AAEA 2000 Selected Paper:
A Meta Analysis of Contingent Values for Groundwater Quality in the United States

Gregory L. Poe (presenter/primary contact)
Associate Professor
454 Warren Hall
Cornell University
Ithaca, New York 14853 (USA)
Voice: 607-255-4707, FAX: 607-255-9984, e-mail: GLP2@cornell.edu

Kevin J. Boyle
Libra Professor of Environmental Economics
200 Winslow Hall
University of Maine
Orono, Maine 04469 (USA)
Voice: 970-295-5961, FAX: 207-581-4278, e-mail: kboyle@maine.maine.edu

John C. Bergstrom
Professor
208 Connor Hall
University of Georgia
Athens, Georgia 30602 (USA)
Voice: 706-542-0749, FAX: 706-542-0770, e-mail: Jbergstrom@agecon.uga.edu

Abstract: This paper provides an overview and a meta analysis of existing US contingent valuation studies of groundwater quality. Using 108 observations from 14 studies, core economic variables, risk variables, and elicitation effects are found to systematically influence groundwater values. Other research design features are also investigated.

Subject Code: Environmental Economics

A Meta Analysis of Contingent Values for Groundwater Quality in the United States

Introduction

In 1994, we collaborated on an Association of Environmental and Resource Economics/American Association of Agricultural Economics invited paper entitled "What Do We Know About Groundwater Values? Preliminary Implications from a Meta Analysis of Contingent-Valuation Studies" (Boyle *et al.* 1994). At that time, application of contingent valuation methods to groundwater quality was still very novel, beginning with Edwards' pioneering paper in 1988. And thus the number of data points in our study were limited to a selection of unique estimates that could be gleaned from the eight studies that had been completed through early 1994. Given this small base, we cautiously adopted a meta analysis approach using estimated values from individual studies "to statistically investigate whether the eight contingent valuation studies of groundwater protection collectively provide a richer picture of the benefits from groundwater protection than can be developed from a qualitative comparison of the study features and results" (p. 1055). In pursuing this effort our intent was not to identify absolute magnitudes of coefficients or an equation that would serve as a base for benefit transfers of estimated groundwater values to unstudied sites. We acknowledged that such a pursuit would be misleading and premature. Rather, we simply sought to explore whether there was a systematic consistency across studies. We were pleasantly surprised: concluding that "groundwater valuation studies, despite their limitations, are not producing random noise. These studies are reflecting systematic differences in groundwater values..." (p. 1060).

With five years of additional research in contingent valuation and the valuation of groundwater quality, we feel that we still do not we have a homogenous enough or comprehensive enough base for identifying the absolute effects of experimental designs and the divergent methodological strategies adopted by individual researchers. In spite of some collaborative efforts each research project has tended to pursue a novel methodological innovation (see Bergstrom *et al.,* 2000). Thus, rather than additional research bringing about a more cohesive and comparable data set for meta analyses as we had hoped would result subsequent to our

1994 study, we now have an even more disparate set of observations with which to conduct meta analyses. Nevertheless, this broadening of the research agenda is useful in the sense that the pursuit of general methodological innovation has encouraged applications of contingent valuation to groundwater. This added depth compensates somewhat for the increased dispersion in methods, and enhances our confidence in identifying directional effects associated with different experimental designs and sampling frames.

The present study builds upon our original work in 1994. It differs however in a number of dimensions. First, our library of studies to draw from has broadened with the addition of new studies conducted by de Zoysa (1995), Crutchfield *et al.* (1997), Delavan (1997), and Bergstrom et al. (2000), and revisiting of data that was still nascent in 1994 (e.g., Bergstrom and Dorfman, 1994; Poe, 1998). This additional data has allowed us to reevaluate our selection of observations for the application and to modify the composition of explanatory variables. Our empirical analysis differs from the previous work in that instead of treating each unique value as an equally weighted observation, each study is now given equal weight. That is a study with 23 observations has equal weight in this analysis as a study that provides two observations. Adopting an equal weighting approach across studies dilutes the effects of additional within-study observations -- which was of substantial concern in our 1994 data -- and allows us to be less parsimonious in our selection of data points. Willingness to pay values have also been updated to 1997 dollars and we now use a linear, as opposed to a log-linear, function in our analyses.

This chapter is organized as follows. The next section provides a broad conceptual framework for our analyses. With an eye towards the meta analysis we then briefly review the individual studies and identifies the variables to be used. The results and implications from this research are discussed in the final two sections.

2. Conceptual Framework

Following Glass's (1976) article describing the meta-analysis approach, this term refers to "the statistical analysis of a large collection of results for individual studies for the purposes of integrating the findings. It connotes a rigorous alternative to the casual, narrative discussion of research studies which typify our attempt to make some sense of the rapidly expanding research literature" (p. 3). As noted by van den Bergh *et al.* (1997) this technique has a major potential for developing a consensus on point estimates in the valuation of environmental goods and for exploring factors that have influenced variations within and across individual studies: "Meta-Approaches may be used to summarize over a collection of similar relationships and indicators, or to average, possibly using weights, over a collection of values obtained in similar studies. It is suited to this because point estimates are, by definition, quantified and, hence, conventional statistical methods can usually be applied with relative ease" (p. 5). Correspondingly several studies have used this technique to synthesize valuation research concerning a range of environmental goods, including urban pollution valuation, visibility improvement, recreation benefits, and noise nuisance (see van den Bergh *et al.*, 1997).

The present meta analysis builds upon the following conceptual framework, which implicitly defines willingness to pay as a state independent option price (OP) in a utility difference framework as follows:

$$\sum \pi^{w}_{i,j} V_i(P_{gw}, P_s, M^{w}_{i,j} - OP_i; Q_j, S_i) = \sum \pi^{o}_{i,j} V_i(P_{gw}, P_s, M^{o}_{i,j}; Q_j, S_i) \quad (1)$$

where $\pi_{i,j}$ is individual i's subjective probability that groundwater is contaminated at level Q_j and will adversely affect human health, V_i (.) is an indirect utility function, P_{gw} is the state independent price of ground water for drinking, P_s is the state independent price of substitute sources of potable water, $M_{i,j}$ is the individual's disposable income in state j, OP_i is person i's option price (or willingness to pay) for the ground water quality change, and the superscripts o and w refer to no project and with project policy conditions. S_i indicates other individual specific factors that may condition the utility function. The subjective probabilities and utilities are indexed by i to indicate that different individuals, or groups of individuals, may have different preferences regarding health risks and potable water. Given this notation, we can rewrite the value definition as OP = $f(\Delta(\pi_{j,i} * Q_j), P_{gw}, P_s, S_i)$.

This framework provides the basic insight for identifying the variables that need to be included in the meta analysis to control for differences in structure and approach in the various contingent valuation studies. Option price is derived from a change in groundwater quality and related economic factors entering the indirect utility function. As such, the change in the probability that a water supply is contaminated, the price of water and its substitutes, and income level, should be consider core economic variables. In addition, the conceptual framework specifies that values should be dependent on overall water quality and program attributes, as well as the individuals' socioeconomic characteristics.

