

Commonwealth of Massachusetts, Division of Water Pollution Control

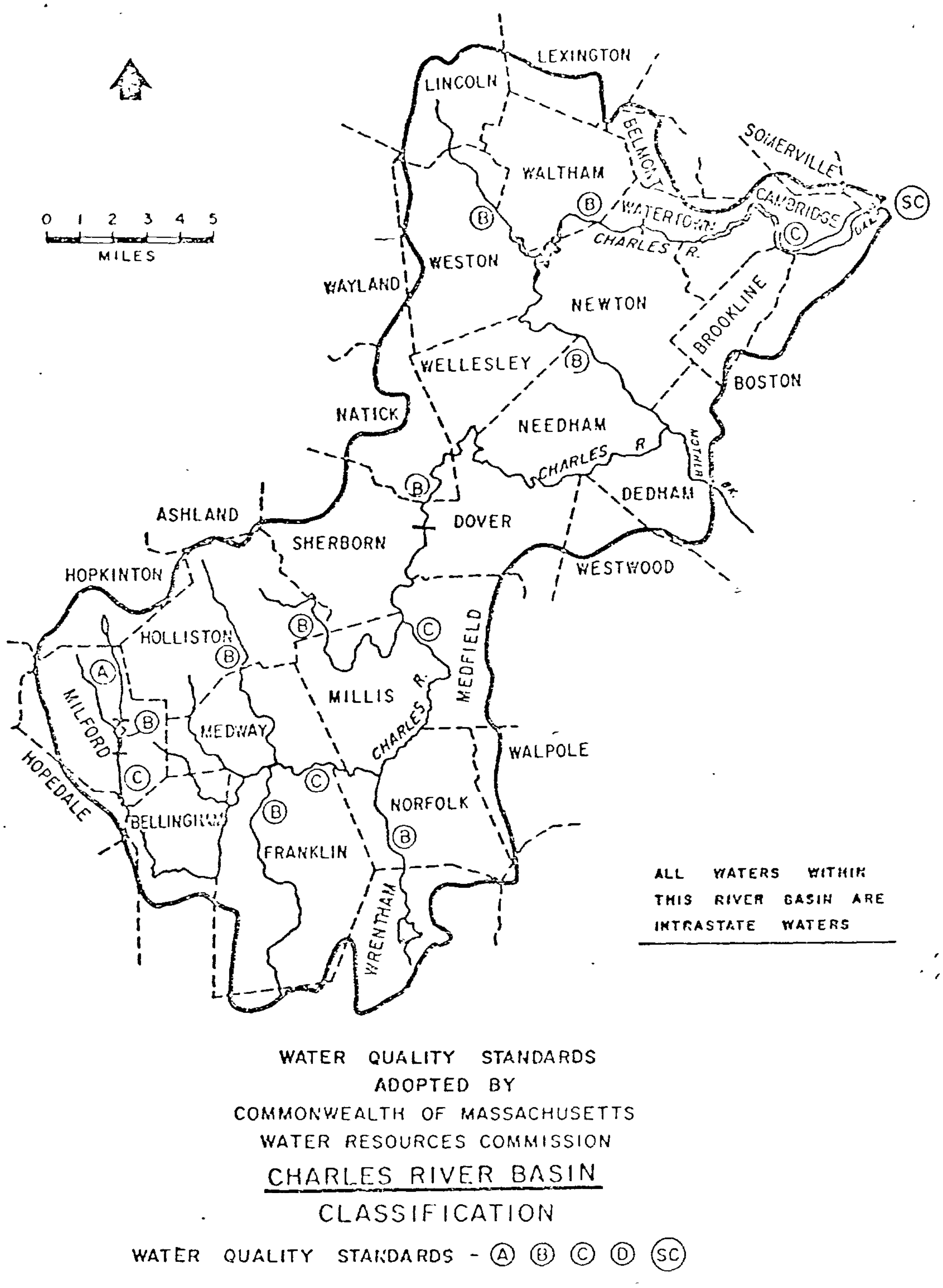


Figure II.3. The Charles River Basin

Of the larger towns along the river, Milford has secondary treatment facilities but has so far failed to comply with a court order to install effluent polishing, phosphorous and nitrogen removal processes. The treatment plant was last expanded in 1959 at a cost of about $300,000. In addition there is a combined sewer problem and the disposal of the treatment plant sludge does not meet state requirements. Two other communities Medway and Franklin, are considering a $19 million joint regional system based on the existing Franklin plant, which does provide secondary treatment. Medway now relies on septic tanks. A fourth community, Medfield, also has a secondary treatment plant and is in the final planning stages for a new tertiary treatment facility aimed at phosphorous removal and effluent polishing. This will be constructed in part with federal funds at a cost of $5 million.

