Fraser River Action Plan

Benefits of Improving Water Quality in the Abbotsford Aquifer:

An Application of Contingent Valve Methods

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BENEFITS OF IMPROVING WATER QUALITY IN THE ABBOTSFORD AQUIFER: AN APPLICATION OF CONTINGENT VALUATION METHODS

by

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Executive Summary

Nitrate pollution is a problem in many agricultural regions of the United States and Canada. In British Columbia, the Abbotsford aquifier is a local exmple of groundwater pollution. This aquifer is the primary source of municipal water for the District of Abbotsford. It is one of the largest aquifers in B. C., and encompasses the districts of Langley, Matsqui, Abbotsford and Sumas (USA). The aquifer is shallow with a water table that is only 3 to 9 feet below the surface in many places; this does not allow the soil to filter much fertilizer or fecal waste. Water pollution is currently attributed to nitrate and occasional coliform pollution, but there is also a concern that, with further development of the region, there may be pesticide or heavy metal leaching problems.

Concerns over increased pollution may be justified since the aquifer failed to meet federal water quality standards for nitrate concentrations on occasions. In 1982, nitrate concentrations of 23 out of 24 wells tested in the airport region in the south west corner of the aquifer exceeded the 10mg/L nitrate concentration limit set out by the ***Guidelines for Canadian Drinking Water Quality 1978.*** The water nitrate concentration limit is set to prevent extensive exposure of infants to higher levels that can cause ***methaemoglobineamia,*** also known as "blue baby syndrome". Those children who develop the disease, have bacteria in their intestinal miroflora that break nitrate down into toxic nitrite (Federal-Provincial Working Group on Drinking Water, 1978, ***p.44-45).*** Few studies have been conducted as to the danger of extensive nitrate pollution to adults; however, animals such as cows and sheep are also susceptible.

Given risks to health and lack of knowledge concerning the benefits of improved water quality, a contingent valuation survey was conducted in the Abbotsford region. The survey sought to elicit responds' willingness to pay for improvements in water quality. As well, defense expenditures (actual outlays on bottled water and water filters) and a ranking method were used to determine the value of improved water quality in Abbotsford. The survey was mailed to 347 households in the Central Fraser Valley region in May of 1993, with a reminder following approximately 3 weeks later. The response rate was 27.4%, not unlike that of similar studies in the

region.

A lower bound estimate of the off-farm benefits of improving water quality is given by defense expenditures of $70/year per household; assuming about 6,300 households in the Abbotsford region, this provides an estimate of the benefits of improved water quality of $0.44 million. Based on willingness to pay estimates of $78-$90/year per household, the estimate of benefits is somewhat higher--$0.49-$0.57 million. If WTP estimates for those who own ALR land are used ($114-$125/year), then the benefits of improved water quality are $0.72-$0.79 million. Finally, using the results from the fuzzy pairwise comparisons gives benefits of $ 128-$284/year per household. The total benefits of improved water quality would then be $0.81-$1.79 million. Questions concerning the appropriateness of willingness to pay as a measure of benefits (Knetsch 1993) suggest that the latter estimates may be a more appropriate measure of benefits. Hence, the appropriate measure of benefits of improving water quality in the Abbotsford region is about $1.8 million annually.

Benefits of Improving Water Quality in the Abbotsford Aquifer:
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1. Introduction

The Abbotsford aquifer is a large underground source of water that is important for domestic, municipal, agricultural, and industrial uses in both Canada and the United States; the aquifer encompasses the districts of Langley, Matsqui and Abbotsford in British Columbia, and Sumas in the United States. Bacterial and nitrate contamination of the aquifer is the result primarily of livestock wastes, and recent boil orders and high nitrate levels in well samples have drawn attention to water quality issues in the aquifer. Although there has been ecoli bacterial contamination on occasion, the major problem is considered to be nitrate pollution. Both forms of pollution are caused by manure management practices, such as stockpiling, overapplication and unsuitable application times.

With federal and provincial funding, efforts have been made to carry out research of the externality problem and undertake analysis of potential alternatives to reduce nitrate leaching. To date, extensive environment-related information on the industry has been identified and analyzed. The following alternative solutions are being considered: adopting adequate on-farm and regional storage facilities; comporting manure either on or off farm; converting poultry manure to cattle feed; and transporting the manure off the aquifer to regions with nutrient deficient soils. Poultry and raspberry farming practices in the study area are also changing to help reduce contamination of the Abbotsford aquifer.

The primary focus in this study will be on nitrate pollution, because efforts to solve this problem will also address that of bacterial contamination. Pollution from pesticides is also a problem, but will not be considered here. The purpose of the current study is to provide estimates of the benefits of reducing the externality impacts of manure on water quality. Since the costs of alternatives to reduce pollution (e.g., comporting) are generally greater than the private benefits, a

contingent valuation instrument is used to determine whether the social (private plus off-farm) benefits from alternative livestock handling methods exceed their costs. The off-farm benefits of proposals to reduce contamination (increase water quality) consist of residents' willingness-to-pay for improved water quality. One aspect of the off-farm benefits that will be considered is the damages that are avoided by improving water quality; these damages are the (defense) expenditures of individuals in purchasing water filters and bottled water.

We begin in the next section by examining the background to the problem of water quality degradation from agricultural pollution. Then, in section 3, we review the use of the contingent valuation method (CVM); included in this review is a theoretical model for measuring the benefits of improved water quality. The survey instrument employed in this study and the empirical results are provided in section 4, with the survey itself found in the Appendix. The conclusions and recommendations ensue.

2. Background

The U.S. Environmental Protection Agency (EPA) determined that agriculture is the largest U.S. source of surface water contamination and a major contributor to groundwater pollution (Napier 1983; Diebel *et al.* 1992). Water problems include bacteria salinity, sediment, pathogenic organisms, toxic material, and nutrient (nitrate) pollution. However, pesticides are considered the largest source of toxic pollution in agriculture in the U.S. (Napier 1983). EPA conducted a national survey on pesticides in drinking water wells and discovered that about 52% of community wel1s have detectable amounts of nitrate, 10% of wells contain at least one pesticide, and 7% may contain both nitrates and pesticides (Diebel et *al* 1992). The U.S. Deputy Minister of Agriculture predicted that water quality will be the leading agricultural issue of the 1990s (Gogerty, 1989); it appears this is true for the Abbotsford aquifer region.

The Abbotsford aquifer covers approximately 100 square kilometres (km) in southwestern

British Columbia and an additional 100 square km in Northwestern Washington. It is the largest of the approximately 200 aquifers in the lower Fraser River valley, and is an important source of residential, industrial and agricultural water in the region. In 1981, groundwater supplied forty-four percent of the water for the area between Surrey and Chilliwack on the south side of the Fraser River, and from Maple Ridge to the district of Kent on the north side (Dorcey and Griggs 1991, p.45). Groundwater provided almost all of the water requirements for the residents of Abbotsford, as well as a large portion of water for other uses.

The area above the aquifer is increasingly subjected to the pressures of population growth. Development in all sectors is evident, and this has increased the extent and intensity of the use of the land. On the Canadian side of the border, the trend has been towards the loss of agricultural land to urban expansion. Approximately 20% of the aquifer's surface is now covered by urban areas, with the remainder in agriculture. Aerial photographs from the Canada Land Use Monitoring Program, in addition to recent surveys by the provincial Ministry of Agriculture, Fisheries, and Food (hereafter BCMAFF), identify poultry farms, row crops (primarily raspberries), and pasture as the main agricultural activities. In recent years, there has also been an expanding greenhouse industry. About three quarters of the total area in agriculture is comprised of raspberry farms, with the remainder largely comprised of poultry farms. Because of the intensive nature of many of the Fraser Valley's agricultural production units these figures are deceiving, since there are also a large number of hog and diary farms in the region.

Land use activities on the U.S. side of the aquifer are less intensive than in Canada. Canadian land uses include dairying, raspberry, corn and potato farming, and residential development; satellite imagery reveals less cultivation, more-extensive dairying, and more forested land in the U. S. (Liebscher ***et al.*** 1992). The more intensive Canadian agricultural activity reflects the increased value of the land due to its proximity to a major urban centre and the existence of an international boundary that prevents spillover of urban expansion into the U.S. Since there is potential to develop this agricultural land for other purposes such as housing or recreation, including golf courses, farmer enterprises are more intensive to earn rates of return that are similar to those realized in other land

uses.