In moving from the conceptual framework to field application, it is clear that other methodological effects need to be accounted for if we are to try to isolate the critical economic features affecting option price. As raised in Poe and Bishop (2000) and other groundwater studies (e.g. Bergstrom and Dorfman, 1994), information is a critical factor in formulating reference probabilities and willingness to pay values. Based on discussions with a number of authors, the level of information provision is a ubiquitous issue in designing ground water valuation questionnaires. Accumulated laboratory experiments and field research also suggest that values provided are not invariant to the elicitation method (see Schulze *et al.* (1996) for a review of experimental economics literature and Welsh and Poe (1998) for references to CV comparisons of elicitation effects). And thus, the elicitation method needs to be accounted for in the empirical analysis.

Each of these issues, what we shall respectively call the core economic variables, respondent other study design effects, and elicitation effects, will be discussed in detail in the "Meta Analysis Variables" section. We now turn to characterizing the studies that serve as a base for this analysis.

3. Study Descriptions

From an organizational perspective we group the 14 studies considered in this analysis into three categories. The first category follows Edwards' focus on changes in probabilities of exceeding government health thresholds. The second category focuses on valuing more general programs, without specifying or eliciting how the probability of exceeding thresholds will change with adoption of the program. The third category instead frames the valuation problem as affecting the quantity, as opposed to the quality of water, available to the community. These three groups are termed threshold, general , and quantity models, respectively. The studies included in each category are discussed below. Boyle (1994) provides additional discussion of the studies contained in our 1994 paper. Numbers in [] refer to the year the survey was conducted.

It is important to note that the entirety of published groundwater studies are not included in the present analysis. Several worthy studies simply did not have enough cohorts along a critical methodological dimension and, hence, were precluded from this meta analysis. Omitted studies include research that was conducted outside the United States (e.g., Hanley, 1989; Stenger and Willinger, 1998), that reported values for marginal or incremental changes in contamination (e.g, Sparco, 1995; Poe and Bishop, 1999), or that used alternative value elicitation techniques such as conjoint analysis (e.g., Stevens *et al.*, 1997).

Threshold Studies: The common theme in these studies is that the reference and target conditions are specified as probabilities of exceeding government health standards in a given time period. In terms of Equation 1, emphasis is given in this research to specifying the with and without project π associated with Q_j exceeding health standards. For example, a participant might be asked to assume that, without a program, their household would face a 75 percent probability of exceeding government health standards for a given contaminant (i.e., $\pi^o = 0.75$). They are then asked to value a program that would reduce that probability to, say, zero (i.e., $\pi^1 = 0$). As an alternative to specifying an "objective" reference probability for the participant, "subjective" approaches allow individuals to identify their without program probabilities of exceeding standards. Implicitly or explicitly, these studies assume that the government health standard provides a discrete safety threshold, a point that had been questioned in Poe and Bishop (1999).

Edwards [1986]: Edwards introduced the probability of contamination threshold approach in a study that considered the issue of nitrate contamination in the Falmouth and Woods Hole communities in Cape Cod. Using a mail survey, participants were asked to "assume that there is a ___ percent chance that all groundwater in Falmouth and Cape Cod will be contaminated with nitrate from sewage 5 years from now if nothing new is done to protect it", wherein the reference probability of contamination varied across a split-sample design and included 25%, 50%, 75% and 100%. The target condition with the program was either that "nitrate contamination will definitely be prevented" or that "the chances of contamination are reduced to 25%".[1] A dichotomous choice response format was used to elicit values, and analyzed in a utility-theoretic framework that isolated option price as a measure of mean willingness to pay. Values for the meta analysis are taken from measures associated with 25%, 50%, 75% and 100% reductions in probabilities of contamination presented in Table III in Edwards (1998).

Sun [1989]: As reported in Sun (1990), Sun *et al.* (1992), and Bergstrom and Dorfman (1994), this study adapted Edwards' approach to include subjective perceptions of the reference probability of contamination. In a mail survey, respondents were asked, "If nothing new is done to prevent groundwater pollution in your area do you expect your sources of drinking and cooking water to become polluted by agricultural pesticides and fertilizers during the next five years?", with response options ranging from "Yes, Definitely (100 percent certain)" to "No, Definitely Not (0 percent chance)" in 25% increments. The target condition was that "pollution of ground water will definitely be kept at safe levels (that is, below the United States health advisory levels of 10 mg/l NO_3-N)". The methodological focus of this research was to assess the effects of information on contingent values for ground water. Using a split sample design, approximately an equal number of respondents received one of the following variants: 1) no additional information about the contamination levels; 2) "characteristic" information (i.e., a discussion of the sources, types, and levels of contamination associated with agricultural fertilizers and pesticides); 3) "specific" information (i.e. the possible health effects associated with contamination from agricultural pesticides and fertilizers); or 4) both characteristic and specific information. Values were elicited using a dichotomous choice question, followed by an open-ended question. Those values used in the meta analysis include follow-up open-ended values associated with each information level (Sun, 1990), three median dichotomous choice values estimated from a pooled information data set using an *ad hoc* option price framework for 0%, 54% and 100% without-program subjective probabilities of contamination (Sun *et al.*, 1992), and 12 observations from differing reference probabilities of contamination (25%, 50%, 75%, and 100%) and information group combinations estimated using a utility-theoretic analytical framework (Bergstrom and Dorfman, 1994).

Jordan and Elnagheeb [1991]: Jordan and Elnagheeb (1993) elicited values for a groundwater treatment/filtration program in Georgia using a mail survey. Current water quality conditions were not specified, but respondents were asked to assume that nitrate levels in water exceeded safety standards (for private well owners) or were increasing (for public well owners). Using a payment card elicitation framework, private well owners were then asked how much they would pay for installing and maintaining new treatment equipment on their well "to avoid the risk of increasing nitrates in my drinking water". Those attached to public supplies were asked how much they would be willing to pay in increased costs on their monthly water bill for treating water with increasing levels of nitrate contamination. The methodological focus was on comparisons of ordinary least squares and maximum likelihood methods of modeling payment card responses, as well as differences in mean willingness to pay associated with private and public well users. Mean and median willingness to pay values were taken from Jordan and Elnagheeb's preferred maximum likelihood estimates (without protest bids) for public and private well users.

