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Measuring the Benefits of Groundwater Protection from Agricultural Contamination: Results from a Two-Stage Contingent Valuation Study

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Growing public concern about environmental safety and the prevailing public opinion that farm chemicals are a major source of groundwater contamination have led to a wide range of policy proposals designed to protect aquifers from further contamination by agricultural sources. In order to rationally assess such policy proposals and to ensure that the policies selected are in the best interest of society as a whole, it is essential to have a good measure of the social benefits of groundwater protection, or conversely, the damages associated with increased levels of groundwater contamination.

This paper is composed of two sections. The first section develops the theoretical foundations for estimating the benefits of groundwater protection programs based on risk of mortality/statistical life theory. The motivating factor for this approach is that economic damages associated with contamination should be assessed from a perspective that accounts for individual preferences for health risks associated with alternative levels of exposure. As such, this approach differs from previous valuation studies which have either ignored individual perceptions of health risk or otherwise focused only on avoided cost techniques.

The second section reports the results of a two-stage dichotomous choice contingent valuation study that focuses on how information affects the value placed on groundwater protection programs. Willingness to pay for a community wide groundwater protection program is elicited before (ex ante) and after (ex post) the results of individual well tests for nitrates are provided to rural residents. In the ex ante survey the level of information about health effects of nitrates, sources of contamination, and opportunities for averting behavior is also varied across groups.

The contingent valuation study was conducted in Portage County, Wisconsin. This area has had extensive nitrate contamination problems and is now considering a broad spectrum of policy proposals ranging from installation of community denitrification plants to regulating agricultural inputs. Sample size is 480 households. Approximately 17 percent of the sample have nitrate levels that exceed EPA standards.

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Agricultural contamination of groundwater is a growing concern in Wisconsin. Monitoring studies across the state indicate that 10 percent of Wisconsin's 700,000 private wells currently exceed public health standards for nitrates. In some Wisconsin counties this proportion exceeds 30 percent, and some communities with public wells have been forced to find alternative sources of water. In addition to actual discoveries of groundwater contamination, a recent USDA study concluded that water supplies in 50 of Wisconsin's 71 counties are potentially at risk from groundwater contamination by pesticides and fertilizers [Nielsen and Lee]. Recognizing this growing problem, the Wisconsin Department of Natural Resources presently lists agricultural activities as the number one source of groundwater contamination in Wisconsin [WDNR, 1988].

Elevated public concern about environmental risk and the general recognition that agricultural practices are affecting water quality have led to a number of new policy proposals to protect aquifers from future contamination by agricultural sources. These proposals include: making polluters (including farmers) strictly liable for the pollution and responsible for the provision of potable water to replace contaminated water; taxes on certain agricultural chemicals and subsidies for non-polluting practices; restricting agricultural practices such as irrigation and selected crop rotations; seasonal and soil related prohibitions on nutrient and pesticide applications; and assisting farmers with management strategies [Segerson; Anderson et al.; Wise and Johnson]. In order to rationally assess such policy proposals and to ensure that the policies adopted are in the best interests of society as a whole, it is necessary to have a good measure of the social costs of groundwater contamination, or, conversely, the benefits of groundwater protection.

This paper reports the preliminary results of a two-stage contingent valuation study of groundwater protection. Attention is focused on how information affects the value placed on groundwater protection programs. Willingness to pay for a community wide groundwater protection program for nitrates is elicited before (ex ante) and after (ex post) the results of individual well tests were provided to rural residents. Information about nitrates was also varied across groups in the ex ante stage of the study.

Information provision is an important issue in contingent valuation of environmental risks. Past research suggests that information will affect contingent values placed on environmental assets [Cummings, Brookshire and Shulze; Bergstrom, Randall and Stoll; Boyle]. Furthermore, various studies show that perceptions of health risk are affected by information [Smith et al.; Smith and Johnson; Smith]. To our knowledge, however, this is the first study that examines the relationship between environmental risks, information and contingent values.

Theoretical Framework and Estimation Methods

People value groundwater protection because groundwater contamination represents a potential health risk to themselves and people they care about. Past investigations into the social costs of groundwater contamination have largely ignored personal preferences over health risks. For example, the mortality avoided approach taken by Raucher (1983, 1986) and the avoided cost techniques applied by various authors (e.g. Walker and Hoehn; Nielsen and Lee) ignore individual preferences for risks altogether. Likewise, Edwards' study of option prices for nitrate protection in Cape Cod reportedly excluded individual health risk considerations in the estimation of benefits[1].

Individual concerns and aversion to health risks should play an integral part in valuing policies that affect environmental risk. Moreover, valuation of groundwater protection should be based on what individuals perceive their health risks to be rather than simply relying on

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[1]. In the text and an explanatory footnote (p. 477), Edwards argues that health risks should not have been a consideration in the valuation exercise because households were informed that "Health effects are not listed because water quality is being monitored to protect us from using contaminated water".

"bright-line" government standards. The deviation between the standards approach (such as that employed in Edwards) and subjective risk perceptions may be large. For example, a recent study found that only 23 percent of the people surveyed nationwide were willing to accept drinking water 'as safe' that contained "only small amounts of chemicals" but met government standards [Batie].

Here, we extend previous work in ex ante valuation of health risks [Jones-Lee; Weinstein, Shepard and Plisken; Smith and Desvousges; Viscusi; Smith] to develop an option price framework for valuing a groundwater protection program. Suppose that, for each nitrate level, a household's expected utility is defined by

$$\bar{U}(\Pi_I, Y_i; N) = (1-\Pi_I(N))U_H(Y_H, N) + \Pi_I(N)U_I(Y_I, N) \qquad (1)$$

where,

$\overline{U}(.)$	=	Expected utility based on subjective probabilities.
$\Pi_I(N)$	=	Subjective probability of a member of the household falling ill at each level of nitrate.
Y_i	=	State dependent income: subscript H denotes a healthy state and subscript I denotes illness.
N	=	Nitrate level in drinking water.
$U_i(.)$	=	State dependent indirect utility: subscript H denotes a healthy state and subscript I denotes illness.

It is important to note that nitrate levels are not simply point values, but are instead random variables defined over a range from zero to a plausible maximum value (A). Letting $f_t(N;0)$ represent the probability density function and $F_t(N;0)$ be the associated cumulative density function of this variable at time t without a groundwater protection program, the ex ante level of well being ($\overline{EU}_t$) becomes

$$\overline{EU}_t = \int_0^A \bar{U}(Y_i, \pi_j(N), N) dF_t(N;0) \tag{2}$$

where all variables were defined previously. Conceptually, equation 2 could be reduced to a two-stage lottery over health states wherein probabilities of exposure and health outcomes are combined into a single probability of illness (e.g. Smith and Desvousges). Such a simplification does not, however, permit nitrate levels to enter the utility function. This distinction is important if individual preferences over nitrate levels are independent of household health risks. Reduction of probabilities to a lottery over health states does not allow for existence values that stem from the satisfaction of knowing that the water resource is safe for others (vicarious consumption) and/or that environmental integrity is being preserved (stewardship) [Raucher, 1983, 1986; Mitchell and Carson, 1989]. Existence values may also derive from bequest motives, which represent concerns for protecting the groundwater for future generations.

