Reference Database for Task 1 Report

Author 1	Author 2	Facility or Agency
		IAEA

Citation
International Atomic Energy Agency, 1999. Near Surface Disposal of Radioactive Waste, Safety Requirements. Safety Standards Series No. WS-R-1.

Journal

Title
Near Surface Disposal of Radioactive Waste, Safety Requirements.

Document	Year
WS-R-1	1999

Why	How	What	Where
Design	Performance		Saturated

Abstract

Author 1	Author 2	Facility or Agency
		Fernald

Citation
2003. Comprehensive Stewardship Plan, Fernald Closure Project, Fernald, Ohio. Report, U.S. Department of Energy.

Journal

Title
Comprehensive Stewardship Plan, Fernald Closure Project, Fernald, Ohio.

Document	Year
	2003

Why	How	What	Where

Abstract

Author 1	Author 2	Facility or Agency
		Yucca

Citation

NEA/OECD/IAEA. An International Peer Review of the Yucca Mountain Project TSPA-SR. NEA-3682.

Journal

Title

An International Peer Review of the Yucca Mountain Project TSPA-SR

Document	Year
NEA-3682	2002

Why	How	What	Where

Abstract

This Summary presents the key results of the international peer review of the US Department of Energy (USDOE) Total System Performance Assessment supporting the site recommendation process (TSPA-SR) issued in December 2000 for the Yucca Mountain site. The review was carried out at the request of the USDOE Yucca Mountain Project (YMP) and was jointly organized by the Nuclear Energy Agency (NEA) of the Organisation for Economic Cooperation and Development (OECD), and the International Atomic Energy Agency (IAEA) of the United Nations. The primary intended audience for this review is USDOE higher level management and relevant technical staff. However, it is hoped that this review will also be of value to the regulators, various ongoing review groups and other stakeholders including the public.

This review is the outcome of the work of an international review team of ten members, over a period of about four months. The main focus of the review is the TSPA-SR document, with partial review of some supporting documents. Given the limited time available, the IRT was primarily concerned with the higher level features of the methodology rather than with details of individual submodels that are subject to change and that are undergoing detailed peer reviews by specialists in the relevant areas. It is therefore an expression of findings based on a brief review and cannot be considered as an in-depth analysis of all of USDOE's work on Yucca Mountain over the last ten years.

Author 1	Author 2	Facility or Agency
		Nuclear Energy Agency

Citation

NEA/OECD, 1999. Water-Conducting Features in Radionuclide Migration, Workshop Proceedings, Barcelona, Spain, 10-12 June, 1998. Nuclear Energy Agency, Organisation for Economic Co-operation and Development.

Journal

Title

Water-Conducting Features in Radionuclide Migration, Workshop Proceedings, Barcelona, Spain, 10-12 June, 1998.

Document	Year
	1999

Why	How	What	Where

Abstract

GEOTRAP is the OECD/NEA Project on Radionuclide Migration in Geologic, Heterogeneous Media carried out in the context of site evaluation and safety assessment of deep repository systems for long-lived radioactive waste. Water-conducting features can, for example, determine the rate of radionuclide release from the near-field to the far-field, the rate at which radionuclides can migrate with flowing groundwater, and the degree of retention in the geosphere. Therefore, the characterisation of the structure and properties of water-conducting features is an important requirement for any performance assessment of deep repository systems. The third GEOTRAP workshop, "Characterisation of Water-Conducting Features and their Representation in Models of Radionuclide Migration" (Barcelona, Spain, 10-12 June 1998), addressed these issues and provided an overview of current developments in this technical field - both within national waste management programmes and the scientific community. These developments reinforce confidence in the concepts and models used for repository performance assessment. In addition to the material presented, this publication includes a technical synthesis of the workshop, reflecting the discussions that took place as well as the conclusions and recommendations made, notably during the working group sessions.

Author 1	Author 2	Facility or Agency
		Nuclear Energy Agency

Citation

NEA/OECD, 2000. Features, Events and Processes (FEPs) for Geologic Disposal of Radioactive Waste, An International Database. Nuclear Energy Agency, Organisation for Economic Co-operation and Development.

Journal

Title

Features, Events and Processes (FEPs) for Geologic Disposal of Radioactive Waste.

Document	Year
	2000

Why	How	What	Where

Abstract

Safety assessments of disposal sites for radioactive waste involve analyses of potential releases of radionuclides from the disposed waste and subsequent transport to the human environment. An important stage of assessment is the identification and documentation of all the features, events and processes (FEPs) that may be relevant to long-term safety. This report provides an international compilation of FEPs as well as a basis for selecting the FEPs that should be included in safety analyses.

Author 1	Author 2	Facility or Agency

Citation

DOE, 1997. Linking Legacies, Connecting the Cold War Nuclear Production Processes to Their Environmental Consequences,. U.S. Department of Energy, DOE/EM-0319.

Journal

Title

Linking Legacies, Connecting the Cold War Nuclear Production Processes to Their Environmental Consequences.

Document	Year
DOE/EM-0319	1997

Why	How	What	Where

Abstract

Author 1	Author 2	Facility or Agency

Citation

Journal

Title
Scenarios at the Greater Confinement Disposal Facility, Area 5 of the Nevada Test Site.

Document	Year

Why	How	What	Where

Abstract

Author 1	Author 2	Facility or Agency
		NEA

Citation

NEA/OECD, 2003. Engineered Barrier Systems and the Safety of Deep Geological Repositories. ISBN 92-64-18498, EUR 19964 EN.

Journal

Title

Engineered Barrier Systems and the Safety of Deep Geological Repositories

Document	Year
EUR 19964 EN	2003

Why	How	What	Where

Abstract

Geological disposal was defined in a 1995 Collective Opinion of the Nuclear Energy Agency (NEA) Radioactive Waste Management Committee entitled The Environmental and Ethical Basis of Geological Disposal. According to page 16 of that publication, geological disposal is provided by a system that will:
(a) "isolate the wastes from the biosphere for extremely long periods of time", and
(b) "ensure that residual radioactive substances reaching the biosphere will be at concentrations that are insignificant compared, for example, with the natural background levels of radioactivity."
Geological disposal should also "provide reasonable assurance that any risk from inadvertent human intrusion would be very small".
Repositories for the disposal of radioactive waste generally rely on a multi-barrier system to isolate the waste from the biosphere. This multi-barrier system typically comprises the natural geological barrier provided by the repository host rock and its surroundings and an engineered barrier system (EBS). This multi-barrier principle creates an overall robustness of the system that enhances confidence that the waste will be successfully contained.
Ensuring that an EBS will perform its desired functions requires integration of site characterisation data, data on waste properties, data on engineering properties of potential barrier materials, in situ and laboratory testing, and modelling.
The NEA Integration Group for the Safety Case (IGSC) EBS project is intended to provide a greater understanding of how to achieve the integration needed for successful design, construction, testing, modelling and performance assessment (PA) of engineered barrier systems. In addition, the EBS project will help to clarify the role that an EBS can play in the overall safety case for a repository.

Author 1	Author 2	Facility or Agency
		International Atomic Energy Agency

Citation

International Atomic Energy Agency, 2002. Scientific and Technical Basis for the Near Surface Disposal of Low and Intermediate Level Waste. Technical Report Series No. 412.

Journal

Title

Scientific and Technical Basis for the Near Surface Disposal of Low and Intermediate Level Waste.

Document	Year
TRS-412	2002

Why	How	What	Where
Design			Unsaturated

Abstract

Providing guidance on the disposal of radioactive waste constitutes and important and integral component of the IAEA programme on radioactive waste management. Low and intermediate level waste, even though it contains only a small fraction of the total activity produced in the world, makes up more than 90% of the total volume of radioactive waste. Most of the radioactive waste produced in many developing Member States is low and intermediate level waste.

This report discusses, in a generic sense, the scientific and technical basis for the disposal of low and intermediate level waste in near surface facilities, drawing on the experience of Member States that have existing operational disposal facilities and on relevant national and international research and development studies. The focus is on basic principles, approaches, methodologies and technical criteria considered to be relevant for the design and safe operation of a near surface disposal facility, and for providing a convincing safety case that also covers the periods following repository closure and the end of institutional controls. As a result of the generic nature of the discussion, the described scientific and technical basis is quite comprehensive. For a specific repository, depending on the quantities and characteristics of the waste, the nature of the engineered barriers and the features of the site, the relative importance of the different scientific and technical elements is subject to change. As a consequence, the detailed scientific and technical basis for a specific repository depends on the various features of the disposal system.

It is worth noting that the information presented in this report is based on the experience of Member States with sizeable nuclear programmes and significant inventories of radioactive waste. It is logical for such Member States to adopt progressively more sophisticated repository designs; this high level of sophistication is reflected in the content of this report. Member States with limited nuclear activities and small amounts of radioactive waste may find that simple repositories with minimal engineering are acceptable, provided such designs are supported by a convincing safety case.

Author 1	Author 2	Facility or Agency
		EMSP

Citation

2001. Research Accomplishments for the Environmental Management Science Program: Vadose Zone Edition, U.S. Department of Energy, Report.

Journal

Title

Research Accomplishments for the Environmental Management Science Program: Vadose Zone Edition.

Document	Year
	2001

Why	How	What	Where
Characterization			Unsaturated

Abstract

Summary of vadose zone projects conducted by the U.S. Department of Energy Office of Environmental Management Office of Science. Project summaries and reports are available on-line at: http://emsp.em.doe.gov/pdfs/FY2001YearEnd/ResAccomp(Nov2001).pdf.

Author 1	Author 2	Facility or Agency

Citation

2001. Long-Term Monitoring Sensor and Analytical Methods Workshop. U.S. Department of Energy, Characterizing, Monitoring, and Sensor Technology Crosscutting Program & Subsurface Contaminants Focus Area, Workshop Report.

Journal

Title

Long-Term Monitoring Sensor and Analytical Methods Workshop.

Document	Year
	2001

Why	How	What	Where
Monitoring	Sensors	mixed	Saturated

Abstract

Author 1	Author 2	Facility or Agency
		INEEL

Citation
Advanced Tensiometer for Vadose Zone Monitoring. Characterization, Monitoring, and Sensor Technology Crosscutting Program and Subsurface Contaminants Focus Area. U.S. Department of Energy, September 2002.

Journal

Title
Advanced Tensiometer for Vadose Zone Monitoring.

Document	Year
DOE/EM-0639	2002

Why	How	What	Where
Monitoring	Devices	tensiometer	Unsaturated

Abstract

Author 1	Author 2	Facility or Agency
		NRC

Citation

NRC, 2000. A Performance Assessment Methodology for Low-Level Radioactive Waste Disposal Facilities. U.S. Nuclear Regulatory Commission, Document NUREG-1573.

Journal

Title

A Performance Assessment Methodology for Low-Level Radioactive Waste Disposal Facilities.

Document	Year
NUREG-1573	2000

Why	How	What	Where
Design	Performance		

Abstract

The relationships between the overall 10 CFR Part 61 data and design requirements, and detailed low-level radioactive waste (LLW) performance assessment needs, are not directly apparent from the existing U.S. Nuclear Regulatory Commission (NRC) guidance documents. To address this concern, NRC's Performance Assessment Working Group (PAWG) has prepared this technical methodology as it relates to the objective concerned with the radiological protection of the general public - 10 CFR 61.41. Specifically, this information includes the PAWG's views on: (a) and acceptable approach for systematically integrating site characterization, facility design, and performance modeling into a single performance assessment process; (b) five principal regulatory issues regarding interpreting and implementing Part 61 performance objectives and technical requirements integral to an LLW performance assessment; and (c) implementation of NRC's performance assessment methodology. Moreover, the PAWG does not expect separate intruder scenario dose analyses would be included in an LLW performance assessment because 10 CFR 61.13(b) requires that analyses of the protection of individuals from inadvertent intrusion must include a demonstration that there is reasonable assurance the waste classification and segregation requirements will be met and that adequate barriers to the inadvertent intrusion will be provided.

Finally, this technical report attempts to share with the Agreement States and LLW disposal facility developers some of the PAWG's experience and insights, as they related to the use of LLW performance assessments. In this regard, these groups may also find this technical report useful, as they proceed with the implementation of their respective programs.

Author 1	Author 2	Facility or Agency
		EPA

Citation

1999. Understanding Variation in Partition Coefficient, Kd, Values, Volume I:The Kd Model, Methods of Measurement, and Application of Chemical Reaction Code.

Journal

Title

Understanding Variation in Partition Coefficient, Kd, Values, Volume I:The Kd Model, Methods of Measurement, and Application of Chemical Reaction Codes

Document	Year
EPA 402-R-99-004A	1999

Why	How	What	Where
Modeling	Geochemical	partition coefficient	Saturated

Abstract

This two-volume report describes the conceptualization, measurement, and use of the partition (or distribution) coefficient, Kd, parameter, and the geochemical aqueous solution and sorbent properties that are most important in controlling adsorption/retardation behavior of selected contaminants. The report is provided for technical staff from EPA and other organizations who are responsible for prioritizing site remediation and waste management decisions. Volume I discusses the technical issues associated with the measurement of Kd values and its use in formulating the retardation factor, Rf. The Kd concept and methods for measurement of Kd values are discussed in detail in Volume I. Particular attention is directed at providing an understanding of: (1) the use of Kd values in formulating Rf, (2) the difference between the original thermodynamic Kd parameter derived from ion-exchange literature and its "empiricized" use in contaminant transport codes, and (3) the explicit and implicit assumptions underlying the use of the Kd parameter in contaminant transport codes. A conceptual overview of chemical reaction models and their use in addressing technical defensibility issues associated with data from Kd studies is presented. The capabilities of EPA's geochemical reaction model MINTEQA2 and its different conceptual adsorption models are also reviewed. Volume II provides a "thumb-nail sketch" of the key geochemical processes affecting the sorption of selected inorganic contaminants, and a summary of Kd values given in the literature for these contaminants under oxidizing conditions. The contaminants chosen for the first phase of this project include chromium, cadmium, cesium, lead, plutonium, radon, strontium, thorium, tritium (3H), and uranium. Important aqueous speciation, (co)precipitation/dissolution, and adsorption reactions are discussed for each contaminant. References to related key experimental and review articles for further reading are also listed.

Author 1	Author 2	Facility or Agency
Aaltonen	Olofsson	

Citation

Aaltonen, J. and B. Olofsson, 2002. Direct Current (DC) Resistivity Measurements in Long-term Groundwater Monitoring Programmes. Environmental Geology, vol. 41(6): 662-671.

Journal

Environmental Geology, vol. 41(6): 662-671

Title

Direct Current (DC) Resistivity Measurements in Long-term Groundwater Monitoring Programmes.

Document	Year
	2002

Why	How	What	Where
Monitoring			

Abstract

Effective leak detection systems are most often needed to enable early warnings of groundwater contamination from landfill areas. In order to monitor the groundwater chemical changes over time direct current (DC) resistivity measurements have been used, since variation in groundwater ion concentration give changes of the electrical potential field. A simple, low-cost system for long-term monitoring has been developed and used for 4 years at an existing operational landfill in central Sweden. The paper describes the construction and operation of the geoelectrical monitoring system based on a fixed electrode Wenner array, situated in a glaciated terrain. The simplicity of the system enables non-experts in geophysics to run the system and evaluate the results. The lateral resistivity variations (up to 10,000% from the mean lateral value) clearly reflect strongly different natural geological conditions, whereas the variations over time (15% from the mean value at each specific point) reflect mainly the seasonal soil humidity and groundwater level variations. Leachates from the landfill have a low resistivity (about 1 ohmm) and the moderate seasonal variations in electrical resistivity favour the possibilities for identification of leakage from the landfill. Evaluation of resistivity data comprises modified double mass calculations versus data from reference measurement sites, which enables detection of contamination although it influences the resistivity less than the natural seasonal variations.

Author 1	Author 2	Facility or Agency
Andersson	Destouni	

Citation

Andersson, C. and G. Destouni, 2001. Risk-cost Analysis in Ground Water Contaminant Transport: The Role of Random Spatial Variability and Sorption Kinetics. Ground Water 39(1): 35-48.

Journal

Ground Water 39(1): 35-48

Title

Risk-cost Analysis in Ground Water Contaminant Transport: The Role of Random Spatial Variability and Sorption Kinetics.

Document	Year
	2001

Why	How	What	Where
Design			

Abstract

We outline a methodology for quantifying the risk (probability) to exceed environmental regulation standards for ground water quality and coupling this risk quantification with an analysis of abatement costs for attaining an acceptable risk level. The methodology accounts for the uncertainty that results from random spatial variability in the subsurface, and for sorption-desorption kinetics. Random spatial variability implies that, with a deterministic regulating framework, the risk (probability) of exceeding given water quality targets may remain high even after abatement measures have been taken. We show how this risk can be set in focus by use of a probabilistic regulating framework, which enables better risk management. Both the environmental risk and the associated abatement costs will depend on the actual combination of subsurface variability, the ground water sampling method, and sorption kinetics, through the underlying quantification of pollutant concentration statistics. Our results emphasize the importance of a relevant account of the kinetics of the sorption-desorption process, by illustrating that neglect, or equilibrium simplification of that process, may result in highly misleading risk and abatement cost estimates.

Author 1	Author 2	Facility or Agency
Andersson	Billaux	NEA

Citation

Andersson, P., D. Billaux, et al., 1996. INTRAVAL Project: To Study Validation of Geosphere Transport Models for Performance Assessment of Nuclear Waste Disposal, Phase 2, Working Group 2 Report: Finnsjon, Stripa and WIPP2. Nuclear Energy Agency, Organisation for Economic Cooperation and Development.

Journal

Title

INTRAVAL Project: To Study Validation of Geosphere Transport Models for Performance Assessment of Nuclear Waste Disposal, Phase 2, Working Group 2 Report: Finnsjon, Stripa and WIPP2, OECD, 1996.

Document	Year
OECD	1996

Why	How	What	Where
Modeling			

Abstract

This report presents the work and conclusions of Working Group 2 within the International INTRAVAL Project. The Working Group focused on the study of ground water and tracer migration in fractured rock formations at three sites. The first field test was carried out at Finnsjon, Sweden, through the use of a number of boreholes in a nearly horizontal fractured zone embedded in a less permeable fractured crystalline rock mass at a depth between 100 to 240 m below the ground surface. A comprehensive series of hydraulic interference tests and tracer migration tests were carried out, with tracer migration distances about 200 m. Both convergent and dipole flow patterns were used.
The second field test was the so-called Stripe-3D experiment, carried out in a drift 360 m underground in fractured crystalline rock in the old Stripa mine in Sweden. Tracers were injected through boreholes at 10 to 55 m above the drift ceiling, and their migration into the drift under supposedly convergent flow field was carefully monitored and evaluated.
The third test case studied by the Working Group was the 8-m thick layer of fractured Culebra dolomite at a depth of 200 m at the WIPP site in New Mexico, USA. This test case is known as the WIPP-2 case within INTRAVAL. An extensive data set of transmissivity, head, and ground water salinity values at more than 40 locations were available for analysis and study.
Each of the test cases was studied by a number of research teams, nine, six and five for the three cases respectively. The teams used a wide range of models and calculational techniques, from equivalent porous and double porosity media, to fracture network and channel models. Of particular note is the application of stochastic models by a number of teams to the study of the large scale SIPP-2 case. The report describes the results of all the efforts of the research teams. Both lessons learned and conclusions from each of the cases and also the general conclusions of the results of the Working Group as a whole are presented.

Author 1	Author 2	Facility or Agency
Andraski		

Citation

Andraski, B.J., 1997. Soil-Water Movement Under Natural-Site and Waste-Site Conditions--A Multiple-Year Field Study in the Mojave Desert, Nevada. Water Resources Research, 33(8), 1901-1916.

Journal

Water Resources Research, v. 33, no. 8, p. 1901-1916.

Title

Soil-Water Movement Under Natural-Site and Waste-Site Conditions--A Multiple-Year Field Study in the Mojave Desert, Nevada.

Document	Year
	1997

Why	How	What	Where
Characterization			

Abstract

Soil-water movement under natural-site and simulated waste-site conditions were compared by monitoring four experimental sites in the Mojave Desert, Nevada, during a 5-year period: one vegetated soil profile; one soil profile where vegetation was removed; and two nonvegetated test trenches. Precipitation ranged from 14 to 162 mm/yr. Temporal changes in water content measured by neutron probe were limited to the upper 0.5-1 m; values ranged from 0.01 to 0.19 m3/m3. Water potential and temperature were measured by thermocouple psychrometers; 77% remained operable for >4.5 years. For vegetated soil, precipitation that accumulated in the upper 0.75 m of soil was removed by evapotranspiration: water potentials decreased seasonally by 4 to >8 MPa. During 2 years with below-average precipitation, water potentials below the apparent root zone decreased by 2.3 (1.2-m depth) to 0.4 MPa (5-m depth) and the gradients became predominantly upward. Water potentials then rebounded during 2 years with near- and above-average precipitation, and seasonally variant water potential gradients were reestablished above the 4.2-m depth. Under nonvegetated waste-site conditions, data indicated the long-term accumulation and shallow, but continued, penetration of precipitation: water potentials showed moisture penetration to depths of 0.75-1.85 m. The method of simulated-waste drum placement (stacked vs. random) and the associated differences in subsidence showed no measurable influence on the water balance of the trenches: subsidence totaled <13 mm during the study. Water potentials below the trenches and below the 2-m depth for the nonvegetated soil remained low (~-5.5 to -7.5 MPa) and indicated the persistence of typically upward driving forces for isothermal water flow. Water fluxes estimated from water potential and temperature data suggested that isothermal liquid, isothermal vapor, and nonisothermal vapor flow need to be considered in the conceptualization of unsaturated flow at the field sites. Below the depth of temporal water content change, the estimated liquid fluxes ranged from 10-10 to 10-15 cm/s, isothermal vapor fluxes ranged from 10-10 to 10-13 cm/s, and the nonisothermal vapor fluxes ranged from 10-8 to 10-10 cm/s.

Author 1	Author 2	Facility or Agency
Andraski	Sandstrom	

Citation

Andraski, B.J, M.W. Sandstrom, et al., 2002. Importance and Use of Plants in Evaluating Water Flow and Contaminant Transport in Arid Environments. Eos, Trans. American Geophysical Union, 83(47), Fall Meeting Suppl., Abstract H52A-0836.

Journal

Eos, Trans. AGU, 83(47)

Title

Importance and Use of Plants in Evaluating Water Flow and Contaminant Transport in Arid Environments.

Document	Year
H52A-0836	2002

Why	How	What	Where
	Ecological		

Abstract

Improved understanding of soil-plant-atmosphere interactions is critical to water-resource and waste management decisions. Multiple-year field studies of soil-water movement at the Amargosa Desert Research Site (ADRS; http://nevada.usgs.gov/adrs/) near Beatty, Nevada identified plants as the primary control on the near-surface water balance and showed that the boundary conditions imposed by plant activity in the uppermost soil layer results in episodic, deep drying well below the root zone during periods of below-average precipitation. The results help to explain the evidence for negligible recharge and upward flow that has been inferred from environmental-tracer and soil-physics based studies of undisturbed, arid sites. The findings have contributed to the development of new conceptual models that incorporate the influence of desert vegetation in analyses of paleo- to present-day water fluxes in deep unsaturated zones.

Studies at the ADRS are also using plants to investigate the transport of contaminants away from a closed low-level radioactive waste disposal area. Soil-gas sampling results indicated that tritium has moved as much as 300 m from the disposal area, and that transport primarily occurs in the gas phase with preferential transport through coarse-textured sediment layers. The need for an efficient means of gathering plume-scale data led to the development of a method that uses plant water to identify the presence and distribution of tritium. The method entails field sampling and solar distillation of foliage to collect plant water, followed by laboratory filtration and adsorption of scintillation-interfering constituents on a graphite-based, solid-phase-extraction (SPE) column. The method was evaluated using an evergreen shrub (creosote bush; Larrea tridentata (DC.) Cov.). Tritium concentrations in plant water determined with the distillation-SPE method did not differ significantly from those determined with the standard (and more laborious) toluene-extraction method or from concentrations in soil-water vapor collected using gas-sampling methods. Thus, the solar distillation-SPE method provides a simple, cost-effective, and accurate alternative approach to identify areas of plant and soil contamination. Although work to date has focused on one plant, the approach may be transferable to other species and environments. Work at the ADRS has confirmed the importance of vegetation in arid-site hydrodynamics. Future studies will attempt to better quantify and understand the flux of tritium from the subsurface to the atmosphere through a combination of soil, plant, and evapotranspiration measurements.

Author 1	Author 2	Facility or Agency
Angulo	Tang	

Citation

Angulo, M. and W. H. Tang, 1999. Optimal Ground-Water Detection Monitoring System Design Under Uncertainty. Journal of Geotechnical and Geoenvironmental Engineering 125(6): 510-517.

Journal

Journal of Geotechnical and Geoenvironmental Engineering 125(6): 510-517.

Title

Optimal Ground-Water Detection Monitoring System Design Under Uncertainty.

Document	Year
	1999

Why	How	What	Where
Design	Uncertainties		Saturated

Abstract

Ground-water detection monitoring decisions are complicated due to uncertainties in contaminant source characteristics and inherent variability of hydrogeologic conditions. The desire to meet multiple monitoring objectives presents an additional challenge. A novel approach using probability tools is presented to optimally determine the number and location of monitoring wells that compose a system for detection monitoring purposes.

Author 1	Author 2	Facility or Agency
Anon		

Citation

Anon (2000). "Decommissioning: The time is now." Nuclear Engineering International 45(552):32-33.

Journal

Nuclear Engineering International 45(552):32-33

Title

Decommissioning: The time is now.

Document	Year
	2000

Why	How	What	Where

Abstract

Author 1	Author 2	Facility or Agency
Arthur	Markham	

Citation

Arthur, W.J. and O.D. Markham. 1983. Small mammal soil burrowing as a radionuclide transport vector at a radioactive waste disposal area in southeastern Idaho. J. Environ. Qual. 12: 117-122.

Journal

J. Environ. Qual. 12: 117-122

Title

Small mammal soil burrowing as a radionuclide transport vector at a radioactive waste disposal area in southeastern Idaho.

Document	Year
	1983

Why	How	What	Where
Characterization	Ecological		Surface

Abstract

Author 1	Author 2	Facility or Agency
Arthur	Janke	

Citation

Arthur, W.J. and D.H. Janke. 1986. Radionuclide concentrations in wildlife occurring at a solid radioactive waste disposal area. Northwest Science 60: 154-159.

Journal

Northwest Science 60: 154-159.

Title

Radionuclide concentrations in wildlife occurring at a solid radioactive waste disposal area.

Document	Year
	1986

Why	How	What	Where
Characterization	Ecological		Surface

Abstract

Author 1	Author 2	Facility or Agency
ASTM		ASTM

Citation
ASTM D6432-99 Standard Guide for Using the Surface Ground Penetrating Radar Method for Subsurface Investigation

Journal

Title
Standard Guide for Using the Surface Ground Penetrating Radar Method for Subsurface Investigation

Document	Year
ASTM D6432-99	1999

Why	How	What	Where
Characterization	Geophysical	GPR	

Abstract

Author 1	Author 2	Facility or Agency
ASTM		ASTM

Citation
ASTM D6639-01 Standard Guide for Using the Frequency Domain Electromagnetic Method for Subsurface Investigations

Journal

Title
Standard Guide for Using the Frequency Domain Electromagnetic Method for Subsurface Investigations

Document	Year
ASTM D6639-01	2001

Why	How	What	Where
Characterization	Geophysical	FDEM	

Abstract

Author 1	Author 2	Facility or Agency
ASTM		ASTM

Citation
ASTM D6431-99 Standard Guide for Using the Direct Current Resistivity Method for Subsurface Investigation

Journal

Title
Standard Guide for Using the Direct Current Resistivity Method for Subsurface Investigation

Document	Year
ASTM D6431-99	1999

Why	How	What	Where
Characterization	Geophysical		

Abstract

Author 1	Author 2	Facility or Agency
ASTM		ASTM

Citation
ASTM D6429-99 Standard Guide for Selecting Surface Geophysical Methods

Journal

Title
Standard Guide for Selecting Surface Geophysical Methods

Document	Year
ASTM D6429-99	1999

Why	How	What	Where
Characterization	Geophysical		

Abstract

Author 1	Author 2	Facility or Agency
ASTM		ASTM

Citation
ASTM D5980-96e1 Standard Guide for Selection and Documentation of Existing Wells for Use in Environmental Site Characterization and Monitoring

Journal

Title
Standard Guide for Selection and Documentation of Existing Wells for Use in Environmental Site Characterization and Monitoring

Document	Year
ASTM D5980-96e1	1996

Why	How	What	Where
Characterization			Saturated

Abstract

Author 1	Author 2	Facility or Agency
ASTM		ASTM

Citation
ASTM D5979-96 (2002) Standard Guide for Conceptualization and Characterization of Ground-Water Systems

Journal

Title
Standard Guide for Conceptualization and Characterization of Ground-Water Systems

Document	Year
ASTM D5979-96	2002

Why	How	What	Where
Characterization	characterizatio		Saturated

Abstract

Author 1	Author 2	Facility or Agency
ASTM		ASTM

Citation
ASTM D5777-00 Standard Guide for Using the Seismic Refraction Method for Subsurface Investigation

Journal

Title
Standard Guide for Using the Seismic Refraction Method for Subsurface Investigation

Document	Year
ASTM D5777-00	2000

Why	How	What	Where
Characterization	Geophysical	seismic	

Abstract

Author 1	Author 2	Facility or Agency
ASTM		ASTM

Citation

ASTM D5730-02 Standard Guide for Site Characterization for Environmental Purposes With Emphasis on Soil, Rock, the Vadose Zone and Ground Water

Journal

Title

Standard Guide for Site Characterization for Environmental Purposes With Emphasis on Soil, Rock, the Vadose Zone and Ground Water

Document	Year
ASTM D5730-02	2002

Why	How	What	Where
Characterization			Unsaturated

Abstract

Author 1	Author 2	Facility or Agency
ASTM		ASTM

Citation
ASTM D4696-92 (2000) Standard Guide for Pore-Liquid Sampling from the VADOSE ZONE

Journal

Title
Standard Guide for Pore-Liquid Sampling from the Vadose Zone

Document	Year
ASTM D4696-92	2000

Why	How	What	Where
Characterization			Unsaturated

Abstract

Author 1	Author 2	Facility or Agency
ASTM		ASTM

Citation
ASTM D4700-91(1998)e1 Standard Guide for Soil Sampling from the VADOSE ZONE

Journal

Title
Standard Guide for Soil Sampling from the Vadose Zone

Document	Year
ASTM D4700-91e1	1998

Why	How	What	Where
			Unsaturated

Abstract

Author 1	Author 2	Facility or Agency
ASTM		ASTM

Citation
ASTM D6235-98a Standard Practice for Expedited Site Characterization of Vadose Zone and Ground Water Contamination at Hazardous Waste Contaminated Sites

Journal

Title
Standard Practice for Expedited Site Characterization of Vadose Zone and Ground Water Contamination at Hazardous Waste Contaminated Sites

Document	Year
ASTM D6235-98a	1998

Why	How	What	Where
Characterization			

Abstract

Author 1	Author 2	Facility or Agency
ASTM		ASTM

Citation
ASTM D6168-97e1 Standard Guide for Selection of the Minimum Set of Data Elements Required to Identify Locations Chosen for the Field Collection of Information to Describe Soil, Rock, and Their Contained Fluids

Journal

Title
Standard Guide for Selection of the Minimum Set of Data Elements Required to Identify Locations Chosen for the Field Collection of Information to Describe Soil, Rock, and Their Contained Fluids

Document	Year
ASTM D6168-97e1	1997

Why	How	What	Where
DQO			

Abstract

Author 1	Author 2	Facility or Agency
ASTM		ASTM

Citation
ASTM D5126-90(1998)e1 Standard Guide for Comparison of Field Methods for Determining Hydraulic Conductivity in the Vadose Zone

Journal

Title
Standard Guide for Comparison of Field Methods for Determining Hydraulic Conductivity in the Vadose Zone

Document	Year
ASTM D5126-90e1	1998

Why	How	What	Where
			Unsaturated

Abstract

Author 1	Author 2	Facility or Agency
ASTM		

Citation

ASTM D5474-93e1. Standard Guide for Selection of Data Elements for Ground-Water Investigations.

Journal

Title

Standard Guide for Selection of Data Elements for Ground-Water Investigations.

Document	Year
ASTM D5474-93e1	1993

Why	How	What	Where
			Saturated

Abstract

Author 1	Author 2	Facility or Agency
ASTM		ASTM

Citation
ASTM D4448-01 Standard Guide for Sampling Ground-Water Monitoring Wells

Journal

Title
Standard Guide for Sampling Ground-Water Monitoring Wells

Document	Year
ASTM D4448-01	2001

Why	How	What	Where
			Saturated

Abstract

Author 1	Author 2	Facility or Agency
ASTM		ASTM

Citation

ASTM D6311-98. Standard Guide for Generation of Environmental Data Related to Waste Management Activities: Selection and Optimization of Sampling Design.

Journal

Title

Standard Guide for Generation of Environmental Data Related to Waste Management Activities: Selection and Optimization of Sampling Design.

Document	Year
ASTM D6311-98	1998

Why	How	What	Where

Abstract

Author 1	Author 2	Facility or Agency
ASTM		ASTM

Citation

ASTM D5717-95e1. Standard Guide for Design of Ground-Water Monitoring Systems in Karst and Fractured-Rock Aquifers.

Journal

Title

Standard Guide for Design of Ground-Water Monitoring Systems in Karst and Fractured-Rock Aquifers.

Document	Year
ASTM D5717-95e1	1995

Why	How	What	Where
Design	Ground-Water		

Abstract

This guide for the design of ground-water monitoring systems in karst and fractured-rock aquifers promotes the design and implementation of accurate and reliable monitoring systems in those settings where the hydrogeologic characteristics depart significantly from the characteristics of porous media. Variances form government regulations that require on-site monitoring wells may often be necessary in karst or fractured-rock terranes (see 7.3) because such settings have hydrogeologic features that cannot be characterized by the porous-media approximation. This guide will promote the development of a conceptual hydrogeologic model that supports the need for the variances and aids the designer or governmental reviewer in establishing the most reliable and efficient monitoring system for such aquifers.

Many of the approaches contained in this guide may also have value in designing ground-water monitoring systems in heterogeneous and anisotropic unconsolidated and consolidated granular aquifers. The focus of this guide, however, is on unconfined karst systems where dissolution has increased secondary porosity and on other geologic settings where unconfined ground-water flow in fractures is a significant component of total ground-water flow.

Author 1	Author 2	Facility or Agency
ASTM		ASTM

Citation
ASTM D6233-98. Standard Guide for Data Assessment for Environmental Waste Management Activities.

Journal

Title
Standard Guide for Data Assessment for Environmental Waste Management Activities.

Document	Year
ASTM D6233-98	1998

Why	How	What	Where

Abstract

Author 1	Author 2	Facility or Agency
ASTM		ASTM

Citation

ASTM D6312-98. Standard Guide for Developing Appropriate Statistical Approaches for Ground-Water Detection Monitoring Programs.

Journal

Title

Standard Guide for Developing Appropriate Statistical Approaches for Ground-Water Detection Monitoring Programs.

Document	Year
ASTM D6312-98.	1998

Why	How	What	Where
			Saturated

Abstract

Author 1	Author 2	Facility or Agency
ASTM		ASTM

Citation

ASTM D6030-96e1. Standard Guide for Selection of Methods for Assessing Ground Water or Aquifer Sensitivity and Vulnerability.

Journal

Title

Standard Guide for Selection of Methods for Assessing Ground Water or Aquifer Sensitivity and Vulnerability.

Document	Year
ASTM D6030-96e1	1996

Why	How	What	Where

Abstract

Author 1	Author 2	Facility or Agency
ASTM		ASTM

Citation

ASTM D5851-95. Standard Guide for Implementing a Water Monitoring Program

Journal

Title

Standard Guide for Implementing a Water Monitoring Program

Document	Year
ASTM D5851-95	1995

Why	How	What	Where
Monitoring			Saturated

Abstract

Author 1	Author 2	Facility or Agency
Aziz	Ling	

Citation

Aziz, J.J., M. Ling, et al., 2003. MAROS: a Decision Support System for Optimizing Monitoring Plans. Ground Water, in press.

Journal

Ground Water, in press.

Title

MAROS: a Decision Support System for Optimizing Monitoring Plans.

Document	Year
	2003

Why	How	What	Where
Design	Optimization		

Abstract

The Monitoring and Remediation Optimization System (MAROS), a decision-support software was developed to assist in formulating cost-effective ground water long-term monitoring plans. MAROS optimizes an existing ground water monitoring program using both temporal and spatial data analyses to determine the general monitoring category and the locations and frequency of sampling for future compliance monitoring at the site. The objective of the MAROS optimization is to minimize monitoring locations in the sampling network and reduce sampling frequency without significant loss of information ensuring adequate future characterization of the contaminant plume. The temporal trend analysis approach recommends the general long-term monitoring category for a site based on plume stability and site-specific hydrogeologic information. Plume stability is characterized using primary lines of evidence (i.e., Mann-Kendall analysis and linear regression analysis) based on concentration trends, and secondary lines of evidence based on modeling results and empirical data. The sampling optimization methodology, consisting of a 2-D spatial sampling reduction method (Delaunay method) and a temporal sampling analysis method (Modified CES method), provides detailed sampling location and frequency results. The Delaunay method is designed to identify and eliminate redundant sampling locations without causing significant information loss in characterizing the plume. The Modified CES method determines the optimal sampling frequency for a sampling location based on the direction, magnitude, and uncertainty in its concentration trend. MAROS addresses a variety of ground water contaminants (e.g., fuels, solvents, metals), allows import of various data formats, and is designed for continual modification of long-term monitoring plans as the plume or site conditions change over time.

Author 1	Author 2	Facility or Agency
Aziz		

Citation

Aziz, et al., 2000. Monitoring and Remediation Optimization System (MAROS) beta version 1.0 users guide. ACFEE.

Journal

Title

Monitoring and Remediation Optimization System (MAROS) beta version 1.0 users guide.

Document	Year
	2000

Why	How	What	Where
Modeling			

Abstract

The AFCEE Monitoring and Remediation Optimization System (MAROS) Software is a Microsoft Access database application developed to assist users with groundwater data trend analysis and long term monitoring optimization at contaminated groundwater sites. This program was developed in accordance with the Long-Term Monitoring Optimization Guide Version 1.1 developed by AFCEE. The software uses both primary lines of evidence (parametric and nonparametric trend analysis) developed by Groundwater Services, Inc., as well as allowing users to enter secondary lines of evidence (empirical or modeling results) for the site. These lines of evidence allow recommendations as to future compliance monitoring goals for their specific site. This User's Guide will walk the user through several typical uses of the software as well as provide screen-by-screen detailed instructions.

Author 1	Author 2	Facility or Agency
Baes	Sharp	ORNL

Citation

Baes, C.F., R.D. Sharp, A.L. Sjoreen, and R.W. Shor. 1984. A review and analysis of parameters for assessing transport of environmentally released radionuclides through agriculture. ORNL-5786. Oak Ridge National Laboratory, Oak Ridge, TN.

Journal

Title

A review and analysis of parameters for assessing transport of environmentally released radionuclides through agriculture.

Document	Year
ORNL-5786	1984

Why	How	What	Where
Characterization	Ecological	plant uptake	Surface

Abstract

Author 1	Author 2	Facility or Agency
Bagtzoglou	Ababou	

Citation

Bagtzoglou, A.C., R. Ababou, et al., 1993. Effects of Some Common Geological Features on 2D Variably Saturated Flow. Scientific Basis for Nuclear Waste Management XVI, Materials Research Society Symposium Proceedings, Vol. 294, pp. 929-936.

Journal

Materials Research Society Symposium Proceedings, Vol. 294, pp. 929-936

Title

Effects of Some Common Geological Features on 2D Variably Saturated Flow

Document	Year
	1993

Why	How	What	Where
Modeling	Uncertainties		Saturated

Abstract

Author 1	Author 2	Facility or Agency
Bagtzoglou	Ababou	

Citation

Bagtzoglou, A.C., R. Ababou, et al., 1992. Effects of Layering, Dipping Angle, and Faulting on Two-Dimensional Variably Saturated Flow. CNWRA 92-004.

Journal

Title

Effects of Layering, Dipping Angle, and Faulting on Two-Dimensional Variably Saturated Flow

Document	Year
CNWRA 92-004	1992

Why	How	What	Where
Characterization	Uncertainties		Unsaturated

Abstract

Author 1	Author 2	Facility or Agency
Bagtzoglou	Stirewalt	Yucca Mountain

Citation

Bagtzoglou, A.C., G.L. Stirewalt, et al., 1995. Evaluation of Uncertainty in Geological Framework Models at Yucca Mountain, Nevada. Proceedings of the Sixth International Conference on High-Level Radioactive Waste Management, American Nuclear Society, La Grange Park, Illinois, pp. 119-122.

Journal

Title

Evaluation of Uncertainty in Geological Framework Models at Yucca Mountain, Nevada

Document	Year
	1995

Why	How	What	Where
Modeling	Geological		Structure

Abstract

Author 1	Author 2	Facility or Agency
Ballard	Deng	

Citation

Ballard, J. H., B. Deng, et al., 2002. Verification and Monitoring System to Access the Construction of Subsurface Barriers. Center for Research and Technology Development, (Publication) CRTD, American Society of Mechanical Engineers 61: 329-333.

