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An Empirical Evaluation of Incremental Conditional Damages and Benefits

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Abstract

Using nitrates found in individual wells and a dichotomous choice contingent valuation framework, this paper estimates the effect of baseline exposure levels on willingness to pay for a 25 percent reduction in nitrate levels and on willingness to pay to avoid a 25 percent increase in exposure. Incremental damages reach a peak at an intermediate level of nitrates and then decline. The eventual decline of incremental willingness to pay does not appear to be attributed to averting actions that have been undertaken. Only a small portion of the households had undertaken averting activities and the coefficients on these actions were insignificant. Instead, the upper bounds on incremental damages and benefits are attributed here to the opportunity for substitution and the fact that the incremental shifts in exposure levels do not greatly affect perceived safety at high levels of exposure.

An Empirical Evaluation of Incremental Conditional Damages and Benefits

Damage and benefit functions that link monetary values to the concentration of residuals are fundamental to environmental economics. Broadly defined, these functions measure the economic loss or gain across exposure levels subject to the condition that reference levels and utility are held constant. The conventional damage function approach adopts a zero or low pollution state as a common reference point, while the benefits approach holds reference conditions at a level that is currently experienced or accessible.

With groundwater contamination and other environmental risks that are individually experienced and for which property rights are not clearly established, a commonly held reference level is inconsistent with the potential Pareto improvement criterion. In these situations individuals experience different exposure levels and risk, and the relevant reference condition for compensation demanded or willingness to pay (WTP) is the level of exposure and expected utility experienced by individuals at the time of the policy determination. To the extent that subjective perceptions of health risks associated with a specific exposure levels depend on the reference level of risk, WTP for changes in exposure will be conditional upon reference exposure levels. Instead of a single damage or benefits function, an alternative conditional damages approach envisions a conditional damage function associated with each initial level of exposure.

Using nitrate levels found in individual well water and a dichotomous choice contingent valuation framework, this paper estimates how conditional WTP values for a 25 percent reduction in exposure levels and for avoiding a 25 percent increase in exposures are affected by initial nitrate levels. Because of the magnitude of the increments and decrements evaluated, the term incremental as opposed to marginal is adopted.

Reference-Based Risk Perceptions and Conditional Damage and Benefit Functions

With respect to exposure to nitrates in well water (N), the consumer's choice problem can be characterized by the minimization of the *ex ante* planned expenditure function [Smith]

$$\dot{e}(g(h;N,S_N),p,q,N,\overline{EU}_N) = \min_{S_N,x} p'[N,S_N]+q'x|\overline{EU}_N \qquad (1)$$

where: $\dot{e}(\cdot)$ is the planned expenditure function; $g(h;N,S_N)$ is the subjective distribution of health outcomes given nitrate exposure levels (N) in personal well water and averting water consumption (S_N) such as purchasing bottled water, installing filtration systems and importing water from a 'pure' source; p is the corresponding state independent vector of prices for different water sources including explicit or implicit prices for water drawn from private wells; q is the state independent vector of prices for all other goods (X); and $\overline{EU}_N$ is the expected utility referenced by nitrate level. Under these conditions, this formulation is the dual of the option price model suggested in Crocker, Forster and Shogren, with the exception that nitrate levels are directly incorporated into the expenditure difference function here in order to capture 'non-use' motivations.

Willingness to pay (WTP) for a 1-δ percent reduction in nitrate exposure is given by

$$WTP_\delta = \dot{e}(g(h;N,S_N),p,q,N,\overline{EU}_N) - \dot{e}(g(h;\delta N,S_{\delta N}),p,q,\delta N,\overline{EU}_N) \qquad (2)$$

Similarly, WTP for a project that avoids a certain increase in contamination of τ -1 is specified as

$$WTP_\tau = \dot{e}(g(h;\tau N,S_{\tau N}),p,q,\tau N,\overline{EU}_{\tau N}) - \dot{e}(g(h;N,S_N),p,q,N,\overline{EU}_{\tau N}) \qquad (3)$$

Corresponding to the direction of the change in nitrate exposure, WTP_δ and WTP_τ are referred to as benefits and damage measures respectively. Because the reference condition is the without project status, WTP is a compensating measure in both models. At the limit, as 1-δ and τ approach 1, these incremental measures become marginal WTP values.

It is important to recognize that the representations in Equations 2 and 3 are different than the 'standard' presentation of damage and benefit functions: in the standard approaches the expected utility value is held at some common reference level (say N^o) that may or may not be related to the initial or target exposure levels associated with the proposed change. For example, if the nitrate reference point was N^o= 2 mg/l, then the WTP for a 1-δ reduction in would be given as

$$\mathrm{WTP}_{\delta} = \dot{e}(g(h;N,S_N),p,q,N,\overline{EU}_2) - \dot{e}(g(h;\delta N,S_{\delta N}),p,q,N,\overline{EU}_2) \tag{4}$$

If it is assumed that state dependent utilities in the healthy state and the unhealthy state are the same regardless of exposure levels and identical across consumers, then any lack of correspondence in the risk-income trade-offs measured in equations (2) and (4) would be attributable to differences in risk perceptions and expected utility indices. Focusing on the former, recognition that risk perceptions are subjective and dependent upon reference levels is a feature of prospect theory [Kahneman and Tversky] and prospect reference theory [Viscusi]. In a WTP framework, the effect of reference-based probability perceptions on risk-income trade-offs is characterized in Figure 1, wherein the expected utility loci across income and objective risks are dependent upon subjective reference-based risks. In this depiction both marginal and total WTP values are assumed to be affected by their reference-based probability perceptions.

One implication of reference-based subjective probabilities and divergent expected utility loci is that a stepwise pattern that sequentially aggregates WTP from A to B and B' to C' for risk reductions will lead to a biased estimate of the value of a complete reduction from A to C. To our knowledge a study by Römer and Pommerehne [1990] of hazardous waste contamination in Germany provides the only such "path" comparisons of WTP for sequential health risk reductions. As depicted by a summary of their results in Table 1, WTP for a risk reduction from 0.0001 to 0.00005 was significantly higher for individuals with an initial reference risk level of 0.0005 when compared with those with a reference risk level of 0.0001. While such differences may be attributed, in part, to income effects [Römer and Pommerehne] or anomalies of the contingent valuation method such as sequencing bias, and embedding or "warm glow" effects [Kahneman and Knetsch], the results depicted in Table 1 are not inconsistent with the concept of subjective reference probabilities.

The implication from the Römer and Pommerehne study and the hypothesis of reference-based subjective risk perceptions is that marginal or incremental WTP across exposure levels cannot be pooled to form a single total damages function. Instead, conditional damage or benefits functions need to be estimated for each distinct reference set of exposures.

