PART 3

USING THE AVERTING COST METHOD TO ESTIMATE THE BENEFITS OF HAZARDOUS WASTE CLEANUP

David Harrison, Jr.
Lane Krahl
Mary O'Keeffe

I. INTRODUCTION

When hazardous wastes contaminate water supplies, individuals and government bodies may act to avert the consequences of contamination. Such actions might include buying bottled water, switching to another source of water, filtering contaminants out of the water, or even cleaning the contaminated aquifer. If they are undertaken, the costs of these actions -- the averting costs -- can be used as a measure of the benefits of improved hazardous waste disposal. The simplest reason for this interpretation of costs as benefits is that if the improved techniques prevent contamination, the averting actions will be unnecessary and individuals and governments will save the costs of the averting action. The common sense explanation for this notion is contained in the adage, "an ounce of prevention is worth a pound of cure."

Although the averting cost approach has been used to assess benefits from air and water pollution, such estimates are typically small components of the total benefits. For example, in the National Academy of Sciences (1974) study of the benefits of automotive air pollution control, reductions in cleaning expenses from improved air quality accounted for only 0.04 percent of the total benefits; the remainder were estimated using the property value and damage assessment approaches. The reason for the small share accounted for by averting costs is clear; there are few opportunities to avert the damages of air pollution control. Households simply must bear most of the residual damages after controls are set.

Averting costs promise to be a much greater component of benefits assessments for hazardous waste controls. As mentioned, there are many opportunities to avoid the health risks of drinking contaminated water. Moreover, most communities are likely to take steps to avoid using contaminated water. Thus, reductions in the likelihood of groundwater contamination will be translated into reductions in the costs communities incur to provide their residents with clean water.

This paper gives an overview of how averting costs can be used to measure the benefits of hazardous waste disposal regulations and provides an example of how the methodology can be applied by presenting results for a site in Acton, Massachusetts. Two of Acton's municipal wells -- accounting for 40 percent of its water supply -- were contaminated by material disposed of in a nearby chemical plant. The town decided not to use the contaminated water and took various actions to restore the lost water. In the case study we estimate the costs that would have been averted if the leakage from the chemical plant had been prevented. This paper is part of a larger effort to assess the applicability of various methods for estimating dollar benefits, with a common empirical focus on the Acton site. (The other techniques are the property value approach, the risk assessment approach, and the contingent valuation technique.

The paper is organized as follows. Section II sets forth the conceptual approach we use to estimate benefits using the averting cost approach. The main element is an analysis of changes in the supply conditions for town water, since the Acton contamination affected community rather than individual wells. Section III applies the conceptual framework to the contamination incident in Acton. Section IV summarizes the results and conclusions of the paper.

II. CONCEPTUAL FRAMEWORK

The measure we seek is the increased costs that result from a contamination incident. Since they would have been avoided by controls on the source of contamination, the added costs can be used to measure the benefits of regulations. These costs might take the form of increases in expenditures to avoid or mitigate the damages from contamination or decreases in consumer or producer surplus resulting from various market adjustments.

A typical scenario is the following. A chemical company operates a disposal lagoon or landfill on its premises to handle wastes from its production process. The facility has no liner or groundwater monitoring wells and eventually the material leaches through the soil, enters an underground aquifer, and contaminates wells used as the local drinking water source. The town water district decides not to use the contaminated water, and takes various actions to restore the lost water. Individuals hear of the contamination and try to reduce their exposure to contaminants. Town, state and federal officials investigate the incident and require the firm to reduce or mitigate the damages. These pressures eventually force the firm to clean up the site and the aquifer.

Raucher (1983) summarizes the circumstances under which averting costs measure the benefits of groundwater protection. Benefits of groundwater protection are defined as the change in expected damages from contamination. Expected damages consist of averting costs if incurred contamination is detected plus costs incurred if contaminated water is used in the absence of detection, weighted by the probability that the contamination is detected, i.e.,

$$E(D) = p[qC_p + (1-q)C_u]$$

where

p = probability (in the absence of policy i) that contamination will occur ($0 \leq p \leq 1$);

q = probability that contamination would be detected before tainted water was used ($0 \leq q \leq 1$);

C_r = expense of the most economically efficient response to the contamination incident ($C_r \geq 0$);

C_u = cost incurred if contaminated water were used in the same manner as prior to the incident ($C_u \geq C_r$).

In our study, we assume that the contamination is detected. As Raucher points out, if the losses associated with the use of tainted water (C_u) are less than the costs of the feasible averting actions, then the losses will be accepted as the least cost response (i.e., $C_r = C_u$). When an averting action is less costly than C_u, it will be selected instead of suffering the losses.

To obtain an empirical estimate of the benefits of groundwater protection requires determination of the averting costs actually undertaken by public and private actors. Our empirical study focuses on the costs incurred by households when their town water supply is contaminated. In this section, we describe the conceptual framework for estimating these costs. We also include a less detailed framework for the other key actors

-- households; the town: state and federal governments; and the firm whose disposal led to the contamination.

There is an added complication in using estimates of averting costs to measure the affected residents' willingness to pay to avoid contamination because so many of the costs are incurred by public bodies. Since public decisions do not necessarily reflect the preferences of local residents, costs of public averting behavior may or may not be measures of the willingness to pay of local residents to avert the hazards of using contaminated water. We discuss the issues surrounding the interpretation of these public averting costs as measures of willingness to pay in the final part of this section.

Municipal Water Supply and Well Contamination

A municipal water system is a producer of residential water. The production process is very simple: raw groundwater is extracted, treated and distributed to users. Empirical studies show that the long-run supply curve for residential water is upward sloping (Hirshleifer et al. 1960, Hanke 1978, and Berk et al. 1981) because extraction costs vary depending upon the groundwater source and the depth of the water extracted. We assume that the water system has some minimum quality level for final water. Thus, contamination of one of the aquifers used by the water district will lead to averting actions to restore the minimum quality level of the water, which increases the water system's costs. These costs might involve using other existing wells more intensively, developing other groundwater sources, or increasing treatment to remove the contaminants before the water is distributed.

Basic Framework

We begin by examining the simple case pictured in Figure 1. Averting the effects of the contaminated aquifer raises the marginal cost of water from MC_0 to MC_1. If the water is sold at marginal cost, water usage would drop from q_0 to q_1. Thus, we can think of the averting cost as having two components:

(1) The increased costs of producing the water now used, q_1. This is represented by the darkly shaded area in Figure 1. To this area should be added any increase in fixed costs resulting from the contamination.

(2) The loss in surplus (excess of value over marginal cost)[2] resulting from the reduction in water use from q_0 to q_1. (The change in surplus is the sum of changes in producer and consumer surplus. However, this distinction may not be meaningful here since the water customers typically own the water supply, at least in the cases where water is supplied by municipal water authorities. Thus, in this report, we shall simply use the term surplus.) This is represented by the lightly shaded area in Figure 1.

Mathematically, the situation facing the water department is the following. In general, the sum of consumer and producer

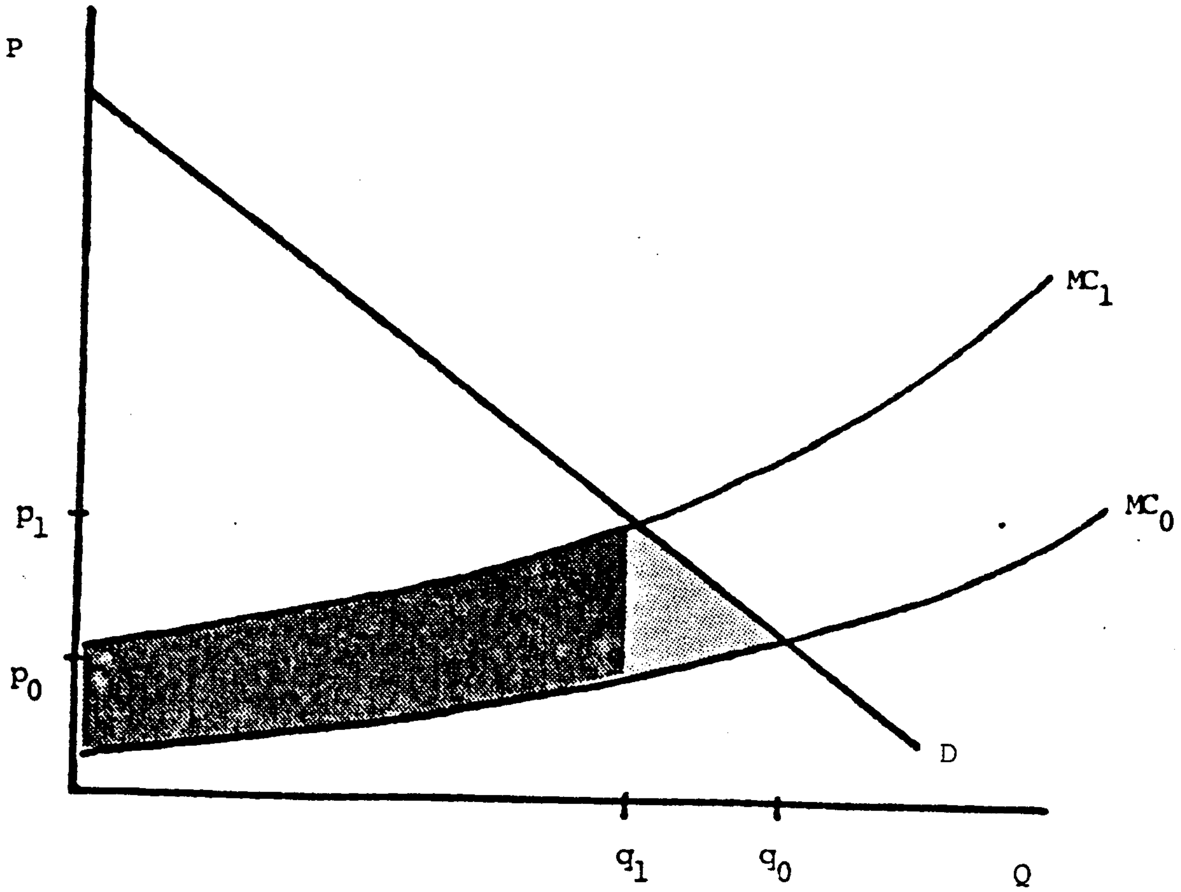

Figure 1. Averting Cost, Simple Case

D = Demand for "clean" water

MC_0 = MC of "clean" water before incident

MC_1 = MC of "clean" water after incident surplus can be expressed as a function of x, the quantity of water sold:

$$TS(x) = \int_0^x [P(q) - MC(q)]dq - F, \qquad (1)$$

where TS = total surplus,

q = quantity of water

P(q) = inverse demand function

MC(q) = the marginal cost function

F = fixed costs.

We assume that the contamination incident has raised the water department's cost function from $\int MC_0(q) + F_0$ to $\int MC_1(q) + F_1$. With marginal cost pricing, the quantity sold declines from q_0 to q_1.

Thus, the change in total surplus due to the incident is the difference between $TS_0(q_0)$ and $TS_1(q_1)$ or

$$\int_0^{q_0} [P(q) - MC_0(q)]dq - F_0 - \left[\int_0^{q_1} [P(q) - MC_1(q)]dq - F_1\right], \qquad (2)$$

which can be rewritten as follows:

$$\int_0^{q_1} [MC_1(q) - MC_0(q)]dq + F_1 - F_0 + \int_{q_1}^{q_0} [P(q) - MC_0(q)]dq. \qquad (3)$$

For the case of marginal cost pricing, the first three terms in (3) represent the first component of the averting costs -- the added expenditures now needed to produce q_1 units of water -- while the last term in (3) represents the second component of the averting costs, the lost surplus on the units of water which are no longer consumed.

In computing the first component, it is important to compare expenditures for producing the same quantity, q_1, with and without the contamination. Thus, a comparison of actual expenditures before and after the incident will not directly yield this component.

If we assume that elasticity of demand is constant, then the key parameters in computing the second component will be the the quantities before and after the incident, q_0 and q_1, the prices before and after the incident, p_0 and p_1, and the incremental cost of producing the inframarginal units, $IC_0(q_0 - q_1)$. (Note that this formula does not apply to the figures we have drawn with linear demand curves.) The prices and quantities before and after the incident determine the values of the elasticity, e, and the constant k, in the demand function, $q = kp^{-e}$, so that the formula for the second component becomes:

$$\left(\frac{1}{1-\frac{1}{e}}\right) k^{\frac{1}{e}} \left[q_0^{\left(1-\frac{1}{e}\right)} - q_1^{\left(1-\frac{1}{e}\right)} \right] - IC(q_0, q_1) \qquad (4)$$

The above analysis abstracts from a number of important factors. In particular:

(1) The short run and long run allow very different kinds of adjustment.