Journal

American Society of Mechanical Engineers 61: 329-333

Title

Verification and Monitoring System to Access the Construction of Subsurface Barriers.

Document	Year
	2002

Why	How	What	Where
Monitoring	Performance	barrier	Unsaturated

Abstract

Author 1	Author 2	Facility or Agency
Becker	Harre	

Citation

Becker, D., K.J. Harre, et al., 2002. Application of Flow and Transport Optimization Codes to Groundwater Pump and Treat Systems. Proceedings: Partners in Environmental Technology Technical Symposium & Workshop, Strategic Environmental Research and Development Program and the Environmental Security Technology Certification Program, Washington, DC, Dec

Journal

Title

Application of Flow and Transport Optimization Codes to Groundwater Pump and Treat Systems.

Document	Year
	2002

Why	How	What	Where
Modeling	Optimization		Saturated

Abstract

With the recent focus on lowering the operating costs of environmental remediation systems, including groundwater pump and treat systems, there has been increased interest in algorithmic approaches to optimization. This ESTLP and United States Environmental Protection Agency (EPA) project evaluates the benefits and utility of transport optimization algorithms, operable on desktop computers, against trial and error approaches, and follows upon an earlier U.S. Environmental Protection Agency effort to determine the efficacy of the hydraulic optimization algorithm MODMAN. The former approach requires a well-calibrated groundwater transport model that addresses attenuating properties of contaminants, while the latter method uses a well-calibrated groundwater flow model that represents just the hydraulic properties of the aquifer. Various criteria were applied to screen DoD pump and treat facilities appropriate for demonstrating transport optimization algorithms, with three systems selected for inclusion in the project. For each facility selected, administrative constraints and factors such as desirable points of compliance, permissible well locations, pumping rate limitations, and new well costs were established with agreement from the facility personnel and contractors, and set forth as mathematical formulations. Three separate optimization formulations were developed for each facility's MT3D transport model, and solved by three groups (two using optimization algorithms and one applying trial and error). Furthermore, the modelers were permitted to propose additional problems they thought might benefit the installation and present corresponding solutions. To meet the four-month computational period allotted for each pump and treat system optimization, an initial solution for each problem was established by the trial and error modeling group to ensure that each problem had at least one feasible solution. It was determined that multiple algorithmic approaches are necessary to address the large search space and non-convergence issues associated with the nonlinear transport optimization problem, which, in some instances, required solving a series of modified problems to establish an ultimate optimal solution. Therefore, especially for large problems, optimization results are very dependent on the expertise of the person using the optimization algorithms. The two modeling groups applying the optimization algorithms were able to evaluate far more alternatives than the trial and error modeling group and generally identified more optimized cost solutions. An iterative approach to formulating and solving mathematically-constrained problems for algorithmic pump and treat optimization may be most practical. Finally, the process of quantitatively stating objective functions and constraints is a valuable step whether or not optimization algorithms are ultimately applied.

Author 1	Author 2	Facility or Agency
Bell	Bonne	International Atomic Energy Agency

Citation

Bell, M., A. Bonne, et al., 1999. Hydrogeological Investigation of Sites for the Geological Disposal of Radioactive Waste. Vienna: International Atomic Energy Agency. Technical Report Series No. 391 (1998).

Journal

Title

Hydrogeological Investigation of Sites for the Geological Disposal of Radioactive Waste

Document	Year
TRS-391	1999

Why	How	What	Where
Modeling			

Abstract

There is a far reaching international consensus that high level radioactive waste can be safely isolated in deep geological repositories using a system of engineered and natural barriers. In a normal situation the pathway having the greatest potential for transferring radionuclides to the human environment is transport by groundwater. Therefore, a good understanding of the hydrogeological characteristics of the repository site is important. The range of variation in the properties of potential sites for deep geological repositories is considerable. For example, saturation states can vary from fully saturated to unsaturated conditions. The approaches used to characterize the hydrogeological environment in the various geological media are correspondingly different. However, despite these differences there are certain hydrogeological criteria which must be fulfilled by any potential geological repository.
As part of the subprogramme on radioactive waste disposal, the IAEA has prepared this report which discusses the approaches used in the hydrogeological investigation of repository sites on the basis of experience gained in the Member States on different rock types considered as having the potential to host a repository.
Sixteen experts from the Member States participated in the preparation of this report. The three IAEA staff members responsible for the project are M. Bell, A. Bonne and J.U. Heinonen.

Author 1	Author 2	Facility or Agency
Ben-Jemaa	Marino	

Citation

Ben-Jemaa, F., M. A. Marino, et al., 1994. Multivariate Geostatistical Design of Ground-Water Monitoring Networks. J. Water Resources Planning and Management 120(4): 505-522.

Journal

J. Water Resources Planning and Management 120(4): 505-522

Title

Multivariate Geostatistical Design of Ground-Water Monitoring Networks.

Document	Year
	1994

Why	How	What	Where
Design	Optimization	geostatistics	Saturated

Abstract

A multivariate approach for the design of ground-water monitoring networks is presented. The proposed technique is based on the geostatistical method of cokriging. The network design problem is posed as an optimization model in which the variance of estimation is minimized. The multivariate approach used herein accounts not only for autocorrelations but also for variable cross correlations. By considering a network design in which several variables are jointly monitored, lower monitoring costs are achieved; also, and more importantly, a better estimation of the monitored parameters is yielded given the fact that lower estimation variances are reached. The method used for selecting the optimal monitoring sites is based on a simultaneous search technique using a branch and bound algorithm guaranteeing optimality of the solution. The methodology is applied for the design of a monitoring network to observe aquifer transmissivity (T) and the specific capacity (SC) in the Yolo County Basin, Calif. The results show the superiority of the multivariate geostatistical approach and how it provides a better and more economical network design than the univariate approach.

Author 1	Author 2	Facility or Agency
Berthold	Jeffers	

Citation

Berthold, J. W. and L. A. Jeffers, 1999. Method for In-situ Detection of Tritium in Water. Proceedings of SPIE - The International Society for Optical Engineering, Proceedings of the 1999 Fiber Optics Sensors Technology and Applications, Sep 20-Sep 22 1999, vol. 3860: 434-442.

Journal

Title

Method for In-situ Detection of Tritium in Water.

Document	Year
	1999

Why	How	What	Where
Monitoring	Devices	optical	Saturated

Abstract

The objective of this project was to design a monitoring system capable of detecting and quantifying tritium in-situ in ground and surface waters, and in water from effluent lines prior to discharge into public waterways. The design work was successfully completed with the predicted capability to detect tritium levels below 20 nanocuries per liter. The designed system was based on the detection of the low energy beta radiation from the radioactive decay of tritium using a special form of scintillating optical fiber directly in contact with the water to be measured. To support the design, laboratory tests were performed in several areas. Different types of scintiallating fiber were tested to determine which would provide optimum system performance. The fibers contained a fluor material in a special cladding configuration which optimizes the absorption of beta radiation. The tritium detection system consists of an immersible sensor module containing the optical fiber and detection electronics as well as signal processing electronics. An umbilical cable is used to interconnect the components. The system design goals included optimal permanent installation for routine water monitoring in wells, process and effluent lines or as a potential portable survey tool which could be moved from one location to another. Not all the design goals were met due to the large physical size of the immersible sensor module. Discussed in this paper are the design details of the in-situ tritium beta detector, the tests performed, and results obtained. The work was supported by U.S. Department of Energy (DOE) contract number DE-AC21-96MC33128.

Author 1	Author 2	Facility or Agency
Binley	Cassiani	

Citation

Binley, A., G. Cassiani, et al., 2002. Vadose Zone Flow Model Parameterisation Using Cross-Borehole Radar and Resistivity Imaging. J. Hydrology 267(3-4): 147-159.

Journal

Journal of Hydrology 267(3-4): 147-159

Title

Vadose Zone Flow Model Parameterisation Using Cross-Borehole Radar and Resistivity Imaging

Document	Year
	2002

Why	How	What	Where
Characterization	Geophysical	electrical resistivity tomograp	Unsaturated

Abstract

Cross-borehole geoelectrical imaging, in particular electrical resistivity tomography (ERT) and transmission radar tomography, can provide high-resolution images of hydrogeological structures and, in some cases, detailed assessment of dynamic processes in the subsurface environment. Through appropriate petrophysical relationships, these tools offer data suitable for parameterising and constraining models of groundwater flow. This is demonstrated using cross-borehold radar and resistivity measurements collected during a controlled vadose zone tracer test, performed at a field site in the UK Sherwood Sandstone. Both methods show clearly the vertical migration of the tracer over a 200 h monitoring period. By comparing first and second spatial moments of changes in moisture content predicted from a numerical simulation of vadose zone flow with equivalent statistics from two- and three-dimensional ERT and cross-borehole radar profiles the effective hydraulic conductivity is estimated to be approximately 0.4 m/d. Such a value is comparable to field estimates from borehole hydraulic tests carried out in the saturated zone at the field site and provides valuable information that may be utilised to parameterise pollutant transport models of the site.

Author 1	Author 2	Facility or Agency
Birgersson	Larsson	NEA

Citation

Birgersson, L., A. Larsson, et al., 1996. INTRAVAL Project: To Study Validation of Geosphere Transport Models for Performance Assessment of Nuclear Waste Disposal, Phase 2, Working Group 4 Report: The Analyses of the Alligator Rivers Natural Analogue. Nuclear Energy Agency, Organisation for Economic Cooperation and Development.

Journal

Title

INTRAVAL Project: To Study Validation of Geosphere Transport Models for Performance Assessment of Nuclear Waste Disposal, Phase 2, Working Group 4 Report: The Analyses of the Alligator Rivers Natural Analogue

Document	Year
OECD	1996

Why	How	What	Where
Modeling			

Abstract

The Alligator Rivers study is based on work conducted at the Koongarra uranium deposit in the Alligator Rivers Region about 200 km east of Darwin, Australia. The Alligator Rivers Analogue Project (ARAP) was set up in 1987 and was later included as a test case in both phase 1 and 2 of INTRAVAL. The objective was to develop a consistent picture of the processes that have controlled the transport in the weathered zone of the Koongarra ore deposit and the time scale over which they have operate.

Uranium mineralisation occurs at Koongarra in two distinct but related ore bodies. Primary mineralisation in the main ore body is largely confined to quartz-chlorite schists and secondary uranium minerals are present from the surface down to the base of weathering at about 25 m depth and forms a tongue-like body of ore dispersing downslope for about 800m. The primary ore body at Koongarra is estimated to be 1000 million years old and geomorphological information indicates that weathering started a few million years ago.

The work included in INTRAVAL phase 1 was mainly concentrated to hydrogeological and geochemical modelling which produced results that in INTRAVAL phase 2 were used in modelling simulations of the uranium migration. The model concepts applied in the migration modelling were based on rather simple performance assessment models accounting for advection, dispersion and linear sorption in one or two dimensions. One 1-D model was extended to include alpha-recoil and transfer between solid phases. The vertical movement of the weathering front was included in the 2-D model.

Studies of the Alligator Rivers Natural Analogue has demonstrated that the system is very complex. The interaction of many geochemical and geohydrological processes occurring over long times makes it difficult to create a quantitative model of the history of groundwater flow and nuclide transport. The study has shown the importance of a joint interpretation of different types of data and an iterative procedure for data collection, data interpretation and modelling in order to get a consistent picture of the evolution of the site. Furthermore, it was shown that sorption is a major retardation mechanism, that uranium fixation in crystalline phases is a potentially important retardation mechanism in geologic media where significant alteration of the rock is expected, and that alpha-recoil may have an impact on the distribution of uranium isotopes in the water. Modelling simulations indicated migration times in fair agreement with independent geomorphological information. A general conclusion from the INTRAVAL study is that rather simple and robust concepts and models seem able to adequately describe the long range migration processes that have occurred.

Author 1	Author 2	Facility or Agency
Bonano	Leon	Sandia

Citation

Bonano, E.J. and A.A. Leon, 1999. Comments on the Legal Admissibility of a Performance Assessment for a Radioactive Waste Disposal Facility. Helton, J. C. (editor), Anderson, D. R. (editor), Performance Assessment for Radioactive Waste Disposal. Risk Analysis, 19 (5), p. 991-993.

Journal

Risk Analysis, 19 (5), p. 991-993.

Title

Comments on the Legal Admissibility of a Performance Assessment for a Radioactive Waste Disposal Facility.

Document	Year
	1999

Why	How	What	Where

Abstract

Author 1	Author 2	Facility or Agency
Bond	O'Sullivan	

Citation

Bond, A. and P. O'Sullivan, 2002. Environmental Impact Assessment Requirements for the Decommissioning of Nuclear Installations. Nuclear Engineer 43(2): 57-62.

Journal

Nuclear Engineer 43(2): 57-62

Title

Environmental impact assessment requirements for the decommissioning of nuclear installations

Document	Year
	2002

Why	How	What	Where
Characterization			

Abstract

Author 1	Author 2	Facility or Agency
Bowerman	Redente	

Citation

Bowerman, A.G. and E.F. Redente. 1998. Biointrusion of protective barriers at hazardous waste sites. J. Environ. Qual. 27: 625-632.

Journal

J. Environ. Qual. 27: 625-632.

Title

Biointrusion of protective barriers at hazardous waste sites.

Document	Year
	1998

Why	How	What	Where
	Ecological		Surface

Abstract

Author 1	Author 2	Facility or Agency
Bradley	Moor	

Citation

Bradley, W.G. and K.S. Moor. 1975. Ecological studies of small vertebrates in Pu-contaminated study areas of the NTS and TTR. In: M.G. White and P.B. Dunaway (Eds.), The Radioecology of Plutonium and Other Transuranics in Desert Environments. USERDA Report NVO-153. Pp. 151-186.

Journal

USERDA Report NVO-153. Pp. 151-186

Title

Ecological studies of small vertebrates in Pu-contaminated study areas of the NTS and TTR.

Document	Year
	1975

Why	How	What	Where
Characterization	Ecological		Surface

Abstract

Author 1	Author 2	Facility or Agency
Braverman	Hofmayer	NRC

Citation

Braverman, J.I, C.H. Hofmayer, et al., 2000. Assessment of Age-Related Degradation of Structures and Passive Components for U.S. Nuclear Power Plants. U.S. Nuclear Regulatory Commission Report. NUREG/CR-6679, BNL-NUREG-52587.

Journal

Title

Assessment of Age-Related Degradation of Structures and Passive Components for U.S. Nuclear Power Plants.

Document	Year
NUREG/CR-6679	2000

Why	How	What	Where

Abstract

This report describes the results of the first phase of a multi-year research program to assess age-related degradation of structures and passive components for U.S. nuclear power plants. The purpose of this research program is to develop the technical basis for the validation and improvement of analytical methods and acceptance criteria which can be used to make risk-informed decisions and to address technical issues related to degradation of structures and passive components. The approach adopted for this research program consists of three phases. The Phase I effort included collection and evaluation of plant degradation occurrences, an assessment of the available technical information on age-related degradation, and a scooping study to identify which structures and components should be studied in the subsequent phases of the research program. Based on the results of the Phase I effort, selected structures and passive components are evaluated in Phase II to assess the effects of age-related degradation using existing and enhanced analytical methods. Phase III will utilize the results of the analyses to develop recommendations to the NRC staff for making risk-informed decisions related to degradation of structures and passive components. This report presents the results of the Phase I portion of the research program.

The Phase I assessment of age-related degradation of structures and passive components at nuclear power plants has been completed. This assessment consisted of three activities. In the first activity, instances of age-related degradation have been collected and evaluated. The data were collected from Licensee Event Reports, NRC generic communications, NUREG reports, and industry reports. A computerized database was developed to summarize important parameters which describe the applicable cases of degradation. Trending analyses were performed to identify which structures are most susceptible to age-related degradation, what are the most common aging mechanisms and aging effects, whether degradation occurrences are increasing, and other important observations. In the second activity, additional information such as NRC requirements/guidance, NRC programs, industry programs, degradation information from other countries, and other reports/papers on aging degradation were evaluated to identify the significant aging issues for those structures and passive components which would have the greatest impact on plant risk. In the third activity, the collection of degradation occurrences, trending analyses, available technical information, and risk significance of aging effects were utilized in a scoping study to identify those structures and passive components that warrant further detailed evaluation in Phase II of this program.

The scoping study concluded that the structures and passive components that warrant further detailed evaluation were masonry walls, flat bottom tanks, anchorages, concrete structures (other than containments) and buried piping. The focus of further research will be on developing and improving analytical methods to assess the effects of age-related degradation on the structural performance of structures and passive components, including fragility evaluations for probabilistic risk assessment and seismic margins assessment studies. The methodologies that will be developed could then be used to quantity the impact of age-related degradation of structures and passive components on overall plant risk. This would lead to greater confidence in the use of risk assessment as a tool for making risk-informed decisions for age-degraded structures and passive components

Author 1	Author 2	Facility or Agency
Brooks		

Citation

Brooks, R.R., 1968. Biogeochemical Methods of Prospecting. Australian Mining 60, 81-83.

Journal

Australian Mining 60

Title

Biogeochemical Methods of Prospecting

Document	Year
	1968

Why	How	What	Where
Characterization	Ecological		Surface

Abstract

Author 1	Author 2	Facility or Agency
Brouillard	Studer	

Citation
Brouillard, L. A., Studer, J.E., et al., 1998. A vapor extraction monitoring system for performance assessment. Wickramanayake, G.B. and Hinchee, R.E. (eds). Risk, Resource, and Regulatory Issues; Remediation of Chlorinated and Recalcitrant Compounds, p. 59-65. ISBN: 1-57477-056-X. Meeting: First International Conference on Remediation of

Journal
Risk, Resource, and Regulatory Issues; Remediation of Chlorinated and Recalcitrant Compounds, p. 59-65. ISBN: 1-57477-056-X

Title
A Vapor Extraction Monitoring System for Performance Assessment.

Document	Year
	1998

Why	How	What	Where

Abstract

Author 1	Author 2	Facility or Agency
Buursink	Lane	USGS

Citation

Buursink, M.L., and J.W. Lane, Jr., 1999. Characterizing Fractures in a Bedrock Outcrop Using Ground-Penetrating Radar at Mirror Lake, Grafton County, New Hampshire. Morganwalp, David W. (editor) (U. S. Geological Survey, United States), Buxton, Herbert T. (editor), U. S. Geological Survey Toxic Substances Hydrology Program; proceedings of the technical

Journal

Title

Characterizing Fractures in a Bedrock Outcrop Using Ground-Penetrating Radar at Mirror Lake, Grafton County, New Hampshire.

Document	Year
	1999

Why	How	What	Where
Characterization	Geophysical	GPR	fractures

Abstract

A study incorporating numerical modeling, physical modeling and field surveys at the U.S. Geological Survey Fractured Rock Research Site at Mirror Lake, Grafton County, New Hampshire, was conducted to test the use of ground-penetrating radar (GPR) surface reflection methods to delineate fractures in heterogeneous bedrock. Results of one- and 2.5-dimensional numerical modeling correlate with results of laboratory-scale physical modeling and establish different GPR reflection characteristics for saturated and unsaturated (dry) fractures. Saturated fractures generate higher amplitude reflections than unsaturated fractures and have an opposite phase. GPR reflection data collected over a highway bedrock outcrop near Mirror Lake were processed to reduce noise and clutter, to correct geometric and topographic distortions, and to enhance weak reflections from structures more than 15 meters (m) deep.

Guided by the results of numerical modeling, 18 reflectors with lengths ranging from 4 to 32 m and dips ranging from 5 to 40 degrees were interpreted as fractures in the processed GPR field records. All of the interpreted fractures that project above land surface correlated with fractures recorded by detailed outcrop mapping. Interpretation of the processed field data was limited to reflectors dipping less than 45 degrees, although more steeply dipping fractures exist at the field site. Spatial aliasing effects and other limitations constrain the range of dip-angles that GPR reflection methods can usefully image from the surface. The results of the field study together with the results of the numerical and physical modeling indicate that surface GPR reflection methods can be used to help characterize fractures in heterogeneous bedrock.

Author 1	Author 2	Facility or Agency
Campbell	Gee	Hanford

Citation

Campbell, M. D., G. W. Gee, et al., 1991. Water Balance Lysimetry at a Nuclear Waste Site. Lysimeters for Evapotranspiration and Environmental Measurements, Proceedings of the International Symposium on Lysimeters for Evapotranspiration and Environmental Measurements, Jul 23-25 1991, Honolulu, HI, USA

Journal

Title

Water balance lysimetry at a nuclear waste site. Lysimeters for Evapotranspiration and Environmental Measurements, Proceedings of the International Symposium on Lysimeters for Evapotranspiration and Environmental Measurements

Document	Year
	1991

Why	How	What	Where
Monitoring	Devices	lysimeter	Unsaturated

Abstract

Lysimeters measure effects of soil, vegetation, and climate on water balance and groundwater recharge at a nuclear-waste site in arid-southcentral Washington State, USA. Data from 4 lysimeter sites illustrate water balance measurements taken over a period of 20 years. Soil sample, weight change, and neutron probe measurements monitored influences of vegetation and precipitation on water balance. Lysimeter drainage was measured directly where possible and was otherwise inferred from deep storage changes and soil moisture tensions. Apparently, deep-rooted plants prevented drainage from the 18-m-deep, sand-filled lysimeter, as water storage fluctuated near the surface but not below the 5-m depth. In contrast, up to 120 mm of water drained from coarse sands in a 7.6-m-deep, bare-surface lysimeter and 100 mm drained from a 1.5-m-deep, vegetated (grass-covered) lysimeter when annual precipitation reached 281 mm. Lysimeters containing silt loam soil did not drain (i.e., zero recharge potential), even when total precipitation was 320 mm/y and the surface was bare. Soil water storage capacity, precipitation timing and amount, and vegetative cover and rooting depth affect water balance and groundwater recharge.

Author 1	Author 2	Facility or Agency
Capilla	Rodrigo	

Citation

Capilla, J.E., J. Rodrigo, et al., 1998. Worth of Secondary Data Compared to Piezometric Data for the Probabilistic Assessment of Radionuclide Migration.

Journal

Title

Worth of Secondary Data Compared to Piezometric Data for the Probabilistic Assessment of Radionuclide Migration.

Document	Year
	1998

Why	How	What	Where
DQO			

Abstract

A common approach for the performance assessment of radionuclide migration from a nuclear waste repository is by means of Monte-Carlo techniques. Multiple realizations of the parameters controlling radionuclide transport are generated and each one of these realizations is used in a numerical model to provide a transport prediction. The statistical analysis of all transport predictions is then used in performance assessment. In order to reduce the uncertainty on the predictions is necessary to incorporate as much information as possible in the generation of the parameter fields. In this regard, this paper focuses in the impact that conditioning the transmissivity fields to geophysical data and/or piezometric head data has on convective transport predictions in a two-dimensional heterogeneous formation. The Walker Lake data based is used to produce a heterogeneous log-transmissivity field with distinct non-Gaussian characteristics and a secondary variable that represents some geophysical attribute. In addition, the piezometric head field resulting from the steady-state solution of the groundwater flow equation is computed. These three reference fields are sampled to mimic a sampling campaign. Then, a series of Monte-Carlo exercises using different combinations of sampled data shows the relative worth of secondary data with respect to piezometric head data for transport predictions. The analysis shows that secondary data allows to reproduce the main spatial patterns of the reference transmissivity field and improves the mass transport predictions with respect to the case in which only transmissivity data is used. However, a few piezometric head measurements could be equally effective for the characterization of transport predictions.

Author 1	Author 2	Facility or Agency
Carroll		EMSP

Citation

Carroll, S. A., 2002. Environmental Management Science Project (EMSP) Strategic Plan for Deployment - Experimental Determination of Contaminant Metal Mobility as a Function of Temperature, Time, and Solution Chemistry

Journal

Title

Environmental Management Science Project (EMSP) Strategic Plan for Deployment - Experimental Determination of Contaminant Metal Mobility as a Function of Temperature, Time, and Solution Chemistry

Document	Year
EMSP-55249	2002

Why	How	What	Where
Modeling	Geochemical	strontium	

Abstract

Because strontium is significantly more mobile than other hazardous radioactive metals, it is important to determine the geochemical processes that control its mobility in the presence of clays (kaolinite, montmorillonite) and iron hydroxides (goethite) as a function of temperature, pH, and time. The objective of this work is to determine the fundamental data needed to predict the behavior of Sr at temperature and time scales appropriate to thermal remediation. The approach combines macroscopic sorption/precipitation and desorption/dissolution kinetic experiments, which track changes in solution composition, with direct molecular characterization of Sr in the solid phase using X-ray absorption spectroscopy. These experiments will be used to identify mechanistic geochemical reactions and their thermochemical properties that will be incorporated into geochemical computer codes.

Author 1	Author 2	Facility or Agency
Chowdhury	Hsiung	

Citation

Chowdhury, A.H., S. Hsiung, et al., 1995. An Evaluation of Performance Goal-Based Seismic Design Approach for Geologic Repository Facilities. Proceedings, Focus '95 Methods of Seismic Hazard Evaluation, ANS.

Journal

Title

An Evaluation of Performance Goal-Based Seismic Design Approach for Geologic Repository Facilities

Document	Year
	1995

Why	How	What	Where
Design	Uncertainties		Structure

Abstract

Author 1	Author 2	Facility or Agency
Clarke	Dunn	INEEL

Citation

Clarke, J. H., R. J. Dunn, et al., 2002. Science and Technology Roadmaps for the Vadose Zone at the Idaho National Engineering and Environmental Laboratory. Center for Research and Technology Development, (Publication) CRTD, American Society of Mechanical Engineers 64: 961-969.

Journal

American Society of Mechanical Engineers 64: 961-969

Title

Science and Technology Roadmaps for the Vadose Zone at the Idaho National Engineering and Environmental Laboratory.

Document	Year
	2002

Why	How	What	Where
Design			Unsaturated

Abstract

Based on a request from the Office of Science and Technology (OST), Office of Environmental Management, U.S. Department of Energy (DOE), a Review Panel (RP) was established to peer review the “Science and Technology Roadmaps for the Vadose Zone at the Idaho National Engineering and Environmental Laboratory” (INEEL) project.
The objective of this project is to determine the science and technology (S&T) needs that will facilitate the monitoring, characterization, prediction, and assessment activities necessary to support the INEEL risk management decisions required by the long-term stewardship of the INEEL contaminated sites. This project aims to ensure that the long-term S&T strategy is aligned with the site programs; that it takes advantage of progress made to date; and that it assists in meeting the milestones and budgets of operations.

Author 1	Author 2	Facility or Agency
Conrad	Daley	LBNL

Citation

Conrad, M. E., Daley, P. F., et al., 1996. Tracing Subsurface Biodegradation by Hydrocarbons with Radiocarbon. Oteyza, Julian (editor) (American Chemical Society, Abstracts of Meeting Papers, Washington, DC, United States), Abstracts of papers; 211th ACS national meeting, Abstracts of Papers - American Chemical Society, National Meeting, 211, p. GEOC 019,

Journal

Title

Tracing Subsurface Biodegradation by Hydrocarbons with Radiocarbon

Document	Year
	1996

Why	How	What	Where
Characterization			

Abstract

Author 1	Author 2	Facility or Agency
Craig		NRC

Citation

Craig, J.W., 1998. DRAFT: Decision Methods for Dose Assessment to Comply With Radiological Criteria for License Termination. U.S. Nuclear Regulatory Commission Report. NUREG-1549.

Journal

Title

DRAFT: Decision Methods for Dose Assessment to Comply With Radiological Criteria for License Termination

Document	Year
NUREG-1549	1998

Why	How	What	Where

Abstract

This draft NUREG-series report describes a methodology for calculating doses to demonstrate compliance with the radiological criteria for decommissioning and license termination. The methodology is designed to allow each licensee the flexibility to optimize their decommissioning activities within the context of the License Termination rule. Note that although this document is divided into multiple sections to simplify the discussion for different situations, the underlying modeling process is a smooth continuum of options.

The simplest method for calculating dose, generic screening (see Chapter 3), uses models and default parameters that the NRC developed for compliance screening calculations [Kennedy and Strenge, 1992]. The generic models and default parameters are intended to estimate the upper range of the dose that an individual could receive and are expected to overestimate the dose for most sites. The purpose of generic screening is to allow the licensee a simple and cost-effective method to demonstrate compliance with NRC regulations using a minimum amount of site specific information. Such a screening approach is based on reasonably conservative assumptions since it must provide a reasonable level of assurance and must be applicable to a wide range of licensees, radionuclides, and processes. As such, it is expected to be appropriate for NRC licensees who have relatively simple decommissioning situations. The calculated value under generic screening conditions is simply a marker used to demonstrate compliance and is not intended to be a realistic dose estimate.

Generic screening may not be appropriate for licensees who have complex mixtures of radionuclides, unusual or unique decommissioning situations, or where the use of very conservative assumptions would result in unwarranted costs or inefficient and illogical remediation requirements. Licensees who prefer to use site-specific information can use the same models as are used for generic screening, but must substitute site-specific values in place of some or all of the generic default parameters (see Chapters 4 and 5). The resulting dose estimates are expected to be more realistic and provide less of an over-estimate of dose than that provided by the generic screening approach. Site-specific screening utilizes additional site specific data to support the modification or elimination of a particular scenario or pathway, or to demonstrate that a parameter or group of parameters can be better represented by site specific values. Alternative exposure scenarios may be appropriate based on site-specific factors that affect the likelihood and extent of potential future exposure to residual radioactivity. Guidance has been included in this document regarding sources of information available to licensees that can be used to support modification of parameter values.

Two other documents that provide background for this publication are available for viewing or reproduction in paper or diskette for a fee at NRC's Public Document Room, located at 2121 L Street, N.W., Lower Level, Washington, DC 20555-0001; Web address <http://www.nrc.gov/NRC/PDR/pdr1.htm>; Telephone: 1-800-397-4209, or locally, 202-634-3273. These background documents are titled "Review of Parameter Data for the NUREG/CR-5512 Building Occupancy Scenario and Probability Distributions for the DandD Parameter Analysis" and "Review of Parameter Data for the NUREG/CR-5512 Residential Farmer Scenario and Probability Distributions for the DandD Parameter Analysis."

Author 1	Author 2	Facility or Agency
Crumbling		

Citation

Crumbling, D., 2002. In Search of Representativeness: Evolving the Environmental Data Quality Model. Quality Assurance, 9:179-190.

Journal

Quality Assurance, 9:179-190.

Title

In Search of Representativeness: Evolving the Environmental Data Quality Model.

Document	Year
	2002

Why	How	What	Where
DQO	Uncertainties		Saturated

Abstract

Environmental regulatory policy states a goal of "sound science." The practice of good science is founded on the systematic identification and management of uncertainties; i.e., knowledge gaps that compromise our ability to make accurate predictions. Predicting the consequences of decisions about risk and risk reduction at contaminated sites requires an accurate model of the nature and extent of site contamination, which in turn requires measuring contaminant concentrations in complex environmental matrices. Perfecting analytical tests to perform those measurements has consumed tremendous regulatory attention for the past 20-30 years. Yet, despite great improvements in environmental analytical capability, complaints about inadequate data quality still abound. This paper argues that the first generation data quality model that equated environmental data quality with analytical quality was a useful starting point, but it is insufficient because it is blind to the repercussions of multifaceted issues collectively termed "representativeness." To achieve policy goals of "sound science" in environmental restoration projects, the environmental data quality model must be updated to recognize and manage the uncertainties involved in generating representative data from heterogeneous environmental matrices.

Author 1	Author 2	Facility or Agency
Crumbling	Griffith	

Citation

Crumbling, D., J. Griffith, et al., 2003. Improving Decision Quality: Making the Case for Adopting Next-Generation Site Characterization Practices. Remediation, 91-111.

Journal

Title

Improving Decision Quality: Making the Case for Adopting Next-Generation Site Characterization Practices

Document	Year
	2003

Why	How	What	Where
Characterization		Triad	

Abstract

Better site characterization is critical for cheaper, faster, and more effective cleanup. This fact is especially true as cleanup decisions increasingly include site redevelopment and reuse considerations. However, established attitudes about what constitutes "data quality" create many barriers to exciting new tools capable of achieving better characterization, slowing their dissemination into the mainstream. Traditional approaches to environmental "data quality" rest on simplifying assumptions that are rarely acknowledged by the environmental community. Data quality assessment focus on the quality of the analysis, while seldom asking what impact matrix heterogeneity has had on analytical results. Assessments of data quality typically assume that chemical contaminants are distributed nearly homogenously throughout environmental matrices and that contaminant-matrix interactions are well behaved during analysis. Yet, these assumptions seldom hold true for real-world matrices and contaminants at scales relevant to accurate risk assessment and efficient remedial design. For the site cleanup industry to continue technical advancement, over-simplified paradigms must give way to next-generation models that are built on current scientific understanding. If reuse programs such as Brownfields are to thrive, the scientific defensibility of individual projects must be maintained at the same time as characterization and cleanup costs are lowered. The U.S. Environmental Protection Agency (EPA) offers the Triad Approach as an alternative paradigm to foster highly, defensible, yet extremely cost-effective reuse decisions.

Author 1	Author 2	Facility or Agency
Crumbling	Groenjes	

Citation

Crumbling, D., C. Groenjes, et al., 2001. Applying the Concept of Effective Data to Contaminated Sites Could Reduce Costs and Improve Cleanups. Environmental Science and Technology, 405-409.

Journal

Environmental Science and Technology

Title

Applying the Concept of Effective Data to Contaminated Sites Could Reduce Costs and Improve Cleanups.

Document	Year
	2001

Why	How	What	Where
DQO	Uncertainties		Saturated

Abstract

Author 1	Author 2	Facility or Agency
Dakins	Porter	

Citation

Dakins, M. E., P. S. Porter, et al., 1996. Using Uncensored Trace-level Measurements to Detect Trends in Ground Water Contamination. Water Resources Bulletin 32(4): 799-805.

Journal

Water Resources Bulletin 32(4): 799-805

Title

Using Uncensored Trace-level Measurements to Detect Trends in Ground Water Contamination.

Document	Year
	1996

Why	How	What	Where
Characterization			

Abstract

Author 1	Author 2	Facility or Agency
Daley	Landgraf	LLNL

Citation

Daley, P. F., R.K. Landgraf, et al., 1995. Building 834; cost-effective and innovative design of remediation systems using surplus equipment from former weapons programs, UCRL-JC-120620; CONF-950868-45, p. 11, 1995. Presented at the ER '95; Environmental remediation conference; committed to results, Denver, CO, Aug. 13-15, 1995.

Journal

Title

Building 834; cost-effective and innovative design of remediation systems using surplus equipment from former weapons programs.

Document	Year
	1995

Why	How	What	Where
Design			

Abstract

The Building 834 Complex at the Lawrence Livermore National Laboratory (LLNL) Site 300, has been used by the weapons development programs at LLNL as a testing facility for measuring component response to environmental stresses such as extreme temperature. The heat-exchange system at the facility used trichloroethene TCE as the primary heat-transfer media for over 20 years. Accidental spills, pipe failures, and seal blowouts over that period contributed to a substantial contaminant plume in a perched water-bearing zone underlying the Complex. Individual wells near the source area have produced ground water samples with TCE concentrations exceeding 800,000 ppb. In the last several years, the authors have developed a modular ground water and soil vapor extraction system for remediating the plume source area. The modular facility design permits the testing of new technologies to expedite remediation, and/or reduce the quantity of hazardous wastes generated as by-products of the primary remedial activities. To contain costs, the authors have used equipment and components recycled from the original Building 834 Complex heat-exchange system, and surplus equipment from other LLNL divisions. The authors have executed two large-scale tests of energy injection systems for TCE destruction in air (a free-air electron beam and a pulsed, ultraviolet photolysis system), and a soil heating test for accelerating vapor extraction. New work plans for this unique site are being prepared, incorporating the lessons learned in developing new technology with recycled equipment.

Author 1	Author 2	Facility or Agency
Daley	Carlsen	

Citation

Daley, P. F., Carlsen, et al., 1991. Development of Innovative Approaches to Site Investigation and Remediation at Lawrence Livermore National Laboratory Site 300. Anonymous, Geological Society of America, 1991 annual meeting, Abstracts with Programs - Geological Society of America, 23 (5), p. 254, 1991. Meeting: Geological Society of America, 1991 annual

Journal

Title

Development of Innovative Approaches to Site Investigation and Remediation at Lawrence Livermore National Laboratory Site 300.

Document	Year
	1991

Why	How	What	Where

Abstract

Author 1	Author 2	Facility or Agency
Daley	Colston	

Citation

Daley, P. F., B. W. J. Colston, et al., 1992. Fiber Optic Sensor for Continuous Monitoring of Chlorinated Solvents in the Vadose Zone and in Groundwater: Field Test Results. Chemical, Biochemical, and Environmental Fiber Sensors III, Sep 4-5 1991, Boston, MA, USA.

Journal

Title

Fiber Optic Sensor for Continuous Monitoring of Chlorinated Solvents in the Vadose Zone and in Groundwater: Field Test Results.

Document	Year
	1992

Why	How	What	Where
Monitoring	Sensors	optical	Saturated

Abstract

A fiber optic chemical sensor has been designed for groundwater and vadose zone monitoring of volatile halogenated hydrocarbons. The principle of detection is a quantitative, irreversible chemical reaction that forms visible light absorbing products. This absorption is measured remotely using fiber optics. Modifications of our previous sensor design have resulted in lower detection limits and increase durability.
In this paper we describe the measurement system and present the new sensor design along with calibration data and preliminary field test results.

Author 1	Author 2	Facility or Agency
Daniel	Burton	

Citation

Daniel, D. E., P. M. Burton, et al., 1992. Evaluation of Four Vadose Zone Probes Used for Leak Detection and Monitoring. Symposium on Current Practices in Ground Water and Vadose Investigations, Jan 30-Feb 1 1991, San Diego, CA, USA.

Journal

Title

Evaluation of Four Vadose Zone Probes Used for Leak Detection and Monitoring.

Document	Year
	1992

Why	How	What	Where
Monitoring		probe	Unsaturated

Abstract

Author 1	Author 2	Facility or Agency
Datta	Dhiman	

Citation

Datta, B. and S. D. Dhiman, 1996. Chance-Constrained Optimal Monitoring Network Design for Pollutants in Ground Water. J. Water Resources Planning and Management 122(3): 180-188.

Journal

Journal of Water Resources Planning and Management 122(3): 180-188

Title

Chance-Constrained Optimal Monitoring Network Design for Pollutants in Ground Water.

Document	Year
	1996

Why	How	What	Where
Design	Optimization		Saturated

Abstract

A mathematical model for designing a ground-water-quality monitoring network is developed that links a ground-water pollution-transport simulation model and an optimization model. Tritium is considered as the (radioactive) pollutant. The model is formulated using chance constraints and solved by using a mixed-integer programming algorithm. It incorporates uncertainties in the prediction of pollutant movement in the saturated zone. Nonlinearities due to the inclusion of cumulative distribution functions (CDFs) of actual spatial concentrations are accommodated in the optimization model through a piecewise linearization scheme. The design of the optimal monitoring network is based on the solution of two mathematical models: a simulation model for the prediction of radioactive pollutant transport in the saturated zone, and an optimization model. Constraints of the optimization model are formulated by incorporating results from the prediction-simulation model. The simulation model provides information about pollution transport with respect to time and space. The chance-constrained optimization model solution specifies the optimal location of the monitoring wells subject to the maximum limit on the number of such wells. Performance evaluation of the developed model demonstrates potential applicability of this model for designing ground-water-quality monitoring networks.

Author 1	Author 2	Facility or Agency
DeLozier		ORNL

Citation

DeLozier, F., 1995. Risk-based Cleanup and Recycling of Residuals from United States Department of Energy Decontamination and Decommissioning Facilities in Oak Ridge, Tennessee, U.S.A. Proceedings of the 1995 5th International Conference on Radioactive Waste Management and Environmental Remediation, ICEM'95. Part 1 (of 2), Sep 3-7 1995.

Journal

Title

Risk-based Cleanup and Recycling of Residuals from United States Department of Energy Decontamination and Decommissioning Facilities in Oak Ridge, Tennessee, U.S.A.

Document	Year
	1995

Why	How	What	Where

Abstract

Author 1	Author 2	Facility or Agency
Devillers	Allan	NEA

Citation

NEA/OECD, Confidence in the Long-term Safety of Deep Geological Repositories - Its Development and Communication. Report, 1999.

