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THE VALUATION OF GROUNDWATER POLLUTION POLICIES: THE DIFFERENTIAL IMPACTS OF PREVENTION AND REMEDIATION

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ABSTRACT

THE VALUATION OF GROUNDWATER POLLUTION POLICIES: THE DIFFERENTIAL IMPACTS OF PREVENTION AND REMEDIATION

By

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Groundwater pollution is a subject of continuing policy debate at the local, state, and private levels. Past efforts in the economic evaluation of groundwater pollution policies have typically focused on the health benefits of pollution control. Emphasis has been on health costs of pollution and material costs of remedial action as the basis for estimating pollution control benefits.

A potential weakness of these studies is their focus on mortality and material costs. Two potentially important reasons exist as to why the exclusive focus on mortality may result in incomplete or erroneous benefit estimates. First, values not directly related to the impact of groundwater pollution on household health may be a significant source of benefits. Altruistic, aesthetic and moral concerns may, in a given context, represent motivations with significant explanatory power regarding variations in household bids for pollution control policies. Second, a considerable divergence may exist between values obtained from the mortality benefits approach and those derived from the households' perception of health risk from groundwater pollution.

To address these ideas, a research study was developed comprised of both theoretical and empirical components with the main objective of examining the relationship between benefits and their underlying motivations and determinants. A contingent valuation mail survey of over 2000 randomly selected Michigan households was completed.

An analysis of the empirical data shows two important results. First, values not directly related to the health impact of groundwater pollution are a significant source of policy benefits. A comparison of subsets characterized by households with a high concern for the possible non-health related environmental impacts of groundwater pollution with households having a low level of concern showed that high concern households typically had policy bids twice as large as low concern households. Second, household perceptions of groundwater pollution health risks are systematically related to a number of qualitative risk characteristics. The significance of these characteristics indicates that they are important both in being able to capture household risk perceptions in a fairly consistent manner and providing a systematic link to the economic trade-offs household's are willing to make in a given context.

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CHAPTER 1

THE VALUATION OF GROUNDWATER POLLUTION POLICIES: THE DIFFERENTIAL IMPACTS OF PREVENTION AND REMEDIATION

Groundwater pollution is a subject of continuing policy debate at the local, state and federal levels. Fueling the concern are the importance of groundwater as a water supply, particularly in rural areas, and increasing evidence of groundwater pollution in regions across the U.S. (Pye et al., 1987; U.S. Environmental Protection Agency, 1984; Nielsen and Lee, 1988). Past efforts in the economic evaluation of policies to address groundwater pollution have typically focused on the health benefits of pollution control (Raucher, 1983; Sharefkin et al., 1984; and Schechter, 1985 a, b). The frameworks used in these studies rely on the health costs of pollution and material costs of remedial action as a basis for estimating groundwater pollution control benefits.

Two potential problems are evident. First, these studies derived health costs using mortality probability and an estimate of the value of a statistical life. However, there may be a considerable divergence between an estimate of benefits obtained from a mortality based probabilistic approach, and benefits estimated from an explicit consideration of people's perceptions of the mortality *and* morbidity risk from groundwater pollution. A substantial body of research, both in psychology and economics, suggests that people frequently perceive health risks in a much different manner than might be expected from a technical risk assessment based on mortality probabilities and the economic value of a statistical life.

Second, people may value groundwater services which are unrelated to any direct health effect of groundwater pollution. Existence and bequest value may be two values which people obtain from groundwater. In certain situations, these values may be a significant source of policy benefits, and excluding them from the evaluation process may result in inefficiencies in both the level and mix of groundwater pollution policies.

This Chapter develops a rationale for the development and empirical testing of a more comprehensive economic valuation framework for groundwater pollution policies which explicitly takes into account household perceptions of groundwater pollution risk.

Groundwater Usage

Groundwater is an important source of freshwater for households in the U.S. and Michigan. Groundwater comprises about one-fourth of all freshwater used annually in the U.S. (U.S. Geological Survey, 1985). Most groundwater is used for agricultural purposes. However, a substantial portion of household freshwater needs for both the U.S. and Michigan is supplied by groundwater. Thirty percent of the U.S. population relies on publicly supplied groundwater, while 21 percent depends on private household wells (Solley et al., 1983). Groundwater withdrawals have been steadily on the rise. In the U.S., withdrawals from public systems increased 164 percent from 1950 to 1980, and withdrawals from private wells increased 60 percent (Solley et al., 1983).

Groundwater provides a substantial portion of Michigan's freshwater needs. Fifteen percent of all households obtain groundwater from public systems, while 28 percent depend on private wells (Solley et al., 1983). Consequently, nearly 43 percent of Michigan's households rely on groundwater as a water source.

Groundwater Pollution

Groundwater pollution is caused by both naturally occurring and anthropogenic substances that are potentially harmful to humans, plants and animals. Naturally occurring pollutants include dissolved minerals, salts and radionuclides such as radon (Pye et al. 1987). Anthropogenic sources include: (a) industrial surface impoundments and injection wells, (b) landfills, (c) septic tanks, (d) land spreading of sewage, (e) accidental chemical spills and leaks, (f) farm production, (g) lawn and garden chemicals, (h) sub-surface oil and gasoline storage tanks, (i) storage areas for road de-icing chemicals, (j) mining activities and (k) intensive groundwater pumping which in certain areas may lead to saltwater encroachment (Ward et al., 1985).

The impact of groundwater pollution depends on a variety of factors. These include: (a) the type and extent of groundwater use, (b) the source and chemical composition of contaminants, and (c) the contaminant concentration level in the water (U.S. Geological Survey, 1984). The magnitude of resulting health impacts will depend on (a) the duration of exposure, (b) route of exposure, and (c) the age and physical condition of exposed individuals (Environ Corporation, 1983).

Pollution poses a greater hazard in areas where water use patterns and hydrogeological conditions make the area more vulnerable. For example, groundwater pollution from agricultural chemical use is a concern in rural areas where farm chemicals are applied extensively. Approximately 22 percent of wells sampled in the southern portion of Michigan's Van Buren County had nitrate concentrations equal to or exceeding the federal water quality standard of 10 mg/l (U.S. Geological Survey, 1985). A non-random sample of 1476 private rural wells throughout Michigan showed that 8 percent exceeded nitrate drinking water standards (Michigan Farm Bureau, 1989). A sampling of 50 wells in Michigan, which were identified ex ante to be at high risk from agricultural chemical contamination, showed 24 percent as exceeding drinking water standards for nitrates. Four percent of the wells had pesticide concentrations exceeding EPA Health Advisory levels for Atrazine (Olson, 1989).

The Health Benefits of Groundwater Pollution Control

Depending on the type of contaminant and length and magnitude of exposure, groundwater pollution can adversely affect health in several ways. For example, ingestion of nitrates by infants may result in methemoglobinemia, a condition characterized by a reduction in the oxygen carrying capability of the blood (National Academy of Sciences, 1979). High nitrate ingestion has also been associated with stomach cancer (National Academy of Sciences, 1979). Heavy metals such as lead, mercury, iron, cadmium and nickel have been linked to a variety of adverse health ailments such as birth defects, increased frequency of miscarriages, renal dysfunction and developmental disabilities (Craun, 1985).

Several economic studies have developed frameworks to estimate the health benefits of groundwater pollution control (Raucher, 1983, 1986; Sharefkin et al., 1984; and Shechter, 1985 a,b). These frameworks use the health costs of pollution and material costs of remedial action as the basis for estimating the benefits of groundwater pollution control.

Raucher

Raucher's two studies (1983, 1986) address two different approaches to the estimation of health benefits: the materials cost approach and the expected benefits approach. The materials cost approach (1986) assesses the policy costs necessary to reduce the health impacts of a groundwater pollution episode. An estimate is made both of the number of excess cancer deaths which would occur in the absence of the policy and policy costs per cancer avoided.

The expected benefits approach (1983) describes the value of reducing mortality risks from groundwater pollution. This approach to the estimation of groundwater policy benefits and its implications for a more comprehensive estimate of policy benefits forms the basis for the dissertation research. Because the expected benefits approach explicitly incorporates benefits into the framework, the subsequent discussion will focus on this approach.

Raucher (1983) uses the expected benefits approach to estimate the benefits associated with several hypothetical situations. These situations differ in terms of a variety of physical and economic parameters, including contaminant plume size and growth, time horizon, discount rate and the type of groundwater use. Health benefits are based on the hypothetical assumption that 1.43 excess deaths per year would occur among the exposed population in the absence of any pollution control policies. From previous research on the value of a statistical life, a figure of $1,000,000 is used as the value of avoiding one excess mortality. As a result, annual health benefits of a policy which was certain to eliminate the mortality threat from groundwater pollution equals $1.43 million. Mean annual per capita health benefits are $14.30 based on an exposed population of 100,000. To these health benefits are added the avoided material costs of remedial action to obtain a measure of the expected benefits of a groundwater policy.

The main findings of Raucher's analysis indicate that benefit estimates are sensitive to a number of physical and economic parameters. Physical parameters include local hydrological conditions, water consumption and land-use patterns and waste disposal practices. Economic factors include the time horizon and the discount rate. The analysis shows that the expected benefits of groundwater pollution control are greatly dependent on plume size, rate of growth and whether the water is used as drinking water or for agricultural irrigation. For example, expected benefits in a situation characterized by a small, slow growing plume in groundwater used for agricultural purposes, is $146,600.

Expected benefits in a situation characterized by a large, fast growing plume in groundwater used for drinking water is, other things equal, $887,200. The specific conditions which characterize the situation under study will have a considerable impact on estimates of groundwater policy benefits.

Sharefkin et al. and Shechter

Sharefkin et al. (1984) and Shechter (1985 a,b) extend Raucher's framework by incorporating physical groundwater models and dose-response models to analyze specific groundwater pollution episodes. An estimate or range of estimates is obtained of the value of a statistical life. This number is multiplied by the incremental reduction in mortality risk due to the implementation of a particular policy to obtain an estimate of health benefits.

Sharefkin et al. estimate an aggregate mortality risk by summing incremental mortality risks across wells and across chemical contaminants for the area under study. Using a range of $100,000 to $1,000,000 for the value of a statistical life and multiplying these values by the high and low aggregate mortality estimates, health benefits were estimated to be in the range of $176 million to $2.02 billion for an exposed population of one million. A similar approach is used by Shechter.

Implications for Policy Benefit Estimates

Three potential problems exist with regard to the past focus on mortality and material policy costs. First, there may be considerable divergence between values obtained from the expected benefits approach and those derived from people's perception of the mortality risk from groundwater pollution. A substantial body of research, both in psychology and economics, suggests that people frequently perceive mortality risk in a much different manner than would be expected from a technical risk assessment. If such is the case, a question arises as to the appropriate source of information to be used to estimate policy benefits: technical risk assessments or consumer perceptions of the situation or some combination of the two. Integration of information obtained both from technical risk assessments and the study of consumer risk preferences would seem to offer the best chance that the design and implementation of environmental risk policies would result in a pareto better situation. However, this integrated approach is predicated on a systematic relationship between perceptions and behavior. More specifically, are risk perceptions, including both probabilistic and non-probabilistic components, systematically related to economic behavior? If not, then any divergence between technical risk assessments and household perceptions is rendered mute. If there is such a relationship, then household preferences may be an important consideration in estimating the economic benefits of risk reducing policies.

Second, aside from mortality risk, morbidity risk may be an important component of health effects but is typically not considered as a possible source of policy benefits.

Third, values not directly related to the impact of groundwater pollution on a consumer's or households health may still be a significant source of policy benefits. People may value the knowledge that future generations have access to unpolluted groundwater. Consumers may value the knowledge that the groundwater resource itself is free of pollution or that animals and plants which depend on it are not affected by pollution, regardless of any current or future direct use. These values may be significant and excluding them from valuation process may result in the misallocation of resources.

Toward a More Comprehensive Framework

Raucher (1983, 1986), Sharefkin et al. (1984) and Shechter (1985 a,b) acknowledge possible shortcomings of relying solely on health values as a measure of policy benefits.

Raucher notes that his conceptual framework omits intrinsic benefits of groundwater protection. He defines intrinsic benefits as "values that society may place on groundwater protection independent of an aquifer's current use value or near-term costs of contamination" (p. 323, 1983). The main component of these benefits is existence value, which he defines as "the willingness to pay for the knowledge that a particular level of environmental quality exists, regardless of any present or anticipated use by the individual" (p. 323, 1983). Raucher notes that these intrinsic values associated with groundwater may be significant.

Sharefkin et al. (1984) and Shechter (1985) both note the potential significance of household perceptions of risk associated with groundwater pollution. Sharefkin et al. note that "it is risk perceptions that matter to individuals and that determine individual valuations of risk" (p. 1782).

Nonhealth Benefit Estimates

Edwards (1988) is unique in attempting to estimate non-health benefits of groundwater pollution control. The objective of the study was to determine the economic benefits of a policy which eliminated or reduced the probability of nitrate groundwater pollution. Health risks of nitrate pollution were not considered as a component of policy benefits. "The list of [policy] benefits included wanting a cost-effective supply of water for personal use and protecting groundwater for use by future generations, but excluded direct health risks" (p. 477). Direct health effects were not considered because the state and county "systematically monitor nitrate levels in each of the public wells in order to prevent dangerous exposures to nitrate" (p. 477).

A major finding is that values motivated by altruistic concerns such as bequest value are a significant source of benefits from groundwater pollution control. Annual per household willingness to pay (wtp) for groundwater protection ranged from $364 to $1437 depending on the probability of a successful policy. Total wtp was comprised of three components: (a) personal use value, (b) bequest value, and (c) option value.

Personal use value is the value people place on the availability of a low cost potable water supply. Personal use value comprised between 10 and 30 percent of total wtp. Bequest value is the value to individuals of knowing that future generations have access to clean groundwater. Bequest value contributed between 70 and 90 percent of total wtp. Option value is a risk premium people would be willing to make to ensure future supply of clean groundwater. Option value was estimated to be 1 percent or less of total wtp.

The comparatively large bequest values estimated by Edwards brings up the question of their source. High values could be an artifact of methodology. For example, ambiguities in Edwards' questionnaire may have resulted in direct health values, and possibly other non-health values besides bequest value, to be included in estimated benefits. In addition, the range of probabilities of nitrate contamination presented to respondents were comparatively high, ranging from 25 percent to 100 percent. Nevertheless, it is clear that policy impacts on non-direct health values may be a significant source of benefits. Understanding the possible motivations behind values associated with non-direct health effects of groundwater pollution will result in more accurate and comprehensive benefit estimates.

Alternative Motivations Behind Perceptions of Policy Benefits

Perceptions of policy benefits may arise from several motivations, including: (a) household concern over the potential health effect of exposure to groundwater pollution; (b) concern over the health effects of groundwater pollution on other households and future generations; (c) the effect of groundwater pollution on a household's use of resources which depend on groundwater as a water source, completely aside from any potential health effects; and (d) the effect of groundwater pollution on a household's non-use values associated with groundwater.

The health risk from groundwater pollution presents a particular type of health risk. Household health risk perceptions may be the result of the subjective assessment of the risk in terms of a number of economic factors and risk characteristics. Household perceptions of these characteristics may affect their perception of the seriousness of the risk, and in turn, their valuation of groundwater pollution policies.

Aside from the direct health threat of groundwater pollution, households may be affected by groundwater pollution in three ways: (a) by using resources dependent on groundwater, for example the recreational use of a lake or river that is recharged by groundwater; (b) altruistic concern over the potential health effects of groundwater pollution on others; and (c) altruistic concern with respect to the existence value of groundwater. This may include perceptions of groundwater as an integral part of a pollution-free ecosystem, the intrinsic value in groundwater remaining unpolluted, and that pollution (or the act of polluting), completely aside from any possible effects on humans, plants or wildlife, violates a moral principle or social norm. These non-direct health related effects may be a significant source of benefits from pollution control policies.

Research Objectives

The dissertation research has three objectives. The first is to develop a valuation framework that considers alternative sources of value in addition to direct health effects. As existing research indicates, the relationship between health and non-health values is not well understood. Previous research has focused primarily on the direct health impacts of groundwater pollution. Yet, as Edwards' study shows, indirect non-health policy impacts may comprise a significant part of policy benefits.

The second objective is to examine the relationship between benefit values and their underlying motivations or determinants. These motivations include: (a) such conventional economic concerns as income, education, and other demographic characteristics; (b) values associated with household perceptions of groundwater pollution health risks; and (c) household attitudes toward values derived from altruistic concerns. These motivations will be examined and linked to a utility theoretic model. Hypotheses regarding the significance and sign of these relationships will be derived.

The third objective is to develop and implement an empirical study to test the derived hypotheses. A contingent valuation mail survey is used to obtain the necessary data. The data include measures of: 1) perceived health and environmental risk, 2) willingness to pay for policies which reduce groundwater pollution, and 3) socio-demographic characteristics of respondents in the sample. The population sampled are Michigan households statewide, categorized as urban or rural. This is discussed in greater detail in Chapter 5.

Organization of the Dissertation

Chapter 2 develops an analytical framework, and examines the implications of economic and environmental factors on the valuation of alternative groundwater pollution policies. Chapter 3 specifies how subjective assessments of the health risk from groundwater pollution may affect policy bids. Chapter 4 discusses the development of a contingent valuation survey to empirically test the relationship between household perceptions and wtp for groundwater pollution policies. Chapter 5 discusses the questionnaire responses.

Chapter 6 includes an econometric analysis of the questionnaire responses. Finally, Chapter 7 discusses the implications of the research and identifies future research needs.

CHAPTER 2

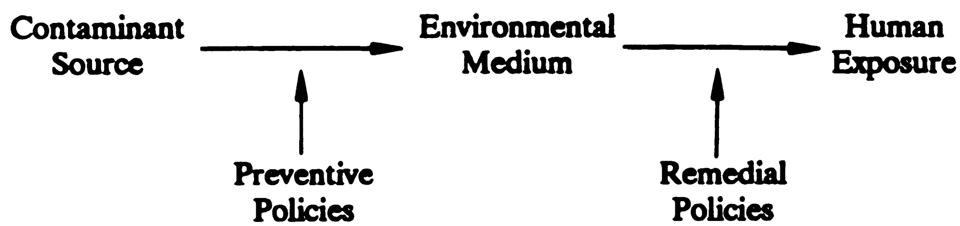
AN ECONOMIC VALUATION MODEL OF GROUNDWATER PROTECTION POLICIES

Groundwater pollution may be controlled using very different policy instruments. Some policies seek to prevent pollution at the source while others intervene with remedial action at points of potential human exposure. These different instruments provide different services to those affected by groundwater pollution. Pollution prevention protects natural resources, aesthetic services, and human health. Remedial action is typically aimed only at protecting human health (Raucher 1983). Since they provide different services, the economic values of prevention and remedial policies are likely to diverge.

This chapter develops an economic model to link consumer preferences to the economic valuation of groundwater policies. More specifically, economic value is associated with the policy services provided. Consumer preferences regarding both health related services and non-health related environmental services are shown to be key determinants of economic value. In situations where households perceive significant environmental services from groundwater in addition to health considerations, prevention policies may be the most economically efficient response to groundwater pollution. In cases where health effects of groundwater pollution are the primary concern, remedial policies may be the most economically efficient response. Finally, expressions for marginal policy benefits are derived and show the potential importance of household perceptions in estimating household wtp for groundwater pollution policies.

An Economic Model of Groundwater Pollution

Raucher's analysis (1983) suggests that groundwater pollution is characterized by a sequence of uncertain events. Pollutants originate at some source and pass through an environmental medium (in this case the groundwater system) resulting in some level of actual or potential exposure, as shown in the diagram below:



The pollution sequence of release leading to environmental effects and exposure leading to health effects suggests a two-stage model of groundwater policy. The first stage involves prevention of groundwater pollution. Preventive policies control pollution at the source. Preventive policies use source reduction and various types of barriers to intervene between the source and the environmental medium, as shown in the diagram above. Consequently, prevention protects both the environmental medium and human health. For simplicity, pollution is viewed as a threshold event: groundwater is polluted if the concentration of some contaminant exceeds a certain level; it is not polluted if the concentration falls below a given level. This view of pollution as a threshold event is embodied in the maximum contaminant levels implemented under Federal drinking water regulations (HOCFR Part 141).

A common feature of pollution strategies is that success is not certain. Policy success, i.e. preventing or reducing pollution below a certain threshold level, is uncertain. Typically, from a regulatory perspective, the probability of policy success depends, inter alia, on the amount of public and private investment in a particular strategy or combination of strategies. The probability of a successful prevention policy is therefore noted denoted $\pi_P = \pi_P(c_P)$, $\partial\pi_P/\partial c_P > 0$, where c_P is the level of public and private expenditure on prevention.

Remedial regulatory action decisions are made at the second stage of the two-stage pollution sequence. As the diagram indicates, remedial action policies intervene only after environmental pollution has occurred. Remedial action would include filtering or treating water used for human consumption, providing alternative drinking water sources, and other means of avoidance. Remedial action tends to focus on reducing human exposure in order to protect human health. Even if human exposure occurs, health effects remain uncertain and are potentially remediated through medical treatment. As with preventive strategies, the likely success of remedial action depends upon the level of both public and private investment. The probability of successful remedial action is denoted $\pi_R = \pi_R(c_R)$ where c_R denotes the level of expenditures on remediation and $\partial\pi_R/\partial c_R > 0$.

The discussion above indicates that two types of services are provided to households depending on the policy: (1) health services provided by both preventive and remedial action policies, and (2) environmental services provided by the prevention policy only. The following section develops a simple model which focuses on those features with potentially important implications for policy valuation.

Household Willingness to Pay for Groundwater Pollution Policies

Household willingness to pay (wtp) represents the households' valuation of policy services. A household's willingness to pay for prevention and remedial action depends on the intended policy outcomes and a policy's effectiveness in attaining these outcomes. The model of willingness to pay, therefore, begins by describing a household's well-being as a utility index $v(m,s,q,e)$ where m is household income, s is a vector of socioeconomic characteristics describing the household, q is an index of non-health environmental services, and e is an index of exposure to groundwater contaminants. For simplicity, it is assumed that groundwater contamination has no effect on m or s.

The success or failure of each stage of groundwater policy has a different outcome and a different welfare effect. Let q^o be the initial level of non-health environmental services and e^o be the initial level of exposure. If prevention is successful, environmental services are q^0 and exposure to contaminants is e^0. Household well-being is therefore $v_P(m) = v(m,s,q^0,e^0)$. If prevention fails but remedial action prevents exposure, the outcome is a lower level of environmental services q^1, but no additional exposure to contaminants, e^0. Household well-being is $v_C = v(m,s,q^1,e^0)$ with failed prevention and successful remedial action. Finally, if both prevention and remedial action fail, policy outcomes are q^1 and e^1 and household utility is $v_E = v(m,s,q^1,e^1)$. The utility index v_E is implicitly an expected utility index conditioned on the health effects due to exposure as perceived by the household. Hence, exposure and perceived health effects are discussed below as qualitatively equivalent issues.

The three utility indexes conditioned on policy outcomes are state dependent indexes where utility depends upon the policy state. Following Graham (1981), the expected utility of a given expenditure on prevention and remedial action is formulated by combining the state dependent utility indexes with the probability of a given policy outcome. This yields, *ex ante*, expected household utility from an initial prevention and remedial action policy as

(1) $$u^0 = \pi_{P0}\, v_P(m) + (1-\pi_{P0})[\pi_{R0}\, v_C(m) + (1-\pi_{R0})v_E(m)]$$

where π_{P0} is the household's subjective probability of the effectiveness of the initial or existing prevention policy and π_{R0} is the household's subjective probability that the initial or existing remedial action policy will be successful.

Equation (1) describes the household's baseline level of well-being. It depends upon both the effectiveness of prevention and remedial action.

The Welfare Effects of an Alternative Groundwater Policy

The welfare effects of an alternative groundwater policy are derived by comparing the baseline utility with the expected utility obtained from an alternative groundwater policy. This alternative level of utility is

(2) $$u^1 = \pi_{P1}\, v_P(m) + (1-\pi_{P1})[\pi_{R1}\, v_C(m) + (1-\pi_{R1})v_E(m)]$$

where π_{P1} is the household's subjective probability that the new policy is successful in preventing aquifer pollution, and π_{R1} is the household's subjective probability that the remedial action component of the new policy is successful.

The welfare effect of a policy change may be measured by the Hicksian compensating welfare measure. The Hicksian compensating measure is the maximum amount of income that an individual is willing to give up, or pay, in order to get the policy change. This maximum amount would leave an individual indifferent between the baseline level of utility and that obtained after paying for the alternative. Algebraically, the Hicksian compensating measure, t^*, for a policy that offers both a change in protection and remedial action is

$$(3) \qquad u^0 = \pi_{P1} v_P(m-t^*) + (1-\pi_{P1})[\pi_{R1} v_C(m-t^*) + (1-\pi_{R1})v_E(m-t^*)]$$

A positive t^* represents a household's maximum willingness to pay for a groundwater policy that improves household well-being. If an alternative policy worsens household well-being, t^* is negative and the absolute value of t^* is the household's minimum acceptable compensation for voluntary acceptance of the policy change.

At t^*, the marginal benefit of additional prevention and remedial action can be derived by taking the total differential of equation (3) with respect to π_{P1} and t^*, and π_{R1} and t^*. Taking this approach, the marginal benefit of additional prevention is

$$(4) \qquad mb_P = dt^*/d\pi_{P1} = v_P/Eu_m - [\pi_{R1} v_C + (1-\pi_{R1}) v_E]/Eu_m$$

where $v_P = v_P(m-t^*)$, $v_C = v_C(m-t^*)$, $v_E = v_E(m-t^*)$, and Eu_m is expected marginal utility of income derived from equation (3). Adding and subtracting v_C to equation (4) and rearranging yields the marginal benefit of additional prevention as

$$(5) \qquad mb_P = (v_P - v_C)/Eu_m + (1-\pi_{R1})(v_C - v_E)/Eu_m$$

The right-hand side of equation (5) separates the marginal benefit of prevention into two terms. The first term on the right-hand side is the marginal benefit of protecting environmental services. It arises due to the ecological, intrinsic, or bequest value of protected groundwater services. The second term on the right-hand side is the health benefit of protection. This health benefit depends not only upon the welfare effect of exposure, $v_C - v_E$, but also upon the probability the remedial action fails to prevent exposure, $(1-\pi_{R1})$. Hence, the health benefit attributable to prevention increases with the probability of failed remedial action. The health benefit of prevention declines with the probability of successful remedial action.

The marginal benefit of additional remedial action is

$$(6) \qquad mb_R = dt^*/d\pi_{R1} = (1 - \pi_{P1})(v_C - v_E)/Eu_m$$

Equation (6) shows that the marginal benefit of remedial action is the product of (a) the probability that prevention fails and (b) the welfare effect due to exposure. The benefit of remedial action increases as the probability of prevention failure increases and decreases as the probability of successful prevention increases.

It is useful to examine the marginal benefits of prevention in a case where a household perceives no ecological, intrinsic, or bequest services from groundwater. In this case, v_P is equal to v_C and the first term in equation (5) equals zero. Without the environmental effect, the marginal benefit of prevention is similar, but not identical, in content to the marginal benefit of remediation action. This can be shown by equating the two marginal benefits expressions--an efficient policy mix will equate marginal benefits across policies. This is shown in equation (7).

$$(7) \qquad mb_P = mb_R = (1-\pi_{P1})(v_C-v_E)Eu_m = (1-\pi_{P1})(v_C-v_E)/Eu_m$$

Both marginal benefit expressions are based on the utility gain from avoiding exposure, $(v_C - v_E)/Eu_m$. The crucial difference between the two expressions in equation (7) is, respectively, that the utility gain from avoiding exposure through prevention is discounted by the probability that remedial action fails, while the utility gain from avoiding exposure through remedial action is discounted by the probability that prevention fails.

Implications of the Theoretical Framework

The framework developed in this chapter has several implications for groundwater policy valuation. First, the framework presented here shows the effect of sequential policy implementation on the measurement of policy benefits. The discounting of the marginal benefits of prevention and remedial policies is a reflection that the two policies are substitutes for one another, insofar as health benefits are concerned. This is consistent with the finding by Hoehn (1989) that because of substitution effects, the sum of policy impacts valued separately will be greater than the same impacts valued together as one policy.