(2) Water is generally not priced at marginal cost and/or non-price rationing schemes (e.g., bans on outdoor uses of water) are frequently used, especially in emergency situations.

(3) Some averting actions may not restore the water to the same quality it had before the contamination.

The third complication cannot be dealt with completely within the averting cost framework. If some residual damages remain, they must be evaluated separately and the total regulatory benefits would equal the sum of the averting cost and valuation of the residual damages. (Raucher 1983) However, the averting cost framework can handle the first two complications.

Short run/Long Run Differences. In the long-run, the water district has time to adjust its operations and can choose the least cost means of providing clean water. The long-run options include drilling alternative wells, developing connections and purchasing water from other districts, and the like. But in the short-run these options may not be available and the water district will have to adjust to the contamination incident using only its current facilities.

Figure 2 shows the difference between the SR and LR situation facing the water district. The SR marginal cost curves are more steeply sloped than the LR curves, indicating the more limited options for expanding capacity. Essentially, the contamination shifts both the SR and LR marginal cost curves to the left. In this sense, the SR and LR analysis of the increased costs of water production due to aquifer contamination is no different from the SR and LR analysis of increased costs of producing a private good following the loss of a factory. There is, however, a key difference.

In the long run, the cost of replicating factories to produce many goods will be constant, if the industry does not use specialized factors of production which are in inelastic supply.

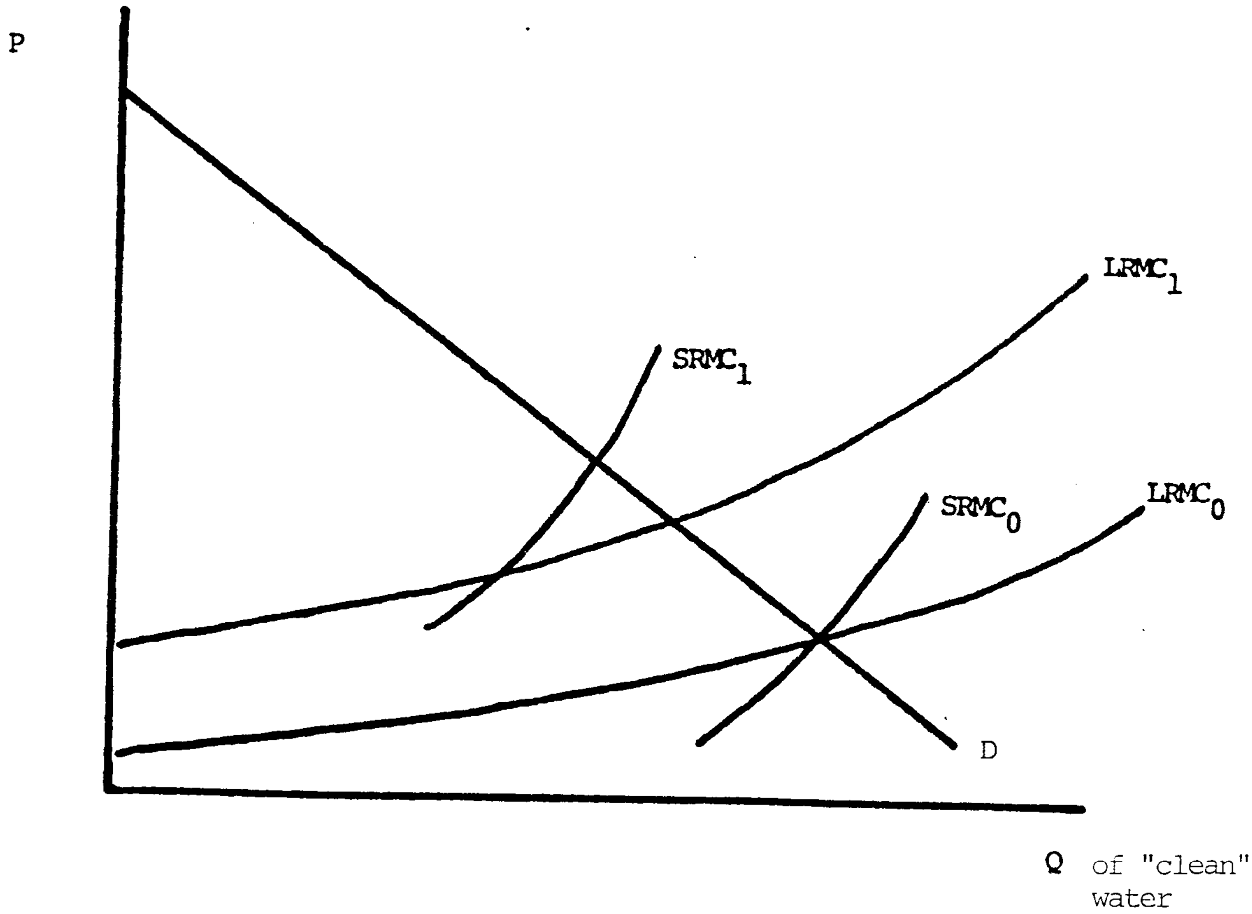

Figure 2. Differences Between Short-Run and Long-Run Situation Facing the Water District

That is, we expect the LR marginal cost curve to be perfectly elastic so that shifting it to the left leaves it unchanged. Thus, if a factory were destroyed, there would be only a short-term effect on costs to replace the factory; the long run costs would be unaffected.

However, in general the long run cost of replicating clean water sources will not be constant. The water department has three long-run ways of dealing with contamination of one of its wells:

(1) Treat the contaminated water forever:

(2) shut down the wells in the contaminated aquifer and replace with new wells drilled in other aquifers or with more intensive use of existing wells; or,

(3) stop the disposal of contaminated material, clean up the source of the contamination and let the aquifer eventually purify itself.

If option (1) is chosen, there is a clearly identifiable permanent long-run increase in water costs. If option (2) is chosen, there will generally also be a permanent long-run increase in water costs, because those aquifers which are least expensive will tend to be used first and the contamination has forced the use of more expensive alternatives. For example, the alternative aquifers may be more distant, requiring maintenance and operation of longer pipelines. Only if option (3) is used (the analog of rebuilding the original factory), will there be no permanent long-run effect on water costs. (The option may involve long-run costs outside the water system if stopping disposal of hazardous substances is costly; this issue is discussed in the case study.)

The distinction between short-run and long-run costs of course simplifies the actual set of responses to the well water contamination. As our case study of contamination of the Acton aquifer indicates, the actual pattern will consist of a series of responses over time. The total averting cost consists of the discounted present value of the costs of these responses. The annual costs are typically greater in the short-run, although the total averting costs will probably be dominated by long-term adjustments if discount rates are not too large and if the long-run supply curve is fairly inelastic (and thus there are substantial costs for replacing the lost capacity).

Non-marginal cost pricing and non-price rationing. Water is generally not priced at marginal cost. Typically, water is supplied by a government department or by a regulated water company. Some form of average cost pricing is used instead. Indeed, fully efficient marginal cost pricing for water exists nowhere since it would require differential rates by day of the year, zone, etc. In general, average cost pricing means that the price is set above marginal cost during periods of off-peak use because of the high proportion of fixed costs. However, during periods of peak use (e.g., summer), average cost pricing would mean that price is set below marginal cost. The simple analysis presented above in Figure 1 does not apply if price is not equal to marginal cost.

Figure 3 represents the situation where price is set above marginal cost. The two components of averting cost are:

(1) The increased costs of producing the water now used, q_1. This is represented by the darkly shaded area in Figure 3. To this area should be added any increase in fixed costs resulting from the contamination.

(2) The loss in surplus (excess of value over marginal cost) resulting from the reduction in water use from q_0 to q_1. This is represented by the lightly shaded area in Figure 3.

Figure 4 represents the situation where price is set below marginal cost. In this case, the averting costs would have two components:

(1) The increased costs of producing the water now used, q_1. This is represented by the darkly shaded area in Figure 4. To this area should be added any increase in fixed costs resulting from the contamination.

(2) The loss in surplus (excess of value over marginal cost) resulting from the reduction in water use from q_0 to ql. This is represented by the lightly shaded area minus the black area in Figure 4. This component could actually be negative if the divergence between price and marginal cost is large both before and after the contamination.

While Figures 3 and 4 appear quite different from Figure 1, close examination of the mathematical formulation in the basic