Poe [1991-92]: The Poe study closely corresponds with the Sun research. As discussed in Poe (1998), the reference contamination conditions were subjectively specified by the respondents using a scale similar to that used by Sun, target conditions were to reduce the probability of exceeding health standards to zero, an *ad hoc* dichotomous choice framework was used to estimate willingness to pay distributions, and information was varied across samples. The methodological focus of this mail survey of rural residents with private wells was the effect of information on risk perceptions (Poe *et al*. 1998) and willingness to pay (Poe and Bishop, 2000). The study consisted of two sequential stages. Respondents to the first stage [listed in Tables 1 and 2 as Poe 1991] were asked to base their values on their existing knowledge of their household water quality, with approximately one half receiving no additional information and the other half receiving general information about the sources of nitrates, the health effects of nitrates, government standards for nitrates , and possible averting options. Separate no-information and with-information mean willingness to pay values for this first stage of the study are taken from Poe and Bishop (1992). In the second stage (listed in Tables as Poe 1991-92), respondents were provided with general information of the type described above along with specific information about their water quality based on an actual nitrate test of their household water supply. For the meta analysis 10 observations associated with 0%, 25% , 50%, 75%, and 100% change in probability of exceeding government standards were taken from the Stage 2 survey. Five of these were median willingness-to-pay values taken from Poe (1998) and the other five were mean values reported in the Poe and Bishop (2000). In classifying the two stages as separate studies in this analysis, we maintain that the information conditions were different enough so as to constitute separate samples.

de Zoysa [1994]: The de Zoysa mail survey focused on nitrate contamination and groundwater quality in the Maumee river basin of Northwestern Ohio. As described in de Zoysa (1995), Randall and de Zoysa (1996) and Randall *et al.* (2000), this research contained a number of methodological innovations: it tested embedding/adding up effects of groundwater in a more comprehensive wetlands/surface water/ groundwater protection program, it used explicit graphics to indicate the relative levels of water contamination, it employed a one time payment rather than repeated payment over the years, it used a Turnbull lower bound approach to model the dichotomous choice responses, and it argued that open-ended responses following a dichotomous choice question were valid measures of willingness to pay. This study is included in the threshold group for the meta analysis with a 0% change in probabilities of exceeding the EPA health thresholds because the graphics included in the survey indicated that the without-program nitrate levels would fall in a range of 0.5 to 3 mg/l NO_3-N. This range is above the natural levels of 0.5 mg/l for the region but far less than the 10 mg/l health standards. With the program nitrate levels would fall between 0.5 and 1 mg/l. Three willingness to pay estimates were taken from Randall *et al.* for the meta analysis: the estimated dichotomous choice median value, the lower bound dichotomous choice mean value, and the mean open-ended-after-dichotomous-choice continuous raw data value.

Crutchfield [1994]: This study deviated from the other research used in the meta analysis in that it was included in a national telephone survey conducted as part of the National Survey of Recreation and the Environment. Questions regarding drinking water appeared in the middle of the survey, following a set of questions on water-based recreation activities. The reference and target conditions for both private and public well users was "Suppose your home tap water is contaminated by nitrates to a level that exceeds the EPA's minimum standard by 50%. However, assume that the local agency could install and maintain a filter in your home to the minimum safety standards set by the EPA... Note that if you chose not to have this filter installed, nitrate will be present in your tap water at the original levels." A second question was asked that indicated that "due to technological advances, instead of only partially eliminating nitrates, this system can completely eliminate nitrates from your tap water", begging the question of whether the EPA safety standard is regarded by respondents as safe. The authors found a premium for the more effective filter came to about 3 percent over the standard filter, suggesting some nominal additional value for moving beyond the threshold. The study was conducted in four regions of the US -- the Mid-Columbia basin in Washington State, Central Nebraska, White River Basin in Illinois, and the Lower Susquehanna River in Pennsylvania. Altogether, this study provided eight mean willingness-to-pay values for the meta analysis derived from dichotomous choice question formats. These values were incorporated into the threshold model assuming that the change in probability equaled 100% for both type of filters.

Delavan [1996]: Although the Delavan study modeled subjective safety responses in the valuation framework in a manner similar to the Bergstrom *et al.* (2000) option price framework [see Delavan and Epp, 2000; Epp and Delavan, 2000] and used a survey design that closely approximated the Bergstrom [1997] and Boyle [1997] studies discussed below, we categorize Delavan's research for this meta-analysis as a threshold study with a change in probability of 25%. This is because the reference conditions for the program specified that

“Currently, only about 50% of all private wells in your area have nitrate levels which meet the safety standard of 10 milligrams per liter. In some places the nitrates per liter are well above the standard while in other place the water is ‘safe’ to drink”. The target conditions were described as a program that “would improve the quality of water so that in 10 years 75% of the private wells will meet the standard”. The mail survey was conducted in Lancaster and Lebannon countries in southwestern Pennsylvania. As described in Epp and Delavan (2000) the dichotomous choice questions were followed up with an open-ended question. Five values from Delavan’s research were used in the meta analysis, two protest/no protest informed-open-ended and two protest/no protest open-ended-after-dichotomous-choice values reported in Epp and Delavan (2000), and the median dichotomous choice value reported for Pennsylvania in Delavan and Epp (2000).

General Safety and Protection Studies: Whereas the threshold studies focused on valuing specific reductions in the probabilities of exposure to specific contaminants, usually nitrates, this set of studies focuses on general programs designed to increase safety and protect water supplies. That is, emphasis is given to describing and valuing a comprehensive program, frequently without specifying a change in outcomes. In the conceptual framework, this corresponds to shifting the distributions of Q without specifying numerical values for these changes. Often, the types of pollution considered were much broader than those contaminants considered in the threshold models.

Schultz [1988]: The Shultz (1989) study used a mail survey to elicit willingness to pay for a groundwater protection program in Dover New Hampshire (N.H.). Reference conditions were established by informing respondents that “several other nearby N.H. towns have recently had their groundwater supplies contaminated... On the other hand, many N.H. towns have never had any serious groundwater pollution problems”. An alternative program was then described as an “attempt” to protect community water supplies by “purchasing land overlying sensitive groundwater areas, formulating stricter zoning ordinances, hiring inspectors to enforce groundwater pollution laws and standards and a variety of other strategies”. After specifying that these protection plans cannot guarantee the prevention of groundwater pollution, but are instead intended to reduce the risk of such problems occurring, a dichotomous choice willingness-to-pay response was asked for the program. The meta analysis uses the mean and median willingness to pay values reported in Schultz and Lindsay (1990).

Powell (1989): The Powell mail survey study marks the initiation of what might be termed a safety difference approach. Conducted in 12 towns across three northeastern states (see Vandenberg *et al.* 2000 in this book), the survey was conducted as part of a study of how the information gained from contingent valuation research could be used in groundwater managers in local communities (see Powell, 1991 and Powell *et al*., 1994). After noting that "Many areas in the northeastern United States are discovering actual or potential threats to drinking water supplies", individuals were asked to identify those sources that they feel likely to contaminate their local groundwater supplies in the future. Using pen and ink drawings as an aid, options included agricultural chemicals (pesticides, fertilizer), landfills, toxic chemicals (use, storage, disposal), accidental spills (road, rail, pipeline), underground storage tanks, and septic tanks. Subjects then identified the safety level of their current household supply, with safety response options including "very safe", "safe", "somewhat safe", and "unsafe", each with an associated descriptive paragraph for clarification. An "area wide special water protection district" was described, and a payment card method was used to elicit willingness- to-pay values for a program that would move their water quality from their specified safety level to a "very safe" level. Willingness to pay values and other data for the 12 towns were taken from VandenBerg *et al.* (2000), Powell (1991), and access to the original data.

Caudill [1990]: The Caudill study used a mail survey to obtain statewide estimates for prevention and well protection programs in Michigan. Respondents were asked to specify their risk of "death from groundwater pollution" in Michigan using 22 comparative risks ranging from chicken pox (0.1 deaths per million) to heart disease (3,306 deaths per million) on a reference risk ladder. The prevention scenario used an open-ended format to elicit willingness to pay for a program that "would prevent any further increase in groundwater pollution in your county" by identifying source of groundwater pollution and taking "educational, regulatory and legal action". An alternative well protection scenario would eliminate the "remaining health threat from groundwater pollution" by testing all wells for harmful chemicals once a year, and installing and maintaining filtration devices for water used by a household to remove any harmful chemicals that are detected. A complete program included both the prevention and well treatment activities. Six values are taken from Caudill's (1992) dissertation: rural and urban values for prevention, well protection, and the complete program.