Second, with respect to the estimation of health benefits, Raucher's mortality-based approach[1] to estimating policy benefits is essentially a special case of the more general framework described in this chapter. Raucher's approach is appropriate when mortality is the only outcome important to people and there is agreement on the "correct" mortality probability. In the absence of these conditions, health benefit estimates based on the general framework are more appropriate.

Third, the conceptual framework shows the effect on marginal policy benefits of an explicit consideration of the environmental services provided by a prevention policy.

In cases where environmental services are an important source of benefits to people, the approach used by Raucher will underestimate policy benefits.

Fourth, the derived expressions for the marginal benefits of prevention and remediation show the potential importance of household's subjective perceptions in affecting their wtp for groundwater pollution policies. Equations (4) and (6) specify the marginal benefits from prevention and remediation respectively. Holding Eu_m constant, three terms will affect the magnitude of policy benefits: (a) the perceived probabilities of a successful policy; (b) the health benefits component, $(v_C - v_E)$; and (c) the environmental benefits component, $(v_P - v_C)$. These terms imply that as perceptions change (or differ across households), wtp will change accordingly. To take a simple example, suppose that household A believes that exposure to groundwater pollution will result in death while B believes that exposure will result in a mild stomach upset. Other things equal, $v_{EB} > v_{EA}$. As a result, the term $(v_C - v_E)$ and consequently wtp, will be greater for household A, holding the other arguments of the expression constant.

Perceptions, especially baseline perceptions, may differ across households for a variety of reasons, including, for example, differences in: (a) past experiences with and knowledge of groundwater services and pollution, (b) education, (c) income, (d) environmental concern, and (e) attitudes towards regulatory activity.

An important question for policy valuation is the extent to which household perceptions of policy services are related to perceived policy benefits as measured by wtp. The empirical testing of the relationship between health and environmental risk perceptions and wtp for groundwater policies necessitates the development of variables which are an accurate reflection of household risk perceptions. Chapter 3 addresses this question in greater depth.

NOTES

1. Raucher's approach to estimating the health benefits from reductions in the probability of groundwater contamination is based on reductions in mortality from groundwater contamination exposure. Raucher (1983, 1986) defines the expected benefits of a policy as the change in expected damages from groundwater contamination due to a change in the probability that contamination will occur. Expected damages is a weighted function of (a) the cost of the most economically efficient response to the contamination incident and (b) the cost incurred if contaminated water were used in the same manner as before the contamination incident (p. 320-1, 1983). Excess annual mortality due to groundwater contamination among the exposed population is used as an estimate of the value of the health effects of groundwater contamination. The value attached to each excess death is derived from a range of values specified in the value of a statistical life literature (p. 324, 1983).

CHAPTER 3

GROUNDWATER RISK PERCEPTIONS IN ECONOMIC VALUATION

The theoretical framework developed in the previous chapter identified three elements of a choice situation under risk: (a) the outcomes that might occur, v_P, v_O, and v_E; (b) the probability that these outcomes will occur; and (c) the ability on the part of the household to affect the outcome and probability (in this case the payment of t^*). These three elements are similar to what Rescher identifies as the elements of a risky situation (1984).

An important implication is that household perceptions of the probabilities and outcomes in a groundwater risk situation may be significant determinants of the benefits associated with groundwater pollution policies. The importance of perceptions in affecting economic behavior has been documented in psychological research, which has shown that typical citizens are unlikely to perceive risk in the abstract terms of an economic model (e.g.: Tversky and Kahneman, 1981; Slovic et al., 1984; Slovic, 1987). Households appear to view both probabilities and utility outcomes in terms of a multi-dimensional set of descriptors. Households are also likely to vary in their risk perceptions. Consequently, to elicit policy values that are accurate reflections of consumer preferences, it is necessary to find ways to specify probabilities and outcomes in terms that are meaningful to ordinary citizens .

The objective of this chapter is to examine the likely relationships between risk perceptions and willingness to pay for groundwater pollution policies. To develop the rationale for an explicit consideration of risk perceptions in policy valuation, the chapter is organized as follows: (a) three empirical studies dealing with risk perceptions (Fischhoff et al., 1978, Gardner et al., 1982, Kraus and Slovic, 1988) are examined; (b) the implications of the empirical work for policy valuation are addressed; and (c) risk descriptors and their hypothesized relationship to individuals' willingness to pay for groundwater protection policies are specified.

Risk Perception Studies

Three risk perception studies are discussed as to their general methodology and findings regarding the empirical significance of qualitative risk descriptors.

Fischhoff et al.

Fischhoff et al. (1978) developed a psychometric study of attitudes towards technological risk. Seventy-six members of the League of Women Voters were asked to make quantitative judgements concerning perceived risk, perceived benefit and acceptable risk for 30 different activities and technologies. The responses were used to see if any systematic relationship existed between perceived risk, perceived benefit and acceptable risk.

Nine risk descriptors were studied. According to Fischhoff et al., each of these risk descriptors had been hypothesized in previous studies (e.g., Lowrance, 1976) as influencing risk perceptions. The risk descriptors included (1) voluntariness, (2) immediacy of effect, (3) scientific knowledge about risk, (4) exposed knowledge about risk, (5) control over risk, (6) newness, (7) chronic-catastrophic, (8) common-dread, and

(9) severity of consequences. Participants rated the 30 activities and technologies on each of these nine descriptors. The risk descriptors were rated on a scale of 1 to 7, with the end points representing extremes on a continuum. For example, 1 on the scale for voluntariness was labelled "voluntary" and 7 was labelled "involuntary" (Fischhoff et al., 1978, p. 133).

Means were calculated for each risk descriptor for each technology. In a sense, there were 30 observations (each technology being an "observation") for each descriptor with each observation being a mean derived from 76 individual responses. The means were used in three ways: (a) to ascertain the correlation (r) between risk descriptors and perceived risk; (b) to find possible underlying dimensions of risk through factor analysis; and (c) specifying perceived risk as a function of perceived benefits and risk descriptors, and analyzing this relationship using regression analysis.

Correlation with perceived risk. Only two descriptors were significantly correlated (r) with perceived risk, common/dread and severity of consequences, with correlations of 0.64 and 0.67 respectively. A number of risk descriptors were intercorrelated. For example, voluntariness was significantly correlated with seven other risk descriptors (r coefficients ranging from .54 to .76), and newness was significantly correlated with five risk descriptors (r coefficients from .53 to .83). The degree of intercorrelation indicated that they could potentially be represented by a few underlying dimensions.

Factor analysis. A principal components factor analysis was completed for the nine risk descriptors. Two underlying variables were identified (loadings in parentheses). Factor 1 is identified as representing technological risk. It included voluntariness (.89); immediacy (.70); knowledge of exposed (.88); knowledge of science (.88); control (-.83); new (-.87); chronic (.62); and common (.67). This factor is "associated with new, involuntary, highly, technological [hazards], which have delayed consequences for masses of people" (p. 147). An example would be nuclear power. The second factor represents severity, and includes chronic (.55); common (.60); and severity (.91). This factor is correlated with familiar hazards whose consequences are likely to be fatal, such as general aviation and hand guns. These two factor variables accounted for 80 percent of the total variability.

Regression analysis. The next step analyzed the relationship between perceived risk and possible explanatory variables including perceived benefits and factors 1 and 2. Estimated coefficients for the independent variables were not given, but the variables as a group were significant (multiple R score of .67 and F=6.96 significant at the .005 level.

Gardner et al.

While the Fischhoff et al. approach elicits mean risk descriptor judgements across 30 different technologies, two other studies look at a single technological risk and elicit individual risk descriptor responses. Gardner et al. (1982) elicit people's risk perceptions towards nuclear power. A component of the study, in a manner similar to Fischhoff et al., addresses individual risk perceptions of nuclear power by eliciting responses to questions on perceived risk and several risk descriptors. Zero order correlations for perceived risk and the risk descriptors dread, catastrophic potential and scientific knowledge were obtained. Perceived risk had a correlation coefficient of .63 with catastrophic potential, .44 with dread, and .33 with scientific knowledge. Gardner et al. conclude that these findings show that "perceived risk ratings correlated with [the risk] characteristics..." (p. 189). Gardner et al. give two reasons to explain the comparatively low coefficients in the study: (a) the use of individual responses to risk questions as opposed to respondent means used in Fischhoff et al.; and (b) the lack of independence between the Fischhoff et al. observations in that risk data for each of the 30 technologies came from the same respondents (p. 191).

Kraus and Slovic

The research by Kraus and Slovic (1988) is comprised of two studies. The first study develops risk perception regression models for six technologies which are compared to previous models using group means and diverse technologies. The second study takes one of these technologies, railroads, and investigates the relationship between perceived risk and risk descriptors using individual responses. Since the second study is comparable to Fischhoff et al., the focus will be on the results of the second study.

For the second study, respondents were asked to rate 49 railroad hazards on seven 11-point scales. One of the scales was overall risk, with 1 = not risky and 11 = extremely risky. Six risk scales similar to those used in Fischhoff et al. were included; voluntariness, societies' knowledge about the risk, control, dreadedness, catastrophic potential, and newness. A principal components analysis of the risk characteristics identified two descriptors representing basic risk dimensions. Factor 1 is identified strongly with voluntariness (.93), control (.90) knowledge (.84) and dread (.76). The second factor is identified strongly with catastrophic potential (.90) and newness (.85).

A correlation matrix showed that overall risk was significantly correlated (r) with the following risk descriptors: Catastrophic potential (.85), newness (.72), and dread (.67). The other risk descriptors, voluntariness, knowledge and control were not significantly correlated.

Implications of the Empirical Work

The studies by Fischhoff et al., Gardner et al., and Kraus and Slovic show that risk descriptors are systematically related to consumer risk perceptions. Although these studies are not directly comparable, since they examine different technologies using different methodology, the fact that certain risk descriptors appear to be significant in each of the studies suggests that risk descriptors may have a significant degree of explanatory power concerning consumer risk perceptions both within and across technologies.

Table 3.1 shows the correlation between risk perceptions and risk descriptors for each of the three studies. The data shows that only one to three descriptors in any one study have correlation coefficients above 0.6 with respect to consumer risk perceptions. These descriptors include severity, dread, catastrophic potential and newness, which are significant components of the two risk dimensions identified by principal components analysis in both Fischhoff et al. and Kraus and Slovic.

Table 3.2 shows the components of each of the two measured risk factors for each study. Severity is a major component of the second factor in Fischhoff et al., dread is an important component of factor 1 for both studies, catastrophic potential is an important component of factor 1 in Fischhoff et al. and factor 2 in Kraus and Slovic, and newness is major component of factor 1 in Fischhoff et al. and in factor 2 in Kraus and Slovic.

Other descriptors may be important components of underlying risk dimensions yet not highly correlated with perceived risk individually. For example, Table 3.2 shows that voluntariness and control are major components of factor 1 for both studies but in neither study are they correlated with perceived risk. This may be explained by the fact that Fischhoff et al. found both voluntariness and control to be highly intercorrelated

Table 3.1 Comparison of Selected Studies Showing Correlation (r) between Risk Perceptions and Risk Factors[1]

Risk Factor	Fischhoff et al.	Gardner et al.	Kraus and Slovic
Seriousness	.67	-	-
Dread/Fear	.64	.44	.67
Catastrophic Potential	.30	.63	.85
Newness	.05	-	.72
Control	-.04	-	-.07
Known to science	-.17	.33	-.03
Known to exposed	-.20	-	-
Immediacy	-.07	-	-
Voluntariness	.08	-	.25

1. Fischoff et al. use perceived risk, defined as "the risk of dying as a consequence of this activity or technology." (p. 131, 1978). Gardner et al. include the risk of injury and illness along with the risk of death (p. 184). Kraus and Slovic use "overall level of risk" which refers to the overall riskiness of a hazard" (p. 447).

Table 3.2 Comparison of Risk Factors Identified by Factor Analysis in Fischhoff et al. (F) and Kraus and Slovic (KS).

Factor 1				Factor 2			
F		KS		F		KS	
Voluntariness	.89	Voluntariness	.93	Seriousness	.91	Catastrophic	.90
Knowledge of exposed	.88	Control	.90	Dread	.60	Newness	.85
Knowledge of scientists	.88	Knowledge (Society)	.84	Catastrophic	.55	Dread	.50
Newness	-.87	Dread	.76	Immediacy	-.45	Knowledge	-.34
Control	-.83	Catastrophic	-.22	Knowledge of exposed	-.39	Control	-.20
Immediacy	.70	Newness	-.20	Scientific knowledge	-.28	Voluntariness	.07
Dread	.67			Control	-.24		
Catastrophic	.62			Newness	.14		
Seriousness	.11			Voluntariness	.03		

with other risk descriptors. Voluntariness was found to be significantly correlated with seven other risk descriptors while control was significantly correlated with six. Consequently, these risk descriptors, and perhaps others, may not be individually correlated with risk perceptions but may be so as part of a group of risk descriptors.

The studies suggest that an explicit consideration of risk descriptors may be beneficial in the valuation of groundwater protection policies. As the above studies suggest, risk descriptors, either individually or in a group, potentially affect risk perceptions. To the extent that willingness to pay is affected by risk perceptions, risk descriptors may help explain the variation in individual wtp for groundwater protection policies.

The idea that risk descriptors are systematically representative of risk perceptions and are economically meaningful will be developed by specifying that risk perceptions can be represented by specific risk descriptors, which are conceptually similar to concepts that are characteristic of an economic choice situation, specifically, the outcome and the likelihood of the outcome occurring. The objective is to show that the subjective perception of these two elements within the context of specific risk descriptors will be affect wtp in a predictable or testable manner.

Descriptors Associated with Perceptions of Choice

Consumer perceptions of the degree of choice available when confronted with potential or actual exposure to groundwater pollution may affect their overall risk perceptions of groundwater pollution. Two characteristics of choice are: (a) voluntariness, the extent to which people voluntarily expose themselves to risk; and (b) control, the ability to reduce or eliminate damages once pollution has occurred.

This section examines choice descriptors identified by Fischhoff et al. (1978). Hypotheses will be derived concerning the relationship between these descriptors and wtp.

Voluntariness

Fischhoff et al. (1978) asked respondents to assess an activity or technology in terms of its voluntariness. Respondent's were asked the question (p. 131), "Do people get into these situations voluntarily?" A dictionary definition of voluntary is free to choose (Webster's New World Dictionary, 3rd College Edition, 1988). For the present discussion, this implies that an individual only submits to risk if, on the whole, the benefits outweigh the costs.

In one sense, voluntariness may be negatively correlated with wtp since there is no need to expose oneself to voluntary risk unless one is made better off by it. On the other hand, if one is exposed to involuntary risk, by definition this implies that based on their own preferences, individuals would have chosen not to be exposed to the risk. However, whether a consumer is better or worse off depends on how they perceive the resultant level of risk. Even if exposure to the risk is involuntary, if the marginal benefits of the risk level are perceived to be greater than the marginal costs, consumers may not be willing to pay for a risk reducing policy. In this case, increased perceptions of involuntariness are negatively correlated with wtp for risk reducing policies. Alternatively, if the marginal costs of the involuntary exposure to risk are perceived to be greater than the benefits, perceptions of involuntariness will be positively correlated with wtp for risk reducing policies. In general, the relationship between perceptions of involuntariness and wtp will be ambiguous.

Control

Control refers to the ability to affect the probability of a detrimental event occurring given continued exposure. Fischhoff et al. (1978) ask respondents "if you are exposed to the risk of each activity or technology, to what extent can you, by personal skill or diligence, avoid death while engaging in the activity?" (p. 133). Alternatively, control is the technical feasibility of personally controlling the level of health risk one is exposed to. In one sense, controllability from the perspective of the household is likely to be associated with cost. High likelihood of controllability can be associated with perceptions that given reductions in risk can be achieved at relatively low cost. Perceptions that groundwater pollution is relatively uncontrollable at the household level are likely to be associated with perceptions of the high cost of household action to reduce risk. Consequently, perceptions of high costs associated with individual household action motivate perceptions of uncontrollability. As perceptions of uncontrollability increase, wtp for groundwater pollution policies (collective action) increase. Alternatively, as perceptions of controllability (low perceived cost of household action) increase, policy wtp decreases.

Descriptors Representing Knowledge

Knowledge descriptors can be categorized as two types: (a) descriptors which are representative of the degree to which scientific experts and exposed individuals are knowledgeable about the risks from a specific technology, and (b) the degree to which society is experienced with a risk.

Knowledge

Knowledge refers to both the knowledge exposed individuals have about the risks they face and scientific knowledge about the risk. Fischhoff et al. (1978) ask respondents, "To what extent are risks known precisely by the persons who are exposed to the risks?" and "To what extent are the risks known to science?" (p. 133).

One definition of knowledge is the fact or condition of knowing something with familiarity gained through experience or association (Webster's New World Dictionary, 3rd College Edition, 1988). Knowledge in the psychological literature appears to mean how well the individual knows the full dimensions of risky situation. If they know it well, it is understood and the distribution of outcomes and likelihoods is known with some certainty. A risk is not well known if the distribution of outcomes and likelihoods is very uncertain.

An individual's degree of knowledge about the risks from a specific activity will influence optimal risk levels. The more knowledge possessed by exposed individuals the greater the probability they will make choices consistent with their preferences. For example, suppose a consumer can influence mortality probability by taking some level of action α. To the extent possible, individuals choose a level of α which maximizes their welfare. The level of α chosen directly corresponds with a given level of optimal risk. The greater the knowledge, the more likely the chosen level of α, say α^O, will approach the utility maximizing level of α with full information, α^1. With full information, $\alpha^O = \alpha^1$. With less or more uncertain knowledge, the probability that α is less than or greater than α^1 increases. In this case, the maximized utility level when α^O does not equal α^1 will be less then when the equality holds.

Perceptions of scientific knowledge about health risks from groundwater pollution may also affect risk perceptions. However, it is unclear whether the relationship between scientific knowledge and wtp is positive or negative. The relationship will be negative if people perceive that the scientific community has little knowledge concerning the extent, magnitude or cause of groundwater pollution, they may have a significant wtp for groundwater protection policies. Alternatively, the relationship will be positive if people believe that little knowledge on the part of the scientific community will translate into ineffective policies. If such is the case, then wtp would decrease.

Newness

Newness refers to how long society has known about a particular risk and how much experience society has with it (Kraus and Slovic, 1988). Fischhoff et al. (1978) ask respondent's "Are these risks, new novel ones or old familiar ones?" (p. 133). Newness is conceptually similar to knowledge in that it represents perceptions of the degree or depth of experience with a given risk. The greater the perceived experience, the greater the likelihood that society has learned to "live with" a particular risk in the sense that (a) its causes are known, (b) people know when they are at risk, and (c) people can take action to prevent or eliminate potential damage from exposure. Consequently, the greater groundwater pollution risk is perceived to be a new risk, the higher the wtp for groundwater protection policies.

Descriptors Associated with Severity of Outcome

If groundwater pollution occurs, there is some positive probability that exposure will occur. If exposure occurs and damage results, peoples' perception of the severity of the damages will influence their overall level of perceived risk. Descriptors included in this category include: (a) seriousness of outcome, (b) immediacy of outcome, (c) catastrophic potential, and (d) dread/fear.

Seriousness of Outcome

Seriousness of outcome refers to the individuals perception of the health outcome of exposure to groundwater pollution. Fischhoff et al. ask respondents "When the risk from the activity is realized in the form of a mishap or illness, how likely is it that the consequences will be fatal?" (p. 133).

Conceptually, seriousness of outcome can be represented by a continuous scale with "no health effects" on one end and "death" on the other. The utility associated with the exposure state, v_H, will be a function of the perceived seriousness of the exposure outcome. The more serious the perceived outcome, the lower the utility associated with the state of exposure.

Immediacy of Health Effects

Immediacy of effect refers to whether the effects of exposure are immediate or delayed. Fischhoff et al. ask respondents "To what extent is the risk of death immediate, or is death likely to occur at some later time?" (p. 133).

Perceptions of immediacy may affect perceived marginal benefit derived from a groundwater policy. For example, the consumer maximizes expected utility by choosing a level of payment that equates the MB of a reduction in π with the marginal costs of obtaining that reduction. In comparing two risk situations, suppose that two risks are identical in terms of probabilities and outcomes except that, with exposure, death occurs in time period t for one risk and time period t + 1 in the other. The present value of MB for a given discount rate r for the two risks are $MB/(1+r)^t$ and $MB/(1+r)^{t+1}$, respectively. The present value of the MB of a reduction in risk is higher the sooner death occurs. In policy terms, this implies that the benefits of avoiding a death is greater in time t than in t + 1. The preferred level of risk associated with t will be lower in comparison with the level of preferred risk associated with death occurring further in the future at time t + 1. The more immediate the health effects, the lower the utility associated with the exposed state.

Catastrophic Potential

Catastrophic is defined as having the character of a momentous tragic event ranging from extreme misfortune to utter overthrow or ruin (Webster's New World Dictionary, 3rd College Edition, 1988). Fischhoff et al. ask respondent's "Is this a risk that kills people one at a time or a risk that kills large numbers of people at once [catastrophic]?" (p. 133).

Household perceptions of groundwater pollution exposure having catastrophic consequences is similar to believing that the occurrence of a pollution episode results in multiple exposures. Regardless of whether it is believed that the health effects of such exposures are manifested as illness or death, perceptions of pollution exposure as catastrophic entail perceptions of a number of households affected, as opposed to a single affected household. In this case, as catastrophic perceptions increase, the utility associated with the state of exposure decreases.

Fear/Dread

Dread is defined as intense fear, especially of something that may happen (Webster's New World Dictionary, 3rd College edition, 1988). Fischhoff et al. ask respondents, "Is it a risk that people can think about reasonably calmly, or is it one that people have a great dread for?"(p. 133).

It has been previously noted that knowledge, newness, control and voluntariness affect optimal risk. Fear/dread may in part be comprised of these descriptors in the sense that an individual's perceived degree of dread with respect to a given activity may be related to their judgement of the risk as: (a) new, (b) a great deal of uncertainty associated with the risk, (c) little or no control, and (d) being exposed involuntarily. If the concept of dread is associated with these descriptors, then dread would affect acceptable risk and wtp.

Summary of Risk Descriptor and WTP Hypotheses

Table 3.3 summarizes the hypotheses developed in this section which address the relationship between risk descriptors and consumer wtp for risk reducing policies. The hypothesis regarding the choice descriptors voluntariness and control is ambiguous since wtp will depend on the perceived benefits and costs of risk exposure characterized by degrees of voluntariness and controllability.

The direction of the relationship between knowledge risk descriptors and wtp depends on what consumers associate with a perceived lack of knowledge. A perceived lack of knowledge with respect to the health effects of exposure to groundwater pollution may be associated with the need for a "better safe than sorry" approach. In essence, groundwater pollution should be addressed, even though knowledge regarding health effects is perceived to be low, just in case future information shows health effects to be significant. Alternatively, if the perceived lack of knowledge is associated with the inability to design and implement a successful policy, then perceptions of knowledge will be positively correlated with wtp.

The hypothesis regarding severity descriptors and wtp is unambiguous; as perceived severity increases, wtp for risk reducing policies decrease.

Table 3.3. Summary of Factor Hypotheses

Factor	Description	Hypothesis
1. Choice	Includes: a) voluntariness: the extent to which individuals freely choose to be exposed to risk; and b) control: the ability to affect the probability of a detrimental event occurring given continued exposure.	a. If perceived mc exceeds mb of involuntary exposure, the greater the perceived involuntariness the higher the wtp. b. If perceived mb exceeds mc, ambiguous association.
2. Knowledge	Includes: a) scientific knowledge of the health risks of exposure; b) knowledge of exposed individuals of health risks of exposure; c) newness, how long society has known about a risk and how much experience it dealing with it.	a1. Perceptions of degree of knowledge are negatively correlated with wtp: As perceptions of lack of knowledge increase, wtp increases. a2. If perceived lack of knowledge is associated with the unlikelihood of a successful policy, then perceptions of the degree of knowledge are positively correlated with wtp: as perceptions of the degree of knowledge increase, wtp increases.
3. Severity	Includes: a) seriousness of outcome; b) immediacy of health effects; c) catastrophic potential; and d) fear/dread.	a. Perceptions of severity are positively correlated with wtp: As perceived severity increases, wtp increases.

CHAPTER 4

CONTINGENT VALUATION DESIGN AND PROCEDURES

This chapter develops a contingent valuation (CV) survey to elicit necessary information to test the relationship between household perceptions and wtp for groundwater pollution policies. The chapter will outline and explain the development of a questionnaire using information obtained in a series of focus groups and pretests.

Development of a Contingent Valuation Questionnaire

The goal of the empirical study is to obtain information on the tradeoffs individuals are willing to make, in order to reduce the threat of groundwater pollution. A contingent valuation mail survey for obtaining economic information on groundwater pollution policies was used for the dissertation research. A major advantage of using contingent valuation is the ability to present consumers with a choice situation that directly focuses on a particular value (or set of values) of interest (Cummings et al., 1986). This attribute is of particular importance in situations where markets for the commodity of interest either do not exist, or are poorly developed (Bishop and Herberlein, 1979).

The usefulness of a contingent valuation survey in the policy evaluation process depends on the extent to which the survey is constructed, to have a reasonable degree of success in obtaining accurate valuation information. The next section will discuss the development of a CV questionnaire on groundwater pollution in terms of its component parts.

The Use of Focus Groups in CV Questionnaire Development

A series of focus group sessions were organized to assist in the development of a questionnaire effective in representing the choice context to consumers. An in-person pretest and mail pretest evaluated the questionnaire for comprehension, clarity, and relevance. The following sections will address the objectives, development, format and general findings of these sessions.

Focus Group Objectives

The focus group sessions had two objectives. The primary objective was generally to explore the topic of groundwater pollution with consumers, focusing on (a) how individuals perceived groundwater pollution and (b) the type of vocabulary consumers used in thinking about and discussing the issue (Fischhoff and Furby, 1988).

The second objective was to present participants with alternative policy descriptions and costs to elicit their reaction and criticism. Using the information gained from the focus groups, a mail contingent valuation survey was developed and refined. This approach was undertaken in order to construct a survey which was understandable and convenient to answer, yet of sufficient detail to elicit required information to test the hypotheses developed in Chapters 2 and 3.

Focus Group Development

Four sessions were held over a three week period in April, 1990. Two-hour sessions were held on 11 April and 19 April, 1990. Two two-hour sessions were held simultaneously on 24 April, 1990. Potential participants were contacted by dialing random computer generated telephone numbers for the Williamston, Michigan area. This area was chosen because of its dependence on groundwater, its proximity to the campus of MSU, and its combination of suburban, rural and farming demographics.

The caller was identified as a researcher at Michigan State University who was working on a project that dealt with social issues (environmental issues for the 19 April session) currently faced by Michigan citizens. A prepared script was read to the individual, who was then invited to attend a meeting at Michigan State University, where each would have an opportunity to express his or her opinion about these issues. Individuals would be paid $50 to attend (See Appendix E for text of phone script.).

For the 11 April session, a total of 308 calls were made to obtain 10 participants. Of the total number of calls, 137 (44.4 percent) were valid numbers, including both residential and commercial numbers. Of the valid numbers, 61 (44.5 percent) answered. Of people contacted, 10 (16.3 percent) agreed to take part in the focus group session.

For the second session on 19 April, a total of 127 calls were made. Of these, 61 (47.7 percent) were valid numbers. Of the valid numbers, 31 (50.8 percent) answered. Of those contacted, 10 (32.3 percent) accepted.

For the third and fourth sessions on 24 April, a total of 228 calls were made. Of these calls, 98 (42.9 percent) were valid. Of the valid numbers, 40 (40.8 percent) answered. Of those that answered, 10 (25 percent) accepted.

Focus Group Session Format

The focus group sessions were held at the Kellogg Center, a conference center on the Michigan State University campus. Participation of respondents who agreed to come was 100 percent (one person brought his spouse). The sessions typically lasted two hours with a 10- minute break at the end of the first hour.