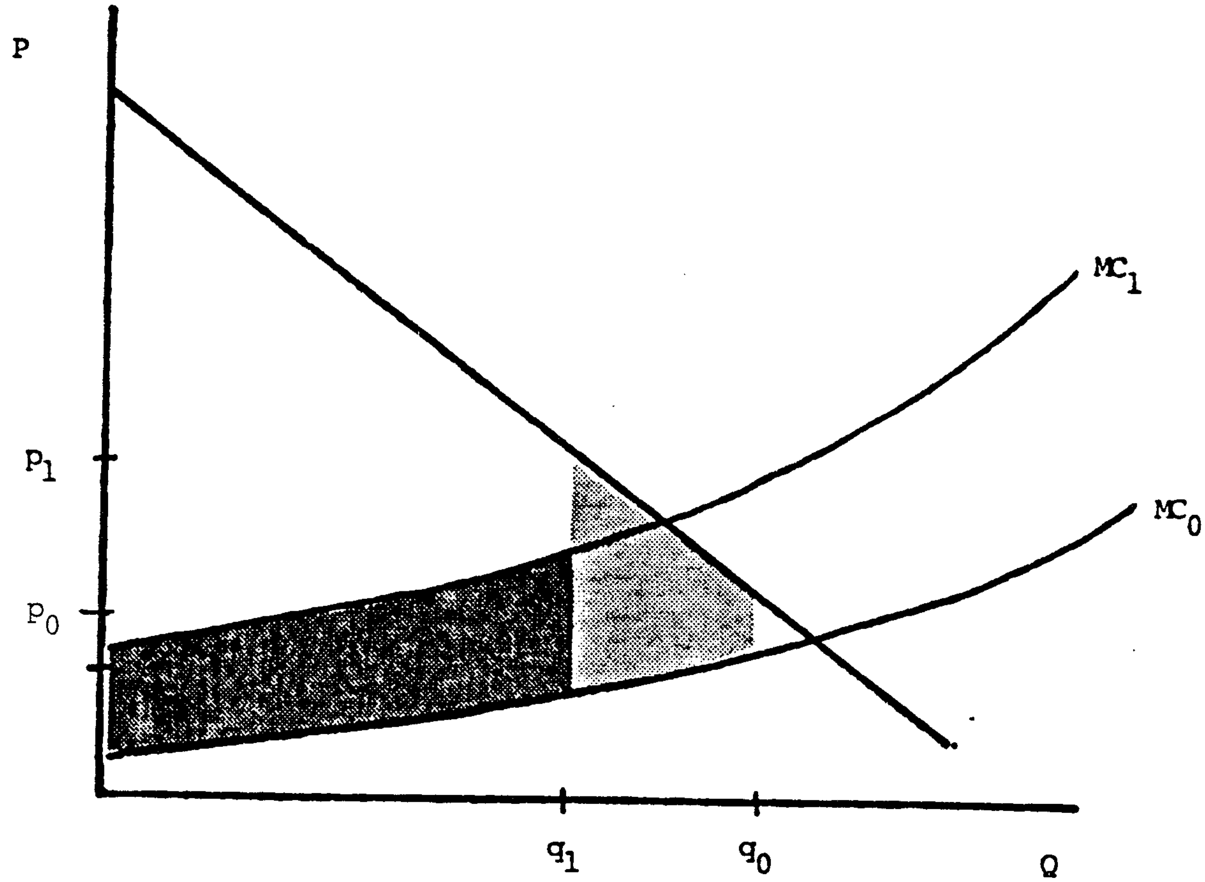

Figure 3. Averting Costs with Price set Above Marginal Cost

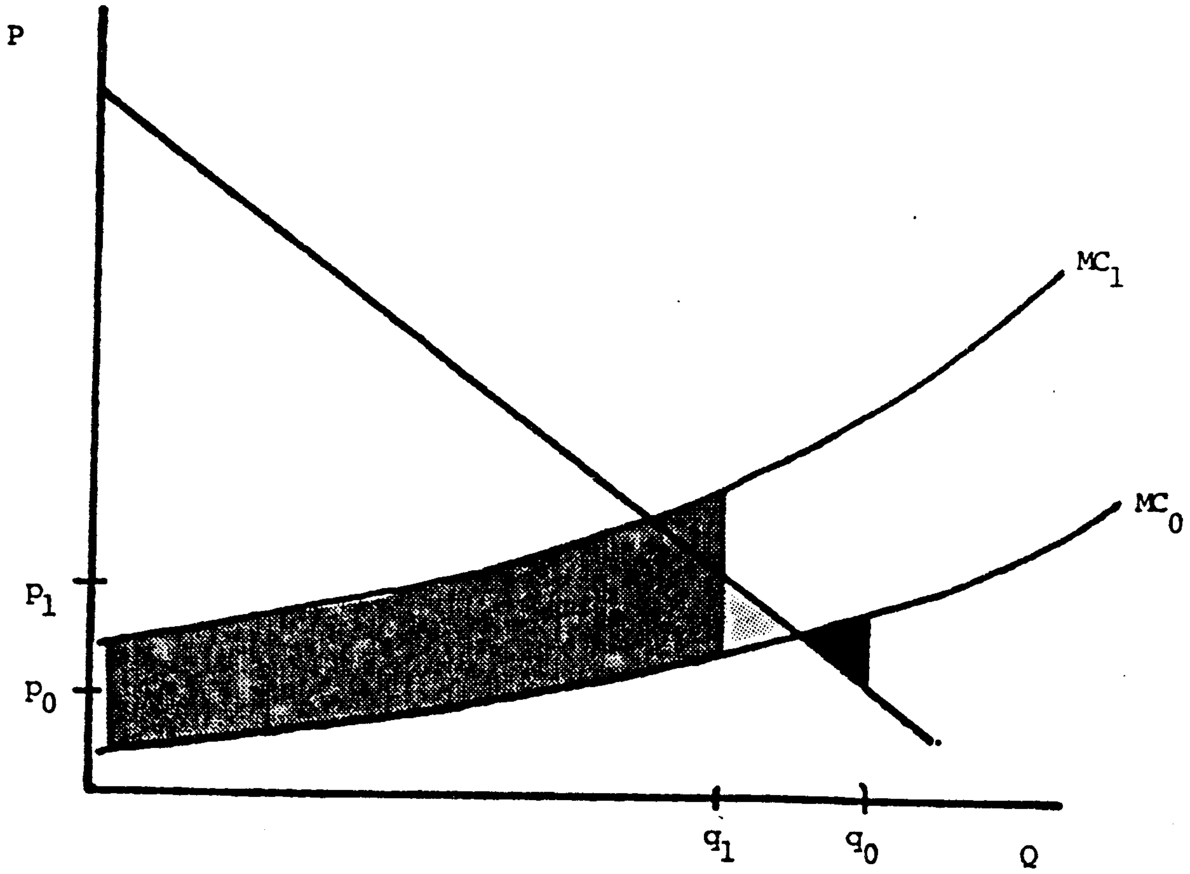

Figure 4. Averting Costs with Price set Below Marginal Cost

framework reveals that the computational scheme outlined there for determining the size of the two components still works for the case of non-marginal cost pricing.

Another possible water department response to the contamination problem, especially in the very short run, is the use of non-price rationing schemes to allocate the restricted supply of uncontaminated water. This measure may or may not accompany increased water department expenditures but generally it does affect surplus. The amount of surplus lost cannot be shown simply on a simple graph of water supply and demand for it depends on more than just price and quantity. However, the lightly shaded area shown in Figure 5 is a lower bound on the reduction in surplus from any rationing scheme which reduces water use from q_0 to q_1. The exact amount of surplus lost in this case will depend on the particular rationing mechanism used (e.g., bans on outdoor water use, household water quotas, etc.). If rationing existed before as well as after the incident, the analysis becomes still more complex.

Summary. To sum up, there are two basic components of water department averting costs, no matter what the pricing system. One component is the additional expenditure needed to produce the amount of water now being produced, compared to what would have been necessary without the contamination. The second component is the loss of surplus which was previously being obtained on units of water not now being produced. Non-marginal cost pricing merely adds the wrinkle that the second component may be slightly more complicated to estimate and may in fact be negative.

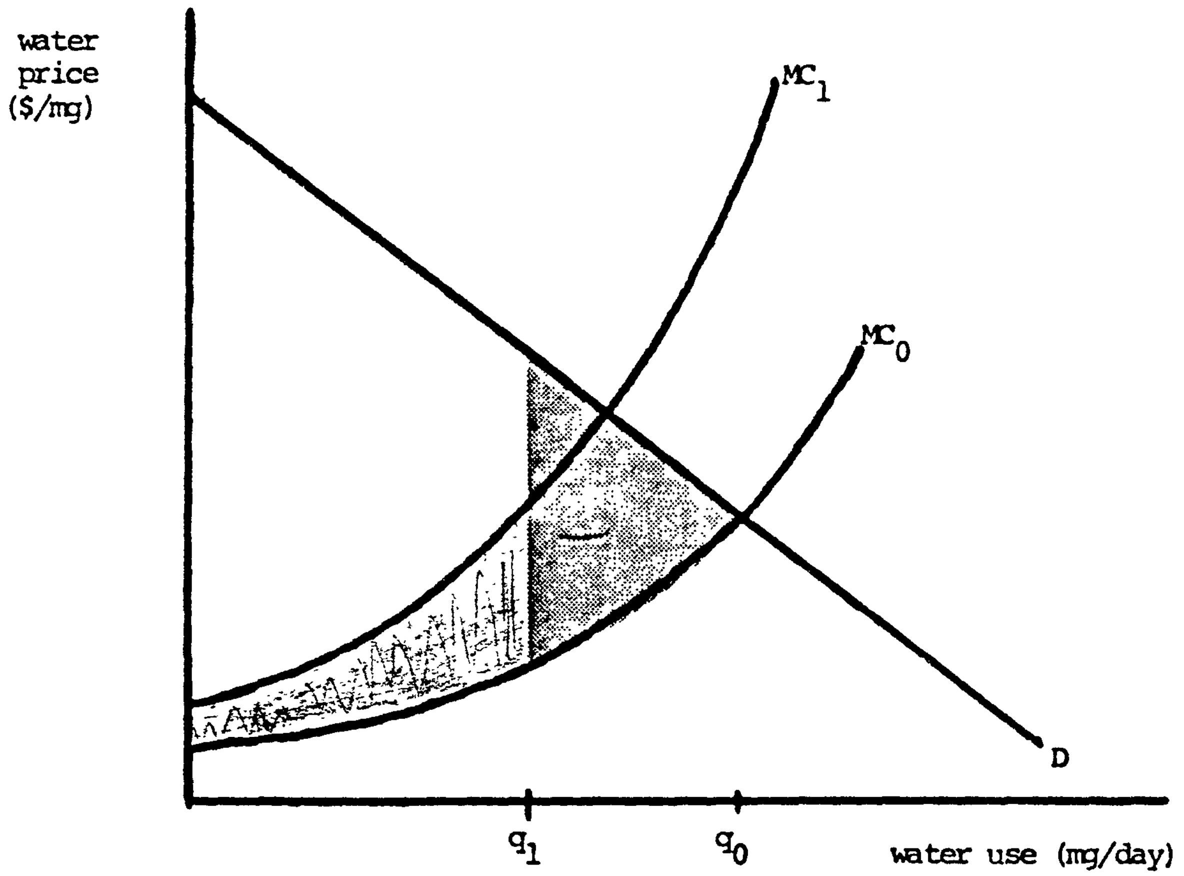

Figure 5. Lower Bound on Averting Costs when Rationing is Used to Keep Price Constant

Other Costs

Thus far we have only considered averting costs related to the production of residential water. As mentioned in the illustrative scenario, other costs might be incurred as a result of the contamination incident that fall outside the municipal water system. These costs might be incurred by individuals, by local, state or federal governments, or by companies held responsible for the contamination incident. In this conceptual section we briefly review the types of costs that might be involved. The case study provides a more detailed discussion of these costs.

Private Averting Behavior. When water users learn that their municipal water is contaminated, they may take actions to avoid avoid their own exposure to this contamination. The most straightforward response would be to purchase bottled drinking water. But some households might use other means, such as installing a treatment device to filter the municipal water or boiling their tap water. In effect, such actions raise the price they face for clean water. Thus, such averting actions give rise to the same two components of averting costs as in the case of water district expenditures: increased expenditures for a given quantity of water and loss in surplus on inframarginal units of water no longer consumed. In addition, in some cases the averting action does not eliminate all risks. For example, use of bottled water for drinking may leave the consumer exposed to contaminated water for bathing or home filtration systems may remove only some of the contaminants.

Observations of private averting costs in a community may be much more informative than observations of averting costs incurred by public bodies or the water supply authority. There are two reasons for this. The first is simply the fact that there are many more households in a community than public bodies so that observing private averting actions yields more data points about responses to a particular action. Data on individuals' averting actions potentially reveal a wealth of information on the diverse preferences and information held by various households in a community. Secondly, decisions about private averting actions directly reflect households' preferences whereas decisions about public averting actions are made by bodies acting, in effect, as agents for the households. If we try to infer citizen preferences from observing a public decision to take a particular averting action, we are forced to deal with difficult issues such as the principal-agent problem, aggregation of preferences, and the like.

On the other hand, analysis of individual averting actions in this context introduces an added complication. There is an interaction between public and private averting actions because both are means to avert the same damages. In principle, if public averting actions can eliminate exposure risks at lower cost than private averting actions, then we should not expect to observe private averting actions. (Of course, if public actions do not eliminate the hazard entirely, then households might undertake varying levels of supplementary averting actions.) The efficient solution is for the appropriate public body to act and for households to do nothing. Even in such a case, however, we may continue to observe households incurring averting costs, because they do not believe that that public averting actions have eliminated the exposure risk. This may be a simple problem of inadequate publicity about public actions or the more difficult problem of insufficient credibility attached to information about public actions. We would expect that households whose members actively participate in public decision-making processes (attending town meetings, city council meetings, special water district meetings, or writing their legislators) would have better information about public averting actions and would also tend to attach more credibility to that information than households whose members do not participate.

The issue of the interaction between public and private averting actions is further complicated in cases where some private citizens may have immediately taken averting actions which reduce the need for public averting action. For example, suppose that some citizens have installed elaborate water treatment devices in their homes or drilled private wells in uncontaminated aquifers (this last might be particularly likely in the case of new development projects). Such citizens may not support expensive public averting actions. The situation is similar to the case where the public school system deteriorates, and a number of families respond by sending their children to private schools rather than by participating in a public effort to restore the quality of public education.

As the discussion above shows, information about private averting actions is extremely useful even in situations where it is clear that public averting actions are more effective and less expensive.

Government Costs. Governments at the local, state, and federal levels may incur added costs as a result of the contamination incident. One set of costs relates to information collection and planning. For example, the town (and perhaps the state or federal government) is likely to undertake a study of the contamination, including monitoring of the contaminated wellwater, monitoring of the contamination in the aquifer, and analyses of alternative actions to deal with the problems. If the water district has a separate budget, none of these costs would be reflected in the costs of providing municipal water.

Business Costs. Some of the costs of averting actions may be borne by the firms judged to be responsible for the aquifer contamination. It is likely, for example, that firms faced with accusations that their disposal was responsible for aquifer contamination would fund studies to investigate the claim and to determine what might be done about the contamination. In addition, some of the remedial efforts undertaken (or mandated) by governments might be paid for by private firms. For example, the Superfund legislation provides for recovery of the cost of clean-up from both the firms operating disposal sites and the firms whose wastes are at the site. In addition, a business not responsible for the contamination may incur averting costs, e.g., to filter the water it uses, just as a household user would.

Costs as a Measure of Willingness to Pay

The sum of the added costs resulting from the contamination incident provides a conceptually sound measure of the benefits of land disposal regulations for any given site. (Of course, if some of the adverse effects of contamination are not eliminated by the averting costs, the averting cost estimate is an incomplete measure of total benefits.) But an individual empirical case study would be of greater value if the costs could be interpreted as a measure of the willingness to pay of local residents to avoid exposure to contaminated water. This section discusses the conditions under which such an interpretation would be valid. We consider three separate cases: averting actions taken by individual residents, averting actions taken by local government bodies, and averting actions taken by other parties.

Averting Actions Taken by Individuals

Consider an averting action taken by an individual household (e.g., buying bottled water). If the following conditions hold, then the cost of that action will reflect the household's willingness-to-pay for avoiding the risks of contaminated water. The necessary conditions are (1) the household has good information about the contamination; (2) the household has a consistent set of preferences; and (3) the household expects to bear the costs of its averting action.