Within this framework, option price (OP) for a project that affects the probability distribution of nitrates within a given period would be implicitly defined as

$$\int_0^A \bar{U}(Y_i - OP, \Pi_j(N), N) dF_t(N,1) = \int_0^A \bar{U}(Y_i, \Pi_j(N), N) dF_t(N,0) \tag{3}$$

where 1 indicates that the project is undertaken and 0 represents the absence of such a project.. Although we offer no formal mechanism, it is assumed that this option price, which is for a specific time frame, can be discounted and annualized into an annual willingness to pay value.

Information is an important factor in this valuation process. To understand the role of information it is helpful to first consider a household that has very little knowledge (or previous information) about nitrate contamination. Such a household would not be able to identify the possible health effects of nitrates (e.g. blue baby syndrome) and would be very uncertain about the probabilities associated with each of these unknown states (in this case $\Pi_i(N)$). To coin the terminology of Zeckhauser and Viscusi, these individuals would be in a state of ignorance and uncertainty. In addition, households would be unable to formulate their probabilities of exposure. In the above framework this condition is characterized by a poorly defined distribution over nitrate levels as specified by $f_t(N,j)$.

General information (GI) about nitrates would affect individual preferences with respect to nitrates and would enable the household to formulate the probabilities of each health state associated with different nitrate levels. It is important to note that this new information would not necessarily make risk assessments more accurate. Before receiving nitrate information individuals may have been relatively unaware and hence unconcerned about nitrates in groundwater. This new, and perhaps unwanted, information may create confusion rather than allow for the household to better formulate their values. Specific information (SI) about their own nitrate level would affect values by altering the beliefs about the distribution of nitrates in groundwater. That is, the perceived distribution of nitrates in drinking water is contingent upon specific data about current levels of nitrates.

On this basis, general and specific information can be incorporate into equation 3 as follows.

$$\int_0^A \bar{U}(Y_i - OP, \Pi_i(N|GI), N; GI)\, dF_t(N,1;SI) = \int_0^A \bar{U}(Y_i, \Pi_i(N|GI), N; GI)\, dF_t(N,0;SI) \qquad (4)$$

The only difference between equations 3 and 4 is that general information is now an argument in perceived risks and preferences and specific information affects the perceived distribution of nitrates in drinking water. As discussed above, it is assumed that the option prices can be restated in terms of annualized willingness to pay values for a groundwater protection program that affects the distribution of nitrates.

To elicit these willingness to pay values, this study uses a dichotomous choice contingent valuation model (DC–CVM) based on a tolerance or expenditure difference approach [Cameron; McConnell; Duffield and Patterson]. An assumption underlying the tolerance approach is that each individual has a true maximum value that he or she places on a resource or proposed project. Let the distribution of this value for the population, which shall be represented by willingness to pay (WTP), be characterized by the cumulative density function G(A) where A is a continuum of dollar amounts. Within this framework, the probability of a "Yes", $\pi(A)$, response to a bid value, A, is given by

$$\pi(A)=Pr(true\ \ WTP>A)\ =\ 1-G(A) \tag{4}$$

Estimation of $\pi(A)$ (or G(A)) is accomplished by distributing bids $A_1,...A_m$ across 1,...,n individuals with $m \leq n$. For each individual a Yes/No response (r_n) is obtained. This sampling strategy provides a data set of n observations (n, A_m, r_n), from which $\pi(A)$ is estimated by assuming some underlying distribution. In this study, the following standard logistic distribution is assumed to represent the cumulative distribution function

$$\pi(A)=[1+e^{-(\alpha+\beta A)}]^{-1} \tag{6}$$

Parameters estimated in the logit equation can, in turn, be used to estimate desired welfare measures and their distributions. For example, mean willingness to pay in DC–CVM has been shown to be [Hanemann, 1989]

$$E(WTP)=\int_0^\infty \pi(A)dA=\frac{1}{-\beta}\ln(1+e^{\alpha}) \tag{7}$$

where α and β correspond to the coefficients defined in equation (6). In the following analyses, empirical distributions and confidence intervals for this estimate were simulated using the Krinsky and Robb technique as extended by Park, Loomis and Creel. Difference tests between distributions were made using the convolutions technique detailed in Poe, Lossin and Welsh.

Study Design

The contingent valuation study was conducted in rural portions of Portage County, Wisconsin. This county has had extensive nitrate contamination problems over the last two decades. Approximately 18 percent of private wells in the county currently exceed the government standards for nitrates, and a public well has been closed because of nitrate contamination. Local lending institutions require that homes meet nitrate standards in order to obtain a mortgage.

Here, "rural" is defined as the 1980 census tracts which do not have municipally provided water. This group, which contained 27,746 residents in 1990, was selected for this study for the following reasons: 1) Past research on groundwater contamination indicated that a wide range of nitrate levels existed in this area; 2) The major source of elevated nitrates in the study area "appears to be agricultural activities up gradient from the well" [Portage County Groundwater Management Plan, Vol. 1, p. 128]; 3) Public concern in the area has led to a variety of policy proposals including rezoning, installation of community wells and denitrification systems, establishment of buffer zones and regulation of farmers; and, 4) Rural residents are not protected by state and EPA standards for nitrates. Currently, remedial actions at the household level offer the only options for private well owners with excessive nitrates in their water. In contrast to other chemicals such as atrazine and aldicarb, cost sharing from state coffers for well improvement or purification systems is not available for nitrates.

In the <u>ex ante</u> survey, one-half (with-info) of the participants were provided general information about the health effects of nitrates, sources of nitrate contamination, government standards for nitrates, distribution of nitrate levels in Portage County wells and opportunities for averting or mitigating behavior (see Figure 1). This information packet represented a composite of information taken from government pamphlets available from local extension, university and other government sources. The other half (no-info) of the sample received no information. This design allowed us to evaluate the general awareness and knowledge about nitrates and to test the impact on contingent values of 'general' information about environmental risks.

Participants in the ex ante survey were invited to submit water samples that would be tested for nitrates at the Wisconsin State Laboratory of Hygiene. In the ex post survey all participants who returned samples were provided the nitrate test results on their household water supply along with general information about nitrates and their level of exposure. A graphical depiction of their exposure relative to safety standards and natural levels was also included inside the questionnaire (Figure 2). Willingness to pay for groundwater protection programs were again elicited with this complete set of general and specific information.

Following Dillman's total design method and using a residential list purchased from AmericaList/Donnelley, ex ante questionnaires and water sampling kits were sent to 480 randomly selected households. After correcting for bad addresses[2] approximately 77.9 percent of the households returned a completed questionnaire and a household water sample. The response rate to the ex post survey was approximately 83.0 percent. Combined the overall response rate to both stages was about 64.4 percent after correcting for bad addresses. Of these, around 15 percent were not usable because of item non-response.

Ex ante Analysis

This section evaluates how general information about nitrates affects the distribution of willingness to pay by comparing the DC-CVM responses from the ex ante no-info and with-info groups. This comparison consists of three parts. First, we examine whether individuals were able to comprehend and assimilate information by evaluating responses to different survey questions.

[2]. The bad addresses represent a total of 9.3 percent of the original surveys sent out. In part, this proportion was relatively high because the geographical coding from the marketing list was not as precise as required, and some questionnaires were mailed to areas outside of the target population (e.g. homes attached to public wells or outside of Portage County).