The sessions were structured so that participants' perceptions and opinions regarding groundwater and groundwater pollution were elicited in a systematic and comprehensive manner. The topics consisted of: a) ranking of social issues (11 April and 24 April sessions only), b) ranking of environmental issues, c) general perceptions of the physical characteristics of groundwater, d) perceptions of groundwater pollution, e) assessment of groundwater pollution effects, f) prevention of pollution effects, g) perceptions of the mortality risk from groundwater pollution, and h) risk factor assessment. This last component entailed the participant's subjective assessment of groundwater pollution risk in terms of the psychological risk characteristics examined in Chapter 3.

The above components were addressed by asking the group a set of specific questions dealing with that particular component. Typically, the discussions were wide ranging and enthusiastic. The purpose of the session was to obtain information on people's perceptions and ways of thinking about groundwater and groundwater pollution. It is likely that for most people, the topic is one which they have not often thought about in detail, and with which they have little direct experience. Open and free discussion was encouraged.

General Findings

A variety of opinions and perceptions were brought forth, which proved to be very useful in designing an appropriate questionnaire. General findings from the sessions can be summarized as follows: a) a wide variation exists in knowledge about groundwater and groundwater pollution, b) groundwater perceptions are sensitive to the wording used to describe the problem, c) there is a large variation in underlying values regarding groundwater, and d) the strength of people's prior beliefs concerning groundwater pollution and policies has important implications for policy development.

Groundwater Knowledge

The focus groups show a wide variation in people's knowledge about groundwater and groundwater pollution. The initial portion of each session was devoted to eliciting their thoughts about groundwater, groundwater pollution, effects of groundwater pollution and prevention of effects.

Definition of groundwater. Most people were at least superficially familiar with the concept of groundwater. The descriptive nature of the term was helpful, for as one participant put it, "It means the water in the ground. It's sort of obvious." People generally agreed that groundwater is water in the ground that can usually be pumped to the surface and used as a source of fresh water. However, when more specific questions were asked, the responses varied.

For example, some individuals thought that groundwater existed within 18-20 feet of the surface. Others said that depth does not really matter; whether it is just a few feet or hundreds of feet it is still groundwater.

Opinions also varied concerning the rate of flow of groundwater. Some individuals said that groundwater is essentially like a pond; that it accumulates in a particular area and moves very slowly or not at all. Most concurred that groundwater does move, but slowly, such as "I think it's just the underground water in pools ... that moves slowly through the earth."

Consistently throughout the sessions, groundwater was thought of as water in the ground available for human use. The following comments were typical: a) "To me it means any of the water that's available that you can pull up to use either for irrigation or for drinking"; b) "Water that you pump; either the city does or you pump personally out of a well to drink and for the basics of living"; and c) "I think it's just the underground water in pools ... that moves slowly through the earth. That's my vision of it and with wells tapping into the underground reservoirs."

It is clear that most people have not given much thought to groundwater, nor do they have precise knowledge about its physical attributes, even those who rely on their own wells for water. One person explained, "Water must run under the ground but I never thought about it before. I always thought it was a lake down there that my well went into. I just keep sucking it up and don't think about it."

Groundwater pollution. People were asked about sources of pollution and how common groundwater pollution is in Michigan. The most frequently mentioned sources include industrial and manufacturing waste products, household lawn and garden chemicals, agricultural chemicals, underground water storage tanks for gasoline and oil, salt storage areas for road de-icing, dumping of used motor oil, and septic tanks. There was great variation in perceptions of how common groundwater pollution is. Some individuals thought groundwater pollution is common in urban areas due to the degree of development and manufacturing, but relatively uncommon in rural areas. Others thought that rural areas are worse because of the extent of lawn and garden and agricultural chemical use.

No general consensus was reached on how extensive the pollution problem is, but most people feel that the problem is getting worse. A representative sentiment is, "...I'll tell you one thing, I don't know how rare or common it is but I'll tell you one thing I know, it's getting commoner and commoner."

Effects of groundwater pollution. The most frequently cited adverse health effect of exposure to chemical groundwater pollution is cancer. Others frequently mentioned are birth defects, miscarriages, and liver and kidney disease. Several participants stated they did not know what the health effects might be.

When asked how common death from groundwater pollution is, the majority of people said death is an uncommon occurrence. Non-fatal health effects are judged to be relatively more common. However, several individuals believe that health effects from groundwater pollution were rare. For example, one person stated, "I think it would be rare [death] because I think the system basically is monitored enough where if something is that serious to cause death that ... it is brought to the public's attention and something is done about it." A different person had a similar viewpoint, "I don't know that I really believe that there is a lot of adverse health effects from groundwater contamination. Further, I think if there is groundwater contamination it tends to be pretty local and it is not a widespread thing."

Prevention of groundwater pollution effects. The focus in this portion of the session concerned the type of actions that could be taken to prevent negative effects of groundwater pollution and what the appropriate role and level of government is. A majority of the participants mentioned increased monitoring and information programs about groundwater pollution. A number of people want increased enforcement of existing laws, especially with regard to large industrial sources of pollution. However, quite a few are skeptical of whether the necessary funds would be available.

Most people think the emphasis should be on the prevention of groundwater pollution. To understand how people think about remedial policies, the topic of point-of-use filtration systems was brought up by the focus group leader. This idea received little support because few people think filters would be effective in removing contaminants from the water.

Most people seem to favor state or county governments for the implementation and administration of groundwater pollution policies. As one person who favors state government put it, "Local government doesn't care and the feds are too far away." Most of the support for state or county involvement is due to the perception that state agencies: (a) are familiar enough with the specifics of a particular problem to be effective; (b) are capable of having a sufficient budget to address the problem; and (c) have the required technical expertise. Local government is perceived to be lacking (b) and (c) and the federal government is lacking (a).

Sensitivity to Wording

During the course of the focus group sessions people were asked if the terms "contamination" and "pollution" have similar or different meanings. A slight majority felt that they have different meanings. The rest indicated that the terms meant more or less the same thing. Overall, the term pollution has a more general, less severe connotation. Generally, polluted groundwater is thought of as still being usable; that chemicals might be present in the groundwater but the water is still usable, if not for drinking at least for other non-consumptive uses. Contamination is perceived to mean that the water is unfit for any use. The following comments are typical: a) "When you think of something contaminated, you can't use it"; b) "When it gets to the degree that you can't use it anymore, then it's contaminated"; c) "If something is just polluted I would think ... how polluted is it? Is it still safe to drink? When I hear the word contaminated I would say no, you can't use it without some way of purifying it or doing something to it"; and d) "I guess pollution to me is something that's polluted. It's being overwhelmed by something that's not natural to it and it may or may not necessarily result in contamination per se. Contamination to me would be something that I don't want to have any contact with because it will be harmful to me. Pollution doesn't necessarily do that for me..."

Variation in Underlying Groundwater Values

Chapter 2 describes various uses of groundwater and how people might conceivably be affected by its pollution. The focus groups showed that everyone is concerned about the health effects of groundwater pollution on their own household. Additionally, most seem to be concerned about their community at large and future generations. The importance of other groundwater services varies greatly across participants.

A number of people were concerned about the impact of pollution on animals and plants. It is apparent that most were not aware of the potential for groundwater pollution to affect plants and wildlife. However, during ensuing discussions, participants talked of their concern over the potential impact of groundwater pollution on plants and wildlife.

Less prevalent, but still significant were people's concern over what might be termed "system integrity." System integrity has two components. One is the ecosystem where people value the knowledge that the components of an ecosystem are unpolluted, completely aside from any current or future use. The other component is that the act of polluting violates a person's moral system of values, completely aside from any damage that actually occurs. For example, one person stated, "Making any part [of the ecosystem] worse, there is really no reason for us to do that. We should try to at least, if we can't make it better, to keep it as good as it is now." Another person stated, "It really doesn't matter if anything is harmed or not, people shouldn't be allowed to pollute." In response to this statement, another person added, "Well, I'm not ready to give away an entire years' paycheck just so that some pollution which isn't harming anything can be cleaned up. But I think that within some reasonable limit pollution shouldn't be allowed even if there is no apparent effect on anything." In other words, it is simply wrong to pollute.

The discussions in the focus groups did not directly address the question of protecting groundwater for its own sake, to the extent that this means something different from pollution's effects on animals and wildlife and system integrity. This is not to say that intrinsic groundwater services are not important, rather that it appears difficult to separate the intrinsic groundwater services from ecological system services provided from groundwater.

To summarize, the level of concern over different groundwater values, from most common to least common, is: (a) health of own household, (b) their own community at large, (c) future generations, (d) animals and wildlife, (e) system integrity, and (f) groundwater itself.

Strength of Prior Beliefs

People's prior beliefs may affect how policy services and effectiveness are perceived, and in turn how the policy is valued. A major hypothesis of the research is that non-health groundwater values are a significant component of the total value people place on groundwater services.

Three general policies were initially hypothesized to be of relevance to Michigan; information, monitoring and enforcement. Information refers to the generation of scientific information on the extent, magnitude and characteristics of groundwater pollution in Michigan. Monitoring refers to the sampling and chemical analysis of groundwater used for consumption (private and public wells) and aquifers adjacent or close to known or suspected sources of pollution. Enforcement refers to regulatory programs to prevent exposure to pollution and to prevent the occurrence of groundwater pollution.

The initial specification of these policies reflected: a) policies which were being considered both by Michigan and other states (State of Michigan 1987, 1988 and Henderson et al., 1987) and b) previous research studies on alternative policies for addressing groundwater pollution (Pye et al., 1987 and Libby and Kovan, 1986).

The initial hypotheses about relevant groundwater policies for Michigan were strengthened in the focus groups. A significant number of people are supportive of monitoring programs and obtaining more precise information on groundwater problems in Michigan. Support is less widespread for regulatory programs. A number of people think regulation should be a major part of any type of groundwater policy while others are not convinced that it is necessary until more scientific information is obtained. Still others think there is no need for any type of program at the present time. Reasons given are: (a) not wanting their tax bills to increase for any reason and (b) the existence of more urgent problems than groundwater pollution on which to spend tax dollars.

A previous section discussed perceptions of the appropriate role and level of government to address groundwater pollution problems. It was found in the focus groups that while there might be a high degree of support for a particular policy, individual perceptions vary as to how effective federal, state, and local governments would be in implementing the policy. For example, some people felt that laws might be enacted but not implemented because of budgetary constraints. Others questioned the expertise or motivation of the level of government responsible for the policy. For some individuals these perceptions were true for all levels of government, while for others certain levels of government (e.g. local) evoked different perceptions of effectiveness. Consequently, the questionnaire was explicitly designed to account for individual's prior beliefs about program effectiveness.

Contingent Valuation Survey Format

Hoehn (1987) identifies the objective of a contingent valuation format as "... to set up an exchange situation in which an individual may price policy impacts" (p. 412). The design of such a format involves consideration of five components: (1) presentation medium; (2) description of policy impacts; (3) method of provision; (4) method of payment; and (5) value elicitation (Hoehn 1987, p. 413).

Presentation Medium

Presentation medium refers to the manner in which responses are obtained from survey participants. Three general methods are used: personal interviews, telephone interviews and mail surveys. Mitchell and Carson (1989) identify three characteristics which should influence the choice of survey method (p. 109). First, the more complex and unfamiliar the valuation scenario, the more important it is to provide photographs, charts and other types of visual references. Second, asking respondents to place values on policies places a high demand on their attentiveness to the survey. It is important to choose a method which can motivate people to make the necessary effort. Finally,

> "...the need to extrapolate from the sample to make benefit estimates for populations necessitates the use of survey methods which support techniques to compensate for missing data." (p. 109).

Based on these criteria, the in-person interview would be the method of choice, other things equal. The face-to-face interview allows for the answering of questions and the use of visual aids to help respondents understand complex valuation scenarios. It also allows for respondent-interviewer interaction which may help motivate respondents. Finally, in-person interviews support missing data techniques (p. 110).

A significant drawback to in-person interviews is the expense. For a given cost, much larger sample sizes can be drawn with mail and telephone surveys. Consequently, a trade-off exists between choosing a survey method which has the desirable characteristics and cost. However, Mitchell and Carson (1989) and Dillman (1978) note that well designed mail surveys perform adequately compared with in-person interviews. In addition, mail surveys have the added benefit of reduced cost for a given sample size or an increased sample size for a given cost (and increased degrees of freedom for statistical analysis). An additional reason to consider mail surveys is that due to the comparatively low cost, sample sizes can be chosen on the basis of research needs instead of strictly in terms of cost considerations (Dillman, 1978).

The focus groups were beneficial in identifying ways for the potential weaknesses of a mail survey to be overcome. First, mail surveys limit the amount of information that can be conveyed to respondents. However, one of the objectives of the survey was to evoke responses based on an interrogative examination of respondents' prior beliefs. Consequently, a minimum amount of information was needed regarding the method of provision and method of payment. Policy objectives were described but impact measurements were based on respondents' perceptions rather than on a technical projection or expert guess.

Second, mail surveys limit the ability to control the sequencing of information and responses. To address this, the questionnaire was designed to be relatively free of the need for sequencing. There was no need to reveal certain types of information in a sequenced manner. The fact that respondents fill in the risk perception questions would be adequate to ensure that this portion of the questionnaire was considered as part of the overall response.

Third, unfamiliar technical information concerning the valuation scenario may have to be conveyed to respondents. A lack of understanding on their part may result in the need for enumerator assistance. One difficulty in developing the questionnaire is the lack of available information on the extent of groundwater pollution in Michigan. This was dealt with by basing the valuation on people's prior beliefs rather than including a lengthy explanation of available information, its strengths and weaknesses. This approach fits: a) the lack of consensus among scientific experts regarding extent and effects of groundwater pollution; b) constraints that are typical of mail surveys that limit the amount of information given to respondents; and c) the likelihood that choice of policy (e.g., information, monitoring, and enforcement) will, in fact, be based on widely varying perceptions rather than a consensus.

Finally, since contingent values are to be conditioned primarily on prior knowledge, a major portion of the questionnaire is designed to conduct people through their beliefs in a Socratic manner. This interrogative method encourages respondents to think through various aspects of the groundwater pollution problem based on perceptions, and also elicits responses to questions that serve as independent variables in the analysis of CV responses. To address this, the questionnaire was designed so that the conveyance of complex information was not required. Questions and wording were carefully checked in the focus group sessions and in pre-tests. Focus group and pre-test participants were debriefed for any doubts, questions, and negative responses.

Fourth, in mail surveys there is a lack of control over non-responses. However, there is a trade-off in forcing a response versus eliciting a response. An in-person survey may allow the enumerator to obtain a response after several iterations but this may result in an answer being given just for the sake of giving an answer, as opposed to being truly indicative of a respondent's preferences. A mail survey may result in a greater number of non-responses, but those that are answered likely reflect the respondents' true preferences. The focus groups were used to evaluate survey questions for comprehension and to identify questions that were perceived to be trivial or difficult.

Fifth, mail surveys suffer from biased sampling and low response rates. In response, the mail survey sample was obtained from an extensive statewide database on Michigan households developed by a marketing research firm. The firm did a systematic sample of the population of Michigan heads of household who were listed in telephone directories and auto registration records. Since a significant number of households are not listed in telephone directories, the use of auto registration records results in a significant number of households being contacted that would not have been otherwise.

To address low response rates, the total design method of mail surveys was used (Dillman, 1978). This method essentially entails the use of a variety of techniques in the development, printing and mailing out of questionnaires to minimize item non-response and maximize the likelihood that surveys will returned.

Description of Policy Impacts

This component provides the respondent with a description of the potential impacts of a given policy. It is the respondents' only direct source of information about the valuation situation they face. As such, if the description is incomplete, misleading, or inconsistent with actual alternatives, inaccurate valuations may result (Hoehn, 1987). Hoehn (1987) states that "The challenge is to develop a policy description that is both technically accurate and intelligible in terms of routine experience" (p. 413).

A major reason for concern over groundwater pollution is the potential effect on human health (State of Michigan 1987, 1988, Pye et al., 1987, and Henderson et al., 1987). Chapter 2 identified two general types of policies which address groundwater pollution; preventive and remedial policies. Preventive policies affect both health and non-health values from groundwater pollution where remedial policies affect only health values. Initially, both types of policies were included in the valuation scenario presented to respondents in anticipation that the difference in value (if any) between a preventive and remedial policy would be attributable to the value which individuals placed on the non-health aspects of groundwater use. More specifically, define wtp^P as willingness to pay for a prevention policy and wtp^R as willingness to pay for a remedial policy. If wtp^P = f(health services, non-health services) and wtp^R = f(health services), then (wtp^P-wtp^R) is the value of the non-health services of groundwater.

The accuracy of the term (wtp^P -wtp^R) in representing the value of non-health groundwater services depends on the ability of the questionnaire to convey sufficient information on the alternative impacts of the two policies. However, in the focus group sessions, it was discovered that individuals have difficulty attributing non-health impacts to prevention policies. People have difficulty making a link between non-health values and the policy impacts of prevention policies. However, in a different context, non-health impacts were found to be of significant importance to a number of individuals. Consequently, non-health values could not be reliably estimated by inferring such values only from the wtp estimates for preventive and remedial policies.

One alternative method for evoking getting at non-health values is to simply ask individuals about their wtp for a policy which only affects non-health values. When presented with such a question (which dealt with q-altruism) in the focus groups, most people had difficulty in understanding the purpose or rationale of the policy.

Consequently, variables which measure held values are used as independent variables to infer the impact of these held values on wtp in a CV analysis.

A major objective of the survey was to elicit respondents' perceptions rather than convey a detailed (and perhaps controversial) policy impact description. Therefore, the valuation questions specified what the policy was supposed to achieve and how it was going to achieve it, but did so in a very general manner. This forced individuals to rely on their prior beliefs. In light of this, a relevant set of policies and objectives needed to be developed. The focus groups were an excellent source of information and feedback in developing the set of policies eventually used in the final questionnaire.

Additionally, the questionnaire needed to be structured to obtain relevant perceptions. The set of questions preceding the valuation questions were in part developed with this in mind. The focus groups and in-person pre-test participants provided very useful information in developing these questions.

The Method of Provision

The method of provision refers to the manner in which the policy is implemented (Hoehn, 1987). The particular method of providing the policy may affect the respondent's valuation of the policy. This poses no problem if the purpose of the study is to examine the effect on wtp of alternative methods of provision. However, if this is not the purpose of the study, then measurement bias may be introduced (Mitchell and Carson, 1989). The source of bias is derived from consumer attitudes towards the agency, organization, or level of government responsible for implementing and administering the policy. Other things equal, some organizations may evoke a higher wtp than others. This might be the case if an agency is perceived to be more competent, less wasteful of tax dollars, and more knowledgeable about the issue at hand (Cummings et al., 1986).

Participants in the focus groups indicated that their main concern is the appropriate level of government for policy administration. Concern was expressed over the financial capability and technical expertise of local government to effectively deal with groundwater pollution. Federal government is perceived to have the necessary expertise and finances to effectively deal with the problem, but concerns were voiced over its familiarity with local conditions. In further discussions, people's attitudes about state and county government in general are either neutral or fairly positive in regard to their ability to effectively administer groundwater pollution policies. A specific agency or organization was not specified in developing the policy questions. This was done because the focus groups indicated that the specific agency within a particular level of government is peripheral information from a respondent's point of view, whereas the level of government itself is always a concern.

The Method of Payment

The method of payment refers to the manner in which policy costs are passed on to individuals affected by the policy (Hoehn, 1987). A number of studies have found that the type of payment mechanism employed in a questionnaire can influence wtp (summarized in Cummings et al., 1986, and Mitchell and Carson, 1989). This does not represent a problem if the objective of the study is to examine the effects of alternative payment vehicles on wtp, or if it is known in advance that, if implemented, policy costs will be collected via a specific mechanism. A problem occurs in generalizing the results obtained in a given study to other situations where a different payment vehicle is more appropriate or is less controversial (Mitchell and Carson, 1989). As a result, the recent trend has been to frame the payment mechanism in general terms, such as a general rise in taxes or prices, whichever is more appropriate (Hoehn, 1987, Mitchell and Carson, 1989).

For the groundwater questionnaire, the option of higher taxes was chosen as the method of payment, primarily because it is a way of paying for public policies which is familiar to people. Discussion in the focus groups indicated that there was not an overly negative reaction to higher taxes as a means of paying for a policy. However, this is dependent on perceptions of the need for the policy, whether the policy would actually achieve its objectives, and whether the tax revenue would be applied directly for its intended purposes. A typical comment along these lines is, "If I thought there was an actual need for groundwater protection, I wouldn't mind paying higher taxes [within reason] as long the money isn't wasted on just fattening up the bureaucrats. I want some guarantee that the money will actually be used for groundwater protection."

The questionnaire was designed to address this concern by including questions on: a) the perceived effectiveness of the policies in accomplishing their stated objectives, and b) the importance to the respondent of taxes in answering the policy valuation questions.

Value Elicitation

The value elicitation section is the questionnaire component that obtains value information from respondents (Hoehn, 1987). The appropriate format for the value elicitation section depends primarily on two items (Hoehn, 1987). First, the property rights inherent in the issue under study will affect the value elicitation format. Second, there are a variety of methods for eliciting individual estimates of policy values.

Property rights. The property rights situation will dictate the appropriate Hicksian measure of value to use in the questionnaire. If consumers have entitlement to the initial policy situation, then a Hicksian value measure is required. For the groundwater survey, it is assumed that the initial situation is without policy action--whether this policy action be sampling and monitoring, remedial action, or prevention. If the policy results in improvements from this initial situation, wtp is the proper format. For decrements from this initial situation, wta is the valid format. If consumers do not have property rights to the initial situation, then Hicksian equivalent value measures are appropriate. For an improvement from the initial situation, wta payment to forego the improvement is appropriate. For decrements to the initial situation, wtp to avoid the decrement is the appropriate valuation format (Brookshire et al., 1980).

Hoehn and Randall (1987) define a satisfactory benefit cost indicator as one that "identifies at least a portion of the true PPI [potential pareto improvement] proposals as having positive net value and all non-PPI proposals as having negative net value" (p. 240). The Hicksian compensating value measure is identified as a satisfactory benefit cost indicator for a particular set of CV formats. These formats are differentiated by the costs conveyed to respondents including per capita costs, payments proportional to an individual's own bid and individually parametric costs (pp. 236-237). The Hicksian equivalent measure is shown to be an unreliable indicator (Hoehn, 1987).

The approach taken in the groundwater pollution survey is that individuals have an entitlement to the initial policy situation. Essentially, consumers have a property right to an initial probability of having access to groundwater of adequate quality. The policy valuation estimate in this case is defined to be the wtp to obtain increments in the probability of having future access to unpolluted groundwater. This is a Hicksian compensating value measure and thus is a satisfactory benefit cost indicator as well, given an appropriate elicitation format as discussed above.

Elicitation format. There are two types of elicitation formats: open ended and binary. With open-ended questions, respondents are asked to state their actual maximum wtp or minimum wta for a policy. A binary format asks respondents to accept or reject a given policy cost. For example, policy impacts are described and respondents are asked to accept or reject the policy based on a specific cost. This is typical of the binary choice approach (also referred to as the referendum model [Hoehn and Randall, 1987] and the "take it or leave it" approach [Bishop and Heberlein, 1979,1980]).

Independent Variables

In order to adequately test the hypotheses developed in the previous chapter, a number of independent variables were measured. These variables address a) risk perceptions, b) held values, and c) demographic and water-use characteristics.

Risk Perceptions

Thirteen qualitative risk questions were included in the survey. Respondents were asked ten questions about their subjective assessment of groundwater pollution in the context of risk factors specified in Chapter 3. Testing of these questions in focus group sessions and pretests indicated that the risk factor questions were, in general, both understandable and interpreted correctly by respondents. Each risk factor question has four or five possible responses. Individuals chose the response which most closely represented their own opinion. Discrete answers were provided in order to make the choice process easier for the respondent. In the Fischhoff et al. study, respondents marked their answers on a scale of 1-7, as in the following example:

> If you are exposed to the risk of each activity or technology, to what extent can you, by personal skill or diligence, avoid death while engaging in the activity?

1	2	3	4	5	6	7
uncontrollable						controllable

This question was modified for the groundwater pollution survey as follows:

> If groundwater pollution occurs, do you believe the damage can be controlled through technology? (Circle one.)
>
> 1. EASY TO CONTROL
> 2. POSSIBLE TO CONTROL
> 3. SOMEWHAT POSSIBLE TO CONTROL
> 4. UNLIKELY TO BE CONTROLLED
> 5. NOT POSSIBLE TO BE CONTROLLED

Discussion in the focus groups showed that marking one of several potential responses led to less confusion and potentially higher response rates than asking respondents to mark a point on an interval scale. Since the survey was administered by mail, every effort was made to make the questionnaire straightforward and easy to respond to.

Three of the questions deal with perceptions of water quality in the home and the community. These questions address: (a) consumer perceptions of the safety of tap/faucet water in the home, (b) consumer confidence that tap/faucet water is safe from groundwater pollution, and (c) the seriousness of the health threat from current levels of groundwater pollution in their own county.

The final risk perception question addresses the likely adverse health effects from exposure to groundwater pollution.

Q-altruism and Bequest Perceptions

From the theoretical framework in Chapter 2, it is hypothesized that environmental concerns as embodied in q-altruism and bequest risk have have a differential impact on wtp, depending on whether preventive or remedial policies are being valued. Five questions were used to measure the intensity of concern with respect to these perceptions: (a) the threat of groundwater pollution to future generations, (b) the threat of groundwater pollution to wildlife and plants, (c) whether groundwater should be protected for its own sake or because it is part of a natural system, (d) whether pollution is bad because it is the wrong thing to do or because it has bad effects, and (e) whether other reasons exist to protect groundwater from pollution besides the potential effect on human health.

Demographic and Water-use Characteristics

A number of demographic and water-use characteristics are included as possible explanation for variations in wtp. Demographic variables include: (a) location of home, (b) farming as a source of income, (c) rent or own home, (d) number of people in household, (e) children 16 years or younger in household; (f) age: (g) male or female; (h) last year of school completed, and (i) household income. Water-use characteristics include: (a) household water source, (b) type of water used for drinking, and (c) testing of water.

CHAPTER 5

QUESTIONNAIRE RESPONSES

This chapter discusses the responses to the mail survey. The focus will be on a broad overview of the important questionnaire responses. A detailed summary will be found in various appendices as noted below.

Survey Response Rates

Sample households were mailed up to three questionnaires in order to increase the likelihood that questionnaires would be returned (Dillman 1979). A total of 2020 Michigan households were sent questionnaires. The statewide sample consisted of two subsamples; the urban subsample consisted of 673 households, the rural subsample 1347 households. The rural-urban classification is based on whether a county is in a metropolitan statistical area (MSA) or not. MSA's "are made up of one or more counties around a large population center together with adjacent communities which are socially and economically integrated with the central city" (U.S. Department of Commerce 1988). For the purposes of this study, counties within an MSA are considered urban and counties outside an MSA are considered rural. A total of 173 surveys were returned as undeliverable (9 percent of the total). Consequently, a total of 1847 households received questionnaires.

Returned questionnaires numbered 1229, for a gross response rate of 67 percent. This figure includes all returned questionnaires. Of the total returned questionnaires, 16 were not usable. Nine questionnaires had missing identification labels. Without the ID labels it was not possible to classify the questionnaires as coming from the urban or rural sample. Four questionnaires were returned unanswered. Three questionnaires had responses which indicated the questionnaire was not taken seriously by the respondent. This left a total of 1213 usable questionnaires for a net usable return rate of 66 percent. "Usable" means most of the questionnaire was answered. Appendix C has a more detailed discussion of return rates.

Survey Responses

The questionnaire elicited from respondents four types of information: (a) socio-economic characteristics, (b) water use information, (c) risk perceptions, (c) environmental perceptions, and (e) policy bids.

Socio-economic Characteristics

The survey elicited information on expected annual income, highest level of education completed, age, home location, home ownership, household size, and number of children under 16 years of age living at home (See Appendix D for tables which display the full range of responses for these questions.). The Mann-Whitney test for testing the null hypothesis that the distributions of two variables are equal will be used to compare responses for the two samples. A significance level of 95 percent will be used to reject the null hypothesis that the variable distributions are equal.

