AIIM

Association for Information and Image Management

1100 Wayne Avenue, Suite 1100
Silver Spring, Maryland 20910
301/587-8202

Centimeter

Inches

MANUFACTURED TO AIIM STANDARDS
BY APPLIED IMAGE, INC.

1 of 1

Conf-9405183--1

PNL-SA-24336

INTEGRATED ENVIRONMENTAL MONITORING - PROTOTYPE DEMONSTRATION

R. W. Bryce
L. W. Vail
D. D. Hostetler
P. D. Meyer
T. J. Carlson
P. L. Miller

May 1994

Presented at the
6th National Technical Information
Exchange Workshop
May 10-12, 1994
Kennewick, Washington

Prepared for
the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
Richland, Washington 99352

Integrated Environmental Monitoring

Prototype Demonstration

Integrated Environmental Monitoring expedites the monitoring process and reduces costs by:

- optimizing the scheduling and allocation of monitoring resources
- ensuring relevant information is communicated to stakeholders
- quantifying stakeholder objectives
- ensuring feedback is immediate and continuous
- explicitly and quantitatively considering uncertainty.

Introduction

Groundwater monitoring is an important activity at U.S. Department of Energy (DOE) sites. Monitoring programs at DOE facilities have evolved in response to operational needs at the facilities, public outcries for information, regulatory requirements, DOE orders, and improvements in monitoring technology. Decisions regarding sampling location, sampling frequency, analyses performed, and other aspects of monitoring network design can have major implications for detecting releases and for making subsequent higher level decisions about facility operation and remediation.

Decisions about monitoring network design are usually based on project staffs' interpretations of regulatory requirements and technical guidance documents, and on negotiations between facility representatives and regulatory agencies. Traditionally, decisions about technical aspects of monitoring network design have not been based on an evaluation of quantitative objectives. It is thus difficult to justify the cost of a monitoring network in terms of reduced uncertainty, improved efficiency, or other objective measurements of monitoring network performance.

Massmann and Freeze (1987) (and, more generally, Freeze et al. 1990) suggested a framework for making hydrogeologic decisions, taking into account the objectives of the decision makers, regulatory requirements, uncertainties in the geology and hydrology of the site and the economics of the various options. PNL's Integrated Environmental Monitoring Initiative (IEM) is extending the Massmann and Freeze framework to enhance its applicability to groundwater monitoring problems at Hanford. A prototype tool set has been assembled and, through the IEM initiative, will be demonstrated.

Description of the IEM Concept

The IEM concept is a set of analytical procedures and software tools that can be used to improve monitoring network design decisions. Such decisions include the choice of monitoring locations, sampling frequencies, sensor technologies, and monitored constituents. IEM provides a set of monitoring alternatives that balance the tradeoffs between competing monitoring objectives such as the minimization of cost and the minimization of uncertainty. The alternatives provided are the best available with respect to the monitoring objectives, consistent with the physical and chemical characteristics of the site, and consistent with applicable regulatory requirements. The selection of the best monitoring alternative to implement is made by the stakeholders after reviewing the alternatives and tradeoffs produced by the IEM process.

IEM is consistent with other monitoring approaches such as the Data Quality Objectives process, the Observational Approach, and the Streamlining Approach for Environmental Restoration (SAFER). IEM complements these approaches by providing a formal, quantitative means to design monitoring networks. Like these other approaches, the IEM is not intended to function as a black box analytical tool, but as an iterative procedure involving stakeholders and a variety of technical analysts.

The framework of IEM is represented in Figure 1. The IEM process begins with a precise, quantifiable statement of the monitoring objectives as defined by the stakeholders. The next step is to generate a set of monitoring alternatives that represent the tradeoffs that must be made between competing objectives. Several components are required to generate optimal monitoring network design alternatives. A conceptual model that represents the current understanding of the site ensures that the monitoring alternatives are consistent with the physical and chemical characteristics of the site. An uncertainty assessment quantifies what is unknown and uncertain about site characteristics. The conceptual model, the uncertainty analysis, and the objective statements are combined in a decision model that provides the actual mechanism for the generation of optimal monitoring alternatives. The decision model is a mathematical statement of the monitoring network decision process.