Then we evaluate the estimated logistic response function and their differences across information groups using standard statistical tests. Finally, distributions of mean willingness to pay across information groups are compared.

As demonstrated in Table 1, the demographic characteristics of the respondents (age, sex, household size, education, involvement in farming and environmental concerns), well characteristics (depth, type of construction, year constructed) and perceptions and knowledge levels are similar across information groups. A significant difference does occur in the knowledge section, wherein individuals who were provided information ranked themselves higher on the question

> Before receiving this survey, how much had you read or heard about nitrate contamination of groundwater in Portage County?

We offer no explanation for this difference at this point in time, but do note that the overall knowledge base as represented by the sum of the responses to the four knowledge questions is not significantly different across groups. There is also an observed difference in household size, with the with-info group having significantly fewer household members on average. None of the other variables examined were significantly different including beliefs about the levels of nitrates in their wells and the possibility of future contamination.

In addition to these background questions, participants also responded to a nine question quiz about nitrate contamination. In spite of the demographic similarities noted previously, the mean score on this quiz was significantly different across information groups (t=10.1 in a difference of means test). This provides evidence that individuals were able to comprehend and retain the information provided.

As shown in Figure 3, the dichotomous choice question consisted of two parts. In the first part, individuals were asked to provide their expectation about the likelihood that their own wells would exceed the government standards for nitrates during the next 5 years. As demonstrated by the 'future' category in Table 1, mean values for future expectations did not deviate statistically across information groups. In the second part individuals were asked the following question

> Would you vote for the groundwater protection program described above if the total annual cost to your household (in increased taxes, lower profits, higher costs, and higher prices) were $____________ each year beginning now and for as long as you live in Portage County?

Bid values were randomly assigned to individuals and the distribution of assigned bids was identical across information groups.

The estimated logit response functions for each group are presented in the first two columns of Table 2. As demonstrated by the χ^2 values, both equations are highly significant. Except for the coefficient on future expectations in the no-info group, individual coefficients are all significant at the 1 percent level.

Log likelihood ratios (LLR = 9.435) for the difference between the estimated functions exceeded the critical values at the 5 percent levels ($\chi^2_{0.05,3}$=7.815). Thus we can conclude that general information does have a significant effect on the distribution of willingness to pay among this sample of rural Portage County residents. Two aspects of this difference are noteworthy. First, general information appears to reduce the goodness of fit statistics as demonstrated by the reduction in χ^2 values for the with-info group. In addition, when expectations of future contamination are set at their means, general information lowers the constant and flattens out the response function (see Figure 4). That is, a relatively large proportion of people are not willing to pay anything at all, and a separate group appear to be willing to pay quite a lot for groundwater protection.

The significant differences between logit estimates are reflected in the distribution of mean willingness to pay. Application of the Krinsky and Robb technique to equation (6) demonstrates that these observed differences in estimated logit equations do have a considerable effect on the distribution of mean willingness to pay. As presented in the first two rows of Table 3, the no-info group has a relatively low mean willingness to pay ($269.3) with a much tighter distribution. General information apparently increases both the mean ($414.8) and the spread of the distribution. Although the two empirical distributions of the mean willingness to pay do overlap, the level of significance of the difference between these two distributions is estimated at 5.12 percent. That is, we are 94.88 percent confident that we can reject the null hypothesis that there is no difference in distributions of mean willingness to pay.

In all, general information about nitrates does have a considerable effect on the distribution of willingness to pay and mean willingness to pay in this example. This type of information does appear to increase mean willingness to pay, a fact that is consistent with other studies (e.g. Bergstrom, Randall and Stoll). In contrast with Boyle's results, which suggest that more information increases the precision of willingness to pay estimates, this study finds that the spread of the distribution of mean willingness to pay is increased with more information. We offer two plausible explanations for this shift in precision. Risk information differs considerably from better descriptions associated with natural resource assets such as fishing and wetlands, and it may be that individuals are more selective in their information processing when dealing with risks. In other words, individuals may selectively focus and react to the information aspects that are most pertinent to their life situation. For example, a household with small children will likely react quite differently to information about blue baby syndrome than a household of retirees. In short, different facets of the general information packet will likely have different meanings or effects on different households.

Another factor in the large spread of mean willingness to pay and the associated flat response function across bids for the with-info group is 'information overload' or 'cognitive dissonance'. Previous research has suggested that too much information will create confusion about the value of a resource or commodity [e.g. Bergstrom and Stoll; Grether and Wilde]. Alternatively, one could argue that, in this case, there is not enough information presented in the general information packet. Individuals are presented with an abundance of general information about risks of nitrates but remain uncertain about their exposure level and, subsequently, become more confused about the values that they place on groundwater protection. In this manner information overload is viewed as a relative rather than an absolute concept. On this basis, reliable assessments about the value placed on protection programs may necessitate the provision of a complete set of information that contains both general information about environmental risk and specific information about individual exposure levels. Some support for this hypothesis is found in the following section which examines the ex post analysis.

Ex post Analysis

As discussed previously, the Wisconsin State Laboratory of Hygiene tested individual water samples for nitrates. The nitrate distribution of the water samples provided by participants closely reflects that of previous studies of nitrate levels in Portage County. Approximately 17 percent of the sample had nitrates in excess of the EPA standard of 10 mg/L and about 29 percent had nitrate levels at or below background levels[3].

The combination of general information about nitrates and specific information about their household's exposure appears to have been understood and assimilated by the participants. Perceptions of groundwater safety across nitrate levels seems to anchor on the 10 mg/l standard As demonstrated in Figure 5, the percentage of 'Definitely not safe' responses rose most rapidly over the range from 8-12 mg/l in response to the following question:

> Suppose that your water test had indicated one of the nitrate levels listed below. In your opinion would you believe that the water is safe or unsafe for your household to use as the primary source of drinking water?

This sharp rise suggests that individuals do incorporate government standards into their formulation of risk perceptions. Individuals also appear to be able to better formulate their health risk assessments related to their own drinking water. Figures 6 and 7 demonstrate that the proportion of people who were unable to formulate risk perceptions about the safety of the nitrate levels found in their drinking water (as represented by the Don't Know category) fell dramatically

[3]. The highest natural levels in Wisconsin are 2 mg/L of NO_3-N.

between the ex ante and ex post surveys.

Some evidence lends support to the hypothesis that individuals updated their assessments of the likelihood of future contamination (see Figure 8). Responses change from a fairly bell shaped response function centered on "Maybe (50 percent chance)" in the ex ante survey to a bimodal distribution that was more biased towards lower probabilities of exceeding standards and has a second peak at the "Yes, Definitely (100 percent chance)" category in the ex post survey.

In sum, participants with the complete set of information appear to be more capable of formulating their present and future risk assessments. This greater certainty also appears to have been translated into a more precise assessment of their willingness to pay as demonstrated by the increased significance of individual parameters and the entire model as presented in the last column of Table 2. Comparisons with the pooled data from the ex ante study indicate that some updating of values may have occurred. The log likelihood ratio (LLR=6.381) for the comparison was significant at the 10 percent level but not at the 5 percent level.

The distribution of mean willingness to pay also appears to be affected by the increase in information. Using the Krinsky and Robb simulation technique, the mean estimate was $257.1 for the ex post group, which compares to a mean of $269.3 and $414.8 for the no-info and the with-info groups respectively. Difference tests of these empirical distributions indicates that the ex post and the with-info groups are significantly different at the 3.46 percent level. The difference test for the ex post and the no-info groups show that the distributions overlap substantially and are only significant at the 90.24 percent level. Whether the closeness of these two distributions is an anomaly of the data or a more general trend is not clear at this point in time.