A few years ago there were 12 major industrial sources along this reach of the river. Three of these, all in textiles, and one rubber company, have since closed. Of these three large food processers Cliquot Club is being required to connect to a municipal system and Garelick Brothers is still in the process of negotiating a compliance schedule with the state. Parker Products, meanwhile, has complied with a requirement for subsurface disposal. Of the remaining firms, three manufacturing companies are in various stages of compliance, some after court orders, while a laundry has been ordered to connect up to a municipal system.

Along the Middle Charles, all the communities (with the exception of Weston, whose pollution load is comparatively small) discharge into the Metropolitan Sewerage System. Aside from the high <u>natural</u>

phosphate levels, the problem appears to result in part from storm runoffs from the separated municipal sewer systems.

The major industrial problem along this segment of the river arises from petroleum distributors. Of six such companies subject to enforcement actions, one has completed a project and another has gone out of business. The response of four others are still in the planning stage. One of these was moved to action by the initiation of criminal charges and another was encouraged by a court order. Three other sources, two metal platers and a pottery, have complied with enforcement requirements.

The stretch of the river from the Watertown Dam to the mouth is often called the Basin, or the Lower Charles. Combined sewers are the root of the quality problems in this area.[8] Only a handful of industrial firms discharge into the river in this section; the Massachusetts Division of Water Pollution Control projects the completion of the requisite in-plant treatment facilities by September, 1973. An elaborate construction program, as well as a number of feasibility studies, are now underway to deal with the remaining problems of the combined sewers.

As of May, 1971, the Cottage Farm Stormwater Detention Facility was put into operation (located at the B.U. bridge). Since that date it has been operated 84 times. The facility screens (1/2" screens) and chlorinates combined sewer water overflows. It has been designed to accomodate overflows whose size will be exceeded once every 5 years. Average retention time has been 20-30 minutes. According to an ongoing report by the MDC, not yet published, the station has had a marked impact on water quality, substantially curtailing suspended solids while reducing the coliform count to almost zero. BOD, however, as one would expect, remains essentially unchanged.

In order to catch the combined sewer overflows and transport them to the Cottage Farm facility, two relief sewers are employed. The South Charles Relief Sewer, already completed, catches 13 overflows, while the North Charles Relief Sewer, still under construction (to be completed within the next 5 years), will catch 15 overflows.

In addition to these MDC projects, the city of Cambridge, pursuing the suggestions of McGuire Associates, Inc.[9] is proceeding with a 5-year program of sewer separation costing $15 million. The projected reduction of storm sewer overflows is from 50-75%.

Earlier reports pointed out the failings of the Boston Marginal Conduit.[10] Virtually level, with inefficient tide gates, the Conduit discharged into the Charles even in dry weather (when the tide came in). The Conduit also discharged into the Charles during heavy storms. Several steps are now underway. A program to repair the tide gates is being pursued. In addition, McGuire Associates is pursuing a design program for a new Charles River Estuary Detention, Chlorination, and Pumping Facility to handle the overflows of the Marginal Conduit. Contract plans and specifications for this facility are due by April, 1974; anticipated construction time is 3-4 years. Because of the severe problem with tides, flow will enter the station by gravity and will be pumped out against the tide.[11]

The Back Bay Fens, which ultimately discharges into the Charles River at Charlesgate, received flow from the Muddy River (untreated) as well as a certain amount of combined sewer overflow. McGuire Associates is in the process of preparing a research and demonstration study for Massachusetts Division of Water Pollution Control on eliminating this source of pollution of the Charles. Recommendations include a dredging of sludge from the Fens and modifications of operations of the sewer systems along the Fens.

The Warren Avenue Dam, initially proposed by the U.S. Army Corps of Engineers in a 1968 report,[12] is now in its design phase. Its impact on the ambient levels of the Charles will be marginal; it serves merely to prevent saltwater infiltration.

Two other projects, which may affect the water quality of the Charles, are in early phases. Tonics, Inc. is investigating the possibility of using the Cottage Farm Stormwater Detention facility on a full-time basis, rather than intermittently, running Charles River water through the plant in order to kill coliform and to decolorize the water. At present, results have been disappointing: color strength has been reduced by 1/3 (from 125 color units to 85) instead of the desired 2/3 (down to 40 color units). Other alternatives include combining the Cottage Farm chlorination with sand filtration, further reducing suspended solids and improving color. This study should be completed within the next few months.

In November, 1969, Process Research, Inc. submitted a four-phase program for reclamation of the Charles River based in part on in-stream treatment.[13] They are planning a pilot version of their facility, to be located in the Storrow Lagoon. By removing color, suspended solids, phosphorous, and nitrogen and cutting down on bacteria, this plant should make Storrow Lagoon swimmable at , a cost of $250,000.