Bergstrom [1997] and Boyle [1997]: As reported in the Bergstrom *et al.* (2000), parallel valuation studies of groundwater protection programs were conducted in Dougherty County, Georgia (Bergstrom) and Aroostook County, Maine (Boyle). Providing a questionnaire similar in many respects to that used by Delavan [1996], this research provided a rich information base about nitrates (containing information boxes about "How Does Groundwater Exits Underground?", "Nitrates in Ground Water", "Potential Health Effects of Nitrates: Blue Baby Syndrom", and Potential Health Effects of Nitrates: Cancer"). Monitoring data was referred to in order to establish reference conditions indicating that 98% of public and private wells in Dougherty County have nitrate levels that meet safety standards (87% in the Maine study), suggesting that ground water in most places in the county is "safe" to drink. The target conditions described a technical and financial ground water program that would protect and maintain this "safe" level of ground water quality. Values were elicited using a dichotomous choice question. Building on the safety difference approach introduced in Powell (see below), safety values with and without the program were elicited using a 0 (definitely will not remain safe) to 100 (Definitely will remain safe) scale.[2] Nine willingness to pay values were drawn from each of these studies. *Ad hoc* mean and median values were taken from the protest and no-protest estimations presented under Model 1 in Table 5.2a and Table 5.2b in Bergstom *et al.* (2000). Parallel utility-theoretic values were included for each study using Model 1 in Table 5.3a and Table 5.3b. Finally, the 9th observation for each study was the open-ended value as reported in Delavan and Epp (2000)..

<u>Quantity or Change in Supply Studies (ΔS)</u>: The conceptual framework presented above focuses on a change in quality or risk of exposure. This poses a problem when valuing public water supplies, because the quality of such supplies are already protected by the Safe Drinking Water Act (SDWA) standards. Such a contradiction seems to have been noticed by most studies that have included participants attached to public water supplies. For example, Edwards included a directions indicating that "Health risks are not listed because water quality is being monitored to protect us from using contaminated water". Similarly, the Crutchfield and Jordan and Elnagheeb studies include separate valuation scenarios for respondents using private supplies and respondents attached to municipal or public supplies.

McClelland et al. [1991] directly addressed the public supply issue by characterizing the situation as a supply shortage problem in a national mail survey. That is, reflecting real policy situations, public or community water that is contaminated has to either be treated to meet SDWA safety standards, or not used. In the latter case, a rationing program may be necessary. Water that is threatened can also be contained or otherwise isolated.

In the McClelland *et al.* (1992) report to the USEPA, various strategies to protect drinking water were evaluated using a split-sample design and a payment card elicitation technique. In all versions the contamination was described as a slow-moving plume emanating from a landfill. All participants were asked to value a complete clean up program that would pump and clean up the contaminated water. A containment option that would stop the spread of the plume and draw household water from outside the containment area was offered to a sub-sample of respondents. Willingness to pay for a public treatment program was elicited from another sub-sample. And, yet a third sub-sample was asked to consider rationing where water rationing would require cuts in water use of 10% and 70%. Finally, separate use values were derived from the complete cleanup approach with a sequence of embedding questions in which individuals were asked to identify the proportion of their stated values were directed to environmental good causes in general and the proportion of value that specifically addressed their personal benefits from this groundwater protection program. Using this technique, which is described in detail in Schulze *et al.* (1998), about 33% of the complete value program was assigned to use value. Five full sample and five predicted sample values were taken from the complete cleanup, containment, public treatment, 10% shortfall, and 70% shortfall scenarios. An eleventh point estimate was derived from the disembedded use values.

4. Meta Analysis Variables

Building on the conceptual framework, the variables used in this analysis are grouped into core economic variables, design effects, and elicitation effects. Unfortunately, because some of the studies did not include information on the level of variables included in their analyses, the variables selected for the meta analysis can only be loosely aligned with the conceptual framework. The core economic variables pertain to study design and sampling features identified in the indirect utility function difference conceptual framework. The design effects capture information features of the studies as well as relevant population characteristics not accounted for in the core. The elicitation effect variables attempt to control for the type of question format. Selection of these latter two variable groups was based on examination of within study hypothesis testing and the criterion that these design effects had to appear in a minimum of three studies. This minimum studies requirement precluded some obvious variables raised in individual studies (e.g. phone versus mail (Crutchfield *et al.*, 1997) or onetime v. multi year comparisons (de Zoysa, 1995)). Such exclusion subjects the analyses to possible relevant excluded variable biases. While such biases may exist, the binary nature of these variables in combination with other binary covariates creates very unstable coefficients in the limited number of observations used here. Because of this result, a proliferation of additional explanatory variables would undermine the stability and replicability of our results - hence the arbitrary cutoff of three observations or more for inclusion in the analysis.

Mean willingness to pay values reported in the individual studies were adjusted to 1997 dollars using the annual consumer price index. As indicated in Tables 1 and 2, there is a wide range in values both within and across studies. The following description of the explanatory variables used in the meta analysis is organized by variable group.

Core variables: The core variables used in all regressions in the analyses define the program by the type of change that will occur, the price vector of water including substitute sources, and the income level. Summaries of these variables by study are provided in Table 1.

The first variable in this core, *USE*, pertains to whether the program focused broadly on groundwater protection or solely on drinking water protection. The difference between measures being broad environmental or non-use values associated with aquifer protection. Non-use motives for groundwater protection have been demonstrated generally for groundwater (Mitchell and Carson, 1989) and shown empirically to exert a substantial influence on willingness to pay for groundwater protection (Edwards, 1988; McClelland *et al.*, 1992). On this basis we would expect those studies that concentrated on filtration devices (e.g., Caudill, 1992; Jordan and Elnagheeb, 1993; Crutchfield *et al.*, 1997) or containment strategies (e.g., McClelland *et al.*, 1993) to demonstrate lower values than studies which value more broadly defined groundwater protection programs. Such divergence in values is demonstrated within the McClelland *et al.* (1993) report. Letting USE=1 if the study limited its focus to use values and zero otherwise, our expectation for the sign of this coefficient would be negative.

General programs, as defined above, are used as the base for this analysis. Threshold studies are incorporated into the analysis with a binary variable (DUM($\Delta\pi$)) to measure whether specifying or eliciting contamination probabilities results is a general shift in values. This binary variable is multiplied by the contamination probability difference to create the variable $\Delta\pi$. By default, studies that did not use a threshold approach are assigned a $\Delta\pi$ value of zero. A similar set of variables are created to isolate the quantity or change in supply studies, consisting of a binary variable (DUM(ΔS)) and a change in supply variable (ΔS). We formulate no expectation on the coefficients of each of these binary variables. However, coefficients on $\Delta\pi$ and ΔS are expected to be positive based on the within study results for the threshold studies (e.g., Edwards (1988), Sun et al. (1992), and Poe and Bishop (2000)) and the McClelland *et al.* (1993) research.