Overall, this analysis suggests that the complete set of information helped individuals better formulate their risk assessments and contingent values in comparison to the partial information group. Combined with the previous analysis this indicates that general and specific information are joint inputs into the valuation process. Provision of only general (and perhaps only specific) information will likely lead to relative information overload.

Summary and Discussion

Thus far, this paper has demonstrated the following points about the contingent valuation of groundwater protection programs:

* General information about nitrate contamination presented in contingent valuation surveys appears to be understood and assimilated by individuals.
* Individuals are able to use the specific and general information together to update their present and future risk perceptions.
* Both general and specific information affect the distribution of willingness to pay for groundwater protection programs.
* Partial information about nitrates inflates the mean willingness to pay values relative to the no-info and the complete (or ex post) levels of information provision. This partial information also appears to create confused values and reduce the precision of the benefit estimates.

Important questions remain. What is the appropriate level of information provision for contingent valuation studies of groundwater protection programs? Does this method provide a valid measure of willingness to pay for groundwater protection? And, how can these values be related to the resolution of groundwater quality conflicts?

It is our opinion that the information packet corresponding to the ex post survey is the most appropriate for valuation of groundwater protection programs. While the no-info approach might better reflect the current knowledge base in the population, it does not satisfy the framing conditions necessary for satisfactory transactions and sound choices [Fischhoff and Furby; Bishop and Welsh]. Just because the public does not have knowledge about groundwater contamination does not mean that they have no underlying preferences with respect to contamination and protection. It may be that they just have not found the need to acquire such information. Along these lines, we adopt a delegate philosophy. Those individuals who participate in a given survey are perceived to be delegates of the entire population, and offer insights into the underlying preferences of the population. In order to be able to identify their own best interests and preferences these delegates need to be fully informed. The no-info approach does not meet these conditions. Similarly, the bundle of information provided to the with-info group does not appear to approximate this criterion of being fully informed. Possessing only general information, individuals still do not have a "reference" risk to compare with the "target" risk associated with the proposed groundwater protection program. Unfortunately, these observations may not bode well for contingent valuation of groundwater protection programs. Water tests are expensive (Nitrate tests cost $7.00 and other chemicals range into the hundreds of dollars), a fact which will certainly escalate the costs of conducting contingent valuation surveys in this area.

The validity of the contingent valuation measures is a longstanding and widely debated topic that will not be settled here. Our measures do appear to fall in a reasonable range, and certainly provide more realistic values for Wisconsin than previous studies conducted in other regions and socio-economic groups which estimated mean willingness to pay at or near $1,000 (e.g. Edwards; Sun). Some convergent validity is found in the fact that when ex post respondents are certain that their well will be contaminated (future=0) the estimated mean willingness to pay is about $477. This value is fairly close to costs of remediation: rental of a reverse osmosis system to remove nitrates would cost around $420 per annum and bottled water for a three person household would cost $480 to $705 per annum.

It may not be the exact dollar amounts that matter, but the fact that we have narrowed the bounds of possible values. This study shows that groundwater protection does matter to individuals, and that they are, on average, willing to give up some of their scarce resources to protect the quality of the water supply. Further investigation into these values may add some perspective to the heated policy debate over groundwater protection. For instance, at the aggregate level these values placed on groundwater do not even approach the level of funds needed to compensate farmers not to farm. Restating the values on a per capita basis (approximately $85) and extrapolating to the entire rural population in Portage County suggests an aggregate willingness to pay of about $2.35 million per annum. This compares to a much higher value of net returns to farming of $34.87 million and fertilizer and pesticide costs of $10.37 million in Portage County [U.S. Department of Commerce]. Clearly it would not be desirable, using a benefit-cost criteria to eradicate farming in Portage County because of potential nitrate contamination. The value of protection to residents is simply not enough to compensate farmers for their lost profits.

This does not mean, however, that in particular localized instances the cost would not exceed the benefits of contamination. A fertilizer intensive farm might be located up gradient from a large subdivision with nitrate levels nearing or above the standards. A critical ratio between homes and farms might shift the benefit cost ratio in such cases. Moreover, maintaining groundwater standards may only entail marginal changes in farming practices and willingness to pay might exceed the losses to farmers to make this adjustment.

In summary, the simple values provided in this paper will not, in themselves, provide deep insights into the optimal solutions to this important debate. They do provide a base for evaluating individual cases and offer a starting point for site specific avenues of investigation.

Table 1
Comparison of Characteristics Across Information Groups

Demographic Characteristics

Variable	No-Info			With-Info			T-Value[a]	
	NOBS	Mean	Std.	NOBS	Mean	Std.		
Live Past	153	4.464	0.987	150	4.333	1.060	0.411	
Live Future	153	1.444	0.802	149	1.409	0.647	-0.418	
Own Age	152	2.671	0.779	149	2.711	0.756	0.456	
Sex	150	0.427	0.496	149	0.376	0.486	-0.895	
Household Memb.	152	3.145	1.621	151	2.841	1.276	-1.812	*
Education	150	4.133	1.920	150	4.013	1.765	-0.564	
Environment	150	0.213	0.485	150	0.245	0.503	0.556	
Farm	151	0.212	0.410	150	0.167	0.374	-1.000	
Income	134	4.045	2.113	124	3.77	1.946	-1.102	

Well Characteristics

Variable	No-Info			With-Info			T-Value
	NOBS	Mean	Std.	NOBS	Mean	Std.	
Welltype	153	1.922	1.073	146	2.055	1.280	0.973
Well Year	122	75.16	11.40	108	76.69	11.90	0.998
Well Deep	114	66.09	41.12	109	68.44	43.89	0.411
NO3 Test	147	0.558	0.498	146	1.568	0.497	0.183
NO3 Levels	154	6.419	7.774	151	5.460	5.433	-1.254

Perceptions and Knowledge Base

Variable	No-Info			With-Info			T-Value	
	NOBS	Mean	Std.	NOBS	Mean	Std.		
Future	152	2.026	1.133	148	2.087	1.081	0.481	
Know1	152	3.125	0.992	152	3.421	0.967	2.635	***
Know2	152	2.677	1.007	152	2.618	0.927	-0.533	
Know3	152	1.618	0.754	152	1.736	0.761	1.362	
Know4	152	1.559	0.658	152	1.539	0.753	-0.243	
KnowT	152	8.980	2.656	152	9.316	2.548	1.123	
Quiz Score	155	3.212	2.284	152	6.013	2.566	10.092	***

a. $t_{0.10}$= 1.645 = * ; $t_{0.05}$= 1.960 = ** ; $t_{0.01}$= 1.960 = ***.

Description of Variables:

Live Past	Categorical variable for number of years of residence in Portage County: 1= Less than 1 Year, 2= 1 to 5 years, 3= 6 to 10 years 4= 11 to 15 years, 5= Over 15 years.
Live Future	Categorical variable of expectation of living in Portage County in 5 years: 1= Yes, Definitely (100%), 2= Probably (75%), 3= Maybe (50%), 4= Probably not (75%), 5= No.
Own Age	Categorical variable: 1= Less than 18, 2= 18 to 44, 3 = 45 to 64, 4= 65 or older.
Sex	Categorical variable: 0= Male, 1 = Female.
Household Memb.	Sum of members currently living in household.

