

Water Resources Center

Annual Technical Report

FY 1998

Introduction

Research Program

Basic Project Information

Basic Project Information	
Category	Data
Title	The Feasibility of Cost Sharing in Nonpoint Source Pollution Control
Project Number	C-01
Start Date	09/01/1998
End Date	12/31/1998
Research Category	Social Sciences
Focus Category #1	Economics
Focus Category #2	Management and Planning
Focus Category #3	Non Point Pollution
Lead Institution	University of Rhode Island

Principal Investigators

Principal Investigators			
Name	Title During Project Period	Affiliated Organization	Order
Jon G. Sutinen	Unknown	University of Rhode Island	01
Dennis Wichelns	Unknown	University of Rhode Island	02

Problem and Research Objectives

Both the Rhode Island State and municipal governments are looking for an abatement policy which is both cost-effective and accepted by the public. Cooperative policies involving cost sharing have been used to encourage the adoption of best management practices to control nonpoint source (NPS) pollution.

Cooperative programs involving cost sharing can make cost minimizing programs more acceptable to

the public. Alternative solutions to NPS pollution may be less efficient programs which require significant amounts of enforcement or expensive community wide sewer.

A game-theoretic framework, incorporating a bargaining process between subpopulations within a watershed, can be used to determine acceptable cost allocations (e.g., cost share ratios) for NPS pollution control. A game-theoretic framework involving joint social cost or social welfare functions can be used to model cost sharing agreements and cooperative solutions to environmental protection. A new framework is used in this study which acknowledges water quality benefits indirectly through empirical public preference models. The framework also acknowledges the potential for cooperation towards NPS pollution control between neighborhoods within a watershed which also is a tool for designing optimal cost sharing programs.

The objectives of this study are (1) to provide an analytical and empirical framework for comparing the acceptability of cooperative and noncooperative programs for mitigating NPS pollution, and (2) to test the hypothesis that publicly acceptable cost share programs for NPS pollution control can be designed which minimize NPS pollution abatement costs.

Methodology

An analytical framework for determining the feasibility of cooperative (e.g., cost sharing) water quality protection programs involving septic systems improvements has been specified. The framework relies on calculating "values" for players involved in cooperative games in characteristic function form (e.g., Shapley values) and partition function form. Values determine benefit and cost allocations for property owners within watersheds. Games in partition function form are able to better characterize games involving public goods and behavior such as free-riding. Values for games in partition function form are theoretically more applicable to situations involving water quality improvements and nonpoint source pollution control, while values for games in characteristic function form have traditionally been used in wastewater management.

To test the existence of an acceptable cost share solution which minimizes the cost of controlling nonpoint source pollution, cooperative games values have been used to allocate septic system management costs among three areas of Potowomut, RI (e.g., players): (1) a wellhead protection district, (2) a riparian zone, and (3) an area with no abatement requirements. The framework is also being used to demonstrate the applicability to other communities or watersheds where environmental conditions may differ. Issues such as the need for weighting factors to adjust for population size and the impact of assumptions about player threats are being evaluated using different Wastewater Management District Plans in Potowomut, RI.

Principal Findings and Significance

In 1996, the City of Warwick proposed an ordinance requiring specific septic system management measures for a wellhead protection district to protect drinking water from sewage in Potowomut. Some homeowners resisted the ordinance at the meeting and no further action has been taken to protect drinking water from sewage. The situation in Potowomut is characterized by two conditions: (1) the city decides abatement levels or action to be taken by individual homeowners, and (2) program approval must be unanimous. If cost sharing is implemented through the use of homeowner fees, the process for defining homeowner fees is a cooperative game and cooperative game values are suitable focal points for arbitration. The cooperative game consists the three players representing the wellhead protection district(player W), the Greenwich Bay shoreline area (player G), and the non-abatement or non-sensitive

area where septic systems are assumed to have no effect on water quality (player N).

Cooperative game values in this study are weighted to insure that no homeowners are being paid to participate in programs, and, in the case of the Shapley value, to insure that the results for the three-player game (where players are assumed to represent a partnership of identical homes) are equal to the results for a complex game between the individual homes in Potowomut (e.g., insure that the partnership axiom is met). The weighting scheme applied to the Shapley value is applied to the incomplete cooperation (IC) value, but the partnership axiom is not guaranteed to be satisfied for the weighted IC value. An alternative system for weighting IC values for three-player games is developed and appears to satisfy the partnership axiom.