Non-Convexities in Damage and Benefit Functions

Irrespective of the reference level used, little consensus has emerged in the theoretical and empirical economics literature concerning the convexity of WTP measures across risk levels. Early theoretical models in the statistical life literature supported the maintained hypothesis that marginal WTP should rise with the level of damages [Jones-Lee; Weinstein, Shepard and Pliskin]. More recent formulations indicate that the convexity of WTP for risk reductions is indeterminate when averting behavior is possible unless restrictive *a priori* assumptions are imposed [Shogren and Crocker; Quiggen]. Empirical evaluations of reducing hypothetical risk have similarly found conflicting evidence supporting convexity and non-convexity of damages. In a study of hypothetical transportation risk Jones-Lee *et al.* [1985] found evidence of convexity of damages across risk levels. In contrast, Smith and Desvousges [1987] observed increasing marginal valuation with decreasing baseline risks in a study of hypothetical risk changes associated with a toxic waste disposal site[1].

The above conceptual and empirical evaluations focused on the relationship between WTP and risk. More conventionally, damage functions are expressed as a function of physical exposure levels rather than risk [e.g. Conrad and Olsen; Xepapadeas]. Convexity in damages, or lack thereof, across exposure levels may be determined by the convexity of the transformation function between exposure levels and health risks. Even if damages across probabilities were convex, a sufficiently concave transformation function between exposure levels and subjective health risks could result in a convex damage function across exposure levels.[2] For instance, an individual's subjective transformation function may be such that a sudden jump from a zero health risk to a positive probability occurs at a positive non-zero "threshold" level of exposure [Kask and Maani]. In other words, below a certain level of exposure (T) individuals simply assume that risk is zero such that $g(h;N)= 0 \ \forall \ N \leq T$.[3, 4] Some evidence of the threshold effects are found in radon studies, which demonstrate that subjective risks anchor on government action and safety limits of exposure and shift dramatically at these points [Smith *et al.*]. Discontinuities of this sort may induce an unexpectedly large WTP for small shifts in objective risks that cross subjective threshold levels simply because the change in perceived probability far exceeds the shift in objective probability.

It is also arguable that discontinuities may be more pervasive than the single threshold model, in that individuals combine ranges of probabilities into discrete safety groupings such as definitely safe, probably safe, etc. Evidence of such judgmental heuristics could imply a step damage function: marginal damages of a shift in exposure would conceivably be zero if the increment in exposure did not involve a shift to another safety level [i.e $g(h;\delta N)=g(h;N)$], and the magnitude of damages might be large if a small shift in exposure involves a perceived change in safety levels.[5]

The convexity of damages might be also be affected by averting opportunities [Zeckhauser and Fisher; Shitaba and Winrich; Repetto, 1987; Shogren and Crocker]. First, if averting actions offer complete protection and the cost of averting is unaffected by the level of contaminant to be removed (e.g. bottled water), then marginal damages associated with increased ambient levels could conceivably be zero once individuals adopt averting actions. If complete averting behavior is adopted, the 'effective' exposure and risk remains constant regardless of contamination level. Anecdotal evidence from this research support the hypothesis that endogenous averting actions that are already undertaken are viewed as substitutes and act to lower WTP. In response to a $216 dichotomous choice bid value for reducing exposure levels, one respondent wrote, "No, but I would have if I hadn't recently put in a H20 softener and reverse osmosis system for this reason". A pre-survey participant indicated that his WTP was bounded because he was able to "truck" all the good quality drinking water from his daughter's well in town. With high investment in transporting equipment, this alternative represented a relatively permanent solution.

To the extent that the probability of adopting such averting behavior is positively correlated with ambient risks [Smith and Desvousges, 1985], the aggregate damage function would be concave from below at high levels of exposure as a greater proportion of households adopt effective averting practices. Moreover, WTP may be bounded simply by the opportunity for substitution. As for any commodity with reasonable substitutes a choke price will likely exist, above which the commodity is not consumed. Thus, we would expect marginal damages to be bounded due to opportunities for substitution.

Combined, the subjective perceptions of risk, non-linearities in the exposure-safety transformation function, and averting opportunities suggest that damage and benefit functions will have both convexities and non-convexities. A plausible depiction of such a damage function is presented in Figure 2, in which a sharp increase in WTP is associated with crossing of threshold levels, and total WTP is truncated by averting opportunities. By similar logic, it is expected that functions of conditional damages will have local concavities and convexities.

Survey Design

This study was conducted in rural portions of Portage County, Wisconsin which do not have municipally provided water ($N_{1990} = 22,432$). Portage County has had extensive nitrate contamination problems in the last two decades, and past research suggests that 18 percent of private wells exceed government standards for nitrate (NO_3-N) of 10 mg/l. The source of elevated nitrates in this region is attributed to agricultural activities upgradient from wells [Portage County Groundwater Management Plan].

A sequential two-stage survey design was used to measure nitrate exposure levels and to elicit contingent values. Households participating in the survey were randomly drawn from a private mailing list covering the targeted rural areas. In the first stage (Stage 1), individuals were asked to complete an initial questionnaire and to submit water samples that would be tested at the Wisconsin State Laboratory of Hygiene for nitrates. In the second stage (Stage 2), the participants who had returned the Stage 1 questionnaire and a water sample were provided their nitrate test results, general information about nitrates, and a graphical depiction of their exposure levels relative to maximum natural levels of nitrates and government safety standards (see Appendix). Thus when answering the contingent valuation questions individuals had a full set of specific information that included their current exposure levels and general information about sources of nitrates, possible health risks, government standards for nitrates, and possible mitigating activities. Remedial options for individual households included repairing or improving the existing well, constructing a new well, purchasing bottled water, and installing a denitrification system. Participants were informed that these activities would cost about $200 to $700 per year for a three member household.

The implementation of the survey followed established procedures detailed in Dillman. A total of 480 Stage 1 surveys were mailed. After correcting for bad addresses the response rate to both stages was approximately 64 percent. Nitrate levels ranged from not detectable to over 43 mg/l with a mean of 5.90 mg/l (s.d.=5.00). Approximately 16 percent of the tests exceeded government standards of 10 mg/l.

Evidence of Reference-Based Exposure-Safety Transformation Functions

General safety perceptions reflect government health standards for nitrates of 10 mg/l.

Using a return potential response format, participants were asked "*Suppose that your water test had indicated one of the nitrate levels listed below. In **your opinion** would you believe that this well is safe or unsafe for **your household** to use as the primary source of drinking and cooking water?*". Nitrate levels included 2, 4, 6, 8, 10, 12, 15, 20, 30 and 40 mg/l and response categories were "*Definitely Safe*", "*Probably Safe*", "*Probably not Safe*", and "*Definitely not safe*". Figure 3 provides average safety responses for the three different reference groups corresponding to levels at or below natural nitrate levels found in Wisconsin aquifers (low: <2 mg/l), levels corresponding to evidence of human impacts but within nitrate health standards (moderate:2-10 mg/l), and levels that exceed nitrate safety standards (high: >10 mg/l). In all cases the rate of decrease in safety perceptions is highest across the 8-12 mg/l range, which suggests that risk perceptions are anchoring on government health standards. Yet, at the same time it is clear that the standard is not necessarily regarded as a safe/unsafe threshold: some individuals appear to accept the threshold while others consider it to be too conservative or liberal. Thus, the safety standard is not perceived to demarcate safety zones by all respondents, which conflicts with the safe/unsafe default assumptions used in past research of groundwater valuation [Edwards; Sun, Bergstrom and Dorfman].