The full program would involve construction of a large scale in-stream treatment facility, channel dredging at Longfellow Bridge (to remove polluted bottom waters from the Basin), modification of the present Charles River Dam, and intensive management of the Boston sewer system to prevent buildups which would lead to contaminated stormwater overflows. Estimated cost of the entire system is $3,480,000 (in 1969 dollars), with operating costs of $450,000 annually (1969 dollars). The aim of the proposed system would be to improve the water quality in the Basin to the swimmable level.

While the benefits of cleaning the Charles up to swimming levels are apparent enough, it is less clear what tangible benefits are to be realized from cleaning up the Charles from class D to class C water quality. The major observable change would be in the occasion of odor problems. In addition, now parts of the Basin are totally incapable of supporting fish life. With a move to class C and a concerted effort by the Department of Natural Resources to stock the river, the Charles could become a significant sport fishery.

To be swimmable, the river would have to meet the state health code test for swimmable water use. The coliform count criteria is only indicative. The department will close a beach under such conditions if there is a direct discharge of waste anywhere upstream. The rules also require that the Secci Disc be visible from the surface at a water depth of four feet.[14] This is said to be an aid to lifeguards. However, in our view it would seem a dubious restriction. It does not seem one that is strictly enforced at sites around the state.

Furthermore, there is reason to be uncertain if class B could ever be attained in the Charles River because of the high natural phosphate counts which bring up the color. These are due to the swampy wetland origin of the stream. The U.S. Public Health Service recommends that in swimmable waters the color should not exceed 15 standard units. Parts of the Basin have color over 120 standard units.[15] The best efforts to date have not succeeded in reducing color to anywhere near the requisite levels.

In some ways, the problems of the Charles are separable. In terms of bacteria and, to a lesser degree, dissolved oxygen, the point source polluters of the Upper Charles can be handled apart from the combined sewer runoffs of the Basin. Problems are localized by reach; there is little or no long distance transmission of coliform. Nutrients, however, are carried for considerable distances.

The projected completion of a number of treatment facilities on the Upper Charles within the next three years should produce some discernible improvement in water quality, especially with respect to dissolved oxygen, nutrients, and bacteria. Hopefully, this will bring parts of the Middle Charles up to class B, making it swimmable. However, stormwater runoff may raise the bacteria count above the tolerable level. Treatment of stormwater runoff is given lowest priority by the MDC, probably because of the enormous costs such a project would entail.

With completion of the North Charles Relief Sewer and Cambridge's sewer separation project, most sections of the Basin will suffer from overflows only occasionally. Hopefully, the new pumping station willameliorate the problems of the Boston Marginal Conduit. The additional problem area in the Basin, the Back Bay Fens, will cause difficulties of uncertain magnitude, depending on what corrective measures are undertaken.

II.2.3. The Neponset River

Of the three major rivers in the Boston metropolitan area, the Neponset appears to be closest to meeting, if not surpassing, the water quality standards adopted by the Division of Water Pollution Control. Upstream, the river and its tributaries have been classified as "B." The main stem of the river--that reach extending from Norwood to Milton--has been tagged with a "C" rating (see Figure 2.4). The "C" classification, which in light of present water quality is quite lenient, may well have reflected the industrial pollution of the river at the time of classification. In-plant-treatment was thought insufficient to attain swimmable quality. However, the recent diversion of industrial wastes into town sewers and ultimately into MDC trunk lines has virtually eliminated this source of pollution, making "B" levels of water quality quite possible. Further downstream the tidal portion of the Neponset has been classified "SB''--the saltwater equivalent of the "B" classification (see Figure 2.4).

There is a notable shortage of data on Neponset River water quality. Sampling programs have been intermittent at best. The Division of Water Quality is currently conducting a full survey and detailed results should be available shortly. According to the officials responsible for the sampling program, the Neponset is far cleaner than it was 10 years ago.[16] Phosphates, nitrates, and coliforms all show marked