Expected annual income. Respondents from both the rural and urban samples have relatively high incomes. Mean expected annual income for the rural sample is $39,000 and $47,000 for the urban sample. Approximately 38 percent of the rural sample expect an annual income of $40,000 or more. For the urban sample, over 54 percent expect an annual income of $40,000 or more. Almost half the rural sample, 45 percent, expect an annual income of less than $30,000. Less than 30 percent of the urban sample expected similar incomes. The difference in sample distributions is statistically significant.

Level of education. Educational attainment differed significantly between the urban and rural samples. Almost one-third of the rural sample completed high school but did not continue their formal education. Of the urban sample, only 20 percent of respondents listed high school as the highest level of formal education completed. About a third of each sample attended college but did not graduate. Almost one-third (32 percent) of the urban sample had completed college compared with 22 percent of the rural sample. The difference in sample distributions is statistically significant.

Age. The two samples differed in the age profile response. The most pronounced differences were in the 26-35 and 66 and over categories. The rural sample had 16 percent of respondents in the 26-35 age category. The urban sample had 28 percent in the same category. In the 66 and over category, 26 percent of the rural sample and 16 percent of the urban sample fell in this category. Both the rural and urban samples had relatively few respondents in the 18-25 age category, 4 and 3 percent respectively. The difference in sample distributions is statistically significant.

Housing characteristics. The two samples differed significantly in selected housing characteristics. In the urban sample, over 75 percent listed their home location as being in a city or suburb compared with slightly over 30 percent for the rural sample. Similarly, over 52 percent of the rural sample listed their home location as either a rural area (but not a farm) or a farm. This compares with slightly over 16 percent for the urban sample. Additionally, the urban sample had a higher percentage of respondents who rent their homes, 17 to 11 percent for the rural sample. The differences in the sample distributions for both home location and ownership are statistically significant.

<u>Household size</u>. Both samples are similar in household size profiles. About half of the households in each sample (53 and 51 percent for the rural and urban samples, respectively) consisted of one or two persons. Slightly less than a third of each sample consisted of households with four or more people. There is no statistically significant difference in the sample distributions.

<u>Children at home</u>. A majority of respondents in both samples did not have children 16 or under living at home. Of the rural households, 64 percent did not have children living at home. The figure for the urban households is 63 percent. One or two children living at home characterized 27 and 28 percent of the rural and urban households respectively. Three or more children characterized 8 and 9 percent of the rural and urban samples, respectively. There is no statistically significant difference in sample distributions.

Water Use

Three types of water information were collected: (a) the water source, (b) type of drinking water preferred, and (c) whether the tap or faucet water has been tested. In the rural sample, 58 percent used a household well and 40 percent relied on publicly supplied water. In the urban sample, 78 percent relied on publicly supplied water while 22 percent relied on domestic wells.

In both samples, most respondents rely on water from the faucet. In the rural sample 93 percent rely on tap or faucet water as do 92 percent of the urban sample. About 6 percent in both samples use bottled water.

The overall percentage of rural respondents who tested their water was about twice the rate for the urban sample. Of the households in the rural sample, 17 percent had their tap water tested in the past year. Of the urban sample, 9 percent of the urban households had their tap water tested. Table 5.1 below shows testing broken down by water source.

About 20 percent of the households in each sample which rely on well water had their water tested. Of households who rely on publicly supplied water, 15 percent of the rural sample tested their wells compared with 5 percent for the urban sample.

Table 5.1 Cross Tabulation of Water Source and Water Testing

	Rural			Urban		
	All	Public	Well	All	Public	Well
Tested	17%	15%	20%	9%	5%	20%
Not tested	83%	85%	80%	91%	95%	80%
N	811	326	473	363	279	79

The differences in sample distributions for water source and testing were statistically significant. The difference in sample distributions for source of home drinking water is not significant.

Water Quality Perception

A majority (56 percent) of rural households perceive their tap water to be very safe. Of the urban households, 42 percent believe that their tap water is very safe. Relatively few households in either sample believe their tap water relatively unsafe to drink. For both the rural and urban sample, 3 percent believed their tap water is somewhat unsafe or very unsafe to drink. Urban households displayed a greater degree of uncertainty than the rural households over the safety of their water. In the urban sample, 31 percent were not sure of the safety of their water while 21 percent of the rural sample were not sure.

Rural households are generally more confident than the urban sample that their tap water is safe from the effects of groundwater pollution. Of the rural households, 23 percent were very confident while only 13 percent of the urban households were similarly confident. Of the urban households, 40 percent were not confident or not confident at all while 32 percent of the rural sample had similar perceptions.

Differences in the sample distributions for both questions were statistically significant. This implies that urban households in general are less certain than rural households about the safety of their tap water. A majority of both samples do not believe that tap water is unsafe to drink. However, a significant number of households in each group (with urban households less confident then rural households) believe their tap water is not safe from groundwater pollution.

Table 5.2 shows a cross-tabulation between water source and water safety perceptions for the rural sample (row sums do not add up to 100% due to rounding). Table 5.3 shows a similar table for the urban sample.

Table 5.2 Cross Tabulation for Rural Sample Between Water Source and Degree to Which Tap Water is Perceived Safe to Drink

	All	Very safe	Somewhat safe	Not sure	Somewhat unsafe	Very unsafe
Public Supply	41%	44%	27%	25%	3%	1%
Private well	58%	64%	15%	18%	2%	0%
N	814	459	168	177	19	3

Table 5.3 Cross Tabulation for Urban Sample Between Water Source and Degree to Which Tap Water is Perceived Safe to Drink

	All	Very safe	Somewhat safe	Not sure	Somewhat unsafe	Very unsafe
Public Supply	77%	42%	24%	31%	2%	1%
Private well	21%	42%	26%	30%	1%	1%
N	359	153	89	111	7	3

For the rural sample, 25% of those who rely on a public system are not sure of the safety of their water compared with 18 percent of those who rely on their own private wells. For the urban sample, 31 percent of private well users and 30 percent of households who rely on public supplies were unsure of the safety of their tap water.

How respondents perceive tap water safety is associated with their level of confidence that their tap water is safe from the effects of groundwater pollution. Tables 5.4 and 5.5 show cross tabulations for the rural and urban sets respectively. The association was analyzed by testing the independence of the rows and columns (association) of the two variables with Pearson's chi-square test (Walpole and Myers 1978). The null hypothesis of no association is rejected at the 95 percent level. The data indicates that people who rate the safety of their tap water as high are also confident that their tap water is safe from the effects of groundwater pollution.

Table 5.4 Cross Tabulation for Rural Set of Tap Water Safety Perceptions and Degree of Confidence that Tap Water is Safe from Effects of Groundwater Pollution.

	All	Very confident	Confident	Not confident	Not confident at all
Very safe	**56%**	40%	53%	7%	0%
Somewhat safe	**21%**	4%	55%	34%	7%
Not sure	**21%**	0%	24%	62%	15%
Somewhat unsafe	**2%**	0%	0%	37%	63%
Very unsafe	**0%**	0%	0%	0%	100%
N	**824**	189	377	203	55

Table 5.5 Cross Tabulation for Urban Set of Tap Water Safety Perceptions and Degree of Confidence that Tap Water is Safe from Effects of Groundwater Pollution.

	All	Very confident	Confident	Not confident	Not confident at all
Very safe	**42%**	30%	61%	8%	1%
Somewhat safe	**25%**	1%	51%	44%	5%
Not sure	**31%**	0%	29%	56%	15%
Somewhat unsafe	**2%**	0%	0%	43%	57%
Very unsafe	**1%**	0%	0%	0%	100%
N	**363**	189	377	203	55

A chi-square test was also conducted on the association of well testing and the degree of confidence in the safety of their water from groundwater pollution. There was no association for the urban sample. For the rural sample the two variables are associated. Table 5.6 shows the cross tabulation between the two variables. In general, households who tested their wells were typically more confident their drinking water is safe from the effects of groundwater pollution.

Table 5.6 Cross Tabulation Between Well Testing and Degree of Confidence that Tap Water is Safe from Groundwater Pollution

	All	Very Confident	Confident	Not Confident	Not confident at all
Tested	17%	27%	15%	12%	18%
Not Tested	83%	72%	85%	88%	82%
N	811	188	366	200	55

Risk Perceptions

Respondent risk perceptions corresponding to the severity, knowledge and choice risk descriptors as specified in Chapter 3 are discussed below.

Severity. Urban households perceived the seriousness of the health risk from groundwater pollution to be greater than the rural sample. About 38 percent of the urban sample believed the health risk from groundwater pollution to be serious or very serious compared with 23 percent in the rural sample. Of the rural households, 40 percent believed the health risk as not serious or not a threat at all. For urban households, 27 percent had similar beliefs. The difference in sample distributions is statistically significant at the 95 percent level.

About one-fourth of each sample (24 and 23 percent, respectively, for the rural and urban samples) greatly feared groundwater pollution. In rural households, 47 percent somewhat feared groundwater pollution while 52 percent of urban households held similar views. About one fourth of each group (29 percent for rural households and 25 percent for urban households) either fear groundwater pollution very little or not at all. There is no statistically significant difference in the sample distributions.

The third element of severity is the perceived likelihood that exposure to groundwater pollution is fatal. Of the rural households, 15 percent believed that groundwater pollution exposure would likely or very likely be fatal compared with 19 percent of the urban households. About 40 percent in each sample believed that groundwater pollution was either unlikely to be fatal or not fatal at all. The difference in sample distributions is not statistically significant.

The consistency of responses to the severity questions was addressed by using Pearson's chi-square test. It is used to test the hypothesis that the row and column variables are independent (Blalock 1979). The 95 percent level of significance was used to test the hypothesis of independence. A cross-tabulation of the three severity variables was accomplished by considering the variables two at a time. Responses to the questions were consistent for both samples across all three variables. More specifically, the more serious people perceived the health threat from groundwater pollution, the higher the percentage of respondents who feared or greatly feared the risk of groundwater pollution.

Other associations investigated using Pearson's chi-square test included the association of severity variables with water source and testing. There was no association indicated between the severity variables and water source for either sample. There was no association between severity variables and water testing for the rural sample. For the urban sample, there was no association between well testing and perceived fear but an association is indicated between well testing and both perceived fatalness and perceived seriousness of the threat from groundwater pollution. Table 5.7 shows that, in general, the greater the perceived seriousness, the higher the percentage of people who have had their wells tested.

Table 5.7 Cross Tabulation of Well Testing and Perceived Seriousness of Health Threat from Current Levels of Groundwater Pollution in County.

	All	Not a Threat	Not Serious	Somewhat Serious	Serious	Very Serious
Tested	9%	0%	11%	3%	12%	19%
Not tested	91%	100%	89%	96%	88%	81%
N	348	13	79	124	84	48

Table 5.8 below shows the cross tabulation of well testing and perceived fatalness. Of those respondents who said current pollution levels would very likely be fatal, 23% had tested their wells compared with 14 percent of those who believed that current pollution levels would not be fatal.

Table 5.8 Cross Tabulation of Well Testing and Perceived Fatalness of Current Levels of Groundwater Pollution in Michigan

	All	Not Fatal	Unlikely to be fatal	Sometimes Fatal	Likely to be Fatal	Very Likely to be Fatal
Tested	8%	14%	10%	4%	7%	23%
Not tested	92%	86%	90%	96%	93%	77%
N	350	22	122	143	41	22

<u>Knowledge</u>. Over one-third of the rural and urban samples (37 and 38 percent respectively) believed that the health risks of groundwater pollution are known or known precisely by scientific experts. For both samples, 46 percent believed health risks to be

somewhat known. Less than one-fifth of either sample perceived that health risks were only suspected or guessed at by scientists or not known at all.

The second component is knowledge of the health risks from groundwater pollution by exposed individuals. Less than 10 percent of each sample believe that exposed individuals are knowledgeable about the health risks of groundwater pollution. Conversely, 51 percent of the rural sample and 59 percent of the urban sample perceive that health risks are only guessed at or are not known at all by individuals exposed to groundwater pollution. For both of the above knowledge components, the difference in sample distributions are not statistically significant.

The third knowledge component is the concept of newness, or the extent to which groundwater pollution is perceived to be a new or old environmental problem. In the rural sample, about one-third believe groundwater pollution to be a relatively old environmental problem while 40 percent of urban households hold the same view. In comparison, 26 percent of the rural sample and 23 percent of the urban sample believe that groundwater pollution is a relatively new environmental problem. The difference in sample distributions is statistically significant at the 95 percent level.

Choice. Choice variables include: 1) controllability, the degree to which damage from groundwater pollution can be controlled by technology, and 2) voluntariness, the degree to which exposure to groundwater pollution is voluntary. Perceptions of controllability were fairly evenly divided across possible, somewhat possible and very difficult (36, 30 and 30 percent respectively for the rural sample, 33, 29, and 31 percent for urban sample). The difference in sample distributions is not significant.

A majority of both samples believed that exposure to groundwater pollution risks is involuntary. For the rural sample, 55 percent believed that exposure is involuntary while 67 percent of the urban sample have the same perception. Only 13 percent of rural households and 9 percent of urban households believe that exposure is somewhat voluntary or voluntary. The sample distribution difference is statistically significant.

Environmental Perceptions

Environmental perceptions refer to perceptions of the effects of groundwater pollution aside from direct health effects to the household. The survey questionnaire elicited responses to five questions related to environmental perceptions: (1) the extent to which households believe that future generations will be harmed by groundwater pollution, (2) household perceptions of the potential threat of groundwater pollution to wildlife and plants, (3) belief that groundwater should be protected for its own sake (aside from any human or non-human impacts), (4) household beliefs as to whether pollution is bad because it is the wrong thing to do or because it has bad effects, and (5) whether groundwater should be protected from pollution only when pollution poses a direct health threat to humans. The first two questions relate to a kind of bequest risk motivated by intergenerational and interpersonal concern (Randall and Stoll 1983). The last three comprise a type of altruism motivated by both intrinsic and ethical concerns which reflect the perception that human health is not the only reason to protect groundwater from pollution. In general, this is similar to Randall and Stoll's q-altruism (1983).

Bequest risk. Both rural and urban households believe future generations would be harmed by groundwater pollution. Of rural households, 27 percent believe future generations were likely to be harmed. The urban sample had 34 percent with similar beliefs. For the rural sample, about 76 percent believe future generations are likely or very likely to be harmed. For the urban sample about 80 percent hold similar views. The difference in sample distributions is statistically significant.

The rural and urban samples have significant differences regarding the threat of groundwater pollution to wildlife and plants. For the urban sample, 21 percent believe the threat to be very serious compared with 12 percent for rural households. For rural households, 22 percent believe there is not a serious threat. For urban households it is 17 percent. The difference in sample distributions is statistically significant at the 95 percent level. As with the previous question, urban households perceive the threat to wildlife and plants as more serious than rural households.

Pearson's chi-square test indicates an association between perceived seriousness of the health threat from current levels of groundwater pollution in the respondents' counties and perceptions of groundwater pollution's threat to future generations and wildlife and plants. Specifically, the greater the perceived severity, the greater the perceived threat to wildlife and plants. Both the rural and urban samples show this association.

O-altruism. A majority of both rural and urban households believe that other reasons exist to protect groundwater besides human health. For the rural sample, 69 percent believe that groundwater should be protected because it is part of a natural system while 68 percent of the urban sample hold a similar belief. Both the rural and urban sample had 20 percent of respondents who believed that groundwater should be protected for its own sake. There was no statistical difference in the sample distributions.

A significant majority of both samples believe pollution is bad because it is the wrong thing to do, as opposed to being bad only when it has bad effects on people and other living or non-living things. For both the rural and urban sample, 75 percent believe that pollution is the wrong thing to do. Only 14 percent of the rural sample and 17 percent of the urban sample believe pollution is bad only when it has bad effects.

As to whether groundwater should be protected from pollution only when pollution poses a direct health threat, 60 and 62 percent of the rural and urban households respectively strongly disagree. For the rural sample, 24 percent either strongly agree or agree somewhat with the statement. For the urban sample, 22 percent hold similar perceptions.

A number of cross-tabulations between the q-altruism variables and water source, education and income were conducted. Using the chi-square test, no association was found between water source and q-altruism variables. Education had a varied association with the q-altruism variables. Neither sample showed an association between wanting to protect groundwater for its own sake and education. Both samples indicate an association between perceptions that pollution is the wrong thing to do and education. Table 5.9 shows a cross-tabulation between q-altruism perceptions and education. Up to the education level of having attended but not completed college, as the level of education increases, a greater percentage say that pollution is the wrong thing to do. However, for those who have completed college, there is a marked increase (about 15 percent for both samples) in those who respond that pollution is bad only if it has bad effects. Both rural and urban samples show an association between education and perceptions that other reasons exist for protecting groundwater from pollution besides human health and education. Generally, as education increases, a greater percentage of respondents are more likely to respond that other reasons exist besides human health for protecting groundwater from pollution.

Similar to education, the association between income and the q-altruism variables is varied. The rural sample shows an association between income and perceptions that groundwater should be protected for its own sake while the urban sample does not. For the rural sample, a higher percentage of people in the middle income brackets, as opposed to those in the lower and higher brackets, perceive that groundwater should be protected for its own sake. The urban sample shows an association between income and perceptions that

Table 5.9 Cross Tabulation of Q-altruism Perceptions and Education Level.

	Education level									
	All		Elementary		High school		Some college		Last year or more	
	rural	urban	rural	urban	rural	urban	rural	urban	rural	urban
Wrong thing to do	76%	75%	65%	47%	75%	70%	83%	88%	70%	71%
Bad only when it has bad effects	14%	16%	10%	20%	12%	13%	11%	11%	23%	25%
Disagree with both	5%	2%	6%	0%	6%	6%	4%	1%	5%	1%
Don't know	5%	6%	19%	33%	7%	11%	3%	1%	2%	3%
N	786	353	31	15	332	104	224	120	179	114

pollution is the wrong thing to do. As income increases, a greater percentage of people respond that pollution is bad only when it has bad effects. Finally, both samples show an association between income and other reasons to protect groundwater from pollution besides human health. As income increases, a greater percentage of people perceive other reasons to protect groundwater besides human health.

Policy Bids

Table 5.10 summarizes policy bid means for both samples. The nonresponse rate for the policy bid questions ranged from 20 to 25 percent. All bids are statistically different from zero. Policy bids from the rural sample are fairly constant for the scientific information policy, the prevention policy and the well protection policy, ranging from $43.53 to $45.07. The rural policy bid for the combined program is substantially higher than the other three policies and is statistically significant at the 95 percent level. The urban policy bids are also fairly constant across three of the policies (scientific information policy, the prevention policy and the combined policy). The bids for the three policies ranged from

$61.53 to $68.66. The mean urban bid on the well protection program is significantly different from the other policies.

In comparing the bids across the samples, two of the policy bids are similar and two are different. Specifically, the mean bids for the rural and urban samples are statistically different at the 95 percent level for the scientific information and prevention policy. The urban bids are considerably higher for these two policies than the rural mean bids. Unlike the rural sample, the mean bids for the urban sample for the prevention and well protection policies are statistically different at the 95 percent level. There is no statistically significant difference in the mean bids across the two samples for the well protection and combined policies.

The combined policy is a multidimensional policy in that it provides multiple services. Hoehn shows that the presence of substitution effects across policy impacts will affect the value of the incremental policy impact (1991). For example, with the presence of substitution effects, the valuation of a single policy which has two impacts will be less than the sum of the valuation of the two impacts separately. This is seen in the policy bids for both the rural and urban samples. For households in the rural sample who valued the groundwater protection policy first, the mean bid for the protection policy was $45.07 and the incremental value of the well protection policy was $3.45. For households who valued the well protection policy first, the mean bid for the well protection policy was $44.24 and the incremental value of the prevention policy was $20.52.

For households in the urban sample who valued the groundwater protection policy first, the mean bid for the protection policy was $64.52 and the incremental value of the well protection policy was $15.63. For households who valued the well protection policy first, the mean bid for the well protection policy was $34.11 and the incremental value of the prevention policy was $24.66.

Two points are evident. First, a comparison of the combined policy bids and the bids for the prevention and well protection policy bids when valued separately show the empirical results presented here are consistent with Hoehn's findings. Second, the incremental values are consistent with the change in services offered. Since both prevention and well protection provide health services and only prevention provides environmental services, it would be expected that the incremental value of well protection would be low while the incremental value of prevention would be greater.

Table 5.10 Mean Policy Bids

	Policy							
Mean (standard error)	Scientific Information	N	Prevention	N	Well protection	N	Combined	N
Rural	$43.53 (2.68)	659	$45.07 (3.64)	337	$44.24 (4.74)	324	$56.47 (4.03)	625
Urban	$61.53 (5.82)	301	$64.52 (8.19)	138	$34.11 (4.19)	152	$68.66 (6.79)	281

CHAPTER 6

DATA ANALYSIS

The groundwater questionnaire identifies a number of potential variables which may useful in analyzing the relationship between risk perceptions and household wtp for groundwater pollution policies. This chapter provides a rationale and methodology for identifying variables to include in the analysis. Testable hypotheses regarding the relationship between these variables and policy bids are then developed. An econometric equation is specified and the estimated coefficients and test results are discussed.

Identification of Independent Variables

The groundwater questionnaire obtained three general types of information: (a) household risk perceptions in the context of qualitative risk descriptors, which describe different dimensions of risk (adapted from Fischhoff et al. 1978), (b) environmental perceptions which measure bequest risk and q-altruism, and (c) demographic information. A major consideration is how the information obtained in the survey can be used to test hypotheses regarding the relationship between perceptions, and socioeconomic characteristics with wtp for groundwater pollution policies.

One way to approach this problem is to look at the objective of this analytical section in a broad, general sense; to find out whether a change in risk or altruistic perceptions results in a change in policy bids. It is important to note that the survey variables in all likelihood do not represent the exact motivations responsible for behavior in a given context. This implies the existence of certain underlying variables which determine people's behavior. The difficulty lies in obtaining direct measures of these underlying variables given the complexity of the human cognitive process. By careful attention to wording and through repeated testing in focus groups, the questionnaire attempts to elicit information about risk and altruistic perceptions which is indicative of their actual, unobserved perceptions.

One approach to obtaining measures of the unobserved motivations through measures of observed variables is the use of latent variable models (Loehlin 1987). These models were developed to address situations where multiple variables, including unobserved ones, are involved (Loehlin 1987). Latent variable models can be used to develop measures of the underlying motivations which generate observable phenomenon. In the case of groundwater, a latent variable model can be used to develop variables for both risk and altruistic perceptions, which are a measure of the underlying motivations which determine the behavior of the individual in a given context; e.g., in the formulation of a policy bid. The underlying motivations also generate responses to such questions as "How greatly do you fear groundwater pollution?."

One type of latent variable model is principal components analysis. Principal components analysis is a multivariate statistical method, which is used in the analysis of correlation coefficients among variables. In essence, principal components analysis is used to identify measures of underlying variables by analyzing the variation and cross correlation within an observed variable set (Babbie 1973). This is accomplished through the generation of variables (factors) that are highly correlated with some subset of the variables of interest and are independent of one another. Consequently, principal components analysis reduces an original set of proxy variables to a smaller set of underlying variables.

The discussion in Chapter 3 regarding psychological research into risk perceptions noted the importance of risk as a multi-dimensional concept. The use of principal components analysis has the potential to identify from a comparatively large set of answers to risk related questions a few variables which represent the true dimensions of risk as people perceive them.

Altruistic concerns as reflected in observed behavior are motivated by a variety of considerations, including the nature of the individual's relationship with their immediate community and society in general. As with risk, a number of survey questions related to altruistic concern can be analyzed using principal components analysis to identify a few variables which represent underlying motivations associated with altruistic concern.

Principal Components Analysis of Independent Variables

For both the rural and urban samples, separate analyses were carried out for the risk perception variables and the altruistic variables. The set of risk descriptor variables included: (a) scientific knowledge of groundwater pollution health risks, (b) exposed individuals knowledge of groundwater pollution health risks, (c) newness, (d) catastrophic potential, (e) control, (f) voluntariness, (g) fear, (h) fatalness, and (i) perceptions of the seriousness of the health threat from current levels of groundwater pollution in the respondent's county. The set of altruistic variables included: (a) harm to future generations, (b) health threat to wildlife and plants, (c) whether groundwater should be protected for its own sake, (d) whether pollution is bad because it is the wrong thing to do or is bad only when it has bad effects on other living and non-living entities, and (e) if there are other reasons besides health effects to protect groundwater from pollution. The analysis proceeds by computing a correlation matrix of the independent variables and then identifying linear combinations of the observed variables. These linear combinations are extracted factors.

Extracted factors are identified in descending order beginning with the factor that accounts for the largest proportion of total variance in the sample. Two criteria were used to constrain the number of factors derived from the sample data: (a) total variance explained by the extracted factor, and (b) scree plots. The observed variables and derived factors are standardized to have a mean of zero and a variance of one. If a particular factor has a variance of less than one, this implies that it is no better than a single variable in explaining total variance. Consequently, the criterion that extracted factors have a variance greater than one ensures that an extracted factor is better than a single variable in explaining total variation. Scree plots graphically show the total standardized variance for each factor. This allows a graphical comparison of the factors. There is usually a sharp break between large and small factors in terms of the size of their loadings. This break does not necessarily occur at the point where variance equals one (Cattell 1966). Consequently, both of these techniques were used to identify factors suitable for extraction.

Scree plots for the risk descriptor analysis for both the urban and rural samples identified two factors. Using the total variance criteria, three factors were identified. The third factor for each sample appeared to be of marginal significance. For example, the third factor for the rural sample had a total variance measure (eigenvalue) of 1.08, compared with the first two factors with measures of 2.35 and 1.51 respectively. For the urban sample, the third factor had a total variance measure of 1.15 compared with the first factors with measures of 1.92 and 1.38 respectively. Given the marginality of the third factor, this initial extraction phase was repeated with the extracted factors constrained to two.

Using the total variance criteria, the initial extraction phase identified two factors for the altruistic variable set for both the rural and urban sets. For the rural set, the first extracted factor had a total variance measure of 1.86 with the second factor having a measure of 1.07. For the urban sample, the first factor had a variance measure of 1.66 with the second factor having a measure of 1.14. The scree plots for both samples were ambiguous. Since the extracted factors were comprised of the expected variables, it was judged that constraining the initial extraction phase to one factor would not be necessary.

The next step rotates the extracted factors, that is, the factors are transformed to make them more interpretable (Ferguson 1971). The equamax method of factor rotation was employed for both the rural and urban samples. This method is a combination of two other methods; the varimax method, which attempts to minimize the number of variables which have high loadings on a particular factor, and the quartimax method which attempts to minimize the number of factors needed to explain a variable (Ferguson 1971).

A priori, a minimum coefficient standard of .50 was set for each factor. Any variables which comprise a factor and have a coefficient less than .50 were to be deleted and the initial extraction phase rerun. Inspection of the constrained initial extraction phase for the risk descriptors analysis for the rural set showed three variables in the second factor to have comparatively low coefficients. Newness had a coefficient of -.24, control .47 and voluntariness .55. Even though voluntariness had a coefficient greater than .50, all three variables were dropped and the factor extraction repeated. A judgement was made that keeping the control and voluntariness variables together would result in a more consistent analysis than splitting them apart by including one in an extracted factor and the other as a separate independent variable. For the urban set, three variables had coefficients less than .50. Newness had a coefficient of -.25, voluntariness .48 and control .49. Consequently these variables were deleted and the initial extraction phase repeated. As with the rural sample, these variables will be included as separate independent variables in the subsequent regression analysis.

For the altruistic variables, all coefficients for the rural set were above .50. For the urban set, the variable associated with perceptions that other reasons exist besides human health to protect groundwater had a coefficient of .42. Since this variable is conceptually a component of q-altruism which includes the other two variables in the factor, a decision was made to keep these variables together as a set which comprises the second extracted factor.

Lastly, factor values were calculated for each observation in both samples. In this manner, the extracted, rotated factors can be used to represent underlying variables in a regression equation to estimate a policy bid function.