There are other institutional factors that also impact upon different land use intensities. These include the B.C. Agricultural Land Reserve; the land-use distorting effects of national marketing boards for eggs, broilers and milk, current and historical barriers to agricultural trade between Canada and the U. S.; and the unique characteristics of the food processing industrieson the Canadian and U.S. sides of the border.

The Abbotsford aquifer is largely unconfined, and is covered with sand and gravel deposits. These features, combined with high precipitation over the winter months, explain why effluent from land use practices readily percolates into the groundwater below. The aquifer's only water inflow is from a small underground stream on its northern end. Since large amounts of water are being tapped by the Abbotsford municipal water system and the fish hatchery on the east side of the aquifer, and because there is no regulation on well drilling on private property, the flow patterns of the aquifer are likely to be affected, and drawdown could occur if water use exceeds the refill rate. Water level drawdown will cause pollution levels to increase, and will augment any problems the aquifer currently has (Dorcey and Griggs 1991, p.25). Since the water from the aquifer flows south into the U. S., Canadian activities related to the aquifer are subject to the Boundary Waters Treaty of 1909. This treaty states that water flowing across the boundary "shall not be polluted on either side to the injury of health and property on the other side"; therefore, water quality is an international concern.

To date, nitrates and pesticides originating from agricultural land use practices have been held hugely responsible for the contaminated water (Liebscher et *aZ..* 1992). Farm practices that have been targeted as causes of groundwater pollution include exposed stockpiling of manure(Gilmour ***et aI.*** 1987; Ritter et ***al.*** 1984) and overapplication of chemical fertilizer and manure for fertilization and soil enhancement. Since less recognized pollution sources, such as septic field effluent, landfill Ieachate, leaking underground storage tanks, accidental chemical spills and airport de-icing urea formaldehyde, may also contribute to the pollution well sampling has recently been extended to include some of these (Liebscher ***et al.*** 1992; Canter and Knox 1986).

During the summer of 1993, residents who used water from the aquifer were asked to boil their drinking water due to contamination by ecoli bacteria originating with livestock wastes. While bacterial contamination is certainly a concern, a more long-term problem has been contamination of groundwater by nitrates, originating mainly with livestock wastes. Since 1955, the National Hydrology Research Institute (NHRI) and Environment Canada, along with the B.C. Ministry of Environment, Lands, and Parks (BCMOE), Agriculture Canada, the B.C. Ministry of Health, and local municipalities, have collected over 450 domestic well and piezometer samples of groundwater from the Abbotsford aquifer region. Sampling locations were on a large grid, but, initially, chemical analyses were confined to traditional inorganic constituents and the frequency with which the water was sampled was highly variable. In 1984, however, a noticeable increase in localized nitrate concentrations raised concern, and sampling was focused on the south Matsqui region where the problem appeared to be most severe (Liebscher el ***al.*** 1992). [1]

Nitrates in drinking water pose a health risk to infants, particularly those under six months of age who are on a formula based diet, rather than breastmilk (Addiscott ***et al.*** 1992). When infants consume too much nitrate they can develop a blood disorder called ***methaemoglobinaemia, also known as*** "blue-baby syndrome". In infants' digestive systems nitrate converts to nitrite, which, when in the blood, prevents hemoglobin from carrying oxygen. The infant suffers oxygen deprivation, and in severe cases may die. In those infants who already have a respiratory or intestinal infection the disease can be especially acute (Muia and Thomas 1990).

Although the majority of cases of blue baby syndrome have occurred when water concentrations exceeded 100 mg/L of nitrate (Addiscott ***et al.*** 1992), nitrogen levels as low as 10 parts per million (ppm) in drinking water have been linked to ***methaemoglobinaemia*** (Cogger and McConnell 199 1). Few cases of ***methaemoglobinaemia*** have been recorded in the United States in recent years, but many are never reported (Cogger and McConnell 1991, p.247). The long-term effect of nitrate consumption in older infants, children and adults is not known for certain at this time;

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[1] As of March 1991, regular sampling was extended to pesticides.

however, ruminant animals such as cattle and sheep can also develop the disease.

After many years of testing, a recent report by Liebscher et *aL* (1992) stated that: "Approximately 60% of the samples collected from the south Matsqui study area have nitrate-nitrogen concentrations. that exceed the 10 mg/L maximum acceptable concentration for drinking water as defined in the Health and Welfare Canada ***Canadian Drinking Water Quality Guidelines"*** (pi). Environment Canada's 1989 sampling results found 46 out of 73 sample sites with nitrogen concentrations greater than 10 mg/L. The "mean for these samples was 13.08 mg/L, with 0.0 mg/L and 41.5 mg/L as minimum and maximum concentrations detected" (Liebscher et ***al.*** 1992, p.3 5).

While a variety of human activities have had an impact on the groundwater quality of the aquifer, the primary focus in this study is nitrate contamination. Current water quality standards require that nitrate concentrations not exceed 10 mg/L, while a future government target is for them to be less than 1 mg/L. The foregoing information is used in the CVM study. Theoretical aspects of CVM are discussed in the next section, while the Abbotsford water quality survey used in this study is reported on is section 4.

3. **The Contingent Valuation Method (CVM)**

In order to measure the benefits that individuals place on improved water quality in the Abbotsford region, a contingent valuation device is employed. In this section, we first provide a theoretical framework for CVM analysis, including thereby a model for deriving willingness to pay (WTP) estimates. This is followed by a discussion of surveys and the means of eliciting contingent values. The survey instrument and results used in this study are examined in the following section.

Theoretical Model

Consumers are assumed to maximize their utility, which is a function of the amounts of market goods (x) that they consume and the quantity of the public good that is available, which, in this case,

is the quality of the water, denoted by Q. Given a choice, consumers prefer higher water quality for drinking and other consumptive purposes. The budget constraint is given by the household's income. The household's economic problem is represented by the following:

$$\begin{aligned} &Max_x\ u(x,\ Q) \\ &s.t.\ m = px, \end{aligned}$$

where m is household income, **p** is a vector of prices, and **z** is a vector of social and other factors that affect utility. The latter are dropped from the remaining analysis for convenience, but they do enter the empirical estimation. For given water quality Q^0, the household achieves utility level u_0, as indicated in Figure 1.

The indirect utility function is:

$$v(p,Q,m) = \max_x \{u(x,Q) \mid px - m = 0\} = u\{x(p,Q,m),Q\}.$$

The associated expenditure function is:

$$e(p,Q,u) = \min_x \{px \mid u(x,Q) \geq u^0\} = px(p,Q,u) = v^{-1}(p,Q,m).$$

The indirect utility function and the expenditure function are assumed continuous and twice differentiable in **p**, Q and m. The indirect utility function is non-decreasing and quasi-concave in Q; the expenditure function is non-increasing and convex in Q. Since prices remain fixed throughout the analysis, we drop price as a variable in the remaining analysis.

Hicksian compensated measures are used to evaluate welfare changes from increments or decrements in the availability of a public good, in this case increments and decrements in water quality (e.g., Boadway and Bruce 1984; Johansson 1987; Hoehn 1992). These welfare measures and the contingent valuation method that is used to elicit them are required for assessing natural resource damages and evaluation of projects (i.e., in cost-benefit analysis) (Hoehn 1992). In the case of groundwater, for example, the Hicksian compensating variation (CV) gives the maximum amount that the household is willing to pay (WTP) for an improvement in water quality from Q^0 to Q^1 (Figure 1). Likewise, the Hicksian equivalent variation (EV) is the minimum amount that the household would

be willing to accept (WTA) as compensation to forgo the improvement in water quality (Figure 1). Notice that CV assumes individuals have a right to water quality Q^0, while EV assumes they have the property right Q^1.