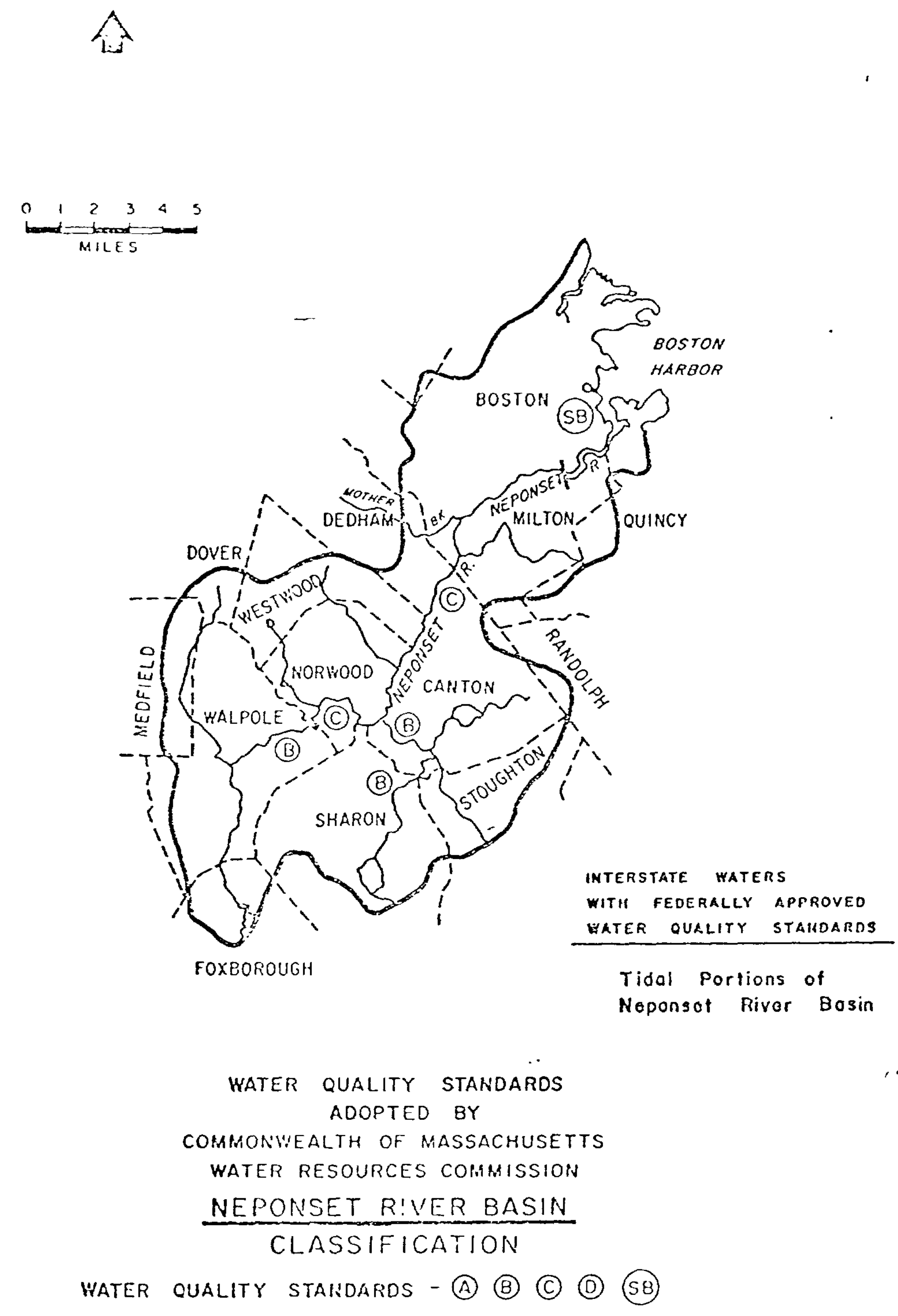


Figure II.4. The Neponset River Basin

improvement. However, continued poor water quality in the mouth of the river remains an exception to the otherwise optimistic forecast.

Here the data is fragmentary as to services of pollution because of the paucity of sampling programs. The ongoing study, however, does point to serveral polluters.

Although Foxborough State Hospital is presently equipped with secondary treatment, followed by sand filtration and chlorination, there is some disagreement as to how well the system is working. But, in any case, a tertiary treatment facility will be completed within the next few years. The project, to cost $500,000 to $700,000 is a demonstration facility, funded by the Department of Natural Resources, to show the potential of advanced waste treatment methods.[17]

The Bay State Raceway also in Foxborough remains a major source of coliform. Animal wastes are dumped on a hill adjoining the river; following rain, they are washed into the river, causing very high coliform levels.

In several areas of the river adjacent to swampy areas, the water appears highly turbid, with dissolved oxygen levels quite low. This is a condition quite characteristic of such situations and is another example of "natural pollution"-i.e. poor quality due to natural processes.

The Walpole/Norwood industrial complex remains a problem, despite the fact that most of the major industries (e.g., Kendall Mills, Bird and Sons, Perkit Folding Box, Hollingsworth and Voes, and Tilleston and Hollingsworth) have tied into the MDC sewer system. Toxics and oil continue to enter the river from various sources, while oil has entered the river at two points (Kendall Mills, with an inefficient method of handling oil, and an asphalt rooting plant in Norwood, where a tank burst, are under state approved implementation plans).