Risk descriptors. Principal components analysis of the risk descriptors for the rural and urban samples is shown in Table 6.1. The values shown are the rotated factor loadings. Two underlying variables are identified for both samples. For the rural sample, the first underlying variable (highlighted in bold) has relatively high coefficients of over .60 for the first four risk variables. The urban sample obtained similar results except for the lower loadings on perceived fatalness (1.c) and the catastrophic potential of groundwater pollution (1.d). The underlying variable severity is associated with perceptions of fear, the potential threat of pollution, the likelihood of exposure being fatal and the catastrophic potential of groundwater pollution.

The second underlying variable has high loadings for two of the three risk descriptors associated with knowledge and discussed in Chapter 3. This variable for knowledge has large coefficients for the risk variables representing scientific knowledge of the health risks from groundwater pollution and knowledge of the health risks of exposed individuals. The knowledge variable represents household perceptions of the level of knowledge regarding the health effects of groundwater pollution possessed both by the scientific community and exposed households.

Table 6.1 Principal Components Analysis of Risk Variables

Variable (mean)	Underlying Variables			
	Severity		Knowledge	
1. Risk Variables	Rural	Urban	Rural	Urban
a. Degree to which households fear groundwater pollution in Michigan on a four point scale with 1=fear not at all and 4=fear greatly (Rural=2.89; Urban=2.95).	.829	.780	.058	-.083
b. Perceived seriousness of health threat from current level of groundwater pollution in county on a five point scale with 1=not a threat at all and 5=very serious (Rural=2.85; Urban=3.26).	.737	.752	.049	.086
c. Whether current levels of groundwater pollution in Michigan are likely to be fatal on a five point scale with 1=not fatal and 5=very likely to be fatal (Rural=2.71; Urban=2.79).	.713	.570	.022	-.146
d. Whether health risks of groundwater pollution injure people one at a time or a large number of people at once on a five point scale with 1=one at a time and 5=a very large number at once (Rural=2.50; Urban=2.89).	.633	.515	-.051	.072
e. Extent to which health effects of groundwater pollution are known by scientific experts on a five point scale with 1=known precisely and 5=not known at all (Rural=2.79; Urban=2.72).	.076	-.065	.830	.755
f. Degree to which health risks are known by people who are exposed to groundwater pollution on a five point scale with 1=known precisely and 5=not known at all (Rural=3.49; Urban=3.62).	.112	.041	.814	.782

<u>Altruism variables</u>. Table 6.2 shows the results of principal components analysis applied to five variables representing different types of altruism. For both the rural and urban sample, the first factor has high loadings on variables representing household perceptions of the health likelihood of groundwater pollution harming future generations and the threat to wildlife and plants.

The second factor is associated with altruistic motivations associated with both intrinsic and ethical concerns regarding groundwater pollution. Intrinsic motivations are captured in variables 1.c and 1.d in Table 6.2. Question 1.e in particular and 1.d in addition are associated with an ethical concern regarding pollution which is over and above concern regarding health impacts to both human and other living things. Question 1.e in a senserepresents the idea that, aside from any harmful effects, the act of polluting violates a held ethical norm.

Independent Variables and Testing of Hypotheses

Three sets of variables were used to analyze the relationship between policy bids and motivating concerns as represented by independent variables. The three sets of variables include risk factors, altruism, and socio-economic variables.

Risk Variables

Two underlying variables and three proxy variables will be used for hypothesis testing. The underlying variable severity measures the households perception of the severity of groundwater pollution as a health threat. As perceptions of severity increase, policy bids will increase. Bids for all four policies are expected to be affected by severity perceptions.

Table 6.2 Principal Components Analysis of Bequest and Q-altruism Variables

Variable (mean)	Underlying Variables			
	Bequest Risk		Q-altruism	
1. Altruism Variables	Rural	Urban	Rural	Urban
a. Household perceptions of the extent to which future generations are harmed by groundwater over the next 5 to 10 years; on a five point scale with 1=not harmed at all and 5=very likely to be harmed (rural=3.93; urban=4.05).	**.884**	**.832**	.061	.226
b. Perceived seriousness of current level of groundwater pollution in Michigan as a health threat to wildlife and plants; on a five point scale with 1=not a threat at all and 5=very serious (Rural=3.25; Urban=3.51).	**.856**	**.894**	.143	-.023
c. A 0-1 dummy variable where 1 indicates if households believe groundwater should be protected for its own sake (Rural=0.20; Urban=0.20).	-.025	-.082	**.707**	**.809**
d. Households level of agreement with the statement that groundwater should be protected from pollution only when the pollution poses a direct threat to humans; on a four point scale with 1=strongly agree and 4=strongly disagree (Rural=3.20; Urban=3.24).	.072	.132	**.670**	**.422**
e. A 0-1 dummy variable where 1 indicates if households believe that is bad simply because it is the wrong thing to do (Rural=0.75; Urban= 0.75)	.274	.109	**.604**	**.625**

Consequently, severity, severity 1, serverity 2, severity 3, severity 23 will have positive and significant coefficients.

The underlying variable knowledge measures household perceptions of the degree of knowledge possessed by scientists and exposed individuals. The hypothesis regarding the relationship between knowledge and wtp will be ambiguous, as discussed in chapter 3. Similarly, the choice variables, voluntariness and control, are also expected to have an ambiguous correlation with wtp.

Newness was specified as a knowledge variable in Chapter 3. The factor analysis did not identify newness as a component of the knowledge dimension. Consequently, newness will be tested separately. The newer groundwater pollution is perceived to be an environmental problem, the less knowledge and experience people have in dealing with the problem. As with the other knowledge variables, the relationship between newness and wtp will also be ambiguous.

Q-altruism and Bequest Risk

Q-altruism is associated with existence value of groundwater. Existence value is comprised, at least in part, of intrinsic value and ethical concerns. Households who obtain utility from intrinsic value and from knowing that held ethical norms are not being violated will have higher bids for policies which prevent aquifer pollution than households who do not hold those views. The presence of q-altruism will not affect bids for remedial policies, since these policies do not affect aquifer pollution and therefore do not affect existence value.

The estimated coefficients on the q-altruism variable will be positive for those policies which prevent aquifer pollution. The effect of existence value perceptions on bids for the scientific policy is less clear. The main objective of the policy is to obtain more precise information about the extent of groundwater pollution and the population at risk from exposure. While the policy does not directly prevent aquifer pollution or exposure, it does not seem unreasonable to assume that people would think that the information is being collected for some constructive purpose; i.e., to formulate and implement programs that reduce groundwater pollution and potential exposure. Consequently, motivations for paying some positive amount for either prevention and remedial policies would seem to apply to the scientific information policy also. The following variables will have positive and significant estimated coefficients: (a) q-altruism, (b) q-altruism 1, (c) q-altruism 2, and (d) q-altruism 23.

Bequest risk measures the perceived threat of groundwater pollution to future generations and wildlife and plants. The greater the perceived threat, the greater the policy bid. Perceptions of both aquifer pollution and exposure risk are measured by this variable. Consequently, both prevention and remedial policies will be affected by bequest risk. The following variables will have positive and significant estimated coefficients: (a) bequest risk, (b) bequest risk 1, (c) bequest risk 3, (d) bequest risk 4, and (e) bequest risk 23.

Socio-economic Variables

Two variables will be included in this category, expected annual income and education level of the household. Two previous contingent valuation studies addressing groundwater pollution problems found income to be a significant variable in explaining the variation in wtp for groundwater protection policies (Edwards 1988, Shultz and Lindsay 1990). Studies cited by Shultz and Lindsay (1990) showed that households with a high degree of education had high levels of concern over groundwater pollution. Consequently, the estimated coefficients on education and income will be positive and significant. Independent variable definitions are summarized in Table 6.3.

Table 6.3 Independent Variables Used in Policy Bid Estimation

Variable	Definition
D1	A 0-1 dummy variable where 1 indicates the scientific information policy.
D2	A 0-1 dummy variable where 1 indicates the prevention policy.
D3	A 0-1 dummy variable where 1 indicates the remedial policy.
D23	A 0-1 dummy variable where 1 indicates the combined policy.
Severity	A variable identified by principal components analysis associated with the perceived severity of the health risk from exposure to groundwater pollution.
Severity $_i$	An interactive variable defined as D_i*Severity where i=1, 2, 3, 23 corresponding to dummy policy variables.
Knowledge	A dimension of risk identified by principal components analysis associated with the perceived level of existing scientific and personal knowledge of groundwater pollution.
Knowledge $_i$	An interactive variable defined as D_i*Knowledge where i=1, 2, 3, 23.
Bequest risk	A variable identified by principal components analysis associated with the level of concern for others (both human and non-human) affected by groundwater pollution.
Bequest risk $_i$	An interactive variable defined as D_i*Inter-being altruism where i=1, 2, 3, 23.
q-altruism	A variable identified by principal components analysis associated with perceived importance of the existence value of groundwater.
q-altruism $_i$	An interact variable defined as D_i*Q-altruism, where i=1, 2, 3, 23.
Newness	A 0-1 dummy variable where 1 indicates that households perceive groundwater pollution risk as a new or somewhat new environmental problem.
Control	A 0-1 dummy variable where 1 indicates household perceptions that the damage from groundwater pollution is very difficult or impossible to control through technology.
Voluntariness	A 0-1 dummy variable where 1 indicates household perceptions that people are involuntarily exposed to groundwater pollution.
Education	Last year of school completed on a six point scale with 1=no school and 6=last year of college or more.
Income	Expected annual income in one year, thousands of dollars.

Regression Analysis

The objective of the regression analysis is to empirically test the specified hypotheses regarding risk perceptions, altruism, and socioeconomic variables with wtp for alternative groundwater policies. To test the hypotheses, two alternative specifications of an econometric model are used. The first specification is

$$\text{(6.1)} \qquad \text{BID} = \beta_1 \text{D1} + \beta_2 \text{D2} + \beta_3 \text{D3} + \beta_4 \text{D23} + \beta_5 \text{Severity} + \beta_6 \text{Knowledge} + \beta_7 \text{Newness} + \beta_8 \text{Control} + \beta_9 \text{Voluntariness} + \beta_{10} \text{q-altruism} + \beta_{11} \text{Bequest risk} + \beta_{12} \text{Education} + \beta_{13} \text{Income} + e.$$

where D1, D2, D3, and D23 are policy dummy variables denoting the scientific, preventive, remedial and combined policy respectively and e is an error term assumed to be normally distributed with a mean of zero.

This equation defines a linear relationship between the dependent and independent variables. Consequently, a linear regression technique such as OLS can be used to estimate the coefficients. The use of the policy dummy variables allows coefficient estimation to be derived from one equation instead of using one equation for each policy. By specifying the independent variables in mean deviations form and suppressing the constant term, the coefficients for the policy dummy variables will equal the sample mean for that particular policy.

The second model is the same as equation (6.1) except that all variables derived from the principal components analysis are used to create interactive variables which specifically link the underlying variables q-altruism, inter-being altruism, severity, and knov

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knowledge with each of the four different policies. This model shows the specific impact of household perceptions as embodied in these variables on each of the policy bids.

The regression analysis for both the rural and urban sets is based on a "restricted" set of usable surveys. This subset consists of questionnaires for which all nonresponses have been eliminated. In the regression analysis, alternative sets of independent variables will be tested as to their significance in explaining bid variation for groundwater policies. Since the set of questions not answered in a given survey differed across respondents, analysis based on the complete sample will result in different sets of variables having different number of observations. In effect, households will drop in and out of the analysis according to which questions were answered. Tests of statistical significance will be affected and the generality of results may be limited if respondents to different questions differ markedly in some important characteristic. Consequently, by restricting the urban and rural samples to households that have responded to a given set of variables, the set of respondents will be constant across alterative specifications of explanatory variables.

A comparison was made of the complete and restricted samples for both the rural and urban sets, with respect to the independent variables used in the regression. The Mann-Whitney test was employed to test the null hypothesis that the two variables (from the complete set and from the restricted set) have the same distribution. The only statistically significant difference noted was for the income variable for the rural sample. The restricted set has a greater percentage of people in the higher income brackets compared with the complete set.

Results

Tables 6.4, 6.5 and 6.6 show results of the OLS estimation of the bid equations. The independent variables are identified in the left-hand column. Table 6.4 shows the estimated

Table 6.4 Estimated Coefficients for Bid Equation with Impact of Underlying Variables Averaged Across Policies.[1]

Variables	Rural[2]	Urban[2]
Severity	8.48*	17.21*
	(2.64)	(5.96)
Knowledge	4.70*	-9.64*
	(1.94)	(4.49)
Bequest risk	11.12*	0.98
	(2.58)	(5.79))
q-altruism	5.06*	15.61*
	(1.96)	(4.39)
Newness	6.62	-9.14
	(4.33)	(10.06)
Control	-2.06	-0.36
	(4.04)	(9.52)
Voluntariness	-2.79	7.12
	(3.97)	(9.36)
Education	10.36*	3.25
	(1.90)	(5.04)
Income	0.24*	0.20
	(0.07)	(0.18)
Adjusted R^2	.39	.32

[1] Estimated coefficients for policy dummy variables are equal to the mean bids for that sample when independent variables are in mean deviations form:
Rural: D1=$45.35; D2=$51.54; D3=$40.16; D23=$57.89.
Urban: D1=$71.22; D2=$73.19; D3=$38.54; D23=$75.15.

[2] The "*" signifies the estimated coefficient is statistically different from zero at the 95 per cent confidence level.

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Table 6.5. Estimated Coefficients for Bid Equations with Interactive Policy Variables[1]

Variables		Rural[2]	Urban[2]
q-altruism		Coefficient (SE)	Coefficient (SE)
	Science Policy	6.12* (3.66)	14.25* (7.59)
	Prevention	8.20* (4.74)	23.97* (11.84)
	Well Preotection	-2.51 (4.74)	3.32 (10.12)
	Combined Policy	6.06* (3.36)	20.01* (7.59)
Bequest risk			
	Science Policy	8.52* (4.46)	1.74 (9.98)
	Prevention	13.81* (5.88)	3.01 (14.82)
	Well Protection	7.74 (7.00)	10.73 (14.13)
	Combined Policy	13.40* (4.47)	-0.93 (9.98)
Severity			
	Science Policy	6.43* (4.54)	20.19* (10.10)
	Prevention	5.34 (6.09)	29.16* (14.60)
	Well Protection	9.39 (6.92)	-2.43 (15.11)
	Combined Policy	12.26* (4.54)	17.56* (10.12)
Knowledge			
	Science Policy	4.07 (3.29)	-4.27 (7.59)
	Prevention	6.35 (4.70)	-17.81 (11.79)
	Well Protection	0.20 (4.61)	-2.80 (10.67)
	Combined Policy	6.72* (3.29)	-15.62* (7.60)
Newness		6.42 (4.33)	-11.98 (10.17)
Control		-1.68 (4.06)	-0.25 (9.57)
Voluntariness		-2.72 (3.98)	7.70 (9.41)
Education		10.58* (1.90)	3.36 (5.04)
Income		0.23* (0.07)	0.19 (0.18)
Adjusted R^2		.39	.31

1. Estimated coefficients for policy dummy variables are approximately equal to the mean bids for that sample:
   Rural: D1=\$45; D2=\$52; D3=\$40; D23=\$58.
   Urban: D1=\$71; D2=\$73; D3=\$39; D23=\$75.

2. The "*" signifies the estimated coefficient is statistically different from zero at the 95 percent confidence level.

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Table 6.6. Estimated Coefficients for Final Bid Equations with Interactive Policy Variables[1]

Variables		Rural[2]	Urban[2]
Severity		Coefficient (SE)	Coefficient (SE)
	Science Policy	6.43 (4.52)	19.70* (9.98)
	Prevention	5.33 (6.09)	22.75* (10.31)
	Well Protection	15.13* (4.57)	-
	Combined Policy	12.26* (4.54)	16.36* (7.48)
Knowledge			
	Science Policy	4.06 (3.29)	-
	Prevention	6.35 (4.70)	-
	Well Protection	0.42 (4.60)	-
	Combined Policy	6.71* (3.29)	-14.09* (7.46)
q-altruism			
	Science Policy	6.10* (3.36)	14.28* (7.51)
	Prevention	8.19* (4.74)	24.83* (11.62)
	Well Protection	-	-
	Combined Policy	6.05* (3.36)	20.33* (7.51)
Bequest risk			
	Science Policy	8.52* (4.47)	-
	Prevention	14.58* (5.80)	-
	Well Protection	-	-
	Combined Policy	13.40* (4.47)	-
Newness		6.24 (3.29)	-
Control		-1.69 (4.06)	-
Voluntariness		-2.74 (3.98)	-
Education		10.69* (1.90)	-
Income		0.23* (0.07)	-
Adjusted R^2		.39	.32

1. Estimated coefficients for policy dummy variables are approximately equal to the mean bids for that sample:
   Rural: D1=\$45; D2=\$52; D3=\$40; D23=\$58.
   Urban: D1=\$71; D2=\$73; D3=\$39; D23=\$75.

2. The "*" signifies the estimated coefficient is statistically different from zero at the 95 percent confidence level.

coefficients for the specification in equation 6.1. In this specification the impact of the independent variables on policy bids are averaged across the different policies. In Table 6.5, interactive variables are used to partition out the effects of selected variables on each type of policy. Table 6.6 shows the final bid equations which are the result of reestimating the equations in Table 6.5 with insignificant variables dropped from the equation.

Underlying Variable Effects Averaged Across Policies

Table 6.4 shows the estimated coefficients of the specification which tests the averaged effect of the independent variables on policy bids. The estimated coefficients represent the dollar change in the mean policy bid due to a unit change from the mean value of the specified independent variable. For example, the estimated coefficient for the variable Severity for the rural sample is $8.48. For those households with a one-unit difference from the mean sample value for this variable, the policy bid would increase or decrease by $8.48 with respect to the mean policy bid for the sample as a whole, given that the remaining independent variables are evaluated at their respective means.

Rural results. For the rural set, severity, knowledge, q-altruism, and bequest risk, education and income had positive and statistically significant coefficients. This finding confirms (reject the null hypothesis that the estimated coefficient is equal to zero) the hypotheses regarding these variables.

For the variable severity, the statistical results show that as household perceptions of the severity of groundwater pollution increase, household policy bids increase. This follows in straightforward manner from the perceptions that comprise the variable severity: fear, seriousness of the health threat (including mortality risk) from current levels of groundwater pollution and catastrophic potential.

For the knowledge variable, the greater the perception that scientific experts and exposed households know little about the health risks from groundwater pollution, the greater the household policy bid. One interpretation is that if households feel that little is known about either the health effects of exposure to perceived levels of groundwater pollution or the likelihood of exposure, then it is difficult for households to know when or if they are at risk, and what the health consequences will be if exposed. If significant uncertainty is perceived to exist, then households are supportive of policies which will reduce or eliminate exposure to groundwater pollution. In one sense, this is a kind of "better safe than sorry" perspective in response to perceived uncertainty.

For the bequest variable, the greater the perceived threat to both future generations from future pollution and to wildlife and plants from current levels of pollution, the greater the household policy bid. With respect to future generations, the bequest variable explicitly addresses the households' perceived level of threat to future generations and also implicitly addresses the degree of concern for future generations. Since the statistical results show that perceived threat and wtp are positively correlated, this would seem to imply that in addition to the perceived threat there is also concern for future generations. A similar argument holds for the second component of the bequest variable, the perceived threat to wildlife and plants. The important point here is that the bequest variable incorporates primarily values derived from the use of the groundwater source by entities other than the household. Included are both future generations and entities which are affected by groundwater pollution and which in turn are used by others.

For the q-altruism variable, as the level of importance of q-altruism to the household increases, household policy bids increase. Alternatively, the greater the importance of nonuse values to the household, the greater the policy bid. It should be noted that q-altruism perceptions were hypothesized to be correlated with those policies which provide nonuse environmental services, i.e., policies which prevent the groundwater aquifer from being polluted. In the specification shown in Table 6.4, the estimated coefficients are derived by averaging the effect of the independent variable across all four policies, one of which does not provide nonuse environmental services. Consequently, the estimated coefficient for this variable should be considered as only a broad indication of the relationship between wtp and q-altruism.

For three variables--newness, control, and voluntariness--the hypotheses cannot be confirmed (fail to reject the null hypothesis). A linear restrictions test (Kmenta 1988) tested the hypothesis that the estimated coefficients associated with the three variables as a group are equal to zero. The test showed estimated coefficients of the group to be significant at the 95 percent level.

Both demographic variables are statistically significant and of the correct hypothesized sign. Both level of education and expected annual income are positively correlated with policy bids.

Urban results. As with the rural sample, severity perceptions are positively correlated with wtp. Even though most urban households rely on centrally supplied water as opposed to domestic wells for rural residents, urban households can still be affected by groundwater pollution. First, there may be the perception that publicly supplied water may be contaminated by groundwater pollution and not be detected by routine water monitoring. Second, households which rely on surface water may still be affected by groundwater pollution to the extent that wells are used to extract the water as opposed to direct diversion from the surface water body. Third, almost 20 percent of the urban sample rely on domestic wells for their freshwater source. Consequently, these households will probably have the same motivation behind wtp as shown for rural households.

The estimated coefficient on knowledge for the urban sample is of opposite sign from the hypothesized sign. The negative knowledge coefficient means the greater the level of scientific knowledge and awareness of exposed individuals with respect to the health effects of groundwater pollution, the higher the policy bid. One possible explanation is that respondents in the urban sample associate higher levels of knowledge and awareness with greater likelihood of an implemented policy successfully achieving its objectives. In other words, urban respondents may believe that as more is known about a particular risk, the greater the likelihood that a successful policy can be designed, which in turn results in correspondingly higher policy bids.

Bequest risk and severity show a relatively high simple correlation of .67. Consequently, one possible reason for the statistical insignificance of bequest risk is multicollinearity. Intuitively, this seems plausible since a significant component of bequest risk as derived from principal components analysis is concern over future generations. In many households the concern over the threat of groundwater pollution probably extends to other households as well. The equation was estimated again with severity deleted. In this case, the estimated coefficient on bequest risk was positive and highly significant ($\beta = 14.38$ with a t-score of 3.26).

The estimated coefficient for q-altruism is statistically significant and of the correct sign. The coefficient for the urban sample is over three times the size of the coefficient for the rural sample.

Three of the risk factor variables, newness, control and voluntariness are not statistically significant. A linear restrictions test found these variables to be insignificant as a set.

Neither of the demographic variables are statistically significant. However, a linear restrictions test on education and income as a set showed these variables to be statistically significant.

Underlying Variables Specified with Interactive Policy Variables

The purpose of the interactive variables specified in Table 6.5 is to test the effect of specific independent variables on specific policies. Table 6.5 lists four policies for each of the four interactive policy variables as defined in Table 6.3. Three of the risk factor variables, newness, control and voluntariness are considered individually, as are the two demographic variables education and income. The estimated coefficients for the four interactive independent variables show the change in the mean policy bid for the specified policy due to a unit deviation from the mean value for the specified independent variable. For example, under the rural sample heading for the severity variable, the estimated coefficient for the science policy is 6.43. This means that a unit change in the mean value for the variable severity results in a change in the mean value of the science policy of $6.43, evaluating the other variables at their mean.

Severity. The variable representing severity is not significant for three of the four policies for the rural sample. The combined policy has a positive and statistically significant coefficient. A linear restrictions test on severity 1, severity 2 and severity 3 finds these three variables significant as a set. Additionally, a correlation matrix of the independent variables shows that correlation coefficients between bequest risk and severity variables range from .63 to .68. Removing bequest risk from the analysis results in making all four of the severity interactive variables positive and statistically significant. Consequently, all the hypotheses regarding severity and policy bids are confirmed for the rural sample.

The urban sample shows that three of the four interactive variables are positive and significant. Only the interactive variable associated with the well protection program is not significant. Since most respondents in the urban sample do not rely on domestic wells as a water source, the insignificance of the severity variable associated with the well protection policy seems appropriate.

Knowledge. For both the rural and urban sets, only the combined policy coefficient is significant. For the rural sample, the estimated coefficient can be interpreted as meaning that as household perceptions of the level of both scientific knowledge and exposed peoples' awareness of the health effects of groundwater contamination decrease, policy bids for the combined policy increase. A linear restrictions test shows that for the rural sample, the estimated coefficients for the variables knowledge 1, 2, and 3 are statistically significant as a set.

The estimated coefficient on the combined policy for the urban sample is negative. This is interpreted as meaning the lower the perceived level of scientific knowledge and awareness of exposed individuals with respect to the health effects of groundwater pollution, the lower the policy bid. Alternatively, the higher the perceived level of knowledge and awareness, the greater the bid. Similar to the discussion concerning averaged independent variables, the negative coefficients on knowledge for the urban group might be associated with perceptions of the likelihood of the policy actually achieving its stated objectives. The reasoning may be that the greater the level of scientific knowledge and personal awareness, the greater the possibility that policies can be designed and implemented with a reasonable chance of success.

For the urban sample, a linear restrictions test shows that the estimated coefficients on knowledge 1, 2, and 3 are not statistically significant as a set.

Q-altruism. For the rural sample, the estimated coefficients on q-altruism are positive and statistically significant with the exception of the well protection program. This confirms the hypotheses developed for the impact of measures of existence value on policy bids. Since the well protection policy does not protect the groundwater aquifer, policy bids are not affected by the importance of existence value to the household. Similarly, the coefficients for the urban sample, again with the exception of the well protection program, are positive and statistically significant. The size of the coefficients for the urban sample are two to three times larger than the coefficients for the rural sample.

Bequest risk. Three of four bequest risk variables for the rural sample are positive and statistically significant. As with q-altruism, the coefficient on the well protection policy is not significant. Unlike existence value, it was hypothesized that the coefficient on the well protection program would be significant. However, this hypothesis is not confirmed. None of the estimated coefficients for bequest risk for the urban sample are significant. A linear restrictions test on the set of bequest risk variables fails to reject the hypothesis that the estimated coefficients as a set are zero.

Newness, control, voluntariness. Individually, none of these variables are statistically significant for either sample. However, for the rural sample, these variables are statistically significant as a set. The calculated F statistic was 26.20, an indication of the strength of the significance. However, the hypotheses associated with these variables cannot be confirmed since the sign on the coefficients is unknown. The estimated coefficients for the urban set are not significant as a set. Consequently, the hypotheses associated with these variables are not confirmed.

Education and income. For the rural sample, both education and income variables are positive and statistically significant. For the urban sample, neither variable is significant independently. A linear restrictions test shows that the variables as a set are not significant as a set. Consequently, the hypotheses associated with education and income for the rural sample only, are confirmed.

Final Bid Equation Using Interactive Policy Variables

Table 6.6 shows the estimated coefficients for the final bid equations with variables having insignificant estimated coefficients dropped from the equations.

Severity. For the rural sample, the estimated coefficient for the well protection and combined policies are statistically significant and of the correct hypothesized sign. For the urban sample, the estimated coefficients for all three of the included interactive variables--science information, prevention and the combined policies--are statistically significant and of the correct sign. As hypothesized, severity perceptions are a significant motivation in rural household willingness to pay for well protection policies. However, the estimated coefficients for the scientific information policy and the prevention policy are not statistically significant. This contrasts with urban households, who are not typically dependent on private domestic wells as a water source. For urban households, both the scientific information policy and the prevention policy are statistically significant and of the correct hypothesized sign. As previously established, severity is not correlated with well protection bids for the urban sample.

Knowledge. For both rural and urban households, the estimated coefficients for the knowledge variable are statistically significant for the combined policy. As was previously the case, the sign on the coefficient for the rural sample was as hypothesized, while the sign for the urban sample was opposite from that hypothesized.

O-altruism. The estimated coefficients for both samples for all three interactive variables are statistically significant and of the correct hypothesized sign.

Bequest risk. For the rural sample, all of the estimated coefficients for bequest risk are statistically significant and of the correct hypothesized sign.

Other variables. The results for the rural sample are similar to the results previously discussed. Newness, control and voluntariness are not significant individually but are significant as a set for the rural sample. Education and income are statistically significant and of the correct hypothesized sign.