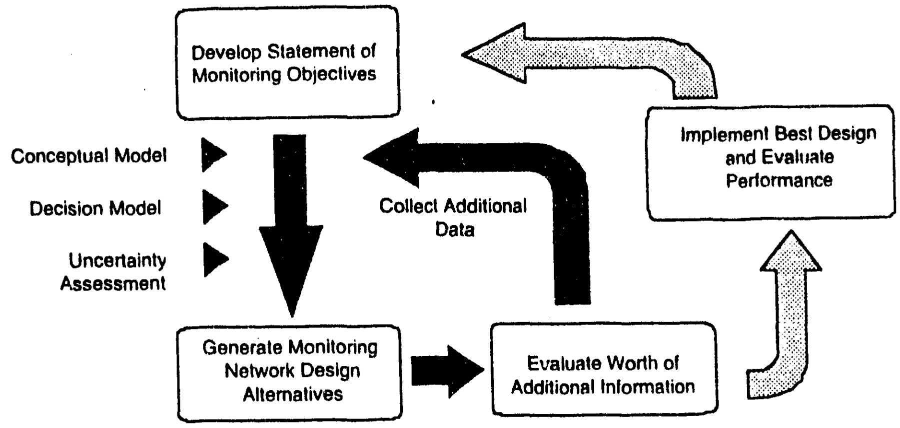

Figure 1. IEM Framework

For situations where the uncertainties in monitoring network performance are large, IEM provides a means to evaluate the worth of additional data in reducing that uncertainty. This evaluation balances the cost of collecting additional data against the impact of this data on the monitoring network alternatives generated by the decision model. When additional data is expected to significantly alter the network design, the data should be collected. This new data will result in changes to the conceptual model and the uncertainty assessment and, potentially, in the generation of a new set of network design alternatives. When additional data is not expected to alter the network design or when this data is very costly to collect, the best design from the current set of alternatives should be implemented. If the performance of the implemented monitoring network fails to meet the expectations, the monitoring objectives may be refined and the IEM process revisited.

Application Identification

A monitoring scenario has been chosen to demonstrate the IEM toolset. The criteria for selection of a problem included:

- relevance and applicability to current Hanford monitoring needs
- good prospects of stakeholder (DOE, users, regulatory agencies, public) acceptance
- a demonstration that achieves results with the available resources.

Two processes were used to identify the first two criteria (relevant monitoring issues for the Hanford Site and determining if the application would have stakeholder acceptance). The first process was to interview technical staff and project managers involved in groundwater monitoring on the Site. The second was to examine the regulatory environment in which the IEM toolset may be applied. Hanford's regulatory environment includes requirements of the Tri-Party Agreement and its revisions as well as the Resource Conservation and Recovery Act (RCRA) and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) requirements.

The third criterion requires that the demonstrations be achievable with the resources available.

The following decribes the processes in more detail.

Technical Interviews

Technical staff and project managers from the Groundwater Surveillance Project, RCRA compliant monitoring program, Operational Monitoring program, and CERCLA characterization effort were briefed on the IEM concept and were then asked a series of questions designed to identify the objectives and constraints of the monitoring programs. The Tri-Party Agreement was reviewed to identify any objectives it may include that are not yet factored into the ongoing monitoring programs.

The interviews confirmed that quantitative tools for monitoring design are needed and that a similar set of tradeoffs exist for a variety of monitoring programs on the Site. The need to quantify the tradeoffs between the number of points sampled, frequency of sampling, number of analyses performed, and cost of sample collection and analysis is a problem common to the monitoring programs.

All interviewees recognized the utility (even necessity) of having quantitative tools to help configure their monitoring networks and justify program resource needs. The objectives quantified in the IEM tools must be clearly related to the actual objectives of concern for the people who are program "stoppers," DOE in one case, the regulators in the other. The IEM toolset needs to communicate its results in an instinctive, visceral way. The tools do not have to be ultra-sophisticated but must be technically defensible.

Regulatory Framework

Though many of the specific requirements applicable at Hanford's 55 past practice area operable units and 78 RCRA treatment storage and disposal facility groups will vary; virtually all will require monitoring, characterization, and subsequent consensual decisions about detection and remediation of any contaminant releases. In general, monitoring networks are required to detect releases from waste disposal units, or, if a release has occurred, they are required to determine the extent of contamination so that decisions can be made about remediation or corrective action.

Recent changes to the Tri-Party Agreement were based in part on a response to values expressed by the public. Among the values expressed by the public was the need to protect the Columbia River. The U.S. Department of Energy, Washington State Department of Ecology, and the U.S. Environmental Protection Agency have responded to this value by agreeing to accelerate cleanup along the river and to accelerate the process to transform hazardous and radioactive tank waste into a solid, safer, and more stable form.