Education	Catagorical Variable: 1= Eighth grad or less, 2= Some high school, 3= High school graduate, 4= Some college or technical school, 5= Technical or trade school graduate, 6= College graduate, 7= Some graduate work, 8= Advanced degree.
Environment	Categorical vaiable for membership in environmental groups: 1= None, 2= 1 to 2 groups, 3= More than 2 groups.
Farming	Categorical variable for involvement in farming (includes spouse): 0= no, 1= yes.
Income	Categorical variable for income: 1= Under $10,000, 2=$10,000 to $19,999....10=$90,000 to $100,000, 11= Over $100,000.
Well Type	Categorical variable: 1= Drilled, 2= Driven Point, 3= Dug, 4= Other.
Well Year	Date of construction.
Well Deep	Depth of well in feet.
NO3 Test	Categorical variable for previous nitrate test: 0= no, 1= yes.
NO3 Levels	Level of nitrate found in State Laboratory of Hygiene Test
Future	Categorical variable for likelihood own well will exceed nitrate standards in 5 years. 0= Yes, Definitely (100%), 1= Probably (75%), 2= Maybe (50%), 3= Probably not (75%), 4= No.
Know1	Categorical variable for self ranking knowledge about nitrates: 1= Nothing at all, 2= Very little, 3= Some, 4= A fair amount, 5= A great deal.
Know2	Categorical variable for frequency of reading about nitrates in mass media in last year: 1= Never, 2= 1 to 3 times, 3= 4 to 6 times, 4 = More than 6.
Know3	Categorical variable for reading extension publications: 1= Never, 2= 1 to 3 times, 3= 4 to 6 times, 4 = More than 6.
Know4	Categorical variable for attending public meetings: 1= Never, 2= 1 to 3 times, 3= 4 to 6 times, 4 = More than 6.
KnowT	Sum of Know1 to Know4.
Quiz Score	Number of correct answers on 10 point quiz.

Table 2
Estimated Logit Equations for Different Information Flows

Variables[a,b]	Ex-Ante		Ex-Post
	No-Info	With-Info	
Intercept	1.080 (2.242)	1.351 (2.563)	1.834 (5.162)
Future	-0.128 (-0.688)	-0.466 (-2.461)	-0.534 (-4.550)
Bid Amount	-0.0045 (-5.198)	-0.0040 (-4.215)	-0.0035 (-5.547)
Model χ^2	54.30	28.99	67.21
N	147	146	244

[a] Asymtotic t-values in parentheses.
[b] $t_{0.05,295} = 1.9600$.

Table 3
Empirical Willingness to Pay for Different Flow Scenarios Based on 1000 Draws

Info Group	Calculated from Parameter Means	Based on 1000 Draws				
		Mean	Lower Tail 5%	Median	Upper Tail 5%	Skewness[a]
No-info	263.1	269.3	197.1	265.5	366.7	1.35
With-info	401.2	414.8	295.9	400.3	593.1	2.57
Ex-post	251.5	257.1	199.6	253.3	338.2	0.95

[a] $g_{0.01,1000}$ = 0.180 [Table 34b; Tables for Statisticians and Biometricians].

The next section and the remainder of the survey deals specifically with nitrates. Here, we provide you with important information about nitrates in your groundwater. PLEASE READ THIS PAGE AND THE FOLLOWING PAGE CAREFULLY!

Nitrates in Groundwater

* Nitrate (NO_3) is an inorganic chemical form of nitrogen (N) that can pollute groundwater.
* Some nitrates in groundwater come from natural sources, but high levels are usually caused by human activities.
* The most common sources of high nitrate levels in groundwater are septic tanks; farm, lawn and garden fertilizers; livestock holding areas; and abandoned wells.
* Causes of contamination of any given well depend on local factors such as well location and regional factors such as geology, land use, and farming practices. For this reason, sources of high nitrate levels in individual wells vary from area to area.
* Unless they drink water from wells with high nitrate levels, most people get more nitrates from food than from water.

Nitrates and Blue Baby Syndrome

* For some infants, consumption of high nitrate water can reduce the ability of the blood to carry oxygen. Affected infants experience symptoms of suffocation, and they may turn a bluish-gray color. This disease is called "blue baby" syndrome.
* Blue baby syndrome can be fatal. Infants can be protected from blue baby syndrome by using water that meets the government safety standards for nitrates.
* This disease is only thought to affect infants less than 6 months old; older children and adults are not known to be affected.

Nitrates and Cancer

* Some areas with high nitrate levels in the drinking water have unusually high rates of stomach, gastric, and lymph node cancer, although scientists have not yet determined whether these cancers were caused by nitrates in well water.
* Nitrates may be converted to nitrosamines, which are chemicals that are known to cause cancer.

Government Standards for Nitrates

* Federal and state authorities have established a safety standard of 10 milligrams per liter (mg/l) of nitrates (NO_3 as N) for municipal or other public water supplies.
* This standard was established to protect infants from blue baby syndrome. Possible cancer risks were not considered when creating this standard.
* If the nitrate levels of a public water supply exceed this standard the water has to be treated or another water source has to be found. For example, the public well in the Village of Whiting has been closed since 1979 because of high nitrate levels.
* The federal and state standards do not apply to private wells serving individual homes.

Nitrates in Portage County Wells

* About 18 percent of the private wells that have been tested in Portage County have nitrates in excess of the safety standard, compared to 10 percent of all wells in Wisconsin.
* Many more Portage County wells meet the standard of 10 mg/l, but have nitrates that exceed natural levels. Natural levels in Wisconsin are 2 to 3 mg/l or less.
* Nitrate levels are increasing in many Wisconsin wells.

Solutions to High Nitrates found in Drinking Water:

* Communities can avoid high nitrates in drinking water by regulating or eliminating sources of contamination, installing a community well, or by finding other sources of water.
* Individuals can avoid high nitrates in drinking water by using one of the following options:

  Well reconstruction or installation of a new well can cost several hundred to several thousand dollars. However, improving your well does not guarantee low nitrate levels.

  Bottled water that is delivered to your home costs about $160 to $235 per person per year.

  Single-tap purification systems cost $525 to $700 to purchase and install, with annual maintenance costs of $20 to $40. These systems use reverse osmosis, and they remove 85 percent or more of nitrates in water.

  Whole-home purification systems cost $1500 or more to purchase and install, with annual maintenance costs of $50 to $100. These systems use anion exchange processes and keep nitrates to less than 6 mg/l.

* Water softeners and simple charcoal filters do not remove nitrates. Also, do not boil water to remove nitrates. Boiling actually concentrates nitrates due to evaporation.

Figure 1

Figure 2

Your Nitrate Test Result: ______ mg/l

Your nitrate level is depicted by (   ) on the chart below:

0— — + — — 2	— — + — — 4— — + — — 6— — + — — 8— — + — —	10 or above ☐
Natural Level	Level of Concern	Level Exceeds Health Standards
The natural level of nitrate in Wisconsin groundwater is less than 2 mg/l.	Levels exceeding 2 mg/l are of concern because they indicate contamination of groundwater by human activities.	The Federal and State drinking water health standards for nitrate are 10 mg/l.