To demonstrate cost allocation procedures, homeowner fees are determined for a program requiring 50 connections in the Greenwich Bay Shoreline area and 50 connections in the wellhead protection district. Homeowner fees are derived by (1) specifying non-cooperative payoffs to all coalitions using empirical models of program preferences, (2) Solving for equilibrium conditions in non-cooperative games, (3) defining characteristic function and partition function values based on non-cooperative equilibrium payoffs, (4) calculating Shapley values and IC values from characteristic and partition functions, and (5) allocating costs based on Shapley and IC values.

Grants are available to reduce the cost of new septic systems in Potowomut, and cost allocations are calculated for a range of grant levels. The results indicate that when weighted Shapley values are used, homeowner fees exceed WTP values for player G at grant levels between 10% and 20% under rational threats and at grant levels between 5% and 15% under Nash solutions. When partially weighted IC values are used, fees for player G again exceed WTP values under Nash solution but to a lesser extent, but never exceed WTP under rational threats. The use of fully weighted IC values decreases the expected benefits of free-riding, and fees are noticeably larger under fully weighted IC values for players with the greatest expectations about free-riding.

Homeowner fees are a discontinuous function of grant levels due to discrete changes in characteristic and partition function values and threat conditions. Discontinuities are more frequent and of greater magnitude when Nash solutions to non-cooperative games are assumed. The size of benefits from free-riding also increases the magnitude of discontinuities.

In cases of water quality and other public goods, optimal levels of provision occur when the sum of marginal benefits is equal to the marginal cost of public good provision. However, actual situations where optimal levels of abatement are defined and implemented are rarely encountered. A more common situation involves government assurances that water quality will be protected if certain abatement plans are implemented. Water quality benefits are commonly defined in terms of numerical criteria that must be met, and the existence of discrete or binary water quality protection goals guarantees positive net benefits to be allocated among players in most situations.

The cooperative game solutions used to allocate costs in this study are expected to be useful in other situations involving nonpoint source pollution control where the perceived benefits of water quality protection are discrete. These procedure are also applicable to games with more than three players, but determination of characteristic and partition function values requires solutions to more complex non-cooperative payoff matrices.

The first draft of the project report is near completion. The outline of the report is shown in Figure 1.

Figure 1. Outline of Project Report

I. INTRODUCTION

II. A COOPERATIVE GAME FRAMEWORK FOR COST ALLOCATION

- Optimal Public Good Provision
- Solutions for Two-player Cooperative Games
- Solutions for N-player cooperative Games
 - Solution values for games in characteristic function form
 - Values for games in partition function form
- Modeling Cooperative Agreements for Wastewater Management Districts
- Estimating Cost Allocations Using Cooperative Game Values

III. COST ALLOCATION FOR SEPTIC SYSTEM IMPROVEMENTS IN A COASTAL COMMUNITY

- Description of the Cooperative Game and the Players
 - Characteristic Functions
 - Partition Functions
- Cooperative Games Solutions and Net Benefit Allocations
 - Shapley Values
 - Incomplete Cooperation Values
- Cost Allocation and Homeowner Fees
- A Comparison of the Applicability of Shapley and IC Values
 - The impact of grants on cooperative agreements

IV. GENERAL APPLICABILITY AND SENSITIVITY OF THE COST ALLOCATION MODELING FRAMEWORK

- The Impact of Free-riding
- Limitations of Modeling Assumptions
- Other Institutional Considerations

V. CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER WORK

Sections four and five of the report discuss relevant issues such as (1) how do the allocation procedures discussed in this study compare to allocation procedures used in the past by federal agencies, (2) what institutional characteristics (e.g., political representation and voting rules) must be considered when assessing the applicability of different cost allocation methods, and (3) what recommendations can be given to managers and planners based on the results of this study. It should be noted that the US Environmental Protection Agency is expected to provide guidance to states about efficient and acceptable methods for allocating waste treatment responsibilities across point and nonpoint source dischargers within watersheds not currently meeting water quality standards (i.e., TMDL program). The cooperative game methods and results discussed in the project report outlined above can be compared to the allocation methods currently referenced by EPA and may help predict stakeholder behavior in watershed management.

