NCERQA ANNUAL REPORT

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Title: **Risk Based Urban Watershed Management-Integration of Water Quality and Flood Control Objectives**
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Research Category: US EPA/NSF/USDA STAR Watershed Program
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Objectives of the Research:

This annual report covers activities of the third year of the project that was awarded to Marquette University on October 1, 1997. The overall research objectives and goals of the project outlined in the proposal are:

(1) Develop statistical flow, loading and water quality models applicable to risk assessment;
(2) Develop objective and quantitative risk assessment procedures for estimating ecological risks of stormwater and subsurface discharges from urban and suburban watersheds;
(3) Develop methodology for assessment of flood control and water quality benefits and resolve conflicts between flood control and ecological preservation-restoration objectives;
(4) Develop benefits/cost models for urban watershed management to optimize both flood control and receiving water integrity;
(5) Research innovative financing of urban watershed management, identify key players, and assess the willingness to pay for different watershed resident groups; and
(6) Examine homeowners' risk/benefit perceptions, values, effective responses to the risk, subjective norms, socio-cultural backgrounds, and use of communication in the willingness to pay for these different types of benefits.

The goal of the research is to examine urban water bodies along two different dimensions: the degree to which the urban development influences flooding risks, and the degree to which it influences the ecology of the water bodies as represented by the ecological risks. These two dimensions are related and are often conflicting.

Progress Summary/Accomplishments (1999-2000)

1. *Completed work*

Monitoring Program

The second wave of biological monitoring was conducted during the Summer of 2000 in cooperation with Wisconsin Lutheran College. The monitoring program of Oak Creek and the Menomonee River expanded fish sampling when compared to previous years. An index of biotic integrity (IBI) based on fish species composition was calculated based on procedures developed by Lyons (1992). A high percentage of tolerant species and low species diversity indicated very poor stream quality. The IBI scores indicate that all locations, with the exception of the reference site, do not support a typical fish community for this region.

Macroinvertebrates were collected at 5 sites on Oak Creek and 9 sites on Menomonee River, including 2 sites in the headwaters without significant impairment by urbanization (reference sites). Sampling followed protocols for

multihabitat using a D-frame dip net. Sampled habitat types included cobble, snags, vegetated banks, submerged macrophytes, sand and other fine sediment. Samples were collected in the Summer of 2000. IBI scores indicated fair conditions of Oak Creek when compared to reference site scores, i.e., a loss of intolerant forms.

Flood Risk

The methodology developed during the first year of the project was expanded and modified to include changes of the floodplain with urbanization. Originally, only an existing 100-year floodplain and information on risk of channel overtopping was used to interpolate or extrapolate the floodrisk inside and outside the floodplain. The modified methodology uses data from an existing hydraulic model (HEC-RAS) to delineate floodplain based on the flow of a specified recurrence interval. Simple regression that ties the flow to depth and floodplain width was developed in Excel spreadsheet. The results are then imported into ArcView where custom developed scripts draw floodplain. This allows for more precise interpolation both inside and outside the 100-year floodplain as locations of 10-year, 20-year, 50-year, 100-year, 200-year, and 500-year floodplain are determined. This methodology, combined with previous statistical analysis of flow and changes in distribution with increasing urbanization, also allows evaluating the increase in risk of flooding as watersheds are urbanized.

ArcView extension has been developed to facilitate estimation of flood risk for households included in the questionnaire. The extension combines several scripts into a file that can be distributed. The extension, once loaded into ArcView, adds a new menu to the existing choices. The scripts are divided into four groups: (1) creating required themes, if not already present; (2) calculating distances to a floodplain and a river; (3) estimating the flood risk measure (negative logarithm of flood risk); and (4) checking and refining the calculation for points inside the floodplain.

Ecological Risks

Physical integrity. The information on habitat suitability and ecological risk due to chemical contamination is being analyzed with respect to overall biotic integrity (fish and macroinvertebrate IBIs). The biological data collected during the course of the study were combined with existing data from the Wisconsin Department of Natural Resources (DNR) on the investigated watersheds, both fish and macroinvertebrate data. However, habitat data on DNR macroinvertebrate sites are limited to substrate composition while data on fish collection sites include habitat index. Habitat index has been used to assess the effect of habitat on IBI. All sites investigated within this study show a decrease in IBI greater than the decrease in habitat index, or the level of habitat impairment, would indicate. This shows significant chemical impairment of water bodies, confirmed by risk calculations

Chemical integrity. From the heavy metals analyzed, lead causes the highest risks – about 10^{-3} chronic toxicity risk. The additional analysis are required to separate chronic toxicity due to water column concentration from chronic toxicity due to sediment contamination, and to evaluate the effect of urbanization. The methodology for calculating ecological risk due to water column concentration has been modified for sediments. The specifics pertaining to sediment include: (i) limited number of samples makes it impossible to determine probability distribution of a contaminant; (ii) only organisms coming directly in contact with benthos are affected (benthic organisms); and (iii) only chronic effects are considered. The calculations will be completed by January 2001. A simple Excel-based software package has been developed to facilitate calculation of ecological risks from chemical contamination.