In this study, a contingent valuation instrument is used to elicit the respondents' WTPs; therefore, we focus on measurement of compensating variation. For household k, the compensating variation of the improvement in water quality from Q^0 to Q^1 is given by:

$$CV^k(Q^1, Q^0, m_k) = m_k - e(Q^1, v(Q^0, m_k)).$$

A Taylor series expansion about Q^0 and the mean income level, $\bar{m}$, gives the following expression for CV:

$$\begin{aligned} CV^k = {} & CV(Q^0, Q^0, \bar{m}) + (Q^1 - Q^0)\frac{\partial CV}{\partial Q} + (m_k - \bar{m})\frac{\partial CV}{\partial m} \\ & + \frac{1}{2}(Q^1 - Q^0)^2 \frac{\partial^2 CV}{\partial Q^2} + \frac{1}{2}(m_k - \bar{m})^2 \frac{\partial^2 CV}{\partial m^2} \\ & + (Q^1 - Q^0)(m_k - \bar{m})\frac{\partial^2 CV}{\partial Q \partial m} + R, \end{aligned}$$

where R refers to remaining terms. Then the willingness to pay of the kth household for the improvement in water quality can be written as:

$$\begin{aligned} WTP^k = {} & \alpha_0 + \alpha_1 \Delta Q + \alpha \Delta Q^2 + \alpha_3 (m_k - \bar{m}) + \alpha_4 (m_k - \bar{m})^2 \\ & + \alpha_5 \Delta Q (m_k - \bar{m}) + \varepsilon_k, \end{aligned}$$

where $\alpha_0 = CV(Q^0, Q^0, \bar{m}) = 0$ since the CV of no change in water quality must be zero; $\alpha_1 = \partial CV/\partial Q$; $\alpha_2 = \partial CV/\partial m$; $\alpha_3 = 1/2\ \partial^2 CV/\partial^2 Q$; $\alpha_4 = 1/2\ \partial^2 CV/\partial^2 m$; $\alpha_5 = \partial^2 CV/\partial Q \partial m$; and $\epsilon = R$. The empirical model is completed by adding social factors describing attitudes, age, household makeup and size, and so on.

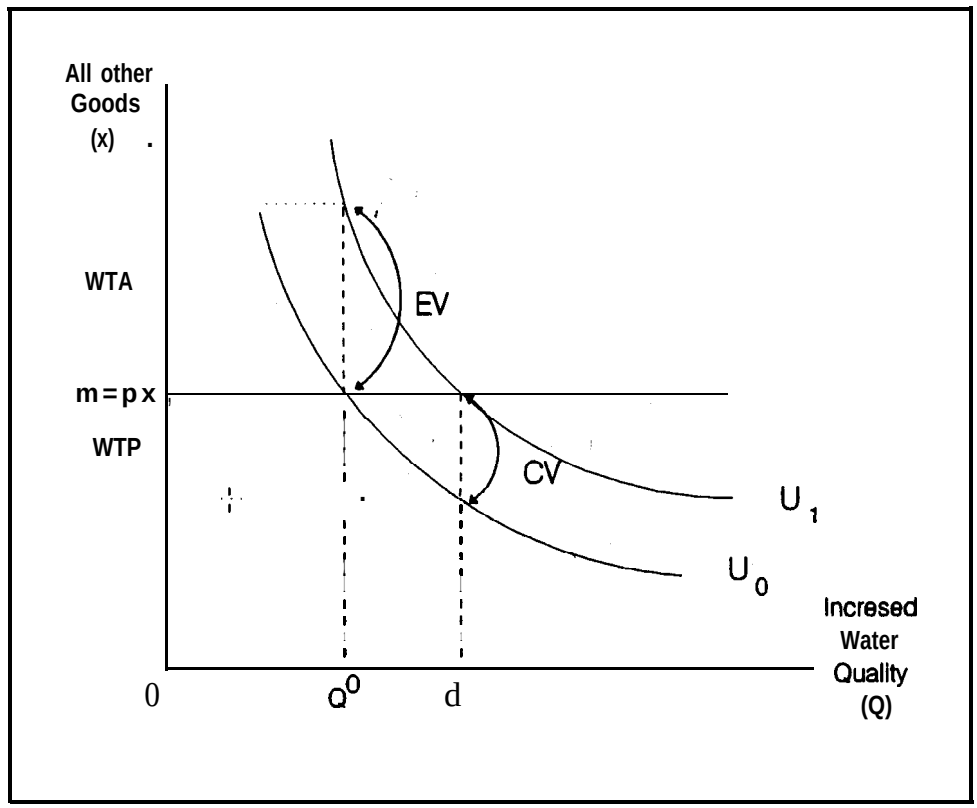

Figure 1: Welfare Measures Related to Changesin Water Quality

Designing Surveys: Asking about WTP

Data on willingness to pay for improvements in water quality are determined from contingent valuation questionnaires. Individuals are essentially asked to reveal the maximum amount they are WTP for a hypothetical change in water quality. Due to the hypothetical nature of WTP questions, it is important that surveys be appropriately designed and implemented.

McMeiken (1973) points out that researchers and bureaucrats have opinions that differ from those of the general public about what is important when accessing situations and creating policy. Therefore, survey studies are important because they indicate to scientists and politicians where research efforts should be focused. Two important issues when using surveys to determine public perception are their construction and analysis. Surveys must be designed so respondents understand the questions and feel comfortable answering candidly. Survey analysis is also crucial, since these

results are then used in policy making and further research.

Survey development is difficult It includes extensive testing and requires that certain criteria be followed. Metuchen (1 974) discusses the best survey design method, pointing out that surveys should always include return addresses, that people will only answer a survey if they feel it applies to them and that people maybe concerned with anonymity, especially if income or personal questions are asked in the survey (p. 54). He also point out, that followups should always be used, since they usually increase the response rate, thereby increasing the validity of the results (Metuchen 1974, p.69).

Another aspect of survey analysis concerns survey errors. Since survey responses are opinions, they can be influenced by different people, situations, and scenarios. Trying to reduce error as much as possible is a goal of every researcher. These authors address the types of error that can occur, and make suggestions useful for survey development. It is recommend that, even when respondents do not answer all questions, surveys should not be eliminated, but the general response of that particular class of respondent should be taken to fill in the missing information. Other concerns with contingent valuation are: strategic bias, where respondents think that they can influence the final results; design bias, where the information influences the conclusions; instrument bias, which causes respondents to provide biased answers because of the payment vehicle; and starting-point bias, where the responses are influenced by the choices given in the question.

Sundeman and Bradburn (1982) consider problems in survey analysis; they state that income is often deflated because of tax risks, or inflated to make respondents appear more wealthy (p. 18). Since our survey was mailed and returns were anonymous it is likely that there will be no problems with income being altered. Another point that the authors make is that some respondents find ranking dfficult and, therefore, only indicate their first choice (p. 164). A ranking question was included in the current survey (see Appendix) despite this concern, but it appears that it was a poor choice of methodology, because it was badly answered or often left out altogether. Sundeman and Bradbum (1982, p.249) also stated that a long question should not be followed by a short one, or it may be

overlooked; although our pretest group answered the question on gender, it is most likely survey respondents left it out because they did not see it, despite its being labelled as part of the question above it.

It is important of course to identify the group that is being targeted. Important questions that need to be considered include the following (Winnpenny 199l): Who is a user of the amenity? Who, are the gainers and losers from the proposed change? Is the sample a good representation of the user group? Variation in responses to WTP questions comes from natural variation across populations, from improper survey design, from improper population representation, and from the time of year when the survey is done (Reiling *et al.* 1990, p. 129). For example, it may have been inappropriate to survey respondents at the time of an order to boil water; likewise, groundwater is generally at its worst at the end of the summer, so this would bean inappropriate time of year to ask people about their WTP for improvements in water quality (Musser *et al.* 1992). Maddala (1983), and Sellar, Stoll and Chavas (1985), describe probit and logit models appropriate for analyzing dichotomous choice responses, while Maddala describes the Heckit model for testing for sample selectivity when zero WTP responses are excluded in the regressions.

There are different ways to setup the contingent valuation question, and there are different types of error that can be encountered with each method. With the dichotomous choice (take-it-or-leave-it or closed) model, different respondents are asked whether or not they would be willing to pay $x (with x randomly varying between respondents) for the same improvement in an environmental amenity (Winnpenny 1991; Cooper and Loomis 1992). A variant of this approach asks individuals a second question requiring them to provide an upper (if they answered yes) or lower (if no) bound on their responses. This increases the statistical accuracy of the subsequent welfare measures (Kannien 1993).

Another approach is to provide an open-ended willingness-to-pay question, where the respondent fills in the value. Research indicates that, when people are faced with this type of choice, 25% felt they could not give accurate answers while if they were given choices 9.2% felt their answer

lacked accuracy (Sellar, Stolland Chavas1985, p.165). Nonetheless, it appears that open-ended formats generate lower values of WTP than do closed formats(Kealy and Turner 1993).

A third approach is contingent ranking where a set of outcomes with different combinations of goods and payment requirements are given. The respondent identifies the most preferred combination. Measurement biases are discussed in great detail, including some which are not mentioned in other literature. These include importance bias, where the person feels the item being valued must be important; simply because a study is being done on it, and position bias, where people are affected by how a question is positioned in the survey. Important points that are mentioned about survey construction include leaving provocative questions, like those about income, until the end or people may choose not to complete the survey.