Two previously unknown sewer overflows were discovered in the process of sampling. High coliform levels were recorded in Hawes Brook on one day only. This is probably a discharging drain, although the source has not yet been located. In Norwood, also, regular storm overflows were observed at one point.

Although much of the upstream waste is carried downstream as far as the East Branch, that reach of the river is less polluted than the section above. Salt water intrusion is prevented by the dam at Milton Lower Mills. However, runoff from the many highways which cross the Neponset--Routes 495, 95, 1, 1A, 3, 28, and 138--provides a persistent nonpoint source of pollution. Salt, oil, and other contaminants, as well as unsightly litter, are washed into the river.

The mouth of the Neponset remains grossly polluted due to quite large combined sewer overflows from the Boston system. The shellfish flats are unusuable, while Tenean Beach is closed regularly because of excessive coliform counts.[18]

The Neponset, far more than either the Mystic or the Charles, suffers from wide variations in flow. Floods have occurred in 1937, 1938, 1944, 1948, 1955, and 1968, with the latter two being especially severe. As a result, several studies have been undertaken by the Department of Natural Resources and the Metropolitan District Commission.

The first report, published in 1955 and commonly known as the "Turner Report," proposed state-of-the-art engineering solutions to the Neponset Flood problem: dredging and straightening the channel, replacing or improving bridges, dams and other obstructions, and filling in adjacent land.[19] With the exception of the dredging and straightening of the main channel--never completed because of the bitter protests of some communities adjoining the river, who objected to the environmental consequences of such action--these recommendations have been met.

Conservationists, however, have criticized the report on the grounds that it gives short shrift to the value of the wetlands. Others have pointed out that the recommendations are inadequate--the floods they are designed to control occur more frequently than Turner calculated. Thus, a second study--the so-called "Gullion Report"--was commissioned in 1963.[20] Gullion in fact accepted some of the conservationist positions. position. It argued that zoning the meadow lands for industrial development was both shortsighted and dangerous. It ignored their potential as a recreational resource and increased flood hazard since the wetlands serve as a natural drainage area.

In 1969 another report was filed. Written jointly by the MDC and DNR, it reviewed the preceding literature and re-affirmed Gullion's conclusions.[21] In 1970 legislation was filed authorizing the MDC to purchase additional meadow lands. As much as $2,500,000 was to be allocated for that purpose. However, no action was taken.

Not only is high flow (floods) a problem, but low flows are also. The quality problems in the Neponset are aggrevated by the river's low flow. The naturally low flow is further diminished by the diversion of industrial process water into the MDC sewers for the purpose of pollution control. In response to a worsening situation, the major industrial water users have reduced their water consumption to prevent further degradation of the river. In 1960, daily water consumption of the three largest users (Kendall Company, Bird and Sons, Inc., and Hollingsworth and Voes Company) totaled 8.6 mgd; today they use less than 4.7 mgd.[22] Still the lower stretches of the river have very low flows in summer periods. A 1969 report by Metcalf and Eddy suggested construction of a pumping station on Hawes Brook by which 5.0 mgd could be supplied to the Hollingsworth and Voes Pond during periods of low flow.[23] No action has been taken on that recommendation.

At present the Neponset is subject to a privately administered stream management program. In 1845 the Neponset Reservoir Company was founded; its present stockholders are the Kendall Company, Bird and Son, Inc., Hollingsworth and Voes Company, and Tileston and Hollingsworth. The company operates a reservoir on the river in Foxborough partly to maintain summer flows. In 1954 the stockholders created the Neponset Reservoir Corporation, purchasing Willett Pond and adjoining lands in order to increase their ability to supply water.[24] The management program has prevented the Neponset's low flow problems from becoming even more serious than they are today.

What has happened to the meadow lands along the river?[25] Some 900 acres of the Foul Meadow marshes are under MDC jurisdiction. They have been preserved, relatively untouched, as the Neponset River Reservation. Of the remaining 2000 or so acres of marsh lands, most are located in Canton, Sharon, Norwood, Walpole, and Westwood. They remain largely undeveloped. This is due to several factors. Canton-and Westwood have adopted restrictive flood plain zoning, which is also being considered in Walpole. In Sharon the Conservation Commission purchased several tracts of marshland for preservation purposes. While much of the marsh of Norwood does remain zoned for industrial development, building has been limited in recent years. The 600 acres allocated to Norwood Airport is still undeveloped. Yet the potential of the wetlands as a recreational resource has not been developed. For walking, fishing, or picnicing, the marshlands of the Neponset remain one of the last large open spaces in the Boston metropolitan area. Because of the river's small size, shallowness and sluggish flow, it is probably unsuitable for swimming in most areas. Thus if water pollution control is to provide recreation benefits along the river (as distinct from its impact on Boston Harbor) it must be coordinated with appropriate plans for utilizing the wetlands for such purposes.[26]

II.2.4. Boston Harbor

With the exception of the Inner Harbor and the mouths of the Chelsea, Mystic, and Charles Rivers, all of Boston Harbor has been classified SB or above. Water quality should be suitable for swimming, while shellfish harvested in the area should be edible after depuration. For the most part, Boston Harbor fails to meet these standards.