Importantly, the distribution in safety perceptions differs in a systematic manner that is consistent with a reference-based risk perception hypothesis. Participants with "low" nitrate levels within natural bounds perceive "moderate" exposure levels to be relatively unsafe when compared to participants in the with "moderate" or "high" reference nitrate levels. At the other extreme, respondents experiencing "high" exposure levels are relatively tolerant of "moderate" and "high" exposure levels than the other groups.

In all, the evidence from this survey indicates that subjective risk/safety perceptions are indeed influenced by reference exposure levels. Individuals with different baseline exposure levels have different perceptions of the exposure-risk transformation function. This result supports the rationale for pursuing conditional damage and benefit functions.

Econometric Model of WTP

Two separate contingent valuation questions regarding incremental changes in exposure were posed to each respondent. One dichotomous choice question asked respondents to consider a 25 percent decrease in their exposure levels using the following format to convey target and reference levels of exposure:

* *__With__ the groundwater protection program the nitrate levels in __all__ Portage County wells would be reduced by __25 percent__ over the next five years. This means that the nitrate levels in your well would fall to __________ mg/l.*

* *__Without__ the groundwater protection program, please assume that the nitrate levels in Portage County will remain at their __current level__. This means that without the program your nitrate level will remain at ___________mg/l.*

This question, which corresponds to WTP_δ in equation (2) above, is referred to as the "benefits" function in the analyses that follow, reflecting the fact that lower exposure levels are expected to reduce, or at least not increase, the subjective probability of illness.

Target and reference levels for the dichotomous choice question that elicited WTP to avoid an increase in exposure (damages) were depicted as follows:

* *__With__ the groundwater protection program, nitrate levels in all Portage County wells __will definitely__ be kept at their current levels. This means that the nitrate levels in your well will remain at _________mg/l, and that future increases in nitrate levels would be avoided.*

* *__Without__ the groundwater protection program, please assume that it has been estimated that the nitrate levels in all Portage Count wells __would rise by 25 percent__ over the next five years. This means that the nitrate levels in your well would rise to ________ mg/l if this groundwater program is not adopted.*

In both the benefit and damage formats the reference and target exposure levels were individually inscribed in the blank spaces of each survey.

Following these descriptions of the reference and target conditions, a YES/NO response was elicited for the following contingent valuation question.

> *Would you vote for the groundwater protection program described above is 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?*

Dollar 'bid' values were individually inscribed in each survey and ranged from \$1 to \$999.

With the dichotomous choice format used in this survey, individual values are not directly observed. A YES or NO response to a dichotomous choice question merely provides an indication between bid values (A) and the individual's "true" value, defined here to be WTP. Thus, although an indicator of the valuation is observed, the actual value remains a random variable. Assuming a logistic functional form, the WTP distribution can be estimated by

$$\Pi(YES;X) = \Pi(WTP \geq A) = 1-F(A;X'\beta,k) = [1+\exp^{(A-X'\beta)/k}]^{-1} \tag{5}$$

where X is a vector of covariates, β is a corresponding vector of coefficients, and k is a scale parameter [Cameron]. In this formulation it follows that $E(WTP|X)=X'\beta$, where the vector X includes a constant. If X includes nitrate exposure levels, then a function of conditional damages can be estimated for the incremental valuation questions described above. In the analysis that follows polynomial functions of nitrate levels are estimated.

As discussed in the conceptual framework, averting actions should affect the marginal rate of substitution between ambient exposure levels and all other goods. The binary variable DAVTPERM pools two averting actions that are regarded has having high and relatively irreversible investment costs: installing a purification system and trucking water in from another source. As discussed, these actions represent an investment in personal protection, and would be expected to have a negative effect on WTP for marginal risk reductions. A similar conclusion does not necessarily follow for purchasing bottled water as an averting activity. While, from the perspective of substitution this may exert a negative effect on WTP, the fact that some individuals would no longer purchase bottled water if their risk was reduced might also have a positive effect on WTP if bottled water expenditures were relatively large. Given these countervailing influences, there is no sign expectation for the coefficient on the binary averting behavior variable DBOTWAT.

Evidence from the psychological literature suggests that the formulation of risk and safety perceptions is more profound than a simple mapping between exposure and probabilities of adverse health states. Investigating the multiple dimensions of perceived risk, Slovic, Lichtenstein and Fischhoff found that nitrogen fertilizers had high scores along principal "undesirable" dimensions in factor space analyses, and, by extension, have low acceptability [Slovic *et al.*]. Translated into the welfare framework, the perceived benefits of reducing ambient levels are high and should be correlated with certain underlying socio-psychological factors.

Voluntariness: Acceptability of risks have been linked to the voluntariness with which they are incurred [Starr; Slovic] or the perceived beneficiality of exposure [Vlek and Stallen]. For example, in examining air pollution standards, Baird [1986] found that "smelter employed respondents were much more likely to be tolerant of the [air pollution] risk" (p. 432). Due to the strong sample association between perceptions that "*nitrates are a problem in Portage County*" and the belief that "*agricultural fertilizers are a major source*" of nitrate contamination,[6] and the scientific evidence that elevated nitrates in Portage County are linked to agricultural activities [Portage County Groundwater Management Plan], a binary variable DFARM for household involvement in farming was included in the model. The coefficient on this variable is expected to be negative.

Familiarity: People who have lived with exposure over a period of time without observing health effects are less likely to be concerned about environmental hazards. Support for this supposition is provided in previous empirical studies of environmental risk, which have found "years in home" [radon; Smith and Johnson], "number of years living in (town)" [groundwater: Schultz and Lindsay], and "long-time" residency [groundwater: Hamilton] to be negatively correlated with risk perceptions, WTP for environmental protection, and environmental concerns, respectively. To account for this factor, a categorical variable (LIVEPAST) of responses to the question *"About how long have you lived in Portage County"* is included in the analysis, with an expected negative coefficient.

Environmental and Non-User Motives: Similar to familiarity, environmental concerns have been linked to risk intolerance and WTP for groundwater protection. With respect to groundwater, Edwards [1988] found bequest motives to be a strong contributor to WTP for groundwater protection. Mitchell and Carson [1989] and McClelland *et al.*[1992] have also found strong bequest, stewardship and intrinsic motives for the perceived benefits of groundwater protection. To capture these non-use values, a simple sum (NON-USE) of categorical responses with regards to health concerns of "*future generations*" and "*other people living today*" was created.