Journal

Title

Confidence in the Long-term Safety of Deep Geological Repositories - Its Development and Communication

Document	Year
	1999

Why	How	What	Where
Design	Performance		Saturated

Abstract

The technical aspects of confidence have been the subject of considerable debate, especially the concept of model validation. It is impossible to describe completely the evolution of an open system, such as a repository and its environment, that cannot be completely characterised and may be influenced by natural and human-induced factors outside the system boundaries. A complete description is not, however, a requirement of decision making in repository development.
Repository development proceeds in stages, and the depth of understanding and technical information available to support decisions will vary from stage to stage. Decision making requires only that a safety case has been compiled that gives adequate confidence to support the decision at hand, and that an efficient strategy exists to deal at future stages with any uncertainties in the description which have the potential to compromise safety.
The safety case involves descriptions of the possible evolutions of the system. Although not capable of proof in a rigorous sense, these descriptions can be supported by relevant observations of the behaviour of the various components of the system, while relying on an understanding of its geological history. Furthermore, flexibility should be built into the process of repository development, allowing account to be taken of new understanding and technical information, as well as the demands of societal review.
The safety case that is provided at a particular stage in the planning, construction, operation or closure of a deep geological repository is a part of a broader decision basis that guides the repository-development process. The basic steps for deriving the safety case at various stages of repository development involve:
- A safety assessment, which includes:
  - the establishment of an assessment basis in which there is confidence, i.e. the strategy for the building of a safety case, the selection of a site and design, and the assembly of all relevant information, models and methods;
  - the application of the assessment basis in a performance assessment, that explores the range of possible evolutions of the repository system and tests compliance of performance with acceptance guidelines;
  - the evaluation of confidence in the safety indicated by the assessment and modification, if necessary, of the assessment basis.
- The documentation of the safety assessment, a statement of confidence in the safety indicated by the assessment, and the confirmation of the appropriateness of the safety strategy, either in anticipation of the next stages of repository development or in response to interaction with decision makers.
The safety case should make explicit the principles adopted, and methods followed, in order to establish confidence. The approaches to establish confidence in the evaluation of safety should aim to ensure that the decisions taken within the incremental process of repository development are wellfounded.
Various aspects of confidence in the evaluation of safety, and their integration within a safety case, are presented in detail in the present report. The key messages arising from their analysis are highlighted below.
- A safety case should make explicit the approaches that are implemented in order to establish confidence in the safety indicated by an assessment.

- The assessment basis, as defined in this report, is a key element of any safety case. In order to establish confidence in the safety indicated by an assessment, confidence in the elements of the assessment basis must be evaluated. If necessary, the elements must be modified with a view to achieving confidence enhancement.
- Confidence evaluation and enhancement are performed iteratively in the preparation of a safety case.
- Methods exist to evaluate confidence in the safety indicated by an assessment in the inevitable presence of uncertainty. In many cases, it can be determined whether safety is compromised by specific uncertainties through a sensitivity analysis, in which the consequences of such uncertainties are evaluated.
- Means exist whereby confidence in the safety indicated by an assessment can be enhanced, by ensuring the robustness of the system concept, the quality of the assessment capability, the reliability of its application in performance assessment and the adequacy of the safety strategy to deal with unresolved, safety-relevant issues.
- Observations of natural systems play an important role in the qualitative evaluation and enhancement of confidence, since such systems have evolved over extremely long timescales.
- A statement of confidence in the overall safety indicated by the performance-assessment results is part of the safety case and should include an evaluation of the arguments that were developed, in relation to the decision to be taken.

When communicating confidence in the findings of a safety assessment, clarity in the communication of concepts is always required. Consistent with this requirement, key concepts are specifically defined in the main text of the report. An index of definitions is provided in Appendix 4. Figures and tables are listed in the table of contents.

Author 1	Author 2	Facility or Agency
DOE		DOE

Citation

USDOE. Corrective Action Management Program Quarterly Report, Second Quarter FY 2003.

Journal

Title

Department of Energy Corrective Action Management Program Quarterly Report, Second Quarter FY 2003

Document	Year
	2003

Why	How	What	Where

Abstract

Summary report of corrective actions ongoing and completed at DOE facilities.

Author 1	Author 2	Facility or Agency
Dougherty	Bagtzoglou	

Citation

Dougherty, D.E. and A.C. Bagtzoglou, 1993. A Caution on the Regulatory Use of Numerical Solute Transport Models. J. Ground Water, 31(6), pp. 1007-1010.

Journal

J. Ground Water, 31(6), 1007-1010.

Title

A Caution on the Regulatory Use of Numerical Solute Transport Models

Document	Year
	1993

Why	How	What	Where
Modeling	Uncertainties		Saturated

Abstract

Numerical models of solute transport in water-saturated porous media are routinely used to make regulatory and design decisions. For many contaminants, decisions are based on concentrations of 5 parts per billion (ppb) or less. This "action level" is usually a small fraction (<0.01) of the concentrations near a source of contamination. Two one-dimensional example problems are used to demonstrate that modeling errors using classical numerical methods are largest where concentrations are lowest. This implies that in regions of low dimensionless concentration, that is near the action level, large relative errors can be expected. Hence, decisions based on numerical model solutions at low concentrations must be taken cautiously. Modern numerical methods for the solution of transport equations provide better behavior, in this sense, than classical methods.

Author 1	Author 2	Facility or Agency
Dunn		

Citation

Dunn, 1980. Bibliography of Uranium Biogeochemistry. Misc. Rept. Miner. Resour. Saskatchewan 80(4), 59 p.

Journal

Misc. Rept. Miner. Resour. Saskatchewan 80(4), 59 p.

Title

Bibliography of Uranium Biogeochemistry

Document	Year
	1980

Why	How	What	Where
Characterization	Ecological		Surface

Abstract

Author 1	Author 2	Facility or Agency
Dunnivant	Porro	INEEL

Citation

Dunnivant, F. M., I. Porro, et al., 1997. Verifying the Integrity of Annular and Back-filled Seals for Vadose-zone Monitoring Wells. Ground Water 35(1): 140-148.

Journal

Ground Water 35(1): 140-148

Title

Verifying the Integrity of Annular and Back-filled Seals for Vadose-zone Monitoring Wells.

Document	Year
	1997

Why	How	What	Where
Monitoring	Access	wells	Unsaturated

Abstract

Monitoring wells were used in characterizing subsurface contamination in the vadose zone during the Large-Scale Pumping and Infiltration Test at the Idaho National Engineering Laboratory. Water movement throughout the vadose zone was determined by the integrity of the seals for the wells. The introduction of bentonite as the sealing materials prevented vertical water flow upon flooding of the infiltration basin. This suggests that bentonite is an effective sealant of monitoring wells.

Author 1	Author 2	Facility or Agency
Eisenberg	Lee	Sandia

Citation

Eisenberg, N.A., M.P. Lee, et al., 1999. Development of a Performance Assessment Capability in the Waste Management Programs of the U. S. Nuclear Regulatory Commission. Helton, J. C. (editor), Anderson, D. R. (editor), Performance Assessment for Radioactive Waste Disposal. Risk Analysis, 19 (5), p. 847-876.

Journal

Risk Analysis, 19 (5), p. 847-876.

Title

Development of a Performance Assessment Capability in the Waste Management Programs of the U. S. Nuclear Regulatory Commission.

Document	Year
	1999

Why	How	What	Where
Design	Performance		

Abstract

The U.S. Nuclear Regulatory Commission (NRC) staff has developed a performance assessment capability to address three programmatic areas in nuclear waste management: high-level waste, low-level waste, and decommissioning of licensed facilities (license termination). The NRC capability consists of: (1) methodologies for performance assessment; (2) models and computer codes for estimating system performance; (3) regulatory guidance in various forms, such as regulations, Branch Technical Positions, and Standard Review Plans; and (4) a technical staff experienced in executing and evaluating performance assessments for a variety of waste systems. Although the tools and techniques are refined for each programmatic area, general approaches and similar issues are encountered in all areas.

Author 1	Author 2	Facility or Agency
EPA	SAIC	EPA

Citation

Innovations in Site Characterization, Case Study: Site Cleanup of the Wenatchee Tree Fruit Test Plot Site Using a Dynamic Work Plan, United States Environmental Protection Agency, EPA-542-R-00-009, 2000.

Journal

Title

Innovations in Site Characterization, Case Study: Site Cleanup of the Wenatchee Tree Fruit Test Plot Site Using a Dynamic Work Plan

Document	Year
EPA-542-R-00-009	2000

Why	How	What	Where
Characterization	Ecological		Surface

Abstract

This case study describes an approach to site cleanup that includes the use of systematic planning, on-site measurement technologies combined with limited fixed laboratory analyses, and rapid decision-making (using a dynamic work plan) to facilitate quick cleanup. Site characterization information, obtained in the field through the use of IA kits, was used to guide removal activities by means of an adaptive sampling strategy. This approach permitted a cost-effective cleanup of the contaminated site.

Author 1	Author 2	Facility or Agency
Erdman	Harrach	

Citation

Erdman, J.A. and G.H. Harrach, 1981. Uranium in Big Sagebrush from Western U.S. and Evidence of Possible Mineralization in the Owyhee Mountains of Idaho. J. Geochemical Exploration 14(1):83-94.

Journal

J. Geochemical Exploration 14(1):83-94.

Title

Uranium in Big Sagebrush from Western U.S. and Evidence of Possible Mineralization in the Owyhee Mountains of Idaho.

Document	Year
	1981

Why	How	What	Where
Characterization	Ecological	plant uptake	Surface

Abstract

Author 1	Author 2	Facility or Agency
Ewing	Tierney	

Citation

Ewing, R.C., M.S. Tierney, et al., 1999. Performance Assessments of Nuclear Waste Repositories: A Dialogue on Their Value and Limitations. Risk Analysis, 19 (5): 933-958.

Journal

Risk Analysis, 19 (5): 933-958.

Title

Performance Assessments of Nuclear Waste Repositories: A Dialogue on Their Value and Limitations

Document	Year
	1999

Why	How	What	Where
Design	Performance		

Abstract

Performance Assessment (PA) is the use of mathematical models to simulate the long-term behavior of engineered and geologic barriers in a nuclear waste repository; methods of uncertainty analysis are used to assess effects of parametric and conceptual uncertainties associated with the model system upon the uncertainty in outcomes of the simulation. PA is required by the U.S. Environmental Protection Agency as part of its certification process for geologic repositories for nuclear waste. This paper is a dialogue to explore the value and limitations of PA. Two "skeptics" acknowledge the utility of PA in organizing the scientific investigations that are necessary for confident siting and licensing of a repository; however, they maintain that the PA process, at least as it is currently implemented, is an essentially unscientific process with shortcomings that may provide results of limited use in evaluating actual effects on public health and safety. Conceptual uncertainties in a PA analysis can be so great that results can be confidently applied only over short time ranges, the antithesis of the purpose behind long-term, geologic disposal. Two "proponents" of PA agree that performance assessment is unscientific, but only in the sense that PA is an engineering analysis that uses existing scientific knowledge to support public policy decisions, rather than an investigation intended to increase fundamental knowledge of nature; PA has different goals and constraints than a typical scientific study. The "proponents" describe an ideal, six-step process for conducting generalized PA, here called probabilistic systems analysis (PSA); they note that virtually all scientific content of a PA is introduced during the model-building steps of a PSA; they contend that a PA based on simple but scientifically acceptable mathematical models can provide useful and objective input to regulatory decision makers. The value of the results of any PA must lie between these two views and will depend on the level of knowledge of the site, the degree to which models capture actual physical and chemical processes, the time over which extrapolations are made, and the proper evaluation of health risks attending implementation of the repository. The challenge is in evaluating whether the quality of the PA matches the needs of decision makers charged with protecting the health and safety of the public.

Author 1	Author 2	Facility or Agency
Filley	May	

Citation

Filley, T.H., I.P. May, et al., 1991. Design Optimization of In Situ Volatilization Systems. Hazardous Materials Control Research Institute, Boston, Mass., July 10-12, pp. 248-252.

Journal

Hazardous Materials Control Research Institute, Boston, Mass., July 10-12, pp. 248-252.

Title

Design Optimization of In Situ Volatilization Systems.

Document	Year
	1991

Why	How	What	Where
Design	Optimization		Saturated

Abstract

The Twin Cities Army Ammunition Plant (TCAAP) located in New Brighton, Minnesota, has experienced, due to past disposal practices, soil contamination by VOCs at several isolated disposal sites. Although several VOCs have been identified, the principal pollutant is 1,1,2-trichloroethylene (TCE). Soil samples analyzed before remedial action commenced have shown VOC concentrations in excess of 5000 milligrams per kilogram (mg/kg).

During the RI, it was determined to conduct an interim remedial measure, an in situ volatilization (ISV) system. Since implementation of the ISV system at TCAAP Site D in late January 1986, in excess of 00,000 lb of total VOCs (as measured in the air flow from the system) have been removed from the soil. However, verification of the extent of soils cleanup and effectiveness of the present system design have been difficult to assess.

In order to better understand the ISV process and provide a tool for the design optimization and evaluate the effectiveness of these systems, a numerical simulator was developed. This multidimensional, multiphase transport simulator incorporates mass, partitioning between the soils, water, vapor and oil phases. The results of the numerical simulations indicate that while VOC as an irreducible oil phase may be induced to volatilize fairly rapidly, VOC within the water phase may keep air phase concentrations detectable for long periods of time. In particular, air phase concentration rebounds related to blower shutdown and startup have been observed and related to the presence of VOC as an oil phase. The numerical model of TCAAP Site D has been able to reproduce the general features of that ISV system.

Author 1	Author 2	Facility or Agency
Fitzner	Gano	PNNL

Citation

Fitzner, R.E., K.A. Gano, W.H. Rickard, and L.E. Rogers. 1979. Characterization of the Hanford 300 Area burial grounds: Task IV - biological transport. PNL-2774. Pacific Northwest Laboratory, Richland, Washington. Pp. 24-27.

Journal

Title

Characterization of the Hanford 300 Area burial grounds: Task IV - biological transport.

Document	Year
PNL-2774.	1979

Why	How	What	Where

Abstract

Author 1	Author 2	Facility or Agency
Fleming	Nourbakhsh	NRC

Citation

Fleming, K.N. and H.P. Nourbakhsh, 2003. Issues and Recommendations for Advancement of PRA Technology in Risk-Informed Decision Making. U.S. Nuclear Regulatory Commission Report. NUREG/CR-6813.

Journal

Title

Issues and Recommendations for Advancement of PRA Technology in Risk-Informed Decision Making

Document	Year
NUREG/CR-6813	2003

Why	How	What	Where

Abstract

The purpose of this report is to assess the adequacy of PRA for use in regulatory decisions and provide recommendations for its advancements. The insights and recommendations documented in this report were developed by conducting interviews, examining case studies in risk-informed regulation, and by applying experience in developing and applying PRA technology and participating in PRA peer reviews. A number of insights were developed from the review of the recent Davis-Besse vessel head degradation and previous risk-informed and deterministic safety evaluations of the Alloy 600 nozzle cracking issue. Using the author's experience in performing and reviewing several of the existing industry PRAs, a number of technical issues were identified that help defines the current state of the art in PRA technology. The results and conclusions of this report include a number of recommendations intended to resolve some of the issues that were identified and to advance the use of PRAs in risk-informed decision making.

Author 1	Author 2	Facility or Agency
Focazio	Szabo	USGS

Citation

USGS (U.S. Geological Survey), 2001. Occurrence of Selected Radionuclides in Ground Water Used for Drinking Water in the United States: A Reconnaissance Survey, 1998. Water-Resources Investigations Report 00-4273

Journal

Title

Occurrence of Selected Radionuclides in Ground Water Used for Drinking Water in the United States: A Reconnaissance Survey, 1998.

Document	Year
WRI 00-4273	2001

Why	How	What	Where

Abstract

The U.S. Geological Survey, in collaboration with the U.S. Environmental Protection Agency, the American Water Works Association, and the American Water Works Service Company, completed a targeted national reconnaissance survey of selected radionuclides in public ground-water supplies. Radionuclides analyzed included radium-224 (Ra-224), radium-226 (Ra-226), radium-228 (Ra-228), polonium-210 (Po-210) and lead-210 (Pb-210).

This U.S. Geological Survey reconnaissance survey focused intentionally on areas with known or suspected elevated concentrations of radium in ground water to determine if Ra-224 was also present in the areas where other isotopes of radium had previously been detected and to determine the co-occurrence characteristics of the three radium isotopes (Ra-224, Ra-226, and Ra-228) in those areas. Ninety-nine raw-water samples (before water treatment) were collected once over a 6-month period in 1998 and 1999 from wells (94 of which are used for public drinking water) in 27 States and 8 physiographic provinces. Twenty-one of the 99 samples exceeded the current U.S. Environmental Protection Agency drinking-water maximum contaminant level of 5 picocuries per liter (pCi/L) for combined radium (Ra-226 + Ra-228). Concentrations of Ra-224 were reported to exceed 1 pCi/L in 30 percent of the samples collected, with a maximum concentration of 73.6 pCi/L measured in water from a nontransient, noncommunity, public-supply well in Maryland. Radium-224 concentrations generally were higher than those of the other isotopes of radium. About 5 percent of the samples contained concentrations of Ra-224 greater than 10 pCi/L, whereas only 2 percent exceeded 10 pCi/L for either Ra-226 or Ra-228. Concentrations of Ra-226 greater than 1 pCi/L were reported in 33 percent of the samples, with a maximum concentration of 16.9 pCi/L measured in water from a public-supply well in Iowa. Concentrations of Ra-228 greater than 1 pCi/L were reported in 22 samples, with a maximum concentration of 72.3 pCi/L measured in water from a non-transient, noncommunity, public-supply well in Maryland.

Radium-224, which is a decay product of Ra-228 in the Th-232 decay series, was significantly correlated with Ra-228 (Spearman's rank correlation coefficient "r" equals 0.82) and to a lesser degree with Ra-226 (r equals 0.69), which is an isotope in the U-238 decay series. The rank correlation coefficient between Ra-226 and Ra-228 was 0.63. The high correlation between Ra-224 and Ra-228 concentrations and the corresponding isotopic ratios of the two (about 1:1 in 90 percent of the samples) indicates that the two radionuclides occur in approximately equal concentrations in most ground water sampled. Thus, Ra-228 can be considered as a reasonable proxy indicator for the occurrence of Ra-224 in ground water.

The maximum concentration of Po-210 was 4.85 pCi/L and exceeded 1 pCi/L in only two samples. The maximum concentration of Pb-210 was 4.14 pCi/L, and about 10 percent of the samples exceeded 1 pCi/L. Areas with known, or suspected, elevated concentrations of polonium and lead were not targeted in this survey.

Three major implications are drawn for future radionuclide monitoring on the basis of this information: (1) grossalpha particle analyses of ground water should be done within about 48-72 hours after collection to determine the presence of the short-lived, alpha-particle emitting isotopes, such as Ra-224, which was detected in elevated concentrations in many of the samples collected for this survey; (2) the isotope ratios of Ra-224 to Ra-228 in ground water are variable on a national

scale, but the two radioisotopes generally occur in ratios near 1:1, therefore, the more commonly measured Ra-228 can be used as an indicator of Ra-224 occurrence for some general purposes other than compliance; and (3) the isotopic ratios of Ra-226 to Ra-228 were less than 3:2 in many samples. These ratios corroborate results of previous studies that have shown the presence of Ra-228 (a beta-particle emitter) can cause a flaw in conventional radium compliance monitoring when the gross-alpha particle screen indicates no need for further analysis (the gross alpha particle activity is less than 5 pCi/L) even though the ratio of Ra-226 to Ra-228 is less than 3:2.

Author 1	Author 2	Facility or Agency
Freeze	James	

Citation

Freeze, R., B.J. Allan, et al., 1992. Hydrogeological Decision Analysis: 4. The Concept of Data Worth and its Use in the Development of Site Investigation Strategies. Ground Water 30(4): 574-588.

Journal

Ground Water 30(4): 574-588

Title

Hydrogeological Decision Analysis: 4. The Concept of Data Worth and its Use in the Development of Site Investigation Strategies.

Document	Year
	1992

Why	How	What	Where
Characterization			

Abstract

In the design of new waste-management facilities, or in the remedial design for contaminated facilities, there are economic tradeoffs possible between the resources assigned to site investigation, facility design, and site monitoring. Hydrogeological decision analysis provides a framework that allows a sequential, iterative approach to design, in which data acquisition through site investigation alternates with economic analysis of alternative design options. In this framework, the purpose of collecting hydrogeological data is to aid in the making of decisions between the alternative design options. Such decisions are made on the basis of a risk-cost-benefit objective function. Additional measurements have worth only if the risk reduction they provide exceeds the cost of obtaining them. The location of measurement points in a site-investigation network should minimize economic regret with respect to design decisions. This paper provides an introduction to the concepts of data-worth analysis for two cases: (1) the reduction of uncertainty in aquitard continuity, and (2) the reduction of uncertainty in hydraulic-conductivity distribution in an aquifer. It is shown how the use of search theory and Bayesian updating can be applied in comparing prior and preposterior analyses to provide a stopping rule for the collection of additional data in site investigation programs at a hypothetical landfill site.

Author 1	Author 2	Facility or Agency
Freeze	Massmann	

Citation

Freeze, R. A., J. Massmann, et al., 1990. Hydrogeological Decision Analysis. 1. A Framework. Ground Water 28(5): 738-766.

Journal

Ground Water 28(5): 738-766

Title

Hydrogeological Decision Analysis. 1. A Framework.

Document	Year
	1990

Why	How	What	Where
Design	Optimization		Saturated

Abstract

This paper is the first in a four-part series that describes the application of decision analysis to engineering design for projects in which the hydrogeological environment plays an important role. The methodology is well-suited to the design of containment facilities at new waste-management facilities, purge-well networks in contaminant remediation applications, or drainage systems in geotechnical projects. It is based on a risk-based philosophy of engineering design. It involves the coupling of three separate models: a decision model based on a risk-cost-benefit objective function, a simulation model for ground-water flow and transport, and an uncertainty model that encompasses both geological uncertainty and parameter uncertainty. The approach can be used for the comparison of alternative engineered components of a system, for the design of monitoring systems, and for the assessment of data worth in the design of site investigation programs. This first paper lays the framework; the subsequent papers describe how the methods can be applied in geotechnical and waste-management applications.

Author 1	Author 2	Facility or Agency
Fresquez	Foxx	LANL

Citation

Fresquez, P.R., T.S. Foxx, et al., 1996. Uptake of Strontium By Chamisa (Chrysothamnus Nauseosus) Shrub Plants Growing Over A Former Liquid Waste Disposal Site at Los Alamos National Laboratory. HSRC/WERC Joint Conference on the Environment.

Journal

Title

Uptake of Strontium By Chamisa (Chrysothamnus Nauseosus) Shrub Plants Growing Over A Former Liquid Waste Disposal Site at Los Alamos National Laboratory

Document	Year
	1996

Why	How	What	Where
Characterization	Geochemical	Sr uptake	Surface

Abstract

A major concern of managers of low-level waste burial sites is the translocation of radioactive contaminants by deep-rooted plants to the soil surface. This study investigates the uptake of strontium (90Sr), a biologically mobile element, by chamisa (Chrysothamnus nauseosus), a deep-rooted shrub plant, growing over a former liquid waste disposal site (Solid Waste Management Unit [SWMU] 10-003[c]) at Los Alamos National Laboratory (LANL), Los Alamos, New Mexico. Surface soil samples (0 to 5 cm depth) were also collected from below (understory) and between (interspace) shrub canopies. Both chamisa plants growing over SWMU 10-003© contained significantly higher concentrations of 90Sr than a control (background) plant¾one plant, in particular, contained 3.35 x 106 Bq kg-1 ash (9.05 x 104 pCi g-1 ash) in top-growth material. Similarly, soil surface samples collected underneath (ave. = 4,237 Bq kg-1 dry [114.5 pCi g-1 dry]) and between (ave. = 529 Bq kg-1 dry [14.3 pCi g-1 dry]) plants contained 90Sr concentrations above upper limit background (30 Bq kg-1 dry [0.82 pCi g-1 dry]) and LANL screening action levels (>163 Bq kg-1 dry [4.4 pCi g-1 dry]); this probably occurred as a result of chamisa plant leaf fall contaminating the soil understory area followed by water and/or winds moving 90Sr to the soil interspace areas. Although some soil surface migration of 90Sr from SWMU 10-003(c) has occurred, the level of 90Sr in sediments collected downstream of SWMU 10-003(c) at the LANL boundary was still within regional upper limit background concentrations.

Author 1	Author 2	Facility or Agency
Gaglio	Padilla	

Citation

Gaglio, M.D., D.I. Padilla, W.P. MacKay, and N.B. Hogue. 1999. Effectiveness of biobarriers at preventing harvester ants from entering shallow waste containment zones: Excavation of harvester ant nests located on the protective cap/biobarrier experiment site. In: Environmental Science Research Foundation, Inc., Ecological Aspects of Waste Covers, Draft. Pp. 32-

Journal

Environmental Science Research Foundation, Inc., Ecological Aspects of Waste Covers, Draft. Pp. 32-35

Title

Effectiveness of biobarriers at preventing harvester ants from entering shallow waste containment zones: Excavation of harvester ant nests located on the protective cap/biobarrier experiment site.

Document	Year
	1999

Why	How	What	Where
	Ecological		

Abstract

Author 1	Author 2	Facility or Agency
Gaines	Lord	

Citation

Gaines, K.F., C.G. Lord, C.S. Boring, I.L. Brisbin, Jr., M. Gochfeld, and J. Burger. 2000. Raccoons as potential vectors of radionuclide contamination to human food chains from a nuclear industrial site. J. Wildlife Management 64(1): 199-208.

Journal

J. Wildlife Management 64(1): 199-208

Title

Raccoons as potential vectors of radionuclide contamination to human food chains from a nuclear industrial site.

Document	Year
	2000

Why	How	What	Where
Characterization	Ecological		Surface

Abstract

Author 1	Author 2	Facility or Agency
Gallegos	Pohl	

Citation

Gallegos, D. P., P. I. Pohl, et al., 1991. Preliminary Assessment of the Impact of Conceptual Model Uncertainty on Site Performance. Proceedings of the 2nd Annual International Conference on High Level Radioactive Waste Management, Apr 28-May 3 1991.

Journal

Title

Preliminary Assessment of the Impact of Conceptual Model Uncertainty on Site Performance.

Document	Year
	1991

Why	How	What	Where
Modeling	Uncertainties		

Abstract

Performance assessment modeling for high-level radioactive waste (HLW) disposal incorporates three different types of uncertainty. These include data and parameter uncertainty, modeling uncertainty (conceptual, mathematical, and numerical), and uncertainty associated with predicting future state of the system. In this study, the potential impact of conceptual model uncertainty on the performance of a hypothetical high-level radioactive waste disposal site in unsaturated, fractured tuff has been assessed for a given group of conceptual models. This was accomplished by taking a series of six, one-dimensional conceptual models, which differed only by the fundamental assumptions used to develop them, and conducting ground water flow and radionuclide transport simulations. Complementary cumulative distribution functions (CCDFs) of integrated radionuclide release to the water table indicate that differences in basic assumptions can have a significant impact on the performance of the site. Because each of the conceptual models employed the same mathematical and numerical models, contained the same data and parameter values and ranges, and did not consider future states of the system, changes in the CCDF could be attributed primarily to differences in conceptual modeling assumptions.

Author 1	Author 2	Facility or Agency
Galson	Swift	

Citation

Galson, D. A. and P. N. Swift, 1994. Scenario Development for the Waste Isolation Pilot Plant: Building Confidence in the Assessment. Proceedings of the 5th Annual International Conference on High Level Radioactive Waste Management. Part 3 (of 4), May 22-26 1994.

Journal

Title

Scenario Development for the Waste Isolation Pilot Plant: Building Confidence in the Assessment.

Document	Year
	1994

Why	How	What	Where
Design	Performance		

Abstract

Scenario development is part of the iterative performance assessment (PA) process for the Waste Isolation Pilot Plant (WIPP). Scenario development for the WIPP has been the subject of intense external review, and is certain to be the subject of continued scrutiny as the project proceeds toward regulatory compliance. The principal means of increasing confidence in this aspect of the PA will be through the use of a systematic and thorough procedure toward developing the scenarios and conceptual models on which the assessment is to be based. Early and ongoing interaction with project reviewers can assist with confidence building. Quality of argument and clarity of presentation in PA will be of key concern. Appropriate tools are required for documenting and tracking assumptions, through a single assessment phase, and between iterative assessment phases. Risks associated with future human actions are of particular concern to the WIPP project, and international consensus on the principles for incorporation of future human actions in assessments would be valuable.

Author 1	Author 2	Facility or Agency
Garrick	Kaplan	Yucca

Citation

Garrick, B.J. and S. Kaplan, 1999. A Decision Theory Perspective on the Disposal of High-level Radioactive Waste. Risk-Analysis, Special Issue: Performance Assessment for Radioactive Waste Disposal, Vol 19(5): 903-913.

Journal

Risk-Analysis, Vol 19(5): 903-913.

Title

A Decision Theory Perspective on the Disposal of High-level Radioactive Waste.

Document	Year
	1999

Why	How	What	Where
Design	Performance	geostatistics	

Abstract

In this paper, the problem of high-level nuclear waste disposal is viewed as a five-stage cascaded decision problem. The first four of these decisions having essentially been made, the work of recent years has been focused on the fifth stage, which concerns specifics of the repository design. The probabilistic performance assessment work is viewed as the outcome prediction for this stage, and the site characterization work as the information gathering option. This brief examination of the proposed Yucca Mountain repository through a decision analysis framework resulted in three conclusions: A decision theory approach to the process of selecting and characterizing Yucca Mountain would enhance public understanding of the issues and solutions to high-level waste management; (2) engineered systems are an attractive alternative to offset uncertainties in the containment capability of the natural setting and should receive greater emphasis in the design of the repository; and (3) a strategy of "waste management" should be adopted as opposed to "waste disposal" as it allows for incremental confirmation and confidence building of a permanent solution to the high-level waste problem.

Author 1	Author 2	Facility or Agency
Garten		

Citation

Garten, C.T. 1995. Dispersal of Radioactivity by Wildlife from Contaminated Sites in a Forested Llandscape. J. Environ. Radioactivity 29: 137-156.

Journal

J. Environ. Radioactivity 29: 137-156.

Title

Dispersal of Radioactivity by Wildlife from Contaminated Sites in a Forested Llandscape.

Document	Year
	1995

Why	How	What	Where
	Ecological		

Abstract

Author 1	Author 2	Facility or Agency
Gillham	Cherry	

Citation

Gillham, R.W., and J.A. Cherry, 1982. Contaminant Migration in Saturated Unconsolidated Geologic Deposits. Geological Society of America, Special Paper #189, p 31-61.

Journal

Title

Contaminant Migration in Saturated Unconsolidated Geologic Deposits

Document	Year
	1982

Why	How	What	Where
Modeling			Saturated

Abstract

Models that are most commonly used in analyzing the migration of nonreactive contaminants in ground water are based on the advection-dispersion equation derived by spatial averaging of microscopic processes to represent conditions of advection, dispersion, and diffusion at the macroscopic scale. The advection-dispersion equation provides good representation of the results of tracer experiments in saturated columns of porous, homogeneous geologic material. In field situations, however, the deposits through which contaminants migrate are invariable heterogeneous at the macroscopic scale; hence the applicability of advection-dispersion models is questionable.

In unfractured silty or clayey deposits, diffusion generally controls the migration of ground-water contaminants. In fractured deposits, where advective transport may occur along the fractures, molecular diffusion acts as a mechanism of attenuation, causing transfer of contaminants from the fractures to the porous but relatively impervious matrix. In contrast to the coefficients of hydraulic conductivity and dispersivity, the diffusion coefficient for nonreactive constituents in unconsolidated deposits varies within a narrow range. For these reasons, diffusion-controlled hydrogeologic zones have become of interest because of the potential they offer for long-term subsurface isolation of toxic wastes.

At higher ground-water velocities, advection and dispersion become more important and the influence of heterogeneities becomes dominant. Descriptions of contaminant migration under these conditions are often based on the assumption that the number of heterogeneities is very large relative to the volume of the contaminated zone and that the complex macroscopic velocity field produces dispersion that can be described by the advection-dispersion equation even though the degree of dispersion is orders of magnitude stronger per unit travel distance than in laboratory columns. In field applications, the advection-dispersion model is commonly applied. In deposits that are more discretely heterogeneous, an alternative conceptualization of the transport process involved rapid migration by advection along the more permeable zones. This results in irregular contaminant patterns with fingers or stringers containing relatively undispersed contaminant concentrations that can extend far in advance of contaminant fronts in zones of lesser permeability. Considerable apparent dispersion can result if pumped wells or piezometers for sampling include water from both the contaminated and uncontaminated heterogeneities.

Although some field studies provide evidence that contaminant patterns can be strongly controlled by advection along distinct zones of higher permeability, most documented, intensively monitored occurrences of contaminant zones in heterogeneous sand or gravel aquifers and some field tracer experiments in these deposits show concentration patterns that have regularity, with markedly little or no evidence of appreciable fingering. This is the case even at sites where samples were collected from point samplers yielding water from zones that are small in volume relative to many or most of the distinctive heterogeneities. To account for such smoothly dispersed contaminant zones in distinctly heterogeneous deposits, a third conceptualization of the transport process is suggested. As the contaminants are transported primarily by

advection in the more permeable heterogeneities, migration by diffusion occurs into the adjacent heterogeneities of lower permeability, thereby reducing the concentrations in the main zones of advection and increasing the concentrations in the zones of lesser flow. Dispersion at the macroscopic scale and at larger scales within the complex flow system is therefore accomplished primarily by molecular diffusion, which acquires its driving force from the numerous local concentration contrasts continually imposed on the system by advection of contaminants in the more permeable heterogeneities. None of the existing mathematical models for contaminant migration in geologic deposits at the field scale has been developed within this conceptual framework.

To account for the behavior of reactive contaminants in porous geologic materials, a reaction term that can be assigned various forms has been used by numerous investigators. The most common form involved a linear sorption isotherm to describe rapid reversible reactions between the solute and the solids. In contrast to nonreactive solutes, solutes that are well described by linear reversible isotherms in batch experiments provide breakthrough results from column experiments that are poorly represented by the advection-dispersion equation with an incorporated linear isotherm. This indicates that the combined processes of advection, dispersion, and sorption are not well represented even at the laboratory scale by the conventional mathematical formulations. Although many contaminant species in ground water are influenced primarily by adsorption-desorption, many others are controlled by precipitation-dissolution or oxidation-reduction. For many years these processes have been a focus of attention by hydrogeochemists, who have concentrated on developing thermodynamically based models for systems in isolation from the effects of dispersion and diffusion, and by soil scientists, who have focused on the behavior of dynamic systems but at the flow-path scales of a metre or two. There is a necessity to incorporate information from these disciplines into concepts and models of more direct relevance to reactive contaminants migrating along flow paths in dispersive, heterogeneous deposits. Integration of the processes of advection, dispersion, diffusion, and chemical reaction into unified models for analysis of contaminant migration in hydrogeologic systems presents problems of scale in measurement of parameters. Chemical and biochemical processes occur in response to very local reaction conditions which are not necessarily best sampled or described at the scale most suitable for measurements of the physical transport parameters such as hydraulic conductivity or the dispersion coefficient.

Although considerable research on contaminant migration in ground-water flow systems has been conducted during recent decades, this field of endeavor is still in its infancy. Many definitive laboratory and field tests remain to be accomplished to provide a basis for development of mathematical concepts that can be founded on knowledge of the transport processes that exist at the field scale. Without these steps, the tools for assessing the impact of man's activities on the quality of the ground-water environmental will remain inadequate.

Author 1	Author 2	Facility or Agency
Gonzales	Saladen	

Citation

Gonzales, G. J. , Saladen, M. T. , Hakonson, T. E., 1995. Effects of Pocket Gopher Burrowing on Cesium-133 Distribution on Engineered Test Plots. J. Environ. Qual., 24 (6), p. 1056-1062.

Journal

J. Environ. Qual., 24 (6), p. 1056-1062.

Title

Effects of Pocket Gopher Burrowing on Cesium-133 Distribution on Engineered Test Plots.

Document	Year
	1995

Why	How	What	Where
Characterization	Ecological		Surface

Abstract

Author 1	Author 2	Facility or Agency
Granato	Smith	

Citation

Granato, G. E. and K. P. Smith, 2001. Automated Ground-water Monitoring with Robowell-Case Studies and Potential Applications. in Jensen, J.O., and Burggraf, L.W., (eds.) Chemical and biological early warning monitoring for water, food, and ground proceedings 4574: Bellingham WA, Society of Photo-optical Instrumentation Engineers, Photonics Boston, 28

Journal

Title

Automated Ground-water Monitoring with Robowell-Case Studies and Potential Applications.

Document	Year
	2001

Why	How	What	Where
Monitoring	Devices	robowell	Saturated

Abstract

Robowell is an automated system and method for monitoring ground-water quality. Robowell meets accepted manualsampling protocols without high labor and laboratory costs. Robowell periodically monitors and records water-quality properties and constituents in ground water by pumping a well or multilevel sampler until one or more purge criteria have been met. A record of frequent water-quality measurements from a monitoring site can indicate changes in ground-water quality and can provide a context for the interpretation of laboratory data from discrete samples. Robowell also can communicate data and system performance through a remote communication link. Remote access to groundwater data enables the user to monitor conditions and optimize manual sampling efforts. Six Robowell prototypes have successfully monitored ground-water quality during all four seasons of the year under different hydrogeologic conditions, well designs, and geochemical environments. The U.S. Geological Survey is seeking partners for research with robust and economical water-quality monitoring instruments designed to measure contaminants of concern in conjunction with the application and commercialization of the Robowell technology. Project publications and information about technology transfer opportunities are available on the Internet at URL.

Author 1	Author 2	Facility or Agency
Gray		Hanford

Citation

Gray, R. H., 1997. Environmental Monitoring at Two Department of Energy Sites. Proceedings of the 1996 6th Symposium on Environmental Toxicology and Risk Assessment, Apr 15-18 1996, Orlando, FL,USA

Journal

Title

Environmental Monitoring at Two Department of Energy Sites.

Document	Year
	1997

Why	How	What	Where
Monitoring	Ecological	chemical	Saturated

Abstract

The U.S. Department of Energy's Hanford Site was established in southeastern Washington to produce plutonium during World War II. The Pantex Plant in the Texas Panhandle was originally used for loading conventional ammunition shells and bombs, but was rehabilitated and enhanced in the 1950s to assemble nuclear weapons. Environmental monitoring has been ongoing at both locations for several decades. Monitoring objectives are to detect and assess potential impacts of facility operations on air, surface and ground waters, foodstuffs, fish, wildlife, soils, and vegetation. Measured concentrations of airborne radionuclides around the perimeters of both sites are currently below applicable guidelines. Concentrations of radionuclides and nonradiological waer quality in the Columbia River at Hanford, and radiological and nonradiological water quality in the Ogallala Aquifer beneath the Pantex Plant are in compliance with applicable standards. Foodstuffs irrigated with river water downstream from the Hanford Site show levels of radionuclides that are similar to those found in foodstuffs from controlled areas. The low levels of 133Cs and 90Sr in some onsite Hanford wildlife samples and concentrations of radionuclides in soils and vegetation from onsite and offsite at both locations are typical of those attributable to naturally occurring radioactivity and to worldwide fallout. The calculated does potentially received by a maximally exposed individual (i.e., based on hypothetical, worst-case assumptions for all routes of exposure) at both sites in 1994 was <= 0.05 mrem. Ironically, by virtue of its size (1,450 km^3 (560 mi^2)), restricted public access, and conservative use of undeveloped land, the Hanford Site has provided a sanctuary for plant and animal populations that have been eliminated from, or greatly reduced on, surrounding agricultural and range lands. Ongoing studies will determine if this is also true of the Pantex Plant.

Author 1	Author 2	Facility or Agency
Grimes	Hirons	Yucca

Citation

Grimes, B., T. Hirons, et al., 1999. Report of the American Nuclear Society: On the EPA Proposed Standard for the Yucca Mountain High Level Waste Repository.

Journal

Title

Report of the American Nuclear Society: On the EPA Proposed Standard for the Yucca Mountain High Level Waste Repository

Document	Year
	1999

Why	How	What	Where

Abstract

The American Nuclear Society is a not-for-profit, international, scientific and technical organization made up of 11,000 members who are engineers, scientists, administrators, physicians and educators working in a wide variety of settings. The Society's main objective is to promote the advancement of engineering and science related to the atomic nucleus. ANS currently has 61 local sections (52 in the U.S. and 9 non-U.S.), 23 plant branches, 42 student sections, and approximately 100 organization members.

This is the report of a Task Group appointed by the President of the American Nuclear Society (ANS) in October 1999 to review and comment on the Environmental Radiation Protection Standards proposed by the Environmental Protection Agency (EPA) for Yucca Mountain, Nevada. Yucca Mountain has been proposed as a potential repository site for United States high level radioactive waste.

The Task Group reviewed the EPA Proposed Rule, 40 CFR Part 197, and Supplementary Information as published in the Federal Register, Vol. 64, No. 166, August 27, 1999. We had available the proposed implementing Rule published February 22, 1999, by the Nuclear Regulatory Commission, "Disposal of High-Level Radioactive Waste in a Proposed Geologic Repository at Yucca Mountain, Nevada." We also had available the report of the National Research Council for the National Academy of Sciences, "Technical Bases for Yucca Mountain Standards."

Our Task Group was composed of individual professionals working in nuclear science and engineering fields who are familiar with the various technical and regulatory aspects of radioactive waste disposal. This report is a consensus of the views of the task group members and does not necessarily represent the views of the organizations by which they are employed. On a few issues the conclusions of individual Task Group members varied, and this is indicated in the text.

The report focuses primarily on the technical aspects of the proposed EPA standard and on the rationale provided by EPA on various aspects of the standard. We also note several policy issues that derive from the legislative mandate given by Congress to EPA regarding the proposed standard.

Author 1	Author 2	Facility or Agency
Groncki	Sauck	

Citation

Groncki, J.M. and W.A. Sauck, 2000. Calibration, Installation Techniques, and Equilibration Considerations for Vertical Resistivity Probes Used in Hydrogeologic Investigations. Powers, M.H., Ibrahim, A-B., and L. Cramer (eds.). Proceedings of the Symposium on the Application of Geophysics to Engineering and Environmental Problems, p. 979-988. Meeting:

Journal

Title

Calibration, Installation Techniques, and Equilibration Considerations for Vertical Resistivity Probes Used in Hydrogeologic Investigations.