Mitchell and Carson (1989) discuss the benefits of using WTP over WTA compensation. WTA values generally decline over time and, although they are a valid welfare measure, people appear to reject the implicit property right in WTA studies. This is indicated by preposterous WTA values. WTP and WTA may vary by several orders of magnitude, although economic theory suggests that they should vary by little. This difference maybe due to difference in property rights (Knetsch 1989).

There is also an ongoing debate concerning the usefulness of CVM-derived values in the assessment of environmental darnages and, hence, cost-benefit analysis. Smith (1990, 1992), Randall (1993) and others argue that CVM values are meaningful and can safely be used in cost-benefit analysis. Others have attempted to statistically adjust CVM values by combining them with travel cost or other choice-based information (Cameron 1992a, 1992b). But others have recently argued that values obtained from contingent valuation devices have no economic meaning and cannot be used in cost-benefit analysis (Desvousges et *al.* 1993; Cambridge Economics 1992; Kahneman and Knetsch 1992a 1992b; Editors of the Harvard Law Review 1992). This debate is ongoing and is not entered into here.

As mentioned above, one check on CVM responses is to use other measures of welfare in addition to WTP. In this study, we employ defense expenditures (purchases of bottled water and water filtration systems) as a lower bound on the WTP estimates. In order to be meaningful, WTP responses must exceed respondents' defense expenditures. We also employ the results of fuzzy pairwise comparisons to WTP in order to obtain a better feel for the range of values obtained from the contingent valuation model. Respondents were asked to provide information on purchases of bottled water and were also asked to make fuzzy comparisons among four items. Defense expenditures and fuzzy pairwise comparisons are discussed in greater detail below.

4. **Abbotsford Water Quality Survey**

A survey of residents in the Abbotsford region was conducted during May 1993. The survey was be sent to 343 households, with 18 returned as undeliverable. Similar studies in the region have had survey response rates of between 30.45%, with the majority of the surveys being returned by people of higher education levels. Reminder notices were sent to all those in the sample approximately 3 weeks after the first mailouts. Eighty-nine completed surveys were returned, providing a response rate of 27.4% for deliverable surveys. This is an adequate return rate for analytical purposes. Since groundwater problems have been highly publicized and have received extensive media attention above average returns were expected. However, the below average return rates can be explained because the same methods of phoning and reminding respondents that have been used in other survey work could not be used due to the UBC Ethical Review process--mailouts and returns had to be kept completely confidential and "harassment" via repeated follow-up would not be permitted. Funding limitations prevented the use of an outside consultant to conduct the survey, as is now done with most CVM surveys.

The main objective of the survey was to elicit respondents' willingness-to-pay for improvements in water quality. In addition, respondents were asked about purchases of bottled water, in-home water filtration systems, and, their WTPS for preserving agricultural land and

preventing golf course development on agricultural land. In addition, respondents provided background and personal information likert-scale responsesto opinion questions, andrevealed their preferences for four items using fuzzy pairwise comparisons (discussed below). Not all sections of thesurvey were analyzed forthis study. Acopyofthe questionnaire isprovided inthe Appendix.

Thesurvey instrument waspretested onagroup of2Ostudents. As a result, questions related. to bottled water, in-house water falters, and water's quality attributes were amended for better clarity. Minor re-wording of other questions also occurred.

Summary of Survey Data

A summary of the personal and background information is found in Table 1. On average, respondents were 41.3 years old and had an average education level of one year of post-secondary education, which is reasonably close to the Statistics Canada 1986 average education level of just over 12 years. Hence, it can be assumed that there is no educational bias between respondents and the general populace in the study region. Statistics Canada's 1991 census indicates that average family size in the region is 2.9, which corresponds with the average of 3.0 for the current survey.[2] There was an average of only 0.385 children under age five, which is understandable considering the average age of respondents.

Respondents have lived in their homes for an average of 7.0 years and in the area for 15.2 years, so they should be aware of water quality issues. Also 89.2 % of respondents own their homes, and 13. 8% have land in the Agricultural Land Reserve (ALR). If these owners have a farm enterprise, their views towards agricultural pollution and water quality maybe affected by the fact that they own farmland. Hence, this variable is included in the WTP model below.

According to the 1986 census, average household income in the study region was $46,493 in 1992 dollars, which is not too different from the average household income of survey respondents--

[2]0nly some census data are available for 1991. Where possible, 1991 data is used; otherwise we rely on 1986 census data.

approximately $44,620.[3] Respondents average monthly rent or mortgage payment was $600 (assuming owners paid some property taxes).

Two scaled scores were constructed from the opinion questions. Because perceptions regarding externality might be important to individual behaviour or their willingness-to-pay, opinion questions 2 and 10 were combined into a single scaled score. The scaled score takes on a value of 1 when externality from farm operations is perceived to be at its highest, and a score of zero at its lowest. Likewise, the opinion question regarding belief about water quality was scaled to take on values between O and 1. The averages for these scaled scores are also provided in Table 1, and these indicate that there is greater concern over water quality than general farming externalities.

Questions pertaining to residential sewage and septic systems were included along with those on water quality; a summary of responses is provided in Table 2. Sewage disposal questions are important because poorly maintained septic fields are believed to contribute to aquifer nitrogen-nitrate pollution. Of respondents, 40.6% indicated that they have a septic system, while the remainder believed they were connected to municipal sewers. (One respondent admitted that they did' not know what type of sewer system they had.) Of those who knew they had a septic system, only 55 .2% had cleaned their system within the last four years (as required), 10.3°/0 cleaned it in the last 5-10 years, 3.5% had not cleaned their system in 10 years, 20.7% did not know when their system had last been cleaned, and 10.4°% had never cleaned their system. In conclusion, only one-half to three-quarters of respondents who own a septic system maintain it according to acceptable practices.

Water titration systems and water bottle purchases are indicative not only of a minimum WTP for improved water quality, but also perceived water quality. Of respondents, 37% had purchased bottled water within the last year, and 27% owned some type of water purification filter. This indicates that there is some concern over local water quality, but it is generally not considered to be a serious problem. Respondents paid an average of $69.59/year on defensive expenditures.

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[3] The 1986 income ($35,572) was converted to a 1992 basis using the index for average hourly earnings.

Table 1: Summary of Personal and Background Information

Item	Mean	Coefficient of Variation
Age of respondents	41.3 years	43.5%
Female respondents	27.6%	163.5
Family size	3.0	44.5
Number of children under five	0.385	182.1
Own their homes	89.2%	35.0
Length of time living in neighbourhood	15.2 years	91.8
Length of time living in current home	7.0 years	107.4
Education	13.14 years	19.3
Household income	$44,620	61.1
Scaled scores:		
- Concern about water quality	0.5371	61.5
- Concern over externality from farming	0.3516	85.0

Table 2: Water Quality and Sewer Maintenance

Item	Mean	Coefficient of Variation
Respondents with septic system	**40.63%**	121.8%
Length of time since septic system last cleaned	approx. 8 yrs	49.5
Perceived water source	municipal-don't know	46.1
Respondents using bottled water or filters	36.9%	131.7

Willingness-to-Pay for Improved Water Quality

The WTP model for improved water quality was developed in an earlier section. Respondents were not asked to provide their WTP in an open-ended format, but, rather, were asked to identify their location on the supply curve for water quality (see Appendix). The average WTP for all respondents was $63. 86/year, and it was $70.85/year for those who indicated that they were on groundwater or did not know whether they were on groundwater. However, because the supply tune was presented to respondents, it was not possible to include quantity--the measure of water quality--in the regression. However, income and income squared were included in the ordinary least squares (OLS) regression as required by the economic theory. Socioeconomic variables (such as education and age) were also included in the regression as was the scaled opinion question regarding water quality. The regression results are provided in Table 3.

The estimated regression equations were used to predict possible values for willingness to pay. These indicate that those with land in the ALR are willing to pay more than those owning no agricultural land, perhaps because they see themselves as contributing to nitrogen-nitrate pollution. WTP ranges from about $78 to $90 per year for those without land in the ALR and $114-125/year for those with land in the ALR (ignoring regression A3). These values are generally higher than the average stated WTPS, except for regression A3 (where predicted WTP was less than statedWTP).