Adequate Information. The decision-makers should have adequate information about the nature and extent of the contamination. If, for example, the household believes that the risks of drinking contaminated water are much smaller than is actually the case, trying to infer their "true" willingness to pay from their actions will lead to an underestimate. Similarly, if they believe that the risks of drinking contaminated water are greater than is actually the case, we may infer a willingness to pay that is an overestimate. In general, if decision makers have poor information, their decisions may reflect the information rather than their preferences.

Consistent Preferences. The household should have a consistent set of preferences. Economists generally assume this automatically holds for private decision-makers. However, there is a good deal of recent experimental evidence (see, e.g., Tversky, 1969 or Grether and Plott, 1979) that individuals may not have well-defined, transitive preferences in choosing between risky alternatives. Since there is substantial uncertainty about outcomes in choosing, say, a home filtration system, this means that there is some difficulty in interpreting averting costs taken by households as measures of their willingness to pay to reduce risks from contaminated water.

Cost Bearing. The household should expect to bear the costs of its decisions. For example, if the household expects some other party (e.g., the corporation responsible for the contamination) to pay all or part of the costs the community incurs, the decision to take averting actions may not reflect the household's willingness to pay. However, if the compensation is independent of the averting actions taken, we can infer a willingness to pay from the averting actions.

Averting Actions Taken by Local Governments

The simplest way to view local government (including the water department) is as a sort of generalized "extended household," whose actions reflect the preferences of its citizens. This view is valid only if the local government's decision-making process is responsive to its citizens' preferences. Under this assumption, we can interpret costs of averting actions taken by a local government as a measure of the collective willingness-to-pay of its citizens as long as the analogous conditions for individual decisions hold: adequate information, consistent preferences, and cost-bearing.

Thus, the main new issue which arises in the case of local government averting decisions is the extent to which they reflect the preferences of their citizens. One factor affecting this would be the form of local government; a direct town meeting form might have different properties from a representative council form.

Another factor would be the diversity of preferences among voters. If all voters have the same preferences on a given issue, local government decisions would tend to reflect those preferences, for any typical American form of local government. However, if citizens have different preferences, particularly different intensities of preferences, local decisions might reflect the preferences of "special interest groups" rather than the preferences of the entire town. In the context of hazardous waste contamination, homeowners near the contamination source might be one example of such a special interest group.

Diversity of preferences also gives a certain amount of power to the individual or body responsible for determining the agenda of town meetings or council meetings. Strategic manipulation of the order of items on the agenda can lead to outcomes which reflect the preferences of the agenda-setters rather than the preferences of the majority of those voting on the agenda issues. (See, e.g., Plott and Levine, 1981.)

From the discussion above, it is clear that interpreting the costs of averting actions taken by local governments as reflecting the preferences of its citizens is somewhat problematic. It is far more straightforward to analyze the implications of averting costs incurred by individual households.

However, in many situations involving water contamination, the local water department may be the party with the apparently lowest cost of avoiding damages from the incident. Thus, asignificant portion of averting expenditures will generally be incurred by local government bodies.

Averting Actions Taken by Other Parties

In addition to households and local governments, other parties may take averting actions as well: state and federal government agencies, and the party responsible for the contamination. The last section of this paper dealt with the problems of interpreting averting costs incurred by the local government as a reflection of its citizens' willingness to pay; these problems are only intensified in the case of averting costs incurred by state and federal government agencies. The cost of actions voluntarily taken by the party responsible for the contamination may not reflect anyone's willingness to pay to avoid the damage of hazardous wastes but rather the party's willingness to pay to avoid bad publicity and/or costly litigation. Moreover, the cost of actions involuntarily taken by the party responsible for the contamination (e.g., under court order) do not necessarily reflect the residents' preferences.

Summary

This section has set forth a conceptual framework identifying the various decision-makers, the nature of the costs incurred by each, and the conditions under which averting costs are likely to reflect the preferences of the affected households. The next section uses this framework in analyzing the case study of an incident in Acton, Massachusetts.

III. ACTON CASE STUDY

In 1978, the Town of Acton, Massachusetts, was informed by the U.S. Environmental Protection Agency that water from two of its wells (Assabet #l and #2) was contaminated. These two wells provided about 40% of the Town's water. The contamination consisted of concentrations of various organic chemicals. (The companion damage assessment study provides a detailed analysis of the well water contamination. See Cooper et al. 1984.)

Similar chemicals were produced by a nearby chemical plant operated by W. R. Grace and Company, and officials suspected that the chemicals migrated through the aquifer from disposal lagoons operated on the plant site. In this case study we assume that the contamination would not have occurred if the disposal lagoons had been regulated under land disposal regulations adopted under the Resource Conservation and Recovery Act.

The well water contamination set in motion a host of actions by the Acton Water Supply District (AWSD), the Town of Acton, the Massachusetts Department of Environmental Quality Engineering (DEQE), the U. S. EPA, and W. R. Grace and Company. Appendix A provides a chronology of the actions taken.

Summary of Results

Following the conceptual framework described in Section II, we distinguish costs borne by Acton residents as a result of the AWSD action, costs borne by Acton residents directly, costs incurred by other government agencies, and costs to W. R. Grace and Company. Table 1 summarizes our estimates of the range of total averting costs. Our "best guess" estimate is that $4,844,000 in costs would have been avoided if controls had been in place at the Acton site. (All costs estimates in this report are in 1982 discounted dollars unless indicated otherwise.) We put the range of plausible costs between $2,200,000 and $19,877,000. The range is so large because of uncertainty about how W. R. Grace and Company will clean up its site and the aquifer; the clean-up could add as much as $15 million to averting costs. We do not expect the clean-up to be so extensive; the "best guess" estimate of averting costs includes an estimate of $1 million for clean-up of the Grace lagoons and the Assabet aquifer.

We also evaluated which costs in Table 1 could be interpreted as estimates of the willingness to pay of Acton residents to eliminate the risks of water supply contamination. Table 2 summarizes our conclusions. The criteria described in the previous section imply that only expenses incurred by Acton residents -- either directly as individuals or indirectly through town expenses or water district expenses -- could qualify as willingness to pay. We conclude that Acton residents would be willing to pay at least $1,255,000 to avoid these ill effects, or $228 per household for each of the 5,500 Acton households. This figure represents a lower bound, both because Acton residents might have been willing to pay for some of the costs in Table 1

Table 1. Estimated Averting Costs for the Acton Case Study

Actor	Total Costs ($000s)[a] "Best Guess"	Range
AWSD	1,534	1,375 - 1,567
Private[b]	-	-
Town of Acton	123	123
Massachusetts DEQE[b]	-	-
U.S. EPA	187	187
W.R. Grace	3,000	515 - 18,000
TOTAL	4,844	2,200 - 19,877

Notes:

[a]Costs are in discounted 1982 dollars using a real discount rate of 10 percent.

[b]We have no information on costs incurred by private citizens or the Massachusetts DEQE.

Source: Calculations in Appendix C.

Table 2. Estimated Willingness to Pay of Acton Residents

Actor	Total Costs ($000s)[a] "Best Guess"	Range[b]
AWSD	1,207	1,047 - 1,240
Private[c]	-	-
Town of Acton	48	48
Massachusetts DEQE	NA	NA
U.S. EPA	NA	NA
W.R. Grace	NA	NA
Total	1,255	1,095 - 1,280
Cost per Household ($s)	228	199 - 233

[a]Costs are in discounted 1982 dollars using a real discount rate of 10 percent.

[b]The range is based solely on costs incurred by Acton residents; expenses by other groups are not included.

[c]We have no information on the costs incurred by private households.

NA = not applicable

Source: Calculations reported in Appendix C.

that are excluded from Table 2, and because some of the adverse effects from the Grace site leakage are not included in our averting cost framework.

Acton Water Supply District (AWSD) Actions

The response of the AWSD to discovery of contamination at the Assabet wells has ranged from the immediate closing of the wells in December 1978 to recent decisions to re-activate the wells and treat the water. Appendix A lists the actions, while Appendix B provides our estimates of the expenditures the AWSD has incurred as a result of the contamination. In addition to these expenditures, the total costs include reductions in consumer and producer surplus.

To organize the analysis of averting costs, we distinguish the following three time periods and major averting actions:

Long-run (1983 and beyond): AWSD reopened the Assabet wells and used a granular activated carbon (GAC) treatment system, supplemented by an aeration system, to eliminate the contamination, connected to the water supply of an adjacent town, and implemented a water quality monitoring program.

Intermediate-run (1980-1982): AWSD commissioned a hydrogeologic study, drilled a new well, increased water quality monitoring to define the extent of the contamination, and initiated legal action against W. R. Grace.

Short-run (1978-1979): AWSD closed the Assabet wells and imposed a ban on all outside and non-essential water use.

In this section we summarize our results for these various time periods. Appendix C provides the details of our cost calculations.

Long-Run Costs. The AWSD decided to treat the contaminated will water rather than to rely upon other well fields. The major long-run expenditures consist of $375,000 for construction of the GAC treatment system, $143,000 for the aeration treatment system, $30,000 for the Concord connection, and $15,000 for an analytical laboratory. (W. R. Grace contributed $100,000 toward the construction of the treatment plant, however, in this section, the $100,000 is treated as if it were a cost borne by the AWSD.) Operation and maintenance expenses include $45,000 per year for the treatment plants and $5,000 per year for the laboratory.

There is some question of how long the treatment plant will need to be operated because of uncertainty over how long the aquifer will be contaminated. The consultants for Grace estimated that with normal pumping the contamination will be eliminated at the Assabet well field 12 years after the Grace lagoons are cleaned up. In February 1980, Grace discontinued its chemical operations at the Acton site and moved the operations to a plant in Texas. We assume Grace will clean up the Acton site in 1984, and thus that the treatment plant will be operated until 1996. Total discounted treatment costs amount to $760,000 under this scenario, or about $138 per household.

The Grace consultant also indicated an alternative scenario in which the aquifer would be cleaned up in 6 years. This accelerated clean-up involves installation of several wells to withdraw, treat and recharge the aquifer water. Reducing the time the treatment would be required to six years (to 1990) reduces the long-run costs to $668,000.

The Concord connection and laboratory are permanent improvements built in response to the contamination. The total discounted costs of these improvements, including operation and maintenance, amount to $94,000. Thus the total discounted costs in the long-run range from $762,000 for the 7 year treatment scenario to $854,000 for the 13 year scenario.

These added costs will result in an increase in the water price in Acton, which in turn will lead to reductions in the quantity of water demanded. As discussed in Section II, these changes generate costs in the form of reductions in consumer surplus. The size of the price increase and quantity decrease -- and thus the consumer surplus loss -- will depend upon the elasticity of demand for water and the shape of the demand curve.

Figure 6 shows the "current" conditions for the Acton water market. In 1978, the price of water was $24 per year for the first 14,960 gallons and $0.802 for each additional 1,000 gallons. Since the base flow amounts to only 41 gallons per household per day, well below the amount of water for in-house use (Bond and Straub 1973) the relevant price of water is $802 per million gallons (MG). We estimate the quantity of water used in 1978 to be 640 MG.[1]

The AWSD doubled its water rates in 1980, but only part of that price increase can be attributed to the added costs from the contaminated aquifer. Since the AWSD prices on the basis of average cost, the price increase due to contamination will be

