A Bayesian Network-Based Decision Analytical Approach to Watershed Management Decisions

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ABSTRACT

This paper describes a decision analytical approach to ambient water quality control strategies for mercury contamination in the Cache Creek watershed, which is a significant source of mercury to the San Francisco Bay in California, USA. Both the San Francisco Bay and Cache Creek are designated as "impaired" due to elevated mercury levels in water and fish tissue. The development of a mercury control strategy is required under the Clean Water Act's Total Maximum Daily Load (TMDL) regulations, which are currently being implemented around the United States. The major local sources of mercury in the Cache Creek watershed include diffuse (nonpoint source) legacy mercury mining wastes, geothermal groundwater sources, high naturally-occurring mercury soil concentrations, and atmospheric deposition from local sources. Possible mitigation controls include mine waste load reductions, soil/stream bank erosion controls, sediment traps, and controls on environmental factors that promote the introduction of mercury into the aquatic food chain. This research explores the use of decision analysis in a "watershed approach" context, an approach that brings together stakeholders and regulatory personnel to devise integrated watershed strategies that take into consideration the multiple interests and goals of the participants. In particular, we are exploring the use of Bayesian networks for predicting the consequences of mitigation strategies on the principal environmental endpoints of interest to stakeholders, i.e., methylmercury concentration in fish tissue and water. In this work, we are framing the decision problem as designing a mercury mitigation strategy that is predicted to meet regulatory limits for these two endpoints with acceptable certainty at minimum mitigation cost. We are exploring the use of penalty functions based on the "probability of compliance" with targets (regulatory limits) for methylmercury concentration in water and fish, transforming the decision problem into a cost-effectiveness exercise. By varying the penalty parametrically, the group can explore tradeoffs between costs and compliance certainty without having agreed upon consensus penalty values. This approach improves upon the use of arbitrary "margins of safety" to hedge against uncertainty in TMDL deliberations and the common use of deterministic environmental models to predict TMDL decision outcomes. Such a model and approach could be modified to support a variety of TMDL decision situations, including information gathering decisions, load allocation decisions, mitigation project evaluations, and the evaluation of various adaptive management approaches.