U.S.NRC
UNITED STATES NUCLEAR REGULATORY COMMISSION
Protecting People and the Environment

Modeling, Monitoring and Remediating Radionuclide Transport in Ground Water

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Overview

- Regulatory Basis for Assessing Ground-Water Transport
- Conceptual Site Model of Radionuclide Transport
- Site-Specific Modeling Coupled to Monitoring
- Modeling Issues and Benefits
- Monitoring and Modeling Interface - Performance Indicators
- Remediation Decisions based on Modeling and Monitoring
- Application to Nuclear Facility Sites
- Information Sources

Regulatory Basis

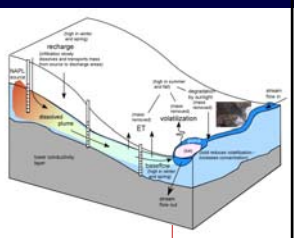
20.1406 Minimization of Contamination:

(a) Applicants for licenses, other than early site permits and manufacturing licenses under part 52 of this chapter and renewals, whose applications are submitted after August 20, 1997, shall describe in the application how facility design and procedures for operation will minimize, to the extent practicable, contamination of the facility and the environment, facilitate eventual decommissioning, and minimize, to the extent practicable, the generation of radioactive waste.

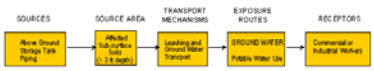
(b) Applicants for standard design certifications, standard design approvals, and manufacturing licenses under part 52 of this chapter, whose applications are submitted after August 20, 1997, shall describe in the application how facility design will minimize, to the extent practicable, contamination of the facility and the environment, facilitate eventual decommissioning, and minimize, to the extent practicable, the generation of radioactive waste.

Conceptual Site Model

- Hypothetical representation of the site
- Organize and communicate information
- Subject to testing with new characterization and monitoring data
- Supports remediation decision

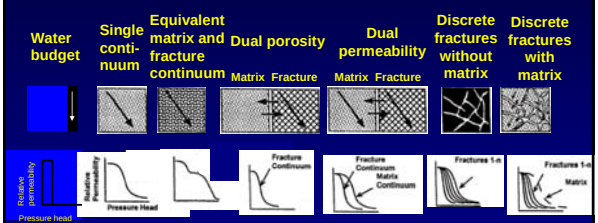


Exposure Pathway Flowchart



Hierarchy of Conceptual Flow Models

Models to simulate flow in soils, sediments, unsaturated fractured rock (after Altman et al., 1996)



Complexity

Model abstraction

ARS – Yakov Pachepsky, 2006

Site-Specific Modeling Coupled to Monitoring

Why monitor and model?

Characterize natural and engineered systems:

- ✓ Collect information to identify significant Features, Events and Processes
- ✓ Develop and evaluate site conceptual models
- ✓ Guide data collection including monitoring, sampling and geophysical surveys
- ✓ Technical bases for determining remediation

Photo by John Selker, Oregon State University

Ground-Water Modeling Benefits

- ✓ Integrates disparate characterization and monitoring data into a logical framework
- ✓ Reduces uncertainties and help to identify location of monitoring to confirm hydrogeologic system behavior
- ✓ Forecasts impacts (doses due to exposure and uptake)
- ✓ Provides bases for decision-making on the need to interdict, mitigate and remediate abnormal releases
- ✓ Assists in designing and monitoring remediation program (e.g., monitored natural attenuation thru pump-and-treat)
- ✓ Communicates understanding of the system to the public and facilitates technical interactions

Monitoring and Model Interface

✓ Confirm system behavior is within envelope of the expected performance

- ➢ of engineered structure, systems and components
- ➢ of natural systems
- ➢ of regulatory requirements

✓ Site-Specific Model

- ➢ will probably not be simplified (abstracted) version used in PA
- ➢ may include state variables not in abstracted version
- ➢ state variables are potential ***Performance Indicators***
- ➢ should evolve with performance monitoring analyses

Remediation Decisions Based on Modeling & Monitoring

Table 1.1. Context for *In Situ* Bioremediation of Uranium in the Saturated Zone

	←Increasing cost ——— Increasing technical uncertainty→						
	←Active remediation Passive remediation→						
	Physical removal		*Chemical remediation*	*Bioremediation*			*"No action"*
PROCESS	Excavation and removal	Pump and treat	Abiotic treatment zones or walls	**Forced gradient displacive amendment**	**Forced gradient non-displacive amendment**	**Natural gradient displacive amendment**	**Natural gradient non-displacive amendment**	Monitored natural attenuation
COMMENTS	Usually highest cost and worker risk	May require extended operation period with limited results	Issues with pore clogging and rerouting of flow or breakthrough and predicted lifetime	Cost for maintaining gradient provides control on flow direction, displacement of contaminant may confound results.	Cost for maintaining gradient. Control on flow direction	Difficult to separate injectate dilution from microbial effects	Minimal dilution effect. Limited donor concentration	May require extended period of monitoring with risk that outcome may not meet regulatory requirements

from Long, Yabusaki et al, 2008 (PNNL-17295)