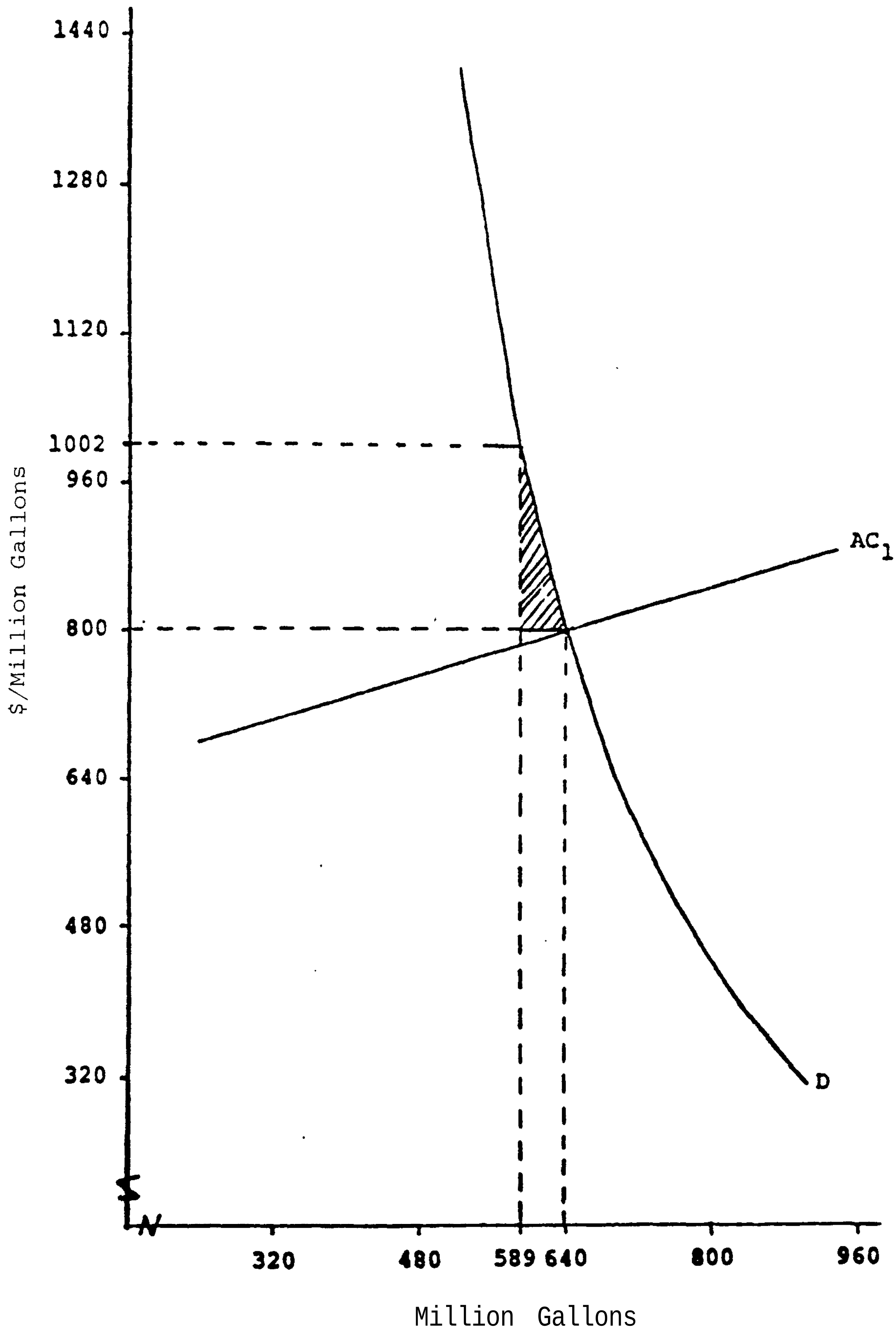

Figure 6. Consumer Surplus Loss from Long-Run Cost Increase for the Acton Case Study

proportional to the increase in average cost. Appendix C describes our calculations of average cost increases, price increases, and consumer surplus losses from the change in water production costs. Our results use a price elasticity of -0.37, a figure reported by Male et al. (1979) using a sample from communities in the Eastern U.S. For the time horizon to 1996, these calculations result in a long-run annual price increase of $200/MG, a 25% increase, and a reduction in quantity demanded of 55 MG. This quantity reduction results in a loss in consumer surplus of $4,800 per year -- the shaded area in Figure 6 --, or a discounted total of $31,000. For the alternative time horizon to 1990, the consumer surplus loss is $32,000.

Intermediate-Run Costs. It took the Water District about four years to plan for its long-run solution to the well water contamination. In the interim, the AWSD added a new well and increased its water quality monitoring program. In addition, the district commissioned a hydrogeologic study to aid in its long-term planning, and engaged in litigation to recover its costs from Grace.

The major task in determining the averting costs in this intermediate period is to separate costs attributable to the contamination from those that would have been incurred anyway. Acton is a growing town, located on the fringe of the Boston metropolitan area. Thus, the decisions to add a new well and upgrade the existing well in 1980 are likely to represent an acceleration of additions to new capacity that would eventually have been required by new growth. This acceleration, of course, represents an added cost.

We assume that the contamination accelerated capital costs three years, and that the operating and maintenance costs of the new well were equal to those costs for the Assabet wells. Our calculations (reported in Appendix C, Table C-2) estimate that the added capital cost of the new well and the hydrogeologic study in 1980 amounted to $181,000. Using a capital recovery factor of .402, these costs amount to $73,000 per year.

In addition to accelerating the main well, the AWSD spent $200,000 for litigation in a suit against W. R. Grace and $85,000 for monitoring designed to identify the extent of pollution at the Assabet wells. These represent an added annual cost of $102,000 over the three year period. Thus the total annualized costs for the intermediate expenditures is $175,000, or a present value of $525,000 in 1982 dollars at the discount rate of 10% for the three years. This figure may understate the costs if the AWSD would not have added the new wells and upgraded an existing well before 1983.

These added costs result in price increases and quantity reductions which in turn impose costs on Acton residents in the form of reductions in consumer surplus. Using a price elasticity of -0.37 and a constant elasticity demand function, we estimate that 34% of the doubling in price was attributable to the cost acceleration and the increased monitoring and legal expenses and that water use was reduced by 66 million gallons per year. These changes imply a reduction in consumer surplus of $8,400 per year, or a discounted total of $25,000 (Table C-3) in 1982 dollars.

Short-Run Costs. In December 1978 the AWSD closed the two Assabet wells and began the planning process that eventually led to the GAC filter and aeration treatment solution. But its options for the next year were very limited; the lost capacity could not be replaced until 1980 and thus some rationing of the remaining 60% capacity was required. The AWSD decided to ban outside use of water and thus Acton residents were not able to water their lawns in the summer of 1979. As discussed in Section II, a ban leads to a larger net consumer surplus loss than the alternative of a price increase. The size of the consumer surplus cost can be predicted from estimates of the quantity restriction and the demand elasticity.

We estimated that the ban on outside water use would reduce the quantity of water used during the year by 92 MG, a reduction of 14.4% of total estimated annual use. Valuing this quantity restriction is problematic. The elasticity used for the long-term and intermediate-term changes (-0.37) was based on overall residential use. Howe and Linaweaver (reported in Russel 1970) calculated a price elasticity for sprinkling water of -1.57, confirming the general impression that demand for outside water is more elastic than for overall residential use. But using the constant elasticity assumption to compute the lost surplus may be inappropriate. Since the elasticity, -1.57, is elastic, the computed figure is a finite value, $166,000. If the demand for outdoor water becomes more inelastic as outdoor water decreases, this number might even be an underestimate of the true loss. The computed figure comes to roughly $30 per household, a plausible figure for a summer of brown lawns and dirty cars. For comparison, Russel (1970) calculated a value of $13 per household (updated to 1982 dollars) for the annual consumer loss from the 1961-1966 drought, which eliminated outside water use. We would expect an affluent suburban community like Acton, to have a higher than average value.

Our best guess is that the loss of consumer surplus is approximately $100,000, or $18 per household. The constant elasticity function for sprinkling water may overstate the value of the first gallons (the estimates assume households would pay $0.014 per gallon for the first two gallons per day of sprinkling water); but the total figure is probably reasonably accurate.

Summary. Table 3 summarizes our estimates of the costs of the well water contamination resulting from averting actions by the AWSD.

Private Averting Actions

Like public actions, we expect that private averting actions would have begun in December 1978, since before then there had been no concrete evidence that the town water supply was contaminated. However, town residents near the Grace site had been complaining about odors since 1973 and water from test wells drilled in 1973 and earlier in 1978 had objectionable odors, so it is possible that some Acton residents might have suspected that their water supply was contaminated before public official

Table 3. Estimated Averting Costs from AWSD Actions

Time Period	Increased cost of Water	Reduced Consumer Surplus	Total
	Total Costs ($000s)[a]		
Short-Run (1979)	0	72-166	72-166
Intermediate-Run (1980-1982)	525	25	550
Long-Run (1983+)	762-853	31-32	794-884
TOTAL	1,287-1,378	128-223	1,416-1,600
	Cost per Household ($s)[a]		
Present Value	234-251	23-41	250-285
Annualized	29-31	2-4	31-36

Notes:

[a]Costs are in discounted in 1982 dollars using a real discount rate of 10 percent.

Source: Appendix C.

confirmation of that fact and might have taken averting actions before December 1978, or taken actions to avert the odor, even if they thought the water was safe.

The two most likely private actions are to purchase bottled drinking water or to install a water filter. Buying bottled drinking water costs $264 per household per year (Belmont Springs Water Company, 1983). Filters capable of treating the contaminants in the Acton water range in price from $27 to $132 per household per year (Metropolitan Pipe et al, 1983). These figures represent the cost of treating drinking and cooking water only; moreover, systems do not treat the water as thoroughly as the ASWD water treatment system. Thus, if public and private averting actions are alternative options, the public solution would probably dominate, since the public averting actions taken by the AWSD cost approximately $31 to $36 per household per year. Because the full costs of buying bottled water or installing filtration systems include the inconveniences and required space and because the public averting actions remove contamination from water for all purposes, including bathing, dishwashing, and laundry, we might not expect to observe private averting actions in Acton as long-run solutions to contamination.

As discussed in Section II, there are reasons to expect that such public actions are not perfect substitutes, and thus that some residents of Acton might have purchased bottled water or installed filters. Some residents might not be aware of the public actions, while other might mistrust the town or the AWSD. These reactions might in turn be a result of household characteristics, including participation in the decisions taken by the Water District and the town. In addition some residents may prefer purer water then that provided by the town.

The importance of private averting costs could be determined by surveying the Acton population. The survey would collect the following information: the use of bottled water and other private averting actions: knowledge of the contamination incident, the actions taken by government and other officials, and their likely effectiveness; participation in town meetings and other involvement in the decision-making process for public averting actions: and household characteristics, such as income and household size, that influence the attitudes toward risk. Such survey information would enable us to estimate the size (and pattern) of private averting behavior in Acton and test hypotheses about the mutual relationship between private and public averting actions.

Town of Acton

Regardless of the level of private expenses, all town residents did bear additional costs through actions taken by the Town of Acton. The Town has spent a total of $105,000 in Town funds for additional engineering, technical and legal services (Appendix B). This total consists of a 1980 appropriation of $50,000 by the Acton Town Meeting for legal, engineering and technical services, and a chemical analysis; a 1982 additional appropriation of $25,000 for legal, engineering and technical services; and a 1983 appropriation of $30,000 for legal expenses. These expenditures can be considered costs due to the contamination.

An earlier expenditure for a hydrological study is, however, problematical, since before the groundwater contamination was confirmed, the Town Board of Selectmen required that W. R. Grace fund a Town hydrogeologic study as a condition for approval of a proposed plant expansion. The Town appropriated funding for the study, but was eventually reimbursed the $130,000 cost by W. R. Grace. When the study began, the contamination had been detected and the purpose of the study became identification of the pollution, its source, and distribution.

We conclude that the added expenses by the Town due to the contamination total $123,000 in discounted 1982 dollars, the total for the engineering, technical and legal studies mentioned above. This cost represents a present value of about $22 per household.

Massachusetts DEQE and U.S. EPA

The Massachusetts DEQE has spent considerable time on the Acton problem but has not spent any money on external contracts. The DEQE participated in water sampling and defining the contamination problem. It has issued administrative orders to W. R. Grace. The DEQE provided the AWSD with the granular activated carbon treatment plant that the AWSD used in its pilot program. The DEQE had acquired the plant at no cost from the Calgon Corporation for use in demonstration projects. All of these activities required internal expenditures: however, the Department has no estimate of the manpower expenditures it has made in dealing with the Acton problem.

The EPA did not keep a record of its internal expense caused by investigation and enforcement of the Acton problem. It did, however, spend approximately $100,000 in 1980 on contracts in preparation for litigation. In addition, an attorney from the U.S. Attorney General's office worked half-time for six months and full-time for five months on the case with additional staff support from a 3/4-time student for nine months. We estimate that these legal activities cost approximately $46,000.

W. R. Grace Expenditures

Expenditures on W. R. Grace and Company are the most difficult both to characterize and to predict. To properly measure averting costs we need to eliminate expenditures that would be required under the land disposal regulations -- those expenditure are costs rather than benefits. For example, the company will eventually spend money to cover the disposal lagoon and to develop and maintain monitoring wells. Since these actions would be required under regulations, the costs do not represent added costs to avoid the dangers of contamination.

The company estimates that it has spent $3 million addressing the problem caused by the discovery of chemical contamination in the Assabet wells. Appendix B lists some of the components. Some items are quite clearly averting costs -- costs that would not have been incurred if controls prevented aquifer and well contamination. These costs include $100,000 given to the AWSD for the GAC treatment facility, and $400,000 for a partial clean-up of the site ordered by the court in a consent decree between W. R. Grace and the U. S. EPA entered on December 4, 1980. The $100,000 has already been included in the estimate for the AWSD, so only the $400,000 is an additional cost. One of the itemized components in Appendix B -- $130,000 provided to the Town for the study of the contamination problem -- is not an averting cost because the company would have had to pay for the study even if the contamination had not been discovered.