In 1967 the harbor was found to be grossly polluted.[27] Aside from isolated stretches of beach, most areas showed excessive coliform counts. Floating debris marred the aesthetic values of the harbor, at the same time providing a major navigational hazard. Oil was found to have collected on the sea floor, killing off benthic organisms.

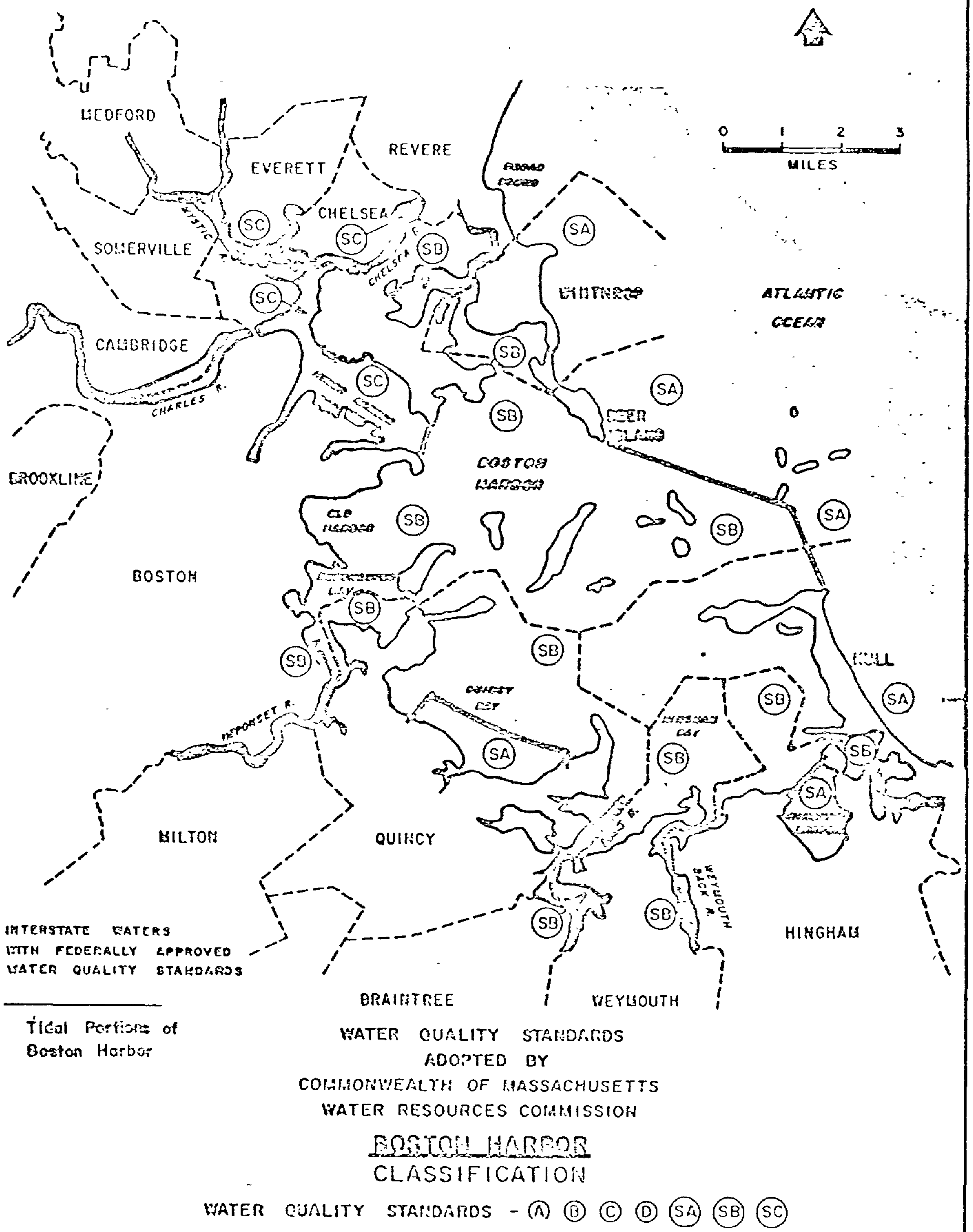


Figure II.5. Boston Harbor

Dissolved oxygen, while acceptable in some areas, varied widely, showing the influence of combined sewer overflows and tidal mixing.