Document	Year
	2000

Why	How	What	Where
Monitoring	Geophysical	ER	Saturated

Abstract

Vertical Resistivity Probes (VRPs) are being increasingly used in a variety of applications where detailed vertical resistivity information in both the vadose and saturated zones is needed. We have twenty installations at five sites in Michigan of probes varying between 15 and 30 feet in length, with stainless steel screw-head electrodes every two inches. They are being used to monitor resistivity in residual LNAPL plumes, dissolved LNAPL plumes, and vadose zone water content / infiltration fronts in an agricultural problem area. All the different possible array types and spacings must be calibrated for the effect of the 2" (outer diameter) insulating PVC cylinder on which the electrodes are mounted. Apparent resistivities must be corrected by calibration factors ranging between 0.72 for the 2" Wenner array, to nearly 1 for the 6" pole-pole array. Varying the installation parameters greatly influences the measured apparent resistivity because of the disturbed annulus and the composition of the backfill materials. Depending upon the purpose, installations are made with or without heavy bentonite slurry that also contains silica flour or very fine sand. Where the saturated zone is of primary interest, the installation can be with a hollow-stem auger, using natural collapse or an introduced sand to fill the annulus around the PVC pipe. In this application, the electrodes are always in good, wetted contact with the formation. For sites where vadose zone monitoring is desired, installations are usually into a pilot hole, which is kept open by bentonite slurry. After installation of the probe, this material then serves to provide electrical contact with the unsaturated zone. Otherwise, particularly for the case of dry sand formations, extremely high contact resistances will preclude making reliable resistivity measurements. However, it is known that the bentonite will be initially quite conductive, but with the passage of time loses ions to the formation by diffusion or leaching. The equilibration time for this process is thus important to document, if repeat readings of resistivity are to be interpreted properly. The effect of the bentonite slurry is also a function of the initial volume required, whether it was mixed with distilled water, and whether it was uniformly distributed vertically along the annular space. Properly calibrating for geometry, and correcting for temporal changes in the bentonite-based annular space filling, allow for very useful resistivity/conductivity information to be extracted from these probes.

Author 1	Author 2	Facility or Agency
Gureghian	Wu	

Citation

Gureghian, A.B., Y-T. Wu, et al., 1992. Deterministic and Probabilistic Performance Assessment Methods Applied to Radionuclide Migration Through Fractured Geologic Medium. Proceedings of the Third International Conference on High-Level Radioactive Waste Management, American Nuclear Society, La Grange Park, Illinois, pp. 985-993.

Journal

Title

Deterministic and Probabilistic Performance Assessment Methods Applied to Radionuclide Migration Through Fractured Geologic Medium

Document	Year
	1992

Why	How	What	Where
Modeling	Performance		Fracture

Abstract

Author 1	Author 2	Facility or Agency
Guzowski		WIPP

Citation

Guzowski, R.V., 1990. Preliminary Identification of Scenarios that May Affect the Escape and Transport of Radionuclides from the Waste Isolation Pilot Plant, Southeastern New Mexico. SAND89-7149, Sandia National Laboratories, Albuquerque, NM.

Journal

Title

Preliminary Identification of Scenarios that May Affect the Escape and Transport of Radionuclides from the Waste Isolation Pilot Plant, Southeastern New Mexico.

Document	Year
	1990

Why	How	What	Where

Abstract

Author 1	Author 2	Facility or Agency
Guzowski	Newman	

Citation
Guzowski, R.V. and G. Newman, 1993. Preliminary Identification of Potentially Disruptive

Journal

Title

Document	Year
	1993

Why	How	What	Where

Abstract

Author 1	Author 2	Facility or Agency
Hakem	Allen	Hanford

Citation

Hakem, N.L., P.G. Allen, et al., 1999. Sorption and Diffusion Studies of Pu(lV) and Pu(lV)-EDTA onto and through Hanford Soil. U.S. Department of Energy, Report UCRL-JC-135799.

Journal

Title

Sorption and Diffusion Studies of Pu(lV) and Pu(lV)-EDTA onto and through Hanford Soil

Document	Year
UCRL-JC-135799	1999

Why	How	What	Where

Abstract

Widely present in the mixed wastes at the Hanford site, ethylenediametetraacetic acid (EDTA) can solubilize radionuclides such as plutonium and may increase their mobility in the environment. In the present study, we evaluated the effect of EDTA on the migration of Pu(IV) at the Hanford site through laboratory-based sorption and diffusion experiments at ambient temperature and atmosphere. The sorption ratio, R%, was determined as a function of pH, EDTA concentration, and solid-liquid ratio. At a plutonium concentration of 5x10^-5 M in the presence of EDTA (> 10e3M), the Pu(IV) sorption ratio decreased significantly. The effective diffusion coefficient, De, <was estimated at 3.54 x 10e6 cm2/sec for Pu(IV)-EDTA at pH=5.5.

Author 1	Author 2	Facility or Agency
Hakonson	Martinez	

Citation

Hakonson, T.E., J.L. Martinez, and G.C. White. 1982. Disturbance of a Low-Level Waste Burial Site Cover by Pocket Gophers. Health Physics 42: 868-871.

Journal

Health Physics 42: 868-871.

Title

Disturbance of a Low-Level Waste Burial Site Cover by Pocket Gophers.

Document	Year

Why	How	What	Where
Characterization	Ecological		Surface

Abstract

Author 1	Author 2	Facility or Agency
Hasemeier	Knight	

Citation
Hasemeier, R. F. and M. A. Knight, 1997. Bethlehem Landfill Groundwater Containment Monitoring. In Situ Remediation of the Geoenvironment, Proceedings of the 1997 ASCE Annual Fall National Convention, Oct 5-8 1997, Minneapolis, MN, USA

Journal

Title
Bethlehem Landfill Groundwater Containment Monitoring.

Document	Year
	1997

Why	How	What	Where
Monitoring			

Abstract

Author 1	Author 2	Facility or Agency
Healey		

Citation

Healey, D.L., Gravity and Seismic Study of Yucca Flat, Nevada Test Site, Nye County, Nevada.

Journal

Title

Gravity and Seismic Study of Yucca Flat, Nevada Test Site, Nye County, Nevada.

Document	Year

Why	How	What	Where
Characterization	Geophysical		

Abstract

Author 1	Author 2	Facility or Agency
Helton	Anderson	WIPP

Citation

Helton, J. C., D. R. Anderson, et al., 2000. Summary Discussion of the 1996 Performance Assessment for the Waste Isolation Pilot Plant. Reliability Engineering and System Safety 69(1): 437-451.

Journal

Reliability Engineering and System Safety 69(1): 437-451.

Title

Summary Discussion of the 1996 Performance Assessment for the Waste Isolation Pilot Plant.

Document	Year
	2000

Why	How	What	Where
Design	Performance	geostatistics	

Abstract

The Waste Isolation Pilot Plant (WIPP) is under development by the US Department of Energy (DOE) for the geologic disposal of transuranic waste. The construction of complementary cumulative distribution functions (CCDFs) for total radionuclide release from the WIPP to the accessible environment is described. The resultant CCDFs (i) combine releases due to cuttings and cavings, spallings, direct brine release, and long-term transport in flowing groundwater; (ii) fall substantially to the left of the boundary line specified by the US Environmental Protection Agency's (EPA's) standard 40 CFR 191 for the geologic disposal of radioactive waste; and (iii) constitute an important component of the DOE's successful Compliance Certification Application to the EPA for the WIPP. Insights and perspectives gained in the performance assessment (PA) that led to these CCDFs are described, including the importance of: (i) an iterative approach to PA; (ii) uncertainty and sensitivity analysis; (iii) a clear conceptual model for the analysis; (iv) the separation of stochastic (i.e. aleatory) and subjective (i.e. epistemic) uncertainty; (v) quality assurance procedures; (vi) early involvement of peer reviewers, regulators, and stakeholders; (vii) avoidance of conservative assumptions; and (viii) adequate documentation.

Author 1	Author 2	Facility or Agency
Helton	Anderson	Sandia

Citation

Helton, J. C., D.R. Anderson, et al., 1999. Performance Assessment in Support of the 1996 Compliance Certification Application for the Waste Isolation Pilot Plant. Helton, J. C. (editor), Anderson, D. R. (editor), Performance assessment for radioactive waste disposal. Risk Analysis, 19 (5), p. 959-986.

Journal

Risk Analysis, 19 (5), p. 959-986.

Title

Performance Assessment in Support of the 1996 Compliance Certification Application for the Waste Isolation Pilot Plant.

Document	Year
	1999

Why	How	What	Where

Abstract

Author 1	Author 2	Facility or Agency
Helton	Anderson	WIPP

Citation

Helton, J.C., D.R. Anderson, et al., 1999. Confidence in the Long-term Safety of Deep Geological Repositories - Its Development and Communication, Reliability Engineering & System Safety 69, 437-451, 1999.

Journal

Reliability Engineering & System Safety 69, 437-451

Title

Summary discussion of the 1996 performance assessment for the Waste Isolation Pilot Plant

Document	Year
	1999

Why	How	What	Where
Design	Uncertainties	performance assessment	Structure

Abstract

The Waste Isolation Pilot Plant (WIPP) is under development by the US Department of Energy (DOE) for the geologic disposal of transuranic waste. The construction of complementary cumulative distribution functions (CCDFs) for total radionuclide release from the WIPP to the accessible environment is described. The resultant CCDFs (i) combine releases due to cuttings and cavings, spallings, direct brine release, and long-term transport in flowing groundwater; (ii) fall substantially to the left of the boundary line specified by the US Environmental Protection Agency's (EPA's) standard 40 CFR 191 for the geologic disposal of radioactive waste; and (iii) constitute an important component of the DOE's successful Compliance Certification Application to the EPA for the WIPP. Insights and perspectives gained in the performance assessment (PA) that led to these CCDFs are described, including the importance of: (i) an iterative approach to PA; (ii) uncertainty and sensitivity analysis; (iii) a clear conceptual model for the analysis; (iv) the separation of stochastic (i.e. aleatory) and subjective (i.e. epistemic) uncertainty; (v) quality assurance procedures; (vi) early involvement of peer reviewers, regulators, and stakeholders; (vii) avoidance of conservative assumptions; and (viii) adequate documentation.

Author 1	Author 2	Facility or Agency
Helton	Garner	WIPP

Citation

Helton, J. C., J. W. Garner, et al., 1993. Uncertainty and Sensitivity Analysis Results Obtained in a Preliminary Performance Assessment for the Waste Isolation Pilot Plant. Nuclear Science and Engineering 114(4): 286-331.

Journal

Nuclear Science and Engineering 114(4): 286-331.

Title

Uncertainty and Sensitivity Analysis Results Obtained in a Preliminary Performance Assessment for the Waste Isolation Pilot Plant.

Document	Year
	1993

Why	How	What	Where

Abstract

Uncertainty and sensitivity analysis obtained in a preliminary performance assessment for the Waste Isolation Pilot Plant (Wipp) in southeastern New Mexico are presented. The most appropriate conceptual model for performance assessment at the Wipp is believed to include gas generation due to corrosion and microbial action in the repository and a dual-porosity (matrix and fracture porosity) representation for solute transport in the Culebra Dolomite Member of the Rustler Formation. Under these assumptions, complementary Cumulative functions (CCDFs) summarizing radionuclide releases to the accessible environment due to both cuttings removal and ground water transport fall substantially below the release limits promulgated by the U.S. Environmental Protection Agency (EPA). This is the case even when the current of the uncertainty in analysis inputs are included. Performance assessment results are dominated by cuttings removal. The releases to the accessible environment due to groundwater transport make very small contribution s to the total release. The variability in the distribution of CCDFs that must be considered in comparisons with the EPA release limits is dominated by the rate constant in the Poisson model for drilling intrusions. The variability in releases to the accessible environment due to cuttings removal is dominated by drill bit diameter. For a single borehole, whether or not a release due to groundwater transport from the repository to the Culebra occurs is controlled by Salado halite permeability, with no release for small values (i.e., 10⁻²¹m₂). Further, release that do reach the Culebra for larger values of halite permeability are small and usually do not reach the accessible environment. A potentially important scenario for the WIPP involves two or more boreholes through the same waste panel, of which at least one penetrates a pressurized brine pocket and at least one does not. For these scenarios, the uncertainty in release to the Culebra due to groundwater transport is dominated by borehole permeability, brine pocket pressure, and the solubilities for individual elements (i.e., americium, neptunium, plutonium, thorium, uranium). Once a release the Culebra, matrix distribution coefficients for the individual elements are important, with releases to the Culebra often failing to reach the accessible environment over the 10,000-yr period specified in the EPA regulations.

Author 1	Author 2	Facility or Agency
Helton	Anderson	WIPP

Citation

Helton, J. C., D. R. Anderson, et al., 1995. Effect of Alternative Conceptual Models in a Preliminary Performance Assessment for the Waste Isolation Pilot Plant. Nuclear Engineering and Design 154(3): 251-344.

Journal

Nuclear Engineering and Design 154(3): 251-344.

Title

Effect of Alternative Conceptual Models in a Preliminary Performance Assessment for the Waste Isolation Pilot Plant.

Document	Year
	1995

Why	How	What	Where

Abstract

The most appropriate conceptual model for performance assessment (PA) at the waste isolation pilot plant (WIPP) is believed to include gas generation resulting from corrosion and microbial action in the repository, and a dual-porosity (matrix and fracture porosity) representation for the solute transport in the Culebra dolomite member of the Rustler formation. Under these assumptions, complementary cumulative distribution functions (CCDFs) which summarize the radionuclide releases to the accessible environment, resulting from both cuttings removal and groundwater transport, fall substantially below the release limits promulgated by the US Environmental Protection Agency (EPA), with the releases being dominated by cuttings removal. To provide additional views, the following alternative conceptual models were considered as part of a preliminary PA for the WIPP: (1) no gas generation in the repository and a dual-porosity transport model in the Culebra; (2) gas generation in the repository and a single-porosity (fracture porosity) transport model in the Culebra; (3) no gas generation in the repository and a single-porosity transport model in the Culebra; (4) gas generation in the repository and a dual-porosity transport model in the Culebra, without chemical retardation; (5) gas generation in the repository, chemical retardation in the Culebra, and extremes of climatic variation. These variations relate to groundwater transport, so do not affect the releases resulting from cuttings removal. Several of these variations substantially increase the importance of releases resulting from groundwater transport relative to releases resulting from cuttings removal. However, the total amount of releases generally remained small, with the CCDFs which summarize the releases to the accessible environment falling below the EPA release limits.

Author 1	Author 2	Facility or Agency
Helton	Anderson	WIPP

Citation

Helton, J.C., D.R. Anderson, et al., 2000. Conceptual Structure of the 1996 Performance Assessment for the Waste Isolation Pilot Plant. Reliability Engineering & System Safety, 69 (1-3): 151-165.

Journal

Reliability Engineering & System Safety, 69 (1-3): 151-165.

Title

Conceptual Structure of the 1996 Performance Assessment for the Waste Isolation Pilot Plant

Document	Year
	2000

Why	How	What	Where

Abstract

The conceptual structure of the 1996 performance assessment (PA) for the Waste Isolation Pilot Plant (WIPP) is described. This structure involves three basic entities (EN1, EN2, EN3): (i) EN1, a probabilistic characterization of the likelihood of different futures occurring at the WIPP site over the next 10,000 years; (ii) EN2, a procedure for estimating the radionuclide releases to the accessible environment associated with each of the possible futures that could occur at the WIPP site over the next 10.000 years; and (iii) EN3, a probabilistic characterization of the uncertainty in the parameters used in the definition of EN1 and EN2. In the formal development of the 1996 WIPP PA, EN1 is characterized by a probability space (f(st,) G(st), p(st)) for stochastic (i.e. aleatory) uncertainty; EN2 is characterized by a function f that corresponds to the models and associated computer programs used to estimate radionuclide releases; and EN3 is characterized by a probability space (f(su), G(su), p(su)) for subjective (i.e. epistemic) uncertainty. A high-level overview of the 1996 WIPP PA and references to additional sources of information are given in the context of (f(su), G(su), p(su)), f and (f(st), G(su), p(su)), Published by Elsevier Science Ltd.

Author 1	Author 2	Facility or Agency
Hooten	Markwiese	

Citation

Hooten, M.M., J.T. Markwiese, et al., 2001. A Literature Review of Biotic Components, Processes, and Characteristics Central to Biotic Transport Modeling of Soils at the Nevada Test Site, prepared for U.S. DOE, Nevada Operations Office.

Journal

Title

A Literature Review of Biotic Components, Processes, and Characteristics Central to Biotic Transport Modeling of Soils at the Nevada Test Site

Document	Year
	2001

Why	How	What	Where
	Ecological		Surface

Abstract

Author 1	Author 2	Facility or Agency
Horseman	Higgo	Nuclear Energy Agency

Citation

Horseman, S.T. and J.J.W. Higgo, 1996. Water, Gas and Solute Movement Through Argillaceous Media. Nuclear Energy Agency, Organisation for Economic Co-operation and Development.

Journal

Title

Water, Gas and Solute Movement Through Argillaceous Media

Document	Year
CC - 96/1	1996

Why	How	What	Where
Characterization	Geochemical	gas movement	

Abstract

Throughout NEA Member countries geological disposal in argillaceous media is being considered as a viable option by many national programmmes on radioactive waste management. In order to determine their suitability for waste disposal, it is necessary to undertake evaluations of the transport of radionuclides from such a disposal system to the accessible environment. These evaluations require not only site specific data from a site characterisation programme, but also a sound general understanding of the basic physical and chemcial processes that govern solute transport.

Author 1	Author 2	Facility or Agency
Horton	Reidel	Hanford

Citation

Horton, D., S. Reidel, et al., 1999. Monitoring Guidance for Vadose Zone Monitoring of Liquid Waste Disposal Facilities for the Hanford Groundwater Project. Rev.2. Pacific Northwest National Laboratory.

Journal

Title

Monitoring Guidance for Vadose Zone Monitoring of Liquid Waste Disposal Facilities for the Hanford Groundwater Project.

Document	Year
PNNL-11958	1999

Why	How	What	Where
Monitoring	Performance	mixed	Unsaturated

Abstract

This document is prepared by Pacific Northwest National Laboratory in response to a U.S. Department of Energy request for a description of vadose zone monitoring of liquid waste disposal facilities that are not part of the Tank Waste Remediation System. This document includes the needs and objectives of vadose zone monitoring and provides a rationale and general framework for vadose zone monitoring of past-practice cribs, ditches, trenches and other disposal facilities. The monitoring described herein will be modified as necessary so as to be incorporated into the Groundwater/Vadose Zone Integration Project.

Vadose zone monitoring addressed in this document is part of the Hanford Groundwater Monitoring Project. As such, the major objective of the monitoring is protection of groundwater. However, the Hanford Groundwater Monitoring Project's vadose zone monitoring compliments the 200 Area soil remediation strategy developed by the Hanford Site's environmental restoration contractor. Most 200 Areas past-practice, liquid waste, disposal facilities are slated for remediation, ranging from complete cleanup to in-place management. The monitoring discussed in this document will track vadose zone contamination until remedial actions can occur. Also, if in some instances vadose contamination is managed in place, periodic monitoring to assess the effectiveness of that remedial decision may be necessary. It is expected that the Hanford Groundwater Monitoring Project's vadose zone activities will undergo changes as the priorities and activities of the Hanford Site environmental restoration activities evolve.

Author 1	Author 2	Facility or Agency
Hossner	Loeppert	ANRCP

Citation

Hossner, L., R. Loeppert, et al., 1998. Literature Review: Phytoaccumulation of Chromium, Uranium, and Plutonium in Plant Systems. Amarillo National Resource Center for Plutonium, ANRCP-1998-3.

Journal

Title

Literature Review: Phytoaccumulation of Chromium, Uranium, and Plutonium in Plant Systems.

Document	Year
ANRCP-1998-3	1998

Why	How	What	Where
Monitoring	Geochemical	biota	Surface

Abstract

Author 1	Author 2	Facility or Agency
Hsieh	Bahr	NRC

Citation

Hsieh, P., J. Bahr, et al., 2002. Conceptual Models of Flow and Transport in the Fractured Vadose Zone. National Academies Press.

Journal

Title

Conceptual Models of Flow and Transport in the Fractured Vadose Zone.

Document	Year
	2001

Why	How	What	Where
Modeling			Unsaturated

Abstract

Fluid flow and solute transport within the vadose zone, the unsaturated zone between the land surface and the water table, is the cause of expanded plumes arising from localized contaminant sources, and an understanding of vadose zone processes is an essential prerequisite for cost-effective contaminant remediation efforts. Contamination of the vadose zone can result from many causes, including chemical spills, leaky underground storage tanks, leachate from waste disposal sites and mine tailings, and application of agricultural chemicals. Another major environmental concern is the potential for long-term migration of radionuclides from low- and high-level nuclear waste disposal facilities. Development of flow and transport models for the vadose zone is a key requirement for designing remediation and long-term stewardship strategies. The presence of fractures and other channel-like openings in the vadose zone poses a particularly significant problem, because such features are potential avenues for rapid transport of chemicals from contamination sources to the water table.

The underpinning of any vadose zone fluid transport model is the conceptualization of (1) the relevant processes, (2) the structure of the subsurface, and (3) the potential events or scenarios that impact the behavior of the modeled system. These conceptualizations together form a "conceptual model," and it is such conceptual models that are the focus of this Panel's study. In cases where multiple competing conceptual models could lead to drastically different conclusions, strategies for evaluating these models must be based on sound technical criteria. The need to develop such strategies and criteria was a key reason for the appointment of this Panel.

Author 1	Author 2	Facility or Agency
Hubbert		

Citation

Hubbert, M.K., 1940. The Theory of Ground-Water Motion. Jour. Geology, 48(8) Part 1:781-944.

Journal

Jour. Geology, 48(8) Part 1:781-944.

Title

The Theory of Ground-Water Motion.

Document	Year
	1940

Why	How	What	Where
Modeling	Ground-Water		Saturated

Abstract

This is a classic paper on ground-water flow. Figures from this paper have been reproduced in most geo-hydrology textbooks.

Author 1	Author 2	Facility or Agency
Hudak		

Citation

Hudak, P. F., 1998. Procedure for Shifting Groundwater Monitoring Locations to Enhance Detection Efficiency Near Landfills. J. Environ. Sci. and Hlth., Part A: Toxic/Hazardous Substances & Environmental Engineering 33(8): 1771-1780.

Journal

J. Environ. Sci. and Hlth. B 33(8): 1771-1780

Title

Procedure for Shifting Groundwater Monitoring Locations to Enhance Detection Efficiency Near Landfills.

Document	Year
	1998

Why	How	What	Where
Design	Optimization		Saturated

Abstract

A heuristic was devised for shifting contaminant detection wells near landfills. The heuristic establishes an initial configuration of monitoring wells and then shifts the wells iteratively until it reaches a specified release detection efficiency. Computer simulations of contaminant transport gauge the performance of the monitoring configurations. In configurations derived by the heuristic, all wells are located the same distance from a landfill, measured parallel to groundwater flow. This facilitates a uniform lag time for release detection. However, the distance between wells, measured perpendicular to groundwater flow, can vary to enhance overall detection efficiency. In practice, the heuristic can be used to identify effective monitoring configurations for detecting potential releases from landfills.

Author 1	Author 2	Facility or Agency
Hudak		

Citation

Hudak, P.F., 1999. A Method for Designing Upgradient Groundwater Monitoring Networks. Environmental Monitoring and Assessment 57: 149-155.

Journal

Environmental Monitoring and Assessment 57: 149-155.

Title

A Method for Designing Upgradient Groundwater Monitoring Networks

Document	Year
	1999

Why	How	What	Where
Design	Optimization		Saturated

Abstract

A graphical heuristic was devised for locating upgradient groundwater monitoring wells near landfills. Utilizing computer-simulated contaminant plumes, the heuristic considers the direction of groundwater flow relative to the shape of a landfill, the location of the downgradient migration boundary used for configuring detection wells, and uniformity of spatial coverage. The heuristic positions upgradient wells far enough from a landfill to avoid contamination, but close enough to measure ambient water quality near the landfill. It can be adapted to nonuniform flow fields, nonlinear migration boundaries, and irregularly shaped landfills. An application to a rectangular landfill, oriented at various angles to the direction of groundwater flow, demonstrates the utility of the approach.

Author 1	Author 2	Facility or Agency
Hudak		

Citation

Hudak, P. F., 1998. Configuring Detection Wells Near Landfills. Ground Water Monitoring & Remediation 18(2): 93-96.

Journal

Ground Water Monitoring & Remediation 18(2): 93-96.

Title

Configuring Detection Wells Near Landfills.

Document	Year
	1998

Why	How	What	Where
Design	Optimization		

Abstract

Author 1	Author 2	Facility or Agency
Hudak	Loaiciga	

Citation

Hudak, P. F. and H. A. Loaiciga, 1999. Conjunctive Vadose and Saturated Zone Monitoring for Subsurface Contamination. Environmental Monitoring and Assessment 59(1): 15-29.

Journal

Environmental Monitoring and Assessment 59(1): 15-29

Title

Conjunctive Vadose and Saturated Zone Monitoring for Subsurface Contamination

Document	Year
	1999

Why	How	What	Where
Design	Optimization		Saturated

Abstract

A comprehensive subsurface monitoring program should include contaminant detectors in both the vadose and saturated zones. Vadose zone detectors can provide an early warning of an impending groundwater contamination problem, and also yield information relevant to placing groundwater monitoring wells. Moisture probes, gas monitoring wells, and pore-liquid samplers deployed in the vadose zone complement groundwater detections wells. The objective(s) of a monitoring program, spatial-scales, and hydrogeology are important considerations for designing subsurface monitoring networks. Often, these networks are used to detect potential releases or characterize existing contamination beneath land-based waste storage facilities. A case study in Santa Barbara, California, U.S.A., illustrates the utility of vadose zone monitoring in characterizing a gasoline contamination problem and guiding the placement of groundwater monitoring wells.

Author 1	Author 2	Facility or Agency
Huff	Borders	ORNL

Citation

Huff, D. D., D. M. Borders, et al., 1997. Performance Monitoring for Source Stabilization. In Situ Remediation of the Geoenvironment Proceedings of the 1997 ASCE Annual Fall National Convention, Oct 5-8 1997, Minneapolis, MN, USA.

Journal

Title

Performance Monitoring for Source Stabilization.

Document	Year
	1997

Why	How	What	Where
Monitoring	Performance	chemical	Saturated

Abstract

A site investigation at a radioactive solid waste storage area (SWSA) 4 at the Oak Ridge National Laboratory, identified two seeps, fed by portions of four trenches, that appear to contribute about 70% of all 90Sr releases from SWSA 4. Baseline investigations indicate that interaction between wastes and water that inundates trenches is responsible for the releases. The pathways involve both saturated zone groundwater flow and more rapid shallow subsurface transport to seeps that discharge during storms. Evaluation of flow rate and 90Sr concentration shows they are correlated and the relationship can be used with flow rate alone to estimate dynamic release rates. During summer, 1996, multi-grout source stabilization inside the target trenches was completed using low-pressure permeation grouting. This presentation summarized the hydrologic monitoring data collection and analysis, and modeling results used to design a procedure for quantifying changes in 90Sr releases that result from the source control action.

Author 1	Author 2	Facility or Agency
IAEA		IAEA

Citation

International Atomic Energy Agency, 2002. ASAM: The International Project on Application of Safety Assessment Methodologies for Near Surface Radioactive Waste Disposal Facilities, Scope, Objectives, Content and Work Programme.

Journal

Title

ASAM: The International Project on Application of Safety Assessment Methodologies for Near Surface Radioactive Waste Disposal Facilities, Scope, Objectives, Content and Work Programme.

Document	Year
	2002

Why	How	What	Where

Abstract

Author 1	Author 2	Facility or Agency
IAEA		IAEA

Citation

International Atomic Energy Agency, 1999. Safety Assessment for Near Surface Disposal of Radioactive Waste, Safety Guide. Safety Standards Series No. WS-G-1.1.

Journal

Title

Safety Assessment for Near Surface Disposal of Radioactive Waste, Safety Guide.

Document	Year
WS-G-1.1	1999

Why	How	What	Where

Abstract

Author 1	Author 2	Facility or Agency
Irving		INEEL

Citation

Irving, J. S., 1993. Environmental resource document for the Idaho National Engineering Laboratory; Volume 1. EGG-WMO-10279-VOL.1, p. 291, 1993.

Journal

Title

Environmental resource document for the Idaho National Engineering Laboratory; Volume 1

Document	Year
	1993.

Why	How	What	Where
Characterization			

Abstract

This document contains information related to the environmental characterization of the Idaho National Engineering Laboratory (INEL). The INEL is a major US Department of Energy facility in southeastern Idaho dedicated to nuclear research, waste management, environmental restoration, and other activities related to the development of technology. Environmental information covered in this document includes land, air, water, and ecological resources; socioeconomic characteristics and land use; and cultural, aesthetic, and scenic resources.

Author 1	Author 2	Facility or Agency
Irwin	Brouillard	Sandia

Citation

Irwin, M. and L. Brouillard (1999). Real-Time Monitoring Capability for Performance Assessment Corrective Action Management Unit Containment Cell Sandia National Laboratories, New Mexico.

Journal

Title

Real-Time Monitoring Capability for Performance Assessment Corrective Action Management Unit Containment Cell Sandia National Laboratories, New Mexico.

Document	Year
	1999

Why	How	What	Where
Monitoring	Devices	mixed	Saturated

Abstract

Sandia National Laboratories in Albuquerque, New Mexico, operates a Corrective Action Management Unit (CAMU) for the DOE. The CAMU containment cell has a capacity to permanently store up to one million cubic feet of treated soil. The containment cell has a capacity to permanently store up to one million cubic feet of treated soil. The containment cell is situated approximately 500 feet above groundwater in a region with low rainfall and infiltration. These site conditions required a unique approach to monitoring cell integrity and protecting groundwater. To satisfy RCRA groundwater monitoring requirements, a Vadose Zone Monitoring System (VZMS) for detecting leaks was incorporated into the containment cell design. One component of the VZMS, the Primary Subliner (PSL) monitoring subsystem, utilizes the containment cell subliner to focus potential leakage into five longitudinal trenches, which are filled with a wicking material surrounding vitrified clay piping. The vitrified clay piping provides access for neutron probes to measure soils moisture content directly under the containment cell. The other component of the VZMS, the Vertical Sensor Array (VSA), consists of 22 time-domain reflectometers that provide a backup to the PSL. These two vadose zone monitoring subsystems allow for real-time leak detection, as well as long-term assessment and assurance of containment cell performance.

Author 1	Author 2	Facility or Agency
James	Gorelick	

Citation

James, B.R. and S.M. Gorelick, 1994. When Enough is Enough: The Worth of Monitoring Data in Aquifer Remediation Design. Water Resources Research, Vol. 30, No. 12, 3499-3513.

Journal

Water Resources Research, Vol. 30, No. 12, 3499-3513.

Title

When Enough is Enough: The Worth of Monitoring Data in Aquifer Remediation Design.

Document	Year
	1994

Why	How	What	Where
Monitoring	Optimization	geostatistics	Saturated

Abstract

Given the high cost of data collection at groundwater contamination remediation sites, it is becoming increasingly important to make data collection as cost-effective as possible. A Bayesian data worth framework is developed in an attempt to carry out this task for remediation programs in which a groundwater contaminant plume must be located and then hydraulically contained. The framework is applied to a hypothetical contamination problem where uncertainty in plume location and extent are caused by uncertainty in source location, source loading time, and aquifer heterogeneity. The goal is to find the optimum number and the best locations for a sequence of observation wells that minimize the expected cost of remediation plus sampling. Simplifying assumptions include steady state heads, advective transport, simple retardation, and remediation costs as a linear function of discharge rate. In the case here, an average of six observation wells was needed. Results indicate that this optimum number was also sensitive to the variance of the hydraulic conductivity, annual discount rate, operating cost, and sample unit cost. It was relatively insensitive to the correlation length of hydraulic conductivity. For the case here, points of greatest uncertainty in plume presence were on average poor candidates for sample locations, and randomly located samples were not cost-effective.

Author 1	Author 2	Facility or Agency
James	Gwo	

Citation

James, B. R., J.-P. Gwo, et al., 1996. Risk-Cost Decision Framework for Aquifer Remediation Design. Journal of Water Resources Planning and Management 122(6): 414-420.

Journal

Journal of Water Resources Planning and Management 122(6): 414-420.

Title

Risk-Cost Decision Framework for Aquifer Remediation Design.

Document	Year
	1996

Why	How	What	Where
Design			

Abstract

The writers present a framework for increasing the effectiveness of remedial design decision-making at ground-water contamination sites where there is uncertainty in many parameters that affect remediation design. It is specifically designed for broad, `big picture' analyses, such as in the preliminary stages of remedial design. The presented framework is used to (1) select the best remedial design from a suite of possible ones; (2) estimate if additional data collection is cost-effective; and (3) determine the most important parameters to be sampled. The framework is developed by combining elements from Latin-Hypercube simulation of contaminant transport, economic risk-cost analysis, and regional sensitivity analysis (RSA). The framework is demonstrated using a hypothetical contamination problem where radionuclide strontium (⁹⁰Sr) is leaching from a trench into the ground water. Three remediation design alternatives are considered: monitoring only, isolating the source trench, and installing a plume containment and treatment system. Uncertainty in remediation design performance is due to uncertainty in 13 flow and transport parameters including hydraulic conductivity and source strength. The methodology can be applied to a variety of remediation problems.

Author 1	Author 2	Facility or Agency
Janke	Arthur	

Citation

Janke, D.H. and W.J. Arthur, 1985. Radionuclide Transport by Cottontail Rabbits at a Radioactive Waste Disposal Area. Northwest Science 59(3): 221-229.

Journal

Northwest Science 59(3): 221-229.

Title

Radionuclide Transport by Cottontail Rabbits at a Radioactive Waste Disposal Area.

Document	Year
	1985

Why	How	What	Where
Characterization	Ecological		Surface

Abstract

Author 1	Author 2	Facility or Agency
Jarayssi		Hanford

Citation

Jarayssi, M.N., 2001. Environmental Control Plan for Groundwater/Vadose Zone Technology Development Projects. U.S. Department of Energy, Report BHI-01471.

Journal

Title

Environmental Control Plan for Groundwater/Vadose Zone Technology Development Projects

Document	Year
BHI-01471	2001

Why	How	What	Where
	Devices		Unsaturated

Abstract

This environmental control plan (ECP) is applicable to field activities to groundwater/vadose zone technology development projects. These activities include excavation, soil sampling, borehole geophysical surveying, dye application, tracer injection, and waste management. Field activities that are common to other projects or subcontracted are covered under a separate ECP. These activities include well drilling, well development, groundwater extraction, groundwater injection, and groundwater sampling (see the Environmental Control Plan for Groundwater Well Services [BHI 2000]). When the technology is deployed as part of investigation activities for a specific project, the ECP for that project also applies.

This ECP is a compilation of existing environmental and regulatory requirements applicable to the technology development projects. This ECP provides summary-level information to assist personnel in the field working on such activities. As this ECP provides only an overview, the source documents (e.g., Record of Decision, Bechtel Hanford, Inc. procedures, work plans) should be consulted for detailed information regarding the requirements. If discrepancies arise between this ECP and the source documents, contact the Project Environmental Lead (PEL) and the Field Environmental Coordinator (FEC). The FEC is responsible for field implementation of this ECP.

Author 1	Author 2	Facility or Agency
Jardine	Smith	

Citation

Jardine, K., L. Smith, et al., 1996. Monitoring Networks in Fractured Rocks: A Decision Analysis Approach. Ground Water 34(3): 504-518.

Journal

Ground Water 34(3): 504-518.

Title

Monitoring Networks in Fractured Rocks: A Decision Analysis Approach.

Document	Year
	1996

Why	How	What	Where
Monitoring			fracture

Abstract

Author 1	Author 2	Facility or Agency
Johnson	Chou	Hanford

Citation

Johnson, V.G., and C.J. Chou, 1998. Results of Phase I Groundwater Quality Assessment for Single-Shell Tank Waste Management Area S-SX at the Hanford Site. U.S. Department of Energy, Report PNNL-11810, UC-502.

Journal

Title

Results of Phase I Groundwater Quality Assessment for Single-Shell Tank Waste Management Area S-SX at the Hanford Site.

Document	Year
PNNL-11810	1998

Why	How	What	Where

Abstract

Pacific Northwest National Laboratory (PNNL) conducted a Phase I, Resource Conservation and Recovery Act of 1976 (RCRA) groundwater quality assessment for the Richland Field Office of the U.S. Department of Energy (DOE-RL), in accordance with the Federal Facility Compliance Agreement. The purpose of the investigation was to determine if the Single-Shell Tank Waste Management Area (WMA) S-SX has impacted groundwater quality.

The WMA is located in the southern portion of the 200 West Area of the Hanford Site and consists of the 241-S and 241-SX tank farms and ancillary waste systems. The unit is regulated under RCRA interim-status regulations (40 CFR 265, Subpart F) and was placed in assessment groundwater monitoring (40 CFR 265.93 [d]) in August 1996 because of elevated specific conductance and technetium-99, a non-RCRA co-contaminant, in downgradient monitoring wells. Phase I assessment, allowed under 40 CFR 265, provides the owner-operator of a facility with the opportunity to demonstrate that the regulated unit is not the source of groundwater contamination.

Major findings of the assessment are summarized below:
- Distribution patterns for radionuclides and RCRA/dangerous waste constituents indicate WMA S-SX has contributed to groundwater contamination observed in downgradient monitoring wells. Multiple source locations in the WMA are needed to explain spatial and temporal groundwater contamination patterns.
- Drinking water standards for nitrate and technetium-99 are currently exceeded in one RCRA compliant well (299-W22-46) located at the southeastern corner of the SX tank farm. Technetium-99, the constituent with the highest concentration relative to a standard, is currently four to five times the U.S. Environmental Protection Agency (EPA) interim drinking water standard of 900 pCi/L. Technetium-99 also recently increased to just above the drinking water standard in an older well (299-W23-1) inside the S tank farm.
- Technetium-99, nitrate, and chromium concentrations in downgradient well 299-W22-46 (the well with the highest current concentrations) appear to be declining after reaching maximum concentrations in May 1997. Observations during the next four quarters are needed to confirm the apparent declining trend in this well.
- Cesium-137 and strontium-90, major constituents of concern in single-shell tank waste, were not detected in any of the RCRA-compliant wells in the WMA network, including the well with the highest current technetium-99 concentrations (299-W22-46). This observation is consistent with the low expected mobilities of these constituents under Hanford Site conditions.
- Low but detectable strontium-90 and cesium-137 were found in one old well (2-W23-7), located inside and between the S and SX tank farms. Additional investigation is needed to determine if the low level contamination is borehole related or is more broadly distributed in the aquifer.
- Preliminary results for groundwater samples collected on 1/13/98 from a new borehole (41-09-39), drilled through the primary contaminant zone down to groundwater in the SX tank farm, suggest little if any tank waste reached the water

table at this location. Gross alpha and gross beta concentrations, 2.3 ± 0.7 and 16.6 ± 4.0 pCi/L (based on 10 sample results), respectively, are within the range of Hanford Site natural groundwater background and hexavalent chromium, an important indicator of mobile constituents in tank waste, was not detected (<10 µg/L).
- Infiltration of snow melt runoff and/or artificial sources of water near vadose zone contamination sites within the WMA are possible causes of the short-term transients in contaminant concentrations observed in WMA groundwater monitoring wells between 1986 and the present. Continuing efforts are underway to identify and eliminate potential water sources around tank farms.
- A Phase II investigation of the nature, extent and source(s) of recurrent groundwater contamination at this WMA is indicated.

Author 1	Author 2	Facility or Agency
Johnson	Conboy	DOE

Citation

Johnson, R., D. Conboy, et al., 2001. Adaptive Sampling and Analysis Programs (ASAPs). U.S. Department of Energy, Characterization, Monitoring, and Sensor Technology Crosscutting Program and Subsurface Contaminants Focus Area, DOE/EM-5092, August 2001.

Journal

Title

Adaptive Sampling and Analysis Programs (ASAPs)

Document	Year
DOE/EM-5092	2001

Why	How	What	Where
Characterization	Optimization		Saturated

Abstract

Traditional site characterization methods rely on preplanned sampling programs and off-site analysis of samples to determine the extent and level of hazardous waste contamination. This process is costly and time-consuming. Static work plans specify the numbers and locations of samples to be collected, as well as the analyses to be performed on collected samples. Sampling crews are mobilized, samples are collected, and the crews are demobilized before final results become available. Additional sampling programs are often required to resolve uncertainties raised by the initial sampling and analysis results. The drawbacks of a traditional approach to sampling program design and execution are high costs per sample, pressure to over sample while at the site, and inevitable surprises in the analytical results that require additional sampling to resolve.

A key step in the characterization of hazardous wastes at U.S. Department of Energy (DOE) sites is determination of the extent of contamination. The proper number and placement of sampling locations is required to both minimize characterization costs and guarantee that contamination extent can be estimated with reasonable confidence. Because "soft" information (i.e., historical records, computer modeling results, past experience, etc.) for a site are usually just as important as "hard" laboratory results, the approach taken must include a quantitative way of accounting for both hard and soft data.