Demographic Characteristics: A number of demographic or socioeconomic characteristics have been linked to risk perceptions and contingent values, and are thus incorporated as control variables in the analysis. Adoption of averting behavior [toxic wastes, Smith and Desvousges, 1986], learning about risks [radon: Smith *et al.*], and WTP for risk reductions [transportation: Jones-Lee, Hammerton and Philips] have been found to be negatively correlated with age. The sex of respondent is also routinely included in studies of environmental concerns. While Hamilton [1985] observed a "motherhood effect" in which women with small children viewed water pollution as a particularly serious problem and Viscusi, Magat and Huber [1987] note a "parental altruism" effect in risk-dollar tradeoffs, a general survey of environmental risk studies suggests that the sex of the respondent is not related to environmental concerns [Van Liere and Dunlap]. Various forms of education variables are also a mainstay of risk analyses, with some evidence that there is a negative relationship between education and risk tolerance (e.g. Loomis and Duvair). These parameters are included in the analysis with the variables AGE, DSEX, and DCOLLEGEGRAD.

Definitions, descriptive statistics, and the expected signs of the coefficients are provided for each variable in Table 2.

Incremental Conditional Damages and Benefits

The econometric evaluation of a function of incremental damages across nitrate levels was estimated using the logistic function presented in Equation (5) and the two stage-estimation process detailed in Cameron [1988]. The paucity of observations at high nitrate levels and the polynomial approach used to model responses across nitrate levels limited the analysis to an upper bound of 25 mg/l. A lower bound of 0.20 mg/l was set to account for reductions that would be measurable: the testing method used by the Wisconsin State Laboratory of Hygiene was not able to measure nitrate levels below 0.15 mg/l.[7] As a result, 28 observations were deleted from the lower tail and 7 observations were deleted from the upper tail of the nitrate distribution. Because of item non-response, there was a different number of observations for the benefit (n=221) and damage (n=218) estimates. After accounting for this truncation, the number of observations represented about 55 percent of the mailable Stage 1 surveys for both questions.

Econometric estimates for full and reduced forms of the first, second and third order polynomials are provided in Tables 3a and 3b. In general, the significant coefficients on the non-nitrate covariates have the expected sign. Non-use motivations and the age of the respondent have positive and negative coefficients, respectively. Involvement in farming has a negative effect on WTP in the benefits estimate, but is not a significant explanatory variable in the damages model. In contrast, the coefficient on the education variable is positive in the damages estimate, but is not significant in the benefit models. Being a female has a negative effect on WTP in this data set.

It is interesting to note that purchasing bottled water in the past has a positive effect on WTP to avoid a 25% increase in exposure. However, a similar result is not observed for risk reductions. Permanent averting actions were not a significant explanatory variable in either model, a result that might be attributed, in part, to the fact that only a small number of participants had adopted permanent averting actions. Regardless of cause, the results of this analysis do not support the hypothesis that actual averting actions negatively impact WTP.

In spite of this result, WTP pay for incremental reductions and avoiding incremental increases in exposure levels does appear to be bounded. While incremental WTP rises with exposure levels as indicated by the positive coefficient on the linear models for both the benefit and damage functions, the quadratic and the cubic models suggest that the functions of conditional benefits and damages have regions of convexity. The cubic form, which provides the best 'fit' of the polynomial functions investigated[8], suggests that damages are convex for relatively low levels of exposure, but are eventually concave. Points of inflection are determined to be approximately 7.29 mg/l and 7.86 mg/l for the benefit and damage functions, respectively.

Using the "Reduced Cubic" estimates, a graphical depiction of WTP for incremental changes in exposure is provided in Figure 4. It is obvious from this figure that WTP reaches a maximum and then diminishes for both benefits and damages.[9] It is interesting to note that the maximum value for the benefits function, 14.58 mg/l, closely corresponds to a point where a 25 percent reduction will place the final level very close to the 10 mg/l standard. The incremental damages function reaches a maximum at 15.72 mg/l.

Based on the previous results, the eventual decline in incremental WTP does not appear to be attributed to averting actions that have been undertaken. As noted, only a small number of households had undertaken averting activities and the coefficients on these actions were insignificant. Instead, it is hypothesized that WTP is bounded simply by the opportunity for substitution through the establishment of a choke price. The fact that incremental WTP for risk reductions actually declines after an intermediate level of exposure may be related to the fact that individuals may not perceive a change in safety levels across high nitrate levels. Over two thirds of the respondents felt that water with high nitrate levels of 15 mg/l or higher was definitely not safe for their household to use as their principal source of drinking water. For those individuals, for example, a shift from 20 to 15 mg/l would still leave them in a definitely unsafe zone. In spite of these majority feelings however, a small positive reduction is observed over the range because some individuals still perceive the reduction to improve their health probabilities.

Summary and Implications

This paper argues that if risk perceptions are a subjective function of reference exposure levels, then damage functions should be conditional upon the exposure level. In a case study of nitrates, subjective safety perceptions of nitrate exposure levels were found to be related to baseline exposure levels. Individuals in different baseline exposure categories had different exposure-risk transformation functions on average. In spite of their differences, however, the exposure-safety transformation for all reference groups responded to government standards as predicted by a threshold model.

Adopting the conditional damages perspective, functions of incremental damages and benefits were estimated and found to have areas of convexity and concavity. Importantly, perceived benefits and damages appear to be based on the information provided, and the benefits were highest for exposure levels for which incremental reductions in exposure approach government health standards. A second result from the empirical analysis is that incremental damages and benefits diminish after reaching a peak at an intermediate nitrate level. This result contrasts with the conventional approach to damage assessment which suggests that WTP for a small reduction in exposure monotonically increases with exposure levels. The implication of this finding is that the greatest benefits from intervention will occur at some intermediate level of exposure.

The eventual decline of incremental WTP does not appear to be attributed to averting actions that have been undertaken. Only a small portion of the households in the study had undertaken averting activities and the coefficients on these actions were insignificant. Instead, the upper bounds on WTP are attributed here to the opportunity for substitution and the fact that the incremental shifts in exposure levels do not greatly affect perceived safety at high levels of exposure.

Notes:

1. Evidence of non-convexities in environmental damages for "technical" reasons have been discussed by Repetto [1981, 1987]. This source of non-convexity is, however, beyond the scope of this paper.

2. Page and Ferejohn [1974] raise this issue in discussing the convexity of "environmental transfer functions" for production externalities.

3. In an influential paper, Lichtenstein *et al.* [1978] observed that there is a tendency to overestimate low probability events such that there is a discontinuity between subjective risks and observed frequencies at zero. The approach offered here suggests that this discontinuity may actual occur at a positive level of "objective" risks. See Kask and Maani [1992] for further discussion.

4. The function g(N) is used here rather than $g(N, S_N)$ to indicate the subjective health probabilities in the absence averting actions.

5. Kopp and Smith [1993, p. 128-29]] use a similar argument in discussing the relationship between dollar damages and an index of physical injury associated with oil spills.

6. Kruskal's Gamma (γ) statistic for measuring association in ordered variables had a highly positive and significant value of association [0.471(sd=0.058)] between beliefs that "*agricultural fertilizers are a major source of contamination*" and the perception that "*nitrates are a problem in Portage County*" [Poe, p. 108].

7. Further support for this lower truncation point is that the United States Geological Survey assumes that levels less than 0.2 mg/l represent natural background levels. In the USGS classification system, levels from 0.2 mg/l to 3 mg/l are transitional, and may or may not represent human influence. As noted in the nitrate information sheet, 2 mg/l is regarded as the upper bound for natural levels in Wisconsin.