Demonstration of the IEM with Available Resources

To meet the third criterion, the framework and toolset will be applied to the hypothetical problem through the use of a high-resolution aquifer simulator. A hypothetical problem has been chosen rather than a real one so that the available funding can be focused on the development of the framework and its implementation and not spent constructing wells and analyzing actual groundwater samples. The next step in the process will be to demonstrate the prototype on an actual monitoring problem.

The Demonstration

The hypothetical monitoring problem used to demonstrate the framework is defined by both the characteristics of the site and the objectives of the investigation. The characteristics of the hypothetical site are:

- The waste site is located 10 to 20 kilometers from a high quality river relied upon for recreational and domestic uses.
- The waste site may potentially leak conservative contaminants (e.g., tritium or iodine-129) into the groundwater.
- The hydrogeology of the site is similar to the Hanford Site unconfined aquifer hydrogeology. The details of the specific waste site and potential contaminant pathways are not known to the investigators.

The objectives of the monitoring effort are based on the public value stated in the Tri-Party Agreement to protect the river. Three objectives for the demonstration have been chosen:

- minimize the probability that contaminants will reach the river undetected
- maximize the number of years of advance notice before contamination reaches the river
- minimize the cost of site characterization and monitoring.

The second objective is important because an early notification that the contaminants will reach the river allows more remedial alternatives than a late notification.

Two possible monitoring network designs that reflect these objectives in different ways are shown in Figures 2 and 3. While these are not network designs that are likely to come out of the optimization process they are presented here to illustrate the benefits of the methodology. Figure 2 represents a network designed to emphasize the first objective. The monitoring wells have all been located close together along the river. With this monitoring configuration, the probability is very low that a plume will reach the river undetected. The drawback to this design is that no advance notice is given, so no remedial action can be taken and the plume will ultimately reach the river. Figure 3 shows a monitoring network that balances the first two objectives allowing for significant advance notice of river contamination and preserving a low probability that a plume will reach the river undetected.

Figure 4 shows one representation of the tradeoffs between the three objectives. The x-axis represents the number of months of advance notice a network will provide between detection of a contaminant plume and its arrival at the river. The y-axis represents the cost of network construction and operation. The contours represent increasing probability that an undetected plume will reach the river.

Any individual monitoring network is represented by a single point on Figure 4. For instance, the network portrayed in Figure 3 might be represented as point A in Figure 4. This network has a cost of $18 million and provides an advance warning of 28 months with a 25% probability of an undetected plume reaching the river. If an alternative monitoring network with costs reduced by one-third is implemented, Figure 4 shows that the probability of an undetected plume will increase to as much as 35% (point B) or the advance warning will be reduced to as little as 4 months (point C). Evaluation of these tradeoffs provides a quantitative basis for network design. The demonstration will generate a similar set of relationships for the simulated environment.

The benefits of using the IEM to design monitoring networks are that the design selected will be based on quantitative objectives derived from stakeholder interests, uncertainty is quantitatively factored into the network design, and the process is documented through the construction of the conceptual, decision, and data worth models. The value of additional data is assessed quantitatively and the characterization/monitoring effort will proceed in an iterative fashion to gather information on hydrologic characteristics and contaminant distribution information until it is determined that the value of additional data does not justify its collection.

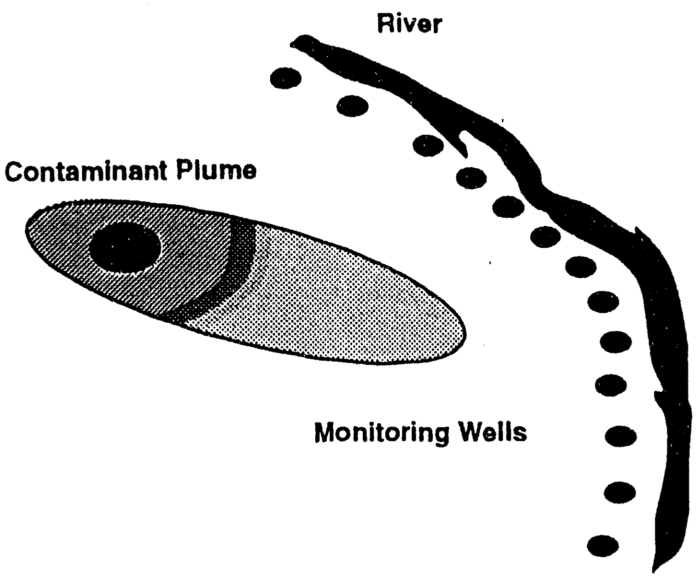

Figure 2. A Monitoring Network Designed to Emphasize the Objective of Minimizing the Probability that a Contaminant Will Enter the River Undetected