Author 1	Author 2	Facility or Agency
Kennedy	Cadwell	

Citation

Kennedy, W.F., L.L. Cadwell, and D.H. McKenzie. 1985. Biotic transport of radionuclide wastes from a low-level radioactive waste site. Health Physics 49(1): 11-24.

Journal

Health Physics 49(1): 11-24.

Title

Biotic Transport of Radionuclide Wastes From a Low-Level Radioactive Waste Site.

Document	Year
	1985

Why	How	What	Where

Abstract

Author 1	Author 2	Facility or Agency
Kessler	McGuire	Yucca

Citation

Kessler, J.H., R.K. McGuire, et al., 1999. Alternative Assessments of the Performance of the Yucca Mountain Candidate HLW Repository. Proceedings of the 1998 MRS Fall Meeting - Symposium 'Scientific Basis for Nuclear Waste Management XXII', Nov 30-Dec 4 1998, Boston, MA, USA.

Journal

Title

Alternative Assessments of the Performance of the Yucca Mountain Candidate HLW Repository.

Document	Year
	1999

Why	How	What	Where
Design	Performance	comparison	

Abstract

This paper summarizes some of the most recent total system performance assessment (TSPA) work supported by EPRI for the proposed repository at Yucca Mountain, Nevada. In Part I of the paper, `standard' TSPA analyses are presented. In Part II examples of two types of analyses that augment standard TSPAs are provided that suggest: (1) many components of the Yucca Mountain system contribute to overall hazard reduction; and (2) the biosphere dose conversions used, based on reasonably maximizing assumptions about future human behavior, provide a reasonable upper bound. These additional analyses should provide further confidence when considering more `standard' TSPA analyses.

Author 1	Author 2	Facility or Agency
Kessler	McGuire	

Citation

Kessler, J.H. and R.K. McGuire, 1999. Total System Performance Assessment for Waste Disposal Using a Logic Tree Approach. Risk-Analysis, Special Issue: Performance Assessment for Radioactive Waste Disposal, Vol 19(5): 915-931.

Journal

Risk-Analysis. 1999 Oct; Vol 19(5): 915-931.

Title

Total System Performance Assessment for Waste Disposal Using a Logic Tree Approach.

Document	Year
	1999

Why	How	What	Where
Design	Performance		

Abstract

The Electric Power Research Institute (EPRI) has sponsored the development of a model to assess the long-term, overall "performance" of the candidate spent fuel and high-level radioactive waste (HLW) disposal facility at Yucca Mountain, Nevada. The model simulates the processes that lead to HLW container corrosion, HLW mobilization from the spend fuel, and transport by groundwater, and contaminated groundwater usage by future hypothetical individuals leading to radiation doses to those individuals. The model must incorporate a multitude of complex, coupled processes across a variety of technical disci0plines. Furthermore, because of the very long time frames involved in the mdoeling effort (>>10,000 years), the relative lack of directly applicable data, and many uncertainties and variabilities in those data, a probabilistic approach to model development was necessary. The developers of the model chose a logic tee approach to represent uncertainties in both conceptual models and model parameter values. The developers felt the logic tree approach was the most appropriate. This paper discusses the value and use of logic trees applied to assessing the uncertainties in HLW disposal, the components of the model, and a few of the results of that model. The paper concludes with a comparison of logic trees and a Monte Carlo approaches.

Author 1	Author 2	Facility or Agency
Klepper	Gano	Hanford

Citation

Klepper, E.L., K.A. Gano, et al. 1985. Rooting Depth Distributions of Deep-rooted Plants in the 200 Area Control Zone of the Hanford Site. Pacific Northwest Laboratory Report No. 5247. National Technical Information Service, Springfield, VA.

Journal

Title

Rooting Depth Distributions of Deep-rooted Plants in the 200 Area Control Zone of the Hanford Site.

Document	Year
PNL-5247	1985

Why	How	What	Where
Characterization	Ecological		Surface

Abstract

Author 1	Author 2	Facility or Agency
Knight	Dvorkin	

Citation

Knight, R.J., J.P. Dvorkin, et al., 1995. Seismic Signatures of Partial Saturation. Society of Exploration Geophysicists, 65th annual international meeting; SEG Annual Meeting Expanded Technical Program Abstracts with Biographies, 65, p. 870-873. Meeting: Society of Exploration Geophysicists, 65th annual international meeting, Houston, TX, United States, Oct. 8-13,

Journal

Title

Seismic Signatures of Partial Saturation

Document	Year
	1995

Why	How	What	Where
Characterization	Geophysical		Unsaturated

Abstract

The sensitivity of seismic velocities to the degree of gas saturation in a water-gas saturated reservoir is small if the two fluids are homogeneously distributed throughout the pore-space of the reservoir. In this situation seismic can only differentiate between a gas saturation equal to zero (the fully water-saturated state) and a gas saturated greater than 0 (the partially water-saturated state). However, if fluid distribution in the reservoir is heterogeneous such that there exist macroscopic water-saturated patches adjacent to partially water saturated regions then it may be possible to accurately determine the average degree of saturation in the reservoir from seismic. Different regions of the reservoir can have different local saturation levels if a reservoir is composed of patches of varying rock type - saturation heterogeneity can exist at the reservoir scale. We investigate this link between seismic velocity and reservoir-scale saturation, by generating models of heterogeneous reservoirs. We assume a state of capillary equilibrium in the reservoir, and determine the saturation level of each patch within the reservoir from the corresponding capillary pressure curve for the rock type at that location. At capillary equilibrium, a fully saturated patch may be located next to a partially saturated region. The velocities we calculate for these models show that saturation heterogeneity, due to rock type variation, can lead to a distinct dependence of velocity on saturation. Capillary pressure curves are strongly affected by permeability; therefore, an important factor that controls saturation heterogeneity and thus seismic velocity in a partially saturated reservoir is the permeability of the different lithologies. This effect opens a potential avenue for inferring permeability from seismic data.

Author 1	Author 2	Facility or Agency
Knowles	Hansen	WIPP

Citation

Knowles, M. K., F. D. Hansen, et al., 2000. Review and Perspectives on Spallings Release Models in the 1996 Performance Assessment for the Waste Isolation Pilot Plant. Reliability Engineering and System Safety 69(1): 331-341.

Journal

Reliability Engineering and System Safety 69(1): 331-341.

Title

Review and Perspectives on Spallings Release Models in the 1996 Performance Assessment for the Waste Isolation Pilot Plant.

Document	Year
	2000

Why	How	What	Where
Design	Performance		

Abstract

The Waste Isolation Pilot Plant was licensed for disposal of transuranic wastes generated by the US Department of Energy. The facility consists of a repository mined in a bedded salt formation, approximately 650 m below the surface. Regulations promulgated by the US Environmental Protection Agency require that performance assessment calculations for the repository include the possibility that an exploratory drilling operation could penetrate the waste disposal areas at some time in the future. Release of contaminated solids could reach the surface during a drilling intrusion. One of the mechanisms for release, known as spallings, can occur if gas pressures in the repository exceed the hydrostatic pressure of a column of drilling mud. Calculation of solids releaes for spallings depends critically on the conceptual models for the waste, for the spallings process, and assumptions regarding driller parameters and practices. This paper presents a review of the evolution of these models during the regulatory review of the Compliance Certification Application for the repository. A summary and perspectives on the implementation of conservative assumptions in model development are also provided.

Author 1	Author 2	Facility or Agency
Kram	Keller	

Citation
Kram, M.L., A.A. Keller, et al., 2002. DNAPL Characterization Methods and Approaches, Part 2: Cost Comparisons GWMR Winter 2002, pp 46 -61.

Journal

Title

Document	Year
	2002

Why	How	What	Where
Characterization			

Abstract

Author 1	Author 2	Facility or Agency
Kram	Keller	

Citation

Kram, M.L., A.A. Keller, et al., 2002. DNAPL Characterization Methods and Approaches, Part 1: Performance Comparisons GWMR, Fall 200, pp 109-123.

Journal

Title

Document	Year
	2002

Why	How	What	Where
Characterization			

Abstract

Author 1	Author 2	Facility or Agency
Kramer	Cullen	

Citation

Kramer, J.H, S.J. Cullen, et al., 1994. Vadose Zone Monitoring with the Neutron Moisture Probe. In "Handbook of Vadose Zone Characterization and Monitoring". L.G. Wilson, L.G. Everett and S.J. Cullen, editors. CRC Press, Inc.

Journal

Title

Vadose Zone Monitoring with the Neutron Moisture Probe.

Document	Year
	1995

Why	How	What	Where
Monitoring	Devices	probe	Unsaturated

Abstract

The neutron moisture probe is increasingly being applied to vadose zone hydrogeologic problems such as site characterization, contaminant leak detection and monitoring, remediation, infiltration, and recharge. Ground-water scientist and engineers should be acquainted with the principles of operation, limitations, and advantages of neutron measurements. This chapter reviews the theory and application of neutron moisture probes and presents results from its use. The first part provides background necessary to understand the technique. The second part describes three monitoring projects which successfully employed the method. The intent of the authors is to provide a useful guide to the advantages of this monitoring approach.

Author 1	Author 2	Facility or Agency
Kumar	Ahmed	National Geophysical Res. Inst., India

Citation

Kumar, D., S. Ahmed, 2003. Seasonal behaviour of spatial variability of groundwater level in a granitic aquifer in monsoon climate. Current Science, 84 (2).

Journal

Current Science, Vol. 84, No. 2

Title

Seasonal behaviour of spatial variability of groundwater level in a granitic aquifer in monsoon climate

Document	Year
	2003

Why	How	What	Where
Modeling	Ground-Water	Geostatistics	Saturated

Abstract

Groundwater flow in a small watershed in a hard rock region of Andhra Pradesh, India mainly exists in a coupled system of weathered and fractured rock aquifers. However, due to heavy extraction, groundwater level has declined and the weathered part has become unsaturated. In general, the water-table aquifer exists in the area under semi-confined or unconfined conditions. Monthly water-levels from 32 wells fairly evenly distributed over the area were collected to analyse the variability and finally to calibrate a groundwater flow model. Universal kriging technique with a linear drift was applied to analyse the available groundwater levels during different periods for one cycle during the year 2000. The bounded variograms, i.e. without the effect of a drift, were calculated using the directional variogram in the direction perpendicular to the major mean flow. All the variograms were then cross-validated to get final acceptable models for each time period. Subsequently, two variograms, one for the monsoon period with the presence of recharge component and the other for the non-monsoon period without the presence of recharge component were evolved. A common variogram was also determined to represent the average over all time periods. Crossvalidation tests were done to check that the variograms representing monsoon and non-monsoon periods were able to reproduce field values for the corresponding periods more satisfactorily than a single common variogram. Thus application of geostatistics could be simplified for time-varying parameters such as water level.

Author 1	Author 2	Facility or Agency
Kumar	Ahmed	

Citation

Kumar, D and S. Ahmed, 2003. Seasonal Behaviour of Spatial Variability of Groundwater Level in a Granitic Aquifer in Monsoon Climate. Current Science, Vol. 84, No. 2, 25.

Journal

Current Science, Vol. 84, No. 2, 25.

Title

Seasonal Behaviour of Spatial Variability of Groundwater Level in a Granitic Aquifer in Monsoon Climate.

Document	Year
	2003

Why	How	What	Where

Abstract

Groundwater flow in a small watershed in a hard rock region of Andhra Pradesh, India mainly exists in a coupled system of weathered and fractured rock aquifers. However, due to heavy extraction, groundwater level has declined and the weathered part has become unsaturated. In general, the water-table aquifer exists in the area under semi-confined or unconfined conditions. Monthly water-levels from 32 wells fairly evenly distributed over the area were collected to analyse the variability and finally to calibrate a groundwater flow model.
Universal kriging technique with a linear drift was applied to analyse the available groundwater levels during different periods for one cycle during the year 2000. The bounded variograms, i.e. without the effect of a drift, were calculated using the directional variogram in the direction perpendicular to the major mean flow. All the variograms were then cross-validated to get final acceptable models for each time period. Subsequently, two variograms, one for the monsoon period with the presence of recharge component and the other for the non-monsoon period without the presence of recharge component were evolved. A common variogram was also determined to represent the average over all time periods. Crossvalidation tests were done to check that the variograms representing monsoon and non-monsoon periods were able to reproduce field values for the corresponding periods more satisfactorily than a single common variogram. Thus application of geostatistics could be simplified for time-varying parameters such as water level.

Author 1	Author 2	Facility or Agency
Kung	Boll	

Citation

Kung, S., J. Boll, et al. (1991). Use of Ground Penetrating Radar to Improve Water Quality Monitoring in the Vadose Zone. Proceedings of the National Symposium on Preferential Flow, Dec 16-17 1991, Chicago, IL, USA.

Journal

Title

Use of Ground Penetrating Radar to Improve Water Quality Monitoring in the Vadose Zone.

Document	Year
	1991

Why	How	What	Where
Characterization	Geophysical	ground penetrating radar	Unsaturated

Abstract

Author 1	Author 2	Facility or Agency
Kunkel	Thompson	Rocky Flats

Citation

Kunkel, J. R. and J. S. Thompson, 1994. Vadose-zone Monitoring, Sanitary Treatment Plant Sludge-drying Beds, Rocky Flats Plant, Golden, Colorado. Proceedings of the 21st Annual Conference on Water Policy and Management: Solving the Problems, May 23-26 1994, Denver,CO,USA

Journal

Title

Vadose-zone Monitoring, Sanitary Treatment Plant Sludge-drying Beds, Rocky Flats Plant, Golden, Colorado.

Document	Year
	1994

Why	How	What	Where
Monitoring	Devices	mixed	Unsaturated

Abstract

The NPDES Federal Facilities Compliance Agreement (NPDES FFCA) of March 25, 1991 between the U.S. Department of Energy (DOE) and the U.S. Environmental Protection Agency (EPA), pursuant to Executive Order 12088, provides for compliance with water pollution control standards and appropriate operation of the Building 995 Sanitary Treatment Plant (STP) at the Rocky Flats Plant (RFP). Since 1952, digested sludge from the STP processes has been dried in seven covered and uncovered drying beds at the Building 995 STP. Because the beds were unlined, some water percolated into the unsaturated soil column beneath the beds. EPA requested that RFP characterize the soils beneath the sludge-drying beds and install and operate a vadose-zone monitoring system to assess the potential for contaminant movement. Statistical tests were used to assess if the concentrations of selected constituents in soil and soil water made these constituents potential contaminants of concern.

Author 1	Author 2	Facility or Agency
Lamarre	Carlsen	LLNL

Citation

Lamarre, A. L., Carlsen, T. M., et al., 1991. Environmental Investigation and Remedial Activities at Lawrence Livermore National Laboratory Site 300, Anonymous, Geological Society of America, 1991 annual meeting, Abstracts with Programs - Geological Society of America, 23 (5), p. 76, 1991. Meeting: Geological Society of America, 1991 annual meeting, San Diego,

Journal

Title

Environmental Investigation and Remedial Activities at Lawrence Livermore National Laboratory Site 300.

Document	Year
	1991

Why	How	What	Where
Monitoring	Geophysical		

Abstract

Author 1	Author 2	Facility or Agency
Lane	Joesten	USGS

Citation

Lane, John W., Jr., P.K. Joesten, et al., 1999. Monitoring a Permeable Reactive Iron Wall Installation in Unconsolidated Sediments by Using a Cross-Hole Radar Method. Morganwalp, David W. (editor) (U. S. Geological Survey, United States), Buxton, Herbert T. (editor), U. S. Geological Survey Toxic Substances Hydrology Program; proceedings of the technical

Journal

Title

Monitoring a Permeable Reactive Iron Wall Installation in Unconsolidated Sediments by Using a Cross-Hole Radar Method.

Document	Year
	1999

Why	How	What	Where
Monitoring	Geophysical	crosshole radar	Saturated

Abstract

Cross-hole common-depth (CD) radar scanning was used at the Massachusetts Military Reservation (MMR) in Cape Cod, Massachusetts, to monitor pilot-scale testing of a hydraulic-fracturing method to install permeable reactive zero-valent iron walls in unconsolidated sediments. The pilot-scale study was undertaken to assess the feasibility of using zero-valent iron to remediate ground water that is contaminated with chlorinated solvents at depths exceeding the range of conventional iron wall installation methods. The pilot-scale test was conducted at the site near the source area of Chemical Spill 10 (CS-10), a chlorinated-solvents plume that underlies the MMR. Two iron walls 5 meters (m) apart and 12 m long were designed to intersect the contaminated ground water at depths ranging from 24 to 37 m below land surface.

A series of post-installation cross-hole CD radar-scanning surveys were conducted in boreholes installed on opposite sides of the walls. The presence of iron significantly reduces the radar-pulse amplitude and can be identified using CD radar scanning. Significant decreases in cross-hole radar-pulse amplitude were observed in field data after the iron alls were installed. Changes in cross-hole radar-pulse amplitudes observed in the field data were compared to results of two-dimensional finite-difference time-domain models used to predict the effects of holes in the wall and wall edges. Analysis of these data from the south wall indicates the presence of an irregularly shaped wall about 8 m wide, extending from about 27 to 37 m below land surface. Analysis of data from the north wall is presently underway.

Author 1	Author 2	Facility or Agency
Larsson	Pers	NEA

Citation

Larsson, A., K. Pers, et al., INTRAVAL Project: To Study Validation of Geosphere Transport Models for Performance Assessment of Nuclear Waste Disposal, Phase 2, Summary Report, Nuclear Energy Agency, Organisation for Economic Cooperation and Development.

Journal

Title

INTRAVAL Project: To Study Validation of Geosphere Transport Models for Performance Assessment of Nuclear Waste Disposal, Phase 2, Summary Report.

Document	Year
OECD	

Why	How	What	Where
Modeling	Performance		

Abstract

The international project INTRAVAL addresses the validation of models of transport of radionuclides through groundwater in the geosphere. Such models are used in the assessment of the long-term safety of radioactive waste disposal systems. INTRAVAL is the third in a series of international projects concerned with related issues. The INTRACOIN project (1981-1986) dealt with verification of geosphere transport models, involving checking of the accuracy of computer programs. The HYDROCOIN project (1984-1990) addressed verification, validation, and sensitivity and uncertainty analysis of groundwater flow models. The INTRAVAL study has to a large extent built upon the experiences gained from these previous projects.
The purpose of INTRAVAL was to increase the understanding of mathematical models that describe various geophysical, hydrogeological and geochemical processes of importance in the safety assessment of nuclear waste repositories. This has been dealt with systematically using information from laboratory and field experiments and from natural analogue studies. A wide range of processes on various length and time-scales have been studied. An essential objective of INTRAVAL has been the study of the process of validation of employed computer models.
The first phase of the INTRAVAL study started in 1987 and lasted for three years. During that period, the main emphasis of the work was put on identification of important processes in model validation, based on laboratory and field experiment test cases.
22 organisations from 12 countries took part in this first phase of INTRAVAL, including both organisations responsible for the disposal of radioactive waste and regulatory agencies. The Swedish Nuclear Power Inspectorate (SKI) was responsible for initiating the study and acted as managing participant. Reports from INTRAVAL Phase 1 were published during 1992 to 1994.
The second phase of INTRAVAL, which started in 1990, was concluded at the end of 1993. The objective of Phase 2 was to increase the understanding how various geophysical, geohydrological and geochemical phenomena of importance for radionuclide transport from a repository to the biosphere could be described by mathematical models and to study the model validation process. 23 organisations from 13 countries, mostly the same as in Phase 1, participated in this second phase of INTRAVAL.
As in Phase 1, each organisation set up one or more project teams responsible for work within the project. Kemakta Consultants Co. has acted as principal investigator and has provided the secretariat in collaboration with the OECD Nuclear Energy Agency and Her Majesty's Inspectorate of Pollution, UK.
Only field cases were included in INTRAVAL Phase 2. The cases treated different rock types that have been proposed as suitable for nuclear waste repositories, namely unsaturated rock (Las Cruces Trench, and Apache Leap in USA), saturated fractured rock (Finnsjön and Stripa in Sweden), salt (WIPP in USA and Gorleben in Germany) and clay (Mol in Belgium). In addition, the natural analogue at Alligator Rivers in Australia was included. Different models were studied, including stochastic models. As was pointed out in the previous studies, it was difficult to find field studies that were particularly suited to the objective of INTRAVAL Phase 2. Nevertheless the project teams were provided with a wealth of data from the selected sites.

The modellers fitted the results of their predictions to the data obtained in the field and supporting laboratory data. It was found that often a simple model could give nearly as good results as a complicated model. This was partly explained by a lack of experimental data on input parameters for the complicated model.
Stochastic models were extensively tested in a couple of cases and provided interesting results when fractures and layering were only partly known, as is nearly always the case.
In some cases, it was found that 1-D modelling gave as good, or sometimes better, results than 2-D or 3-D modelling.
Only in one instance, at Las Cruces Trench, was it possible to test the ability of the models to predict the outcome of performed experiments.
The scale problem was also treated. Obviously, it is not possible to perform studies over time scales that are related to the real lifetime of a nuclear waste repository. However, some information might be found from comparisons with natural analogues, for instance from studies of the uranium deposits at Alligator Rivers in Australia. The two teams that treated this test case found that, with reasonable assumptions of the climate over the last million years, the uranium migration at Koongarra has continued over a time period from half a million up to a few million years. This result agreed reasonably well with results from independent geomorphological information.
In addition to the summarised results from Phase 2 of the INTRAVAL study, which are presented in this report, detailed reports are also available.

Author 1	Author 2	Facility or Agency
Lawrence		

Citation

Lawrence, J.R., B.N. Zanyk, et al., 1993. Design and Evaluation of a Mesoscale Model Vadose Zone and Ground-Water System. Ground Water, 31(3), 446-455.

Journal

Ground Water, 31(3), 446-455.

Title

Design and Evaluation of a Mesoscale Model Vadose Zone and Ground-Water System.

Document	Year
	1993

Why	How	What	Where
Design			

Abstract

Author 1	Author 2	Facility or Agency
Lee	Bogardi	

Citation

Lee, Y. W., I. Bogardi, et al., 1991. Fuzzy Decision Making in Dredged-Material Management. J. Environ. Engr. 117(5): 614-630.

Journal

J. Environ. Engr. 117(5): 614-630

Title

Fuzzy Decision Making in Dredged-material Management.

Document	Year
	1991

Why	How	What	Where
Design	Uncertainties		Saturated

Abstract

Author 1	Author 2	Facility or Agency
Lee	Dahab	

Citation

Lee, Y., W., M. Dahab, F., et al., 1992. Nitrate Risk Management Under Uncertainty. J. Water Resources Planning and Management 118(2): 151-165.

Journal

J. Water Resources Planning and Management 118(2): 151-165.

Title

Nitrate Risk Management Under Uncertainty.

Document	Year
	1992

Why	How	What	Where
	Uncertainties		

Abstract

Author 1	Author 2	Facility or Agency
Lee	Kitanidis	

Citation

Lee, S.-I. and P. K. Kitanidis, 1996. Optimization of Monitoring Well Installation Time and Location During Aquifer Decontamination. Water Resources Management 10(6): 439-462.

Journal

Water Resources Management 10(6): 439-462.

Title

Optimization of Monitoring Well Installation Time and Location During Aquifer Decontamination.

Document	Year
	1996

Why	How	What	Where
DQO	Optimization		Saturated

Abstract

An important question in the systematic and objective design of general-purpose ground-water quality monitoring networks involves the quantitative evaluation of the information they provide This paper presents a method to determine the installation time and location of an additional monitoring well while the aquifer is being cleaned up. While rates of pumping and treatment are determined by the dual control method, a method of optimization with incomplete information, candidate well locations are ranked according to a 'cost-to-go' index that measures the costs expected until the goals of remediation are met. This index accounts for the cost associated with uncertainty about the system and thus is useful in appraising the value of information from new measurements in the context of the specific cleanup effort. The usefulness of the method is illustrated through application to a hypothetical two-dimensional aquifer with uncertain initial estimates of the system parameters and variables. Monte Carlo simulations demonstrate the cost effectiveness of solution obtained through this method.

Author 1	Author 2	Facility or Agency
Lee	Dahab	

Citation

Lee, Y. W., M. F. Dahab, et al., 1995. Nitrate-risk Assessment Using Fuzzy-set Approach. J. Environ. Engr. 121(3): 245-256.

Journal

J. Environ. Engr. 121(3): 245-256.

Title

Nitrate-risk assessment using fuzzy-set approach.

Document	Year
	1995

Why	How	What	Where
Characterization			

Abstract

Author 1	Author 2	Facility or Agency
Leinz	Hoover	USGS

Citation

Leinz, R.W., D.B. Hoover, 1993. The Russian CHIM method; Electrically or Diffusion-driven Collection of Ions?. Explore, 79, p. 1, 5-9.

Journal

Explore, 79, p. 1, 5-9.

Title

The Russian CHIM method; Electrically or Diffusion-driven Collection of Ions?

Document	Year
	1993

Why	How	What	Where

Abstract

The electrogeochemical exploration method, CHIM, developed over twenty years ago in the former Soviet Union, is claimed to be a means of collecting ions emanating from ore deposits concealed by thick cover (Goldberg et al., 1990). Available treatises on CHIM (the term is an acronym derived from the Russian phrase "Chastichnoe Izvlechennye Metallov", meaning partial extraction of metals) in the English language are limited. Summaries may be found in Shmakin (1985), Bloomstein (1990), and Antropova, et al., (1991). The method is based on the premise that an applied electric field will drive ions in the soil into specially designed collector electrodes. Ions accumulate in an electrolyte within the electrode. The electrolyte, typically nitric acid of 2N to 4N concentration, also serves to conduct current from the power source to the soil through a low-permeability membrane of synthetic parchment located at the base of the electrode.

Author 1	Author 2	Facility or Agency
Litaor	Barth	Rocky Flats

Citation

Litaor, M. I., G. Barth, et al., 1998. The Behavior of Radionuclides in the Soils of Rocky Flats, Colorado. J. Environ. Radioactivity 38(1): 17-46.

Journal

J. Environ. Radioactivity 38(1): 17-46.

Title

The Behavior of Radionuclides in the Soils of Rocky Flats, Colorado.

Document	Year
	1998

Why	How	What	Where
Monitoring	Devices	mixed	Unsaturated

Abstract

Radionuclide contamination of soils at Rocky Flats, Colorado, resulted from leaking drums of Pu-contaminated oil stored at an outdoor area. To evaluate the mechanisms of radionuclide transport from the contaminated soils to groundwater, an advanced monitoring system was installed across a toposequence. The impact of natural rain, snowmelt, and large-scale rain simulations on the mobility and distribution of the radionuclides in soil interstitial water was studied. The distribution of radionuclides during the monitoring period from 1993 to 1995 suggested that Pu-339 + 240 and Am-241 are largely immobile in semi-arid soils. Large-scale rain simulations with a 100-year recurrence interval occasionally remobilized large fluxes of radionuclides that constitute between1 and 3.3% of the stored Pu and Am in these soils. Fractionation of Pu-239 + 240 and Am-241 to different particle sizes in the soil interstitial water suggested that most of the radionuclides (83-97%) were associated with suspended particles, whereas the level of radionuclides associated with colloidal and nonfilterable (<1 nm) fractions ranged from 1.5 to 15%.

Author 1	Author 2	Facility or Agency
Loaiciga		

Citation

Loaiciga, H. A., 1990. Analysis of Uncertainity in Ground-Water Quality Monitoring Network Design. Optimizing the Resources for Water Management - Proceedings of the ASCE 17th Annual National Conference, Apr 17-21 1990, Fort Worth, TX, USA.

Journal

Title

Analysis of Uncertainity in Ground-water Quality Monitoring Network Design.

Document	Year
	1990

Why	How	What	Where
Design	Optimization	geostatistics	Saturated

Abstract

The paper reviews alternative approaches to ground-water quality monitoring network design. Four general approaches to network design are reviewed: (1) hydrogeologic, (2) simulation, (3) variance-reduction, and (4) optimization. The relative advantages and disadvantages of each of these approaches to specific ground-water quality network design applications depend on: (1) the scale of the monitoring program (i.e., field-scale or regional scale); (2) the type of data available (hydrogeologic, geologic, etc.); (3) the nature of the investigated subsurface process (vadose zone, saturated-zone contamination); (4) the steady-state vis a vis transient nature of ground-water quality properties; and (5) the objective of the monitoring program and the resources available to accomplish it.

Author 1	Author 2	Facility or Agency
Loaiciga		

Citation

Loaiciga, H.A., 1989. An Optimization Approach for Groundwater Quality Monitoring Network Design. Water Resources Research, Vol. 25, No. 8, 1771-1782.

Journal

Water Resources Research, Vol. 25, No. 8, 1771-1782.

Title

An Optimization Approach for Groundwater Quality Monitoring Network Design.

Document	Year
	1989

Why	How	What	Where
Design	Optimization	geostatistics	Saturated

Abstract

The optimal sampling plan for groundwater quality monitoring is formulated as a mixed integer programming (MIP) problem. A sampling plan consists of the number and locations of sampling sites as well as the temporal sampling frequency. The MIP network problem is defined by the minimization of the variance of estimation error subject to resource and unbiasedness constraints. The mean and covariance of the spatial/temporal variable (chloride concentration measurements) are derived from the advection-dispersion equation governing mass transport. The solution for the optimal sampling proceeds in two stages: (1) parameter estimation and (2) network optimization. The MIP model was successfully tested with a network design problem in a buried valley aquifer in Butler County, Ohio. The application illustrates the role of objective function, resource constraint, mass transport processes, and hydrogeologic setting in groundwater quality monitoring network design.

Author 1	Author 2	Facility or Agency
Long		ORNL

Citation

Long, L.T., 2001. Seismic Surface Wave Tomography of Waste Sites. EMSP-55218, U.S. Department of Energy.

Journal

Title

Seismic Surface Wave Tomography of Waste Sites

Document	Year
EMSP-55218	2001

Why	How	What	Where
Characterization	Geophysical	seismic tomography	

Abstract

Because the Rayleigh waves generally have the largest amplitude of all waves generated by a vertical surface impact and because the near-surface shear-wave velocity primarily determines the Rayleigh wave velocity, the Rayleigh waves may be used to image shallow shearwave structures. The Rayleigh wave group velocity can be measured from records of surface waves that have traversed a study area, typically, with a surface source on one side and an array of geophones along the opposite side. After data processing and noise suppression, groupvelocity travel times from different source and receiver locations can be used in a tomographic inversion to image the distribution of group velocity within the study area. Then, vertical shearwave velocity structure at any point can be interpreted from its dispersion curve. The objective of this study was to develop analysis programs for surface-wave groupvelocity tomography and apply these to three test areas. We succeeded by obtaining data covering two square areas that were 30 meters on a side and one that was 16 meters on a side, in addition to processing data from the Oak Ridge National Laboratory site, a collaborative effort. At all sites, usable group velocities were obtained for frequencies from 16 to 50 Hz using a sledgehammer source. The resulting tomographic images and velocity anomalies were sufficient to delineate suspected burial trenches (one 4-meters deep) and anomalous velocity structure related to rocks and disturbed soil. The success was not uniform because in portions of one area the inversion for shear-wave structure became unstable. More research is needed to establish a more robust inversion technique.

Author 1	Author 2	Facility or Agency
Looney	Paquett	Brookhaven

Citation

Looney, B.B. and Paquett, Tritium Source Characterization at the High Flux Beam Reactor Brookhaven National Laboratory. In Looney, B.B. and R.Falta,

Journal

Title

Tritium Source Characterization at the High Flux Beam Reactor Brookhaven National Laboratory.

Document	Year

Why	How	What	Where
Characterization			

Abstract

Author 1	Author 2	Facility or Agency
Lucius		USGS

Citation

Lucius, J.E., 1999. Ground Penetrating Radar Research at the Bemidji, Minnesota, Crude-Oil Spill Site. Modreski, Peter J. (compiler) (U. S. Geological Survey, Denver, CO, United States), Abstracts of the 11th annual U. S. Geological Survey, central region, 1999 poster review, Open-File Report - U. S. Geological Survey, OF 99-0321.

Journal

Title

Ground Penetrating Radar Research at the Bemidji, Minnesota, Crude-Oil Spill Site.

Document	Year
OF 99-0321	1999

Why	How	What	Where
Characterization	Geophysical	GPR	Saturated

Abstract

At the Bemidji, Minnesota, crude-oil spill site, the USGS collected ground penetrating radar (GPR) data to determine the distribution of oil concentrated in two subsurface pools, which remained after cleanup efforts. Physical property information from analysis of mixtures of sand and crude oil assisted in the interpretation of the GPR data. Laboratory measurements show that the crude oil is still very electrically resistive (greater than 10^6 ohm-m). Mixing clean sand with crude oil does not significantly change the relative dielectric permittivity (RDP) or electrical conductivity of the mixture. Four GPR lines were selected, from the large number of radar lines collected at the spill site since 1984, as typical examples of 80 MHz and 300 MHz data collected over the oil pools. At the spill site, GPR is sensitive to changes in electrical conductivity and RDP related to variations in water content, due to grain size and porosity, rather than variations in the oil saturation distribution (fraction of pore space occupied by oil). The oil pools at the Bemidji site are not easily detected using GPR. Nonetheless, GPR can detect those geologic features, such as silt or gravel layers in sand, that may affect the transport and fate of petroleum in the subsurface.

Author 1	Author 2	Facility or Agency
MacKay	Mena	

Citation

MacKay, W.P., R. Mena, et al. 1998b. Seasonal changes in concentration and distribution of heavy metals in creosotebush, Larrea tridentata (Zygophyllaceae), tissues in the El Paso, Texas/Cuidad Juarez, Mexico area. Sida 18: 287-296.

Journal

Title

Seasonal changes in concentration and distribution of heavy metals in creosotebush, Larrea tridentata (Zygophyllaceae), tissues in the El Paso, Texas/Cuidad Juarez, Mexico area.

Document	Year
	1998

Why	How	What	Where
Characterization	Ecological	plant uptake	Surface

Abstract

Author 1	Author 2	Facility or Agency
Mahar	Datta	

Citation

Mahar, P. S. and B. Datta, 1997. Optimal Monitoring Network and Ground-Water-Pollution Source Identification. J. Water Res. Planning and Management 123(4): 199-207.

Journal

J. Water Resources Planning and Management 123(4): 199-207.

Title

Optimal Monitoring Network and Ground-Water-Pollution Source Identification.

Document	Year
	1997

Why	How	What	Where
Design	Optimization		Saturated

Abstract

A methodology combining an optimal ground-water-quality monitoring network design and an optimal source-identification model is presented. In the first-step of the three-step methodology, an embedded nonlinear optimization model is utilized for preliminary identification of pollutant sources (magnitude, location, and duration of activity) based on observed concentration data from arbitrarily located existing wells. The second step utilized these preliminary identification results and a simulation optimization approach to design an optimal monitoring network that can be implemented in the subsequent time periods. In the third step, the observed concentration data at the designed monitoring well locations are utilized for more accurate identification of the pollutant sources. The design of the monitoring network can be dynamic in nature, with sequential installation of monitoring wells during subsequent time periods. The monitoring network can be implemented in stages, in order to utilize the updated information in the form of observed concentration data from a time-varying (dynamic) network. The performance evaluation of the proposed methodology demonstrates the potential applicability of this methodology and shows significant improvement in the identification of unknown ground-water-pollution sources with limited observation data.

Author 1	Author 2	Facility or Agency
Majer	Williams	Hanford

Citation

Majer, E.L., K.H. Williams, et al., 2001. High Resolution Imaging of Vadose Zone Transport Using Crosswell Methods. U.S. Department of Energy, Pacific Northwest National Laboratory, PNNL-13792.

Journal

Title

High Resolution Imaging of Vadose Zone Transport Using Crosswell Methods.

Document	Year
PNNL-13792	2001

Why	How	What	Where
Characterization	Geophysical	mixed	Unsaturated

Abstract

This work addresses the need to have accurate predictive models for transport in the vadose zone. Crosswell methods are designed to provide a detailed understanding of how the physical properties (layering, lithology, etc.) affect the transport of fluids. Understanding contaminant migration through the vadose zone has not only been hampered by inadequate conceptual models, but has suffered from inadequate monitoring technologies. In the past, contaminant plumes at Hanford have most often been mapped with gross and spectral gamma logging tools. Migration was documented by observing changes in gamma logs that failed to fully describe the contaminant plume since the dominant gamma emitters (e.g., 137Cs, 90Sr) are reactive and hence retarded in Hanford sediments, while non-reactive contaminants such as technetium, tritium, and nitrate, move readily with the water. The inability to track highly mobile species through the vadose zone highlights an important need, namely, methods other than gamma logging to describe the complete vadose-zone plume and to determine processes controlling accelerated contamination of groundwater at Hanford.

Author 1	Author 2	Facility or Agency
Mansell	Ma	

Citation

Mansell, R.S., L. Ma, et al., 2002. Adaptive Grid Refinement in Numerical Models for Water Flow and Chemical Transport in Soil: A Review. Vadose Zone Journal 1:222-238.

Journal

Vadose Zone Journal 1:222-238

Title

Adaptive Grid Refinement in Numerical Models for Water Flow and Chemical Transport in Soil: A Review

Document	Year
	2002

Why	How	What	Where
Modeling			Unsaturated

Abstract

Insufficient spatial or temporal resolution is a common source of errors in numerical solutions for both water flow and solute transport in the variably unsaturated vadose zone. Evaporation near the surface, as well as infiltration into initially dry soil profiles, typically create mobile local regions with large gradients of the pressure head. Convection-dominant transport of solutes during water flow in soil also tends to create steep moving fronts of concentration with large localized concentration gradients. Groundwater flow and solute transport in highly heterogeneous aquifers similarly tend to be preferentially channeled through regions of high flow rates. Without due consideration of special resolution requirements for such critical cases of flow and transport, simulations using traditional finite difference (FDM) and finite element (FEM) numerical methods typically provide inaccurate solutions characterized by undesirable features such as oscillation and numerical dispersion. Incorporation of local adaptive grid refinement (LAGR) algorithms in numerical models for solving such cases is an effective approach that has been used to provide accurate numerical approximations by automated adjustment of local spatial resolution. Local error estimates are typically utilized to optimize spatial resolution. Definite advantages, as well as some limitations, exist for using LAGR algorithms in FDM and FEM numerical models for flow and transport in soils.

Author 1	Author 2	Facility or Agency
Manteufel		

Citation

Manteufel, R. D., 1996. Variance-based Importance Analysis Applied to a Complex Probabilistic Performance Assessment. Risk Analysis 16(4): 587-598.

Journal

Risk Analysis 16(4): 587-598.

Title

Variance-based Importance Analysis Applied to a Complex Probabilistic Performance Assessment.

Document	Year
	1996

Why	How	What	Where

Abstract

The most important input parameters in a complex probabilistic performance assessment are identified using a variance-based method and compared with those identified using a regression-based method. The variance-based method has the advantage of not requiring assumptions about the functional relationship between input and output parameters. However, it has the drawback of requiring heuristic assessments of threshold variance ratios above which a parameter is considered important, and it also requires numerous executions of the computer program, which may be computationally expensive. Both methods identified the same top 5 and 7 of the top 10 most important parameters for a system having 195 inputs. Although no distinct advantage for the variance-based approach was identified, the ideas which motivate the new approach are sound and suggest new avenues for exploring the relationships between the inputs and the output of a complex system.

Author 1	Author 2	Facility or Agency
Massmann	Freeze	

Citation

Massmann, 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 23(2): 351-367.

Journal

Water Resources Research 23(2): 351-367.

Title

Groundwater Contamination from Waste Management Sites: The Interaction Between Risk-Based Engineering Design and Regulatory Policy. 1. Methodology.

Document	Year
	1987

Why	How	What	Where
Design	Optimization		Saturated

Abstract

This paper puts in place a risk-cost-benefit analysis for waste management facilities that explicitly recognized the adversarial relationship that exists in a regulated market economy between the owner/operator of a waste management facility and the government regulatory agency under whose terms the facility must be licensed. The risk-cost-benefit analysis is set up from the perspective of the owner/operator. It can be used directly by the owner/operator to assess alternative design strategies. It can also be used by the regulatory agency to assess alternative regulatory policy, but only in an indirect manner, by examining the response of an owner/operator to the stimuli of various policies. The objective function is couched in terms of a discounted stream of benefits, costs, and risks over an engineering time horizon. Benefits are in the form of revenues for services provided; costs are those of construction and operation of the facility. Failure requires a breach of the containment structure and contaminant migration through the hydrogeological environment to a compliance surface. The probability of failure can be estimated on the basis of reliability theory for the breach of the containment structure and with a Monte-Carlo finite-element simulation for the advective contaminant transport. In the hydrogeological environment the hydraulic conductivity values are defined stochastically. The probability of failure is reduced by the presence of a monitoring network operated by the owner/operator and located between the source and the regulatory compliance surface. The level of reduction in the probability of failure depends on the probability of detection of the monitoring network, which can be calculated from the stochastic contaminant transport simulations. While the framework is quite general, the development in this paper is specifically suited for a landfill in which the primary design feature is one or more synthetic liners in parallel. Contamination is brought about by the release of a single, inorganic nonradioactive species into a saturated, high-permeability, advective, steady state horizontal flow system which can be analyzed with a two-dimensional analysis. It is possible to carry out sensitivity analyses for a wide variety of influences on this system, including landfill size, liner design, hydrogeological parameters, amount of exploration, extent of monitoring network, nature of remedial schemes, economic factors, and regulatory policy.