Fuzzy Pairwise Comparisons

Fuzzy logic is increasingly used to control everything from washing machines to cement kilns and subway systems (Klir and Folger 1988; Kosko 1992; Kosko and Isaka 1993), to aggregate communities for regional analysis (Harris, Stoddard and Bezdek 1993), to determine planting strategies in agriculture (Flick and van Kooten 1993), and so on. While the use of fuzzy logic has had a slow start in North America, it has recently started to become more popular as a result of success by the Japanese in developing products that use this technology. In the current research, fuzzy pairwise comparisons are used to determine the value of water quality to respondents in the Abbotsford region.

Table 3: Regression Analysis of Willingness-to-Pay for Improved Water Quality

	WTP of all respondents			WTP of those on ground-water or who do not know their water source		
Item /Model	A1	A2	A3	WI	W2	W3
Income	5.56 (1.22)	8.64 (2.50)		1.3205 (0.24)	4.1962 (1.06)	
Square of Income	1.53 (1.04)		2.69 (2.41)	1.335 (0.81)		1.61 (1.32)
Belief about water quality	-31.73 (-1.39)	-28.2 (-1.25)	-35.34 (-1.56)	-67.66 (-2.34)	-66.73 (-2.32)	-68.61 (-2.43)
Own ALR land	24.10 (1.15)	25.81 (1.23)	-24.65 (1.17)	42.53 (1.71)	44.98 (1.84)	42.66 (1.74)
Constant	69.37 (4.76)	73.94 (5.31)	66.32 (4.60)	96.19 (4.70)	101.80 (5.315)	95.57 (4.77)
R*	0.1646	0.1480	0.1418	0.2287	0.2142	0.2274
Predicted **WTP ($/yr)**:						
if ALR land	114.38	114.71	55.35	123.19	125.56	120.93
no ALR land	90.28	88.90	80.00	80.66	80.58	78.27

*Where A regressions include all the respondents independent of their water source, and W regressions include only those who do not know their water source, or who know they are using well water.

Fuzzy pairwise comparisons were first used by van Kooten, Schoney and Hayward (1986) to study farmers' goal heirarchies for use in multiple-objective decision making. As noted by these authors, the fuzzy pairwise method results in a ratio scale (p.43) that can then be used to value nonmarket goods and services if one of the items in the set is traded in the marketplace. Fuzzy pairwise comparisons require that all items to be ordered are compared in pairwise fashion; thus, there are n(n- 1)/2 pairwise comparisons that need to be made.

A measure of the intensity of preference between two items, A and B, is made by marking on a line, with endpoints denoted A and B, the degree of preference for one over the other; a mark placed at the centre of the line indicates indifference. A measure of the intensity of the preference of item A over item B is determined by measuring the distance from the left-hand-side endpoint (where A is assumed to be located) to the respondent's mark, where the line is of unit length (at least after normalization). Denote this distance by r_{AB}. If $r_{AB} < 0.5$, then A is preferred to B; if $r_{AB} > 0.5$, then B is preferred to A; and if $r_{AB} = 0.5$, A is equally preferred to B. of course, $r_{AB} = 1 - r_{BA}$.

Van Kooten, Schoney and Hayward (1986) develop a measure indicating the intensity of preference of one item over another. Once all of the pairwise measures r_{ij} are obtained, the measure of intensity for the item is determined as:

$$m_j = 1 - \left(\frac{\sum_{i=1}^{k} r_{ij}}{k-1} \right)^2,$$

where the numerator in the second term on the right-hand-side of the equation is the Euclidean norm and the denominator, $(k-1)^{1/2}$, is its maximum value; k is the number of items that are ranked by the fuzzy pairwise comparison. Finally, suppose we obtain the following measures: $m_A = 0.2$; $m_B = 0.6$; $m_C = 0.3$; and $m_D = 0.75$. Further suppose that item C is valued at $100. Then, by independence of irrelevant alternatives (one's preference of an orange over an apple does not depend on whether or not one has to determine preference of an orange or apple over a grapefruit), item C is valued at $250 ($100 x 0.75/0.3).

In the questionnaire, respondents were asked to make fuzzy paired comparisons over the following four items:

1. reducing one'commuting time to work byone-half,
2. improving the availability and quality of one's drinking water,
3. preventing the development of a golf course on agricultural land, and
4. a 33-inch, split-screen, stereo colour television set with remote control.

For the 40th respondent, for example, the following matrix of normalized distances was constructed

Item	1	2	3	4
1	0	0.2121	0.9697	0.1212
2	0.7879	0	0.5606	0.4242
3	0.0303	0.4394	0	0.3485
4	0.8788	0.5758	0.6515	0

The matrix indicates that 1P2, 1P4, 2P4, 3P1, 3P2 and 3P4, where P denbtes "preferred to". Using the above formula the preference intensity scores areas follows: m1=0.4227, m2=0.3904, m3=0.6757 and m4=0.2863. This individual ranked "preventing development of a golf course on agricultural land" highest, followed, in order, by a reduction in commuting time, improved water quality, and the colour television. He or she also valued improved water quality 1.36 times (0.3904/0.2863) as much as the television set.

The average scores of all respondents for these items, and their coefficients of variation, are provided in Table 4. These indicate that the respondents ranked the four items presented them in the following order: improved water quality, halving commuting time, preventing golf course development on agricultural land, and the television. Improved availability or quality of drinking water was considered to be 2.1 times more important than the television by the group as a whole.

Table 4: Intensity of Preference for Fuzzy Pairwise Ranked Items

Item	Mean	Coefficient of Variation
Halve commuting time	0.4605	32.1%
Improve "water quality	0.6528	24.1
Prevent golf course development	0.4395	39.9
33" colour television	0.3026	41.1

The value of the television varies according to brand and where it is purchased, with prices ranging from about $900 to almost $2,000, but it is perceived prices that are important. Upon asking a number of individuals about their perception of price, we found that their average price for such an item was about $1,3 50; answers of less than $1,000 were common. Hence, we employ values of $1,350 and $900, and annualize these simply by dividing by 10--the approximate useful life of a T.V. The subsequent values are then multiplied by 2.1 to obtain an estimate of the value of improved water quality based on fuzzy pairwise comparisons. This provides an estimate of approximately $189-$280/year for water quality improvements.

The fuzzy scores for the four items in Table 4 were regressed on a number of explanatory variables using seemingly unrelated regression, which is the same as independent OLS regression using the same regressors. The explanatory variables used in the regressions were the scaled attitudinal scores, education, income, whether or not the respondent had land in the ALR whether or not the respondent owned their place of residence, and time spent commuting. The regression results are presented in Table 5. Using these results, the predicted fuzzy scores for each of the items were calculated depending on whether or not the respondent owns land in the ALR and their place of residence. The predicted preference intensities are provided in the bottom rows of the Table.

Table 5: Regression Analysis for Intensity of Preferences and Predicted Intensities

Item/Fuzzy Score	Halve Commute Time	Improve Water Quality	Prevent Golf Course Develop.	33" TV
Income	-0.0176 (-1 .66)	-0.0182 (-1.65)	-0.0128 (-1 .06)	0.0148 (1.51)
Dummy=l if own land in ALR	0.1787 (2.67)	0:0164 (0.14)	-0.2142 (-2.88)	.-0.0700 (-1.14)
Dummy=l if own place of residence	0.0707 (1.08)	-0.0787 (-1.16)	0.0163 (0.21)	0.0277 (0.45)
Quality score	-0.0536 (-0.84)	,-0.2138 (-3.24)	0.2525 (3.48)	0.0671 (1.14)
Externality score	0.0246 (0.36)	0.1447 (2.07)	-0.1916 (-2.46)	-0.0060 (-0.09)
Open space score	-0.0992 (-1.04)	-0.0377 (-0.38)	0.0725 (0.66)	-0.0481 (-0.54)
Time spent commuting	-0.0620 (0.94)	-0.0110 (-1.61)	0.0071 (0.95)	-0.0036 (-0.59)
Education	0.0256 (2.86)	-0.0082 (-0.89)	0.0018 (0.17)	-0.0230 (-2.78)
Constant	0.1247 (0.82)	0.9083 (6.03)	0.2637 (1.59)	0.5979 (4.47)
R2	0.3658	0.3981	0.4416	0.269
Predicted Scores ALR land own residence				
1 1	0.2710	0.5198	0.2088	0.2831
1 0	0.2003	0.5985	0.1925	0.2554
0 1	0.0923	0.5034	0.4230	0.3531
0 0	0.0216	0.5821	0.4067	0.3254

From the predicted preference intensities for the ranked items, it is possible to calculate respondents' intensity of preference for water quality relative to the 33" color television. These depend on ownership of land in the ALR and ownership of their residence. Those owning both land and their residence valued improvements in water quality by a factor of 1.836 over the television, or about $248/year. Those who owned their place of residence by did not own land in the ALR valued improvements in water quality at $193/year, while those who owned no property whatsoever valued* it at $242/year.[4] If individuals perceive the price of the television to be lower than $1,350, say only $900, then improvements in water quality are valued at $165, $128 and $161, respectively. In general, improvements in water quality are valued higher by those with ALR land, as was the case for WTP.