CHAPTER 7

IMPLICATIONS OF EMPIRICAL RESULTS AND RESEARCH NEEDS

The empirical analysis shows a number of perception variables as being both economically and statistically significant in explaining the variation in household bids for groundwater policies. The significance of health and environmental risk perceptions for valuation and policy formulation will be addressed in this chapter. Finally, future research needs identified by the theoretical framework and the empirical analysis will be discussed.

Significance of Risk Perceptions

The data analysis showed the empirical significance of risk perceptions associated with severity and knowledge in explaining bid variations. As perceptions of severity and knowledge change, there is a corresponding effect on policy bids. The implications for valuation and policy formulation are discussed below.

Implications for Valuation

An important implication of the empirical results is that the use of probability and a single outcome descriptor, such as death, results in an incomplete and inadequate description of the risk/income trade-off situation faced by households. The empirical significance of the association between risk perceptions and wtp for groundwater pollution policies shows the insight gained from an explicit consideration of the underlying motivations affecting risk perceptions.

In essence, their subjective perception of groundwater pollution risk is expressed through the consideration of the risk in terms of the qualitative risk descriptors. The empirical results showed that policy bids and risk perceptions are systematically related. Consequently, household perception of the risk as embodied in their policy bid may vary dramatically from that predicted by a benefit estimate typically based on a quantitative specification of mortality probability and a dollar figure which represents an estimate of the value of a statistical life.

Given the empirical significance of risk perceptions in explaining bid variations, it would appear that use of the more general valuation framework in the estimation of policy benefits would be the most appropriate approach for policy evaluation. Mortality based benefit estimates can be used as a first cut, or if the opportunity for obtaining survey-based estimates does not exist. However, the research results show the empirical importance of direct estimation of benefits. This would argue for a contingent valuation study as the most appropriate method (cost and time considerations aside) to estimate policy benefits. In fact, it would seem that the mortality-based approach would be a third-best approach. A second-best approach would be to use existing valuation studies, which explicitly account for household risk perceptions. The first-best approach would be to explicitly elicit bids for the specific situation under study.

It can be argued that reliance on people's responses to technically complex risk issues which are typically based on limited experience is hardly an improvement on mortality based benefit estimates. However, the issue seems not to be so much the specification of "the" correct benefits estimate, but more to what extent is society willing to reallocate scarce resources from one purpose to another? This reallocation is based, at least in part, on consumer preferences which in turn are based on how the situation under consideration is perceived. Benefit estimates based on consumer preferences may be considerably larger or smaller than might be expected from a technical risk assessment. It should be noted, however, that consumer preferences are not formed in a vacuum. The empirical importance of preferences points to the need for information, discussion and public debate to increase the likelihood that informed choices are made by consumers.

The empirical importance of risk perceptions implies that risk descriptors associated with these perceptions can aid in setting an appropriate context for policy valuation. For example, policy impacts can be specified in terms of risk descriptors that have been found to be of empirical significance to households. Risk perceptions found to be of economic significance, such as severity and knowledge in the groundwater survey, would be used as a context for describing policy impacts. Explaining the current situation in the context of these variables, or explaining policy impacts in terms of these variables may provide information to respondents for policy valuation purposes, which accurately reflects dimensions of risk which are meaningful to people in formulating their perceptions of groundwater pollution risks.

Implications for Policy

The econometric analysis showed certain risk perceptions to be systematically related to bid variations. Table 7.1 shows how policy bids differ with respect to whether independent variable responses are above or below the sample mean for that variable. Responses to each of the four interactive variables are categorized as either above or below the mean value for that variable. The households with responses above the mean can be characterized as perceiving the health risks from groundwater contamination to be more severe in comparison with households with responses at or below the mean. Households

Table 7.1 Policy Bids Resulting from Evaluation of Variable at Mean Positive and Negative Deviation from Mean, Other Variables Constant [1]

Variable		Scientific Information		Groundwater Protection		Well Protection		Combined Policy	
		Above mean	Below mean	Above mean	Below mean	Above mean	Below mean	Above mean	Below mean
Severity	Rural:	-	-	-	-	$52	$28	$67	$48
	Urban:	$89	$56	$93	$57	-	-	$92	$61
Knowledge	Rural:	-	-	-	-	-	-	$64	$53
	Urban:	-	-	-	-	-	-	$63	$86
q-altruism	Rural:	$50	$40	$59	$46	-	-	$63	$53
	Urban:	$82	$59	$92	$52	-	-	$90	$58
Bequest risk	Rural:	$51	$36	$61	$38	-	-	$67	$45
	Urban:	-	-	-	-	-	-	-	-

1 Policy bids are calculated using statistically significant coefficients from Table 6.6. "-" indicates the estimated coefficient associated with the variable is statistically insignificant.

Policy means (with independent variables evaluated at mean values): Science information, rural: $45, urban: $71; groundwater protection, rural: $52, urban: $73; well protection, rural: $40, urban: $39; combined policy, rural: $58, urban: $75.

with responses below the mean perceive groundwater pollution health risks to be less severe compared to households with responses at or above the mean. The rest of the interactive variables can be interpreted in a similar manner. The mean value for all positive (above the mean) responses and all negative (below the mean) responses for each interactive variable for each sample set is calculated. The positive and negative mean for each variable is multiplied by the estimated coefficient for that variable, and added or subtracted as necessary to the mean policy bid when all variables are evaluated at their respective mean. The indicated dollar value represents the policy bid of an household with above or below average perceptions in terms of a particular variable, with all other variables evaluated at their respective means.

For the rural sample, policy bids for respondents with above average severity perceptions range from $52 to $67. For below average severity perceptions, policy bids range from $28 to $48. For the urban sample, the range for respondents with above average severity perceptions range from $89 to $93. For below average severity perceptions, bids range from $56 to $61. In considering the scientific information, groundwater protection and well protection policies, both the rural and urban samples value the groundwater protection policy more than the other two policies. Above average severity perceptions for the urban sample result in significantly greater policy bids compared with the rural sample for all policies except well protection.

Knowledge perceptions, which were identified as an important underlying dimension of risk through principal components analysis, are not generally of great economic importance. The exception is for the combined policy for both the rural and urban samples. Above average perceptions of the lack of knowledge regarding health risks results in an bid increase for the rural sample and a bid decrease for the urban sample. In other words, the greater rural households perceive that both the scientific community and exposed households know little about the health risks from groundwater pollution, the higher the policy value. For urban households, the greater the perception that little knowledge of health risks exist, the less value placed on policies. One interpretation of this relationship is that urban households perceive that if the scientific community hasn't established the relationship between groundwater pollution and health effects, then groundwater policies are less valued. Conversely, as the people perceive the relationship to be known, groundwater policies are valued more.

The percentage increase in bids as a result of going from below to above average perceptions can be quite significant. For example, the mean bid in the rural sample for the well protection policy increases 86 percent. For the rural sample, averaged across policies, going from below to above average severity perceptions increased policy bids by 63 percent; 21 percent for the knowledge variable. For the urban sample, the increases are 58 percent for the severity variable; 27 percent for the knowledge variable; and 57 percent for the q-altruism variable.

Related to the use of risk descriptors in providing a context for valuation is the design of risk communication programs with the explicit use of empirically significant risk descriptors as a basis for formulating a communication program. Aside from policy evaluation studies, risk communication may be of importance in a variety of situations as how to avoid or significantly reduce certain types of risk; the provision of information to households for assistance in voting on referendums dealing with policies which affect some type of technological or environmental risk; and providing information to people for a particular agencies elicitation of public comments on a proposed project or policy.

The risk descriptor severity is associated with two types of perceptions: (a) perceptions of the effects of exposure and (b) perceptions of the likelihood of exposure. The risk descriptor knowledge is associated with both of these perceptions. Consequently,

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in designing risk communication programs, the empirical results of the survey would seem to indicate that an emphasis should be placed on communicating the risk within the context defined by the risk descriptors that have meaning to households. In this way, the multi-dimensional aspects of risk can better be communicated, as opposed to reliance on some uni-dimensional risk descriptor, such as probability of mortality from some level of exposure.

Significance of Q-altruism and Bequest Risk Perceptions

The empirical significance of household perceptions that other reasons besides direct health threats exist for addressing groundwater pollution has a variety of valuation and policy implications. These implications are discussed below.

Implications for Valuation

The empirical analysis showed that other reasons exist to protect groundwater quality besides consideration of direct health effects to the household. Four implications are evident. First, ignoring this aspect of household concern results in an insufficient amount of pollution prevention. The theoretical framework showed that the marginal benefits of prevention will be understated if benefits derived from altruistic concern are not included in the policy evaluation, and households have some degree of altruistic concern regarding the potential effects of groundwater pollution.

Second, groundwater policies will be biased toward remedial action. The theoretical framework specified the necessary conditions for an efficient allocation of expenditures across preventive and remedial policies. If values derived from altruistic concern are not considered, an inefficient allocation of expenditures will result.

Third, by ignoring altruistic based values, a given expenditure on protection results in a smaller gain in well-being than if prevention and remedial action were efficiently balanced. A given expenditure can result in a higher level of utility by reallocating expenditures away from remedial action, toward prevention, until the marginal costs of prevention are equated with its true marginal benefits.

Fourth, a mortality-based estimate of the value of life may be sufficient for valuation purposes when altruistic-based values are absent. If people have altruistic concerns, then sole reliance on mortality-based estimates of health benefits will underestimate the true marginal benefits.

Implications for Policy

Both q-altruism and bequest concerns are significant explanatory variables for the rural sample. Table 7.1 shows that for the rural sample, above average perceptions of q-altruism result in bids ranging from $50 to $60. Below above average q-altruism perceptions result in policy bids ranging from $40 to $53. For the urban sample, above average q-altruism perceptions result in policy bids ranging from $82 to $92 with below average perceptions resulting in bids ranging from $52 to $59. For bequest risk, above average perceptions for the rural sample result in policies ranging from $67 to $51. Below average perceptions result in bids ranging from $36 to $45. The average percentage increase in bids from below to above average perceptions for the rural sample is 24 percent for q-altruism and 50 percent for bequest risk. For the urban sample, the average percentage increase across policies for the q-altruism variable is 57 percent.

The main implications of the economic significance of q-altruism and bequest perceptions are: 1) that non-users (most of the urban sample) can still have a considerable economic interest in the resource; and 2) actual users of the resource, (most of the rural sample), can be motivated to pay for groundwater pollution policies for reasons besides any actual or potential direct health risks.

perceptions result in bids ranging from $36 to $45. The average percentage increase in bids from below to above average perceptions for the rural sample is 24 percent for q-altruism and 50 percent for bequest risk. For the urban sample, the average percentage increase across policies for the q-altruism variable is 57 percent.

The main implications of the economic significance of q-altruism and bequest perceptions are: 1) that non-users (most of the urban sample) can still have a considerable economic interest in the resource; and 2) actual users of the resource, (most of the rural sample), can be motivated to pay for groundwater pollution policies for reasons besides any actual or potential direct health risks.

An additional policy implication of the significance of existence values is as a defensible way of giving weight to nonusers where it is deemed that such is necessary or appropriate. A nongroundwater example is the observation that much of the criticism of public land management agencies, such as the Forest Service and Bureau of Land Management, for putting too much emphasis on development and not enough focus on species preservation and the ecological integrity of the land, comes from urban households (Gresham, 1991). At least a part of this emphasis may be explained by the importance of q-altruism shown by the urban sample. This is not to suggest that urban households are to be perceived as more environmentally conscious or operate at a higher ethical plane than the rural set. The important implication is that people who do not use the land directly, as indicated by the empirical study, have an economically significant interest in the land. While this should not be interpreted as meaning that these concerns are overriding, the empirical significance does indicate that if these values or sentiments are ignored in policy valuation, then, in an overall sense, too much emphasis will be placed on development and too little on policies whose objectives are to provide for ecological integrity and pollution control.

Future Research Needs

A consideration of the theoretical framework and the empirical findings results in the identification of a number of areas where additional research would aid in understanding the economic significance of risk and altruistic perceptions. Four general areas for further research include: (a) identification of risk variables which get closer to underlying dimensions of risk and altruism; (b) measurement of risk and altruistic perceptions and their effect on policy bids in different contexts; (c) ascertaining the role of information in affecting risk and altruistic perceptions, and the resulting effect on wtp; and (d) a comparison of quantitative and qualitative risk measures, both in explaining bid variations and as information to give to consumers as an aid in thinking about the economic trade-offs they would be willing to make in risky situations. The section below discusses these items in more detail.

Risk Perception Variables

The identification of risk perception variables used in the questionnaire were primarily based on the previous research of Fischhoff et al. The proxy variables for altruism were developed primarily from information gathered from focus groups. While the regression analysis found that a significant amount of bid variation is explained by these variables (and education and income), over 60 percent of the variation is left unexplained. Further investigation into risk and altruistic perceptions may identify proxy variables which more accurately reflect the underlying dimensions of risk and altruism, which affect people's motivations and, subsequently, their observable behavior in a given context.

Perceptions in Different Contexts

The research considered in this study found that for a particular resource, groundwater, risk and altruistic perceptions are important motivations behind policy bids. An important question for policy valuation is how other types of environmental pollution are perceived, and how these perceptions are related to policy bids. For example, the economic significance of perceptions may vary substantially across different types of environmental pollution scenarios. Air pollution, surface water pollution, radon, ozone layer depletion, and the greenhouse effect may each be perceived differently in the context of risk perception variables. Perhaps newness, control and voluntariness will be economically significant for some subset of pollution scenarios. One question to be answered in this regard is the robustness of the empirical findings of the groundwater study. Severity and knowledge were found to be the most significant components of risk perception for the groundwater study. This may, or may not, be the case in other situations or contexts. Similarly, does the economic impact of risk and altruistic perceptions vary? For example, the groundwater study found that severity and bequest risk were economically the most significant explanatory factor for the rural sample, while for the urban sample severity and q-altruism were most significant. It is conceivable and even expected that different valuation contexts will result in different perception components being the most economically significant.

Role of Information

The groundwater research did not provide information as such to survey respondents. The objective was to obtain base-line measures of risk and altruistic perceptions and demographic characteristics. The basic objective of additional research would be to ascertain the extent to which perceptions, and ultimately, wtp are affected by information. The approach to take would depend on the purpose for looking at the impacts of information. For example, is the objective of information provision to measure existing perceptions, or is it explicitly to change observable behavior? The latter objective is similar to Smith's study (1986) of the effect of command and cajole information types on mitigating behavior of people potentially exposed to radon pollution. As an extension of the current work, the effect of different types of information (amount, command, cajole, etc.) on risk and altruistic perceptions, as measured by severity, knowledge, q-altruism and bequest risk and in turn policy wtp can be considered. A useful result might be to measure the sensitivity of the economic trade-offs people are willing to make to the type and amount of information given them. This addresses the question in the Bayesian context of the strength of people's priors. If risk and altruistic perceptions are a weighted function of priors and new information, a pertinent policy question is how these elements are weighted, and are they stable over time or are they dynamic?

Quantitative and Qualitative Risk Measures

Related to information is the respective roles both quantitative and qualitative risk measures play in affecting individual's risk perceptions. These risk measures may be used to assist individuals in the policy evaluation process (including wtp), or as specific information whose purpose is to change behavior in some fashion. The economic significance of these risk measures, as measured by their effect on policy wtp, would be an important consideration in policy design and evaluation. More specifically, two topics seem especially important: (a) the determination of whether there is a systematic relationship between quantitative risk measures and wtp for different types of policy, and (b) the importance or weight people attribute to quantitative and qualitative risk measures.

APPENDICES

APPENDIX A

APPENDIX A

SURVEY DESIGN AND IMPLEMENTATION

The groundwater survey design phase had two objectives: a) to provide respondents with a straightforward, understandable questionnaire, and b) to increase the likelihood that the survey would be completed in a usable manner and returned. The basic survey design and implementation procedure generally followed the "total design method [TDM]" (Dillman, 1978). Dillman states

> "... to maximize both the quantity and quality of responses, attention must be given to every detail that might affect response behavior. The TDM relies on a theoretically based view of why people do and do not respond to questionnaires and a well confirmed belief that attention to administrative details is essential to conducting successful surveys" (p. viii).

Survey design and implementation can be addressed in three components: a) question design, b) questionnaire design, and c) implementation of the mail survey.

Question Design

Dillman (1978) identifies two major considerations in designing a question; the kind of information being sought, and the question structure.

<u>Information types</u>. Four general types of information are identified (p.80): attitudes, beliefs, behavior and attributes. Attitudes reflect a person's normative assessment of a subject or situation, i.e., what should be or what should not be. Beliefs

are what people believe to be true or false, or what is and is not (p. 81). In this sense it is the person's positive assessment of a subject or situation. Behavioral questions address what people have done in the past, what they are currently doing or what they plan to do in the future (p. 83). Finally, attribute questions address personal or demographic characteristics (p. 83).

An important reason for distinguishing between these different types is that the type of information obtained from a question depends on the wording of the question. In rewriting questions to increase clarity and comprehension, there is increased possibility that the type of information obtained from a question may be different then intended (Dillman, 1978). Consequently, survey information objectives need to be precisely identified so that changes in question wording do not change the type of information sought.

Previous sections of this chapter have identified five types of information variables included in the groundwater survey: risk perception questions, held value questions, CV questions and demographic questions. These variables can be correlated to the four question types listed above. Risk perception questions are examples of belief questions. Held value questions are examples of attitude questions. CV questions are examples of behavioral questions. Finally, demographic questions are examples of attribute questions.

Question structure. Dillman identifies four structures based on the response behavior required to answer the question. These structures are characterized as: a) open-ended, b) close-ended with ordered choices, c) close-ended with unordered response choices, and d) partially close-ended (p. 86-87). Open-ended questions require the respondent to provide an answer in their own words. A close-ended questionnaire with ordered choices provides the set of choices on a continuum which represents a single dimension or characteristic. The respondent then chooses the most appropriate response.

Close-ended questions with unordered choices refers to choices which are not gradations on a scale or continuum. The choices typically represent entirely different concepts or alternatives (p. 90). A partially close-ended questionnaire combines a set of ordered or unordered choices with an open-ended response.

For the groundwater survey, close-ended questions were chosen as the primary question structure. An important rationale in using close-ended questions is that they are typically less demanding in respondent effort than other types. This was an important consideration in the groundwater survey, since the focus group sessions made apparent the lack of familiarity and experience with groundwater pollution issues.

Close-ended questions with ordered choices were developed to elicit information on risk perception variables, held values, and demographic values. Close-ended questions with unordered choices were developed for demographic and held values. Open ended questions were developed for policy valuation questions.

Questionnaire Structure

Two design considerations for the questionnaire as a whole are length and physical layout of the questionnaire.

Deciding on questionnaire length involves a trade-off between the amount of information obtained and the likelihood that the questionnaire will be returned, or that answers to questions in the later portion of the questionnaire will be answered (Dillman, 1978). Surveys which have used the TDM show a negative correlation between response rates and questionnaire length (Dillman, p. 55-56, 1978). However, even for a 14-page questionnaire, the average response rate was 62 percent (Dillman, p. 56). While these above results are based on a limited number of studies, it appears that lengthy mail surveys can be developed which result in acceptable return rates.

The groundwater questionnaire finally developed was 14 pages long with a minimum of 49 and a maximum of 59 responses required (several questions provided for multiple responses). While the questionnaire was long, the number of required responses was relatively small in comparison with the studies cited by Dillman (p. 56). It was decided that the length of the questionnaire would not be a significant factor in affecting response rates. The in-person and mail pretests confirmed this initial assessment. In the debriefing portions of the in-person pretest, a majority of the participants stated that the questionnaire length did not seem unduly long. The results from the mail pretest were consistent with these findings. The response rate of the mail pretest was 45 percent after the first mailing, and a postcard reminder a week later. This compares with several surveys of the general public in four states whose response rates ranged from 34 to 62 percent after a similar number of mailings (Dillman et al., 1974). It should be stressed that these surveys were not CV surveys. Given the cognitive demands made on respondents in CV valuation scenarios, plus the unfamiliarity with groundwater pollution issues, the mail pretest showed that the response rate was, nevertheless, competitive with other surveys using state-of-the-art mail survey procedures. The basic objective of the physical layout of the questionnaire is to motivate the respondent to answer, and return the questionnaire. To accomplish this, the questionnaire should be constructed so that its various components combine to form an appealing package with the following characteristics: a) visually appealing, b) conveys to the respondent the importance of the survey and their response, and c) gives impression that completing the survey will not take much time (Dillman, 1978). A variety of design elements should be considered for each of the three main components of the survey: a) the questionnaire itself, b) mailing envelopes, and c) postage.

Questionnaire. The major design elements to be considered include size, shape, weight, color, paper quality, cover design and general layout (Dillman, 1978). The size of the groundwater questionnaire is 8 1/2" by 7", which is legal size paper folded in half. The pages are formed into an 8-page booklet, printed on both sides, for a total of 16 printed pages.

This reduced size booklet form has two advantages: a) cost savings by reducing the amount of paper needed, and lighter postage; and b) the reduced size gives the impression that the questionnaire is shorter than it actually is.

White, legal size 60-pound bond paper was used in printing the questionnaire. The lighter 16- and 20-pound bond was insufficiently opaque with two-sided printing. The increased cost of using 60-pound bond was more than balanced out by the higher quality look and feel of the questionnaire, using the heavier paper. The questionnaire was commercially printed, using high quality photo-copying processes.

The physical layout of the questionnaire was designed to provide a visually appealing format to respondents. Questions were structured so that a large amount of "white space" (blank space) was used both within an individual question and between questions (See Appendix C.). The judicious use of white space provides a degree of visual relief, in comparison with pages of condensed text. Too much white space gives the appearance of an unprofessional and incomplete questionnaire, while too little results in an imposing looking questionnaire which may not get answered (Dillman, 1978).

The objective of the cover page of the questionnaire is to convey the subject matter of the survey, and to make it sound interesting (Dillman, 1978). The cover page has four components: a) the title, b) a graphic illustration, c) directions, and d) name and address of the researchers (Dillman, 1978). Figure A-1 shows the cover page from the groundwater survey. The title is shown against a dark background, which provides a visual contrast with the rest of the cover page. The first sentence states what the survey is about. The second tells the respondent that their opinion is important and that their privacy will be ensured. The third sentence gives a name and address for returning the survey. The fourth, and last, sentence thanks the respondent for their time and effort. Constructing the cover page in this manner increases the likelihood the questionnaire is taken seriously by the respondent and returned.

Figure A-2 shows the last page of the questionnaire which elicits additional comments from respondents and thanks them for their time and effort.

Cover letter. The cover letter is typically the first component of the survey package that is examined by respondents (Dillman 1978). The cover letter has four components: a) to tell people what the study is about, b) to convince them that the study is important, c) to convince them that their answers are important to the success of the study, and d) that their identity and answers will be kept in confidence. Figure A-3 shows the cover letter used for the first mailing of the groundwater survey. The first paragraph specifies what the topic is, and why the research study is being done.

The second paragraph explains that the respondents' opinions and views are important to the success of the study.

Michigan's Groundwater Choices:

Which Do You Prefer?

Michigan's Groundwater Choices is a project designed to find out what Michigan citizens think about groundwater pollution.

Your opinion is what's important to us. To ensure your privacy, the questionnaire is identified by number only.

When completed, place the questionnaire in the business reply envelope and send it to:

James Caudill, Project Director
Department of Agricultural Economics
Michigan State University
East Lansing, MI 48824

We appreciate your time and effort. Thank you!

Figure A-1: Front Cover of Questionnaire

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Thank you *very much* for your help and cooperation. Your opinion on each question counts a great deal.

If you would like to share any additional comments, please write on this page.

Figure A-2: Back Cover of Questionnaire

The third paragraph gives instructions on who is to fill out the questionnaire, and the length of time it should take to complete the questionnaire.

The fourth paragraph specifies that the survey results will be shared with governmental agencies and the general public, and how respondents can obtain copies of the results.

The fifth paragraph addresses the issue of confidentiality, and that they are participating in the survey voluntarily (statement required by university regulations).

Finally, the last paragraph provides a phone number for people to call if they have any questions about the survey. Cover letters were printed on official departmental stationary with a water-marked university seal.

Cover letters for the second and third questionnaire mailouts will be discussed in the following section on mail implementation procedures.

Mailing envelopes. Two types of questionnaire mailing envelopes are needed. Mailout envelopes are used to mail the questionnaire to households in the sample. Return envelopes are used by respondents to mail back the questionnaire upon completion.

The mailout envelopes are 9 1/2" by 12 1/2" white catalog envelopes with a gummed flap and no clasp. A departmental return address label was centered on the front of the envelope. Gummed labels with names and addresses of people in the sample were then attached to the return address label. The large size of the mailout envelope, compared with the size of the questionnaire, was necessitated by the

August 21, 1990

Name
Address
City, State, Zip

Dear Name:

Michigan faces major groundwater decisions. These decisions will shape Michigan's future as a place to live and work. Right now, there is very little information available about the goals that Michigan citizens believe are important.

Your household is one of a small number which is being asked to give an opinion on Michigan's groundwater choices. Households were scientifically selected to give a balanced and accurate picture of statewide citizen opinion. Your answers to the enclosed questionnaire will ensure a truly representative report.

The questionnaire should be filled out by an adult in your household who shares in major household decisions. By household, we mean the people in your home who act as a family unit and who share all major purchase decisions. If you only share rent or mortgage costs with a roommate, complete the questionnaire viewing yourself as the household. The questionnaire will take about 15 or 20 minutes to complete.

The results of this research will be shared with representatives in our state's government, local officials, and all interested citizens. You may obtain a summary of results by writing "copy of results requested" on the back of the return envelope, and printing your name and address below it.

You may be assured of complete confidentiality. The questionnaire has an identification number for mailing purposes only. You indicate your voluntary agreement to participate in this research project by completing and returning this questionnaire.

I would be happy to answer any questions that you might have. Please feel free to write or call. My telephone number is 517-355-2320.

Thank you for your help.

Sincerely,

James Caudill,
Project Director

Enclosures

Figure A-3: Cover Letter for Initial Mail-out desire not to fold the cover letter or questionnaire. To enhance the convenience of returning the questionnaire, the mailout package was designed so that as it was opened, the unfolded cover letter would be encountered first, then the questionnaire and then the return envelope. Keeping the cover letter unfolded would, hopefully, decrease the likelihood that the cover letter would be initially bypassed and the questionnaire perused before the cover letter is read.

The return envelopes were business reply envelopes printed with the researchers' name and address. The size of the return envelopes was the same as the mailout envelopes. Again, the rationale is to make it as convenient as possible for the respondent to return the questionnaire. The use of large envelopes permitted the respondent simply to place the questionnaire in the return envelope without having to fold it.

A cost advantage of business reply envelopes is that postage costs are charged only when the envelope is returned.

Postage. The questionnaires were mailed using first class postage. Using first class postage has two advantages: a) it conveys an image of importance that less expensive postage does not, and b) first class mail receives a high handling priority from the postal service. Additionally, first class mail is automatically forwarded for up to a year in case of an address change (Dillman, 1978). The groundwater questionnaires were mailed using first class, 25 cent stamps. The mailout envelopes required three stamps each. First class business reply envelopes cost 53 cents per returned questionnaire.

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Survey Implementation

The survey implementation has two components: the characteristics of the survey sample and the logistics of the mailout.

Survey Sample

Since little information exists on how Michigan citizens perceive groundwater pollution issues, a state-wide survey would have the advantage of gathering opinions from a cross section of state households. In this way, baseline information could be compiled on consumer perceptions of groundwater pollution issues.

The population to be sampled included heads of households in Michigan. The sample size was 2020. This was divided into two sub-samples, urban and rural. Using the U.S. Bureau of Census definition for metropolitan statistical area (MSA), Michigan counties were divided into urban counties (counties which included an MSA), and rural counties (counties which did not include an MSA). Two-thirds of the total sample came from rural counties, one-third came from urban counties.

Names and addresses were obtained from a marketing research firm in Lansing, Michigan. The names were on a national computerized database which contained names from all fifty states. The Michigan database in June 1990 contained 3,151,507 households. This is 98 percent of the total households listed in the most current census (ref).