Author 1	Author 2	Facility or Agency
Massmann	Freeze	

Citation

Massmann, J. and R. A. Freeze, 1987. Groundwater Contamination From Waste Management Sites: The Interaction Between Risk-Based Engineering Design and Regulatory Policy. 2. Results. Water Resources Research 23(2): 368-380.

Journal

Water Resources Research 23(2): 368-380.

Title

Groundwater Contamination From Waste Management Sites: The Interaction Between Risk-Based Engineering Design and Regulatory Policy. 2. Results.

Document	Year
	1987

Why	How	What	Where
Design	Optimization		Saturated

Abstract

The place a risk-cost-benefit analysis developed in the companion paper (J. Massmann and R.A. Freeze, this issue) is here applied to (1) an assessment of the relative worth of containment-construction activities, site-exploration activities, and monitoring activities as components of a design strategy for the owner/operator of a waste management facility; (2) an assessment of alternative policy options available to a regulatory agency; and (3) a case history. Sensitivity analyses designed to address the first issue show that the allocation of resources by the owner/operator is sensitive to the stochastic parameters used to describe the hydraulic conductivity field at a site. For the cases analyzed, the installation of a dense monitoring network is of less value to the owner/operator than a more conservative containment design. Sensitivity analyses designed to address the second issue suggest that from a regulatory perspective, design standards should be more effective than performance standards in reducing risk, and design specifications on the containment structure should be more effective than those on the monitoring network. Performance bonds posted before construction have a greater potential to influence design than prospective penalties to be imposed at the time of failure. Siting on low-conductivity deposits is a more effective method of risk reduction than any form of regulatory influence. Results of the case history indicate that the methodology can be successfully applied at field sites.

Author 1	Author 2	Facility or Agency
Massmann	Freeze	

Citation

Massmann, J., R. A. Freeze, et al., 1991. Hydrogeological Decision Analysis. 2. Applications to Ground-Water Contamination. Ground Water 29(4): 536-548.

Journal

Ground Water 29(4): 536-548.

Title

Hydrogeological Decision Analysis. 2. Applications to Ground-Water Contamination.

Document	Year
	1991

Why	How	What	Where
Characterization			

Abstract

Author 1	Author 2	Facility or Agency
Mattson	Sisson	INEEL

Citation
Mattson, E.D. and J.B. Sisson, 2000. Monitoring and Characterization Equipment Development at Idaho National Engineering and Environmental Laboratory. U.S. Department of Energy, Idaho National Engineering and Environmental Laboratory.

Journal

Title
Monitoring and Characterization Equipment Development at Idaho National Engineering and Environmental Laboratory.

Document	Year
	2000

Why	How	What	Where
Monitoring	Devices	mixed	Unsaturated

Abstract

Author 1	Author 2	Facility or Agency
Mavko		

Citation

Mavko, G., 2000. Collaborative Research: Hydrogeological Geophysical Methods for Subsurface Site Characterization. EMSP-54655, U.S. Department of Energy.

Journal

Title

Collaborative Research: Hydrogeological Geophysical Methods for Subsurface Site Characterization.

Document	Year
EMSP-54655	2000

Why	How	What	Where
Characterization	Geophysical		

Abstract

The objective of this research has been to improve aquifer characterization. This objective was met by focusing on using rock physics theory and geophysical data to predict flow properties, such as porosity, permeability and clay content. The advantage of using geophysical data to predict these properties stems from the fact that geophysical data are less expensive and more spatially-abundant than lab- or field-measured, flow-property data. This research contributes three newly-developed relationships that significantly improve aquifer characterization: (1) a general relationship between total and channel porosities, (2) a general relationship between electrical resistivity and channel porosity, and (3) bounds on the electrical resistivity - seismic velocity relationship.

Author 1	Author 2	Facility or Agency
McCombie	Pescatore	Nuclear Energy Agency

Citation

NEA/OECD. Progress Towards Geologic Disposal of Radioactive Waste: Where Do We Stand? An International Assessment. Report, 1999.

Journal

Title

Progress Towards Geologic Disposal of Radioactive Waste: Where Do We Stand? An International Assessment.

Document	Year
	1999

Why	How	What	Where

Abstract

Radioactive wastes of all kinds need to be managed responsibly to ensure public safety and protection of the environment, as well as security from malicious intervention, now and in the future. The most challenging task involves management of the long-lived waste that must be isolated from the human environment for many thousands of years. The preferred option for eventual disposal is emplacement in repositories deep underground in well-chosen geologic media.

Since the geologic disposal concept was proposed, research and development efforts world-wide have increased understanding of how underground disposal facilities will function over very long periods of time, and have enhanced confidence in the ultimate safety of the concept. While significant progress has been made towards development of these facilities, there have also been delays and setbacks primarily due to failure of the waste management experts and institutions to win sufficient public or political support. In recent years, as the concept itself is nearing implementation in several countries, support is being voiced in some quarters for postponement of disposal and for more review of alternative waste management options. On the other hand, reflections in international groups of experts have repeatedly confirmed the conviction that geologic disposal is ethical, environmentally sound and safe, and other management options are, at most, complementary to geologic disposal rather than complete, long-term alternatives.

This text draws on information and views collected from radioactive waste management experts from OECD/NEA Member countries and presents an assessment of developments in the field of deep geologic disposal and management of long-lived radioactive wastes over the past ten years. The report reviews both technical and societal aspects, and should be of interest to decision makers with responsibilities encompassing radioactive waste management as well as to interested individuals and groups.

This report is based on, and complements, two publications recently finalised by the members of the OECD/NEA Radioactive Waste Management Committee, which include senior representatives from waste management agencies, regulatory authorities, policymaking bodies, and research and development institutions with responsibilities in waste management. The two publications deal with "Geological Disposal of Radioactive Waste: Review of Developments in the Last Decade" and "Confidence in the Long-term Safety of Deep Geologic Repositories - Its Development and Communication". These and other reports are identified on page 27 as suggestions for further reading.

Author 1	Author 2	Facility or Agency
McDowell-Boyer	Yu	SRS

Citation
Radiological Performance Assessment for the E-Area Low-Level Waste Facility. 2000. Westinghouse Savannah River Company. WSRC-RP-94-218.

Journal

Title
Radiological Performance Assessment for the E-Area Low-Level Waste Facility

Document	Year
WSRC-RP-94-218	2000

Why	How	What	Where

Abstract

Author 1	Author 2	Facility or Agency
McGuire	Vlasity	

Citation

McGuire, R. K. and J. A. Vlasity, 1996. Dose Rates from Repository Performance Assessment. Proceedings of the 1996 7th Annual International Conference on High Radioactive Waste Management, Apr 29-May 3 1996, Las Vegas, NV, USA, ASCE, New York, NY, USA.

Journal

Title

Dose Rates from Repository Performance Assessment.

Document	Year
	1996

Why	How	What	Where

Abstract

Probabilistic performance assessments of high-level waste repositories have the ability to estimate distributions of doses to humans in the future under assumptions of population size, location, and ingestion of water and food impacted by radionuclides. Current work in this aspect uses EPRI models of groundwater infiltration controlled by climate, of the source term, and of hydrologic flow and transport of nuclides. Preliminary result indicate that long-term dose rates are controlled by transport and dilution in the SZ, and are not affected by waste container behavior.

Author 1	Author 2	Facility or Agency
McGuire	Vlasity	

Citation

McGuire, R.K. and J.A. Vlasity, 1995. Comparison of EPRI and Sandia Performance Assessment Assumptions. Proceedings of the 6th Annual International Conference on High Level Radioactive Waste Management, Apr 30-May 5 1995, Las Vegas, NV, USA.

Journal

Title

Comparison of EPRI and Sandia Performance Assessment Assumptions.

Document	Year
	1995

Why	How	What	Where
Design	Performance	comparison	

Abstract

This study was performed to compare the assumptions made in the EPRI (Electric Power Research Institute) and Sandia National Laboratory (herein called TSPA-1993) performance assessments of a potential high-level waste repository at Yucca Mountain, Nevada. A second goal was to compare the effects of these assumptions on performance assessment calculations, to determine which assumptions are critical and which are not. This will provide a check on the robustness of the agreement between the two studies. A more detailed description of the comparisons and conclusions reached in this study are presented in REI (Risk Engineering, Inc.), 1994.

Author 1	Author 2	Facility or Agency
McGuire	Kessler	Yucca

Citation

McGuire, R.K., J.H. Kessler, et al, 1997. Nuclear Repository Performance Assessment: Insights into Critical Models and Parameters Affecting Projected Future Doses. Materials Research Society Symposium - Proceedings, v 465, Scientific Basis for Nuclear Waste Management XX, p 1083-1089. Proceedings of the 1996 MRS Fall Meeting, Dec 2-6 1996, Boston,

Journal

Title

Nuclear Repository Performance Assessment: Insights into Critical Models and Parameters Affecting Projected Future Doses.

Document	Year
	1997

Why	How	What	Where
Design	Performance	comparison	

Abstract

The Phase 3 Total System Performance Assessment (TSPA) sponsored by the Electric Power Research Institute (EPRI) has led to new insights into critical models and parameters affecting estimated doses to humans from a potential repository of high-level radioactive wastes at Yucca Mountain, Nevada. The Phase 3 model has been extended to encompass time-varying climate and infiltration, detailed modeling of the source term and hydrology, and detailed specification of possible interaction between percolating ground water and waste containers.

The three key radionuclides contributing to estimated total doses are Tc-99, I-129, and Np-237. Five other nuclides contributing to dose in lesser (but significant) amounts are U-233, Th-229, Pa0231, Ac-227, and Se-79. These results are consistent with other TSPAs.

From sensitivity studies, the most critical models and parameters are as follows. Infiltration and percolation assumptions, including the amount of lateral diversion of infiltration water, are important and need verification with site data and/or more detailed modeling. Parameters of the unsaturated zone (UZ) and saturated zone (SZ) determine dilution and delay of concentrations and peak doses downstream. The fraction of containers that become wet are not critical in our model, but this lack of sensitivity reflects our coupling of the fraction with a model of focused flow past the containers; a different model might indicate higher sensitivity. Also, the degree of coupling between fracture and matrix flow is important in affecting the times of peak doses but not their magnitudes.

Other critical design assumptions that could lead to reduced and/or delayed doses are a more robust container design, a capillary barrier around each container, the dilution during hydrologic transport from the repository to a potential agricultural community downstream, and the characteristics of an “average” individual in that community who might receive a dose.

Author 1	Author 2	Facility or Agency
McNab	Dooher	

Citation

McNab, W. W. J. and B. P. Dooher, 1998. Uncertainty Analyses of Fuel Hydrocarbon Biodegradation Signatures in Ground Water by Probabilistic Modeling. Ground Water 36(4): 691-698.

Journal

Ground Water 36(4): 691-698.

Title

Uncertainty Analyses of Fuel Hydrocarbon Biodegradation Signatures in Ground Water by Probabilistic Modeling.

Document	Year
	1998

Why	How	What	Where

Abstract

Natural attenuation processes, such as biodegradation, may serve as a means for remediating ground water contaminated by fuel hydrocarbons from leaking underground fuel tanks (LUFTs). Quantification of the uncertainties associated with natural attenuation, and hence the capacity to limit plume migration and restore an aquifer, is important. In this study, a probabilistic screening model is developed to quantify uncertainties involved in the impact of biodegradation on hydrocarbon plume behavior. The approach is based on Monte Carlo simulation using an analytical solution to the advective-dispersive solute transport equation, including a first-order degradation term, coupled with mass balance constraints on electron acceptor use. Empirical probability distributions for governing parameters are provided as input to the model. Application of the model to an existing LUFT site illustrates the degree of uncertainty associated with model-predicted hydrocarbon concentrations and geochemical indicators at individual site monitoring wells as well as the roles of various parameter assumptions (e.g., hydraulic conductivity, first-order decay coefficient, source term) in influencing forecasts. This information is useful for risk management planning because the degree of confidence that biodegradation will limit the impact of a hydrocarbon plume on potential receptors can be quantified.

Author 1	Author 2	Facility or Agency
McTigue	Martinez	Sandia

Citation

McTigue, D. F., M. J. Martinez, et al., 1993. Heat and Vapor Transport Beneath an Impermeable Cap. Proceedings of the 4th Annual International Conference on High Level Radioactive Waste Management, Apr 26-30 1993, Las Vegas, NV, USA.

Journal

Title

Heat and Vapor Transport Beneath an Impermeable Cap.

Document	Year
	1993

Why	How	What	Where
Modeling	Uncertainties	barriers	Unsaturated

Abstract

Vadose-zone moisture transport near an impermeable barrier has been under study at a field site near Albuquerque, NM since 1990. Moisture content and temperature have been monitored in the subsurface on a regular basis; both undergo a seasonal variation about average values. Even though a slab introduces two-dimensional effects on the scale of the slab, moisture and heat transport is predominantly vertical. Numerical simulations, based on the models developed by Philip and de Vries (1957) and de Vries (1958), indicate that the heat flow is conduction-dominated while the moisture movement is dominated by diffusive vapor distillation. Model predictions of the magnitude and extent of changes in moisture underneath the slab are in reasonable agreement with observation.

Author 1	Author 2	Facility or Agency
Meyer	Taira	NRC

Citation

Meyer, P.D. and R.Y. Taira, 2001. Hydrologic Uncertainty Assessment for Decommissioning Sites: Hypothetical Test Case Applications. U.S. Nuclear Regulatory Commission Report. NUREG/CR-6695, PNNL-13375.

Journal

Title

Hydrologic Uncertainty Assessment for Decommissioning Sites: Hypothetical Test Case Applications

Document	Year
NUREG/CR-6695	2001

Why	How	What	Where
Modeling	Uncertainties		

Abstract

This report uses hypothetical decommissioning test cases to illustrate an uncertainty assessment methodology for dose assessments conducted as part of decommissioning analyses for NRC-licensed facilities. This methodology was presented previously in NUREG/CR-6656. The hypothetical test case source term and scenarios are based on an actual decommissioning case and the physical setting is based on the site of a field experiment carried out for the NRC in Arizona. The emphasis in the test case was on parameter uncertainty. The analysis is limited to the hydrologic aspects of the exposure pathway involving infiltration of water at the ground surface, leaching of contaminants, and transport of contaminants through the groundwater to a point of exposure. The methodology uses generic parameter distributions based on national or regional databases for estimating parameter uncertainty. A Bayesian updating method is used in one of the test case applications to combine site-specific information with the generic parameter distributions. Sensitivity analyses and probabilistic simulations are used to describe the impact of parameter uncertainty on predicted dose. Emphasis is placed on understanding the conceptual and computational behavior of the dose assessment codes as they are applied to the test cases. The primary code used in these applications was RESRAD v. 6.0, although DandD v. 1.0 results are also reported. The methods presented and the issues discussed are applicable to other codes as well.

Author 1	Author 2	Facility or Agency
Meyer	Gee	NRC

Citation

Meyer, P.D., and G.W. Gee, 1999. Information on Hydrologic Conceptual Models, Parameters, Uncertainty Analysis, and Data Sources for Dose Assessments at Decommissioning Sites. U.S. Nuclear Regulatory Commission Report. NUREG/CR-6656, PNNL-1309.

Journal

Title

Information on Hydrologic Conceptual Models, Parameters, Uncertainty Analysis, and Data Sources for Dose Assessments at Decommissioning Sites

Document	Year
NUREG/CR-6656	1999

Why	How	What	Where
Monitoring	Uncertainties		Unsaturated

Abstract

This report addresses issues related to the analysis of uncertainty in dose assessments conducted as part of decommissioning analyses. The analysis is limited to the hydrologic aspects of the exposure pathway involving infiltration of water at the ground surface, leaching of contaminants, and transport of contaminants through the groundwater to a point of exposure. The basic conceptual models and mathematical implementations of three dose assessment codes are outlined along with the site-specific conditions under which the codes may provide inaccurate, potentially nonconservative results. In addition, the hydrologic parameters of the codes are identified and compared. A methodology for parameter uncertainty assessment is outlined that considers the potential data limitations and modeling needs of decommissioning analyses. This methodology uses generic parameter distributions based on national or regional databases, sensitivity analysis, probabilistic modeling, and Bayesian updating to incorporate site-specific information. Data sources for best-estimate parameter values and parameter uncertainty information are also reviewed. A follow-on report will illustrate the uncertainty assessment methodology using decommissioning test cases.

Author 1	Author 2	Facility or Agency
Meyer	Orr	NRC

Citation

Meyer, P.D. and S. Orr, 2002. Evaluation of Hydrologic Uncertainty Assessments for Decommissioning Sites Using Complex and Simplified Models. U.S. Nuclear Regulatory Commission Report. NUREG/CR-6767, PNNL-13832.

Journal

Title

Evaluation of Hydrologic Uncertainty Assessments for Decommissioning Sites Using Complex and Simplified Models

Document	Year
NUREG/CR-6767	2002

Why	How	What	Where
Modeling	Uncertainties	geostatistics	

Abstract

This report is the third (and final) report in a series that addresses issues related to hydrologic uncertainty assessment at decommissioning sites. Analyses in the first two reports in this series emphasized the application of relatively simplified models of subsurface flow and transport. Because of their relative computational speed, such simplified models are particularly attractive when the impact of uncertainty in flow and transport needs to be evaluated. These same simplifications, however, have the potential to provide unrepresentative estimates of dose and its uncertainty. Such misrepresentation may have important consequences for decisions based on the dose assessments. The significance of this concern was evaluated by comparing results from uncertainty assessments conducted on a test case using a simplified modeling approach and a more complex/ realistic modeling approach.

The test case used a three-dimensional domain with a U-234 source in the near surface, a 5-m-thick aquifer 7 m below the surface, and a small well pumping directly downstream, on the boundary of the contaminated zone. Exposure was assumed to occur through the drinking water pathway only, with all drinking water originating from the pumped well. A series of Monte Carlo simulations of flow and transport were performed using STOMP as the complex model and RESRAD as the simplified model. Hydraulic conductivity and air entry were modeled as random fields in STOMP using geostatistics from the Las Cruces Trench site. Random distributions for hydraulic parameters in the RESRAD simulations were based on both site-specific data and generic distributions. Sensitivity analyses were conducted on both codes using a combination of Monte Carlo simulation and single parameter variation.

Peak doses predicted by the simplified model were several times higher than peak doses predicted by the complex model. This difference was attributed to the lack of dispersion in RESRAD and differences in aquifer mixing. The RESRAD concentration breakthrough curves exhibited a sharp peak with essentially no contaminant in the well until the time of the peak while STOMP predicted a much earlier arrival of contaminants in the well. Which code provided conservative results thus depended on whether the RESRAD peak occurred before the 1000-year regulatory criterion.

The random field characterization of the subsurface for the complex model used all available site data. Uncertainty in predicted dose was correspondingly small, with the peak dose coefficient of variation being 30%. When the variances of parameters in the simplified model were based on a generic dataset, the uncertainty in predicted peak dose was much larger; the coefficient of variation was 52% in this case. When the variances of parameters in the simplified model were based on the extensive site-specific data, the coefficient of variation for the peak dose was reduced to 22%. In this case, however, the mean peak dose was actually less similar to the STOMP results than the generic case.

For the RESRAD Monte Carlo simulations involving random soil hydraulic properties, the variability of peak dose was entirely attributed to variability in the aquifer hydraulic conductivity. Sensitivity to other parameters was examined by varying one

parameter at a time. These results indicated that the recharge rate, the aquifer gradient, and the depth of penetration of the well were significant contributors to uncertainty in peak dose and the time of the peak dose. RESRAD predicted peak dose was more sensitive to the parameter values than was the STOMP predicted peak dose for the aquifer hydraulic conductivity, aquifer gradient, and depth of well penetration. Sensitivity to the recharge rate appeared to be comparable for the two codes.

Stochastic predictions of mean dose over time for the complex model were relatively insensitive to the geostatistical parameters. Ensemble mean peak dose predicted by the complex model was sensitive to the ensemble mean hydraulic conductivity. For a given ensemble mean hydraulic conductivity, however, the complex model showed no correlation between the spatial geometric mean aquifer conductivity of individual realizations and the resulting peak dose. This was in contrast to the simplified model in which the dose from individual realizations was strongly correlated with the aquifer conductivity. This result has implications for the value of hydraulic conductivity data. Adopting the homogeneous parameterization of RESRAD leads to a conclusion that reducing the uncertainty in the value of the aquifer hydraulic conductivity parameter will have a significant impact on the uncertainty in peak dose. Looking at the individual realization results from the STOMP model suggests that characterization of the average aquifer hydraulic conductivity is relatively unimportant in reducing uncertainty in peak dose. Characterizing the pattern of aquifer heterogeneity is likely to be more important than obtaining a value for the spatial mean hydraulic conductivity.

Author 1	Author 2	Facility or Agency
Michael		

Citation
Michael

Journal

Title

Document	Year
	2000

Why	How	What	Where

Abstract

Author 1	Author 2	Facility or Agency
Mohanty	Manteufel	

Citation

Mohanty, S., R.D. Manteufel, et al., 1995. Fracture Permeability Under Effect of Normal and Shear Stress: A Preliminary Experimental Investigation. Proceedings of the Sixth International Conference on High-Level Radioactive Waste Management, American Nuclear Society, La Grange Park, Illinois, pp. 41-43.

Journal

Title

Fracture Permeability Under Effect of Normal and Shear Stress: A Preliminary Experimental Investigation

Document	Year
	1995

Why	How	What	Where
Characterization			Fracture

Abstract

Author 1	Author 2	Facility or Agency
Mohanty	Lichtner	

Citation

Mohanty, S. and P.C. Lichtner, 1996. Role of Diffusion-Limited Aggregation Models in Predicting Unstable Flow and Solute Transport in Porous Media. EOS Transactions, American Geophysical Union, Vol. 77, No. 17, p. S97.

Journal

EOS Transactions, American Geophysical Union, Vol. 77, No. 17, p. S97, April 1996 Supplement

Title

Role of Diffusion-Limited Aggregation Models in Predicting Unstable Flow and Solute Transport in Porous Media

Document	Year
	1996

Why	How	What	Where
Modeling	diffusion		

Abstract

Author 1	Author 2	Facility or Agency
Mohanty	Bagtzoglou	

Citation

Mohanty, S. and A.C. Bagtzoglou, 1994. Effective Unsaturated Hydraulic Property Determination with the Renormalization Group Approach: Methodology. Proceedings of the Fifth International Conference on High-Level Radioactive Waste Management, Vol. (4):2660-2668, American Nuclear Society, La Grange Park, Illinois.

Journal

Title

Effective Unsaturated Hydraulic Property Determination with the Renormalization Group Approach: Methodology

Document	Year
	1994

Why	How	What	Where
Characterization	Uncertainties	properties	Unsaturated

Abstract

Author 1	Author 2	Facility or Agency
Moline	Beauchamp	

Citation

Moline, G. R., J. J. Beauchamp, et al., 1996. Determining an Optimal Sampling Frequency for Measuring Bulk Temporal Changes in Ground-Water Quality. Ground Water 34(4): 579-587.

Journal

Ground Water 34(4): 579-587.

Title

Determining an Optimal Sampling Frequency for Measuring Bulk Temporal Changes in Ground-Water Quality.

Document	Year
	1996

Why	How	What	Where
Design	Optimization		Saturated

Abstract

In the Data Quality Objectives (DQO) process, statistical methods are used to determine an optimal sampling and analysis plan. When the DQO decision rule for instituting remedial actions is based on a critical change in water quality, the monitoring program design must ensure that this change can be detected and measured with a specified confidence. Usually the focus is on the change at a single monitoring location and the process is limited to addressing the uncertainty inherent in the analytical methods and the variability at that location. However, new strategies that permit ranking the waste sites and prioritizing remedial activities require the means for assessing overall changes for small regions over time, where both spatial and temporal variability exist and where the uncertainty associated with these variations far exceeds measurement error. Two new methods for assessing these overall changes have been developed and are demonstrated by application to a waste disposal site in Oak Ridge, Tennessee. These methods incorporate historical data where available and allow the user to either test the statistical significance of a linear trend or of an annual change compared to a baseline year for a group of water quality wells.

Author 1	Author 2	Facility or Agency
Moss		INEEL

Citation

Moss, G., 1995. Introduction to Radiological Performance Assessment. U.S. Department of Energy, Report, DOE/LLW-187.

Journal

Title

Introduction to Radiological Performance Assessment.

Document	Year
DOE/LLW-187	1995

Why	How	What	Where

Abstract

A radiological performance assessment is conducted to provide reasonable assurance that performance objectives for low-level radioactive waste (LLW) disposal will be met. Beginning in the early stages of development, a radiological performance assessment continues through the operational phase, and is instrumental in the postclosure of the facility. Fundamental differences exist in the regulation of commercial and defense LLW, but the radiological performance assessment process is essentially the same for both. The purpose of this document is to describe that process in a concise and straightforward manner. This document focuses on radiological performance assessment as it pertains to commercial LLW disposal, but is applicable to U.S. Department of Energy sites as well. Included are discussions on performance objectives, site characterization, and how a performance assessment is conducted. A case study is used to illustrate how the process works as a whole. A bibliography is provided to assist in locating additional information.

Author 1	Author 2	Facility or Agency
Murphy		Yucca

Citation

Murphy, W.M., 1989. Constraints on the Chemistry of Groundwater in the Unsaturated Zone at Yucca Mountain, Nevada, and in the Proposed Repository at that Site. CNWRA 89-005.

Journal

Title

Constraints on the Chemistry of Groundwater in the Unsaturated Zone at Yucca Mountain, Nevada, and in the Proposed Repository at that Site

Document	Year
CNWRA 89-005	1989

Why	How	What	Where
Characterization	Geochemical		Structure

Abstract

Author 1	Author 2	Facility or Agency
Murphy		Yucca

Citation

Murphy, W.M., 1990. The High-Level Nuclear Waste Repository Near-Field Environment: Performance Assessment Perspectives with Reference to the Proposed Repository at Yucca Mountain, Nevada. Proceedings of the International Near-Field Performance Assessment Workshop, Madrid, Spain.

Journal

Title

The High-Level Nuclear Waste Repository Near-Field Environment: Performance Assessment Perspectives with Reference to the Proposed Repository at Yucca Mountain, Nevada

Document	Year
	1990

Why	How	What	Where
Design	Performance	Pas	Structure

Abstract

Author 1	Author 2	Facility or Agency
Narbutovskih	Daily	Hanford

Citation

Narbutovskih, S.M., W. Daily, et al., 1996. Electrical Resistivity Tomography at the DOE Hanford Site. Proceedings of the Symposium on the Application of Geophysics to Engineering and Environmental Problems, April 28 - May 2, 1996, Keystone, Colorado.

Journal

Title

Electrical Resistivity Tomography at the DOE Hanford Site.

Document	Year
	1996

Why	How	What	Where
Monitoring	Geophysical	ERT	Unsaturated

Abstract

Recent work at the DOE Hanford site has established the potential of applying Electrical Resistivity Tomography (ERT) for early leak detection under hazardous waste storage facilities. Several studies have been conducted to test the capabilities and limitations of ERT for two different applications. First, field experiments have been conducted to determine the utility of ERT to detect and map leaks from underground storage tanks during waste removal processes. Second, the use of ERT for long term vadose zone monitoring has been tested under different field conditions of depth, installation design, acquisition mode/equipment and infiltration chemistry. This work involves transferring the technology from Lawrence Livermore National Laboratory (LLNL) to the Resource Conservation and Recovery Act (RCRA) program at the DOE Hanford Site. This paper covers field training studies relevant to the second application for long term vadose zone monitoring.

Electrical resistivity tomography is a cross-borehole, imaging technique for mapping subsurface resistivity variations. Electrodes are placed at predetermined depths in an array of boreholes. Electrical current is introduced into one electrode pair located in one borehole while the resulting voltage change is detected between electrode pairs in other boreholes similar to a surface dipole-dipole array. These data are tomographically inverted to image temporal resistivity contrasts associated with an infiltration event. Thus a dynamic plume is spatially mapped as a function of time.

As a long-term vadose zone monitoring method, different field conditions and performance requirements exist than those for short term tank leak detection. To test ERT under these conditions, two vertical electrode arrays were constructed to a depth of 160 feet with a linear surface array between boreholes. The fielding was used to facilitate the technology transfer from LLNL to the Hanford RCRA program. Installation methods, commercial equipment and acquisition mode were evaluated to determine economic and technical feasibility to assist design of long-term monitoring networks. Preliminary results of the training test are presented.

Until recently, vadose zone monitoring techniques could provide only local point of linear coverage for leak detection and thus, are used primarily under liquid collection systems at land disposal units. As developed by LLNL, ERT can provide areal coverage under waste treatment and storage facilities given the right conditions. Advantages of ERT to groundwater protection programs are explored along with suggestions for future uses where ERT can be employed today.

Author 1	Author 2	Facility or Agency
Nativ	Adar	

Citation

Nativ, R., E. M. Adar, et al., 1999. Designing a Monitoring Network for Contaminated Ground Water in Fractured Chalk. Ground Water 37(1): 38-47.

Journal

Ground Water 37(1): 38-47

Title

Designing a Monitoring Network for Contaminated Ground Water in Fractured Chalk.

Document	Year
	1999

Why	How	What	Where
Characterization	Access	drilling	fracture

Abstract

One of the challenges of monitoring network design in a fractured rock setting is the heterogeneity of the rocks. This paper summarizes the activities and problems associated with the monitoring of contaminated groundwater in porous, low-permeability fractured chalk in the Negev Desert, Israel. Preferential flow documented in the study area required siting the monitoring boreholes in the predominant fracture systems. Lineaments traced from aerial photographs were examined in the field to sort out the large-extension, through-going, multiplayer fracture systems crossing the study area. At each proposed drilling site, these fractures were exposed below the sediment cover using trenches. Slanted boreholes were drilled at a distance from the fracture systems so that each borehole would intersect the targeted fracture plane below the water table. Based on their short recovery period and contaminated ground water, these newly drilled, fracture-oriented boreholes appeared to be better connected to preferential flowpaths crossing the industrial site than the old boreholes existing on site. Other considerations concerning the drilling and logging of monitoring boreholes in a fractured media were: (1) coring provides better documentation of the vertical fracture distribution, but dry augering is less costly and enables immediate ground water sampling and the sampling of vadose zone rock for contaminant analysis; (2) caliper and TV camera logs appear to provide only partial information regarding the vertical fracture distribution; and (3) the information gained by deepening the monitoring boreholes and testing fractures crossing their uncased walls has to be carefully weighed against the risk of potential cross-contamination through the monitoring boreholes, which is enhanced in fractured media.

Author 1	Author 2	Facility or Agency
NEA		Nuclear Energy Agency

Citation

NEA/OECD, 1997. Lessons Learnt from Ten Performance Assessment Studies, Disposal of Radioactive Waste. Nuclear Energy Agency, Organisation for Economic Co-operation and Development.

Journal

Title

Lessons Learnt from Ten Performance Assessment Studies

Document	Year
	1997

Why	How	What	Where
Modeling	Performance	Pas	Structure

Abstract

The management of radioactive wastes and, in particular, the safety assessment of radioactive waste disposal systems are areas of high priority in the programme of the OECD Nuclear Energy Agency (NEA). The NEA's Radioactive Waste Management Committee (RWMC) and its Performance Assessment Advisory Group (PAAG) and Co-ordinating Group on Site Evaluation and Design of Experiments (SEDE) are committed to promoting information exchange and cooperation among OECD member countries on subjects related to radioactive waste management strategy, safety assessment of disposal systems, and characterisation of potential disposal sites.
Through international exchanges co-ordinated by the NEA, a general consensus has been reached that:
- the responsibilities of this generation to future generations are better discharged by a strategy of final disposal, and disposal of radioactive wastes in geologic repositories is currently the most favoured option;
- appropriate use of safety assessment methods, coupled with sufficient information from the proposed disposal sites, can provide the technical basis to decide whether specific disposal systems would offer to society a satisfactory level of safety for both current and future generations.
As progress is made in methods of site evaluation and safety/performance assessment, continued co-operation is important to examine and evaluate these developments in international fora. This on-going international exchange provides interested organisations with a basis for re-assessing their national programmes and facilitates peer review.

Author 1	Author 2	Facility or Agency
NEA		Nuclear Energy Agency

Citation

NEA/OECD, 2000. Nuclear Energy Agency, An International Peer Review of Safety Report 97: Post-closure Safety of a Deep Repository for Nuclear Spent Fuel in Sweden. Nuclear Energy Agency, Organisation for Economic Co-operation and Development.

Journal

Title

An International Peer Review of Safety Report 97: Post-closure Safety of a Deep Repository for Nuclear Spent Fuel in Sweden

Document	Year
NEAA 2468-sr97	2000

Why	How	What	Where
Design	Performance		Structure

Abstract

The Swedish Nuclear Fuel Waste Management Company (SKB) recently completed Safety Report 97 (SR 97), a safety assessment of the KBS-3 concept for the disposal of Sweden's spent nuclear fuel. This document describes a peer review of SR 97 organised by the OECD Nuclear Energy Agency and conducted by an International Review Team (IRT). The review was requested by the Swedish Nuclear Power Inspectorate (SKI) with the agreement of the Swedish Radiation Protection Institute (SSI).
The review was carried out between December 1999 and May 2000. In these six months, the IRT reviewed the SR 97 main report and its three chief supporting references, and exchanged information with SKB staff both through the intermediary of SKI and in direct interaction at a workshop in Sweden. The review was guided by two important considerations:
· SR 97 is primarily a study of a conceptual phase of a repository development, so that any question of judging regulatory compliance is still some years away; and
· SR 97 and its various reviews form only part of the decision basis for the future direction of the Swedish spent fuel management programme.

Author 1	Author 2	Facility or Agency
NEA		NEA

Citation

NEA/OECD, 2002. GEOTRAP: Radionuclide Migration in Geologic, Heterogeneous Media: Summary of Accomplishments.

Journal

Title

GEOTRAP: Radionuclide Migration in Geologic, Heterogeneous Media: Summary of Accomplishments

Document	Year
OECD	2002

Why	How	What	Where
Modeling			

Abstract

Most countries using nuclear energy are considering, or actively pursuing, the creation of a deep geologic repository for radioactive waste. As part of the assessment of the performance or safety of such a repository, radionuclide transport through the heterogeneous, geologic environment must be modelled. Research in this field began at individual sites around the world as early as the 1970s.

A series of international collaborative projects [INTRACOIN (1981-1984), HYDROCOIN (1984-1987), INTRAVAL (1987-1993)] began under the aegis of the NEA in 1981, as individual countries came to appreciate the benefits of sharing experiences and comparing approaches to modelling radionuclide transport. These projects focused on the development and validation of models of flow and radionuclide transport (Larsson, 1992).

After the conclusion of INTRAVAL, a continuing need was perceived by NEA Member countries for a forum-like project in which those responsible for the implementation of repository programmes ("implementers"), regulators, and the wider scientific community could interact in a structured fashion on issues specifically relevant to understanding and modelling radionuclide migration in heterogeneous, geologic media. Thus, GEOTRAP - the OECD/NEA Project on Radionuclide Migration in Geologic, Heterogeneous Media - was established in 1996.

Five workshops were carried out as part of the project and covered the following subjects: Field Tracer Transport Experiments; Modelling the Effects of Spatial Variability; Characterisation of Water-conducting Features and Their Representation in Models; Confidence in Models of Radionuclide Transport; and Geological Evidence and Theoretical Bases for Radionuclide-retention Processes.

This report provides an overview of the project's main findings and accomplishments over its five-year life. The authors hope that this summary will help make the valuable information collected and generated by the GEOTRAP project accessible to a wide readership both within and outside the radioactive waste community. It is a reflection of the careful attention paid by this community to the question of radionuclide transport.

Author 1	Author 2	Facility or Agency
NEA		NEA

Citation

NEA/OECD, Strategic Areas in Radioactive Waste Management. Report, 1999.

Journal

Title

Strategic Areas in Radioactive Waste Management

Document	Year
	1999

Why	How	What	Where

Abstract

Radioactive waste arises from commercial nuclear power generation as well as from other industrial activities and from the use of radioactive materials in several human activities. Radioactive waste also exists as a result of past practices, and needs to be managed in a safe, economical, and environmentally and publicly acceptable manner.
In recent years, the programmes under the Radioactive Waste Management Committee (RWMC) have focused primarily on technical aspects related to deep underground disposal of long-lived radioactive waste. One of the achievements reached by these programmes is the establishment of a consensus between experts in the various participating countries that sites can be properly identified and characterised, that geological repositories can be designed so that no short-term detriment to populations will result from the waste disposal, and that an acceptable level of safety is provided for times far into the future, up to and beyond any period of regulatory concern. There also exists consensus, among the experts, that the current generation, who have benefited from the nuclear energy produced, should provide future generations the means to dispose permanently of the waste.
The confidence of the experts in the short- and long-term safety of the geologic disposal option has been confirmed, at national level, in several technical and licensing reviews of safety assessment studies of deep repository systems, but is not necessarily matched by an equally favourable attitude within non-expert groups. In particular, several repository-development programmes have recently undergone increased public scrutiny and despite notable exceptions, e.g. the granting of a nuclear licence to operate the WIPP geological repository, this has resulted in delays in the implementation of some site development programmes. Long-term surface storage and partitioning and transmutation are still being investigated as potential components in an overall waste management strategy leading to disposal. In addition, deregulation of the electricity market and attendant financial pressures affect the whole nuclear-fuel cycle and impact on waste management organisations. These considerations raise issues concerning how best to achieve confidence, and consensus, regarding the economic, political, technical and ethical aspects of a waste management strategy.
In this document strategic areas are defined and further described in which RWMC feels that progress would be most beneficial towards further development of radioactive waste management, and particularly disposal programmes. It is accepted that the RWMC, building upon the technical areas in which it has demonstrated strength, extend its endeavours to the interfaces between technical advances, regulatory developments, societal concerns and their input to the decision making process.

Author 1	Author 2	Facility or Agency
NEA		NEA

Citation

NEA/OECD, 2001. Reversibility and Retrievability in Geologic Disposal of Radioactive Waste - Reflections at the International Level.

Journal

Title

Reversibility and Retrievability in Geologic Disposal of Radioactive Waste - Reflections at the International Level

Document	Year
	2001

Why	How	What	Where

Abstract

The NEA Radioactive Waste Management Committee (RWMC) is a forum of senior representatives of operator, regulator, policy-making, and R&D organisations in the field of radioactive waste management. The Committee assists Member countries by providing guidance on the solution of radioactive waste problems, and promotes safety in the short- and long-term management of radioactive waste.

The RWMC has defined strategic areas where progress would be highly beneficial to the further development of radioactive waste management and geologic disposal programmes, and has also identified key topics within each strategic area (NEA, 1999a). One such topic, within the area of "Overall Waste Management Approaches", is the reversibility of decisions in waste disposal programmes and the potential for retrieval (retrievability) of disposed waste from a geologic repository. A group was set up in order to explore this topic, with members drawn from implementor, regulator, and policy-making organisations from eleven countries, as well as the European Commission. A questionnaire was circulated to obtain preliminary input. The group then met to discuss the issues and drafted a report. That report was further developed with input from other members of the RWMC, the result of which is produced herein.

The concepts of reversibility and retrievability are currently being discussed and defined within the national programmes of several countries and there are, as yet, varying views on the desirability and the methods and degree of their implementation. The intention of this report is to provide an overview of the relevant issues based on the current understanding and views of experts from the waste management community in NEA Member countries. A better understanding and communication of these issues will clarify the value of flexible, step-wise decision making in repository development programmes and may help to generate a climate conducive to the further progress of such programmes.

Author 1	Author 2	Facility or Agency
NEA		NEA

Citation

NEA/OECD, 2000. Stakeholder Confidence and Radioactive Waste Disposal; Inauguration, First Workshop and Meeting of the NEA Forum on Stakeholder Confidence in the Area of Radioactive Waste Management.

Journal

Title

Stakeholder Confidence and Radioactive Waste Disposal; Inauguration, First Workshop and Meeting of the NEA Forum on Stakeholder Confidence in the Area of Radioactive Waste Management.

Document	Year
OECD	2000

Why	How	What	Where

Abstract

In recent years, radioactive waste management institutions have become more and more aware that technical expertise and expert confidence in the safety of geologic disposal of radioactive waste are insufficient, on their own, to justify to a wider audience geologic disposal as a waste management solution, or to see it through to successful implementation.

Partly due to a sensitivity of the public on all matters connected to protection of the environment, nuclear power, and especially nuclear waste; partly because of the unique nature and required longevity of the proposed disposal concepts; and partly because of the changing societal conditions in the processes of decision making; the decisions whether, when and how to implement geologic disposal will need a thorough public examination and involvement of all relevant stakeholders. The latter include waste producers, waste management agencies, safety authorities, local communities, elected representatives, and the technical intermediaries between the public and the decision makers. The involvement of non-technical stakeholders will become increasingly important as more countries move towards siting and implementing geologic repositories.

The decision-making process and avenues for stakeholder involvement differ from country to country. It is important to identify similarities and differences, understand the key concerns of the various stakeholders, and develop means to interact effectively. The Forum on Stakeholder Confidence (FSC) has been charged with investigating and distilling the lessons that can be learnt from national and international experience. The intention is to be useful to the Member countries of the Nuclear Energy Agency (NEA) in their efforts to set up effective means of radioactive waste management while taking into account the input of relevant stakeholders.