Two final core economic variables are included: the price of substitutes and income. The price of substitutes is included in the analysis to try to capture the notion expressed in Poe and Bishop (1999) that willingness to pay for water quality improvement is bounded from above "by the opportunity for substitution through the establishment of a choke price" (p. 356). While the conceptual model also specifies the "own" price of water before and after intervention, such information is not provided in any of the studies used. As such, do not include a proxy for P_{gw} depicted in Equation 1. Also excluded from the analysis is a simple variable indicating whether substitutes (e.g. filtration. bottled water etc.) were mentioned in the survey. Such a variable was not significant in our 1994 analysis, and almost all studies (with the exception of Schultz [1989], Caudill [1988], and de Zoysa [1994]) include a brief question or discussion of such opportunities. Another difficulty in trying to create a generic substitution variable is that there is quite a range of ways in which the substitutes are introduced across studies. In some cases discussion of substitutes is achieved through specific questions. For example, the Delavan [1996] survey asked "In the past 5 years have you undertaken any of the following to improve the safety of your drinking water" with response option including "installed a pollution protection devise", "installed a new well", "boiled your tap water" and "bought bottled water". Other studies (e.g. Poe [1991-92]) have augmented this question-based approach with information directly addressing the availability and cost of substitutes. Income represents the final core variable, with values from individual studies updated to 1997 dollars using the consumer price index. Based on the theoretical construct and empirical findings in each of the studies that included income as an explanatory variable, we expect the coefficient on income to be positive.

Design Effects: Three variables were used to control for variations other design effects across studies. The average of these variables by group are detailed in Table 2.

Discussions with the authors of each study indicate that one of the central debates was whether or not to mention cancer, especially in the nitrate studies. The nature of this debate is characterized in Crutchfield *et al.*(1997, pp. 6): "To avoid alarming respondents or inducing so-called panic responses to the CVM questions, the discussion of the potential risks avoided the uses of trigger words such as 'cancer'. Instead we told respondents that 'nitrates are chemical substances hazardous to human health if taken in large quantities'". Within study comparisons suggest that information bundles that contained mention of cancer do appear to elevate willingness to pay values (e.g., Bergstrom and Dorfman, 1994; Poe and Bishop, 1992). Also, one of the four regressions in our 1994 study indicated that the coefficient for those studies that mentioned cancer was positive. In the three remaining regressions the coefficient was insignificant. On this basis we would expect positive coefficient.

A second design variable, whether the locality was emphasized, is also expected to exert a positive influence on willingness to pay. This expectation draws from the experimental economics literature that suggests that group identification tends to increase cooperation (Ledyard, 1995). Thus, a study which focuses on or emphasizes a local county (e.g. Bergstrom [1997]), watershed (e.g., de Zoysa [1994]), town (e.g., Schultz [1988]) or community (e.g., Edwards [1986]) might have higher values than those studies that were conducted at statewide (e.g., Caudill [1990]) or national (e.g., McClelland *et al.* [1992]) levels.

The proportion of respondents connected to public water supplies may be regarded as an explicit design feature (e.g., Poe [1991, 1991-92]) or simply an outcome of using broad mailing lists. Regardless, some authors have conjectured that this respondent characteristic exerts an influence on willingness to pay. VandenBerg *et al.* (2000) suggest that private and public well users aren't valuing the same commodity in the sense that private well owners do not pay water bills, are not protected by drinking water standards, and may have a more intimate knowledge of their water supply. Hence, we would expect the willingness-to-pay function to be different across households with public and private sources of water. Jordan and Elnagheeb (1993, pp. 242-243) argue "The private well users were willing to pay more than the city/county water users. An explanation for this result is the city county/water users are presently paying the water companies for water, while the private well water users are not. Another possible explanation might be ... the subjective expectations of the reliability of public versus private cleanup activities". In contrast, Caudill found that rural households tend to be more confident that the quality of their water was safe, suggesting that they might have lower willingness to pay for general programs. Based on these mixed arguments, as well as the insignificance of this variable in the 1994 analysis, no sign expectation is reached for the variable Public % (i.e., the percent of the respondents connected to municipal supplies).

Two other design features that were included in the 1994 meta analysis but are dropped here. These are the response rate (as a proxy for study quality) and whether specific contaminant was mentioned. Response rate is not included here because the link between this measure and the quality of the survey is highly conjectural and has not been demonstrated in previous meta analyses (e.g. Boyle *et al.* 1994; Loomis and White, 1996). Specific mention of the type of contamination is excluded in because such mention tends to be highly correlated with the threshold approaches in this data set (the exceptions being Bergstrom [1997] and Boyle [1997]).

Elicitation Effects: A wide body of experimental economics (see Schulze *et al.*, 1996) and contingent valuation research (see Welsh and Poe, 1998) has demonstrated that estimated willingness-to-pay values are affected by how the question is asked. Notably dichotomous choice is substantially higher than open-ended or payment card elicitation methods. To accommodate such effects we have incorporated binary variables to indicate whether the contingent values were collected using open-ended techniques (the baseline), payment card (P Card), or dichotomous choice (DC) methods. Lacking a body of prior experiments, no expectation is formed concerning the coefficient on P Card variable. However, the coefficient on DC is expected to be positive. A binary variable for open-ended values following a dichotomous choice question (OEaftDC) was also included, based on this design feature explored in Sun [1990], de Zoysa [1994], and Delavan [1996], and Randall *et al*'s (2000) argument that such measures are unbiased estimators of median willingness to pay. Following the Epp and Delavan (2000) and Randall *et al.* (2000) findings that willingness to pay is positively correlated with the preceding dichotomous choice bid value, the coefficient on this variable is expected to be positive.

We have also incorporated two binary variables to indicate how the dichotomous choice willingness-to-pay value was calculated. Using the mean (a.k.a. the Hanemann (1994) approach) *ad hoc* willingness to pay as a base, separate binary variables were used to identify whether a median (a.k.a. Cameron (1988)) value is reported and/or whether a utility theoretic approach was used (see Bergstrom *et al.* 2000 for a discussion of *ad hoc* versus utility theoretic approaches). Since the median measure accounts for negative willingness-to-pay values while the mean, as we define it, is restricted to non-negative values, the expected coefficient on DC MED is negative. Based on the findings in Bergstrom *et al.*(2000) we expect a positive coefficient on DC UTIL.

5. Meta Analysis Results

In Table 3, we report three equations estimated by weighted least squares with standard errors derived using the Huber-White consistent covariance estimator. As noted in Smith and Osborne (1996, p. 293-294), "this approach treats each study as the equivalent of a sample cluster with the potential for heteroskedasticity (i.e., differences in error variances across clusters)". The weights were created such that each separate study as depicted in Tables 1 and 2 were given equal weight, and with the weights of the individual observations within a study summing to one.

Each of the three models contain the core variables as discussed above. The first equation consist of only the core variables. The second and third models contain the core variables along with the design and elicitation effects. The "Full" model uses all the variables indicated in the previous discussion. The "Short" model retains all the core variables, but sequentially removes the least significant coefficients outside the core until all remaining coefficients obtained a pretest significance level of 20 percent or better. Consistent with the notion that we are looking for directional effects and consistency, discussion of these models focuses on the direction and the significance of the coefficients.