There are two sources of names and addresses: a) telephone directories, and b) auto registration records. A sample of names and addresses are periodically checked for accuracy, and updated by examining auto registration records and national change of address records. According to the company, the result is that 92-93 percent of names and addresses contained in the database are current and up to date (Personal communication Dan Braun, Beurman-Marshall Corporation, East Lansing, MI).

A systematic random sampling of the Michigan database of every kth name, for both rural and urban counties, was undertaken by the marketing firm. Six thousand names were selected. These names were transferred to a 3-1/2-inch microdisk to be used in the dissertation research. Subsequently, a systematic sampling of both name sets obtained 1347 names from rural counties and 673 from urban counties, for a total of 2020 names and addresses in the survey sample.

Mailout Logistics

The TDM requires an initial mailout of the questionnaire with a minimum of three follow-ups (Dillman, 1978). The follow-ups increase the likelihood that a high response rate is obtained from the sample.

The initial mailout occurred on Tuesday, 31 July, 1990. Tuesday is preferred as a mailout day for three reasons: a) it is early enough in the week for questionnaires to be forwarded to people who have moved and still receive the questionnaire that same week; b) the buildup of weekend mail results in Monday being the busiest day of the week, potentially increasing the likelihood of clerical errors; and c) for the follow-ups, mailing on Tuesday allows time for possible returns from the weekend mail to be acknowledged, thus decreasing the number of follow-ups needed to be mailed on Tuesday (Dillman, 1978).

One week after the mailout, Tuesday, August 7, all households in the survey were sent a postcard follow-up. The basic objective of the postcard is to remind people about the questionnaire and the importance of their responses to the study. Dillman states, "the post card [sic] follow-up is not written to overcome resistance, but to jog memories and rearrange priorities" (1978, p. 183). The timing of the postcard follow-up attempts to convey a sense of importance while not appearing impatient or strident (Dillman, 1978).

Figure A-4 shows the text of the postcard. The first paragraph reminds the addressee that a questionnaire was sent the previous week, and that they were part of a scientifically designed sample of Michigan households.

The second paragraph thanks the person if they have already returned the questionnaire. If the questionnaire has not been returned, they are reminded about the importance of their opinions to the success of the research project.

Finally, the third paragraph requests people to call immediately for a replacement questionnaire, if needed.

August 7, 1990

Last week a questionnaire was mailed to you seeking your household's opinion on key groundwater issues facing our state. Your household was selected in a scientifically designed sample of all Michigan households.

If you have already completed and returned the questionnaire to us, please accept our sincere thanks. If not, please do so today. Because the study involves a small, representative sample of Michigan residents, it is extremely important that your answers be included if the results are to accurately represent the opinions of Michigan citizens.

If by some chance you did not receive the questionnaire, or it got misplaced, please call me right now, collect (517-355-2320), and I will get another one in the mail to you today.

Sincerely,

James Caudill
Project Director

Figure A-4: Post Card Reminder

The second follow-up was sent on Tuesday, 21 August. This was two weeks after the postcard follow-up and three weeks after the initial mailout. The purpose of this follow-up is to convey a more urgent tone than the previous follow-up and to give a personal appeal to the reader that their opinions are vital to the success of the survey. A replacement questionnaire is included.

Figure A-5 shows the text of the second follow-up letter. While the information in the letter is essentially the same as in the previous cover letter and postcard, a greater emphasis is placed on personalizing the message.

The first paragraph addresses the fact that the questionnaire has not been received. The second paragraph gives a rationale for seeking their opinion in the first place. The third paragraph again emphasizes the importance of their response to the success of the research. The last three paragraphs respectively: a) give directions on filling out the questionnaire, b) address the confidentiality of the questionnaire, and c) provide an address and telephone number to contact.

The third and final follow-up was sent on 18 September. A replacement survey was included. The tone of this follow-up is similar to the previous follow-ups but is shorter and more direct in emphasizing the importance of the readers opinions. Figure A-6 shows the text of the third follow-up cover letter. The second paragraph, in particular, shows the emphasis on personalizing the message. For example, the second and third sentences tell the reader that the accuracy of the survey findings depends on their responses, and that their possibly unique views on groundwater pollution issues are important to know for the survey.

Date (planned mailing date, 3 wks. after 1st mailing)

Name
Address
City, State Zip

Dear Name:

About three weeks ago I wrote to you seeking your opinion on major groundwater issues facing our state. As of today, we have not yet received your completed questionnaire.

Our research unit has undertaken this study because of the belief that citizen opinions should be taken into account in the formation of public policies about groundwater.

I am writing to you again because of the importance of your response. Your household was selected as part of a small, representative sample of Michigan citizens. For our study to truly represent citizen opinion, it is essential that you complete and return the questionnaire.

I have enclosed a replacement questionnaire in case the original has been misplaced. The questionnaire should be filled out by an adult in your household who shares in major household decisions. By household we mean the people in your home who act as a family unit and who share all major purchase decisions. If you only share rent or mortgage costs with a roommate, complete the questionnaire viewing yourself as the household.

Please remember that your opinion is confidential. Your name and individual opinion will not be revealed. You indicate your voluntary agreement to participate in this research project by completing and returning this questionnaire.

If you have any questions about filling out the questionnaire, please feel free to write or call. My telephone number is 517-355-2320.

Thank you for your cooperation.

Cordially,

James Caudill
Project Director

Figure A-5: Second Follow-up Letter

Date (planned mailing date, 7 wks. after 1st mailing)

Name
Address
City, State Zip

Dear Name:

I am writing to you about our study of groundwater issues. We have not yet received your completed questionnaire.

The large number of questionnaires returned is very encouraging. However, whether we will be able to accurately describe how Michigan citizens feel on these issues depends upon you. You may have quite different opinions concerning groundwater issues than those who have already responded.

This is the first time a statewide, scientifically designed study of citizen opinion has been done on these issues. The results are of particular importance to the many citizens, private and public agencies, and lawmakers who are concerned about making groundwater decisions that best meet the needs of Michigan's people.

It is for these reasons that I am sending you another copy of our questionnaire to your household. The questionnaire should be filled out by an adult in your household who shares in major household decisions.

I'll be happy to send you a copy of the results of our study. Simply write your name, address, and "copy of results requested" on the back of the return envelope.

Your contribution to the success of this study will be greatly appreciated.

Sincerely,

James Caudill
Project Director

Figure A-6: Third Follow-up Letter

APPENDIX B

APPENDIX B

QUESTIONNAIRE TEXT

Michigan's Groundwater Choices:

Which Do You Prefer?

Michigan's Groundwater Choices is a project designed to find out what Michigan citizens think about groundwater pollution.

Your opinion is what's important to us. To ensure your privacy, the questionnaire is identified by number only.

When completed, place the questionnaire in the business reply envelope and send it to:

James Caudill, Project Director
Department of Agricultural Economics
Michigan State University
East Lansing, MI 48824

We appreciate your time and effort. Thank you!

Michigan's Groundwater

Groundwater is water that collects below the surface of the land in porous rocks and sands. Twenty-eight percent of all Michigan households get their water from groundwater through household wells. Fifty-seven percent of the cities and towns in Michigan use groundwater for part of their water supply.

1. Where does the tap or faucet water in your home come from? (circle one)

   1. A COMMUNITY OR PUBLIC WATER SYSTEM
   2. A HOUSEHOLD WELL
   3. A SPRING, STREAM, OR RIVER
   4. SOME OTHER SOURCE

2. What do you usually use for drinking water in your home? (circle one)

   1. TAP OR FAUCET WATER
   2. PURCHASED BOTTLED WATER
   3. BOTTLED WATER FROM A FRIEND OR NEIGHBOR
   4. WATER FROM SOME OTHER SOURCE

3. In your judgement, how would you rate the tap or faucet water in your home? (circle one)

   1. VERY SAFE TO DRINK
   2. SOMEWHAT SAFE TO DRINK
   3. NOT SURE ABOUT SAFETY
   4. SOMEWHAT UNSAFE
   5. VERY UNSAFE

4. Within the last year, has the tap or faucet water in your home been tested for safety by a laboratory? (circle one)

   1. NO
   2. YES

5. How confident are you that your tap or faucet water is safe from the effects of groundwater pollution? (circle one)

   1. VERY CONFIDENT
   2. CONFIDENT
   3. NOT CONFIDENT
   4. NOT CONFIDENT AT ALL

6. During the last year, have you read or seen any news stories about groundwater pollution? (circle all that apply)

    1. NO
    2. YES, ON TELEVISION
    3. YES, IN A NEWSPAPER
    4. YES, IN A MAGAZINE
    5. YES, SOME OTHER NEWS SOURCE

7. In your judgement, how serious a health threat is the current level of groundwater pollution in your county? (circle one)

    1. VERY SERIOUS
    2. SERIOUS
    3. SOMEWHAT SERIOUS
    4. NOT SERIOUS
    5. NOT A THREAT AT ALL

8. To what extent do you think the health risks of groundwater pollution are known by scientific experts? (circle one)

    1. KNOWN PRECISELY
    2. KNOWN
    3. SOMEWHAT KNOWN
    4. ONLY SUSPECTED OR GUESSED AT
    5. NOT KNOWN AT ALL

9. To what extent do you think the health risks are known by people who are exposed to groundwater pollution? (circle one)

    1. KNOWN PRECISELY
    2. KNOWN
    3. SOMEWHAT KNOWN
    4. ONLY SUSPECTED OR GUESSED AT
    5. NOT KNOWN AT ALL

10. Do you view the risks of groundwater pollution as a new environmental problem or something rather old? (circle one)

    1. NEW
    2. SOMEWHAT NEW
    3. MIDWAY BETWEEN NEW AND OLD
    4. SOMEWHAT OLD
    5. OLD

11. In your judgement, is groundwater quality a good or poor indicator of the general quality of the environment? (circle one)

    1. A GOOD, GENERAL INDICATOR
    2. SOMEWHAT GOOD
    3. AVERAGE
    4. SOMEWHAT POOR
    5. A POOR INDICATOR

12. Do you view the health risks of groundwater pollution as injuring people one at a time or a large number of people at once, like a catastrophe? (circle one)

    1. ONE AT A TIME
    2. A FEW PEOPLE AT ONCE
    3. MANY PEOPLE AT ONCE
    4. VERY MANY PEOPLE AT ONCE
    5. A VERY LARGE NUMBER AT ONCE

13. Where groundwater pollution occurs, do you believe the damage can be controlled through technology? (circle one)

    1. EASY TO CONTROL
    2. POSSIBLE TO CONTROL
    3. SOMEWHAT POSSIBLE TO CONTROL
    4. VERY DIFFICULT TO CONTROL
    5. NOT POSSIBLE TO CONTROL

14. Do you view the risks of groundwater pollution as something that people are exposed to voluntarily or involuntarily? (circle one)

    1. VOLUNTARILY
    2. SOMEWHAT VOLUNTARILY
    3. SOMEWHAT INVOLUNTARY
    4. INVOLUNTARY

15. Is the risk of groundwater pollution in Michigan something that you greatly fear? (circle one)

    1. FEAR GREATLY
    2. FEAR SOMEWHAT
    3. FEAR VERY LITTLE
    4. FEAR NOT AT ALL

16. For a person exposed by drinking water to typical levels of groundwater pollution in Michigan, are health effects likely to occur soon after exposure or at some later time? (circle one)

1. NO HEALTH EFFECTS ARE LIKELY
2. SOON AFTER EXPOSURE
3. SOMETIME WITHIN A YEAR
4. SOMETIME WITHIN A DECADE
5. SOMETIME WITHIN A LIFETIME

17. In your best judgement, what health effects are likely to result from typical levels of groundwater pollution in drinking water in Michigan? (circle all that apply)

1. NO HEALTH EFFECTS ARE LIKELY
2. ALLERGIES
3. BIRTH DEFECTS
4. IMPAIRED IMMUNE SYSTEM
5. CANCER
6. IMPAIRED DEVELOPMENT IN CHILDREN
7. PSYCHOLOGICAL DISORDERS
8. STOMACH, INTESTINAL DISORDERS
9. OTHER (fill in)________________

18. Are current levels of groundwater pollution in Michigan likely to be fatal or not fatal to people? (circle one)

1. VERY LIKELY TO BE FATAL
2. LIKELY TO BE FATAL
3. SOMETIMES FATAL
4. UNLIKELY TO BE FATAL
5. NOT FATAL

19. In your judgement, are future generations likely to be harmed by the groundwater pollution that occurs in Michigan over the next 5 to 10 years? (circle one)

1. VERY LIKELY TO BE HARMED
2. LIKELY TO BE HARMED
3. NOT LIKELY TO BE HARMED
4. VERY UNLIKELY TO BE HARMED
5. NOT HARMED AT ALL

20. In your judgement, how serious is the current level of groundwater pollution in Michigan as a health threat to wildlife and plants? (circle one)

1. VERY SERIOUS
2. SERIOUS
3. SOMEWHAT SERIOUS
4. NOT SERIOUS
5. NOT A THREAT AT ALL

21. Some people say that groundwater should be protected from pollution *for its own sake*. That is, groundwater should be free from pollution whether or not people, plants, and wildlife are affected.

Other people say that groundwater should be protected from pollution *only* because it is *part of a natural system*--if pollution affects groundwater it will eventually affect human beings or other living things.

Which opinion best describes your own? (circle best one)

1. DISAGREE WITH BOTH OPINIONS
2. PROTECT GROUNDWATER *FOR ITS OWN SAKE*
3. PROTECT GROUNDWATER BECAUSE IT IS *PART OF A NATURAL SYSTEM*
4. DON'T KNOW

22. Some people say that pollution is bad because it is simply the *wrong thing to do*. Other people say that pollution is bad *only when it has bad effects* on people, wildlife, and other living *or* non-living things. Which opinion best describes your own? (circle one)

1. DISAGREE WITH BOTH OPINIONS
2. POLLUTION IS THE *WRONG THING TO DO*
3. POLLUTION IS BAD *ONLY WHEN IT HAS BAD EFFECTS*
4. DON'T KNOW

23. Some people say that groundwater should be protected from pollution only when the pollution poses a *direct* health threat to *human beings*. Do you agree or disagree with this opinion? (circle one)

1. STRONGLY AGREE
2. AGREE SOMEWHAT
3. DISAGREE SOMEWHAT
4. STRONGLY DISAGREE
5. DON'T KNOW

24. The table below shows some of the things that people die from in Michigan each year. It shows how many people die and the death rate per million for 1988 as reported by the Michigan Department of Health.

RISK CATEGORY	NUMBER OF DEATHS	RATE OF DEATH
Heart Disease	30,521	3,306
All Cancers	17,669	1,914
Pneumonia	2,354	255
Motor Vehicle Accidents	1,725	187
Breast Cancer (Female)	1,573	170
Emphysema	746	81
Leukemia	647	70
Accidental Fire	169	18
Asthma	166	18
Accidental Poisoning	142	15
Influenza	123	13
Nutritional Deficiencies	101	11
Gastric Ulcer	76	8
Aircraft Accidents	50	5
Tuberculosis	46	5
Viral Hepatitis	27	3
Appendicitis	25	3
Breast Cancer (Male)	10	1
Railway Accidents	8	1
Handgun Accidents	3	0.3
Lightning	2	0.2
Chicken Pox	1	0.1

a. Consider a risk category called "deaths from groundwater pollution." This category would include only the deaths where groundwater is the deciding factor in a death. In your best judgement--your best guess--where would the groundwater risk category fit in the table? (circle one)

1. I AM VERY SURE WHERE IT WOULD FIT.
2. I CAN ONLY GUESS WHERE IT WOULD FIT.
3. GROUNDWATER POLLUTION IS NOT LIKELY TO BE A DECIDING FACTOR IN ANY DEATHS--IT WOULD NOT BE IN THE TABLE.
4. DON'T KNOW.

b. If 1 or 2 circled: Draw a line from left to right straight across the table to show your *best guess* about where the groundwater risk category would fit.

Questions 25, 27, and 31 ask you to vote for or against three different groundwater programs. Consider each program separately. If approved, a program would become a permanent part of state or county government.

25. The State of Michigan is considering a special program to get better scientific information on (1) where groundwater pollution occurs and (2) how many people are exposed. Suppose the only way to finance this program were through a special tax.

This program could be put to a vote. If this program *cost your household* $1 *per month* for a total payment of $12 *per year*, would you vote for or against this program and tax? (circle one)

1. VOTE *FOR* THE PROGRAM AND TAX
2. VOTE *AGAINST* THE PROGRAM AND TAX

26. What is the most you would pay, *per year*, in higher taxes to support the program described in question 25? (fill in an amount equal to or greater than zero).

I WOULD PAY UP TO $__________ PER YEAR

Ground Water version of questionnaire

27. Suppose a special program were proposed for your county that would protect groundwater from pollution.

The program would prevent any further increase in groundwater pollution in your county. It would:

1. Identify sources of groundwater pollution.
2. Take educational, regulatory, and legal action to prevent future pollution of groundwater.

Suppose this two-part program were put to a vote. Would you vote for or against the county-wide program and tax if it *cost your household* $1 *per month* for a total payment of $12 *per year*? (circle one)

1. VOTE *FOR* THE PROGRAM AND TAX
2. VOTE *AGAINST* THE PROGRAM AND TAX

28. What is the most you would pay, *per year*, in higher taxes to support the program described in question 27? (fill in an amount equal to or greater than zero).

I WOULD PAY UP TO $__________ PER YEAR

Well Water version of questionnaire

27. Community and public water systems are routinely tested for groundwater pollution. Household wells are not routinely tested. Suppose a special program were set up in your county to protect the health of people who use household wells.

The program would eliminate the remaining health threat from groundwater pollution to people who use household wells in your county. It would:

1. Test all household wells in the county for harmful chemicals. Each well would be tested once a year.
2. Install filtering devices for water used by a household to remove any harmful chemicals that are detected.
3. Employ trained technicians to monitor and maintain the filtering devices in top working condition.

Suppose this three-part program were put to a vote. Would you vote for or against the county-wide program and tax if it *cost your household* $1 *per month* for a total payment of $12 *per year*? (circle one)

1. VOTE *FOR* THE PROGRAM AND TAX
2. VOTE *AGAINST* THE PROGRAM AND TAX

28. What is the most you would pay, *per year*, in higher taxes to support the program described in question 27? (fill in an amount equal to or greater than zero).

I WOULD PAY UP TO $__________ PER YEAR

29. In your judgement, would the program in question 27 reduce the health threat posed by groundwater pollution in your county? By how much would the health threat really be reduced? (circle one)

1.	90 TO 100 PERCENT	6.	40 TO 49 PERCENT
2.	80 TO 89 PERCENT	7.	30 TO 39 PERCENT
3.	70 TO 79 PERCENT	8.	20 TO 29 PERCENT
4.	60 TO 69 PERCENT	9.	10 TO 19 PERCENT
5.	50 TO 59 PERCENT	10.	0 TO 9 PERCENT

30. In your judgement, would the program in question 27 protect groundwater in your county from further pollution? By how much would further groundwater pollution really be reduced? (circle one)

1.	90 TO 100 PERCENT	6.	40 TO 49 PERCENT
2.	80 TO 89 PERCENT	7.	30 TO 39 PERCENT
3.	70 TO 79 PERCENT	8.	20 TO 29 PERCENT
4.	60 TO 69 PERCENT	9.	10 TO 19 PERCENT
5.	50 TO 59 PERCENT	10.	0 TO 9 PERCENT

<u>Ground Water version of questionnaire</u>

31. The program described in question 27 protects groundwater. The program could be broadened to directly protect peoples' health.

Community and public water systems are routinely tested for groundwater pollution. Household wells are not routinely tested. Suppose a special program were set up in your county to protect the health of people who use household wells.

Like question 27, the program would prevent any further increase in groundwater pollution in your county. It would:

1. Identify sources of groundwater pollution.
2. Take educational, regulatory, and legal action to prevent further pollution of groundwater.

The program would also eliminate the remaining health threat from groundwater pollution in your county. It would:

3. Test all household wells in the county for harmful chemicals. Each well would be tested once a year.

4. Install filtering devices for water used by a household to remove any harmful chemicals that are detected.

5. Employ trained technicians to monitor and maintain the filtering devices in top working condition.

Suppose this five-part program were put to a vote. Would you vote for or against the county-wide program and tax if it *cost your household* $2 *per month* for a total payment of $24 *per year*? (circle one)

1. VOTE *FOR* THE PROGRAM AND TAX
2. VOTE *AGAINST* THE PROGRAM AND TAX

32. What is the very most you would pay, *per year*, in higher taxes to support the program described in question 31? (fill in an amount equal to or greater than zero).

I WOULD PAY UP TO $__________ PER YEAR

<u>Well Water version of questionnaire</u>

31. The program described in question 27 protects people's health. The program could be broadened to directly protect groundwater.

Like question 27, the program would protect the people in your county who use household wells. It would:

1. Test all household wells in the county for harmful chemicals. Each well would be tested once a year.

2. Install filtering devices for water used by a household to remove any harmful chemicals that are detected.

3. Employ trained technicians to monitor and maintain the filtering devices in top working condition.

The program would also prevent any further increase in groundwater pollution in your county. It would:

4. Identify sources of groundwater pollution.

5. Take educational, regulatory, and legal action to prevent further pollution of groundwater.

Suppose this five-part program were put to a vote. Would you vote for or against the county-wide program and tax if it *cost your household* $2 *per month* for a total payment of $24 *per year*? (circle one)

1. VOTE *FOR* THE PROGRAM AND TAX
2. VOTE *AGAINST* THE PROGRAM AND TAX

32. What is the very most you would pay, *per year*, in higher taxes to support the program described in question 31? (fill in an amount equal to or greater than zero).

I WOULD PAY UP TO $__________ PER YEAR

33. In your judgement, does the program in question 31 reduce the health threat posed by groundwater pollution in your county? By how much would the health threat really be reduced? (circle one)

1. 90 TO 100 PERCENT	6. 40 TO 49 PERCENT
2. 80 TO 89 PERCENT	7. 30 TO 39 PERCENT
3. 70 TO 79 PERCENT	8. 20 TO 29 PERCENT
4. 60 TO 69 PERCENT	9. 10 TO 19 PERCENT
5. 50 TO 59 PERCENT	10. 0 TO 9 PERCENT

34. In your judgement, does the program in question 31 protect groundwater in your county from further pollution? By how much would further groundwater pollution really be reduced? (circle one)

1. 90 TO 100 PERCENT	6. 40 TO 49 PERCENT
2. 80 TO 89 PERCENT	7. 30 TO 39 PERCENT
3. 70 TO 79 PERCENT	8. 20 TO 29 PERCENT
4. 60 TO 69 PERCENT	9. 10 TO 19 PERCENT
5. 50 TO 59 PERCENT	10. 0 TO 9 PERCENT

35. How important were the following items in your decision to vote for or against the program and tax described in question 31?

Item	Circle the Level of Importance for Each Item				
a. Health of your household....	VERY IMPORTANT	IMPORTANT	SOMEWHAT IMPORTANT	LEAST IMPORTANT	NOT IMPORTANT
b. Health of other households..	VERY IMPORTANT	IMPORTANT	SOMEWHAT IMPORTANT	LEAST IMPORTANT	NOT IMPORTANT
c. Health of future generations.	VERY IMPORTANT	IMPORTANT	SOMEWHAT IMPORTANT	LEAST IMPORTANT	NOT IMPORTANT
d. Protecting groundwater for its own sake..............	VERY IMPORTANT	IMPORTANT	SOMEWHAT IMPORTANT	LEAST IMPORTANT	NOT IMPORTANT
e. Tax cost of program..........	VERY IMPORTANT	IMPORTANT	SOMEWHAT IMPORTANT	LEAST IMPORTANT	NOT IMPORTANT

You and Your Household

36. Where is your home located? (circle one)

1. A CITY
2. A TOWN
3. A SUBURB
4. A RURAL AREA, BUT NOT A FARM
5. ON A FARM

37. Is farming an important source of income for your household? (circle one)

1. YES
2. NO

38. Does your household rent or own the home you live in?

1. RENT
2. OWN
3. OTHER

39. How many people, including yourself, are there in your household? (circle one)

1. ONE — SIX
2. TWO — SEVEN
3. THREE — EIGHT
4. FOUR — NINE
5. FIVE — 10.TEN OR MORE

40. How many children 16 years of age or younger are there in your household? (circle one)

1. ZERO — FIVE
2. ONE — SIX
3. TWO — SEVEN
4. THREE — EIGHT
5. FOUR — 10.NINE OR MORE

41. What is your age? (circle one)

1. 18-25 YEARS
2. 26-35 YEARS
3. 36-45 YEARS
4. 46-55 YEARS
5. 56-65 YEARS
6. 66-75 YEARS
7. 76 OR MORE YEARS

42. Are you female or male? (circle one)

1. FEMALE
2. MALE

43. What was the last year of school that you completed? (circle one)

1. NO SCHOOL
2. SOME OR ALL OF ELEMENTARY SCHOOL
3. SOME HIGH SCHOOL
4. LAST YEAR OF HIGH SCHOOL
5. SOME COLLEGE OR TRADE SCHOOL
6. LAST YEAR OF COLLEGE OR MORE

44. What do you expect your total household income, from all sources, to be during the next 12 months? (circle one)

1. $0 to $9,999
2. $10,000 to 19,999
3. $20,000 to 29,999
4. $30,000 to 39,999
5. $40,000 to 49,999
6. $50,000 to 59,999
7. $60,000 to 69,999
8. $70,000 to 79,999
9. $80,000 to 89,999
10. $90,000 to 99,999
11. $100,000 to 109,999
12. $110,000 to 149,999
13. $150,000 to 199,999
14. $200,000 and over

****

Thank you *very much* for your help and cooperation. Your opinion on each question counts a great deal.

If you would like to share any additional comments, please write on this page.

APPENDIX C

APPENDIX C

SURVEY RESPONSE RATES

Sample households were mailed up to three questionnaires, in order to increase the likelihood that questionnaires would be returned. Table C-1 summarizes the overall survey response rate. A total of 2,020 Michigan households were sent questionnaires. The statewide sample consisted of two subsamples; the urban subsample consisted of 673 households, the rural subsample 1,347 households. A total of 173 surveys were returned as undeliverable (8.6 percent of the total). Consequently, a total of 1,847 households received questionnaires.

Returned questionnaires numbered 1,229, for a gross response rate of 66.5 percent. This figure includes all returned questionnaires. Of the total returned questionnaires, 16 were not usable. Identification labels were missing on nine questionnaires. As a result, it was not possible to classify these questionnaires as urban or rural; they were not used. Four questionnaires were returned unanswered, and three had responses which indicated they were not taken seriously. This left a total of 1,213 net usable questionnaires, for a net usable return rate of 65.7 percent. "Usable" is used here to mean that at least a portion of the questionnaire was responded to, and the responses were such that the questionnaire appeared to be taken seriously.

Table C-1 Survey Return Characteristics

Michigan Households Surveyed.

Rural:	1,347
Urban:	673
Total:	2,020

Questionnaires undeliverable to addressee: 173 (8.6 percent of total).

Households receiving questionnaire: 1,847

Total returned Questionnaires: 1,229

Gross return rate: 66.5 percent

Unusable Questionnaires: 16

a. ID labels missing: 9

b. Questionnaires returned unanswered: 4

c. Questionable response validity: 3

Net usable returns: 1,213

Net usable return rate: 65.7 percent

Ten of the returned questionnaires were not from the person to whom the questionnaire was addressed. Eight of these questionnaires were from spouses or children of deceased individuals. Two were from individuals who lived at addresses where the original addressee no longer lived. Since the survey attempts to sample rural or urban headsof households, and the number is small, this substitution of respondents does not appear to be crucial to the statistical validity of the survey.

The overall response rate is comparable with other surveys, both generally and specifically with regard to contingent valuation surveys. Dillman (1978, pp. 21-24) summarizes the response rates to 38 different mail surveys, which used the total design method and dealt with a wide variety of topics. The number of responses required for a given survey ranged from 25 to 238 items. The average response rate was 74 percent, with no survey obtaining less than 50 percent. However, none the these surveys required presented respondents with economic valuation questions.