Monitoring Program Considerations

- Environmental Pathway Identification & Assessments

✓ Anticipate what Radionuclides may be released (H-3, Sr-90, Cs-137, Co-60, etc) and their Sources
✓ Detectability of Radionuclides close to the Sources
✓ Identify Surface- and Ground-Water Relationships
✓ Examine Vulnerability of Local Drinking Water Sources (Ground- and Surface-Water Sources)
✓ Estimate Potential Radionuclide Transport Pathways
✓ Site-Specific Data as Input to Dose Assessment Calculations
✓ Ground-Water Transport Analysis for Estimating Radionuclide Fluxes to the Accessible Environment

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Monitoring to Determine Efficacy of In Situ Bioremediation

Photo of wells and sampling apparatus including flow cell for measurement of pH, Eh, DO, T, and conductivity during slow purge sampling. Foreground shows injection manifold and stainless steel injection lines to injection wells. [From Long, Yabusaki et al, 2008 (PNNL-17295)]

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Application to Nuclear Facility Sites

Site Characterization, Performance Assessment & Radiological Environmental Monitoring Programs together should:

✓ Develop Site Conceptual Model
✓ Identify Potential Sources of Radionuclide Leaks, Spills and Releases & Focus on Detectability and Monitoring Methods
✓ Systematically and Quantitatively Assess Predictive Uncertainty in Flow and Transport Modeling
✓ Utilize Monitored Performance Indicators to Parameterize, Calibrate and Test Alternative Conceptual Site Models
✓ Use a Statistically Rigorous Approach, such as the Bayesian Model Average Approach, to Compare Models and Analyze Monitoring Data

Provides the Technical Bases for Decision Making such as the Need for and Approaches to Remediation

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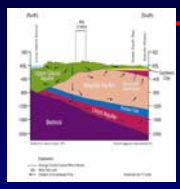
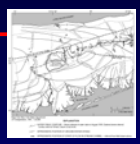
Case Histories - Brookhaven

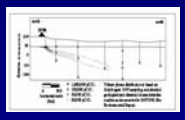


Regional Geologic Setting

Tritium Plume Plan Map



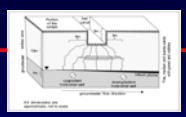
Regional Ground Water Flow

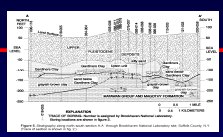


Tritium Plume X-Section

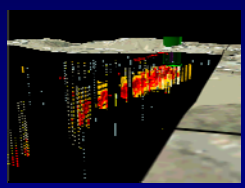
Site Ground Water Flow

Synthesis of CSM & Flow and Transport Models





- AES developed a CSM that incorporated influence of nearby pumping wells and 3-D visualization of data
- Used flow and transport modeling to validate that our CSM reflected observed monitoring data. (Modeling was done in Excel, MODFLOW, and GMS)
- Once validated, used flow and transport modeling to evaluate remediation alternatives



Information Source – NUREG/CR-6948

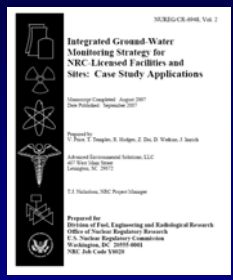
- Technical bases for developing guidance on ground-water monitoring for NRC-licensed sites
- Systematic methodology to integrate monitoring with modeling
- **http://www.nrc.gov/reading-rm/doc-collections/nuregs/contract/cr6948/v1/index.html**

NUREG/CR-6948, Vol. 1

Integrated Ground-Water Monitoring Strategy for NRC-Licensed Facilities and Sites: Logic, Strategic Approach and Discussion

Information Source – NUREG/CR-6948

- Lessons-Learned for developing guidance on ground-water monitoring for NRC-licensed sites
- Case Studies which includes Brookhaven radionuclide plume remediation and monitoring
- **http://www.nrc.gov/reading-rm/doc-collections/nuregs/contract/cr6948/v2/index.html**


NUREG/CR-6948, Vol. 2

Integrated Ground-Water Monitoring Strategy for NRC-Licensed Facilities and Sites: Case Study Applications

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