8. Higher order polynomials were investigated, but added little to the fit of the models. Moreover, the inclusion of higher order polynomials acted to model individual observations at the upper end of the nitrate spectrum.

9. In constructing this figure, WTP was restricted to be non-negative. If values fell below zero, they were recoded to zero. Only four such violation at the upper end of the nitrate distribution (at 22.9 mg/l, 23.6 mg/l, 23.7 mg/l and 24.2 mg/l) were observed for the reduced risk question. These violations are attributed to the restrictive nature of using polynomial functions for the analysis.

References:

Baird, B. N. R., 1986. "Tolerance for Environmental Health Risks: The Influence of Knowledge, Benefits, Voluntariness, and Environmental Attitudes", *Risk Analysis*, 6: 425-435.

Cameron, T. A., 1988. "A New Paradigm for Valuing Non-Market Goods Using Referendum Data: Maximum Likelihood Estimation by Censured Logistic Regression", *Journal of Environmental Economics and Management*, 15:355-379.

Conrad, J. M. and L. J. Olson, 1992. "The Economics of a Stock Pollutant: Aldicarb on Long Island", *Environmental and Resource Economics*, 2:245-258.

Crocker, T. D., B. A. Forster, and J. F. Shogren, 1991. "Valuing Potential Groundwater Protection Benefits", *Water Resources Research*, 27:1-6.

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

Hamilton, L. C., 1985. "Concern About Toxic Wastes: Three Demographic Predictors", *Sociological Perspectives*, 28:463-486.

Kahneman, D. and A. Tversky, 1979. "Prospect Theory: An Analysis of Decision Under Risk", *Econometrica*, 47: 263-291.

Kahneman, D. and J. L. Knetsch, 1992. "Valuing Public Goods: The Purchase of Moral Satisfaction", *Journal of Environmental Economics and Management*, 22:57-70.

Kask, S. B. and S. A. Maani, 1992. "Uncertainty, Information, and Hedonic Pricing", *Land Economics*, 68:170-184.

Kopp, R. J., and V. K. Smith, eds., 1993. *Valuing Natural Assets: The Economics of Natural Resource Damage Assessment*, Resources for the Future, Washington D.C.

Jones-Lee, M., 1974. "The Value of Changes in the Probability of Death or Injury" *Journal of Political Economy*, 82: 835-849.

Jones-Lee, M. W., M. Hammerton, and P. R. Philips, 1985. "The Value of Safety: Results of a National Sample Survey", *The Economic Journal*, 95:49-72.

Lichtenstein, S., P. Slovic, B. Fischhoff, M. Layman, and B. Combs, 1978. "Judged Frequency of Lethal Events", *Journal of Experimental Psychology: Human Learning and Memory*, 4: 551-578.

Loomis, J. B. and P. H. duVair, 1993. "Evaluating the Effect of Alternative Risk Communication Devices on Willingness to Pay: Results from a Dichotomous Choice Contingent Valuation Experiment", *Land Economics*, 69:287-298.

McClelland, G. H. *et al.*, 1992. *Methods for Measuring Non-Use Values: A Contingent Valuation Study of Groundwater Cleanup*, Center for Economic Analysis, University of Colorado, Boulder.

Mitchell, R. C., and R. T. Carson, 1989b. *Using Surveys to Value Public Goods: The Contingent Valuation Method*, Resources for the Future, Washington D.C.

Page, T., and J. Ferejohn, 1974. "Externalities as Commodities", *American Economic Review*, 64:454-459.

Poe, G. L., 1993. *Information, Risk Perceptions and Contingent Values: The Case of Nitrates in Groundwater*, Doctoral Dissertation, University of Wisconsin-Madison.

Portage County Groundwater Management Plan, Volume 1, 1987.

Quiggen, J., 1992. "Risk, Self Protection and Ex Ante Economic Value-Some Positive Results", *Journal of Environmental Economics and Management*, 23:40-53.

Repetto, R., 1981. "The Economics of Visibility Protection: On a Clear Day You Can See a Policy", *Natural Resources Journal*, 21:355-70.

Repetto, R., 1987. "The Policy Implications of Non-Convex Environmental Damages: a Smog Control Study", *Journal of Environmental Economics and Management,* 14: 13-29.

Römer, A. U., and W. W. Pommerehne, 1990. *Valuing Reductions of Public Risks: The Case of Hazardous Waste*, Paper prepared for the Fifth Karlsruhe Seminar on Models and Measurement of Welfare and Inequality, August 12-19.

Schultz, S. D. and B. E. Lindsay, 1990. "The Willingness to Pay for Groundwater Protection", *Water Resources Research*, 26:1869-1875.

Shitaba, H. and J. S. Winrich, "Control of Pollution when the Offended Defend Themselves", *Economica*, 50:425-37.

Shogren, J. F., and T. C. Crocker, 1991, "Risk, Self-Protection and Ex Ante Economic Value", *Journal of Environmental Economics and Management*, 20:1-15.

Slovic, P., 1987. "Perception of Risk", *Science*, 236:280-285.

Slovic, P., B. Fischhoff, and S. Lichtenstein, 1979. "Rating the Risks", *Environment*, 21:14-39.

Smith, V. K., 1986. "Nonuse Values in Benefit Cost Analysis", *Southern Economic Journal*, 54:19-26.

Smith, V. K., and W. H. Desvousges, 1985. "Averting Behavior: Does It Exist?", *Economics Letters*, 20:291-296.

Smith, V. K., and W. H. Desvousges, 1987. "An Empirical Analysis of the Economic Value of Risk Changes", *Journal of Political Economy*, 95:89-114.

Smith, V. K., W. H. Desvousges, F. R. Johnson, A. Fisher, 1990. "Can Public Information Programs Affect Risk Perceptions?", *Journal of Policy Analysis and Management*, 9:41-59.

Smith, V. K., and F. R. Johnson, 1988. "How Do Risk Perceptions Respond To Information? The Case Of Radon", *The Review Of Economics and Statistics*, 70(1):1-9.

Starr, C., 1969. "Social Benefit versus Technological Risk", *Science*, 165:1232-1238.

Sun, H., J C. Bergstrom, and J. H. Dorfman, 1992. "Estimating Benefits of Groundwater Protection Control", *Southern Journal of Agricultural Economics*, 63-71.

Van Liere, K. D. and R. E. Dunlap, 1980. "The Social Bases of Environmental Concern: A Review of Hypotheses, Explanations and Empirical Evidence", *Public Opinion Quarterly*, 44:181-197.

Viscusi, W. K., 1989. "Prospective Reference Theory: Towards an Explanation of the Paradoxes", *Journal of Risk and Uncertainty*, 2:235-264.

Viscusi, W. K., W. A. Magat, and J. Huber, 1987. "An Investigation of the Rationality of Consumer Valuations of Multiple Health Risks", *Rand Journal of Economics*, 465-479.

Vlek, C. and P. J. Stallen, 1981. "Judging Risks and Benefits in the Small and in the Large", *Organizational Behavior and Human Performance*, 28:235-271.