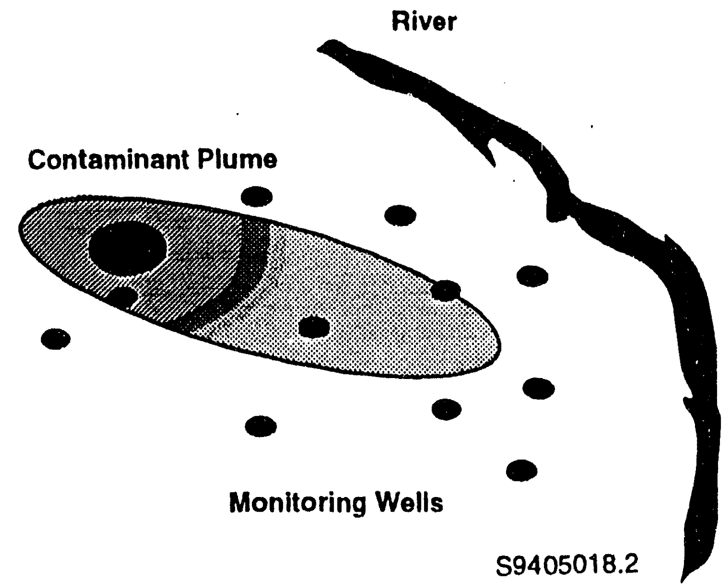

Figure 3. A Monitoring Network Designed to Balance the Three Objectives of the Demonstration Problem

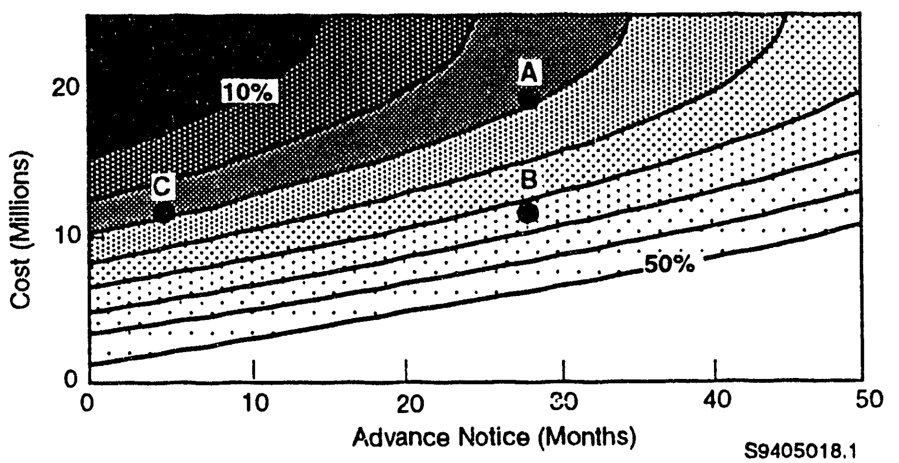

Figure 4. Diagram Illustrating Tradeoffs Between the Three Objectives in the Demonstration Problem. Curves on the graph ranging from 10% to 50% represent increasing probability that a contaminant plume will not be detected.

References

Freeze, R. A., J. Massmann, L. Smith, T. Sperling, and B. James. 1990. "Hydrogeologic Decision Analysis: 1. A Framework." *Ground Water* Vol. 28, No. 5, pp. 738-765.

Massman, J., and R. A. Freeze. 1987. "Groundwater Contamination from Waste Management Sites: The Interaction Between Risk-Based Engineering Design and Regulatory Policy, 1, Methodology." *Water Resources Research* Vol. 23, No. 2, pp. 351-367.

For more information regarding IEM, contact:

Bob Bryce, Pacific Northwest Laboratory
P.O. Box 999, K6-96
Richland, Washington 99352
(509) 376-8345 — email: rw_bryce@pnl.gov

Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
by Battelle Memorial Institute

DATE
FILMED
8/11/94

END