The aim of the Forum's first workshop was to establish contacts amongst Forum participants and to lay the basis of its future programme and methods of work. In order to give guidance to the FSC and, at the same time, to give this initiative high-level input and visibility, the workshop was preceded by a half-day inaugural event. Members of the NEA Radioactive Waste Management Committee and invited speakers provided their perspectives in the area of stakeholder confidence. Over the following days, five themes were addressed through plenary talks. The Forum also broke up into working groups on the five themes. Each working group first heard and discussed a national case study, and then developed orientations for future meetings. The deliberations of these highly interactive working groups were reported in plenary sessions. Finally, a closed-door session reviewed future steps.

Overall, the entire event lasted three days. Its 75 attendees came from 14 countries and three international organisations. The participants had a very wide background, spanning both the technical and social sciences. Affiliations include universities, national academies, technical oversight bodies, safety authorities, implementing agencies, and advisory bodies to government. In addition, a mayor from Sweden and a parliamentarian from France were amongst the invited speakers. Y.

Le Bars, the Chairman of the Board of ANDRA (France), chaired the workshop. He was assisted by C. Pescatore and H. Riotte of the NEA Secretariat. The latter received the professional support of K. Andersson and C. Mays.

Author 1	Author 2	Facility or Agency
NEA		Nuclear Energy Agency

Citation

NEA/OECD, 2001. The Role of Underground Laboratories in Nuclear Waste Disposal Programmes.

Journal

Title

The Role of Underground Laboratories in Nuclear Waste Disposal Programmes

Document	Year
NEA 3142	2001

Why	How	What	Where
Design	Optimization	underground research lab	Structure

Abstract

The concept of engineered geologic disposal has been developed for the safe long-term management of long-lived radioactive waste. This involves the emplacement of such waste in deep underground repositories that provide for the secure and safe isolation of the waste and, consequently, the protection of humans and the environment (e.g. see NEA 2000a). The concept has been developed after wide-ranging consultation, including consideration of other options. Potential host geologic formations are chosen for their long-term stability and ability to accommodate the waste-disposal facility, protect its engineered long-term safety functions, and prevent or attenuate any eventual release of radioactivity. The engineered system is designed to complement the natural geologic barrier and to provide primary physical and chemical containment of the waste. The overall system is designed to be passively safe in the long-term and, thus, to place a minimal burden on future generations. For reassurance purposes, however, as well as to ensure the security of the waste and facility, site supervision and monitoring would continue for some period of time after repository closure.
Implementing and regulatory organizations in many of the NEA Member countries are involved in the investigation and resolution of issues associated with the design, long-term safety, and practical realization of underground repositories for radioactive waste. The feasibility, safety, and appropriateness of the solution must be demonstrated to the satisfaction of the implementing organizations, the regulatory bodies, the wider scientific and technical community, political decision makers and the general public. This requires practical demonstration of key technical elements and confidence in the decision-making process by which the implementers proceed, their plans are reviewed, and developments authorized. Especially, convincing arguments are required that instill confidence in all parties in the safety of the proposed repositories, taking into account the uncertainties that inevitably exist in forecasting the behaviour of complex natural and engineered systems for long times into the future.
A key element envisaged in all major national radioactive waste disposal programmes is the construction of one or more underground facilities in which characterization, testing, technology development, and/or demonstration activities will be carried out. Such facilities, generically known as underground research laboratories or URLs, are essential to provide scientific and technical information and practical experience that are needed for the design and construction of disposal facilities and, importantly, for the development of the safety case that must be presented at various stages or repository development.
This document provides an overview of:
- the purpose of URLs within repository development programmes;
- the range of URLs that have been developed, or are planned, in NEA Member countries to date;
- the various contributions that such facilities can make to repository development programmes and the development of a safety case;
- considerations on the timing of developing a URL within a national programme; and
- opportunities and benefits of international co-operation in relation to URLs.

Author 1	Author 2	Facility or Agency
Neall	Baertschi	

Citation

Neall, F.B., P. Baertschi, et al., 1995. Comparison of the Concepts and Assumptions in Five Recent HLW/Spent Fuel Performance Assessments. Materials Research Society Symposium - Proceedings, v 353, n 1, p 503-510.

Journal

Title

Comparison of the Concepts and Assumptions in Five Recent HLW/Spent Fuel Performance Assessments

Document	Year
	1995

Why	How	What	Where
Design	Performance	comparison	

Abstract

Integrated performance assessments of proposed repositories for HLW involve multidisciplinary studies which include identification of possible paths of future evolution of the repository system (scenario analysis) and quantification of the consequences of each scenario using deterministic or probabilistic modelling approaches. The results of such studies are commonly presented as estimates of consequence (e.g. dose to a representative individual) against time which extends into the distant future. Individual components of the model chains used can be tested to some extent, but how can the integrated assessment be evaluated to give additional confidence in the overall results? In order to address this issue, the Kristallin-1 performance assessment has been compared with other HLW/spend fuel disposal concepts, safety assessment methodologies and models. It is part of a wider study which attempted to put the results of the Kristallin-1 performance assessment into perspective by use of both this technical comparison with other performance assessments and by consideration of other information (e.g. natural analogue studies, environmental radiation data and risk assessments for radiological and non-radiological hazards) which allows the reasonableness of the results and significance of the predicted doses to be illustrated. Due to limitations of space, this aspect of the study has not been included here and the reader is referred to the "Kristallin-1: Results in Perspective" report for more details.

Author 1	Author 2	Facility or Agency
Neill	Lee	WIPP

Citation

Neill, R. H. and W. W.-L. Lee (1995). Non-Conservative Assumptions in the 1992 Performance Assessment for the Waste Isolation Pilot Plant. Proceedings of the 18th International Symposium on the Scientific Basis for Nuclear Waste Management. Part 1 (of 2),Oct 23-27 1994, Kyoto,Jpn.

Journal

Title

Non-Conservative Assumptions in the 1992 Performance Assessment for the Waste Isolation Pilot Plant.

Document	Year
	1995

Why	How	What	Where
Design	Performance		

Abstract

Performance/safety assessments have been conducted for the Waste Isolation Pilot Plant, a repository for transuranic waste in salt. We challenge two key assumptions in the 1992 Performance Assessment that led to non-conservative results. The predicted release rate of radionuclides appears underestimated due to the use of expert elicited solubilities. The overall release has been underestimated due to the use of improperly elicited human intrusion probabilities.

Author 1	Author 2	Facility or Agency
Nicholson	Guzman-Guzman	NEA

Citation

Nicholson, T.J., A. Guzman-Guzman, et al., 1997. INTRAVAL Project: To Study Validation of Geosphere Transport Models for Performance Assessment of Nuclear Waste Disposal, Phase 2, Working Group 1 Report: Flow & Tracer Experiments in Unsaturated Tuff & Soil, Las Cruces Trench and Apache Leap Tuff Studies, Nuclear Energy Agency, Organisation for

Journal

Title

INTRAVAL Project: To Study Validation of Geosphere Transport Models for Performance Assessment of Nuclear Waste Disposal, Phase 2, Working Group 1 Report: Flow & Tracer Experiments in Unsaturated Tuff & Soil, Las Cruces Trench and Apache Leap Tuff

Document	Year
OECD	1997

Why	How	What	Where
Modeling		PA	

Abstract

Author 1	Author 2	Facility or Agency
Nielsen	Van Genuchten	

Citation

Nielsen, D.R., M.Th. Van Genuchten, et al., 1990. Monitoring and Analysing Water and Solute Transport in the Vadose Zone. IAHS Publication (International Association of Hydrological Sciences), n 73, p 367.

Journal

Title

Monitoring and Analysing Water and Solute Transport in the Vadose Zone.

Document	Year
	1990

Why	How	What	Where
			Unsaturated

Abstract

Author 1	Author 2	Facility or Agency
Nielsen	Sara	ASTM

Citation
Nielsen, D.M., and M.N. Sara (eds.), 1992. Symposium on Current Practices in Ground Water and Vadose Investigations. ASTM Special Technical Publication, n. 1118, 431 p.

Journal

Title
Symposium on Current Practices in Ground Water and Vadose Investigations.

Document	Year

Why	How	What	Where

Abstract

Author 1	Author 2	Facility or Agency
Nobel	Anthony	

Citation

Nobel, C. and J. Anthony, Three-Tiered Approach to Monitoring Network Optimization.

Journal

Title

Three-Tiered Approach to Monitoring Network Optimization.

Document	Year

Why	How	What	Where
Design	Optimization		

Abstract

The two primary objectives of a monitoring program are to evaluate temporal trends in contaminant concentrations as a means of monitoring the performance of a remedial measure; and to evaluate the extent to which contaminant migration is occurring. A three-tiered approach to designing and optimizing monitoring networks has been developed for use in evaluating the degree to which a monitoring program is addressing these objectives. The three-tiered optimization approach consists of a qualitative evaluation, an evaluation of temporal trends in contaminant concentrations, and a spatial statistical analysis. The qualitative evaluation considers such factors as hydrostratigraphy, locations of potential receptors with respect to the dissolved plume, and the direction(s) and rate(s) of contaminant migration. Next, a Mann-Kendall statistical analysis is conducted to determine temporal trends at each monitoring well, and an algorithm is applied to determine the relevance of the trends within the monitoring network. Finally, a spatial statistical analysis utilizing kriging error predictions is applied to the monitoring network to determine the relative amount of information contributed by each monitoring well. The results of the three analyses are combined and evaluated to establish the frequency at which monitoring should be conducted, as well as the number and locations of wells in the monitoring network. The approach has been applied to a number of long term monitoring programs at Air Force bases across the country, and used to develop efficient and effective monitoring networks for the sites. Potential cost savings on the order of 80 percent can result from optimizing a particular monitoring network.

Author 1	Author 2	Facility or Agency
Nyhan	Fresquez	Los Alamos National Lab

Citation

Nyhan, J. W. and P.R. Fresquez, 2001. Baseline Concentrations of Radionuclides and Trace Elements in Soils, Sediments, Vegetation, Small Mammals, Birds, and Bees around the DARHT Facility; Construction Phase (1996 through 1999)

Journal

Title

Baseline Concentrations of Radionuclides and Trace Elements in Soils, Sediments, Vegetation, Small Mammals, Birds, and Bees around the DARHT Facility; Construction Phase (1996 through 1999)

Document	Year
LA-13808-MS	2001

Why	How	What	Where
Monitoring	Ecological		Surface

Abstract

The Mitigation Action Plan resulting from the Environmental Impact Statement for the construction and operation of the Dual-Axis Radiographic Hydrodynamic Test (DARHT) facility mandates measurement and monitoring of concentrations of radioactive and stable materials in the environment around the facility. This environmental monitoring is accomplished through the collection and analysis of soils and vegetation, invertebrates, plants, mammals, birds, and animals killed accidentally on roads traversing Los Alamos National Laboratory. This report provides the monitoring baseline for the construction phase of the DARHT facility, and is divided into one background section for each of the following media: soils, sediments, and vegetation; small mammals; birds; and honey bees. The results in this report represent the monitoring baseline for comparison to future analyses during the operational phase of the DARHT facility.

Author 1	Author 2	Facility or Agency
O'Farrell	Gilbert	Hanford

Citation

O'Farrell, T.P. and R.O. Gilbert. 1975. Transport of Radioactive Materials by Jackrabbits on the Hanford Reservation. Health Physics 29: 9-15.

Journal

Health Physics 29: 9-15.

Title

Transport of Radioactive Materials by Jackrabbits on the Hanford Reservation.

Document	Year
	1975

Why	How	What	Where
Characterization	Ecological		Surface

Abstract

Author 1	Author 2	Facility or Agency
Ofoegbu	Hsiung	

Citation

Ofoegbu, G., S.M. Hsiung, et al., 1994. Field Site Investigation: Effect of Mine Seismicity on Groundwater Hydrology. CNWRA 94-017.

Journal

Title

Field Site Investigation: Effect of Mine Seismicity on Groundwater Hydrology

Document	Year
CNWRA 94-017	1994

Why	How	What	Where
Modeling	Ground-Water		Saturated

Abstract

Author 1	Author 2	Facility or Agency
Ogg	Everett	Rocky Flats

Citation

Ogg, R.T., L.G. Everett, et al., 1995. Rocky Flats Solar Evaporation Ponds RCRA Hybrid-Closure Case Study. Radioactive Waste Management and Environmental Remediation,

Journal

Title

Rocky Flats Solar Evaporation Ponds RCRA Hybrid-Closure Case Study.

Document	Year
	1995

Why	How	What	Where
Monitoring	Devices	mixed	Unsaturated

Abstract

The Solar Evaporation Ponds (SEP)/Operable Unit 4 (OU 4), located at the Rocky Flats Plant (RFP) sixteen miles northwest of Denver, Colorado, is currently undergoing remediation/Resource Conservation and Recovery Act (RCRA) closure in accordance with the Rocky Flats Interagency Agreement (IAG) signed by the U.S. Department of Energy (DOE), U.S. Environmental Protection Agency (EPA) and Colorado Department of Health (CDH) on January 22, 1991. Based on the Phase I (source and soils) RCRA Facility Investigation (RFI/RI) data and interpretations, the Doe and EG&G Rocky Flats, Inc. (EG&G) have selected a permanent surface engineered/isolation barrier as the technological option for remediation of the SEP. The DOE and EG&G will utilize all natural materials to create an impermeable barrier/structure to isolate the waste being left in place from impacting human health and the environment for a minimum of 1000 years. Our rationale for utilizing natural materials is two fold: 1) optimize long term performance of the barrier and; 2) design a structure which will be near maintenance free (passive remediation) for 1000 years. The DOE and EG&G have taken a proactive approach in providing post closure performance assessment for this RCRA closure action. An integrated monitoring system has been designed which will include monitoring the engineered barrier, vadose zone and ground water systems. Rocky Flats will integrate instrumentation into the permanent engineered barrier which will provide early warning of potential liquid migration through the barrier and into the waste zone.

Author 1	Author 2	Facility or Agency
Olsen	Dresel	Hanford

Citation

Olsen, K.B., P.E. Dresel, et al., 2002. Hanford 2002 Ground Water Report: 3.3.8 'Soil-Gas Investigations at the 618-10 Burial Ground'.

Journal

Title

Hanford 2002 Ground Water Report: 3.3.8 'Soil-Gas Investigations at the 618-10 Burial Ground'

Document	Year
	2002

Why	How	What	Where
Characterization			

Abstract

Author 1	Author 2	Facility or Agency
Oneacre	Figueras	

Citation

Oneacre, J. and D. Figueras, 1996. Ground Water Variability at Sanitary Landfills - Causes and Solutions. Proceedings of the 1996 Conference on Uncertainty in the Geologic Environment, UNCERTAINTY'96. Part 2 (of 2),Jul 31-Aug 3 1996.

Journal

Title

Ground Water Variability at Sanitary Landfills - Causes and Solutions

Document	Year
	1996

Why	How	What	Where
		geostatistics	

Abstract

New Federal Solid Waste Regulations, Part 258, Subpart E of the Resource Conservation and Recovery Act [RCRA], require substantial ground water monitoring systems at municipal solid waste landfills. Poor understanding of the site hydrogeological conditions can lead to erroneous and non-representative ground water data. Variability of ground water data can be due to well location, well design, drilling method, well development, and sample collection and analysis. This paper discusses steps owners can take to mitigate variability.

Author 1	Author 2	Facility or Agency
O'Rourke		

Citation

O'Rourke, J. E., 1993. Scoping the Monitoring Instrumentation to Meet Repository Design and Construction Needs. Proceedings of the Dynamic Analysis and Design Considerations for High-Level Nuclear Waste Repositories, Aug 19-20 1992, San Francisco, CA, USA.

Journal

Title

Scoping the Monitoring Instrumentation to Meet Repository Design and Construction Needs.

Document	Year
	1993

Why	How	What	Where
Monitoring	Geological	mixed	Unsaturated

Abstract

This paper discusses categories of instruments that are available and recommended for consideration to monitor the engineering performance and interactions of the geologic media, groundwater, and the structural facilities in a high-level waste repository. Instrumented performance monitoring is a means of verifying design assumptions for both the construction, or pre-closure phases, as well as the sealed, or post-closure phase after construction. The seismic response of the media and the constructed facilities is an important consideration in planning the instrumentation. Surface and sub-surface facilities are discussed, and settlement, pore water pressures, soil/rock pressures and displacements, structural stress/strain, and temperature monitoring needs are described.

Author 1	Author 2	Facility or Agency
Oxenham	Kewley	

Citation

Oxenham, M. G., D. J. Kewley, et al., 1996. Measures of Information for Multilevel Data Fusion. Signal Processing, Sensor Fusion, and Target Recognition V, Apr 8-10 96, Orlando, FL, USA.

Journal

Title

Measures of Information for Multilevel Data Fusion.

Document	Year
	1996

Why	How	What	Where

Abstract

In many commercial and military activities such as manufacturing, robotics, surveillance, target tracking and military command and control, information may be gathered by a variety of sources. The types of sources which may be used cover a broad spectrum and the data collected may be either numerical or linguistic in nature. Data fusion is the process in which data from multiple sources are combined to provide enhanced information quality and availability over that which is available from any individual source. The question is how to assess these enhancements. Using the U.S. JDL Model, the process of data fusion can be divided into several distinct levels. The first three levels are object refinement, situation refinement and threat refinement. Finally, at the fourth level (process refinement) the performance of the system is monitored to enable product improvement and sensor suite management. This monitoring includes the use of measures of information from the realm of generalized information theory to assess the improvements or degradation due to the fusion processing. The premise is that decreased uncertainty equates to increased information. At each level, the uncertainty may be represented in different ways. In this paper we give an overview of the existing measures of uncertainty and information, and propose some new measures for the various levels of the data fusion process.

Author 1	Author 2	Facility or Agency
Parra		

Citation

Parra, J. O., 1993. Dispersion and Attenuation of Seismic Guided Waves in Layered Permeable Media. Society of Exploration Geophysicists; expanded abstracts with biographies; 1993 technical program; 63rd annual meeting and international exhibition, SEG Annual Meeting Expanded Technical Program Abstracts with Biographies, 63, p. 796-800, 1993.

Journal

Title

Dispersion and Attenuation of Seismic Guided Waves in Layered Permeable Media.

Document	Year
	1993

Why	How	What	Where
Characterization			

Abstract

Author 1	Author 2	Facility or Agency
Parra	Price	Savannah River Site

Citation

Parra, J.O., V. Price, et al., 1998. Interwell Seismic Imaging at the Savannah River Site, South Carolina. Geophysics, 63 (6), p. 1858-1865.

Journal

Geophysics, 63 (6), p. 1858-1865.

Title

Interwell Seismic Imaging at the Savannah River Site, South Carolina.

Document	Year
	1998

Why	How	What	Where
Characterization	Geophysical	seismic	Saturated

Abstract

Crosswell and continuity logging seismic measurements were made beneath a large tank (27 m diameter) used for processing radioactive waste at the Department of Energy (DOE) Savannah River Site in the Atlantic Coastal Plain of South Carolina. We used the data to delineate a low-velocity zone (soft materials) and image the connectivity of a clay unit between wells. The low-velocity zone depicted on the crosswell seismic tomogram integrated with data from cores and well logs revealed soft materials in the region between 150 and 180 ft (46-55 m). The bottom boundary of this low-velocity zone correlates with a reflection observed in the crosswell seismic image at a depth of 180 ft (55 m). This reflection corresponds to the impedance contrast between the soft materials and the more rigid Tinker Formation. The low-velocity zone of soft materials indicates a dissolution margin of a carbonate unit (which is part of the Utley limestone) and the presence of loose sands of the Griffins Landing Member. Ray tracing and common source seismograms show that the rigid part of the Utley limestone extends horizontally about 12.5 ft (4 m) west of the receiver well. The continuity logging data showed leaky and normal modes in the region between 140 and 150 ft (43-46 m). The computed group velocity contours of leaky and normal modes are consistent with waveguide models based on well logs and crosswell seismic data. This indicates that the low-velocity tan clay (confining unit) within the Griffins Landing Member is connected between wells.

Author 1	Author 2	Facility or Agency
Parsons	Frost	

Citation

Parsons, R. L. and J. D. Frost, 2002. Evaluating Site Investigation Quality Using GIS and Geostatistics. Journal of Geotechnical and Geoenvironmental Engineering 128(6): 451-461.

Journal

Title

Evaluating Site Investigation Quality Using GIS and Geostatistics.

Document	Year

Why	How	What	Where

Abstract

Current practice in the characterization of subsurface conditions usually involves the interpretation of data from laboratory and in-situ tests using deterministic analysis methods. These deterministic methods do not reflect the uncertainty inherently associated with the estimation of geotechnical parameters. In addition there are no commonly accepted methods for evaluation of the quality of the investigation or estimation of the impact of additional sampling in a quantitative manner. In this paper the development and implementation of a performance-based investigation and monitoring approach for assessing the quality, or thoroughness, of site investigation and monitoring activities in a quantitative, spatially sensitive manner is described. Thoroughness images are based on probability values generated using geostatistics and are designed to enable users to better assess the likelihood that design or regulatory criteria will be satisfied. This approach has been implemented within a geographic information system and was evaluated using an existing geotechnical data set.

Author 1	Author 2	Facility or Agency
Parsons	Davis	ASTM

Citation

Parsons, A. M. and P. A. Davis, 1992. Proposed Strategy for Assessing Compliance with the RCRA Ground-Water Monitoring Regulations. ASTM Special Technical Publication, n. 1118, p 39-56.

Journal

Title

Proposed Strategy for Assessing Compliance with the RCRA Ground-water Monitoring Regulations.

Document	Year
	1992

Why	How	What	Where
Monitoring			Saturated

Abstract

Author 1	Author 2	Facility or Agency
Pate-Cornell		

Citation

Pate-Cornell, M.E., 1999. Conditional Uncertainty Analysis and Implications for Decision Making: The Case of WIPP. Risk-Analysis, Special Issue: Performance Assessment for Radioactive Waste Disposal. Vol 19(5): 995-1002.

Journal

Risk-Analysis, Vol 19(5): 995-1002.

Title

Conditional Uncertainty Analysis and Implications for Decision Making: The Case of WIPP.

Document	Year
	1999

Why	How	What	Where
Design	Uncertainties		

Abstract

Uncertainty analyses and the reporting of their results can be misinterpreted when these analyses are conditional on a set of assumptions generally intended to bring some conservatism in the decisions. In this paper, two cases of conditional uncertainty analysis are examined. The first case includes studies that result, for instance in a family of risk curves representing percentiles of the probability distribution of the future frequency of exceeding specified consequence levels conditional on a set of hypotheses. The second case involves analyses that result in an interval of outcomes estimated on the basis of conservative assumptions. Both types of results are difficult to use because they are sometimes misinterpreted as if they represented the output of a full uncertainty analysis. In the first case, the percentiles shown on each risk curve may be taken at face value when in reality (in marginal terms) they are lower if the chosen hypotheses are conservative. In the second case, the fact that some segments of the resulting interval are highly unlikely - or that some more benign segments outside the range of results are quite possible - does not appear. Also, these results are difficult to compare to those of analyses of other risks, possibly competing for the same risk management resources, and the decision criteria have to be adapted to the conservatism of the hypotheses. In this paper, the focus in on the first type (conditional risk curves) more than on the second and the discussion is illustrated by the case of the performance assessment of the Waste Isolation Pilot Plant in New Mexico. For policy-making purposes, however, the problems of interpretation, comparison, and use of the results are similar.

Author 1	Author 2	Facility or Agency
Pearcy		Nopal

Citation

Pearcy, E.C., 1994. Fracture Transport of Uranium at the Nopal I Natural Analog Site. CNWRA 94-011.

Journal

Title

Fracture Transport of Uranium at the Nopal I Natural Analog Site

Document	Year
CNWRA 94-011	1994

Why	How	What	Where
			Fracture

Abstract

Author 1	Author 2	Facility or Agency
Pechard		

Citation

Pechard, R.P., 2000. Historical background on performance assessment for the Waste Isolation Pilot Plant. Reliability Engineering and System Safety 69, 5-46

Journal

Reliability Engineering and System Safety 69 (2000) 5-46

Title

Historical background on performance assessment for the Waste Isolation Pilot Plant.

Document	Year
	2000

Why	How	What	Where

Abstract

In 1979, six years after selecting the Delaware Basin as a potential disposal area, Congress authorized the US Department of Energy to build the Waste Isolation Pilot Plant (WIPP) near Carlsbad, New Mexico, as a research and development facility for the safe management, storage, and disposal of waste contaminated with transuranic radioisotopes. In 1998, 19 years after authorization and 25 years after site selection, the US Environmental Protection Agency (EPA) certified that the WIPP disposal system complied with its regulations. The EPA's decision was primarily based on the results from a performance assessment conducted in 1996, which is summarized in this special issue of Reliability Engineering and System Safety. This performance assessment was the culmination of four preliminary performance assessments conducted between 1989 and 1992. This paper provides a historical setting and context for how the performance of the deep geologic repository at the WIPP was analyzed. Also included is background on political forces acting on the project.

Author 1	Author 2	Facility or Agency
Pirkle	Price	

Citation

Pirkle, R.J. and V. Price, 1986. Leak Detection and Monitoring. Presented at "Hazmat '86", Atlantic City, NJ, June 1986.

Journal

Title

Leak Detection and Monitoring

Document	Year
	1986

Why	How	What	Where
Monitoring	Geochemical	samplers	Saturated

Abstract

This paper has two distinct but related objectives. One is to provide an overview of the various ways in which pipelines and storage tanks can be checked or monitored for leakage. The second is to introduce the field of exploration geochemistry, whose practitioners for over fifty years have developed technology to look for leakage from "natural storage tanks" as a way to prospect for oil and gas. Applications of this technology are already in use to monitor leakage of material from underground geologic storage tanks and several examples of these applications will be discussed.

There are some obvious parallels between detections of materials leaking from fabricated storage tanks and detection of materials escaping from natural reservoirs and geologic storage tanks. We believe that the perspective gained from a brief introduction to geochemical prospecting and its application to geologic storage will help chemists and engineers design and implement effective tank monitoring programs.

Author 1	Author 2	Facility or Agency
Powers	Singha	USGS

Citation

Powers, C.J., K. Singha, et al., 1999. Integration of Surface Geophysical Methods for Fracture Detection in Bedrock at Mirror Lake, New Hampshire. Morganwalp, D.W. and H.T. Buxton, eds. U. S. Geological Survey Toxic Substances Hydrology Program; proceedings of the technical meeting, Water-Resources Investigations - U. S. Geological Survey, WRI

Journal

Title

Integration of Surface Geophysical Methods for Fracture Detection in Bedrock at Mirror Lake, New Hampshire.

Document	Year
	1999

Why	How	What	Where
Characterization	Geophysical	mixed	fracture

Abstract

Five surface geophysical methods were used to determine the locations of fracture zones in crystalline bedrock for predicting fluid flow and chemical migration at the U.S. Geological Survey Fractured Rock Site at Mirror Lake, Grafton County, New Hampshire. Two methods of direct current (dc) resistivity (two-dimensional (2-D) and crossed square-array profiling), two methods of inductive terrain conductivity, and very-low-frequency electromagnetics (VLF) were used over survey lines extending about 200 meters. The results of the five methods were correlated to locate fracture zones; anomalies that were detected in one or two of the results were eliminated, increasing the confidence in the interpretation of anomalies detected in all of the results.

Two low resistivity anomalies were detected with all the geophysical methods in the southeast part of the study area. Based on the geophysical, outcrop, and photolinear data, the anomalous areas were interpreted as steeply dipping fracture zones approximately 10-meters wide. One interpreted fracture zone strikes approximately 45 degrees east and the other strikes approximately north 17 degrees east.

Results of dc-resistivity surveys were analyzed to estimate the secondary porosity of the two interpreted fracture zones. Crossed square-array dc-resistivity profiling data indicates the secondary porosity is between 0.65 to 0.75 percent, whereas the 2D dc-resistivity profiling results indicate the secondary porosity to be 1.6 to 1.9 percent. Estimates from the 2D dc-resistivity profiling could indicate the effects of alteration and/or iron precipitate observed in outcrops near the survey lines.

Author 1	Author 2	Facility or Agency
Prakash	Singh	

Citation

Prakash, M. R. and V. S. Singh, 2000. Network Design for Groundwater Monitoring - A Case Study. Environmental Geology 39(6): 628-632.

Journal

Environmental Geology 39(6): 628-632.

Title

Network Design for Groundwater Monitoring - A Case Study.

Document	Year
	2000

Why	How	What	Where
Design	Optimization		Saturated

Abstract

The applicability and usefulness of Geostatistics (kriging) as a tool for optimum selection of sites for monitoring groundwater levels has been demonstrated through a case study. The criterion used is the estimation of error variance. Groundwater level data (pre-monsoon 1994) obtained from 32 observation wells of Upper Kongal basin, Nalgonda District, A.P. (India) has been stochastically analyzed. The spatial distribution of water levels and its associated error variance is computed and the locations having maximum error variance are selected as additional sites for augmenting the existing observational well network.

Author 1	Author 2	Facility or Agency
Price	Parra	

Citation

Price, V., Parra, J., et al., 1997. Cross-well Seismic Methods for Studies Beneath Existing Buildings. Geological Society of America, Southeastern Section, 46th annual meeting, Abstracts with Programs - Geological Society of America, 29 (3), p. 63, 1997. Meeting: Geological Society of America, Southeastern Section, 46th annual meeting, Auburn, AL, United States,

Journal

Title

Cross-well Seismic Methods for Studies Beneath Existing Buildings.

Document	Year
	1997

Why	How	What	Where
Characterization	Geophysical	seismic	

Abstract

Author 1	Author 2	Facility or Agency
Pruess	Yabusaki	Hanford

Citation

Pruess, K., S. Yabusaki, et al., Fluid Flow, Heat Transfer, and Solute Transport at Nuclear Waste Storage Tanks in the Hanford Vadose Zone,

Journal

Title

Fluid Flow, Heat Transfer, and Solute Transport at Nuclear Waste Storage Tanks in the Hanford Vadose Zone

Document	Year

Why	How	What	Where
Modeling			

Abstract

At the Hanford Site, highly radioactive and chemically aggressive waste fluids have leaked from underground storage tanks into the vadose zone. This paper addresses hydrogeological issues at the 241-SX tank farm, especially focusing on Tank SX-108, which is one of the highest heat load, supernate density and ionic strength tanks at Hanford and a known leaker. The behavior of contaminants in the unsaturated zone near SX-108 is determined by an interplay of multiphase fluid flow and heat transfer processes with reactive chemical transport in a complex geological setting. Numerical simulation studies were performed to obtain a better understanding of mass and energy transport in the unique hydrogeologic system created by the SX tank farm. Problem parameters are patterned after conditions at Tank SX-108, and measured data were used whenever possible. Borrowing from techniques developed in geothermal and petroleum reservoir engineering, our simulations feature a comprehensive description of multiphase processes, including boiling and condensation phenomena, and precipitation and dissolution of solids. We find that the thermal perturbation from the tank causes large-scale redistribution of moisture and alters water seepage patterns. During periods of high heat load, fluid and heat flow near the tank are dominated by vapor-liquid counterflow (heat pipe), which provides a much more efficient mechanism than heat conduction for dissipating tank heat. The heat pipe mechanism is also very effective in concentrating dissolved solids near the heat source, where salts may precipitate even if they were only present in small concentrations in ambient fluids. Tank leaks that released aqueous fluids of high ionic strength into the vadose zone were also modeled. The heat load causes formation dry-out beneath the tank, which is accompanied by precipitation of solutes. These may become remobilized at a later time when tank temperatures decline and previously dried out regions are rewetted. Simulated temperature and moisture distributions compare well with borehole measurements performed in 2000. The temperature maximum observed beneath Tank SX-108 can be explained from past thermal history of the tank; it is not necessary to invoke heat generation from leaked radioactive contaminants. A novel composite medium model is used to explore effects of moisture tension-dependent anisotropy, which is shown to have important impacts on fluid flow and solute transport in the Hanford sediments.

Author 1	Author 2	Facility or Agency
Rasmussen	Rhodes	

Citation

Rasmussen, T.C, and S.C. Rhodes, 1994. Energy-Related Methods: Psychrometers. In "Handbook of Vadose Zone Characterization and Monitoring". L.G. Wilson, L.G. Everett and S.J. Cullen, editors. CRC Press, Inc.

Journal

Title

Energy-Related Methods: Psychrometers.

Document	Year
	1995

Why	How	What	Where
Monitoring	Devices	psychrometer	Unsaturated

Abstract

The measurement of the direction and magnitude of contaminant migration in the subsurface is often hampered by the heterogeneous and complex nature of most geologic media. An alternative to direct measurement of subsurface migration routes and rates in the unsaturated zone is to indirectly determine water flow using the direction and magnitude of the hydraulic gradient and the hydraulic conductivity of the medium. The direction and magnitude of fluid flow is governed by the tensorial form of Darcy's law:

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The estimation of the hydraulic gradient requires knowledge of the distribution of the matric suction and the osmotic potential. The hydraulic conductivity tensor function can be determined in the laboratory using core segments extracted from the site of interest, or from field-scale permeability tests using water or air (see, e.g., Chapter 28 by Evans and Rasmussen in this book). Because the hydraulic conductivity tensor is a strongly nonlinear function of the matric suction, it is important to know the ambient matric suction so that the appropriate value of hydraulic conductivity can be determined for the site.

An important tool for estimating the fluid potential, and hence the flow gradient, is the psychrometer. This device measures the potential of the water vapor present in the subsurface atmosphere. If the potential of the water vapor is equal to the potential of the pore fluid, then the psychromoter provides a means for identifying the pore fluid potential. An additional use of the thermocouple psychrometer is the determination of the moisture characteristic curve for fluid potentials greater than those readily attained using porous plates, approximately 5 bars. The fluid potential of field-collected samples, is estimated by allowing samples to equilibrate at specified water contents, thus extending the characteristic curve to conditions much drier than normally obtained from pressure extraction vessels.

Author 1	Author 2	Facility or Agency
Raturi	Carroll	

Citation

Raturi, S., M.J. Carroll, et al., 2003. Turfgrass Thatch Effects on Pesticide Leaching: A Laboratory and Modeling Study. J. Environ. Qual. 32:215-223.

Journal

J. Environ. Qual. 32:215-223

Title

Turfgrass Thatch Effects on Pesticide Leaching: A Laboratory and Modeling Study

Document	Year
	2003

Why	How	What	Where
Modeling	Geochemical	plant cover effects	Unsaturated

Abstract

Process-based models are frequently used to assess the water quality impacts of turfgrass management emanating from proposed existing golf courses. Thatch complicates the prediction of pesticide transport because surface-applied pesticides must pass through existorganic-rich layer before entering the soil. This study was conducted to (i) compare the use of a linear equilibrium model (LEM) and two-site nonequilibrium (2SNE) model to predict pesticide transport through soil and thatch - soil columns, and (ii) evaluate thatch effects on pesticide transport through soil columns with a volume-averaging approach. Pesticide breakthrough curves were obtained for soil and thatch - soil columns from a 1 cm h-1 flux applied one day after applying triclopyr (3,5,6-trichloro-2-pyridinyloxyacetic acid) and carumebaryl (1-napthyl-methyl carbamate). Pesticide and bromide transport parameters indicated that nonequilibrium processes were affecting pesticide transport. Columns containing zoysiagrass (Zoysia japonica Steud.) thatch had lower triclopyr and carbaryl leaching losses than did soil-only columns, although total reductions attributable to thatch did not exceed 15% of the applied pesticide. When laboratory-based retardation factors were used, the 2SNE model explained 88 to 93% of the variability for triclopyr and 70 to 94% of the variability carbaryl. Laboratory-based retardation factors performed well in 2SNE model to predict the peak concentration and tailing behavior of triclopyr and carbaryl with a volume-averaging approach. These results suggest that separate representation of the thatch layer process-based models is not a prerequisite to obtain reasonable estimates of pesticide transport under steady state flow conditions.

Author 1	Author 2	Facility or Agency
Raum	Schmid	

Citation

Raum, D. and F. J. Schmid, 1991. Experience Accumulated in Expert Consultancy About Decommissioning Nuclear Power Plants. Atomwirtschaft-Atomtechnik 36 (12 Dec): 551.

Journal

Title

Experience Accumulated in Expert Consultancy About Decommissioning Nuclear Power Plants.

Document	Year
	1991

Why	How	What	Where

Abstract

Author 1	Author 2	Facility or Agency
Rechard		WIPP

Citation

Rechard, R.P., 2000. Historical Background on Performance Assessment for the Waste Isolation Pilot Plant. Reliability Engineering and System Safety 69:5-46.

Journal

Reliability Engineering and System Safety 69 (2000) 5-46

Title

Historical Background on Performance Assessment for the Waste Isolation Pilot Plant.

Document	Year
	2000

Why	How	What	Where

Abstract

In 1979, six years after selecting the Delaware Basin as a potential disposal area, Congress authorized the U.S. Department of Energy to build the Waste Isolation Pilot Plant (WIPP) near Carlsbad, New Mexico, as a research and development facility for the safe management, storage, and disposal of waste contaminated with transuranic radioisotopes. In 1998, 19 years after authorization and 25 years after site selection, the U.S. Environmental Protection Agency (EPA) certified that the WIPP disposal system complied with its regulations. The EPA's decision was primarily based on the results from a performance assessment conducted in 1996, which is summarized in this special issue of Reliability Engineering and System Safety. This performance assessment was the culmination of four preliminary performance assessments conducted between 1989 and 1992. This paper provides a historical setting and context for how the performance of the deep geologic repository at the WIPP was analyzed. Also included is background on political forces acting on the project.

Author 1	Author 2	Facility or Agency
Rechard		

Citation

Rechard, R.P. 1999. Historical Relationship Between Performance Assessment for Radioactive Waste Disposal and Other Types of Risk Assessment. Risk Analysis, 19 (5): 763-807.

Journal

Risk Analysis, 19 (5): 763-807.

Title

Historical Relationship Between Performance Assessment for Radioactive Waste Disposal and Other Types of Risk Assessment

Document	Year
	2000

Why	How	What	Where

Abstract

This article describes the evolution of the process for assessing the hazards of a geologic disposal system for radioactive waste and, similarly, nuclear power reactors, and the relationship of this process with other assessments of risk, particularly assessments of hazards from manufactured carcinogenic chemicals during use and disposal. This perspective reviews the common history of scientific concepts for risk assessment developed until the 1950s. Computational tools and techniques developed in the late 1950s and early 1960s to analyze the reliability of nuclear weapon delivery systems were adopted in the early 1970s for probabilistic risk assessment of nuclear power reactors, a technology for which behavior was unknown. In turn, these analyses became an important foundation for performance assessment of nuclear waste disposal in the late 1970s. The evaluation of risk to human health and the environment from chemical hazards is built on methods for assessing the dose response of radionuclides in the 1950s. Despite a shared background, however, societal events, often in the form of legislation, have affected the development path for risk assessment for human health, producing dissimilarities between these risk assessments and those for nuclear facilities. An important difference is the regulator's interest in accounting for uncertainty.

Author 1	Author 2	Facility or Agency
Reed	Berthold	

Citation

Reed, S. E. and J. W. I. Berthold, 1995. Lightguide-Coupled Sensor for In-Situ Radiation Monitoring. Fiber Optic and Laser Sensors XIII, Jun 19 1995, Munich, Ger, Society of Photo-Optical Instrumentation Engineers, Bellingham, WA, USA.

Journal

SPIE Vol 2510

Title

Lightguide-coupled Sensor for In-Situ Radiation Monitoring.

Document	Year
	1995

Why	How	What	Where
Monitoring	Devices	optical	Unsaturated

Abstract

Under contract to the Morgantown (WV) Energy Technology Center for the Office of Technology Development (EM-50), U.S. Department of Energy, we are developing a multi-point radiation monitoring system for long-term, continuous monitoring of radiation levels in the vadose zone of radioactive waste sites. The system is based on gamma detection with a lightguide-coupled scintillator built into a probe buried in the ground. The lightguide transmits the visible light pulses produced by the scintillator to the surface where detection and signal multiplexing take place. The system is to be capable of monitoring large numbers of such passive probes which are to be permanently installed throughout the waste site. We have recently completed tests of a prototype single-probe system. In this paper, we report on the development and testing of the single-probe system.

Author 1	Author 2	Facility or Agency
Reedy	Scanlon	

Citation

Reedy, R.C., B. Scanlon, 2003. Soil Water Content and Water Storage Monitoring Using Electromagnetic Induction, J. Geotechnical and Geoenvironmental Engineering.

Journal

J. Geotechnical and Geoenvironmental Engineering

Title

Soil Water Content and Water Storage Monitoring Using Electromagnetic Induction

Document	Year
	2003

Why	How	What	Where
Modeling	Geophysical	electromagnetic induction	

Abstract

Water content is a critical parameter for evaluating spatial and temporal variability in subsurface water movement. Water storage is also important for monitoring the soil water balance and for validation of water balance models. The purpose of this study was to evaluate the use of electromagnetic induction to predict average water content or storage and changes in water content in the upper 1.50 m of the soil profile at point locations and over an area. The technique was applied to a field-scale prototype engineered cover (17 m × 34 m) designed for waste containment. Water content was monitored with a neutron probe, and bulk soil electrical conductivity was monitored with a Geonics EM38 ground conductivity meter at 10 locations at approximately monthly intervals over a 3-yr period. A simple linear regression model was developed to predict average water content in the upper 1.50 m of the soil profile at any location at any time (R2 0.80, average standard deviation = 0.009 m3/m3) and spatially averaged water content over the entire area at any time (R2 0.99, average standard deviation = 0.003 m3/m3). The model residual water content values did not appear to drift significantly with time, indicating that once the model is calibrated over a sufficient range of water content values with the neutron probe, further neutron probe measurements may not be necessary. EM induction has several advantages over traditional techniques for monitoring water content, including nonradioactivity, speed and ease of use over large areas, and noninvasive character, which is important for avoiding development of preferred pathways.