Weinstein, M. C., D. S. Shepard, and J. Plisken, 1980. "The Economic Value of Changing Mortality Probabilities: A Decision Theoretic Approach", *Quarterly Journal of Economics*, 94: 373-395.

Xepapadeas, A. P., 1992. "Environmental Policy, Adjustment Costs and Behavior of the Firm", *Journal of Environmental Economics and Management*, 23:258-275.

Zeckhauser, R. and A. Fisher, 1976. *Averting Behavior and External Diseconomies*, Discussion Paper, Kennedy School of Government, Havard University.

Figure 1: Reference-Based Risk Perceptions [g(P|P)] and Subjective Expected Utility (EU) Loci

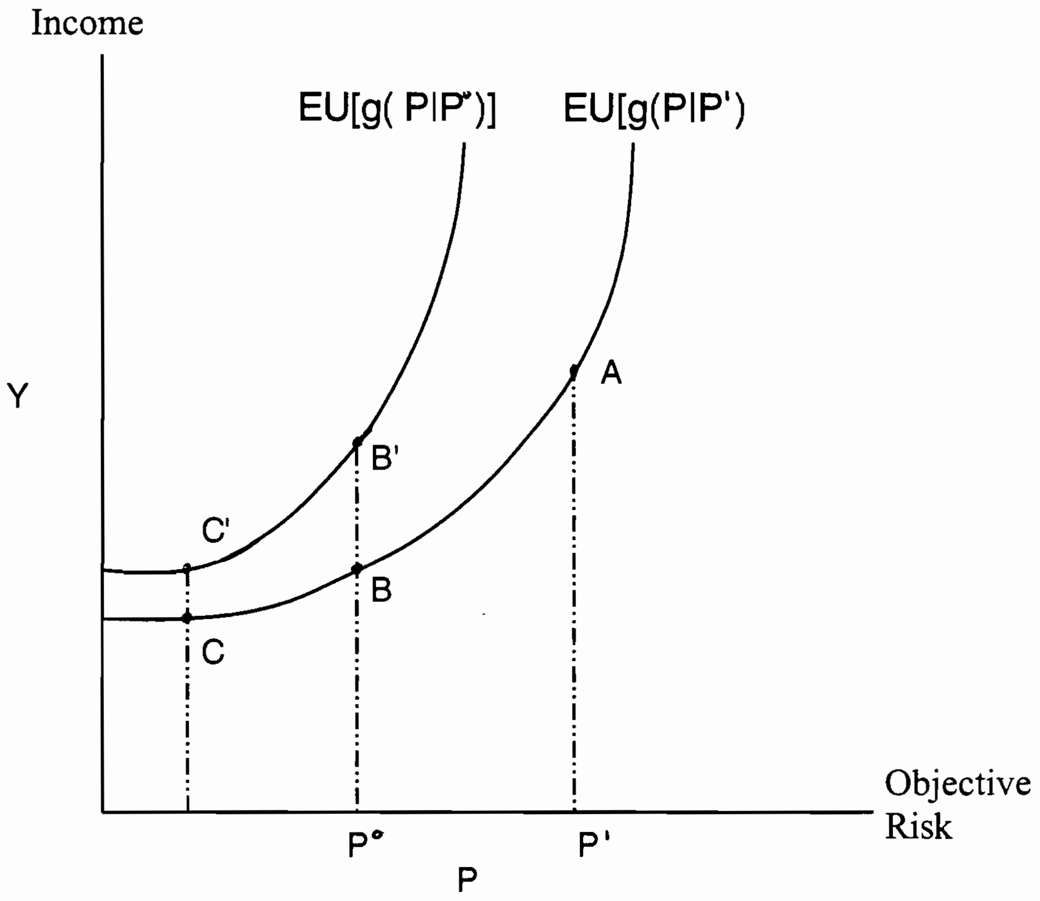


Figure 2: Hypothetical Aggregate Damage Function

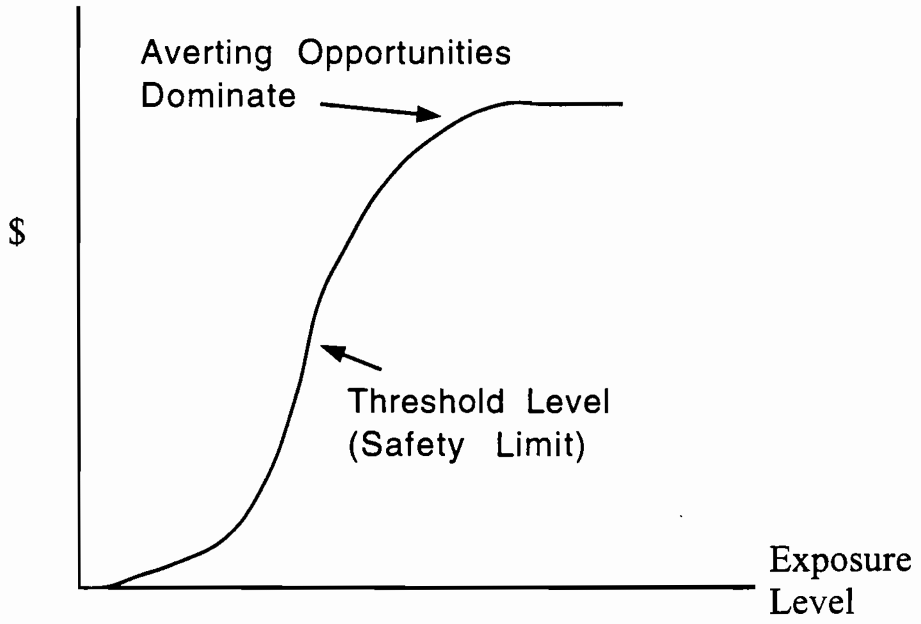
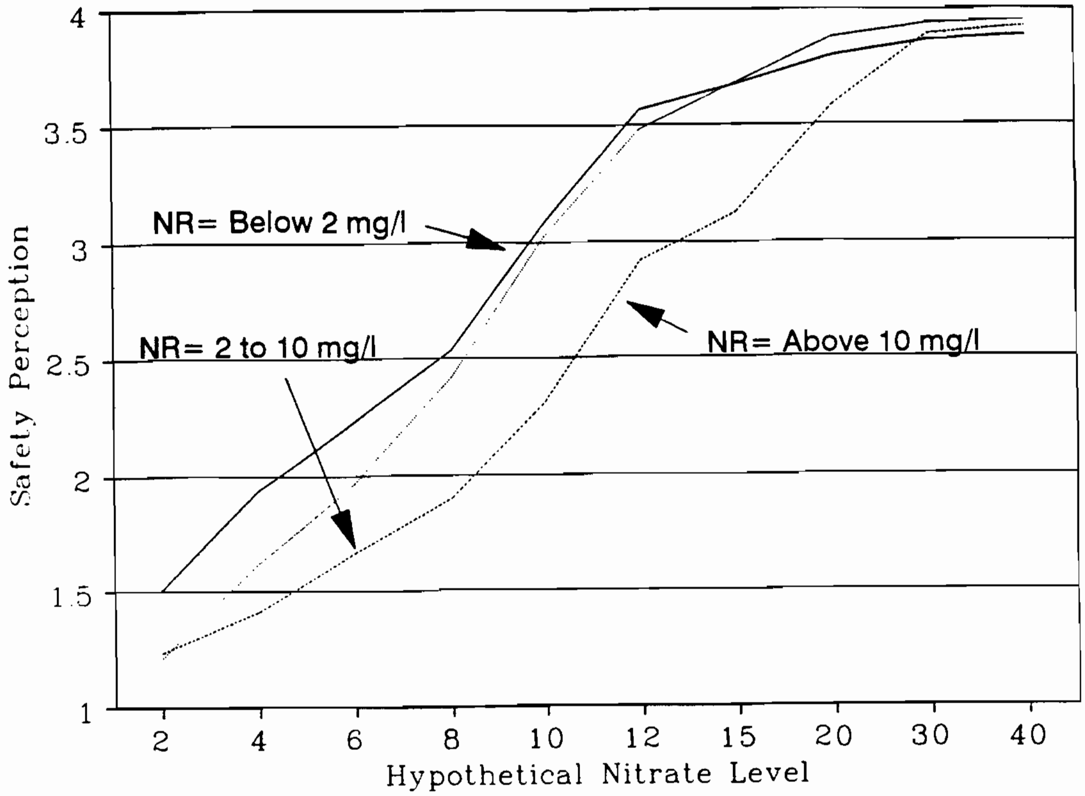