Willingness to pay survey

A 25-minute telephone survey was conducted on nearly one thousand randomly selected adult residents of two metropolitan Milwaukee watersheds, Menomonee River and Oak Creek, in the late fall and winter of 1999-2000. The survey organization also conducted eight focus groups sessions in spring 1999, prior to the survey, to help in the development of the survey instrument (see the 1998-1999 annual report and Report #5).

In the first wave conducted in the 1999-2000 period, respondents were asked the same set of questions and are

provided with a detailed description of the watershed project before being asked a series of questions designed to determine their willingness to pay. The WTP questions were posed in terms of a hypothetical political referendum. Respondents were asked to indicate the maximum amount of money that the plan could require them to pay annually for the next 20 years yet still allow them to vote in favor of the plan. The objectives of the survey are to:

1. Distinguish between the WTP for flood-control and the WTP for ecological restoration of urbanizing watersheds and determine whether the two types of benefits are separable;
2. Test a model that describes the salient drivers (psychological, sociodemographic, locational, and communication-related) that appear to influence WTP responses in the survey;
3. Determine whether WTP responses are stable over time;
4. Relate WTP to the underlying flood and ecological risk improvements in the project and then derive estimates of community-wide benefits from flood control and/or ecological risk reduction in the watershed. Benefits are then compared with project costs to determine optimal watershed policy.

In all, 999 respondents were interviewed in the first wave, 303 (all from the Menomonee River watershed) were interviewed about their willingness to pay for a flood control project on that river (which was dubbed the "flood path" of questions), 459 (from both the Menomonee River and Oak Creek watersheds) were interviewed about their WTP for an ecological restoration project in their respective watersheds (the "environmental path" of questions), and 237 (all from the Menomonee River watershed) were interviewed about their WTP for a combined project that would hold the line on flooding as well as improve ecological quality of the watershed (the "combined path" of questions). Due to interviewing time limitations, only those respondents in the flood and environmental paths of questions were asked a full battery of questions based on the psychological and communication models.

Initial results indicate that there are no statistically significant differences between paths in the maximum amounts individuals would be willing to pay for the projects (overall mean=$84), even though the combined project would deliver more benefits than either of flood control and ecological improvement.

The primary sociodemographic variables (respondent income, education, race/ethnicity, gender, age, dwelling location within the floodplain, and the number of inhabitants of the dwelling) bear weaker relationships with WTP for the flood control project than do a set of variables based on the Theory of Planned Behavior, specifically, subjective norms ($r=.29$, $p<.001$) and an overall index of cognitive structure ($r=.40$, $p<.001$; $r=.46$, $p<.001$, when the belief-evaluation compound items are also multiplied by a separate self-report measure of the importance of the outcome to the decision). Among the belief-evaluation compounds themselves, correlations with willingness to pay for the flood control project are as follows (the second coefficient representing the addition of the importance multiplier):

- Add significantly to my taxes ($r=.03$, ns; $r=.11$, $p<.05$);
- Be personally expensive for me ($r=.15$, $p<.01$; $r=.21$, $p<.001$);
- Make me feel like I am doing something for the environment ($r=.28$, $p<.001$; $r=.34$, $p<.001$);
- Make me feel like I am doing something for the community ($r=.34$, $p<.001$; $r=.45$, $p<.001$);
- Probably help support a long term solution ($r=.36$, $p<.001$; $r=.39$, $p<.001$);
- Probably help future generations ($r=.32$, $p<.001$; $r=.36$, $p<.001$);
- Probably help to hold the line against flooding ($r=.28$, $p<.001$; $r=.33$, $p<.001$) ;

· Probably help people who live in the floodplain ($r=.19$, $p<.001$; $r=.28$, $p<.001$) .

A microscopic analysis of the responses indicates that about 73% of the respondents believe that the flood control projects would produce a *bad* outcome of helping people who live in the floodplain. Only about 4% see the project as helping people who live in the floodplain and put a positive value on that outcome, which suggests that altruistic motives are certainly not strongly at work in the watershed population.