The other $2.37 million is not itemized, and thus is more difficult to attribute to the contamination. The list of activities undertaken include various independent technical studies, runoff control, legal expenses for two major lawsuits (one instituted by the U. S. EPA and the other by the AWSD), drilling and monitoring of test wells, and representation of the company at various public meetings. We expect that the bulk of these activities are directly attributable to the contamination, although there are some exceptions. For example, monitoring wells and runoff control are required under the RCRA land disposal regulations, and thus at least part of those costs would have been incurred anyway. Of course, we have no way of verifying the accuracy of the $3 million estimate. To take into account the possibility of overstated costs or inclusion of non-averting costs, we use a "best guess" of $2 million for W. R. Grace averting expenditures thus far in our overall totals.

The greatest source of uncertainty in the Grace estimates of averting expenditures concerns the actions the firm will be required to take to clean up both the site and the aquifer. As mentioned, the company has decided to move the operation that produced the chemical waste to Texas, and thus no additional chemical wastes will be added to the disposal lagoons. But W. R. Grace officials estimate that clean up of the site would cost between $1 million and $15 million. The low cost solution would be to cover and seal the lagoons,a procedure which is required under the RCRA land disposal regulations for site closure; the high cost option involves removing the contaminated material to a designated hazardous waste disposal site.

Grace will also be required to restore the aquifer to a usable condition. As mentioned, several options are possible. With the Assabet wells pumping, the aquifer would be free of contamination in approximately 12 years. Thus, the cost of this clean-up option is already included in the estimates for the AWSD. The aquifer could be restored in six years if additional recovery wells were added and a treatment plant and recharge system constructed. Estimates of the cost of this accelerated program range from $1 million to several million dollars.

Our best guess is that the Grace expenditures that we classify as averting costs will total $3 million. This figure is based on an estimate of $2 million for costs incurred thus far and an estimate of $1 million for future site clean-up costs. We thus predict that very costly site clean-up options will not be required and that no additional costs to clean-up the aquifer will be required. The range of possible values is very large, however -- from $515,000, if only the clearly identifiable cost categories are included and no additional clean-up is required, to $18 million, if all expenses listed by Grace are averting costs and the company is required to take costly actions to clean up its site and the aquifer.

Willingness To Pay

Much will eventually be spent to avoid the ill effects of the chemical contamination of the Assabet wells. As discussed in Section II, not all averting expenditures represent revealed estimates of the willingness to pay of Acton residents. We want to distinguish expenditures that households in the Town of Acton would have undertaken if faced with information on their costs and effects.[2] Such expenditures must meet three criteria: they must be based on adequate information on the ill effects that would result without averting actions; they must be based on consistent preferences; and the actor must bear the costs of the decision, and thus be presumed to reveal its tradeoff of resource costs for risk reduction. In this section we analyze how well the expenditures by the AWSD, the Town of Acton, the DEQE, the EPA and W. R. Grace meet these criteria.

Adequate Information. The information available to all of the involved groups is relatively extensive. Since the well contamination was discovered, two hydrogeologic studies have been conducted that reveal the type, distribution and source of the contamination. The results of these studies have been made available to the public in the Acton Public Library. These reports have been supplemented by sampling done by DEQE, EPA and

W. R. Grace and by engineering assessments funded by the Town, EPA and W. R. Grace. The AWSD had extensive information on the alternatives for supplying water based on the 1979 hydrogeologic study of alternative groundwater sources and the results of the 1979 pilot treatment project.

While extensive, the information available is far from complete. No study has estimated the magnitude of the cancer risk associated with the chemicals found in the well water. Furthermore, it is not clear what the concentrations of toxic chemicals in the well water would be if the wells had not been shut down. On the whole, however, the information available to decision-makers in Acton seems to be as complete as is likely under the circumstances. Indeed, a major reason why we chose Acton as the case study site was the fact that so much information was available from the engineering studies.

We conclude that all of the groups involved in the Acton case had adequate information about the problem and possible responses, although full information under the circumstances would include estimates of the likely risks from drinking contaminated water.

Consistent Preferences. Public actions might reflect a host of considerations and not conform very closely to the preferences of constituents. In this section we consider whether the relevant decision-makers were likely to reflect the preferences of Acton residents for risk reductions when expenditures were made.

Local. Because averting actions have been taken by local public bodies -- rather than by individuals directly -- we need to examine their responsibilities and powers as well as the extent to which their decisions reflect the preferences of Acton citizens. Acton has a town meeting form of government, with the day-to-day business conducted by an elected Board of Selectmen. The AWSD is an independent government unit with its own town meeting, budget, and taxing and bond issuing authority. The AWSD Commissioners carry on the day-to-day business of the District. Although the Town Board of Selectmen and the AWSD Commissioners have the power to make day-to-day decisions, the operating budgets and special appropriations must be approved by a majority vote of the citizens attending the respective town meetings (Yaffee et al. 1980).

Because decisions to spend money on averting actions must be made by vote of the town meetings, these decisions should reflect citizens' preferences more directly than decisions made by officials elected to represent citizens views on a broad range of concerns. However, only a few hundred citizens actually attend the town meetings, -- out of approximately 9,000 eligible adult residents -- so it is possible that these decisions do not reflect the preferences of the majority of Acton's citizens.

But most of the town meeting votes taken on appropriations related to the contaminated water have been unanimous or close to unanimous, regardless of whether the decision was to fund or not to fund the activity under consideration. The unanimity or near unanimity on these direct votes suggests that the votes reflect the Town's preferences and that social choice inconsistencies are not a problem. The poor attendance at town meetings may not reflect citizen apathy about the contaminated water problem so much as a belief that one's opinions will be represented adequately by one's fellow citizens.

From this analysis we conclude that the local actions do represent the preferences of the Acton residents.

State And Federal. The basis for the involvement of the DEQE and EPA in the Acton problem is enforcement of law. Although in the abstract, State and Federal representatives could be interpreted as expressing a willingness to pay on the part of Acton residents when they litigate to enforce the law, this extension to a specific local site is not very convincing.

The state and federal actions in this case involve preparing material for litigation. The question is whether these expenses can be interpreted as estimates of the willingness to pay of Acton residents to obtain the benefits of the law. Since the AWSD filed its own lawsuit and retained its own counsel and the Town also retained its own counsel, we suspect that the federal actions were not a substitute for Acton actions. Court cases like the one in Acton are likely to have broader implications. In an attempt to set precedent or send a signal to other polluters, the government may well have spent more on the Acton case than it would have had the issue only been to clean up the Acton site.

We conclude that the DEQE and EPA actions cannot be presumed to reflect the willingness to pay of Acton residents.

W. R. Grace. The expenditures made by W. R. Grace were made at the request of public officials or in response to litigation. It is impossible to determine whether Acton officials would have taken the actions Grace did to reduce the threat of contamination, and difficult to speculate about whether Acton would take the future actions to clear up the site or the aquifer. However, as discussed in the next section, other communities in the Boston area faced with contamination incidents have decided not to clean up when they had to bear the costs.

Cost Bearing. The third issue we need to consider is whether those who made the decision to incur averting costs may ultimately expect some other party to repay those costs. This criteria is relevant for the decisions made by the Town and the AWSD. There is evidence that both the Town and the Water District believed that Grace would pay for at least some of the averting costs, and thus that some expenditures do not necessarily reveal the Town's willingness to pay to avoid the right from contamination.

In early 1980, Selectmen and AWSD Commissioners met with W. R. Grace officers and demanded that Grace agree to:

1) stop disposing all hazardous wastes
2) fund replacement water supplies
3) clean up Grace lagoons and landfills
4) restore the aquifer
5) conduct a health study.

In the spring, Grace did agree to these demands (Acton Town Report 1980). Subsequently Grace reimbursed the Town for the Town-commissioned hydrogeologic study, which cost a total of $130,000.

In April 1980, the U.S. Government filed suit against W. R. Grace asking for the same five actions. The resulting consent decree, entered on December 4, 1980, required that Grace do three of the five activities; the decree did not require that Grace fund replacement water supplies or conduct a health study. The AWSD also has filed suit against Grace for contaminating the Assabet aquifer and has asked for reimbursement of past damages as well as future liability. W. R. Grace has already given the AWSD $100,000 for treatment of the water and a settlement of the suit is expected in 1983.

These statements and legal actions make it difficult to determine which actions taken by the Town or Water District were taken assuming that they would bear the costs. Looking at averting actions taken by nearby communities confronted with water supply chemical contamination from unknown sources may shed some light on what actions taken in Acton would have been taken if they thought they would bear the cost themselves.

We reviewed chemical contamination problems and community responses in seven northeastern Massachusetts communities: Bedford, Burlington, Danvers, Groveland, North Reading, Rowley and Wilmington.[3] Although the communities spent town resources on studies, alternative supplies and water treatment, no community had considered an extensive on-site clean-up program unless it had identified a source which could be held liable for the clean-up or was able to receive Massachusetts or Federal grants. Since residents of Acton are similar to those in these seven communities, we conclude that the costs of site and aquifer clean-up do not necessarily reflect Acton residents' willingness to pay.

Finally, the AWSD litigation suggests that some or all of its costs might not have been incurred if Acton water users had to pay for the increased treatment. The greatest uncertainty involves the long-run solution, since it is unlikely that the AWSD would be able to recover for lost consumer surplus from the short-run ban on outside watering or for the costs of accelerating additions to its water supplies. But the Water District may well be able to recover the added costs of treating the Assabet well water; indeed W. R. Grace has already contributed $100,000 to the AWSD for construction of the treatment plant. It is even possible that the District chose to construct a separate treatment plant for the Assabet wells because such costs could be clearly identified as costs that the aquifer contamination imposed on the AWSD. Despite these reservations, however, we conclude that the increased Water District expenditures, minus the $100,000 provided by W. R. Grace, do provide an estimate of the Town's willingness to pay to avoid the use of contaminated water.

IV. CONCLUSIONS

The nation must decide in the coming years what controls will be placed on hazardous waste disposal operations. Much of the impetus for stringent controls comes from the high cost of dealing with uncontrolled sites: towns must find new sources of water, individuals might buy bottled water; and either firms or government agencies might pay to clean up the contamination. But these averting costs can also be used to infer the benefits of control, and thus provide information to determine the correct level and form of controls.

The principal purposes of this paper have been to develop the conceptual foundation for the averting cost approach and to illustrate the technique with a specific example. In this concluding section we first review the conceptual approach and summarize the empirical case study. The final part discusses a promising area for further research, the interaction of private and public averting costs.

Use of Averting Costs to Measure Benefits

Information on the costs that households, government agencies, and private firms incur to avert damages from an uncontrolled hazardous waste facility provides an estimate of the benefits of control because the resources would not have been used if effective controls were in place. Only part of the benefits are accounted for under this approach, since averting actions will not necessarily prevent all adverse effects -- such as the air pollution from the site, the threat of explosion, or effects on the ecosystem. Thus, the technique does not provide a measure of the benefits of effective controls.

Our conceptual approach focuses on the costs of avoiding health risks from contamination of water supplies, and particularly to the costs incurred by public water districts. When an aquifer is contaminated, a local water company adjusts by providing other sources of water, treating the water, or restricting use. The two principal costs of these adjustments are the greater costs of providing water and the cost surplus from any reduction in water use. In the conceptual section of the paper we illustrated the modifications in the basic model to deal with different time periods and with alternative assumptions about the water board's pricing policy.

One of the key advantages of the averting cost technique is its use of actual decisions to obtain information on the willingness to pay to avoid the use of contaminated water. Both private and public decisions to spend money rather than use contaminated water reveal information on the value that households place on clean water, and thus on their willingness to pay to institute controls on hazardous waste disposal facilities. As we discuss in considerable detail in the paper, using these decisions to infer willingness to pay requires that individuals and government agencies have good information on the contamination, that public actions reflect the preferences of the individual households in the town, and that the public body expects to bear the costs of the adjustment rather than shift the costs to another government body or non-government actor. While these assumptions may not always hold, the relationship between decisions and preferences is clearer for the averting cost approach than for the housing value approach, the other principal indirect approach to estimate willingness to pay.

Not all of the benefits from controls will necessarily reflect the willingness to pay of those directly affected by contaminated groundwater or other hazardous waste threats. Expenses that firms or the federal government incur to clean up sites or aquifers represent benefits of controls -- since the clean up would not be required if the controls prevented toxic releases -- but residents affected by the site would not necessarily value the clean up at its cost. General administrative and legal expenses of state and local governments are in the same category; they represent program benefits but cannot be used to assess willingness to pay.