Figure 3. Safety Perceptions for Diff. Nitrate Reference (NR) Groupings



Note: 1 = Definitely Safe, 2 = Probably Safe, 3 = Probably Not Safe, 4 = Definitely Not Safe

Figure 4: Functions of Incremental Cond. Damages & Benefits (25% Change)

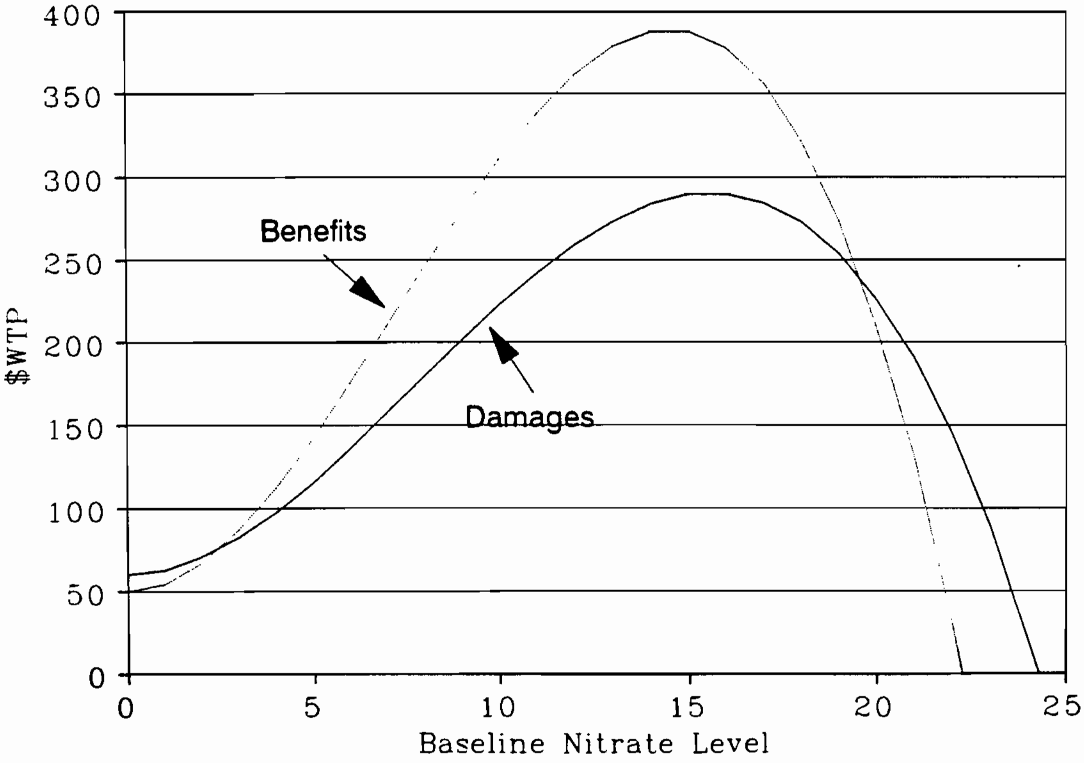


Table 1: Reference Levels and WTP for Hazardous Waste Risk Reduction from Römer and Pommerehne

"Objective" Risk Change	Intitial "Objective" Risk		t Value[a,b]
	0.0005	0.0001	
0.0005 --> 0.0001	37.06	NA	NA
0.0001 --->0.00005	10.76	28.25	4.35***
0.00005 ---> 0.000025	NA	10.29	NA

[a] one-sided test [b] *** = 1% level of significance

Table 2: Descriptive Statistics of Model Variables

Variable	Description	Mean [n=206]	Mean [n=211]
LIVEPAST	Categorical variable for number of years of residence in Portage County: 0 = less than 1 year; 1 = 1 to 5 years; 2 = 6 to 10 years; 3 = 11 to 15 years; 4 = over 15 years.	2.35[a] (1.05)	2.34[b] (1.05)
OWNAGE	Categorical variable: 1 = less than 18; 2 = 18 to 44; 3 = 45 to 64; 4 = 65 or older.	2.70 (0.77)	2.70 (0.77)
DSEX	Binary variable for sex of respondent: 0 = male; 1 = female.	0.38 (0.49)	0.38[b] (0.49)
DCOLLEGE GRAD	Binary variable for college graduate: 0 = no; 1 = yes.	0.25 (0.44)	0.26[b] (0.44)
DFARM	Binary variable for involvement in farming: 0 = no; 1 = yes.	0.20[a] (0.40)	0.20 (0.40)
DAVTPERM	Binary variable for permanent averting activities of installing a purification system or "trucking" water from another source: 0 = no; 1 = yes.	0.04[a] (0.21)	0.04[b] (0.19)
DBOTWAT	Binary variable for purchase of bottled water for health reasons: 0 = no; 1 = yes.	0.03 (0.18)	0.03[b] (0.18)
NON-USE	Categorical variable or nitrate health concerns about other people living today and future generations: Ranging from 2 = not concerned to 8 = extremely concerned.	6.70 (1.31)	6.70 (1.31)
NITRATE	Nitrate level	5.93[a] (4.99)	5.98[b] (4.99)
NITRATE^2	Squared nitrate level	59.67 (102.72)	60.34 (101.77)
NITRATE^3	Cubed nitrate level	835.66 (2127.94)	836.72 (2104.99)

[a] n=205 [b] n=208

Table 3a: Polynomial Functions of Incremental Benefits (25% reduction)