All of the coefficients in the core model are significant and of the expected sign, with exception of the binary variable for change in supply studies (DUM(ΔS)) and the binary variable indicating that respondents were informed of the costs of substitute water sources ($Subs). Importantly, the results in the core model are generally maintained in the more complete models. As indicated by the negative coefficient on USE, studies that focused only on use values had significantly lower willingness to pay than studies that elicited total willingness to pay for complete clean up. Both the binary variable, DUM($\Delta\pi$), and the change in probability variable, $\Delta\pi$, had significant coefficient. The negative coefficient on DUM($\Delta\pi$) is offset by the positive coefficient on $\Delta\pi$: indicating that, on average, those programs with changes in probability of contamination less than 25% provide willingness-to-pay estimates that are lower than the average general study. Those studies with $\Delta\pi$ greater than 25 to 50% tended to have higher willingness-to-pay values than general studies. The high significance on these two variables likely reflects within study variation as well as across study variation in the changes in probability. As noted, the coefficient on DUM(ΔS) was not significant, suggesting that this approach does not systematically raise or lower values compared to the base general model. The extraordinarily high significance on the ΔS coefficient reflects the fact that these observations were drawn from only one study, and that the reported values were highly linear across rationing levels. Income level is also a highly significant explanatory variable.

In the complete model design effects do not appear to exert strong effects on willingness-to-pay. Although positive, the cancer affect is neither very large nor significant. In part this may be due to the fact that many of the surveys that mention cancer do so in a way that is intended to show that cancer is not a problem with the specific contaminant. For example, the Boyle [1997] questionnaire notes that "Another health concern some people may have is whether or not nitrate in ground water are a concern risk for adults. After reviewing available studies, the U. S. Environmental Protection Agency is <u>not</u> convinced at this time that nitrates in drinking water represent a potential risk of cancer". The coefficient on the "local" variable is also not significant, and is dropped in the short model. The percent of respondents on public supplies is positive but not significant. This variable is, however, retained in threshold model with a significance level of about 16 percent.

The elicitation effects variables are universally consistent with prior expectations and the broader literature in contingent valuation. The coefficient on the payment card binary variable tends to be negative, but never approaches standard significance levels. This is consistent with prior research suggesting that the open-ended and payment card approaches provide proximate values. The DC and DC median coefficients are positive and negative, respectively. Again this corresponds with prior expectations. The DC UTIL coefficient is positive and significant. Such a finding is consistent with the conclusions reached in Bergstrom *et al.*(2000).

It should also be noted that the additional explanatory variables in the complete models do appear to moderate the responsiveness of willingness to pay to some of the core variables, raising the concern of relevant excluded variable bias. Notably responsiveness to income and the threshold model variables appears to decline.

6. Discussion

Our conclusions from this research closely reflect our earlier findings, even with the addition of a substantial number of data over the intervening five years. In spite of wide variations in reported willingness-to-pay values reported in individual studies and a divergence of approaches to address the valuation of groundwater quality, the meta analysis indicates that there is a strong systematic element of these studies such that we feel comfortable in concluding that as a whole, the emerging literature on groundwater valuation, appears to be demonstrating systematic variation.

Importantly, the core variables indicate that values do respond to whether total or use values are elicited, the magnitude of the change in probability of exceeding standards in those studies using that framework, and income. Echoing the findings of McClelland *et al.,* willingness to pay was found to vary directly with the level of short fall when a rationing program was indicated. Taken together, the high individual significance of these coefficients and the relatively high explanatory value of the core model (as indicated by R^2 values in the range of 73 percent) suggest that willingness-to-pay values are systematically varying with components of the theoretical construct.

The direction of elicitation effects both reflects and should inform the broader CV literature. While the coefficients on the payment card and the dichotomous choice variables demonstrate what is already well established in the literature, the positive coefficient on the utility theoretic derivation of willingness to pay should be regarded as a new contribution, lending support to the within study findings presented in Bergstrom *et al.* (2000). The positive and significant coefficient on the open-ended following dichotomous choice variable raises further questions about starting point bias effects on this method. That is, this method of obtaining open-ended responses appears to provide significantly higher values than the standard open-ended approach.

In contrast, the lack of significance on the design effects group of variables should cause one pause. On one hand, this might be interpreted as demonstrating that values are invariant to these effects that do not appear in the core model or the elicitation groups. While positive in one sense, this could be regarded as a negative outcome. For example, such invariance to the nature of the consequences of the contaminant, as indicated by the insignificance of the cancer variable, would suggest that fairly benign contaminants would be valued the same a hazardous chemicals. Another plausible explanation for this apparent invariance in design effects is that our present sample is inadequate for isolating such effects because we are drawing from a diverse set of studies with divergent methodologies. This latter interpretation suggests a research agenda in the future that creates greater homogeneity and power by conducting parallel studies that broadly remain within the spectrum of designs used in the current studies but focus on isolating the impacts of design effects. In short, we argue that extending the parallel studies philosophy represented in Bergstrom *et al.* (2000) to design effects will allow researchers to better understand the factors that affect groundwater values, thereby enhancing the policy relevance of this entire body of literature.

Given our finding that values across studies do vary systematically, it is natural to ask, "Can the results of our empirical analysis be used as a benefits transfer function?". Perhaps they could, but we are personally extremely cautious about using our output to provide value estimates for policy decisions. Our viewpoint stems, in part, from the concerns raised by Delavan and Epp (2000), that the amalgamation of a number of studies and theoretical constructs may lead to misleading magnitudes of coefficients. Given the disparity in research approaches adopted in the studies used in our analysis and our limited data set, such a concern is pertinent. It also stems from our longstanding view that, at this time, the objective of meta analyses should be to assess consistency and directional effects of survey design features.

References:

Bergstrom, J. C, K. J. Boyle, and M. Yabe, 2000 "Chapter 5: Ground Water Quality Valuation and Subjective Risk Perceptions: Georgia and Maine Case Study", forthcoming in J. C. Bergstrom, K. J. Boyle, and G. L. Poe (Eds.), *Valuation of Water Quality*, Edward Elgar Publishers, Brookfield, Vermont, USA.

Bergstrom, J. C., K. J. Boyle, and G. L. Poe (Eds.), 2000 *Valuation of Water Quality*, Edward Elgar Publishers, Brookfield, Vermont, USA (forthcoming in March).

Bergstrom, J. C., and J. H. Dorfman, 1994. "Commodity Information and Willingness-to-Pay for Groundwater Quality Protection", *Review of Agricultural Economics*, 16:391-404.

Boyle, K. J., 1994. *A Comparison of Contingent Valuation Studies of Groundwater Protection*, Staff Paper REP 456, Department of Resource Economics and Policy, University of Maine - Orono.

Boyle, K. J., G. L. Poe, and J. C. Bergstrom, 1994. "What Do We Know About Groundwater Values? Preliminary Implications from a Meta Analysis of Contingent-Valuation Studies", *American Journal of Agricultural Economics*, 76(5)L 1055-1061.