To decide what to do about the nitrate level in your well, please refer to the Nitrate Information Sheet that we provided with this survey.

Figure 3

26. Please assume that, in an upcoming election, Portage County residents will vote on whether or not to adopt a groundwater protection program.

* With the groundwater protection program, nitrate levels in all Portage County wells will definitely be kept below government health standards. In some areas this may be difficult, but suppose that it would be possible.

* Without the groundwater protection program, present trends in nitrate levels in Portage County will continue and the number of wells with nitrate levels higher than the government standard will increase in Portage County in the next five years.

26a. Without such a groundwater protection program, do you expect the nitrate levels in your own well to exceed the government standards for nitrates during the next five years? If you are not sure, please give us your best guess. *(CIRCLE ONE NUMBER)*

1 **Yes, my well already exceeds the standard and I expect it to remain above the standard.**

2 **Yes, definitely (100 percent chance)**

3 **Probably (75 percent chance)**

4 **Maybe (50 percent chance)**

5 **Probably not (25 percent chance)**

6 **No, definitely not**

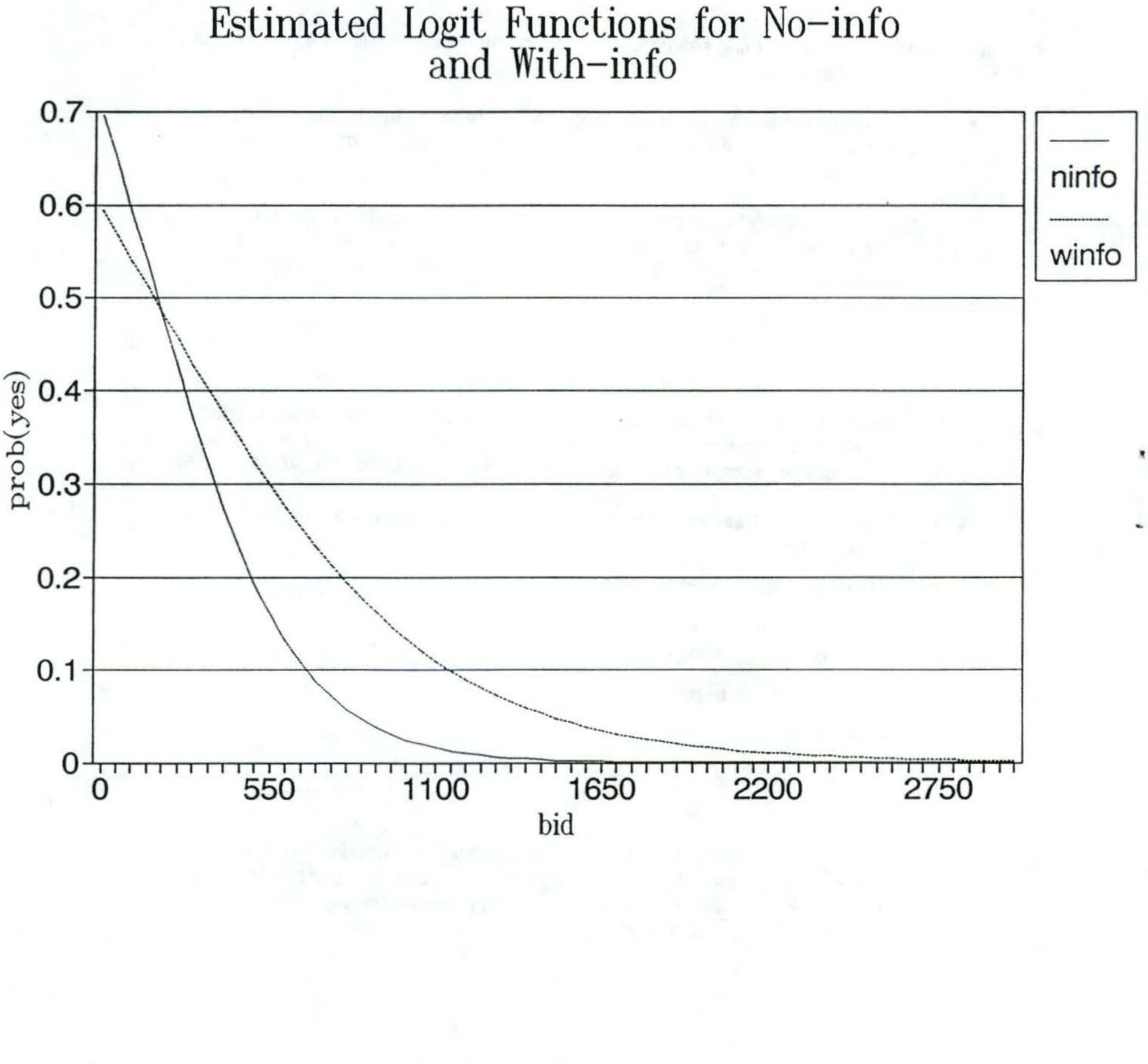
26b. Would you vote for the groundwater protection program described above if the total annual cost to your household (in increased taxes, lower profits, higher costs, and higher prices) were $________ each year beginning now and for as long as you live in Portage County? *(CIRCLE ONE NUMBER)*

1 **No**

2 **Yes**

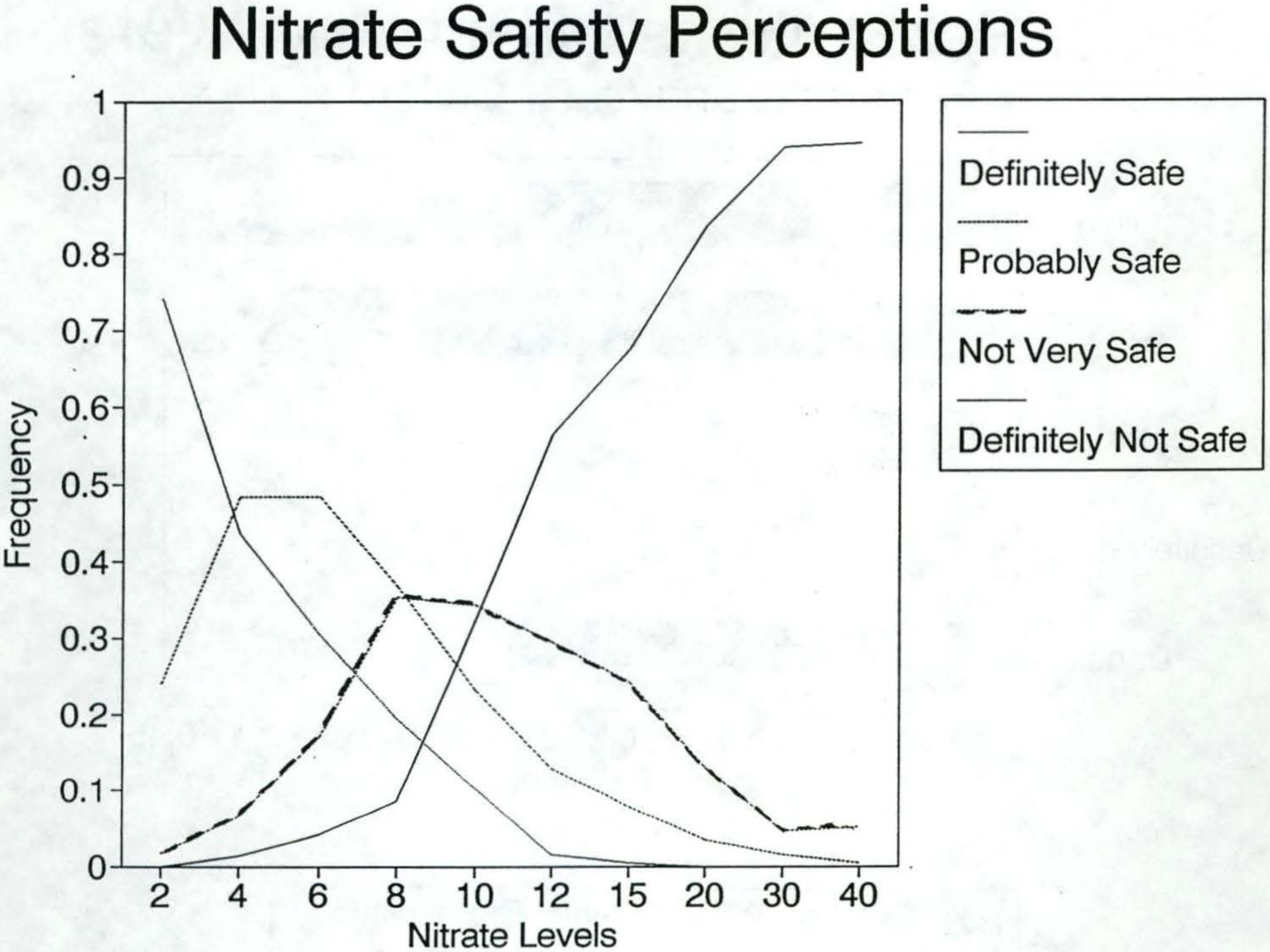
[NOTE: Depending on your situation, the dollar amount written in question 26b may seem ridiculously high or low. It is very important that you still answer the question so we can collect a wide range of opinions]