Cameron and Mitchell (1989, p. 281) summarize the return rates from 16 contingent valuation surveys undertaken between 1974 and 1986. Using a gross response rate (total number of surveys in the sample divided by the total number of questionnaires completed and returned), the average for the surveys cited in Mitchell and Carson is 47.6 percent. It should be noted that not all of these surveys employed the total design method. Two recent contingent valuation surveys dealing with groundwater pollution are Edwards (1988) and Shultz and Lindsay (1990). Both used the total design method in implementing the survey. Edwards obtained a gross response rate of 78.5 percent, while Shultz and Lindsay 57.6 percent. The Michigan groundwater survey obtained a gross response rate of 60.5 percent. It should be noted that both the Edwards and Shultz and Lindsay studies focused on a specific community, while the Michigan study was statewide. It would seem that higher response rates would be expected by focusing on areas where currently there is concern over groundwater contamination (whether government planning purposes or from public perception), as opposed to a statewide survey where that may or may not be the case.

Table C-2 summarizes the return rates for each of the three mailouts. The first questionnaire mailout was Tuesday, 31 July 1990. The total number of surveys mailed was 2,020. Of these, 761 were eventually returned. This results in a gross return rate for the first mailout of 37.7 percent. If all the questionnaires which were post returned are subtracted from the total number of surveys sent, the return rate increases to 41.2 percent.

The second questionnaire mailout occurred three weeks later on Tuesday, 21 August. All households which did not return a questionnaire, and for which no postal return had been received, were sent a second questionnaire. Questionnaires mailed in this second mailout totaled 1,262. A total of 359 were eventually returned for a return rate of 28.4 percent.

The third and final questionnaire mailout took place four weeks later, on Tuesday, 18 September. A total of 749 questionnaires were mailed, and 109 were returned for a return rate of 14.6 percent.

Table C-2 Return Rates for Questionnaire Mailouts

Mailout Date	Number Mailed	Number Returned	Rate[1]
July 31	2,020	761	37.7
August 21	1,262	359	28.4
September 18	749	109	14.6

1 Rate is calculated by dividing number returned by number mailed out. If all post returns are subtracted from the number mailed for the July 31 survey, the return rate is 40.5 percent.

Table C-3 shows the percentage of total questionnaire returns by week for each of the three surveys. For example, the first entry under the July 31 column, 38.6, shows the percentage of total returns for the July 31 mailout that occurred by the end of the first week after the mailout. During the second post mailout week, 41.8 percent of returned surveys were returned. During the third week, 3.7 percent were returned, with the remaining 15.9 percent being returned after the third week. The first two mailouts are fairly comparable in weekly return rates. The 31 July mailout had about 80 percent of all returned questionnaires returned by the end of the second post-mailout week. The 21 August mailout had approximately 78 percent of its total returns by the end of a comparable time period.

Table C-3 Survey Returns by Week

Week	Percentage of Total Return Surveys[1]		
First week	38.6	25.9	33.1
Second week	41.8	52.6	25.4
Third week	3.7	9.2	15.3
After third week	15.9	12.3	26.2
Total	100.0	100.0	100.0

[1] Total Returned surveys for specified mailout date.

The weekly response rate of the initial mailout is comparable with other surveys used the total design method. Dillman (1978, p. 185-186) refers to five surveys of the general public, conducted in four states, where the response rate up to the postcard reminder mailout one week after the initial mailout ranged from 19 to 27 percent. The response rate for the groundwater survey for a comparable period was 16.0 percent. For the period after the postcard reminder, but before the second mailout, the incremental response rate ranged from 15 to 25 percent. For the groundwater survey, the incremental response rate was 23.8 percent.

APPENDIX D

APPENDIX D

SURVEY RESPONSES

This appendix contains a number of tables which detail questionnaire responses. The following seven tables are included: (1) sample demoographics; (2) water use information; (3) respondent water quality perceptions; (4) respondent risk perceptions regarding severity; (5) respondent risk perceptions regarding knowledge; (6) respondent risk perceptions regarding choice; and (7) respondents environmental perceptions.

Responses are included for both the rural and urban samples. For each sample responses for both the complete sample set and the restricted sample set are also included. The presentation order of the tables follows closely the order of the subject matter presentation in the text.

Table D-1. Sample Demographics
(percentage of usable responses in specified category)

	Rural		Urban	
	Complete	Restricted	Complete	Restricted
Expected Annual Income (Q44)				
Under $10,000	0.1	0.2	0.0	0.0
10,000 to 19,999	21.9	17.7	13.8	12.7
20,000 to 29,999	23.2	23.5	15.7	14.7
30,000 to 39,999	16.3	19.2	16.3	14.2
40,000 to 59,999	27.3	26.9	34.1	34.8
60,000 to 99,999	8.0	9.4	14.3	17.1
over 100,000	3.0	3.2	5.6	8.4
Non-responses	14.7	-	12.5	-
Mean	39.20	40.48	47.26	48.53
S.D.	26.53	26.76	29.09	27.51
Education (highest level completed) (Q43)				
No school (1)	0.1	0.0	0.0	0.0
Elementary (2)	3.7	2.8	4.1	1.5
Some high school (3)	9.6	8.5	8.8	5.4
High school (4)	32.0	27.7	20.3	19.6
Some college (5)	30.9	32.8	33.2	35.8
College (6)	22.3	27.1	31.6	36.3
Non-responses	4.4	-	2.7	-
Mean[1]	4.58	4.74	4.81	5.01
S.D.	1.06	1.04	1.10	0.96

[1] Response means are based on the number in parentheses following the response categories for a particular question.

Table D-1 (continued)

	Rural		Urban	
	Complete	Restricted	Complete	Restricted
Age (Q41)				
18-25 (1)	3.6	4.9	2.7	3.4
26-35 (2)	16.1	18.6	28.2	33.8
36-45 (3)	22.0	23.9	19.7	25.0
46-55 (4)	16.8	19.4	18.6	16.7
56-65 (5)	15.5	12.6	14.5	9.8
66 and over (6,7)	26.0	20.7	16.2	11.3
Non-responses	3.6	-	2.4	-
Mean	4.12	3.842	3.67	3.33
S.D.	1.68	1.63	1.58	1.49
Home location (Q36)				
City (1)	25.6	27.3	48.1	47.5
Town (2)	16.4	15.8	7.9	8.3
Suburb (3)	4.9	6.0	27.7	27.5
Rural area but not a farm (4)	40.6	38.4	14.1	13.7
Farm (5)	12.5	12.6	2.2	2.9
Non-responses	3.1	-	1.6	-
Mean	2.98	2.93	2.14	2.16
S.D.	1.45	1.46	1.23	1.24

Table D-1 (continued)

	Rural		Urban	
	Complete	Restricted	Complete	Restricted
Home ownership (Q38)				
Rent (1)	10.5	10.9	16.9	17.2
Own (2)	87.7	87.6	81.4	82.4
Other (3)	1.8	1.5	1.7	0.4
Non-responses	3.3	-	2.1	-
Mean	1.91	1.91	1.85	1.83
S.D.	0.34	0.34	0.40	0.39
Household size (Q39)				
One (1)	16.6	11.9	17.5	17.6
Two (2)	36.7	38.2	33.3	27.5
Three (3)	14.5	14.9	19.4	20.1
Four or more (4-10)	32.1	34.8	29.8	34.8
Non-responses	3.0	-	2.1	-
Mean	2.81	2.92	2.79	2.87
S.D.	1.45	1.42	1.40	1.39
Number of children 16 years or younger in household (Q40)				
None (1)	64.1	61.2	63.4	55.9
One (2)	11.4	12.4	12.8	16.2
Two (3)	16.3	17.9	15.0	19.1
Three (4)	5.6	5.5	6.8	7.4
Four or more (5-10)	2.5	2.9	1.9	1.5
Non-responses	3.7	-	2.1	-
Mean	1.73	1.80	1.72	1.83
S.D.	1.17	1.23	1.10	1.09

Table D-2. Water Use Information
(percent of usable responses in each category)

	Rural		Urban	
	Complete	Restricted	Complete	Restricted
Water Source (Q1)				
Community or public water system (1)	40.9	41.9	77.1	76.0
Household Well (2)	57.7	56.8	21.5	23.5
Spring, stream, river (3)	1.0	0.6	0.5	0.0
Other (4)	0.5	0.6	0.8	0.5
Non-responses	1.0	-	1.3	-
Mean (S.D.)	1.61 (0.54)	1.60 (0.54)	1.25 (0.50)	1.25 (0.47)
Drinking Water Source (Q2)				
Tap (1)	92.6	92.3	91.8	93.1
Bottled Water, purchased (2)	4.5	4.7	6.5	6.4
Bottled water, other (3)	1.6	1.5	0.5	0.5
Non-responses	1.1	-	1.3	-
Mean (S.D)	1.12 (0.47)	1.12 (0.48)	1.09 (0.35)	1.07 (0.30)
Water Tested (Q4)				
No (1)	82.7	85.8	91.2	91.6
Yes (2)	17.3	14.2	8.8	8.4
Non-responses	2.6	-	2.2	-
Mean (S.D.)	1.17 (0.38)	1.14 (0.35)	1.09 (0.28)	1.08 (0.28)

Table D-3. Respondent Water Quality Perceptions (percent of usable responses in each category)

	Rural Complete	Restricted	Urban Complete	Restricted
Tap Water Safety (Q3)				
Very safe (1)	55.5	53.2	41.9	41.2
Somewhat safe (2)	20.4	21.6	24.4	26.0
Not sure (3)	21.4	22.6	30.7	31.4
Somewhat unsafe (4)	2.3	2.6	1.9	1.0
Very unsafe (5)	0.4	0.2	0.8	0.5
Non-responses	0.8	-	1.9	-
Mean (S.D.)	1.72 (0.90)	1.75 (0.91)	1.96 (0.95)	1.94 (0.90)
Confidence that tap water is safe from effects of groundwater pollution (Q5)				
Very confident (1)	22.9	22.0	12.5	10.3
Confident (2)	45.8	44.1	46.9	48.8
Not confident (3)	24.7	25.8	31.9	32.0
Not confident at all (4)	6.7	8.1	8.4	8.9
Non-responses	1.3	-	1.3	-
Mean (S.D.)	2.15 (0.85)	2.20 (0.87)	2.36 (0.81)	2.39 (0.79)

Table D-4. Respondent Risk Perceptions: Severity (percentage of usable surveys in specified category)

	Rural		Urban	
	Complete	Restricted	Complete	Restricted
Seriousness of health risk from groundwater pollution (Q7)				
Very Serious (1)	9.1	9.6	13.6	12.3
Serious (2)	13.5	11.9	24.4	21.1
Somewhat Serious (3)	36.7	37.5	35.7	37.7
Not Serious (4)	33.4	35.0	22.7	27.5
Not a threat at all (5)	6.4	6.0	3.7	1.5
Non-responses	2.4	-	5.1	-
Mean (S.D.)	3.15 (1.04)	3.16 (1.03)	2.78 (1.06)	2.85 (1.01)
Degree of fear of groundwater pollution (Q15)				
Fear greatly (1)	24.0	23.5	23.3	21.6
Fear Somewhat (2)	47.2	48.8	52.0	50.0
Fear very little (3)	22.2	22.0	20.6	24.5
Fear not at all (4)	6.7	5.8	4.1	3.9
Non-responses	1.3	-	0.8	-
Mean (S.D.)	2.11 (0.85)	2.10 (0.82)	2.05 (0.77)	2.11 (0.78)

Table D-4 (continued)

	Rural		Urban	
	Complete	Restricted	Complete	Restricted
Fatalness (Q18)				
Very likely to be fatal (1)	3.5	3.0	6.7	5.4
Likely to be fatal (2)	11.7	11.3	11.8	10.8
Sometimes Fatal (3)	44.3	42.9	41.2	40.2
Unlikely to be fatal (4)	33.4	36.2	34.2	37.7
Not fatal (5)	7.2	6.6	6.2	5.9
Non-responses	3.3	-	4.0	-
Mean (S.D.)	3.29 (0.89)	3.32 (0.87)	3.21 (0.97)	3.28 (0.93)
Groundwater pollution injuring people one at a time or many at once				
One at a time (1)	14.0	12.8	10.1	9.3
A few people at once (2)	40.6	38.2	29.9	33.3
Many people at once (3)	32.5	36.9	34.2	33.3
Very many people at once (4)	6.5	6.8	11.0	11.3
A very large number at once (5)	6.3	5.3	14.2	12.7
Non-responses	2.6	-	1.9	-
Mean (sd)	2.50 (1.02)	2.54 (0.98)	2.89 (1.17)	2.85 (1.15)

Table D-5. Respondent Risk Perceptions: Knowledge (percentage of usable surveys in specified category)

	Rural Complete	Rural Restricted	Urban Complete	Urban Restricted
Scientific knowledge of groundwater pollution health risks (Q8)				
Known precisely (1)	4.2	4.5	8.0	4.9
Known (2)	32.6	34.8	29.9	30.4
Somewhat known (3)	45.6	45.4	45.6	49.0
Only suspected or guessed at (4)	15.2	13.0	14.3	15.2
Not known at all (5)	2.3	2.1	1.6	0.5
Non-responses	1.4	-	2.2	-
Mean (S.D.)	2.79 (0.83)	2.74 (0.82)	2.72 (0.87)	2.76 (0.79)
Knowledge of exposed individuals (Q9)				
Known precisely (1)	0.6	0.9	3.0	1.5
Known (2)	9.2	8.1	5.2	4.4
Somewhat known (3)	39.2	38.0	32.2	30.4
Only suspected or guessed at (4)	42.7	44.1	46.0	50.5
Not known at all (5)	8.0	8.7	13.4	13.2
Non-responses	1.6	-	1.3	-
Mean (S.D.)	3.49 (0.80)	3.52 (0.82)	3.62 (0.89)	3.70 (0.81)

Table D-5 (continued)

	Rural		Urban	
	Complete	Restricted	Complete	Restricted
Groundwater pollution as new or old environmental problem (Q10)				
Old (1)	10.3	10.7	14.4	14.2
Somewhat old (2)	22.3	23.2	25.3	21.6
Midway between new and old (3)	41.5	40.9	37.2	39.7
Somewhat new (4)	21.2	20.9	19.0	19.6
New (5)	4.7	4.3	4.1	4.9
Non-responses	1.3	-	1.1	-
Mean (S.D.)	2.88 (1.01)	2.85 (1.01)	2.73 (1.06)	2.79 (1.07)

Table D-6. Respondents Risk Perceptions: Choice (percentage of usable surveys in specified category)

	Rural Complete	Restricted	Urban Complete	Restricted
Controllability of groundwater pollution damage (Q13)				
Easy (1)	2.9	3.2	4.6	2.9
Possible (2)	36.0	33.9	33.1	33.3
Somewhat possible (3)	29.1	28.4	29.0	28.9
Very difficult (4)	29.1	31.8	30.6	32.4
Not possible (5)	2.7	31.8	30.6	32.4
Non-responses	1.6	-	1.6	-
Mean (S.D.)	2.93 (0.93)	2.97 (0.94)	2.94 (0.96)	2.98 (0.94)
Voluntariness of exposure to groundwater pollution risks (Q14)				
Voluntary	2.25	1.5	1.9	1.5
Somewhat voluntary	11.0	9.6	7.3	6.9
Somewhat involuntary	31.5	34.1	24.2	25.5
Involuntary	55.0	54.8	66.6	66.2
Non-responses	1.3	-	1.1	-
Mean (S.D)	3.39 (0.78)	3.42 (0.73)	3.55 (0.71)	3.56 (0.69)

Table D-7. Respondents Environmental Perceptions (percentage of usable responses in specified category)

	Rural Complete	Restricted	Urban Complete	Restricted
Extent to which future generations will be harmed by groundwater pollution (Q19)				
Not harmed at all (1)	1.4	1.1	1.4	1.5
Very unlikely to be harmed (2)	6.5	6.6	6.6	8.3
Not likely to be harmed (3)	16.3	16.0	11.7	12.3
Likely to be harmed (4)	49.4	51.2	46.2	46.6
Very likely to be harmed (5)	26.5	25.2	34.2	31.4
Non-responses	3.0	-	1.6	-
Mean (S.D.)	3.93 (0.90)	3.93 (0.88)	4.05 (0.92)	3.98(0.95)
Threat of groundwater pollution to wildlife and plants (Q20)				
Not a threat at all (1)	2.9	1.5	2.5	2.9
Not serious (2)	19.1	21.3	13.1	14.2
Somewhat serious (3)	40.2	40.1	36.1	35.8
Serious (4)	25.9	25.4	27.3	30.4
Very serious (5)	11.8	11.7	21.0	16.7
Non-responses	2.0	-	1.6	-
Mean (S.D.)	3.25 (0.99)	3.25 (0.97)	3.51 (1.04)	3.44(1.02)

Table D-7 (continued)

	Rural Complete	Restricted	Urban Complete	Restricted
Protect groundwater for own sake or only because it is a part of a natural system which affects people and other living things (Q21)[1]				
Protect for own sake	20.0	20.9	19.9	18.6
Protect because part of natural system	68.5	69.9	68.0	74.0
Disagree with both opinions	1.8	2.3	2.2	1.5
Don't Know	9.7	6.8	9.8	5.9
Non-responses	2.4	-	1.6	-
Pollution is bad because it is the wrong thing to do or because it has bad effects (Q22)[1]				
Pollution is wrong thing to do	75.4	77.4	74.9	79.4
Pollution is bad only when it has bad effects	14.2	15.6	16.6	16.7
Disagree with both opinions	5.0	4.5	2.2	2.5
Don't know	5.3	2.6	6.3	1.5
Non-responses	1.8	-	1.3	-

1 Means are not relevant for these questions.

Table D-7 (continued)

	Rural Complete	Restricted	Urban Complete	Restricted
Groundwater should be protected from pollution only when pollution poses a direct health threat to humans (Q23)				
Strongly agree (1)	14.6	11.5	13.9	10.8
Agree somewhat (2)	9.6	8.7	7.6	6.9
Disagree somewhat (3)	11.9	12.8	12.0	13.2
Strongly disagree (4)	60.1	65.0	62.0	67.6
Don't Know (5)	3.8	1.9	4.6	1.5
Non-responses	1.7	-	1.1	-
Mean (S.D.)	3.20 (1.12)	3.37 (1.07)	3.24 (1.09)	3.38 (1.02)

APPENDIX E

APPENDIX 5

PHONE SCRIPT

Hello, my name is (state name). I am a researcher at Michigan State University in the Department of Agricultural Economics.

We are doing research on some environmental issues that face Michigan citizens. As part of this project, we are asking people their opinions on some important environmental issues in Michigan.

What I would like to do is to invite you to a small group meeting on campus so that we can get your views on some of these important issues.

The meeting will include about 8-10 people from the Williamston area and will last about two hours.

If you decide to attend, we will pay you $50 to reimburse you for your time and trouble.

Do you think you might like to attend?

The meeting will be held at the Kellogg Center on the M.S.U. campus. It will begin (state time and date). We will pay for your parking.

We would like to mail you a formal invitation and directions to get to the Kellogg Center and which room the meeting will be held. May I have your name and address?

We'll send your invitation out within the next few days, and thank you very much for agreeing to attend.

LIST OF REFERENCES

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Babbie, Earl. Survey Research Methods. Belmont CA: Wadsworth Publishing Company, Inc., 1973.

Bishop, Richard C. and Thomas A. Herberlein. **Simulated Markets, Hypothetical Markets, and Travel Cost Analysis: Alternative Methods of Estimating Outdoor Recreation Demand** Staff Paper Series No. 187. Department of Agricultural Economics, University of Wisconsin, Madison.

Bishop, Richard C. and Thomas A. Herberlein. "Measuring Values of Extra-Market Goods: Are Indirect Measures Biased?." **American Journal of Agricultural Economics.** 61. (1979):926-930.

Brookshire, David; Alan Randall, and John Stoll. "Valuing Increments and Decrements in Natural Resource Service Flows." **American Journal of Agricultural Economics.** 63. (1980):478-488.

Craun, Gunther F. **A Summary of Waterborne Illness Transmitted Through Contaminated Groundwater**. Research Triangle Park NC: U. S. Environmental Protection Agency, 1985.

Cummings, Ronald G.; David S. Brookshire, and William D. Schulze, eds. **Valuing Environmental Goods**. Totowa NJ: Rowman and Allanheld, 1986.

Dillman, Don A. **Mail and Telephone Surveys: The Total Design Method**. New York: John Wiley and Sons, 1978.

Edwards, Steven F. "Option Prices for Groundwater Protection." **Journal of Environmental Economics and Management** 15. (1988):475-487.

Environ Corporation. **Approaches to the Assessment of the Health Impacts of Groundwater Contamination**. Washington DC: Office of Technological Assessment, 1983.

Ferguson, George A. **Statistical Analysis in Psychology and Education**. 3rd edition. New York: McGraw-Hill Book Company, 1971.

Fisher, Ann; Dan Violette, and Lauraine Chestnut. "The Value of Reducing the Risks of Death: A Note on New Evidence." **Journal of Policy Analysis and Management** 8. (1989):88-100.

Fischhoff, Baruch; Paul Slovic, Sarah Lichtenstein, Stephen Read, and Barbara Combs. "How Safe is Safe Enough? A Psychometric Study of Attitudes Towards Technological Risks and Benefits." **Policy Studies** 9. (1978):127-152.

Fischhoff, Baruch and Lita Furby. "Measuring Values: A Conceptual Framework for Interpreting Transactions with Special Reference to Contingent Valuation of Visibility." **Journal of Risk and Uncertainty** 1. (1988):147-184.

Gardner, Gerald T., Adrian R. Tieman, Leroy C. Gould, Donald R. De Luca, Leornard W. Doob and Jan A. J. Stolwijk. "Risk and Benefit Perceptions, Acceptability Judgements and Self-Reported Actions Toward Nuclear Power." **The Journal of Social Psychology** 116. (1982):179-197.

Henderson, Timothy R., Jeffrey Trauberman and Tara Gallagher. **Groundwater Strategies for State Action**. Washington, DC: Environmental Law Institute, 1987.

Graham, Daniel A. "Cost-Benefit Analysis under Uncertainty." **The American Economic Review** 71. (1981): 715-725.

Hoehn, John P. "Contingent Valuation in Fisheries Management: The Design of Satisfactory Contingent Valuation Formats." **Transactions of the American Fisheries Society** 116. (1987):412-419.

Hoehn, John P. and Alan Randall. "A Satisfactory Benefit Cost Indicator from Contingent Valuation." **Journal of Environmental Economics and Management** 14. (1987):226-247.

Hoehn, John P. "Valuing the Multidimensional Impacts of Environmental Policy: Theory and Methods." **American Journal of Agricultural Economics** 73. (1991):289-299.

Kmenta, Jan. **Elements of Econometrics**. 2nd edition. New York: MacMillan Publishing Company, 1986.

Kraus, Nancy Nighswonger and Paul Slovic. "Taxonomic Analysis of Perceived Risk: Modeling Individual and Group Perceptions within Homogeneous Hazard Domains." **Risk Analysis** 8. (1988):435-455.

Libby, Lawrence W. and Jessica T. Kovan. **Rural Groundwater Contamination: Impacts of and Potential Benefits from Land Use Planning and Zoning**. Agricultural Economics Staff Paper No. 86-88. East Lansing: Department of Agricultural Economics, Michigan State University, 1986.

Lichenstein, Sarah., Paul Slovic, Baruch Fischhoff, Mark Layman, and Barbara Combs. "Judged Frequency of Lethal Events." **Journal of Experimental Psychology: Human Learning and Memory** 4. (1978):551-578.

Loehlin, John C. **Latent Variable Models. An Introduction to Factor, Path and Structural Analysis**. Hillsdale NJ: Lawrence Erlbaum Associates,1987.

Lowrence, William W. **Of Acceptable Risk**. Los Altos CA: William Kaufman, Inc., 1976.

Michigan, State of. **Policy and Program Directions for Groundwater Protection in Michigan**. Discussion Paper for the Michigan Water Quality Management Plan. 1988.

Michigan Farm Bureau. **Nitrate Contamination of Groundwater in Michigan: A Survey.** Lansing MI: Michigan Farm Bureau, 1989.

Michigan, State of. **Report of the House Ad Hoc Committee on Groundwater Protection.** Lansing MI: Michigan State Legislature, 1987.

Mitchell, Robert Cameron and Richard T. Carson. **Using Surveys to Value Public Goods**. Washington, DC: Resources for the Future, 1989.

Nielsen, Elizabeth G. and Linda K. Lee. **The Magnitude and Costs of Groundwater Contamination from Agricultural Chemicals**. Washington DC: U.S. Department of Agriculture, Economic Research Service, 1987.

Olsen, Larry G. "Agricultural Chemicals Detected in Groundwater in Michigan by MDA Pilot Survey." **Pesticide Notes** 2. published by Michigan Cooperative Extension Service (1989):2-5.

Pye, Veronica I., Ruth Patrick and John Querles. **Groundwater Contamination in the United States**. Philadelphia: University of Pennsylvania, 1987.

Randall, Alan and John R. Stoll. "Existence Value in a Total Valuation Framework." in Robert D. Rowe and Lauraine G. Chestnutt (eds.) **Managing Air Quality and Scenic Resources at National Parks and Wilderness Areas**. Boulder, CO: Westview Press, 1983.

Raucher, Robert. "A Conceptual Framework for Measuring the Benefits of Groundwater Protection." **Water Resources Research** 19. (1983):320-326.

Raucher, Robert. "The Benefits and Costs of Policies Related to Groundwater Contamination." **Land Economics** 62. (1986):33-45.

Sharefkin, Mark, Mordechai Shechter and Allen Kneese. "Impacts, Costs, and Techniques for Mitigation of Contaminated Groundwater: A Review." **Water Resources Research** 20. (1984):1771-1783.

Shechter, Mordechai. "An Anatomy of a Groundwater Contamination Episode." **Journal of Environmental Economics and Management** 12. (1985a):72-88.

Shechter, Mordechai. "Economic Aspects in the Investigation of Ground-water Contamination Episodes." **Groundwater** 23. (1985):190-197.

Shultz, Steven D. and Bruce E. Lindsay. "The Willingness to Pay for Groundwater Protection." **Water Resources Research** 26. (1990):1869-1875.

Slovic, Paul. "Perceptions of Risk." **Science** 236. (1987):280-285.

Slovic, Paul, Baruch Fischhoff and Sarah Lichtenstein. "Behavioral Decision Theory Perspectives on Risk and Safety." **Acta Psychology** 56. (1984):183-203.

Solley, Wayne B., Edith B. Chase and William B. Mann IV. **Estimated Use of Water in the United States in 1980.** Geological Survey Circular 1001. Washington, DC: Government Printing Office, 1983.

Tversky, Amos and Daniel Kahneman. "The Framing of Decisions and the Psychology of Choice." **Science** 211. (1981):453-458.

U.S. Environmental Protection Agency. **National Statistical Assessment of Rural Water Conditions, Executive Summary**. Washington D.C.: U.S. Environmental Protection Agency, 1984.

U.S. Department of Commerce. **County and City Data Book 1988.** Washington, D.C.: U.S. Government Printing Office, 1988.

U.S. Geological Survey. **Groundwater Hydrology and Water Quality in Kalamazoo County, Michigan.** Washington, D.C.: U.S. Geological Survey, 1985.

U.S. Geological Survey. **National Water Summary 1984: Hydrologic Events, Selected Water Quality Trends and Groundwater Resources.** Washington D.C.: U.S. Government Printing Office, 1985.

U.S. Geological Survey. **Basic Groundwater Hydrology**. Water Supply Paper 2200. (Washington, D.C.: U.S. Government Printing Office, 1984.

Walpole, Ronald E. and Raymond H. Myers. **Probability and Statistics for Engineers and Scientists.** New York: MacMillan Publishing Company, Inc., 1978.

Ward, C.H., W.Geiger and P.L. McCarty. **Groundwater Quality**. New York: John Wiley and Sons, 1985.

Weinstein, Milton C. and Robert J. Quinn. "Psychological Considerations in Valuing Health Risk Reductions." **Natural Resources Journal** 23. (1983):659-673.

Weinstein, Milton C., Donald S. Shepard and Joseph S. Pliskin. "The Economic Value of Changing Mortality Probabilities: A Decision-Theoretic Approach." **The Quarterly Journal of Economics** 84. (1980):373-396.