USGS

WATER RESOURCES RESEARCH GRANT PROPOSAL

Title: Watershed Management: Optimizing the Location of Riparian Buffers

Focus Categories: ECON, SW, MOD, M&P

Descriptors: Riparian buffers, Economics, Stochastic models, Water supply source protection, Optimization

Duration: March 1, 2000 - Feb. 28, 2001

FY 2000 Federal Funds: $16,000

FY 2000 Non-Federal Funds: $32,309

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Critical Water Problem

One of the primary, nonstructural, strategies in watershed management is the acquisition of land or conservation easements to prevent or reduce the flow of pollutants into a stream, lake, or reservoir. As part of its filtration avoidance agreement, the City of New York has agreed to "solicit" the fee title or conservation easement to 355,050 acres in the Catskill/Delaware watershed, and has committed $250 million to this effort (National Research Council, 1999, p. 213). This is a large sum of money and, unless there is a clear understanding of the role particular parcels play in the loading of pollutants and the cost of fee simple or conservation easements, there is great potential for ineffective acquisition and a waste of the City's money. The proposed research will (1) develop a binary optimization model for the cost-effective acquisition of riparian buffers and (2) apply the model to a set of candidate parcels in the Catskill/Delaware watershed.

Expected Benefits

The problem of optimizing the acquisition of riparian buffers, subject to a budget constraint, will be programmed on an Excel spreadsheet. It will be solved using Excel's Solver. This format will facilitate the transfer, refinement, and application of the model

by the City of New York. The program has potential application to other watersheds in New York State.

Objectives

(1) Develop a model which systematically considers (a) the pollution loading with and without buffer zones for a finite set of riparian parcels, (b) a weighting factor for the potential damage of different pollutants, (c) the cost of acquiring fee simple title or conservation easements for each parcel, and (d) the acquisition budget. (2) Illustrate the usefulness of the model through an application within the Catskill/Delaware watershed.

Methods, Procedures, and Facilities

Consider a stream-reservoir system, where riparian parcels, those bordering on streams flowing into the reservoir, or on the reservoir itself, have been identified and numbered. Let i=1,2,...,I denote the parcel index for these properties. Let j=1,2,...,J denote the pollutants of concern in the reservoir (for example, nitrogen, phosphorus, or perhaps the protozoa *Giardia lamblia* or *Cryptosporidium parvum*). Let $X_{i,j}$ denote the estimated annual loading of pollutant j from parcel i under its expected future use and let $X^B_{i,j}$ denote the annual loading of pollutant j if the parcel is used as a riparian buffer. Presumably $X_{i,j} = X^B_{i,j}$, and $(X_{i,j} - X^B_{i,j}) = 0$ indicates the reduced loading of the jth pollutant if the ith parcel is added to a system of riparian buffers, either through purchase of the fee simple title or the acquisition of a conservation easement. The parcels under consideration have been selected because their owners have indicated a willingness to sell or to be compensated for having their title restricted by a conservation easement, as specified by the City of New York. Let P_i denote the purchase price or the cost of the desired easement for the ith parcel. The various pollutants are weighted according to $W_j = 0$, which indicates their relative damage to water quality in the reservoir or water supply system. The decision (or choice) variables are the binary variables $B_i=\{0,1\}$, where $B_i=0$ indicates that the ith parcel has not been added to the system of riparian buffers, while $B_i=1$ indicates that the parcel has been acquired as a riparian buffer; either through purchase or easement acquisition. Finally, let M denote the total budget for purchase or easement acquisition. The problem is to acquire parcels that create a system of riparian buffers which maximizes the weighted reduction in pollutants, subject to $B_i=\{0,1\}$ and the budget constraint $\sum_{i=1}^{I} B_i P_i \le M$. This problem may be stated as

$$\text{Maximize} \quad \sum_{i=1}^{I}\sum_{j=1}^{J} B_i W_j (X_{i,j} - X^B_{i,j})$$

$$\text{Subject to} \quad \sum_{i=1}^{I} B_i P_i \le M$$

$$B_i = \{0,1\} \text{ for } i = 1,2,\ldots,I, \; j = 1,2,\ldots,J$$

Implementation of this model will require working with personnel in the New York City Department of Environmental Protection (NYC DEP) to determine (a) the parcels where fee title or easements might be acquired, (b) the likely reduction in pollutant loadings, $(X_{i,j} - X^{B}_{i,j}) = 0$, for each parcel and each pollutant, (c) the weight, W_j, to be assigned to each pollutant, (d) the reservation price, P_i, for fee title or conservation easement on the ith parcel, and finally, (e) the funds available, M, to establish the system of riparian buffers.

This is only one possible problem statement. After consultation with NYC officials, there may be modifications leading to variations on the above problem. In refining the model, a comparison of the "optimal buffer portfolio" will be made with the parcels actually acquired by NYC. This will help determine if the relative weights, W_j, are adequate in representing the criteria used by the NYC DEP in prioritizing parcels. Such a comparison will hopefully establish a dialogue that will lead to the most useful model for establishing a system of riparian buffers.

This problem can be programmed on an Excel spreadsheet and solved using Excel's Solver. See Conrad (1999) for numerous examples using Solver to solve resource allocation problems and see Martello and Toth (1990) for a discussion of the classic, 0/1, knapsack problem.

REFERENCES

Conrad, J. M. 1999. *Resource Economics,* Cambridge University Press, New York.

Martello, S and P. Toth. 1990. *Knapsack Problems: Algorithms and Computer Implementations,* Wiley Interscience Series in Discrete Mathematics and Optimization, John Wiley & Sons, New York.

National Research Council. 1999. *Watershed Management for Potable Water Supply: Assessing New York City's Approach,* National Academy Press, Washington, D.C.