Willingness to pay for flood and ecological risk reduction in an urban watershed

D.E. Clark1,2, V. Novotny2,5 R. Griffin1,4, D. Booth1,4, A. Bartošová2,5, M.C. Daun2,3 and M. Hutchinson1,2

1 Department of Economics, Marquette University, Box 1881, Milwaukee, WI 53201–1881, USA
2 Institute for Urban Environmental Risk Management, Marquette University, Box 1881, Milwaukee, WI 53201–1881, USA
3 The University of Wisconsin Law School, University of Wisconsin, 975 Bascom Mall, Madison, WI 53706, USA
4 Department of Communications, Marquette University, Box 1881, Milwaukee, WI 53201–1881, USA
5 Department of Civil and Environmental Engineering, Marquette University, Box 1881, Milwaukee, WI 53201–1881, USA

Abstract Urban watershed managers frequently must address alternative policy goals; flood control and ecological risk reduction. This study combines hydrologic models of flood control and biotic models of ecologic risk with economic models of willingness-to-pay and psychological models of risk processing and planned behavior to evaluate these two alternative policy objectives. The findings reveal that flood risk exposure, especially for those individuals who would remain outside the 100 year flood plain if the project were enacted, does influence the financial support that local residents would be willing to make to a flood control project. Other important determinants include demographic factors such as income, and attitudinal measures of the respondent. Expanding the scope of the project to include ecological risk reduction does not, however, appear to change the average willingness-to-pay for a project.

Keywords Ecological; flood; risk; willingness-to-pay

Introduction
Watershed management has been an important issue in the Milwaukee metropolitan area in recent years, with three so-called 100-year flooding events (August 1986, May 1997 and June 1998) occurring within the last 15 years. Increased urbanization combined with misguided flood control efforts (i.e., emphasizing fast-conveyance) during the past three decades have resulted in an increased frequency of downstream flooding in addition to an expanding floodplain. Recently, watershed management practices have begun to focus on alternatives to conveyance-oriented strategies (e.g., emphasizing retention approaches). In addition, managers have begun to consider the ecological consequences of flood control projects as well as environmental restoration of habitat within urban watersheds.

To investigate the relative importance of the flood-control and ecological restoration objectives to watershed management practices, we use the contingent valuation (CV) method applied to a watershed in the Milwaukee metropolitan area. Hydrologic and biological models are employed to quantify the respective flooding and ecological risks associated with continued urbanization. Finally, the CV method is used to evaluate willingness to pay (WTP) associated with maintenance of flood risks as well as reduction in ecological risks, in light of urbanization trends. An overview of the approach and findings from the first wave of survey responses on the WTP function for maintenance of flooding risks are reported in this paper.
Measuring flooding risks and ecological risks from urbanization

Measuring flood risk

A flood is defined for the purpose of this paper as a stream discharge greater than the capacity flow of the stream channel. A flood of certain magnitude occurs or is exceeded with a certain frequency. The extent of the 100-year floodplain, often used for engineering and flood insurance purposes, is delineated by the Federal Emergency Management Agency (FEMA). The flood risk varies within the floodplain and decreases with increased distance from the channel.

A schematic representation of spatial flood risk is shown in Figure 1 above. The channel can contain a flow with a certain recurrence interval. This flow is called a capacity flow. As one moves away from the river’s edge, the probability of flooding decreases, and at some point at a distance \( x \) from the river the recurrence interval of flooding becomes 100 years, i.e., the risk of flooding is \( r(x) = 0.01 \). Channels of natural streams are in equilibrium with regard to the flow. The scale of the risk function \( r(x) \) should be logarithmic, i.e., a zero risk of flooding is expected to occur at an infinitely large distance \( x \) from the river edge. The logarithmic form of the risk function is selected for convenience and simply expresses the fact that floods on rare occasions may extend further than the 100-year floodplain limits. In this paper, flood risk is simulated for an urban watershed, and a unique value of the recurrence interval is defined for every point in the watershed. The methodology for this computation is included in the attached technical appendix. Moreover, the impact of urbanization on flood risks can also be assessed. These estimates of flood risks are subsequently used in the evaluation of WTP.

Ecological risk description

Following U.S. Environmental Protection Agency (EPA) (1992) and WERF (Parkhurst et al., 1996) risk assessment documents, ecological risk for aquatic systems is defined as “a probability that a genus residing in, or potentially indigenous to, the receiving water body will be lost or acutely damaged by existing or potential discharges of pollutants.” The term potentially indigenous reflects the fact that the representative composition of organisms should be selected from a composition in similar unimpacted water bodies located in the same ecoregions.

