Modeling Total Maximum Daily Load Information Collection Decisions with Bayesian Networks

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Abstract: Surface water pollution mitigation (Total Maximum Daily Load) decisions are subject to large uncertainties and controversial value trade-offs involving environmental/ecological targets and conflicting socioeconomic values. Often, pre- and post-mitigation-decision information collection activities are treated as "value-free assessment problems" that ignore the decision-making context. The essential insight is that information gathering/monitoring decisions, whether made before or after allocation decisions, draw their value from making better load allocation/mitigation decisions, which include considerations of risks and value trade-offs. For this reason, information gathering decision models should *build on* load allocation/mitigation decision models. This work explores two approaches for prioritizing TMDL information collection activities using Bayesian network-based decision analytical models, illustrating the approach with a mine-related mercury Total Maximum Daily Load case study. Both approaches make use of a Bayesian network-based decision model (mitigation decision model) for choosing a load allocation/mitigation strategy. The mitigation decision model is a causal Bayesian network relating potential control efforts, total mercury loadings, and the resulting microbially-produced methyl mercury concentrations and is based on the best current causal understanding from the available data, applicable process-based models, and expert judgment. The use of a Bayesian network allows us to propagate uncertainties to estimate the probability of compliance with the TMDL water quality targets for each strategy. Value trade-offs can be explored using a parametric value model that does not require consensus among stakeholders. Because the value model is parametric, it does not generate a "best strategy", but rather maps out best strategies along the dimensions of social costs of non-compliance for the various TMDL targets. The first information collection prioritization approach uses sensitivity analysis and value of perfect information analysis performed directly on the mitigation decision model to suggest which variables are most important for further study. While this approach provides useful information about the upper limit of how much to spend to reduce uncertainty on a particular variable, it does not explicitly evaluate the usefulness of a real-world experiment. The second approach uses an explicit information collection decision model also implemented as a Bayesian network. This involves expanding the TMDL allocation/mitigation Bayesian network to include additional variables that represent the information collection decision. The additional variables comprise the cost and expected results of the study. The cost is conditioned on the information collection decision and the results of the study are conditioned on the environmental variable being studied. The second approach requires additional probabilistic assessments of the likelihood of the experimental results given each state of the variable being studied. While the second approach definitively addresses the question of whether or not a particular experiment is worthwhile, it comes at the price of additional probabilistic assessments and modeling.