A recently completed sampling study reinforces these conclusions.[28] Despite the broad based concern over the fate of Boston Harbor, water quality there has not improved substantially in recent years. True, coliform levels at some sampling stations have improved due to the year-round chlorination at Nut and Deer Island and to the MDC's ongoing program of repairing faulty tide gates. But the improvements have been marginal, with the major problems still unresolved.

Combined sewer overflows remain the major contributor of pollution to Boston Harbor. With over 100 overflows on record, high coliform counts are not entirely unexpected. The city of Boston is the worst offender with an outdated sewer system, constructed early in the century.

The intractability and expense of ameliorating combined sewer problems in an old city like Boston are well known. Camp, Dresser, and McKee, commissioned by the city of Boston, studied four alternatives:[29] (1) surface holding tanks, (2) sewer separation (for the cities of Boston, Cambridge, Somerville, Chelsea), (3) chlorination/detention facilities, and (4) a Deep Tunnel Plan (in which all wastes would be conveyed to rock tunnels set deep under the ocean to be eventually discharged through eight-mile ocean outfalls). The capital cost estimates alone were very high--$814 million for holding tanks, $584 million for sewer separation, $533 million for chlorination/detention, and $430 million for the "Deep Tunnel" project. And this is without operating and maintenance expenditures. Boston, hard-pressed for funds, is understandably not eager to undertake expenditures of this magnitude.

Defective tide gates are a closely related source of high coliform counts. Those gates are supposed to close when tides rise above the level of an outfall. When the gates don't function properly and allow sea water into the system, overflows may result in other parts of the system due to the backing up of pipes. In a combined system domestic sewage is part of such overflows. In addition, a rinsing action may result, drawing sewage into the harbor with the returning sea water.

The MDC is overseeing the repair of the defective tide gates. At present, the gates from the Neponset River to Atlantic Avenue have been completed. The MDC, well behind its projected implementation schedule, is predicting that all gates will be repaired by late 1974.

There are two major MDC treatment plants on the harbor. Both of them, Nut Island, with a flowthrough capacity of 350 mgd, and Deer Island, with a capacity of 925 mgd, have only primary treatment. In accordance with recommendations of early conferences on Boston Harbor water quality, as of 1971 both plants had installed additional chlorination facilities, insuring round-the-clock chlorination. Both plants are being compelled by EPA to upgrade to secondary treatment, with 1985 as the target date for completion. No cost estimates will be available until Metcalf and Eddy completes plans and specifications in March, 1974.

The Massachusetts Division of Water Pollution Control stands firmly opposed to these plans for upgrading to secondary treatment. Pointing to the low coliform levels at the sewage outfalls from Nut and Deer Island, the Division argues that other problems--in particular, the combined sewage problem--are far more pressing.

One serious problem with the current treatment plants is that of sludge disposal. The MDC's recently completed report, _Plan for Sludge Management,_ [30] concludes that incineration is the best alternative. No action has yet been taken on that recommendation.

The Division of Water Pollution Control knows of few direct dischargers into Boston Harbor. Monsanto Chemical, a major violator has tied into the local sewer system, as have Revere Sugar, Domino Sugar, and others. Manpower and financial constraints, however, have precluded an extensive sampling program to search out industrial discharges into Boston Harbor.

The diversion of industrial wastes to local and then MDC sewers has brought problems of its own. While the MDC has regulations specifying the quality and kind of wastes admissable to its system, they are not always observed. According to an official of the MDC sewer division, the standards for effluent quality, formulated in the late 1940's and revised in 1970, have only been applied to firms newly tying into the MDC system or substantially modifying their facilities since the regulations went into effect. Older firms, long connected to the system, have not been closely supervised. Monitoring is lax. As a result, high concentrations of toxic metals were found in the sludge deposits from Nut and Deer Island. The discharges from federal installations--naval shipyards, army bases, hospitals, etc.--have been largely contained, due to the recommendations of the early conferences on Boston Harbor[31] and Executive Order 11288.

Non-point sources are also a problem in the harbor, but progress is being made on some of them. For example, occasional oil spills do occur.

However, the strict regulations of the Massachusetts Clean Water Act have reduced oil pollution in the harbor and its tributaries. Booms are now required at oil terminals to prevent leakage, bonds must be posted for oil vessels entering the harbor, and damages for violation have been multiplied. Oil pollution remains much less of a problem than it was five years ago. Similarly, under the 1972 Amendments to the Federal Water Pollution Control Act, strict regulations for controlling watercraft wastes are being promulgated. The state agencies believe that these will be adequate for eliminating this source of waste to Boston Harbor.