The calculations of individual risks for each stressor are demonstrated in Figure 2. Novotny and Witte (1997) provided an extension of the WERF methodology (Parkhurst et al., 1996). The extension is designed to allow the application of the methodology to...
estimating the ecological effects of the wet weather (storm water) and dry weather flows separately. EPA currently evaluates ecological risks in terms of the loss of species or genera that will result from the environmental impact (Parkhurst et al., 1996; US EPA, 1992). This risk is a joint probability function of (1) probability density function of concentrations \( f(EMC) \), and (2) probability that species will be lethally or chronically impacted when exposed to a given concentration \( g(R|EMC) \). A simple model and method for calculating ecological risks of contaminants present in storm-water discharges was published by Novotny and Witte (1997). The method assumes that the event mean concentrations of pollutants are log-normally distributed and both storm-water and base flow discharges are considered. A simple software package has been developed by Bartošová (2000) to compute the risk measure for a given level of urbanization. The single, dimensionless risk value has numerous advantages over the traditional separate comparison of measured water quality data with criteria. First, it puts all pollutants on the same basis, i.e., the probability of ecological damage to the resident biota (or potentially resident as derived from reference unimpacted water bodies of the same character within the ecoregion). Second, it generates an additive and comparative number, (i.e., risks from several compounds and those from dry weather discharges could be added together to yield an overall risk and approximate synergy and individual risks can be quantitatively compared). This permits the effects of urbanization on the ecological health of the ecosystem to be quantified and hence the hypothetical changes in ecological quality that various watershed management practices generate to be simulated.

The contingent valuation model

An important policy question is how are the alternative objectives of flood control and ecological restoration valued monetarily by watershed residents? Both flood control and ecological restoration have potential private benefits (i.e., benefits borne by an individual resident) and external benefits (i.e., benefits accruing to others). For example, reductions in flooding certainly directly benefit those who would otherwise be flooded, but local residents may also value reductions in such risks for altruistic reasons. Specifically, recent flooding events in the Milwaukee metropolitan area in 1997 and 1998 led to severe residential and commercial property damage, as well as loss of life. Hence, even those residents not directly affected by flooding events may have a WTP to reduce flooding risks. Likewise, reduction in ecological risks resulting from restoration of urban waterways can generate both use and nonuse values for respondents.

Contingent Valuation (CV) is a useful approach to derive both direct and indirect monetary benefits associated with hypothetical changes in pure or local public goods. Briefly, the CV method utilizes surveys (in this case a telephone survey was employed) to

![Figure 2 Ecological risk measure](https://iwaponline.com/wst/article-pdf/45/9/235/425685/235.pdf)
determine the most an individual would be WTP to either improve a local public good, or prevent its degradation. If properly designed, the survey can yield estimates of financial support for a public project that reflect the true benefit to the resident of watershed risk reduction. The WTP response can be interpreted as the payment that is just necessary to keep the respondent indifferent between two states of the watershed. The first state reflects the utility associated with a hypothetical project that reduces watershed risk and the respondent’s WTP payment and the second state reflects an equal level of respondent utility when there is no project (and hence no payment), but a resulting increase in watershed risk. Hence, the stated WTP payment is the monetary payment that compensates for the watershed risk reduction and maintaining constant satisfaction.

Design of contingent valuation survey instrument

In the present study, the CV method is used to evaluate two alternative hypothetical projects. The first project was to maintain flooding risks at their existing level in lieu of continued urbanization: the Flood Protection project emphasized floodwater retention and containment strategies (e.g., retention ponds, wetland creation and restoration), river dredging, removal of brush/debris along shorelines, building dikes, and limiting development. Although it has been argued that the respondent should be asked willingness to accept compensation (WTA) questions when the project avoids reducing the level of a good already being consumed (i.e., flood protection in this case), Mitchell and Carson (1989, pp. 40–41) note that if public expenditures are required to maintain the status quo for a public good, then the contingent valuation question is appropriately phrased as WTP, since without the project, flood risks will increase. The second project describes the same maintenance of flooding risk, but in addition, it emphasizes reduction in the ecological risk in the watershed, again in the face of continued urbanization: the Combined Flood Risk/Ecological Risk questionnaire focused on habitat restoration for animals and fish (e.g., removal of concrete linings, restoration of fish habitat, restoring stream bank vegetation) as well as the pollution reducing benefits of wetland creation and restoration, in addition to the flood risk maintenance.