The willingness to pay estimates are useful primarily because they can be most directly used to generate regional or national benefit estimates. For similar contamination, the value placed on reduction of risks can be generalized -- with some additional analysis to account for differences among households in their attitudes toward risk -- from one group to another. The transfer is equivalent to applying a price elasticity in the literature to a specific situation. In contrast, the other components of averting costs are based upon the specific characteristics of the site and the actors involved in the decisions: transferring the averting cost results is possible but more problematical.

Case Study Results

Our case study of Acton, Massachusetts indicates that the averting cost approach can be implemented successfully. In Acton, lagoons used by a chemical company to dispose of process wastes resulted in contamination of two wells that represented 40% of the town's water supply. The local water board reacted to the contamination by closing the two wells and taking a number of averting actions over the next four years. Using the conceptual foundation laid out in Section II, we calculated the added costs that town residents will bear as a result of the incident and analyzed whether these costs could be interpreted as estimates of the town's willingness to pay.

Our most likely estimate is that the community will pay a total of $1.7 million as a result of the contamination, $1.3 million of which reflect residents' willingness to pay. The costs represent a present value of approximately $228 per household. Thus we conclude that Acton residents would have been willing to pay at least $228 per household for controls that would have prevented the well water contamination.

Most of the public water supply costs are accounted for by the decisions made to construct and operate a treatment plant until the contamination is removed from the aquifer. Although the decisions to ban outside watering in the summer after the wells were closed and to raise prices to recover added costsresulted in losses in surplus, these losses are much smaller than the added costs of providing water.

However, the town costs represent less than a third of the overall costs due to the contamination incident. We estimated that the cost of cleaning up the site and the aquifer -- most of which will be incurred by the chemical company -- will bring the total averting costs to $4.8 million. These estimates are much less certain than the public water supply costs, largely because it is still not certain what level of clean up will be required. We put the range of total averting cost between $2.2 million and $19.9 million.

Private and Public Averting Behavior

The major omission from our empirical study is the lack of extensive information on private averting behavior. In the conceptual section we identified several advantages of information on private actions, including the clear revelation of preferences and the possibility of modeling differences in preferences for control benefits. The most important behavior we expect to observe is private purchases of bottled water, although other adjustments are possible.

Our empirical investigation of private behavior was limited to an analysis of the likely cost to Acton residents of switching to bottled water or installing home treatment systems. We concluded that the per capita cost of purchasing these alternatives would be greater than the cost of the town's switching to alternative public water supplies. Thus, if individuals expected the public and private actions to be substitutes for one another, we would expect few Acton residents to switch to bottled water or install treatment systems.

However, if residents do not know about the public actions or if the public actions are not viewed as effective, residents might take their own actions. On the other hand the residents who participated in the town decisions may be less likely to spend money on private alternatives. An empirical investigation of these issues would require additional information, which could best be obtained from a survey of the Acton population.

APPENDIX A
CHRONOLOGY FOR THE ACTON CASE STUDY

Date	Action
1971	
	-- Acton Water Supply District (AWSD) opens Assabet wells #l and #2 in the Sinking Pond Aquifer.
1973	
	-- AWSD detects odor of chemical contaminants in water from test wells around the Massachusetts Broken Stone Property in the Sinking Pond Aquifer near the Assabet wells.
1978	
June	-- The Department of Environmental Quality Engineering (DEQE) reports that the odor is still present in the water from the Massachusetts Broken Stone Property wells.
July	-- W. R. Grace files site plans with Town Board of Selectment for a proposed plant expansion.
August	-- AWSD and DEQE conduct a limited hydrologic study of the Sinking Pond Aquifer and detect chemical odors in the water.
October	-- DEQE samples the Assabet wells and sends the samples to the Environmental Protection Agency (EPA) for analysis.
November	-- Sample results show chemical contamination of the Assabet wells.
	-- Town conditionally approves the W. R. Grace expan sion subject to completion of a hydrogeologic study to determine if the plant is causing ground-water pollution.
December	-- AWSD closes the Assabet wells.
	-- AWSD imposes a ban on all outside and non-essential water use.
	-- Goldbert, Zoino, Dunnicliff and Associates (GZD) begins the Town-commissioned hydrogeologic study.

APPENDIX A (cont.)

Date	Action
1979	
	-- AWSD commissions a hydrogeologic study to locate alternative groundwater sources.
	-- AWSD institutes a well water quality monitoring program.
July	-- DEQE issues an administrative order requiring W. R. Grace to study its waste generation and disposal problems and develop and implement a plan to control them.
	-- AWSD initiates a pilot project for granular acti vated carbon (GAC) treatment of the water from the Assabet well.
December	-- W. R. Grace commissions Camp, Dresser and McKee (CDM) to conduct a hydrogeologic study.
1980	
	-- AWSD doubles its water rates.
	-- AWSD relaxes the outside water use restrictions to one hour per day.
January	-- Town releases the GZD final report.
February	-- W. R. Grace stops discharging organic chemicals at the Acton site.
March	-- W. R. Grace releases the CDM final report.
April	-- EPA files suit against W. R. Grace asking for cessation of disposal and clean-up of the hazardous wastes at the Acton site.
	-- Town appropriates $50,000 for legal, engineering and technical services and a chemical analysis study.
July	-- DEQE issues a second administrative order based on a draft of the forthcoming consent decree between EPA and W. R. Grace.

Date	Action
Fall	-- AWSD develops a new well (Scribner well)and up grades its Lawsbrook well to replace the capactiy list from the Assabet well closures.
October	-- AWSD imposes a moratorium on new hook-ups to the water system.
November	-- AWSD constructs a connection to the Concord water system as a source of emergency water.
December	-- U.S. Court approves a consent decree between EPA W.R. Grace
	-- W. R. Grace ceases operations using organic chemi cals at the Acton site.
1981	
	-- AWSD removes the water use restrictions.
	-- W. R. Grace begins studies of the site and aquifer cleanup and constructs a runoff diversion and collection system.
	-- AWSD removes the moratorium on new hook-ups.
1982	
July	-- AWSD files suit against W. R. Grace for polluting the aquifer.
Summer	-- AWSD begins GAC treatment at Assabet well #1.
July	-- Town appropriates an additional $25,000 for legal, engineering and technical services.

APPENDIX A (cont.)

Date	Action
1983	
Winter	-- AWSD constructs a laboratory for testing water quality samples from their wells.
April	-- Town appropriates $30,000 for legal services.
August	-- AWSD adds an aeration system to the GAC treatment and begins to treat the water from both the #1 and #2 wells.

Source: Krimsky et al (1981) and telephone conversations with affected parties.

APPENDIX B
EXPENDITURES ON AVERTING ACTIONS IN ACTON

erting ction	Date	Expenditure (current $s) Capital	 O&M (yrs)	Decision Maker	Ultimate Burden
		Town of Acton			
drogeologic Study	1978	$130,000		Board of Selectmen	Grace
g., Legal & Tech. Serv. & Chem. Anal.	1980	50,000		Town Mtg.	Town Residents (General Rev.)
g., Legal & Tech. Serv.	1982	25,000		Town Mtg.	Town Residents (General Rev.)
gal Expenses	1983	30,000		Town Mtg.	Town Residents (General Rev.
ternal Expenses	1978- 1983+		?	Town Man., Selectmen	Town Residents (General Rev.)
g., Legal & Tech. Serv.	1984+	?		Town Mtg.	Town Residents (General Rev.)
		Acton Water Supply District			
drogeologic Study	1979	350,000		AWSD	System Users*
w Well	1980	225,000		AWSD	System Users*
ncord Connection	1980	30,000		AWSD	System Users*
C Treatment	1982	375,000	45,000 (6-12)	AWSD	System Users* 275,000 Grace 100,000
ration Treatment	1983	143,000	Included in GAC Treatment	AWSD	System Users*

APPENDIX B (cont.)

erting ction	Date	Expenditure Capital	(current $s) O&M (yrs)	Decision Maker	Ultimate Burden
		Acton Water Supply District (Cont.)			
sting to-date	1978- 1982	85,000		AWSD	System Users*
ternal Expenses	1978- 1983+		?	AWSD	System Users*
jal Expenses to-date	1979- 1983	200,000		AWSD	System Users*
		Massachusetts Department of Environmental Quality Engineering			
ternal Expenses	1978- 1983		?	DEQE State Law	Federal & State Taxpayers
lot Treat. Program	1979	Equipment donated by Calgon Corp.		AWSD	Calgon Corp.
		Environmental Protection Agency			
jal Contracts	1980	100,000		EPA 6 Att. General Fed. Law	Federal Taxpayers
ternal Legal Expenses	1980		?	EPA & Att. General Fed. Law	Federal Taxpayers
her Internal Expenses	1978- 1983		?	EPA, Fed. LAW	Federal Taxpayers

APPENDIX B (cont.)

erting ction	Date	Expenditure (current $s) Capital	O&M (yrs)	Decision Maker	Ultimate Burden
		W. R. Grace and Company			
drogeologic Study	1979			Grace	Grace
ant Closing	1980	2,370,000		Grace	Grace
noff Control	1981			Court	Grace
gal	1979-1983			Grace	Grace
st wells & Monitoring	1980-1983			Court	Grace
gineering Reports	1980-1983			Court	Grace
blic Mtg.	1981-1983			Court	Grace
z.Was.Disp. before Plant closure and after Decree	1980	400,000		Court	Grace
te Clean-up	1983-1984	1,000,000-15,000,000		Court	Grace
uifer Clean-up	1984+	1,000,000+		Court	Grace
nitoring & Maintenance	1984-2014	500,000		Court	Grace

Pending outcome of AWSD vs W.R. Grace suit.

APPENDIX C
CALCULATIONS OF AVERTING COSTS

Tables 1, 2, and 3 report estimates of the costs of contamination of the Assabet wells. The purpose of this Appendix is to present the calculations used in making those estimates.

The values for all calculations are reported in discounted 1982 dollars. These values are derived using a two-step process. First, all expenditures are converted to inflation-free 1982 dollars using the Consumer Price Index for Urban Wage Earners and Clerical Workers. These values are then discounted to 1982 using a real discount rate of 10 percent. The costs reported for the Town, EPA and W. R.Grace are taken from Appendix B and discounted to 1982 dollars as described above. The estimate of costs to the AWSD and its users, however, involve further calculations. These calculations are described in the following section using the total Averting Costs (Tables 1 and 3) as an example. Similar procedures were used for calculating the willingness to pay values (Table 2).

Total Averting Costs. AWSD

As reported in the text the costs to the AWSD and its users are calculated for three different time periods: long-run (1983+), intermediate-run (1980-82), and short-run (1979).

Long-run. The long-run costs include increased costs of production as well as lost consumer surplus. These costs are reported in Table C-1.

Table C-1. Long-Run Cost Calculations for the AWSD ($000s)

Action	Current $s (Year)	1982 $s	1982 Present Value[a]
Treatment			
GAC	375(82)	374	
Aeration	143(83)	141	
Total[b]		516	469
Other			
Concord Conn.	30(80)	35	
Laboratory	15(83)	15	
Replacement		3	
Total[b]		53	48
Operation and Maintenance			
Treatment			
7 Year Scenario	-	219	199
13 Year Scenario	-	320	291
Monitoring	-	50	45
Total Production Costs[b]			
7 Year Scenario	-	838	762
13 Year Scenario	-	939	853
Annualized Costs			
Treatment			
7 Year Scenario	-	151	
13 Year Scenario	-	118	
Other			
Infinite	-	10	
Total[b]			
7 Year Scenario	-	161	
13 Year Scenario	-	128	
Lost Surplus			
7 Year Scenario	-	7/yr.	32
13 Year Scenario	-	5/yr.	31
Total Costs[b]	-		794
7 Year Scenario	-		884

[a]Using a 10 percent real discount rate.

[b]Total values may not equal the summation of the values in the table due to rounding.

The increased costs of production are shown in the upper portion of Table C-1. To simplify the analysis we assume that all capital is purchased in 1983. The category titled "Replacement" refers to the cost of future replacement of the Concord connection and the analytic laboratory. Since these structures are permanent responses to the contamination incident, they will have to be replaced as they wear out. We assume each has a 30-year operating life and calculate the present value of replacement every 30 years into the indefinite future.

The operation and maintenance costs are reported as the present values of streams of payments into the future. We assume that all of the streams begin in 1983. Operation and maintenance of the treatment facilities will cost $45,000 per year and, depending on the aquifer clean-up program, will continue for 7 or 13 years.

Monitoring will cost $5,000 per year and will continue into the indefinite future.