Cameron, T. A., 1988. "A New Paradigm for Valuing Non-Market Goods Using Referendum Data: Maximum Likelihood Estimation by Censored Logistic Regression", *Journal of Environmental Economics and Management*, 15, 355-79.

Caudill, J. D., 1992. "The Valuation of Groundwater Pollution: The Differential Impacts of Prevention and Remediation", Ph.D. Dissertation, Department of Agricultural Economics, Michigan State University.

Crutchfield, S. R., J. C. Cooper, and Daniel Hellerstein, 1997. "Benefits of Safer Drinking Water: The Value of Nitrate Reduction", Agricultural Economic Report Number 752, United States Department of Agriculture, Washington DC.

Delavan, W. A., 1997. "Valuing the Benefits of Projecting Groundwater from Nitrate Contamination in Southeastern Pennsylvania", Master of Science Thesis, Department of Agricultural Economics and Rural Sociology, Pennsylvania State University, University Park.

Delavan, W., and D. J. Epp, 2000. "Chapter 7: Benefits Transfer: the Case of Nitrate Contamination in Pennsylvania, Georgia and Maine", forthcoming in J. C. Bergstrom, K. J. Boyle, and G. L. Poe (Eds.), *Valuation of Water Quality*, Edward Elgar Publishers, Brookfield, Vermont, USA.

de Zoysa, A. D. N., 1995. "A Benefit Evaluation of Programs to Enhance Groundwater Quality, Surface Water Quality and Wetland Habitat in Northwest Ohio", Ph. D. Dissertation, Department of Agricultural Economics and Rural Sociology", The Ohio State University, Columbus.

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

Epp, D. J., and W. Delavan, 2000. "Chapter 4: Measuring the Value of Protecting Ground Water Quality from Nitrate Contamination in Southeastern Pennsylvania", forthcoming in J. C. Bergstrom, K. J. Boyle, and G. L. Poe (Eds.), *Valuation of Water Quality*, Edward Elgar Publishers, Brookfield, Vermont, USA.

Glass, G.V., 1976. “Primary, Secondary, and Meta-analysis of Research, *Educational Researcher*, 5(10):3-8.

Hanemann, W. M., 1984. "Welfare Evaluation in Contingent Valuation Experiments with Discrete Responses", *American Journal of Agricultural Economics*, 66(2):332-341.

Hanley, N. D. , 1989. “Problems in Valuing Environmental Improvements Resulting from Agricultural Policy Changes: The Case of Nitrate Pollution”, *Discussion Paper in Economics 89/1*, University of Stirling.

Jordan, J. L., and A. H. Elnagheeb, 1993. “Willingness to Pay for Improvements in Drinking Water Quality”, *Water Resources Research*, 29: 237-245.

Loomis, J. B. and D. S. White, 1996. “Economic Benefits of Rare and Endangered Species: Summary and Meta Analysis”, *Ecological Economics*, 18(3):197-206.

McClelland, G. H., W. D. Schulze, J. K. Lazo, D. W. Waldman, J. K. Doyle, S. R. Elliott, and J. R. Irwin, 1992. “Methods for Measuring Non-Use Values: A Contingent Valuation Study of Groundwater Cleanup”, Draft Report, USEPA Cooperative Agreement #CR-815183.

Mitchell, R. C., and R. T. Carson, 1989. Existence Values for Groundwater Protection. Draft Final Report Prepared Under Cooperative Agreement CR814041-01. Washington, D.C. U.S. Environmental Protection Agency.

Poe, G. L., 1998. “Valuation of Groundwater Quality Using a Contingent Valuation - Damage Function Approach”, *Water Resources Research*, 34(12): 3627-3633.

Poe, G. L. and R. C. Bishop, 1992. “Measuring the Benefits of Groundwater Protection from Agricultural Contamination: Results from a Two-Stage Contingent Valuation Study”, *Agricultural Economics Staff Paper Series No. 341*, University of Wisconsin-Madison.

Poe, G. L. and R. C. Bishop, 1999. “Valuing the Incremental Benefits of Groundwater Protection when Exposure Levels Are Known”, *Environmental and Resource Economics*, 13(3): 347-373.

Poe, G. L. and R. C. Bishop, 2000. “Chapter 2: Information and the Valuation of Groundwater Quality: A Case Study of Nitrates in Groundwater, Portage County WI.”, forthcoming in J. C. Bergstrom, K. J. Boyle, and G. L. Poe (Eds.), *Valuation of Water Quality*, Edward Elgar Publishers, Brookfield, Vermont, USA.
Poe, G. L., H. M. van Es, T. P VandenBerg, and R. C. Bishop, “Do Households Update Their Health Risk and Exposure Perceptions with Water Testing?”, Journal of Soil and Water Conservation, 53(4):320-325, Dec. 1998.

Powell, J. R., 1991. “The Value of Groundwater Protection: Measurement and Willingness-to-Pay Information and its Utilization by Local Government Decision-Makers”, Ph. D. Dissertation, Department of Natural Resources, Cornell University.

Powell, J. R., D. J. Allee, and C. McClintok, 1994. “Groundwater Protection Benefits and Local Community Planning: Impact of Contingent Valuation Information”, *American Journal of Agricultural Economics*, 76:1068-1075.

Randall, A., and D. de Zoysa. “Groundwater, Surface Water, and Wetlands Valuation for Benefits Transfer: A Progress Report”, pp. 231-236, *9th Interim Report*, Western Regional Research Publication W-133 Benefits and Costs Transfers in Natural Resource Planning, Compiled by J. A. Herriges, Dept. of Economics, Iowa State University, Ames.

Randall, A., D. de Zoysa, and S. Yu, 2000. “Chapter 3: Groundwater, Surface Water, and Wetlands Valuation for Benefits Transfer”, forthcoming in J. C. Bergstrom, K. J. Boyle, and G. L. Poe (Eds.), *Valuation of Water Quality*, Edward Elgar Publishers, Brookfield, Vermont, USA.

Schultz, S. D., 1989. “Willingness to Pay for Groundwater Protection in Dover, NH: A Contingent Valuation Approach”, Master of Science Thesis, Department of Resource Economics, University of New Hampshire.

Schultz, S. D., and B. E. Lindsay, 1990. “The Willingness to Pay for Groundwater Protection”, *Water Resources Research*, 26(9): 1869-1875.

Schulze, W. D., G. H. McClelland, J. K. Lazo, and R. D. Rowe, 1998. “Embedding and Calibration in Measuring Non-Use Values”, *Resource and Energy Economics*, 20(2): 163-178.

Schulze, W., G. McClelland, D. Waldman, and J. Lazo, 1996. “6: Sources of Bias in Contingent Valuation”, in D. J. Bjornstad and J. R. Kahn, eds., *The Contingent Valuation of Environmental Resources*, Edward Elgar, Cheltenham, UK.

Sparco, J., 1995. “A Conjoint Analysis of Willingness to Pay for Changes in Groundwater Quality”, Selected Paper, Annual Meeting of the Northeastern Agricultural and Resource Economics Association, Burlington VT, June 1995. Abstract in *Agricultural and Resource Economics Review*, 24(2):258.

Stenger, A., and M. Willinger, 1998. “Preservation Value for Groundwater Quality in a Large Aquifer: A Contingent-Valuation Study of the Alsatian Aquifer, Journal of Environmental Management, 53(2), 177-193.