For CV to yield useful information, careful survey design is critical. Once reasonable and realistic hypothetical project outcomes were established, a survey draft was generated. Since the ecological and flood risk changes were defined in terms of the pure risk measurements described in Section II, these were translated into language that could be understood by local residents. Then eight different focus groups were conducted with residents of two Milwaukee watersheds (i.e., the Menomonee River and Oak Creek) to fine-tune each description. The focus groups yielded important insights. For example, respondents in the focus group indicated that the use of terminology such as “100-year flood” was confusing given that two 100-year flooding events had occurred within two years. They also indicated that it was important to describe the hypothetical flood risk changes that the project would prevent in both absolute and relative terms. Thus, the final questionnaire indicated that without the project, current trends would lead to risks of flooding that were “3–5 times higher than their current levels” and that this implied that the risk of flooding for most people in the floodplain “would increase from 1% to 5%”. The respondents were also told that the flood plain would expand without the project, and “up to 30 homes and other buildings that are not currently at risk now will be at risk of flooding as the floodplain expands”. Likewise, focus groups indicated the types of “use” activities in which most residents engage are wading, fishing and walking/running along the shore. Thus, the ecological risk reduction was defined in terms of the types of fish that would be able to survive after the project (i.e., game fish such as small mouth bass versus rough fish such as carp), the improvement in water quality (i.e., cleaner water allowing people and pets to wade in the...
water) and the increased diversity of wildlife along the river (e.g., return of songbirds, ducks, etc.).

A referendum approach was employed in the survey. After respondents were given benchmarking examples of other existing local expenditures in per capita terms (e.g., public schools, police and fire protection, local parks and recreation areas, etc.), they were asked a series of questions regarding willingness to pay for the project. In this paper, we focus on the response to the following question: “If the plan were on the next ballot, what is the most that it could cost you per year for the next 20 years (the typical finance period for large public works projects) and still get you to vote in favor of the plan”. This question was asked separately for the samples getting the Flood Control only description, and the sample for which the Combined Flood Control/Ecological Risk Reduction was asked. In addition, information was obtained on the respondent’s demographic and family circumstances, as well as their attitudes towards government, flooding, and the environment. The study employs a two-wave panel design. A panel design administers the survey to the same individual at two different points in time. The first wave is complete and the second wave is currently in the field. Once the second wave is complete, responses from the two waves will be compared to judge stability of responses over time. A total of 999 households participated in telephone interviews in the first wave.

Empirical findings and discussion
Since nearly 30% of the respondents indicated a zero WTP, the WTP function is estimated using a Tobit model. The Tobit model is a limited dependent variable model that is applied when a nontrivial fraction of the observations on the dependent variable are truncated at zero. This occurs with 28% of the Flood Only respondents, and 35% of the Combined Flood Control and Ecological Risk Reduction respondents. The WTP function is estimated using the following specification, separately for each of the three samples.

\[ WTP = f(\text{risk factors, demographic, attitude/value, other survey controls}) \]

The risk factor category includes measures of flood risk exposure to each respondent. Demographic features include income, education levels, gender, owner/renter status and length of time in the neighborhood. A variety of proxies for respondent attitudes toward government, the environment, and obligations to pay for the good were included as were other controls. To conserve space, we summarize the findings on each of the two models. Full regression results are available from the authors on request.

Flood control only model
The median WTP is $25, and mean WTP is $77. In evaluating statistically significant drivers of WTP:

• Several flooding risk factors drive WTP. Residents living beyond the 100 year floodplain, but within the 1,000 year flood plain have higher WTP than other residents. WTP falls with the risk level within the 1,000 year flood plain, and it is lower for upstream residents as compared to those living downstream.

• The primary demographic factor that is important is income with increases in income increasing WTP. Gender, owner/renter status, education levels and length of residency in the current neighborhood are not statistically important.

• Attitudinal factors play an important role in determining WTP. Respondents that indicate a strong willingness to contribute to citizen organizations have higher WTP. Those who feel strongly that everyone should pay for flood control, are WTP less.
Combined flood control/ecological risk reduction model

The median WTP is $25 and mean WTP is $76. The inclusion of additional ecological risk reduction in the project does not generate significant changes in WTP, since the mean and median values are nearly identical in the two samples. This may be indicative of the embedding problem that Kahnemann and Knetsch (1992) have identified. Embedding exists when the stated willingness to pay is independent of the scope of the public good being described. Kahneman and Knetsch (1992) suggest that respondents may be purchasing moral satisfaction from simply doing something, rather than carefully valuing the good being considered. In addition, the model fit is worse and fewer drivers are statistically significant in the sample that combined flood risk/ecological risk model. Nonetheless, several insights are revealed.

• None of the risk factors are statistically important. This may result from the fact that benefits from ecological risk reduction are not likely to have differential benefits to those locating at different distances from the watershed. Rather, they are more evenly spread among watershed residents.