	Linear Nitrates Only	Full Linear	Quadratic Nitrates Only	Full Quadratic	Cubic Nitrates Only	Full Cubic	Reduced Cubic
CONSTANT	61.64 (50.78)	-72.11 (217.34)	-35.02 (77.63)	-154.38 (224.51)	29.35 (48.19)	-115.10 (220.31)	-207.28 (224.31)
LIVEPAST		-41.91 (31.50)		-41.58 (31.46)		-44.85 (32.17)	
OWNAGE		-116.96 (46.21)**		-122.50 (46.99)***		-121.58 (47.91)**	-121.98 (49.10)**
DSEX		-87.24 (65.43)		-73.19 (65.74)		-86.08 (66.91)	
DCOLLEGE GRAD		54.83 (69.34)		40.83 (69.87)		34.51 (71.49)	
DFARM		-132.15 (77.95)*		-150.23 (79.59)*		-153.32 (81.04)*	-164.24 (85.01)*
DAVTPERM		254.77 (225.44)		240.28 (216.03)		197.35 (234.66)	
DBOTWAT		-42.89 (161.05)		-52.81 (162.53)		-78.68 (167.73)	
NON-USE		95.22 (28.90)***		96.55 (28.95)***		100.45 (29.63)***	92.07 (28.88)***
NITRATE	12.47 (6.49)*	7.84 (6.44)	46.16 (20.87)**	38.98 (20.78)*			
NITRATE^2			-1.71 (0.99)*	-1.57 (0.99)	4.92 (1.67)***	4.26 (1.73)**	4.81 (1.81)***
NITRATE^3					-0.22 (0.08)***	-0.20 (0.09)**	-0.22 (0.09)**
k	213.03 (41.28)***	173.75 (32.21)***	209.73 (40.12)***	173.00 (31.84)***	207.66 (39.84)***	175.16 (32.25)***	189.16 (35.76)***
n	221	208	221	208	221	208	211
χ^2	47.58	82.81	50.84	85.57	55.34	89.12	83.14
McFadden R^2	0.16	0.29	0.17	0.30	0.18	0.31	0.29

Notes: Asymptotic Standard Errors in (). Significance levels are denoted * (10 percent), ** (5 percent) and *** (1 percent)

Table 3b: Polynomial Functions of Incremental Damages (avoid a 25% increase)

	Linear Nitrates Only	Full Linear	Quadratic Nitrates Only	Full Quadratic	Cubic Nitrates Only	Full Cubic	Reduced Cubic
CONSTANT	24.38 (51.48)	-427.09 (217.28)	-34.94 (81.89)	-463.51 (226.51)	23.34 (49.98)	-415.81 (215.25)*	-365.40 (211.10)*
LIVEPAST		54.02 (32.77)		53.91 (32.76)		53.02 (32.48)	
OWNAGE		-84.93 (41.37)**		-88.86 (42.12)**		-88.52 (41.70)**	-69.46 (39.07)*
DSEX		-124.06 (64.73)*		-118.17 (65.41)*		-128.90 (65.09)**	-124.28 (64.11)*
DCOLLEGE GRAD		259.75 (71.56)***		258.51 (71.84)***		258.46 (71.72)***	249.86 (70.53)***
DFARM		-9.35 (70.68)		-16.04 (71.74)		-13.52 (71.18)	
DAVTPERM		-14.35 (197.74)		-13.32 (199.13)		-32.73 (203.07)	
DBOTWAT		424.96 (182.17)**		434.08 (185.32)**		415.89 (184.99)**	359.42 (181.68)**
NON-USE		82.00 (26.18)***		83.30 (26.47)***		83.44 (26.32)***	87.43 (26.91)***
NITRATE	15.49 (6.56)**	13.62 (6.72)**	35.23 (21.09)*	27.18 (20.13)			
NITRATE^2			-1.01 (1.01)	-0.73 (1.00)	3.58 (1.57)**	2.94 (1.49)**	2.83 (1.41)**
NITRATE^3					-0.15 (0.08)*	-0.12 (0.07)*	-0.12 (0.07)*
k	197.00 (36.04)***	156.31 (28.08)***	201.36 (37.65)***	156.78 (28.38)***	200.98 (37.67)***	155.74 (28.33)***	156.29 (28.18)***
n	218	205	218	205	218	205	206
χ^2	49.78	93.42	50.86	93.95	52.25	94.95	91.87
McFadden R^2	0.17	0.34	0.17	0.34	0.18	0.34	0.33

Notes: Asymptotic Standard Errors in (). Significance levels are denoted * (10 percent), ** (5 percent) and *** (1 percent)

Appendix

Stage 2: Nitrate Information Sheet (Front)

Nitrate Information Sheet

Your Nitrate Test Result: ____ mg/l

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.

Health Standards for Nitrates

- Health standards for nitrates were established to protect infants from blue baby syndrome. Possible cancer risks were not considered when creating these standards.
- 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. The federal and state standards are not enforced for private wells serving individual homes, but are used as very important guidelines.
- The following are actions that are recommended by the Central Wisconsin Groundwater Center for different ranges of nitrate test results for private wells:

  Nitrate levels less than 2 mg/l: test your water annually at a certified lab for coliform bacteria and nitrates.

  Nitrate levels 2-10 mg/l: test your water seasonally to find the highest and lowest expected values for the first year. Then test annually as above. Be aware that nitrates should not exceed the 10 mg/l standard. Evaluate your well location and construction. Evaluate potential pollution sources in your area. If other chemicals are extensively used in your area, seek advice on testing for them as well.

  Nitrate levels 10 mg/l or greater: Do not give water to infants under 6 months of age. Try to find details on the type of construction and depth of your well so specialists can help you better. You should consider bringing in water from a known safe source or one of the other options discussed on the opposite side of this page.

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.

(over)

Stage 2: Nitrate Information Sheet (Back)

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.

Nitrates in Portage County Wells

- Based on this survey of 345 Portage County wells, nitrate levels in Portage County are distributed as follows:

  29 percent of Portage County wells have nitrate levels less than 2 mg/l: The natural level of nitrate in Wisconsin groundwater is less than 2 mg/l.

  55 percent of Portage County wells have nitrate levels of 2 to 10 mg/l: These levels are of concern because they indicate contamination of the groundwater by human sources.

  16 percent of Portage County wells have nitrate levels 10 mg/l or greater: The Federal and State standards are 10 mg/l.

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 safe 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. These systems can be rented for $17 to $20 per month.

  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. These systems can be rented for about $35 per month.

- 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.

For Further Advice, Contact:

Central Wisconsin Groundwater Center
Nelson Hall, UWSP
Stevens Point, WI 54481
(715) 346-4270

Water Quality Specialist
Portage County Planing and Zoning Department
1516 Church Street
Stevens Point, WI 54481
(715) 346-1334

Water Supply Specialist
DNR Area Office
1681 Second Avenue South
Wisconsin Rapids, WI 54494
(715) 421-7800

Business and Resource Development Agent
Portage County Extension Office
1516 Church Street
Stevens Point, WI 54481
(715) 346-1316

Front Inside Cover: Stage 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.

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