Figure 4



Estimated Logit Functions for No-info and With-info
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
prob(yes)
0
550
1100
1650
2200
2750
bid
ninfo
winfo

Figure 5



Nitrate Safety Perceptions
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Frequency
2
4
6
8
10
12
15
20
30
40
Nitrate Levels
Definitely Safe
Probably Safe
Not Very Safe
Definitely Not Safe

Figure 6

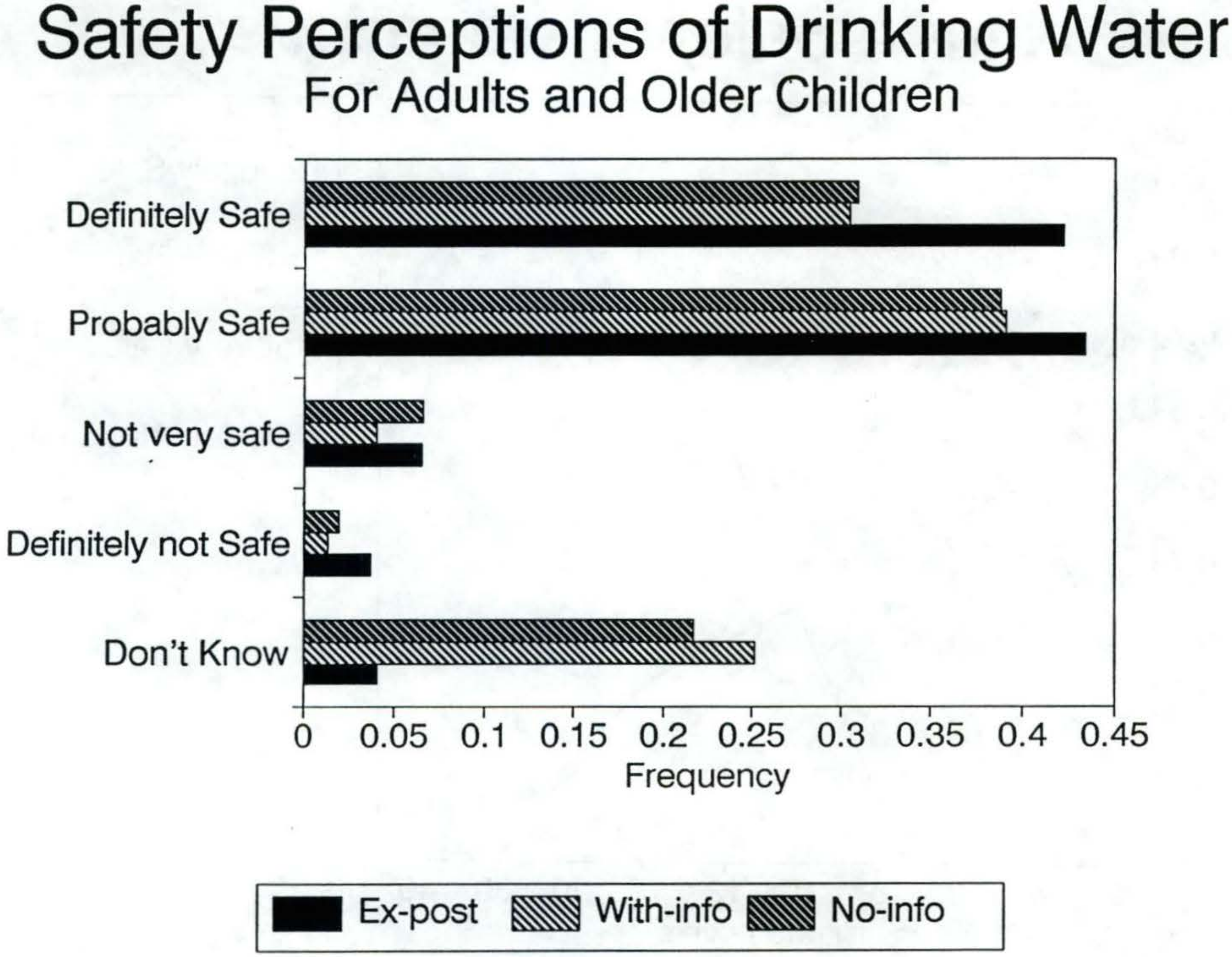
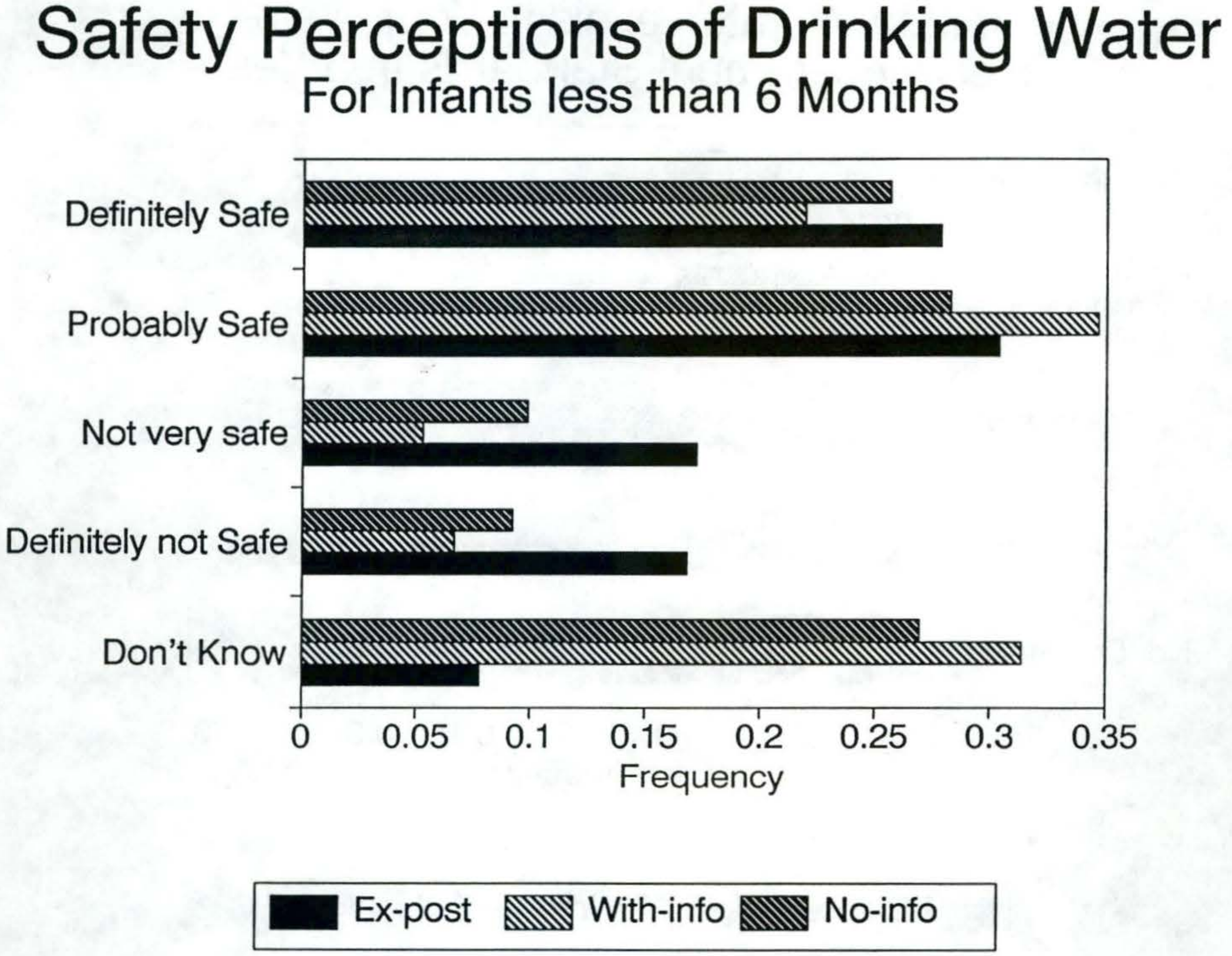
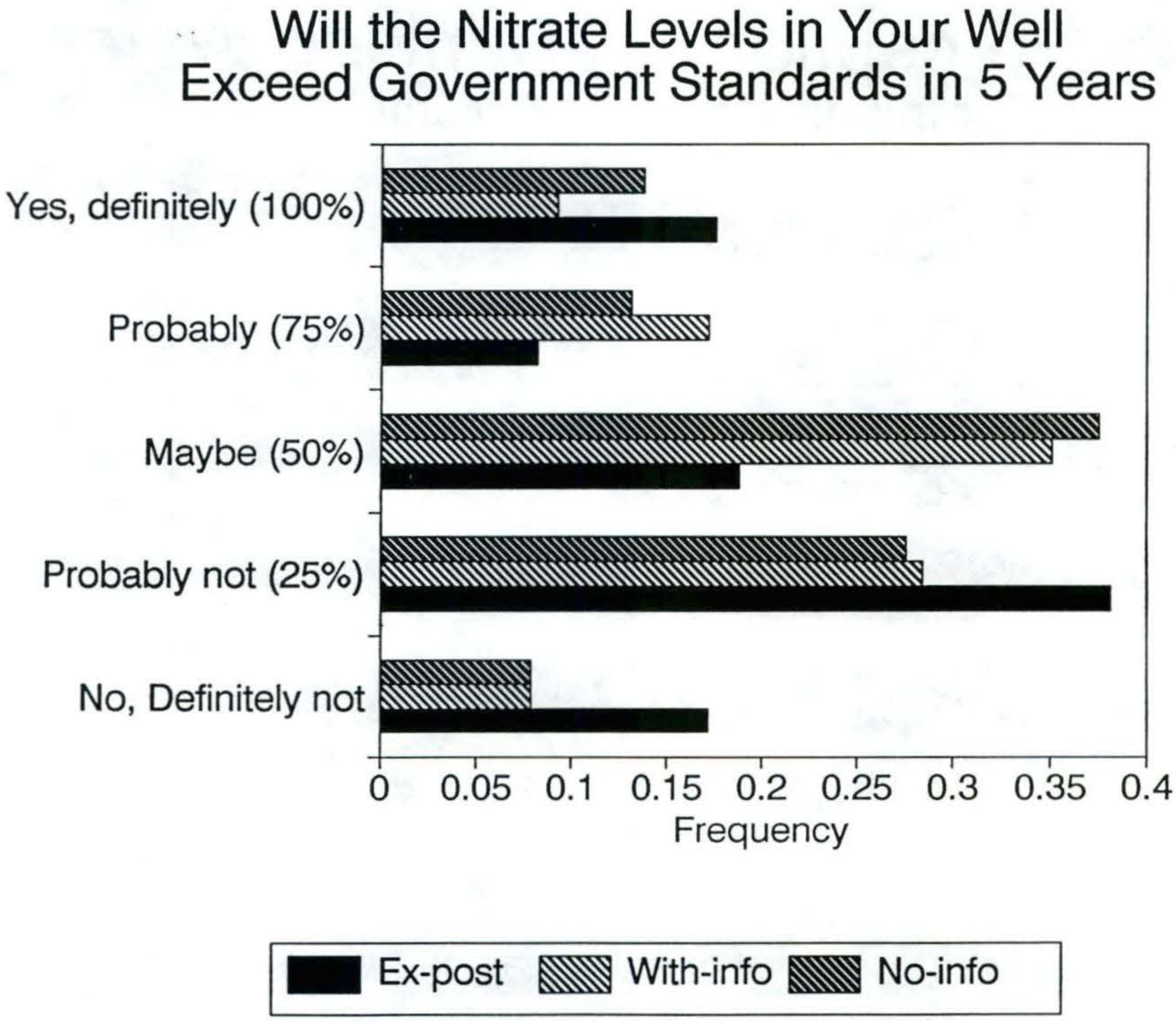

Safety Perceptions of Drinking Water
For Adults and Older Children
Definitely Safe
Probably Safe
Not very safe
Definitely not Safe
Don't Know
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
Frequency
Ex-post
With-info
No-info

Figure 7



Safety Perceptions of Drinking Water
For Infants less than 6 Months
Definitely Safe
Probably Safe
Not very safe
Definitely not Safe
Don't Know
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
Frequency
Ex-post
With-info
No-info

Figure 8


Will the Nitrate Levels in Your Well
Exceed Government Standards in 5 Years
Yes, definitely (100%)
Probably (75%)
Maybe (50%)
Probably not (25%)
No, Definitely not
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
Frequency
Ex-post
With-info
No-info

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