• Income remains the primary demographic driver of WTP, although the number of children appears to have some influence as well, albeit at a level of confidence below standard accepted levels (i.e., 84%). Gender, owner/renter status, education levels and length of time in the neighborhood are not statistically important determinants of WTP.

• Belonging to an environmental group has a positive impact on WTP, but its z-score is only 1.42 (i.e., 84% level of confidence).

Conclusions

The findings from the first wave of survey responses reveal some important insights. First, there is some evidence that WTP is higher among those at higher risk of flooding, and it is especially important for those in the downstream portions of urban watersheds, and also those currently outside the 100 year floodplain, who may risk becoming part of it were flood risks to worsen. Second, it is equally clear that risk is not the only important driver of WTP. For example, demographic factors (especially income) and measures of environmental attitudes are important determinants of WTP, even after accounting for differential risk factors. Third, the potential problem with embedding suggests that voters in a referendum on flood control may not carefully scrutinize the features of the project when determining their level of support. Rather, given the existing perception of ongoing flooding problems in Milwaukee, they may believe that it is important to take some action rather than delay action.

The next step in this project will be to evaluate the stability of the WTP responses by evaluating the second wave of the survey. Once the WTP estimates have been finalized, simulations of the potential changes in flood risk and ecological risk can be used to derive estimates of the benefits to watershed residents from the hypothetical projects. These estimates can be compared with the costs to determine whether such projects are cost effective.

This project has combined the efforts of physical and social scientists to ascertain the policy impacts of specific public works projects. Too often, research in these disciplines has followed parallel and nonintersecting paths. As this study demonstrates, there is much to be gained from crossing those boundaries in research. For example, policy analysis by engineers has frequently focused on damage avoidance as the sole source of public benefits, without investigating other external sources of public benefits that have long been emphasized by economists. On the other hand, economists have often avoided more thorough evaluations of natural hazards, relying instead on simplistic assessments of policy alternatives. Moreover, economists have ignored “non-economic” attitudinal drivers of WTP that psychologists have recognized for many years. Likewise, the risk
communication literature has not thoroughly investigated the economic underpinnings of WTP. While there will always be knowledge silos within each discipline, the need for accurate policy recommendations requires continued efforts to pursue answers to public policy questions in a multidisciplinary setting.

Technical appendix: derivation of flood risk

The logarithmic risk function can be expressed as

$$r(x) = C 10^{-Kx} \quad (A1)$$

The function parameters in Eq. (A1) can be easily estimated from the knowledge of the risk of exceeding the bankfull capacity flow and from the extent of the 100-year floodplain: $C$ corresponds to the risk of exceeding the bankfull flow, or, $C = r(0)$. The risk function can be integrated across the floodplain cross-section, as shown in the following equation, in which subscripts $L$ and $R$ correspond to the left and right bank floodplains:

$$R = \int_{0}^{\infty} r_L(x) dx + \int_{0}^{\infty} r_R(x) dx = r(0) \left[ 10^{0 - Kx_L} + 10^{0 - Kx_R} \right] dx \quad (A2)$$

The magnitude of the floodplain shape coefficient, $K$, can be obtained from the extent of the 100-year floodplain at the point of interest on the river, denoted as $X_{100}$, and from the risk of exceeding the bankfull discharge, $r(0)$:

$$\log \left( \frac{r(X_{100})}{C} \right) = \log \left( \frac{0.01}{r(0)} \right) = -KX_{100} \quad (A3)$$

and

$$K = \frac{\log[r(0)] + 2}{X_{100}} \quad (A4)$$

Finally, substituting for $K$ in Eq. (2) from Eq. (4) yields the following expression for the floodplain risk parameter:

$$R = \frac{r(0)}{2 \cdot 3 \cdot (2 + \log r(0)) \left[ X_{L-100} + X_{R-100} \right]} \quad (A5)$$

The dimension of the floodplain risk parameter $R$ is length/time, and a possible unit is metre/day. However, the unit does not have a physical meaning, as $R$ is only a measure of the flood risk over a floodplain. $R$ increases with an increase in the size of the floodplain and with an increase in the risk of overbank flow. This floodplain risk parameter changes along the stream. The integration of the flood risk over the watershed represents an overall risk of flooding of the watershed, the flood risk factor that can be used in comparing watershed management alternatives.

This characterization of flood risks will be used to assign unique values of flood risk to each property within the floodplain. The flood risk measure, $FRM$, calculated within a GIS environment is a negative logarithm of the flood risk $r(x)$. The anti-logarithm of the flood risk measure is the recurrence interval, i.e., $FRM = 2$ for $T_x = 100$ years.

References