In conclusion, the fuzzy pairwise comparison approach provides an estimate of $128-$284 per year for improvements in water quality in the Abbotsford region.

Defense Expenditures

A third method was used to determine the accuracy of the WTP measure. Respondents were asked to complete a table indicating the brands and amounts of bottled water purchased in the previous month (April 1993), as well as to indicate the brand of any water filter they might own. Some respondents did not answer this question although they indicated that they did purchase bottled water or own a filter; in addition, taxes on purchases of bottled water or water filters were not included in the analysis. As a result, the true stated defense expenditure is likely underestimated. Further, since some respondents purchased only small bottles of water, they can be excluded from the defense expenditure calculation, since this appears to indicate that they do not perceive their residential water quality to be a problem, but rather would purchase this water anyway, despite improvements in the aquifer's water quality. Finally, since filters are often permanent and have little or no maintenance requirements, a 25-year life was assumed unless the manufacturer indicated otherwise.

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[4]The other case was not included because there were no respondents who had land in the ALR and did not also own their place of residence.

Sixty-two of the 89 respondents to the Abbotsford survey are on ground water, and these are the only ones considered in the determination of defense expenditures. The calculations indicate that respondents paid an average of $69.59/year (with standard deviation of $ 147.47) to avoid using well water (drawn from the aquifer) for drinking purposes. As expected, this is less than their stated WTP, as determined above. A regression of defense expenditures on income and family size is provided in Table 6. It indicates that households may have been more willing to purchase bottled water or water filters as the number of individuals affected by poor water quality increased. Household income levels do not appear to affect purchases, however.

In conclusion defense expenditures of about $70/year serve as a lower bound estimate of the benefits of improved water quality.

Table 6: Regression Analysis of Defense Expenditures in the Abbotsford Region of B.C.

Item	Estimated Coefficient	t-statistic
Constant	15.619	0.207
Income	9.935	0.629
Income squared	-8.629	-1.872
Household size	35.049	1.688
R’	0.1489	

5. Summary and Conclusions

In 1991, there were 29,840 private households in the Central Valley Regional District. In drawing our random sample, 90 out of 343 households (or 26.24%) were in regions where groundwater was used for drinking purposes, while 62 out of 89 respondents (69.66%) indicated that they were on groundwater. Hence, some 18.28% of households, or about 5,500, in the Central Valley Regional District are on groundwater. For comparison, according to the latest Census, the

1991 population of the District of Abbotsford was 18,864. Almost all residents in the District are on groundwater. Assuming 3 individuals per household, then some 6,300 households are on groundwater. Multiplying the number of households by defense expenditures of $70/year per households results in a lower bound estimate of the benefits of improved water quality of $0.44 million. This number is very close to the average stated WTP of $70.85 per household ($0.45 million). However, based on WTP estimates from Table 3 of $78-$90/year per household, the estimate of benefits is somewhat higher--$0.49-$0.57 million. If WTP estimates for those who own ALR land are used ($ 114-$ 125/year), then the benefits of improved water quality are $0.72-$079 million. Finally, using the results from the fuzzy pairwise comparisons gives benefits of $128-$284/year per household. The total benefits of improved water quality would then be $0.81-$1.79 million.

The contingent valuation approach was used in this study to estimate the off-fro benefits from improved water quality arising from a reduction in the level of improper disposal of livestock wastes. However, the use of CVM in cost-benefit analysis has been questioned by a number of researchers (e.g., Kahnemann and Knetsch 1992a 1992b; Cambridge Economics 1992). The design of the survey used in this study could likely be improved upon, as indicated by the low response rate. In this regard, a telephone survey of more than 100 households has been implemented (see Athwal 1994). This research will provide a useful check on the conclusions reached here, although preliminary results indicate that the externality benefits are similar to those indicated here.

Finally, Knetsch (1993) argues that individuals' stated willingness to pay for improvements in environmental quality are are likely to be under-estimate the true value of such changes. This is shown by the large disparity between WTP and willingness to accept compensation (WTA). While WTP is the welfare measure of choice in questionnaires, WTA compensation is often much higher in situations where some risk is involved. Partial support for this conclusion comes from the estimates of water quality improvements obtained in this study using fuzzy pairwise comparisons. In that case, the benefits of improved water quality in the Abbotsford region amount to $1.8 million per year. It is clear that further research into these issues and into improved survey design is required.

References

Addiscott, T.M., A.P. Whitmore, and D.S. Powlson, 1992. ***Farming, Fertilizers, and the Nitrate Problem.*** Wallingford, U. K.: CAB International.

Agriculture Canada, 1990. ***Groundwater--Nature's Hidden Treasure.*** Factsheet #5: Water.

Agriculture Canada, 1987. ***An Evaluation of Nitrogen Use in British Columbia Agriculture.*** Research Branch Technical Bulletin 1987-3E.

Athwal, IL K., 1994. ***Costs and Benefits of Improving Water Quality by Comporting Livestock Wastes. A Contingent Valuation Approach.*** Unpublished M. SC. Thesis, Dep. of Agricultural Economics. Vancouver: Univ. of B.C. (In progress)

B.C. Environment, 1991. ***British Columbia's Planning for the Future Sustaining the Water Resource.*** Victoria B. C.: British Columbia Water Management Division.

Beardie, D.R. and J.F. Anderson, 1974. ***Questionnaires, Design and Use.*** Metuchen, New Jersey: The Scarecrow Press Inc.

Boadway, R.W. and N. Bruce, 1984. ***Welfare Economics.*** Oxfordshire, New York: Basil BlackWell.

Cambridge Economics, 1992. ***Contingent Valuation: A Critical Assessment.*** Washington, DC: Cambridge Economics, Inc.

Cameron T. A., 1992a. "Nonuser Resource Values", ***American Journal of Agricultural Economics 74(Dec):*** 1133-37.

Cameron, T. A., 1992b. "Combining Contingent Valuation and Travel Cost Data for the Valuation of Non-Market Goods", ***Land Economics 68(3): 302-17.***

Canter, L. W. and R.C. Knox, 1986. ***Septic Tank Systems Effects on Ground Water Quality.*** Chelsea, Michigan: Lewis Publishers.

Cummings, R. G., D. S. Brookshire and W.D. Schulze (editors), 1986. ***Valuing Environmental Goods: An Assessment of the Contingent Valuation Method.*** Totowa, H. J.: Rowman and Allanheld.

Desvousges, W. H., A!R. Gable, R.W. Dunford and S.P. Hudson, 1993. "Contingent Valuation: The Wrong Tool to Measure Paasive-Use Losses", ***Choices*** (2nd Q): 9-11.

Editors of the Harvard Law Review, 1992. "Ask a Silly Question...: Contingent Valuation of Natural Resource Damages", ***Harvard Law Review*** 105(June): 1981-2000.

Cogger, C.G. and C. McConnell, 1991. ***Clean Water for Washington: Why the Concern about Agricultural Contamination in Groundwater?.*** Washington State University, Cooperative Extension Publication #EB 1632. August.

Cooper, J. and J. Loomis, 1993. "Sensitivity of Willingness-to-Pay Estimates to Bid Design in Dichotomous Choice Contingent Valuation Models", ***Land Economics 68:211-224.***

Crippen Consultants, 1990. ***Municipal Water Supply Issues in British Columbia.*** Victoria: B. C., Round Table on the Environment and the Economy.

Day, J.C. and J.A. Affum 1990. ***Towards Sustainable Water Planning and Management in British Columbia.*** Victoria: B.C. Round Table on the Environment and the Economy.

Diebel, P. L., D.B. Taylor, S.S. Battie, and C.D. Heatwoll, 1992. ***Tradeoffs Between Water Quality and the Economic Impact of Low-Input Agriculture in the CostalPlain of Virginia.*** Working Paper #92- 12. Manhattan: Kansas State University.