Less easy to manage is debris, broken off from the harbor's rotting piers. This is both an eyesore and a hazard to navigation. An Army Corps of Engineers study estimated that the cost of entirely removing all the decaying piers would be between $7 - 10 million.[32] Three years ago orders were issued to the Division of Waterways, Department of Public Works, to take action on such a program. No progress was reported. Recently the Division of Waterways has sent out letters to all pier owners, requesting that they show cause why they should not be compelled to remove decaying piers on their own. If owners neither renovate nor remove the piers, the Division of Waterways proposes to remove any decaying pilings, billing the pier owner for the expense. In order to defray its short-term expenses for removal, the Division is being supplied with gas tax monies.

The pollution problems of Boston Harbor are partly a function of the wastes contributed by its tributaries, especially the Charles River, the Mystic River, and the Neponset River, as reviewed above.

Inadequate treatment of domestic sewage, combined sewer overflows, industrial waste discharges, and low flow all contribute to the problems of these streams. Improvement of water quality in those rivers is certain to have a marked effect on water quality in the harbor.

What benefits could we expect from a cleaner harbor? According to the State Department of Natural Resources's predictions, in the metropolitan area some 49,000 people desired access to swimming areas on an average weekend in the summer of 1970. Yet at the time of the last study in 1965 all of the Boston swimming areas combined could only accommodate 11,100 bathers.[33] And facilities have not expanded in the interim. Obviously, the supply of bathing areas in metropolitan Boston is insufficient. Further, water quality at many of the in-city beaches on the harbor is quite low, e.g., Carson's Beach, Wollasten Beach, Malibu Beach, etc. Tenean Beach, at the confluence of the Neponset River is periodically closed due to coliform problems probably of combined sewer origin.

The benefits of improving the harbor will be even greater since the state is spending about $700,000 to purchase the harbor islands still privately owned. Coupled with the islands owned by the MDC, this would place all the islands under public control. Plans might then proceed on developing the islands for recreation use.[34] In particular, the Massachusetts Bicentennial Corporation has submitted a bill to the legislature calling for completion of initial work by 1976.

Fishing is also a major possible benefit. The Department of the Interior's National Survey of Fishing and Hunting found that in 1965 there were approximately 166,400 salt water fishermen in the Boston area who expend a total of 2,230,000 man days annually.[35] Estimates show Boston Harbor supporting only 84,000 man days annually, a relatively moderate use. Improved water quality would increase the use of the harbor for fishing, as well as improving the experience of people already fishing there. And various estimates project steady growth in the fishing population of the region.

In addition, at present all of the Boston Harbor beds are either restricted (SB) or completely closed (SC) to harvesting. As of 1967, the potential economic damage resulting from pollution of the shellfish beds (i.e., those beds that were closed) was estimated at $78,000 annually (shipper-market loss). This figure has probably increased since 1967 because additional beds have been closed. Again water quality improvements could bring substantial benefits.

II.2.5. Summary

Water quality in the Boston Metropolitan Area has improved in some respects in recent years. However, benefits generated by such improvements are not dramatic--in part because few areas have moved through major quality thresholds (see section I.1 above). The full impact of the pollution control program will depend on what facilities are constructed to make use of any quality enhancements. Throughout, natural sources of color and nutrients are a real problem, as are a variety of non-point sources. Of the point-source problems, stormwater and combined sewer overflows of various kinds present the most serious difficulties.

FOOTNOTES

1. Metropolitan Area Planning Council, Open Space and Recreational Plan and Program for Metropolitan Boston: Mystic, Charles, Neponset Rivers (volume III).

2. For a discussion of the details of this, see:
Experimental College, Tufts University, The Environmental Quality of the Mystic River Basin, volume 1, December, 1970.
Camp, Dresser and McKee, Aberjona River Watershed Committee Report on Aberjona River, November, 1967.
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Fred L. Defea, The Establishment and Operation of the Aberjona River Commission.
Mystic River Watershed Association, Inc., Sampling Program.

3. Mystic River Watershed Association, Inc., Newsletter.

4. See, for example,
Richard Allen Warrington, Tufts University, Hydraulic Survey of the Aberjona River and Operation of the Aberjona River Commission, March, 1973.
Camp, Dresser & McKee, Aberjona River Watershed Committee Report, November, 1967.
Fred L. Defeo, op. cit.

5. Experimental College, Tufts University, op. cit.

6. Commonwealth of Massachusetts, Division of Water Pollution Control survey.

7. Camp, Dresser & McKee, op. cit.

8. This problem is treated in some detail by:
Michael Hanemann, The Management of Water Resources in Metropolitan Boston, September, 1970.
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