Following completion of the project report, a significantly condensed version of the report will serve as draft of a paper for publication in a peer reviewed journal (e.g., Journal of Environmental Economics and Management, Journal of Public Policy, Water Resources Research, etc.). The anticipated title is : "Free riding and Cost Allocation Solutions in Nonpoint Source Pollution Control".

Descriptors

Economics, Policy analysis, Nonpoint pollution, Cost sharing, individual Sewage Disposal System.

Articles in Refereed Scientific Journals

Miller, Christopher, Cost Sharing and the Benefits of Integrated Water Quality Protection Goals, in preparation, journal to be determined.

Miller, Christopher, Free-riding and Cost Allocation Solutions in Non-point Pollution Control, in preparation, journal to be determined.

Book Chapters

Dissertations

Water Resources Research Institute Reports

Conference Proceedings

Other Publications

Basic Project Information

Basic Project Information	
Category	Data
Title	Assessment of Pollution Prevention Opportunities for Mercury in Rhode Island Health Related Industries.
Project Number	S-02
Start Date	12/01/1998
End Date	12/31/1999
Research Category	Biological Sciences
Focus Category #1	Toxic Substances
Focus Category #2	None
Focus Category #3	None
Lead Institution	University of Rhode Island

Principal Investigators

Principal Investigators			
Name	Title During Project Period	Affiliated Organization	Order
Calvin P. C. Poon	Professor	University of Rhode Island	01

Problem and Research Objectives

In June of 1997, the Conference of New England Governors and Eastern Canadian Premiers identified the release of mercury as an important public health and environmental issue that needed further study. Current scientific data indicate that mercury is present in freshwater fish at levels that pose potential health risks to people and certain species of fish eating wildlife. In May of 1998 a Mercury Action Plan was drafted that included 45 recommendations to address a regional goal of elimination of the discharge of anthropogenic mercury into the environment. The Rhode Island Department of Environmental Management has an Action Plan involving cooperation and input from the Office of Waste Management, the Office of Air Resources, and the Office of Technical and Customer Assistance. Among the works in the Action Plan are:

1. Preparing fact sheets providing information about strategies or products which reduce the use of mercury.
2. Conduct a mercury audit at a major Rhode Island hospital for the purpose of developing a source reduction/pollution prevention plan
3. Conduct an outreach and educational program to transfer the results of the mercury audit and impact of a source reduction/pollution prevention program.
4. Evaluate the effectiveness of existing mercury collection and recycling efforts and develop strategies to increase the effectiveness of existing state and local efforts.

The Rhode Island Water Resources Center cooperates with the Office of Technical and Customer Assistance of the RI Department of Environmental Management in carrying out some of the works of the Action Plan. Specifically the objectives are (1) to evaluate the sources of mercury that are disposed of in medical waste including wastewater and solid waste, and (2) to reduce the amount of mercury emitted from Rhode Island hospitals and health related facilities by recommending proper source reduction and waste handling methods.

Methodology

The Water Resources Center will work with the engineers and staff from the Office of Technical and Customer Assistance in mercury pollution assessment. The activities will include identifying medical facilities, compiling mercury data, auditing a major hospital in mercury pollution, and conducting the outreach and education programs.

Principal Findings and Significance

At the time this progress report is prepared, the project is in its fourth month. Up to that time, the following have been accomplished:

1. Identifying all Rhode Island medical facilities which contribute to medical waste incineration.
2. Contacting representatives of these facilities to discuss participation in the project.
3. Through literature survey and contact with various government and hospital/healthfacilities, compile a list of mercury containing products, a list of mercury containing chemicals, and a list of mercury containing cleaning supplies. The lists are part of a mass database for the entire mercury pollution reduction/prevention program.
4. Has scheduled and will present findings in a Mercury Reduction and Pollution Prevention in Hospitals Workshop on April 20, 1999.
5. Will continue updating the mass database, carrying out auditing of mercury pollution in a major hospital, recommend actions to be taken in mercury reduction/prevention for health facilities, and conduct outreach/education programs for technology transfer.

The project is expected to continue throughout the year of 1999.