The losses in surplus are reported in the lower half of Table C-1. These costs are the present values of streams of annual surplus losses over 7 and 13 years. The 7-year scenario has larger surplus losses than the 13-year scenario even though the losses are incurred for fewer years because the annual losses are larger due to the larger annual costs.

Surplus losses can be calculated given the demand function and the new average cost function. Although we have an estimate of the demand function (a constant price elasticity of -.37) we have no estimate of the average cost function. We do, however, know that 639.5 MG were demanded at a price of $802/MG before the incident and can use that information with some simplifying assumptions to estimate the change in surplus.

We assume that the responses to contamination are fixed costs. This allows us to calculate the price of water for the precontamination quantity of 639.5 MG by merely dividing the annual costs by 639.5 and adding the product to the original price of $802/MG.

The second assumption is that the new average cost function is horizontal in the region near 639.5 MG. This allows us to use the price for 639.5 MG as the price faced by consumers after the contamination incident. Using that price, the quantity demanded can be calculated using the formula:

$$q = kp^{e}$$

where: $k = 7592.5$
$e = -.37$

The loss in surplus can then be calculated by integrating the area under the demand curve from the new quantity to 639.5 MG and subtracting the cost of the foregone quantity:

$$CS = \int_{q_1}^{639.5} f(q)\,dq - 802\ (\ 639.5 - q_1\ )$$

where $f(q) = p\ \frac{q}{7592.5}^{-1/.37}$

Figure C-1 shows a graphic representation of these calculations using the 13-year scenario as an example.

Intermediate-run. There are two types of production costs in the intermediate-run: accelerated expenditures and legal and monitoring costs. The cost of the accelerated expenditures is

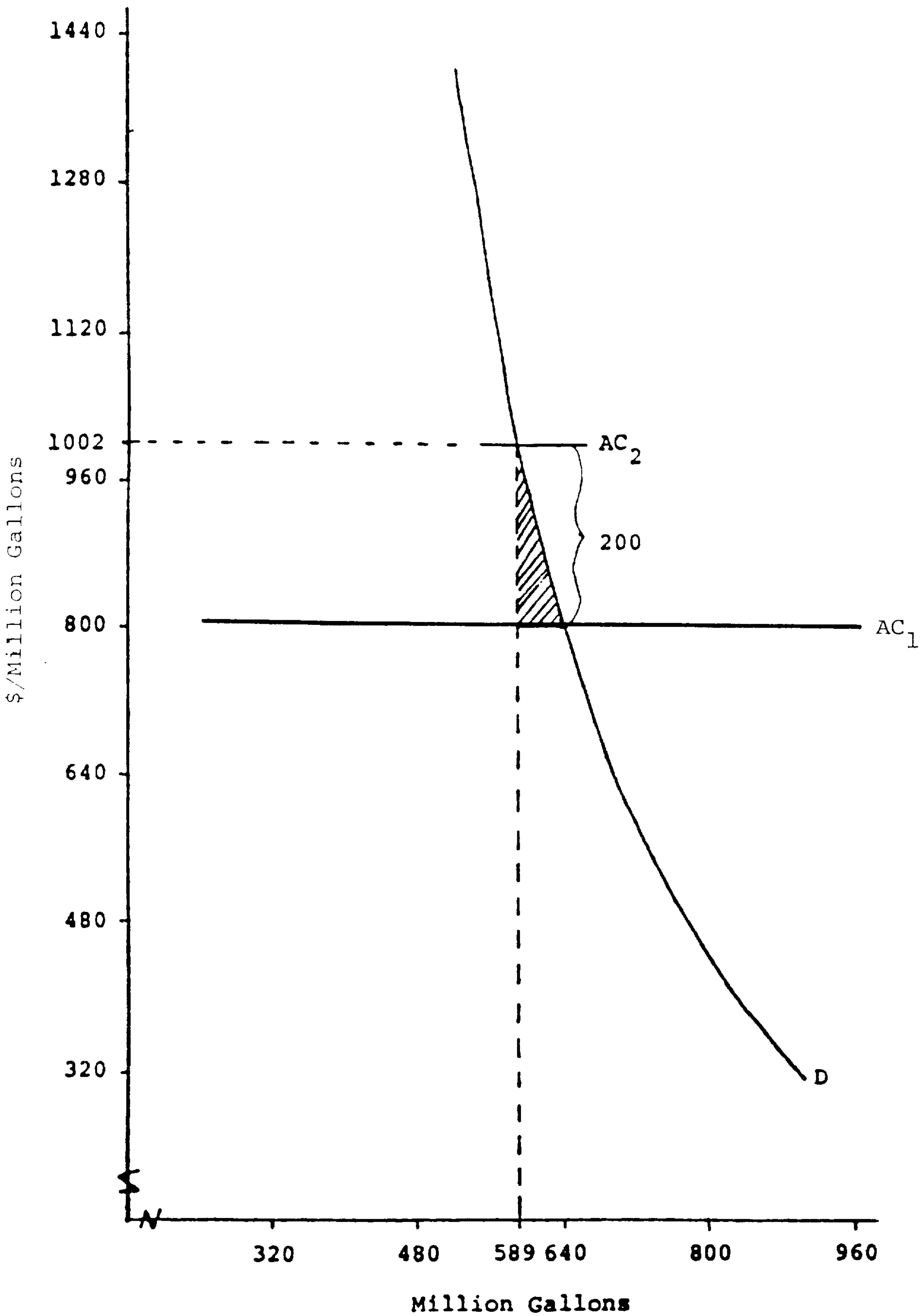

Figure C-1. Calculation of Loss in Consumer Surplus for the Long-Run the foregone use of funds caused by premature investment. Table C-2 shows the schedule of investments with and without the contamination. As explained in the text, we assume that the contamination caused the investments in the hydrogeologic study and the new well to be incurred three years earlier than without the contamination. As can be seen in Table C-2, the accelerated expenditures cost the AWSD $181,000. for simplicity in calculation we assume that this value could have been realized in 1981.

The only information we have on legal and monitoring expenses is that from 1980 to 1982 $200,000 was spent on legal fees and $85,000 on monitoring. To simplify calculation we assume that this money was spent in such a way that the same value in 1982 dollars was spent in each of the three years. This leads to the not-unrealistic assumption that the money was spent as follows: $87,100 in 1980, $96,000 in 1981 and $101,000 in 1982 for an annual expenditure of $101,800 in 1982 dollars.

The accelerated expenditures are annualized using a recovery factor for three years at a 10 percent discount rate and added to the annual legal and monitoring costs to determine the total annual cost. The total annual cost was used to calculate the loss in consumer surplus using the method presented above. The results are reported in Table C-3.

Short-run. The calculation of the costs of a ban on outside water use is straightforward. The loss in surplus is the

Table C-2. Calculation of Cost of Accelerated Expenditures for the AWSD ($000s)

Year	Investment With Contamination Current $	Investment With Contamination 1982 $s	Investment W/O Contamination Discounted 1982 $s[a]	Change 1982 $s
1979	350	464	-	+464
1980	225	263	-	+263
1981	-	-	-	-
1982	-	-	349	-349
1983	-	-	198	-198
			Net Change	-181

[a]Using a 10 percent real discount rate.

Table C-3. Intermediate-Run Calculations of Consumer Surplus Loss for the AWSD ($000s)

Action	Cost/Year (1982 $s)	1982 Present Value[a]
Expenditures		
Accelerated Expenditures	73	
Legal and Monitoring	102	
Total[b]	174	525
Consumer Surplus	8	25
Total Cost		550

[a]Using a 10 percent real discount rate.

[b]Totals may not equal the summation of the values in the table due to rounding.

integral under the given demand curve from the quantity available under the ban to the quantity available under the ban to the quantity available before the ban minus the cost of the foregone water:

$$\hat{}CS = \int_{Q_1}^{Q_0} f(Q)\ dQ - P_0(Q_1 - Q_0)$$

where: Q_0 = Quantity demanded before ban
Q_1 = Quantity available after ban
P_0 = Price before ban = $f(Q_0)$.

The assumptions and results are shown in Table C-4.

Table C-4. Calculations of Loss in Consumer Surplus Due to the 1979 Ban on Outdoor Water Use ($000s)

Demand Function	Integral Limits (MG)	Integral (79$s)	cost of Water Foregone (79$s)	Loss in Consumer (79$s)	Surplus (82$s)
		Sprinkling Water Analysis			
$P=1.4x10^4Q^{-1/1.57}$	0-92	199	74	125	166

NOTES

1. We calculated total water use in 1978 as follows. Before the closure of the Assabet wells the Acton water system had a capacity of 2.5 MG/day, of which 1.0 MG/day was delivered by the Assabet wells. We assume that the 1.0 MG/day represents peak capacity needed for outside water use in the three summer months. Thus total water use would be 639.5 MG (273 days at 1.5 MG/day and 92 days at 2.5 MG/day).

2. This standard for willingness to pay implies that we are only concerned with user benefits that accrue to households directly. Some researchers have estimated an "option value" to measure the value households place on the possibility that they will be affected in the future (see Feenberg and Mills 1980, pp. 51-52).

3. Information for the review came from the report on chemical contamination prepared by the Special Legislative Commission on Water Supply (1981) and telephone conversations with government representatives from each town.

REFERENCES

Acton, Town of. 1980. Acton Town Report, 1980. Acton.

Belmont Springs Water Company, personal communication, 1983.

Berk, R. A., C. J. La Civita, K. Scredl, and T. F. Colley. 1981. Water Shortage: Lessons in Conservation from the Great California Drought, 1976-77. Cambridge: Abt Books.

Bond, R. G. and C. P. Straub, eds. 1973. Handbook of Environmental control, Volume III: Water Supply and Treatment. Cleveland: CRC Press.

Cooper, D. W., J. A. Sullivan, L. A. Beyer, A. M. Flanagan, S. Pancoast, and A. D. Schatz. 1984. Risk Estimation: W. R. Grace Lagoons, Acton, Massachusetts. In this volume.

Courant, R.P. and R. Porter, "Averting Expenditure and the Cost of Pollution," Journal of Environmental Economics and Management, Vol. 8, 1981, pp. 321-329.

Feenberg, D. and E. S. Mills. 1980. Measuring the Benefits of Water Pollution Abatement. New York: Academic Press.

Grether, D. M., and C. R. Plott. "Economic Theory of Choice and the Preference Reversal Phenomenon." American Economic Review. September 1969. Vol. 69. pp. 623-638.

Hanke, S. H. 1978. Pricing as a conservation tool: an economist's dream come true. In Municipal Water Systems: The Challenge for Urban Resource Management, eds. D. Holtz and S. Sebastian, pp. 221-239. Bloomington: Indiana University Press.

Hirshleifer, J., J. C. DeHaven, and J. W. Milliman. 1960. Water Supply: Economics, Technology and Policy. Chicago: University of Chicago.

Krimsky, S. (Supervisor). 1981. Chemical Contamination of Water: The Case of Acton, Massachusetts. Seminar Report, Department of Urban and Environmental Policy. Medford : Tufts University.

Male, J. W., C. E. Willis, F. J. Babin, and C. J. Shillito. 1979. Analysis of the Water Rate Structure as a Management Option for Water Conservation. Water Resources Research Center. Amherst: University of Massachusetts.

Metropolitan Pipe and Supply Company, Water General, and Culligan, personal communication, 1983.

National Academy of Sciences and National Academy of Engineering. 1974. Air Quality and Automobile Emission Control. Prepared for the Committee on Public Works, United States Senate, Serial No. 93-24. Washington: U. S. Government Printing Office.

Plott, C. R. and M. E. Levine. "A Model of Agenda Influence on Committee Decisions." American Economic Review. Vol. 68. March 1981. pp. 146-160.

Raucher, Robert L., "A Conceptual Framework for Measuring the Benefits of Groundwater Protection," Office of Policy Analysis, U.S. Environmental Protection Agency, Washington, D.C., 20460, Paper No. 3W0079.

Russel, C. S., D. G. Avey, and R. W. Hates. 1970. Drought and Water Supply: Implications of the Massachusetts Experience for Municipal Planning. Baltimore: Johns Hopkins Press.

Special Legislative Commission on Water Supply. 1981. Water Quality Issues in Massachusetts: Chemical Contamination. Second Working Paper. Boston.

Tversky, A. "Intransitivity of Preferences." Psychological Review. January 1969. Vol. 76. pp. 31-48.

Yaffee, S. (Supervisor). 1980. Massachusetts Hazardous Waste Management: Building the Local Role. Workshop Report for Planning 440, Department of City and Regional Planning, J. F. Kennedy School of Government, Harvard University, Cambridge.

Zeckhauser, R. and A. Fisher, "Averting Behavior and External Diseconomies," Kennedy School of Government Working Paper #41D, April 1976.