A research project completed at the end of 2000 looks at determination of spatial flood risk reduction potentially to be received by the population on WTP within the larger community-wide benefits of a flood management project. Spatial flood risk is defined as the probability of a flooding event reaching a specific household in a flood plain or in the vicinity of a floodplain. Several hypotheses of the effect of the flood risk on WTP are being tested. Preliminary results indicate that there is no significant difference in WTP received by those with higher spatial risk relative to a similar individual with lower risk. That may imply that the community wide benefits of a flood risk management project are more important than individual benefits for residents of the flood plain. This may indicate the presence of an embedding problem in which the level of WTP is independent of the level of risk reduction described in the questionnaire.

Environmental ethics study. Another project reaching conclusion investigated whether ethical evaluations influence WTP for projects that would improve the ecological health of urban waterways. To this end the literature on environmental attitudes and values was reviewed and scales of environmental attitudes previously used in other studies were pre-tested for inclusion in the ecological track of the Menomonee River and Oak Creek survey instrument. A scale is the summation of numerical Likert-scale responses to a series of questions about environmental attitudes. As a result of pretests, a truncated six-question version of the awareness of consequences scale (AC) was included in the survey along with several ethically oriented Likert-style questions about environmental values. The statistical analysis of the effects of environmental attitudes and ethical valuations on WTP is completed. The statistical analysis explicitly incorporates ethical attitudes toward the environment using the Theory of Planned Behavior and its notions of cognitive structure and subjective norms. The basic hypothesis tested employing multivariate regression analysis is that environmental attitudes affect specific beliefs and values (cognitive structure) about WTP for urban watershed restoration and that these beliefs and values in turn affect WTP. Cognitive structure is a scale variable equal to the summation of Likert responses to attitudinal questions about WTP. The Awareness of Consequences Scale (AC) is a statistically significant explanatory variable in a regression equation for cognitive structure, and cognitive structure is in turn a statistically significant explanatory variable in a regression equation for WTP. The magnitude of the regression coefficients indicates that a change in AC at the margin has a substantial effect on WTP by way of cognitive structure. Moreover, including specific measures of environmental values in addition to the AC scale, such as the degree to which respondents hold biocentric attitudes, adds to the explanatory power of the cognitive structure regression equation. This means that the extent to which respondents believe that the natural world is valuable for its own sake has a positive statistical effect on WTP. The central conclusion to be drawn from these results is that strictly economic variables, such as income, play a comparatively minor role in WTP regression equations relative to psychological variables such as cognitive structure and subjective norms. Cognitive structure is in turn strongly related statistically to environmental attitudes and values. The decision on public goods may well be much more intuitive and value oriented than the practitioners of contingent valuation studies previously thought.

2. *Work in progress*

The period October 2000 - September 2001 is the last year of the project with the following tasks still remaining:

Monitoring

All field work on the two pilot watersheds has been concluded. Final evaluation of the data will continue for several months into 2001. The following projects are continuing and will be concluded in 2001:

1. Loading model of pollutants from the watershed
2. Development and testing of risk assessment procedures for benthic contamination and physical impairment
3. Linking the aquatic risks to the socio-economic finding from the surveys

Contingent Valuation - Willingness to Pay Survey

The second wave survey will be conducted in Winter 2000-2001. The survey format is similar to the first wave completed in the Summer of 2000. As in the first survey, about 1000 citizens living in the two pilot watersheds will be surveyed. This is the largest remaining task of the project. The survey will conclude in Spring of 2001 and will be followed by extensive evaluation and final analyses in Summer of 2001.

Final Report

The final report will be prepared in the Summer-Fall period of 2001 and submitted in or before December 2001.

3. Meeting with Stakeholders and Advisory Committee

On January 28, 2000 the team presented its intermediate results and accomplishment to the local stakeholders. This was our second stakeholder's meeting. About 50 representatives of communities and agencies participated.

The stakeholder meeting was followed by a meeting of the institute's advisory committee that also reviewed the progress and main results of this research.

4. International Cooperation

The institute/research team has established a cooperation with scientists in Japan from Ritsumeikan University in Kyoto. Ritsumeikan University is the largest private university in Japan. After the visit of the primary investigator to the Ritsumeikan University in October 1999 and a visit of professor Yamada to Marquette University, a visiting research scientist from Ritsumeikan is now spending the 2000 - 2001 academic year (plus summer) at Maquette University. Dr. Atsushi Ichiki will participate on the closing phases of this reseaerch. A similar cooperation is now being initiated with the University of Pavia in Italy and will be also initiated with the University of Padova.