Descriptors

Toxic Substance, Pollution Control

Articles in Refereed Scientific Journals

Book Chapters

Dissertations

Water Resources Research Institute Reports

Conference Proceedings

Poon, Calvin P. C., Proposed Actions Taken by Hospitals in Mercury Pollution Prevention, Conference, Mercury Reduction and Pollution Prevention in Hospitals, April, 1999.

Other Publications

Information Transfer Program

Basic Project Information

Basic Project Information	
Category	Data
Title	The Development of a Guideline on the Sampling/Testing of Innovative/Alternative Disposal Technologies for Sewage Treatment and Disposal
Description	Information Transfer Project
Start Date	03/01/1997
End Date	02/28/1999

Type	Publications
Lead Institution	University of Rhode Island

Principal Investigators

Principal Investigators			
Name	Title During Project Period	Affiliated Organization	Order
Calvin P. C. Poon	Professor	University of Rhode Island	01

Problem and Research Objectives

Individual sewage disposal systems (ISDS) have been implicated as a potential cause of degraded water quality in salt ponds, Wickford Harbor, Mount Hope Bay, Narrow River, as well as in many other tributaries to the Narragansett Bay. After years of total dependence on individual groundwater wells as a prime source for drinking water supply, the community of Hope Valley Village in Hopkinton, RI had to install a water distribution system fed from public water well at Richmond. This is primarily attributed to groundwater quality impact by failing septic systems.

More septic/leaching field system will be built in rural areas of Rhode Island. Many of the installations are the newly innovative/alternative sewage disposal system which potentially use less leaching area and more efficient in pollutant removal. These innovative/alternative individual sewage disposal system (I/A ISDS) also will be used more and more to replace the failing septic systems in Rhode Island and in other New England states. The permit section of many state regulating agencies including the one in RI Department of Environmental Management is in the process of establishing an approval list of the I/A ISDS. In preparation of the approval list, it is necessary to provide critical review of the technologies based on their performance history, design adequacy, sound construction, and proper operation/maintenance effort.

While the documentation of the system construction and installation and the instruction of operation/maintenance requirements for many I/A ISDS is adequate, there is a lack of performance data that can convincingly back up the claims made by the I/A ISDS industry. Most performance testing was poorly designed. The testing was carried out sporadically with no systematic approach, no quality control, and with the test period too short to yield a meaningful result. At times the data submitted lead to more questions rather than to demonstrate the successful performance of the technology.

Methodology

Presently twenty-two (22) I/A ISDS systems have been submitted to the New England states for approval. For each technology the design of the system components as well as the system as a whole be examined. Instructions on operation/maintenance will be reviewed critically to see if the technology can be operated and maintained properly to give the system performance it is designed for. Performance can be tested with procedures depending on the specific designed function of the system component and the system as a whole.

For system components intended for biological removal of pollutants, tests of BOD, TOC, DO, total suspended solids, volatile solids, total Kjeldahl nitrogen, ammonia nitrogen, nitrite/nitrate nitrogen are potential candidates for measurement. Each technology is specific such that testing will be specifically

selected from the above list.

Most I/A ISDS technologies claim better treatment of the sewage which leads to their claim of the requirement of a smaller leaching field. The correlation of a better sewage treatment and the smaller leaching field requirement is not established quantitatively. An effluent with lower BOD and nitrogen but applied at a higher loading rate (more gallon per day per square feet of leaching area if a smaller leaching field is used would in effect apply the same or larger amount of pollutant to the soil, resulting in a more dense biomat and lower leaching rate. It is therefore necessary to monitor the hydraulic conductivity or the percolating rate of the field periodically. If the correlation of a better sewage treatment and the requirement of a smaller leaching field can be quantitatively established, a proper design procedure can be derived for leaching field sizing using the tested I/A ISDS.

The performance testing carried out by reputable and independent testing firms also will be reviewed carefully. Coupled with the considerations alluded to previously, a list of the performance testing can be prepared for each system or system component for which the designed functions are known. Also sampling protocol and testing methods will be recommended.

As a member of the Technical Review Committee for the I/A ISDS systems for the Rhode Island Department of Environmental Management, the principal investigator of this transfer project worked closely with all members of the committee in data collection, technical review and discussion of all technologies. The members of the committee consist of environmental engineers, town public work directors, planners, ISDS installers, ISDS designers, citizen group representative, university researchers, and state regulating agency representatives. The collective knowledge, experience, and their connections with some outside experts of ISDS systems are valuable in this information transfer project. Consultation with the New developed England state regulating agencies and the New England Interstate are Water Pollution Control Commission was also sought from time to time.