Dorcey, A.H.J. and J.R. Griggs, 1991. ***Water in Sustainable Development. Exploring our Common Future in the Fraser River Basin.*** Vancouver: Westwater Research Institute, Univ. of B. C..

Easter, W.K , 1991. ***Differences in the Transaction Costs of Strategies to Control Agricultural Chemical Offsite and Undersite Damages.*** St. Paul, Minnesota: University of Minnesota Press.

Federal-Provincial Working Group on Drinking Water, 1978. ***Guidelines for Canadian Drinking Water Quality.*** Hull, PQ: Canadian Government Publishing Centre.

Flick, R. and G.C. van Kooten 1993. "Modelling Management of Agricultural Ecosystems using Fuzzy Set Theory: Methodological Issues". In ***Papers of the 1993 Annual Meeting: Edmonton, July 11-14, 1993*** edited by Harry W. Ayer. Tuscon AZ: Western Agricultural Economics Association. pp.263-269.

Gerking S., M. DeHaan, and W. Schulze, 1988. "The Marginal Value of Job Safety: A Contingent Valuation Study", ***Journal of Risk& Uncertainty*** 1:185-199

Gogerty, R., 1989. "Farming To Keep Groundwater Clean". In The ***Furrow*** February, pp. 11-13.

Gram, G.D., 1990. "Water Use, Farm Management and the Protection of the Aquatic Environment." In ***Farm and Stream.*** Victoria: B.C. Federation of Agriculture Interdepartmental Coordinating Sub-committee.

Harris, T. R., S.W. Stoddard and J.C. Bezdek, 1993. "Application of Fuzzy-Set Clustering for Regional Topologies", ***Growth and Change*** 24(Spring): 155-65.

Hoehn, J.P., 1992. "Natural Resource Damage Assessment and Contingent Valuation: Issues and Research Needs". Staff Paper No. 92-36. East Lansing, Michigan: Department of Agricultural Economics, Michigan State University.

Johansson, P. O., 1987. The ***Economic Theory and Measurement of Environmental Benefits.*** Cambridge: Cambridge University Press.

Kannien, B. J., 1993. "Optimal Experimental Design for Double-Bounded Dichotomous Choice Contingent Valuation", ***Lund Economics 69:138-146.***

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

Kahneman, D. and J.L. Knetsch, 1992b. "Contingent Valuation and the Value of Public Goods: Reply", ***Journal of Environmental Economics and Management 22:90-94.***

Kealy, H.J. and R. W. Turner, 1993. "A Test of the Equality of Close-Ended and Open-Ended Contingent Valuations", ***American Journal of Agricultural Economics 75:321-31.***

Klir, G. and T. Folger, 1988. ***Fuzzy Sets, Uncertainty, and Information.*** Englewood Cliffs, New Jersey: Prentice Hall.

Knetsch, J., 1989. "The Endowment Effect and Evidence of Nonreversible Indifference Curves", ***Amercian Economic Review*** 79(December): 1277-84.

Knetsch, Jack L., 1993. "Resource Economics: Persisten Conventions and Contrary Evidence". Chap. 13 in ***Forestry and the Environment: Economic Perspectives*** edited by W.L. Adamowicz W. White and W.E, Phillips. Wallingford, UK: CAB International. pp.25 1-61.

Kosko, B., 1992. ***Neural Networks and Fuzzy Systems.*** Englewood Cliffs, NJ: Prentice Hall.

Kosko, B. and S. Isaka, 1993. "Fuzzy Logic", ***Scientific American 269(1*** July): 76-81.

Liebscher, H. B. Hii and D. McNaughton, 1992. ***Nitrates and Pesticides in the Abbotsford Aquifer.*** Environment Canada. July.

Maddala G. S., 1983. ***Limited-Dependent and Qualititative Variables in Econometrics.*** Cambridge: Cambridge University Press.

McMeiken E.J., 1973. ***Public Health Professionals and the Environment: A Study of Perceptions and attitudes.*** Ottawa: Inland Water Directorate, Water Planning and Water Management Branch.

Ministry of Environment & Parks, 1986. ***Principles for Preparing Water Quality Objectives in B. C.*** Victoria: Water Management Branch.

Muia M.J. and M.P. Thomas, 1990. "A Question of Nitrates", Environmental Education and ***Information* 9:91-100.**

Musser, W. N., L.M. Musser, A.S. Laughland and J.S. Shortle, 1992. ***Contingent Valuation and Averting Costs Estimates of Benefits for Public Water Decisions in a Small Community.*** Agric. Econ. & Rural Sociology #238. University Park, PA: Pennsylvania State Univ., November.

Randall, A., 1993. "Passive-Use Values and Contingent Valuation--Valid for Damage Assessment", ***Choices*** (2nd Q): 9-1'1.

Reiling, S. D., K.J. Boyle, M.L. Phillips and M. W. Anderson, 1990. "Temporal Reliability of Contingent Values", ***Land Economics 66(2): 128-34.***

Sellar, C., J.R. Stoll, and J.P. Chavas, 1985. "Valuation of Empirical Measures of Welfare Change: A Comparison of Nonmarket Techniques", ***Land Economics 61:156-175.***

Smith, V. K., 1992. "Arbitrary Values, Good Causes, and Premature Verdicts", ***Journal of Environmental Economics and Management 22:71-89.***

Smith V.K., 1990. "Can We Measure the Economic Value of Environmental Amenities?", ***Southern Journal of Economics 56(April): 865-78.***

Sundeman, S. and N. Bradbum, 1992. ***Asking Questions*** San Francisco: Jossey-Bass.

van Kooten, G. C., R.A. Schoney and K.A. Hayward, 1986. "An Alternative Approach to the Evaluation of Goal Hierarchies among Farmers", ***Western Journal of Agricultural Economics*** 11:40-49.

Winpenny, J. T., 1991. ***Values for the Environment. A Guide to Economic Appraisal.*** London: Overseas Development Institute.

March 31, 1993

Dear Sir/Madam:

The Department of Agricultural Economics at the University of British Columbia is studying conflicts in the urban-rural fringe. We are hoping that you will contribute to apart of this research by completing the enclosed questionnaire, which takes about 15 minutes to complete.

The questionnaire deals with transportation open space, preservation of agricultural land and water quality in the lower mainland region. We are attempting to gain insights into how citizens perceive conflicts among different objectives, and their willingness to accept higher or lower levels of public goods and services (e.g., more or less open space). We ask several questions of a more personal nature, such as what income category your household falls in and what you are willing to pay for various levels of public goods and services. However, we assure you that your replies will be kept in strict confidence. We hope that you answer all of the questions because our economic models require this information and our conclusions are weakened without it. Your views are also lessened when questions are left unanswered.

Background information is provided on the first page of the survey, but the questionnaire can be completed without this information.

There are no right or wrong answers; we are only interested in your views, and these will be kept confidential.

Thank you in advance for you cooperation

Sincerely yours,

Rita Athwal/Anke Hauser/Julie McAuley
Research Assistant

SURVEY
Decisions for the Future: Agricultural Land Presentation and Waste Disposal in the Lower Mainland

Preserving Agricultural Land

The government of British Columbia created the Agricultural Land Reserve (ALR) in 1973 in order to preserve agricultural land for future generations. However, in certain areas of the province, particularly the lower mainland, population growth has put increasing pressure on these lands. Consequently, some lands have been removed from the ALR for urban development and for recreation (e.g., golf courses). Farmers have complained that urban encroachment and the rules of the ALR prevent them from having viable farming operations in some cases (e.g., fields are fragmented and there are problems of vandalism). Urban residents might feel that the ALR contributes to higher property values by restricting the availability of building lots. Thus, commuting times increase (as citizens move further from their work to find affordable housing) and living standards are lowered. Others would argue to the contrary, indicating that preservation of agricultural land leads to a better environment. One thing is clear, however it is not possible to achieve abetter environment without some sacrifices. The amount to be sacrificed depends upon urban housing densities, whether or not golf courses are permitted, whether preservation of wildlife habitat on private farmland is an objective, etc.

Water Quality and Agricultural Wastes

The main water quality issue in the Greater Vancouver Regional District (GVRD) appears to be one of turbidity (murky water). Some believe that this is due to logging in the water shed from which the GVRD obtains its water; others dispute this. However, faced with this problem, as well as water shortages due to drought, the GVRD intends to improve water purification, including the development of additional sources of water. Home owners can expect a increase of 35% on their water bills. This is in addition to added charges to upgrade sewage treatment (an increase of 6470 on sewage bills is expected). Rents w-ill also rise to reflect these increases.