Publications and Presentations in 1999-2000:

Refereed Publications and Proceedings:

1. V. Novotny *et al.* (2000) "Reconciling flood and diffuse pollution control objectives in urban watersheds," *Proc. 4th International IWA Conference on Diffuse Pollution,* Bangkok, Thailand, January 16-20,2000, also to be published in *Water Science and Technology*
2. V. Novotny, D. Clark, R. Griffin and D. Booth (2000) "Risk based urban watershed management under conflicting objectives," *Proc. 2st World Water Congress of the International Water*

Association (IWA), Paris (France), July 3-7, 2000, Book 5, Water Resources and Waste Management, pp. 144-151

3. V. Novotny, D. Clark, R. Griffin, and A. Bartosova (2000) "Balancing flood control and ecological preservation/restoration of urban watersheds," to be published in *Source Control Measures for Stormwater Runoff* (J. Marsalek et al., eds.), Proc. of the NATO ARW Workshop, St. Marienthal, Germany, November 8-12,2000, Kluver Academic Publ., Dordrecht, The Netherlands
4. R. J. Griffin, D. Clark, D. Booth, V. Novotny, and J. (2000) "Risk Communication and Public Willingness to Pay for Flood Control and Ecological Improvement in River Watersheds," Society for Risk Analysis Annual Convention, December 2000. To be published in a special issue of the *Journal Risk Analysis*, 2001 or early 2002.

Several manuscripts of papers are being prepared by investigators because the research is concluding.

Technical Reports produced in 1999-2000 research year :

#5. James K. Giese, R. J. Griffin, and D. Clark (2000) *Survey of Attitudes and Willingness to Pay for Flood Control and Water Body Restoration (Survey Design and Result of Focus Groups)*

#6. M. Daun and D. Clark (2000) *Flood Risk and Contingent Valuation Willingness to Pay Studies: A Methodological Review and Applied Analysis*

#7. A. Bartosova, V. Novotny and P. Hajda (2000) *Evaluation of Water Quality and Ecological Risks.*

8 Douglas Booth (2000) *Biocentric Environmental Values and Support for the Ecological Restoration of an Urban Watershed*

All technical reports are deposited in the Marquette University Science Library from which they can be retrieved by the Interlibrary Loan services and/or downloaded in the pdf format from the team's website. Four technical reports were generated in the 1998-1999 research period. A hard copy of each report is also submitted to the EPA project coordinator.

Abstract submitted and accepted for presentation

5th International Conference on Diffuse Pollution and Watershed Management, June 10-15, 2001

1. David E. Clark, M. Daun, M. Hutchinson, R. Griffin, A. Bartosova, and V. Novotny: Willingness to Pay for Flood & Ecological Risk Reduction in an Urban Watershed - platform presentation
2. R. J. Griffin, D. Clark, D. Booth, V. Novotny, J. Giese: Psychological and Information-processing Predictors of Public Willingness to Pay for Flood Control and Ecological Improvements in Urban River Watersheds-platform presentation
3. Douglas E. Booth : Biocentric Environmental Values and Support for the Ecological Restoration of an Urban Watersheds - platform presentation
4. Joshua Kasun, A. Bartošová, and V. Novotny: Combined Ecological Risk Assessment of Sediment and Water Column Contaminated by Diffuse Pollution - Platform presentation
5. Sarah Alamilla : GIS Based Approach to Urban River Corridor Delineation - poster
6. Phillip Blonn : A GIS-based Model of Diffuse Pollution in the Oak Creek and Menomonee River Watersheds (Wisconsin)

Authors will be required to prepare a paper for the proceedings. Some papers may be selected for peer review and included in the *Water Science & Technology* journal of IWA.

Western Regional Science Association (February 2001)

7. D. Clark, V. Novotny, A. Bartošová, . R. Griffin, M. Daun, M. Hutchinson: Flood Risk, Ecological Risk and Willingness to Pay: An Interdisciplinary Approach to urban Watershed Management

Supplemental Keywords:

Urban economics, Hydrological modeling, Water quality modeling, Urban drainage, Property damages, Probabilistic models, Public opinion, Watershed, Risk assessment, Ecological effects, Chemicals, Toxics, PAHs, Heavy metals, Nitrogen, Phosphorus, Restoration, Habitat, Integrated assessment, Decision making, Cost benefit, Contingent valuation, Willingness to pay, Geographical information systems, Great Lakes.

Relevant Web Site: *www.marquette.edu/environment/Research.htm*

This site contains the documents (technical reports and publications) prepared by the research teams. Most documents are in the pdf format and can be read and downloaded by Adobe Acrobat Reader.