Stevens, T. H. , C. Barrett, and C. E. Willis, 1998. Conjoint Analysis of Groundwater Protection Programs”, Agricultural and Resource Economics Review, 27(2):229-236.

Sun, H., 1990. “An Economic Analysis of Ground Water Pollution by Agricultural Chemicals”. Unpublished M.S. Thesis, University of Georgia, Athens,

Sun, H., J. C. Bergstrom, and J. H. Dorfman, 1992. “Estimating the Benefits of Groundwater Contamination Control”, *Southern Journal of Agricultural Economics* , 24(2):63-71.

VandenBerg, T. P., G. L. Poe, and J. R. Powell, 2000. “Chapter 6: Assessing the Accuracy of Benefits Transfer: Evidence From a Multi-Site Contingent Valuation Study of Ground Water Quality”, forthcoming in J. C. Bersgstrom, K. J. Boyle, and G. L. Poe (Eds.), *Valuation of Water Quality*, Edward Elgar Publishers, Brookfield, Vermont, USA.

van den Berg, J. C. J. M., K. J. Button, P. Nijkamp, and G. C. Pepping, 1997. *Meta-Analysis in Environmental Economics*, Kluwer Academic Publishers, Dordrecht.

Welsh, M. P., and G. L. Poe, “Elicitation Effects in Contingent Valuation: Comparisons to a Multiple

Bounded Discrete Choice Approach", Journal of Environmental Economics and Management, 36(2):170-85, Sept. 1998.

Table 1. Core Variable Means for Data Used in Meta Analysis by Study, Organized by Study Type

	Survey [Survey Year]	OBS	WTP[a] ($)	USE	DUM ($\Delta\pi$)	Dπ	DUM (ΔS)	ΔS	$SUBS	INC97[b]
THRESHOLD	Edwards [1986]	4	1,316	0	1	0.63	0	0	0	104
	Sun [1989]	23	1,126	0	1	0.59	0	0	0	55
	Jordan & Elnagheeb [1991]	4	126	1	1	1.0	0	0	0	30
	Poe Stage I [1991]	2	380	0	1	0.49	0	0	0.50	44
	Poe Stage II [1991-92]	10	324	0	1	0.50	0	0	1	47
	DeZoysa [1994]	3	44	0	1	0	0	0	0	45
	Crutchfield *et al.* [1994]	8	691	1	1	1.0	0	0	0	52
	Delavan [1996]	5	59	0	1	0.25	0	0	0	47
GENERAL	Schultz [1988]	2	114	0	0	0	0	0	0	50
	Powell [1989]	12	83	0	0	0	0	0	0	44
	Caudill [1990]	6	64	1	0	0	0	0	0	53
	Bergstrom [1997]	9	199	0	0	0	0	0	0	46
	Boyle [1997]	9	46	0	0	0	0	0	0	32
ΔS[c]	McClelland *et al.* [1991]	11	117	0.82	0	0	1	0.4	1	51
	All Studies (weighted)		334	0.27	0.57	0.31	0.07	0.03	0.18	50

a. $1997.
b. $1997 (thousands)
c. ΔS refers to quantity or change in supply.

Table 2. Survey and Elicitation Effect Means Used in Meta Analysis by Study, Organized by Study Type

	Survey [Survey Year]	OBS	WTP ($)	CANCER	LOCAL	PUBLIC%	P Card	DC	DC MEDIAN	DC-UTIL	OE After DC
THRESHOLD	Edwards [1986]	4	1,316	0	1	0.89	0	1	0	1	0
	Sun [1989]	23	1,126	0.5	1	0.87	0	0.83	0.13	0.70	0.17
	Jordan & Elnagheeb [1991]	4	126	0	0	0.50	1	0	0	0	0
	Poe Stage I [1991]	2	380	0.5	1	0	0	1	0	0	0
	Poe Stage II [1991-92]	10	324	1	1	0	0	1	0.50	0	0
	DeZoysa [1994]	3	44	0	1	0.33	0	0.67	0.33	0	0.33
	Crutchfield *et al.* [1994]	8	691	0	0	0.70	0	1	0	0	0
	Delavan [1996]	5	59	1	1	0.32	0	0.20	0.20	0	0.40
GENERAL	Schultz [1988]	2	114	0	1	0.90	0	1	0.50	0	0
	Powell [1989]	12	83	0	0	0.84	1	0	0	0	0
	Caudill [1990]	6	64	0	0	0.59	0	0	0	0	1
	Bergstrom [1997]	9	199	1	1	0.76	0	0.89	0.44	0.44	0.11
	Boyle [1997]	9	46	1	1	0.35	0	0.89	0.44	0.44	0.11
ΔS[b]	McClelland *et al.* [1991]	11	117	1	0	0.83	1	0	0	0	0
	All Studies (weighted)		334	0.43	0.64	0.56	0.21	0.60	0.18	0.18	0.15

a. $1997

b. ΔS indicates quantity or change in supply study.

Table 3. Meta Analyses of Groundwater WTP Function Estimates[a,b]

	Exp. Sign	Core	Full Complete	Short Complete
Constant		-453.57 (109.57)***	-225.30 (285.86)	-499.94 (102.79)***
Use	-	-391.23 (169.95)**	-493.94 (224.98)**	-328.05 (129.20)**
DUM (Δ π)	?	-241.56 (112.65)**	-118.06 (137.78)	-161.34 (121.60)
Δ π	+	1033.12 (251.46)***	950.80 (240.80)***	951.81 (228.64)***
DUM (Δ S)	?	150.89 (232.37)	328.15 (220.69)	244.97 (199.17)
Δ S	+	289.17 (0.00)***[c]	289.17 (0.00)***[c]	289.17 (0.00)***[c]
$ Subs	-	-94.75 (127.66)	-15.62 (100.73)	8.08 (70.24)
Inc97 (thous.)	+	14.01 (2.19)***	6.82 (2.27)***	7.38 (2.83)***
Cancer	+		35.10 (107.10)	
Local	+		-264.11 (208.21)	
Public %	?		161.96 (114.40)	165.71 (115.93)
OEAFTDC	+		221.33 (108.68)**	278.39 (125.64)**
P Card	?		-201.72 (169.53)	
DC	+		215.26 (112.49)*	260.59 (79.52)***
DC MEDIAN	-		-134.32 (33.07)***	-153.45 (27.89)***
DC-UTIL	?		304.15 (123.31)**	276.12 (134.25)**
n		108	108	108
R^2		0.73	0.81	0.81

[a] Numbers in () are asymptotic standard errors.

[b]. *, **, and *** indicate significant at the 10%, 5% and 1% levels, respectively.

[c] The small standard error on the coefficient for Δs is due to the new linearity of the limit number of WTP observations in this sample.

Endnotes:

1. Edwards also varied the time to contamination, the probability of demand, and the cost of bottled water. The latter aspect is not included in his 1988 paper, and is not apparent from the questionnaire copies provided from the author.

2. The Delavan study described previously closely followed this survey design. A critical difference from the perspective of this meta analysis is that Delavan specified a change in the probability of exceeding the contamination threshold.