The water quality problem in the Central Fraser Valley Regional District is related to agricultural wastes. Water users rely primarily on water from underground aquifers that have become contaminated with nitrogen/nitrates and pesticides (e.g., 1,2,2 tichloroprpoane used to kill a worm-lie creature that attacks raspberries) in underground water reservoirs. Scientists believe that animal wastes are the major contributor to pollution in the Abbotsford region for example. Each day some 2,500 tomes of waste need to be disposed of. Comporting is the most benign method for disposing of wastes, but it costs about $20/tonne.

It should be noted that water quality is not so low that it constitutes a health threat. Scientists only suggest that we need to be careful and that it is possible to do better than currently.

Section 1: Opinion Questions

Please indicate your agreement or disagreement with respect to each of the following statements. (Please circle the number that best represents your response to the statement indicated).

	Strongly Agree				Strongly Disagree	No Opinion
There is a need to preserve open space in British Columbia	5	4'	3	2	1	0
Smell and other farm nuisances are a problem	5	4	3	2	1	0
Water quality in my area is adequate	5	4	3	2	1	0
Government needs to impose strong regulations on fertilizer use and handling of livestock wastes, regardless of cost to farmers	5	4	3	2	1	0
Agricultural land needs to be preserved to ensure future supplies of food	5	4	3	2	1	0
Constructing golf courses on agricultural land constitutes wise economic use of such land	5	4	3	2	1	0
Preserving agricultural land increases residential property values	5	4	3	2	1	0
The Agricultural Iand Reserve is effective in preserving agricultural land	5	4	3	2	1	0
Open space should never be sacrificed for urban development	5	4	3	2	1	0
Air and water pollution from farming lower residential property values	5	4	3	2	1	0

Please indicate your preference for each of the paired items listed by placing an X on the line between them. For example, the following indicates that item B is somewhat preferred to A.

Item A	Indifferent _____|x_____	Item B

For the following, please mark the line with an X to indicate your preference.

Half my Commute Time to Work	Indifferent _____|_____	Item B
Item A	Indifferent _____|_____	Item B
Prevent golf course on Agricultural Land	Indifferent _____|_____	Half my Commute Time to Work
54", Split-Screen, Stereo Television	Indifferent _____|_____	Half my Commute Time to Work
Item A	Indifferent _____|_____	Prevent golf Course on Agricultural Land
Item A	Indifferent _____|_____	Item B

Section 2: Background Information

1. (a) How long have you lived in this area? _____ years

   (b) How long have you lived in your current residence? _____ years

2. Do you own land in the Agricultural Land Reserve (ALR)? (Please circle one)

   YES NO

If YES: How many acres do you own in the ALR? _____ acres

What is its approximate, current value? $ _____

How much money do you think you would gain if the land was taken out of the ALR? $ _____

3. Do you rent or own your current place of residence? (Please circle one)

   rent own

4. What is your monthly rent <u>or</u> mortgage payment (including taxes)?

____ less than $500 ____ $500 to $750 ____ $750 to $1,000

____ $1,000 to $1,250 ____ $1,250 to $1,500 ____ $1,500 to $1,750

____ $1,750 to $2,000 ____ $2,000 to $2,2500 ____ more than $2,250

5. Suppose the government decided to permit various forms of development to occur on the Agricultural Land Reserve.

(a) Would you be willing to pay $ _____ per month in added rent or mortgage payments to prevent ALR land from being developed for residential housing?

YES NO

(b) Would you be willing to pay $ _____ per month in added rent or mortgage payments to prevent ALR land from being developed as golf courses?

YES NO

If you work outside the home, please answer the following.
Otherwise proceed to the next page.

6. How much time do you spend commuting to your place of employment each day? (Please check one)

____ less than 5 minutes ____ 15 to 20 minutes ____ 30 to 40 minutes

____ 5 to 10 minutes ____ 20 to 25 minutes ____ 40 to 50 minutes

____ 10 to 15 minutes ____ 25 to 30 minutes ____ over 50 minutes

How long is your commute? (Please check one)

____ less than 10 kms. ____ more than 10 but less than 20 kms.

____ more than 20 but less than 30 kms. ____ more than 30 kms.

Section 3: Sewage and Water Quality

1. What type of sewer system do you have? (Please check one)

____ city sewer ____ septic tank ____ don't know

If you have a septic tank, when was it last cleaned? (Please check one)

____ within last 4 yrs ____ within 5-10 yrs ____ more than yrs ago

____ never ____ don't know

2. What is the source of your drinking water? (Please check one)

____ private well ____ municipal water from Fraser R. or its tributaries

____ municipal well ____ municipal water from mountain resevoir

____ municipal water but don't know source ____ other (specify)_____

3. Do you use any of the following special filters in your household to improve water quality?
(Please check appropriate choice)

____ N.S.A ____ Water Pick ____ Brita ____ other (specify) _____

4. Have you purchased any bottled water in the last five years? (Please circle).

YES NO

If YES, please complete the following table to the best of your ability since we are interested in knowing about purchases of bottled water; otherwise go to the next section.

Brand Name of Bottled Water	Container Size	**Number Purchased per Month**	Brand Name of Bottled Water	Container Size	**Number Purchased per Month**
Evian	300ml.		Perrier	300ml.	
	750ml.			750ml.	
	1 litre			1 litre	
	4 litres			4 litres	
	Other _____			Other _____	
Canadian Springs	300ml.		Polaris	300ml.	
	750ml.			750ml.	
	1 litre			1 litre	
	4 litres			4 litres	
	Other _____			Other _____	
Clearly Springs	300ml.		Glacier Springs	300ml.	
	750ml.			750ml.	
	1 litre			1 litre	
	4 litres			4 litres	
	Other _____			Other _____	
Other (specify) _____	300ml.		Other (specify) _____	300ml	
	750ml.			750ml.	
	1 litre			1 litre	
	4 litres			4 litres	
	Other _____			Other _____	

5. Well testing in the Abbotsford region indicate that approximately 60% of the samples taken from wells in some regions exceed the 10 mg/L maximum acceptable concentration of nitrate-nitrogen for drinking water as defined in Health and Welfare Canada's Canadian ***Drinking Water Quality Guidelines.*** According to an Environment Canada study, elevated nitrate concentrations also signal the potential for contamination from other pollutants. Concentrations of some pesticides for which Canada guidelines do not exist exceed Washington State water quality standards for ground water. Wastes from farm animals have been identified as one (perhaps major) source of ground and surface water pollution. Cleaning up such wastes is expensive.

Composting offers a solution to the problem of animal wastes. for various levels of nitrogen-nitrate concentrations, we have made some rough calculations of the probable costs of cleaning up the pollution via comporting. Are you prepared to pay the amounts indicated to clean up farm animal wastes assuming charges would show up either on your annual water bill or through an increase in rent?

Please place an X under YES or NO in each row to signify whether or not you would be willing through higher water bills or rent to make the payment indicated.

An answer is required in each row.

Water Quality Objective (Nitrate Concentration)	Remark	Estimated Annual cost to Achieve Objective ($/year)	**Are You Willing to Pay?**	
			YES	**NO**
12 mg/L	May be current level	$0		
10 mg/L	Current gov't standard	$28		
8 mg/L		$57		
6 mg/L		$85		
4 mg/L		$113		
2 mg/L		$142		
1 or less mg/L	Future gov't target	$170		

Section 5: Personal Information

1. a) What is your age? (Please check one)

_ 25 or under _ 26-35 _ 36-45

_ 46-55 _ 56-65 _ over65

b) Are you: _ Male _ Female

2. a) Including yourself, how many individuals are there in your household? _

b) If you have any children under the age of 5 in your household how many?

_ children under 5 years of age

3. What is your level of education? (Please circle)

Secondary (Grade): 8 9 10 11 12

Post Secondary (Years): 1 2 3 4 5 6

4. what was your family's (household's) approximate goss(before tax) income in l992? (If a farm, income after farm expenses but before personal expenses.) PIease check one.

_ less than $30,000 _ $50,001 to $60,000 _$80,001 to less than $90,000

___ $30,001 to$40,000 _ $60,001 to $70,000 _ $90,001 to $100,000

___ $40,001 to $50,000 _ $70,001 to $80,000 _more than $100,0OO

THANK YOU FOR TAKING THE TIME TO FILL OUT THIS QUESTIONNAIRE