Principal Findings and Significance

The guideline for I/A ISDS sampling and testing in a draft form of a booklet is being prepared. The document is divided into two parts. The first part addresses the critical issues of sampling and testing for all I/A ISDS technologies. The following issues are included:

1. BOD and nitrogen removal in the septic tank ----- location for sampling, frequency of solid pump-out, and grab sampling versus composite sampling.
2. Denitrification and nitrification removal ----- Most vendors and many regulating agencies arbitrarily use 50 percent total-N removal as an evidence of denitrification. This is not consistent with the definition of denitrification which is aerobic nitrification of ammonia nitrogen to nitrate followed by anoxic reduction of nitrate to nitrogen gas. Solid pump-out from septic tank alone can remove 50% of total nitrogen which does not have to go through the nitrification-denitrification processes. Also nitrogen is not removed from the system if only nitrification is taking place.
3. Nitrogen analysis ----- All vendors did not report the protocol of nitrogen analysis. However the result of nitrogen analysis can be significantly different depending on if the sample is filtered or not. Also many vendor mistakenly uses the TKN change to imply that denitrification is taking place.
4. Leach field size reduction ----- Special consideration should be given to the septic tank effluent BOD and TSS concentrations. If they different from 150 mg/l, the leach size reduction using Laak's formula should be adjusted.

5. Phosphate removal ----- Similar to nitrogen removal, only the system provides the aerobic-anoxic-aerobic arrangement can a biological P removal be expected. No credit of P removal should be given to the I/A ISDS system if the aerobic-anoxic-aerobic arrangement is not provided.
6. Number of sample/test ----- The volume of data of test results submitted by vendors varies from voluminous to sporadic. No statistical analysis is presented. There is a need to establish the minimum allowable amount of data and statistical analysis to be submitted for review. A log-probability plot of performance with 3 to 5 years data is sufficient to show the probability of the system performance meeting the expected result claimed by the vendor.

The second part of the guideline is to divide the I/A ISDS technologies into five (5) different categories: (1) I/A trench/chamber/bed with no treatment enhancement, (2) I/A trench/chamber/bed with treatment enhancement, (3) I/A technology following a septic tank prior to leaching field application, (4) I/A technology as a stand alone treatment system without a septic tank, (5) Others. The functions and mode of operation of each technology in each category are described. The sampling requirement and analytical protocol are specified. All together 4 technologies in category 1, 1 technology in category 2, 8 technologies in category 3, 3 technologies in category 4, and 2 technologies in category 5 have been reviewed and included in a completion report. More I/A ISDS systems will be added and updated as time and resources allow in the future.

Utilization of Result:

The project is carried out in close cooperation with the Technical Review Committee for the I/A ISDS of Rhode Island Department of Environmental Management. The project is completed in February 1999 with all I/A ISDS technologies in the market or proposed to go into the market reviewed. A completion report providing the guideline for I/A ISDS system sampling/testing will be the finished product available to the public and the vendors, environmental and public work planners, state regulators, the New England Interstate Water Pollution Control Commission, Region 1 Office of USEPA, RI Coastal Resources Management Council, Narragansett Bay Water Quality Management Commission, US Conservation Service, RI Audubon Society, Save the Bay, and other citizen groups.

Articles in Refereed Scientific Journals

Book Chapters

Dissertations

Water Resources Research Institute Reports

Poon, Calvin P. C., Completion Report, Guidelines on the Sampling/Testing of Innovative/Alternative Disposal Technologies for Sewage Treatment and Disposal

Conference Proceedings

Other Publications

Student Support

Student Support					
Category	Section 104 Base Grant	Section 104 RCGP Award	NIWR-USGS Internship	Supplemental Awards	Total
Undergraduate	0	0	0	0	0
Masters	0	0	0	1	1
Ph.D.	0	0	0	0	0
Post-Doc.	0	0	0	0	0
Total	0	0	0	1	1

Awards & Achievements

Publications from Prior Projects

Articles in Refereed Scientific Journals

Book Chapters

Dissertations

Water Resources Research Institute Reports

Conference Proceedings

Other Publications