Author 1	Author 2	Facility or Agency
Reedy	Scanlon	

Citation

Reedy, R C, B.R. Scanlon,2002. Comparison of Different Approaches for Estimating Recharge in the High Plains Aquifer, Texas, Eos Trans. AGU, 83(47), 2002.

Journal

Eos Trans. AGU, 83(47),

Title

Comparison of Different Approaches for Estimating Recharge in the High Plains Aquifer, Texas

Document	Year
	2002

Why	How	What	Where
Characterization	Devices	comparison	

Abstract

Recharge is a critical issue for evaluation of groundwater resources and for assessment of groundwater vulnerability to contamination. We compared a variety of approaches to estimate recharge in the High Plains Aquifer in Texas, including soil physics, environmental tracers, and numerical modeling. The different approaches complement each other and provide information over varying space and time scales. Environmental tracers such as tritium and chloride in groundwater provide spatially and temporally integrated estimates of groundwater recharge. Previous estimates of recharge based on groundwater 3H concentrations in the southeastern part of the High Plains aquifer resulted in recharge estimates of 13 to 80 mm/yr. The average groundwater Cl concentration in non-irrigated regions was 19 mg/L that resulted in an average recharge rate of 7 mm/yr based on annual precipitation of 452 mm/yr and Cl input of 0.3 mg/L (about 3 times Cl concentration in precipitation). The average groundwater Cl concentration in irrigated regions (15.5 mg/L) was lower than that in non-irrigated regions. The Cl data are insufficient to constrain recharge rates beneath irrigated regions. Soil physics and environmental tracer data in the unsaturated zone provide more detailed information on spatial variability in recharge. Deep penetration of bomb pulse 3H, Cl flushing, low calcium carbonate, and high water potentials indicate that playas focus recharge. Water fluxes estimated from 3H profiles in playas were up to 120 mm/yr. In contrast, Cl bulges, calcic soils, low water potentials, and upward water potential gradients indicate negligible recharge in non-irrigated, interplaya settings. The bulge shaped Cl profiles in interplaya settings indicate that water fluxes were higher during the Pleistocene (up to 5 mm/yr) and that Cl has been accumulating during the Holocene. Numerical simulations of nonisothermal liquid and vapor flow using the HYDRUS-1D code indicate that the water potential and Cl profiles can be reproduced by downward flux during the Pleistocene followed by an order of magnitude reduction in downward flux, zero flux, or upward flux during the Holocene. Information on recharge from this study is extremely valuable in predicting groundwater resources during the next 50 yr and for delineating aquifer regions that are particularly susceptible to contamination.

Author 1	Author 2	Facility or Agency
Reedy	Scanlon	

Citation

Reedy, R.C., B. Scanlon, et al., 2003. Groundwater Recharge in the Southern High Plains: The University of Texas at Austin, Bureau of Economic Geology, Draft report for Texas Water Development Board.

Journal

DRAFT

Title

Groundwater Recharge in the Southern High Plains

Document	Year
	2003

Why	How	What	Where
Modeling			

Abstract

This appendix provides a brief overview of previous estimates of groundwater recharge on the Southern High Plains, and presents the results of additional field work and modeling analyses conducted in conjunction with development of the Southern Ogallala GAM model. The field work, conducted in collaboration with the U.S. Geological Survey (USGS) National Water Quality Assessment (NAWQA) program, was included as part of the GAM study to provide additional information concerning irrigation return flow.

Author 1	Author 2	Facility or Agency
Reedy	Scanlon	

Citation

Reedy, R.C., B. Scanlon, 2002. Long-Term Water Balance Monitoring of Engineered Covers for Waste Containment. In 2001 International Containment and Remediation Technology Conference, Orlando, Florida, Institute for International Cooperative Environmental Research, Florida State University, Paper ID. No. 073.

Journal

Title

Long-term Water Balance Monitoring of Engineered Covers for Waste Containment

Document	Year
	2002

Why	How	What	Where
Monitoring	Devices	mixed	Unsaturated

Abstract

The growing realization that remediation of many contaminated sites is technically infeasible has resulted in a shift in emphasis to containment as an alternative to remediation. Monitoring is required to demonstrate the effectiveness of engineered cover systems in minimizing infiltration into underlying waste. The purpose of this study is to evaluate a variety of monitoring technologies. Monitoring systems were installed in a resistive (GCL/asphalt) barrier at 1.3 m depth and a conductive (capillary) barrier at 2.0 m depth constructed near El Paso, Texas, in 1997. The site is heavily instrumented with both automated and manual monitoring systems designed to quantify the soil water balance and to monitor soil water potential energy. All of the water balance components are being monitored except evapotranspiration. Results indicate that electromagnetic induction (EM), once calibrated with neutron probe and temperature data, can reliably monitor water storage changes. The noninvasive nature of EM measurements could preclude the development of preferential pathways resulting from instrument installation. Neutron probe measurements of water storage are more reliable at this site than time domain reflectometry because of signal attenuation resulting from high conductivity soils. Heat dissipation sensors have proved more reliable than thermocouple psychrometers for measuring soil water potential. Results of this study provide valuable information on appropriate technologies for monitoring performance of engineered covers.

Author 1	Author 2	Facility or Agency
Richards	Hall	

Citation

Richards, H. and D. Hall, 2000. Geoenvironmental Issues in Decommissioning. Nuclear Engineer 41(3): 92-98.

Journal

Nuclear Engineer 41(3): 92-98.

Title

Geoenvironmental Issues in Decommissioning.

Document	Year
	2000

Why	How	What	Where

Abstract

The nuclear industry has issues arising from historic ground contamination that are similar to other industries (e.g. chemical, manufacturing). The associated financial liabilities are disproportionately large in relation to other industries because of more stringent regulation. Deferred decommissioning (e.g. the proposed Safestore strategy) additionally requires the potential for future contamination of groundwater to be addressed. Quantification of problems relating to groundwater and ground contamination is inherently subject to order-of-magnitude uncertainties. These uncertainties can be reduced by appropriate site characterisation, although access to the ground close to and beneath buildings undergoing decommissioning can be problematic. These points are illustrated using a case study from Trawsfynydd Power Station.

Author 1	Author 2	Facility or Agency
Robock	Vinnikov	

Citation

Robock, Alan, K. Vinnikov, et al., 1995. Use of Midlatitude Soil Moisture and Meteorological Observations to Validate Soil Moisture Simulations with Biosphere and Bucket Models. J. Climate, 8, 15-35.

Journal

J. Climate, 8, 15-35.

Title

Use of Midlatitude Soil Moisture and Meteorological Observations to Validate Soil Moisture Simulations with Biosphere and Bucket Models.

Document	Year
	1995

Why	How	What	Where
Modeling			Unsaturated

Abstract

Soil moisture observations in sites with natural vegetation were made for several decades in the former Soviet Union at hundreds of stations. In this paper, we use data from 6 of these stations from different climatic regimes, along with ancillary meteorological and actinometric data, to demonstrate a method to validate soil moisture simulations with biosphere and bucket models. Some early and current general circulation models (GCMs) use bucket models for soil hydrology calculations. More recently, the Simple Biosphere Model (SiB) was developed to incorporate the effects of vegetation on fluxes of moisture, momentum, and energy at the earth's surface into soil hydrology models. Until now, the bucket and SiB have been verified by comparison with actual soil moisture data only on a limited basis. In this study, a Simplified SiB (SSiB) soil hydrology model and a 15-cm bucket model are forced by observed meteorological and actinometric data every 3 hours for 6- year simulations at the 6 stations. The model calculations of soil moisture are compared to observations of soil moisture, literally "ground truth," snow cover, surface albedo, and net radiation, and with each other.

For three of the stations, the SSiB and 15-cm bucket models produce good simulations of seasonal cycles and interannual variations of soil moisture. For the other three stations, there are large errors in the simulations by both models. Inconsistencies in specification of field capacity may be partly responsible. There is no evidence that the SSiB simulations are superior in simulating soil moisture variations. In fact the models are quite similar, since SSiB implicitly has a bucket embedded in it. One of the main differences between the models is in the treatment of runoff due to melting snow in the spring - SSiB incorrectly puts all the snowmelt into runoff. While producing similar soil moisture simulations, the models produce very different surface latent and sensible heat fluxes, which would have large effects on GCM simulations.

Author 1	Author 2	Facility or Agency
Ross	Vieux	

Citation

Ross, R. R. and B. E. Vieux, 2000. Probabilistic Method for Estimating Monitoring Point Density for Containment System Leak Detection. Ground Water 38(4): 533-540.

Journal

Title

Probabilistic Method for Estimating Monitoring Point Density for Containment System Leak Detection.

Document	Year
	2000

Why	How	What	Where
Monitoring	Optimization	probability	Saturated

Abstract

The use of physical and hydraulic containment systems for the isolation of contaminated ground water and aquifer materials associated with hazardous waste sites has increased during the last decade. The existing methodologies for monitoring and evaluating leakage from hazardous waste containment systems rely primarily on limited hydraulic head data. The number of hydraulic head monitoring points available at most sites employing physical containment systems may be insufficient to identify significant leaks from the systems. A probabilistic approach for evaluating the performance of containment systems, based on estimations of apparent leakage rates, is used to introduce a methodology for determining the minimum number of monitoring points necessary o identify the hydraulic signature of leakage from a containment system. The probabilistic method is based on the principles of geometric probability. The method is demonstrated using three-dimensional ground water flow modeling results of leakage through a vertical barrier. The results indicate that the monitoring point spacing used at many hazardous waste sites likely is inadequate to detect the hydraulic signatures of all but the largest leaks.

Author 1	Author 2	Facility or Agency
Sagar		

Citation

Sagar, B., 1996. Flow Modeling in Heterogeneous Media in the Context of Geologic Nuclear Waste Repositories. Nuclear Science and Engineering, Vol. 123, p. 443.

Journal

Nuclear Science and Engineering, Vol. 123, p. 443

Title

Flow Modeling in Heterogeneous Media in the Context of Geologic Nuclear Waste Repositories

Document	Year
	1996

Why	How	What	Where
Modeling	Ground-Water		Structure

Abstract

Author 1	Author 2	Facility or Agency
Scanlon		

Citation

Scanlon, B.R., Evaluation of Moisture Flux From Chloride Data in Desert Soils, Elsevier Science Publishers, 1991.

Journal

Title

Evaluation of Moisture Flux From Chloride Data in Desert Soils

Document	Year
	1991

Why	How	What	Where
Characterization			Unsaturated

Abstract

Chloride-concentration data from 10 soil profiles in a 40 km2 area of the Chihuahuan Desert of Texas were used to assess chloride mass balance methods of evaluating moisture flux. The relative importance of advective and diffusive transport mechanisms was determined. Moisture fluxes were calculated from measured chloride concentrations on the basis of a steady-state flow model. To evaluate controls on unsaturated flow, moisture fluxes from this study were compared with those from other regions.

The chloride profiles displayed large variations in concentrations and had (a) low chloride concentrations (= 100 g m -3) near land surface, (b) maximum chloride concentrations (1,900 to 9,300 g m -3) at depths of 1.3 to 4.6 m, and (c) gradually decreasing chloride concentrations with depth below the peak. Steep concentration gradients (up to 12,000 g m -3 m -1), characteristic of chloride profiles in these desert soils, indicate a potential for molecular diffusion; however, low moisture contents (= 0.1) in the zone of steep concentration gradients resulted in diffusive fluxes that were 2 to 3 orders of magnitude lower than the advective fluxes; therefore, diffusive fluxes were neglected in flux calculations. Because the chloride accession rate was assumed to be constant throughout the study area, calculated moisture fluxes are inversely proportional to chloride concentrations in the soil water. Highest moisture fluxes (up to 6 mm/yr) were calculated near land surface and are related to chloride leaching as a result of precipitation. Within the upper meter of the unsaturated zone, soil moisture fluxes decreased sharply to 0.1 mm yr -1 as most of the water evapotranspired in this zone. Soil moisture fluxes decreased to a minimum at the chloride peak and then increased gradually as chloride concentrations decreased with depth below the peak. Reductions in chloride concentrations below the peak are attributed to differences in moisture fluxes as a result of paleoclimatic variations. Comparisons of chloride profiles from different regions indicate that geomorphic setting plays a major role in controlling moisture flux in the unsaturated zone.

Author 1	Author 2	Facility or Agency
Scanlon	Mace	

Citation

Scanlon, B.R., R.E. Mace, et al, Can We Simulate Regional Groundwater Flow in a Karst System Using Equivalent Porous Media Models? Case study, Barton Springs Edwards Aquifer, USA. Journal of Hydrology 276 (2003) 137-158.

Journal

Journal of Hydrology 276 (2003) 137-158

Title

Can We Simulate Regional Groundwater Flow in a Karst System Using Equivalent Porous Media Models? Case study, Barton Springs Edwards Aquifer, USA.

Document	Year
	2003

Why	How	What	Where
Modeling	Performance		Unsaturated

Abstract

Various approaches can be used to simulate groundwater flow in karst systems, including equivalent porous media distributed parameter, lumped parameter, and dual porosity approaches, as well as discrete fracture or conduit approaches. The purpose of this study was to evaluate two different equivalent porous media approaches: lumped and distributed parameter, for simulating regional groundwater flow in a karst aquifer and to evaluate the adequacy of these approaches. The models were applied to the Barton Springs Edwards aquifer, Texas. Unique aspects of this study include availability of detailed information on recharge from stream-loss studies and on synoptic water levels, long-term continuous water level monitoring in wells throughout the aquifer, and spring discharge data to compare with simulation results. The MODFLOW code was used for the distributed parameter model. Estimation of hydraulic conductivity distribution was optimized by using a combination of trial and error and automated inverse methods. The lumped parameter model consists of five cells representing each of the watersheds contributing recharge to the aquifer. Transient simulations were conducted using both distributed and lumped parameter models for a 10-yr period (1989-1998). Both distributed and lumped parameter models fairly accurately simulated the temporal variability in spring discharge; therefore, if the objective of the model is to simulate spring discharge, either distributed or lumped parameter approaches can be used. The distributed parameter model generally reproduced the potentiometric surface at different times. The impact of the amount of pumping on a regional scale on spring discharge can be evaluated using a lumped parameter model; however, more detailed evaluation of the effect of pumping on groundwater levels and spring discharge requires a distributed parameter modeling approach. Sensitivity analyses indicated that spring discharge was much more sensitive to variations in recharge than pumpage, indicating that aquifer management should consider enhanced recharge, in addition to conservation measures, to maintain spring flow. This study shows the ability of equivalent porous media models to simulate regional groundwater flow in a highly karstified aquifer, which is important for water resources and groundwater management.

Author 1	Author 2	Facility or Agency
Scanlon	Paine	

Citation

Scanlon, B.R., J. Paine, et al., 1999. Evaluation of Electromagnetic Induction as a Reconnaissance Technique to Characterize Unsaturated Flow in an Arid Setting. Ground Water, Vol. 37(2).

Journal

Ground Water, Vol. 37(2).

Title

Evaluation of Electromagnetic Induction as a Reconnaissance Technique to Characterize Unsaturated Flow in an Arid Setting

Document	Year
	1999

Why	How	What	Where
Characterization	Geophysical	EM	Unsaturated

Abstract

The use of apparent electrical conductivity (ECa) measured with electromagnetic (EM) induction was examined as a reconnaissance tool for characterizing unsaturated flow in a semiarid region in the Chihuahuan Desert of Texas. Above-ground conductivity meters EM31 and EM38) were used to measure ECa along transects in various geomorphic settings. Eight boreholes were drilled at different locations along the transects, and a downhole conductivity meter (EM39) was used to measure ECa. Samples were collected for analysis of clay, water, and chloride content to evaluate factors affecting spatial variability in ECa. Variations in ECa measured with the above-ground EM31 meter were affected by variations in clay content in a play/interplaya setting, water content in a fissure, and chloride content adjacent to a drainage system. These factors affecting ECa were confirmed by comparing ECa measured with the downhole EM39 meter and clay, water, and chloride content of soil samples from boreholes. The hydrologic significance of parameters controlling ECa was evaluated. Variations in clay content are not hydrologically significant in this basin. High correlations between ECa and water content are difficult to interpret because in some areas water content variations simply reflect variations in clay content, as in the playa/interplaya setting whereas in other areas higher water contents reflect higher water flux, as in the fissure. In some areas water content was below threshold values; therefore, ECa did not respond to water content or salinity in these areas. Although EM induction alone cannot distinguish causes of ECa changes, it provides a valuable tool for delineating variation in ECa that can be used to guide borehole locations and to provide valuable information for interpolating and extrapolating form point estimates provided by borehole data.

Author 1	Author 2	Facility or Agency
Scanlon	Goldsmith	

Citation

Scanlon, B.R., R. Goldsmith, 1997. Field study of spatial variability in unsaturated flow beneath and adjacent to playas, Water Resources Research, Vol. 33, No. 10, 2239-2252.

Journal

Water Resources Research, Vol. 33, No. 10, 2239-2252, 1997.

Title

Field study of spatial variability in unsaturated flow beneath and adjacent to playas

Document	Year
	1997

Why	How	What	Where
			Unsaturated

Abstract

We quantified unsaturated flow beneath playa and adjacent interplaya settings at a site in the Southern High Plains (United States) to resolve issues related to where and how water moves through the unsaturated zone. This is the first study in which the data density (39 boreholes) and the variety of techniques used (physical, chemical, and isotopic) were sufficient to quantify spatial variability in unsaturated flow. Water contents, water potentials, and tritium concentrations were much higher and chloride concentrations were much lower beneath playas than in interplaya settings, which indicated that playas focus recharge. These results refute previous hypotheses that playas act as evaporation pans or that recharge is restricted to the annular region around playas. Water fluxes estimated from environmental tracers ranged from 60 to 120 mm yr-1 beneath playas and were </=0.1 mm yr-1 during the past 2000-5000 years beneath natural interplaya areas not subjected to ponding. To evaluate the apparent inconsistency between high recharge rates and thick clay layers beneath playas, we applied bromide and FD&C blue dye to evaluate flow processes. These applied tracer experiments showed preferential flow along roots and desiccation cracks through structured clays in the shallow subsurface in playas.

Author 1	Author 2	Facility or Agency
Scanlon		

Citation

Scanlon, B.R., Evaluation of Liquid and Vapor Water Flow in Desert Soils Based on Chlorine 36 and Tritium Tracers and Nonisothermal Flow Simulations, Water Resources Research, Vol. 28, No. 1, 285-297, 1992.

Journal

Water Resources Research, Vol. 28, No. 1 285-297, 1992.

Title

Evaluation of Liquid and Vapor Water Flow in Desert Soils Based on Chlorine 36 and Tritium Tracers and Nonisothermal Flow Simulations

Document	Year
	1992

Why	How	What	Where
Modeling			Unsaturated

Abstract

The distribution of anthropogenic 36 Cl and 3 H was used along with numerical flow simulations to evaluate the relative important of liquid and vapor flow in the shallow unsaturated zone of an area within the Chihuahuan Desert of Texas. Chlorine 36 is nonvolatile and is restricted to liquid phase flow, whereas tritiated water is volatile and can move in both liquid and vapor phases. Tritium penetrated 1 m deeper than 36 Cl, although 3H fallout occurred later than that of 36 Cl. Deeper penetration of 3H relative to that of 36 Cl was attributed to enhanced downward movement of 3H in the vapor phase. The moisture flux calculated from the 36 Cl/Cl peak at 0.5 m depth was 1.4 mm/yr, whereas that based on the 3H peak at 1.4 m depth was 7 mm/yr. The difference in moisture fluxes between the two tracers suggests a vapor flux of approximately 6 mm/yr. The vapor flux hypothesis was tested using nonisothermal liquid and vapor flow simulations with the computer code SPLaSH-WaTr. Simulations of 5-day periods in the winter and summer were conducted to represent the extremes in temperature gradients. The calculated vapor flux was two to eight orders of magnitude greater than the liquid flux for the periods simulated. Predicted vapor fluxes were upward in the top 0.04 m of the unsaturated zone in the summer and winter in response to steep water potential gradients induced by surface evaporation. Below the evaporation front, from depths of 0.15 to 1 m, downward vapor fluxes in the summer were much greater than generally upward vapor fluxes in the winter. These results suggest an annual net downward vapor flux that is consistent with the chemical tracer data.

Author 1	Author 2	Facility or Agency
Scanlon		

Citation

Scanlon, B.R., 2000. Uncertainties in Estimating Water Fluxes and Residence Times Using Environmental Tracers in an Arid Unsaturated Zone. Water Resources Research, Vol. 36, No. 2, 395-409.

Journal

Water Resources Research, Vol. 36, No. 2, 395-409, 2000.

Title

Uncertainties in Estimating Water Fluxes and Residence Times Using Environmental Tracers in an Arid Unsaturated Zone

Document	Year
	2000

Why	How	What	Where
			Unsaturated

Abstract

Environmental tracers are used widely to evaluate flow processes and estimate fluxes and ages of pore water in arid regions. The purpose of this study was to evaluate uncertainties in water flux and age on the basis of data from environmental tracers, including meteoric Cl, 36Cl, 3H, d2H, and d18O in porous media. Representative profiles of environmental tracers from drainage and interdrainage areas at a site in the Chihuahuan Desert of Texas were evaluated. The chloride mass balance approach (CMB) was used to evaluate water fluxes and ages. The long residence times indicated by the Cl data in interdrainage areas (55,000 to 105,000 years to 25 m depth) were generally corroborated by residence times estimated from radioactive decay of 36Cl (39,000 +/- 13,000 to 59,000 +/- 14,400 years). Uncertainties in the CMB approach include uncertainties in transport processes, Cl input, and Cl output. Although the CMB approach assumes one-dimensional, downward piston flow, water potential and stable isotope data in interdrainage areas suggest net upward water movement. Cl data indicate that drying of the profiles may have persisted throughout the Holocene (;10,000 years). Therefore the downward flow assumption may only be applicable in the older, deeper sections of the profiles. Cl diffusion is significant near the surface where Cl concentration gradients are steep. Anion exclusion may affect calculated water fluxes based on Cl in clay-rich zones. Although it is difficult to quantify uncertainties in diffusion and anion exclusion processes, they act in concert and result in overestimation of water flux and underestimation of age by the CMB approach. Therefore, in interdrainage areas the CMB approach provides an upper bound on actual water fluxes and a lower bound on actual ages. Error bars on these bounding estimates were evaluated on the basis of uncertainties in Cl input (~+/-35%) and in Cl output (+/-3%) that result in +/- 38% uncertainty in water flux and -24 to 56% uncertainty in water age in interdrainage areas. In drainage areas it is much more difficult to apply the CMB approach because of preferential flow, large uncertainties in Cl input as a result of run-on, reduced sensitivity of Cl to water flux, and analytical uncertainties in Cl measurements. Although preferential flow was shown by 3H data, mixing calculations suggest that 36Cl/Cl ratios cannot be used to evaluate preferential flow when Cl concentrations in the matrix exceed 10 to 100 g m-3, as is found in the playa and the fissure. Neglecting Cl input from run-on results in underestimation of water flux by about an order of magnitude. Therefore the apparent CMB water flux, which ignores preferential flow and run-on, represents a lower bound on the actual water flux in contrast to an upper bound for interdrainage areas. These results have important implications for waste disposal in arid regions because they suggest that water fluxes estimated using the CMB approach are conservatively high in interdrainage areas characterized by porous media.

Author 1	Author 2	Facility or Agency
Scanlon	Keese	

Citation

Scanlon, B.R., K. Keese, 2003. Variations in Flow and Transport in Thick Desert Vadose Zones in Response to Paleoclimatic Forcing (0-90 kyr): Field Measurements, Modeling, and Uncertainties. Water Resources Research, in press.

Journal

Water Resources Research, in press

Title

Variations in Flow and Transport in Thick Desert Vadose Zones in Response to Paleoclimatic Forcing (0-90 kyr): Field Measurements, Modeling, and Uncertainties

Document	Year
	2003

Why	How	What	Where
Monitoring			Unsaturated

Abstract

An understanding of unsaturated flow and potential recharge in interdrainage semiarid and arid regions is critical for quantification of water resources and contaminant transport. We evaluated system response to paleoclimatic forcing using water-potential and Cl profiles and modeling of nonisothermal liquid and vapor flow and Cl transport at semiarid (High Plains, Texas) and arid (Chihuahuan Desert, Texas; Amargosa Desert, Nevada) sites. Infiltration in response to current climatic forcing is restricted to the shallow (~ 0.3-3 m) subsurface. Subsurface Cl accumulations correspond to time periods of 9 to 90 kyr. Bulge-shaped Cl profiles generally represent accumulation during the Holocene (9-16 kyr). Lower Cl concentrations at depth reflect higher water fluxes (0.04-8.4 mm/yr) during the Pleistocene and earlier times. Low water potentials and upward gradients indicate current drying conditions. Nonisothermal liquid and vapor flow simulations indicate that upward flow for at least 1 to 2 kyr in the High Plains and for 12 to 16 kyr at the Chihuahuan and Amargosa desert sites is required to reproduce measured upward water potential gradients and that recharge is negligible (< 0.1 mm/yr) in these interdrainage areas.

Author 1	Author 2	Facility or Agency
Scanlon	Healy	

Citation

Scanlon, B.R., R. Healy, et al., 2002. Choosing Appropriate Techniques for Quantifying Groundwater Recharge. Hydrogeology Journal 10:18-39.

Journal

Hydrogeology Journal (2002) 10:18–39

Title

Choosing Appropriate Techniques for Quantifying Groundwater Recharge.

Document	Year
	2002

Why	How	What	Where
Characterization	Devices	mixed	Saturated

Abstract

Various techniques are available to quantify recharge; however, choosing appropriate techniques is often difficult. Important considerations in choosing a technique include space/time scales, range, and reliability of recharge estimates based on different techniques; other factors may limit the application of particular techniques. The goal of the recharge study is important because it may dictate the required space/time scales of the recharge estimates. Typical study goals include water-resource evaluation, which requires information on recharge over large spatial scales and on decadal time scales; and evaluation of aquifer vulnerability to contamination, which requires detailed information on spatial variability and preferential flow. The range of recharge rates that can be estimated using different approaches should be matched to expected recharge rates at a site. The reliability of recharge estimates using different techniques is variable. Techniques based on surface-water and unsaturated-zone data provide estimates of potential recharge, whereas those based on groundwater data generally provide estimates of actual recharge. Uncertainties in each approach to estimating recharge underscore the need for application of multiple techniques to increase reliability of recharge estimates.

Author 1	Author 2	Facility or Agency
Scanlon	Goldsmith	

Citation

Scanlon, B.R., R. Goldsmith, et al., 1997. Analysis of Focused Unsaturated Flow Beneath Fissures in the Chihuahuan Desert, Texas, USA. J. Hydrology 203:58-78.

Journal

J. Hydrology 203:58-78

Title

Analysis of Focused Unsaturated Flow Beneath Fissures in the Chihuahuan Desert, Texas, USA.

Document	Year
	1997

Why	How	What	Where
Characterization			Unsaturated

Abstract

Localized flow beneath fissures in arid settings has important implications for waste disposal in these regions. Fissures are surface features or gullies that are underlain by sediment filled fractures. The objectives of this study were to compare unsaturated flow beneath different fissures, investigate the vertical and lateral extent of increased flow associated with fissures, and examine different techniques for evaluating flow in zones containing fissures. Boreholes were drilled directly beneath four fissures and at horizontal distances of 10 and 50 m from the fissures. Physical parameters such as water content and water potential were analyzed in sediment samples and water potential was analyzed in plant samples. Environmental tracers such as Cl, 36Cl/Cl, 3H, D, and 18O were analyzed in sediment samples. A trench was dug beneath one fissure for detailed sampling. Electromagnetic induction was used to measure apparent electrical conductivity in transects perpendicular to the fissures.

Unsaturated flow is relatively higher beneath fissures, as evidenced by higher water potentials and lower chloride concentrations there than in surrounding sediments. The lateral extent of high water flux was restricted to the zone directly beneath one fissure but extended to profiles 10 m from two other fissures. The profiles 50 m from all fissures had low water fluxes, as indicated by low water potentials and high maximum chloride concentrations. The vertical extent of high water fluxes was restricted to the upper 10 to 20 m zone, as shown by water potential and chloride fronts within the upper 10 m zone beneath one fissure and by chloride fronts in the upper 20 m zone beneath and 10 m from another fissure. Additional evidence for localized water flux was provided by less enriched D and 18O, and higher plant water potentials in sediments beneath fissures relative to sediments adjacent to fissures. High tritium levels were found in all sampled profiles and cannot readily be explained. Apparent electrical conductivity was higher in two of the four fissures. Multiple independent lines of evidence indicate that subsurface water fluxes are higher at shallow depths beneath fissures; however, the various techniques differ in their effectiveness in delineating higher water fluxes beneath fissures. Multiple profiles drilled in one fissure indicate that there is large variability inflow along this fissure that is attributed to topographic variations and degree of ponding.

Author 1	Author 2	Facility or Agency
Scanlon	Christman	

Citation

Scanlon, B. R., M. Christman, et al., 2001. Intercode Comparisons for Simulating Water Balance of Near-Surface Soils, Eos Trans. AGU, 82(47).

Journal

Title

Intercode Comparisons for Simulating Water Balance of Near-Surface Soils

Document	Year
	2001

Why	How	What	Where
Modeling		comparison	

Abstract

Advances in computer technology, improvements in codes, including computational efficiency and processes simulated, and availability of long-term field monitoring data allow long-term simulations of near-surface flow that is important for groundwater recharge, contaminant transport, and waste containment. A variety of codes are available to simulate the water balance of near-surface soils; however, information on intercode comparisons is limited. The purpose of this study was to compare the characteristics and performance of different codes, including HELP, HYDRUS-1D, SHAW, SoilCover, SWIM, UNSATH, and VS2DT to simulate the water balance of near-surface soils. Factors that differ among these codes include graphical user interfaces, user friendliness, dimensionality, upper and lower boundary conditions, hydraulic properties (Brooks and Corey, van Genuchten, others), and processes simulated (liquid flow, vapor flow, hysteresis). A highly instrumented, engineered cover for waste containment in the Chihuahuan Desert provided information on initial and boundary conditions for the simulations and data to validate the simulation results. Simulations were conducted for the period October 1997 through September 1998 when the site was nonvegetated. Simulation results from all codes reasonably approximated the field-measured water balance. The main difference between the different simulation results was in the partitioning of precipitation into evaporation and soil water storage. These differences can be attributed primarily to the time resolution of the meteorological input data (daily, hourly, or 15 min) and the assignment of fluxes during precipitation events. The intercode comparisons are being used to identify important attributes of codes to simulate infiltration into the shallow subsurface. Such information can be used to make recommendations for modifications of existing codes and/or development of new codes.

Author 1	Author 2	Facility or Agency
Scanlon	Christman	

Citation

Scanlon, B. R., M. Christman, et al., 2002. Intercode Comparisons for Simulating Water Balance of Surficial Sediments in Semiarid Regions. Water Resour. Res., 38(12), 1323, doi:10.1029/2001WR001233.

Journal

Water Resour. Res., 38(12), 1323, doi:10.1029/2001WR001233, 2002.

Title

Intercode Comparisons for Simulating Water Balance of Surficial Sediments in Semiarid Regions.

Document	Year
	2002

Why	How	What	Where
Modeling	Performance	comparison	Unsaturated

Abstract

Near-surface water balance modeling is often used to evaluate land-atmosphere interactions, deep drainage, and groundwater recharge. The purpose of this study was to compare water balance simulation results from seven different codes, HELP, HYDRUS-1D, SHAW, SoilCover, SWIM, UNSAT-H, and VS2DTI, using 1-3 year water balance monitoring data from nonvegetated engineered covers (3 m deep) in warm (Texas) and cold (Idaho) desert regions. Simulation results from most codes were similar and reasonably approximated measured water balance components. Simulation of infiltrationexcess runoff was a problem for all codes. Annual drainage was estimated to within ±64% by most codes. Outliers result from the modeling approach (storage routing versus Richards' equation), upper boundary condition during precipitation, lower boundary condition (seepage face versus unit gradient), and water retention function (van Genuchten versus Brooks and Corey). A unique aspect of the code comparison study was the ability to explain the outliers by incorporating the simulation approaches (boundary conditions or hydraulic parameters) used in the outlying codes in a single code and comparing the results of the modified and unmodified code. This approach overcomes the criticism that valid code comparisons are infeasible because of large numbers of differences among codes. The code comparison study identified important factors for simulating the near-surface water balance.

Author 1	Author 2	Facility or Agency
Schimschal	Wright	

Citation

Schimschal, U. and J. Wright, 1995. Geophysical Logging for Site Characterization of DNAPL Contamination at Butz Landfill. Proceedings of the Sixth International Symposium on Borehole Geophysics for Minerals, Geotechnical and Groundwater Applications, October 22-25, 1995, Santa Fe, New Mexico.

Journal

Title

Geophysical Logging for Site Characterization of DNAPL Contamination at Butz Landfill.

Document	Year
	1995

Why	How	What	Where
Characterization	Geophysical	logs	Saturated

Abstract

During November 1994 Bureau of Reclamation personnel completed a borehole geophysical logging survey in 17 wells at the Butz Landfill Superfund Site, Jackson Township, Monroe County, Pennsylvania. The purpose of the survey was to (1) describe material in the wells (the lithology), (2) determine the frequency, aperture, and orientation of any fractures in these materials, (3) determine the porosity of the materials, and (4) evaluate lithologic units for correlation between wells.

Borehole televiewer (BHTV), caliper (CALI), sonic transit time (DT), fluid temperature (FTEMP), and sonic variable density (SONIC VD) logs were evaluated as fracture indicators. Borehole televiewer (BHTV) data were evaluated by the Borehole Geophysical Laboratory at Stanford University to determine dip, strike, and aperture of any fractures intersecting the wells.

Shale percentages and corrected density porosities were computed for each well. Natural gamma ray (GR) and neutron (NEUT) logs were used as the primary indicators of lithologic units for correlation between wells. Due to the environment of deposition, subsequent tilting of the strata, and wide spacing of the wells, correlation of specific stratigraphic units was arduous. By splicing pieces of gamma logs from different wells, a typical gamma ray correlation log was constructed and used to correlate large units (Units 1, 2, and 3) within the bedrock. Smaller subunit markers (a through J) were then correlated to provided better ties between wells.

Other logs used include density (DENS), induction resistivity (REST), spontaneous potential (SP), single point resistance (SPR), and sonic amplitude (AMPL).

Calculation of formation water resistivities provides "target zones" of possible liquid-phase Trichloroethane (TCE) contamination. These zones are highlighted and potential packer-seat locations are identified for future testing. Calculated permeability and hydraulic transmissivity provides an estimate of aquifer performance and possible contamination movement.

Author 1	Author 2	Facility or Agency
Schmeltzer	Miller	

Citation

Schmeltzer, J. S., J. J. Miller, et al., 1993. Flood Assessment at a Low-Level Radioactive Waste Site in Southern Nevada. Proceedings of the Symposium on Engineering Hydrology,Jul 25-30 1993, San Francisco,CA,USA, Publ by ASCE,New York,NY,USA.

Journal

Title

Flood Assessment at a Low-Level Radioactive Waste Site in Southern Nevada.

Document	Year
	1993

Why	How	What	Where

Abstract

Flood hazard analysis on alluvial fans using Federal Emergency Management Agency (FEMA) methodology is not limited to the FEMA Alluvial Fan Methodology (AFM). Other FEMA-accepted methods may be more appropriate. A flood assessment using a multiple-method approach was performed to determine the 100-year flood hazard at and near the Radioactive Waste Management Site (RWMS) in Area 5 of the Nevada Test Site. Flood hazard delineations using a combination of methods provide a more complete assessment than using only the FEMA AFM. Understanding the limitations and assumptions of these methods is important to determine which method is applicable and when a method can provide reasonable results.

Author 1	Author 2	Facility or Agency
Schoups	Hopmans	

Citation

Schoups, G., J. Hopmans, 2002. Analytical Model for Vadose Zone Solute Transport with Root Water and Solute Uptake. Vadose Zone Journal 1:158-171.

Journal

Vadose Zone Journal 1:158-171 (2002).

Title

Analytical Model for Vadose Zone Solute Transport with Root Water and Solute Uptake

Document	Year
	2002

Why	How	What	Where
Modeling	Uncertainties	plant uptake	Unsaturated

Abstract

An efficient method is presented for calculating one-dimensional solute transport through the vadose zone in the presence of vertically distributed root water and solute uptake. The method is based on an analytical solution of the convective transport equation, which is solved by the method of characteristics. The solution requires a time-invariant leaching fraction, and assumes that transport occurs by convection alone; that is, hydrodynamic dispersion and molecular diffusion are neglected. From this solution, two variables of practical importance are calculated, (i) the average solute concentration in the root zone, weighted by the root distribution, and (ii) the cumulative solute flux to the groundwater. Model parameters are related to water management, crop type, and soil type, through the following parameters: leaching fraction, root distribution, and soil hydraulic properties. Simulation results are presented for both downward and upward flow scenarios. Simulations with a nonuniform moisture profile indicate that nearly identical results are obtained by replacing the profile by a uniform moisture content equal to the arithmetic average or the uptake-weighted average moisture content, so that closed-form analytical expressions for travel time and travel depth can be obtained. A sensitivity analysis of the relevant model parameters shows that solute concentrations are largely determined by the magnitude of the effective water application ratio, defined by the fraction of infiltrated water that is removed by evapotranspiration. We present suggestions of how dispersive mixing and temporal changes in leaching fraction are readily incorporated into the current model. Although potentially simplistic, the presented methodology can be extremely useful for longer-term and field-to-regional scale characterization of contaminant movement.

Author 1	Author 2	Facility or Agency
Scorca	Dorsch	Brookhaven

Citation

Scorca, M.P., William R. Dorsch,, et al., 1999. Stratigraphy and Hydrologic Conditions at the Brookhaven National Laboratory and Vicinity, Suffolk County, New York, 1994-97. U.S. Geological Survey, Water-Resources Investigations Report 99-4086.

Journal

Title

Stratigraphy and Hydrologic Conditions at the Brookhaven National Laboratory and Vicinity, Suffolk County, New York, 1994-97.

Document	Year
WRIR99-4086	1999

Why	How	What	Where
Characterization			

Abstract

Brookhaven National Laboratory (BNL) has installed many test borings as part of an effort to delineate the extent of ground-water contamination at the site. In 1994, the U.S. Geological Survey began a study in cooperation with BNL to define the stratigraphy in the 28-square-mile area encompassing BNL, and to monitor ground-water levels in the 300 squaremile area of central Suffolk County that surrounds BNL.

The uppermost geologic units at BNL are of Pleistocene age. These sediments are underlain unconformably by the Matawan Group-Magothy Formation, undifferentiated (referred to as the Magothy Formation), of Cretaceous age, which typically consists of light- to dark-gray, variably sorted sand interbedded with light- to dark-gray clay layers; it also contains beds of grayish-brown to brownish-gray sand. Bed thicknesses differ substantially within each boring and tend to be laterally discontinuous as a result of their terrestrial deltaic depositional environment, although a prominent clay unit, referred to as the “grayish-brown clay” in this report, was encountered at many borings. Pollen-sample analyses confirm that this unit is of Cretaceous age and is the uppermost unit of Cretaceous sediments in several parts of the study area.

The upper surface of the Cretaceous deposits is irregular within the 28-square-mile study area and has relief of about 120 feet. Several prominent channels and ridges in the surface are aligned generally northwest-southeast. The Cretaceous surface beneath BNL is characterized more by local erosional features than by the regional cuesta shape that was suggested by previous authors.

The overlying Pleistocene-aged units include (1) a sand layer overlain by the Gardiners Clay, (2) the Gardiners Clay, and (3) upper Pleistocene deposits, which include the Upton unit, glacial outwash, glaciolacustrine deposits, and terminal moraine deposits. The sand unit below the Gardiners Clay was the first Pleistocene unit to be deposited atop the irregular surface of the Cretaceous deposits in this area. The Gardiners Clay was deposited during a major rise in sea level as the sea encroached into parts of the present-day BNL study area. The shallow part of the upper Pleistocene deposits generally consists of light-brown sand and gravel but overlies green to grayish-green, variably sorted sand, silt, and clay at altitudes of 50 to 70 feet below sea level in some parts of the study area. This lower part of the upper Pleistocene deposits in the study area was referred to by previous investigators as the unidentified unit and has been designated as the Upton unit in this report.

The discharge of ground water to the Peconic and Carmans Rivers locally affects the water-table configuration. The main ground-water divide on Long Island is about 0.5 miles north of the site; a secondary divide originates near the start of flow of the Peconic River and extends east-southeastward toward the South Fork. The water-table configuration on the BNL site is affected by pumping from supply wells and remediation wells, by infiltration of the water through recharge basins, by discharge from the sewage-treatment plant, and by local near-surface clay units.

The horizontal hydraulic gradient at BNL typically is 0.001 foot per foot but can steepen near recharge basins and pumping wells. Vertical flow gradients within the upper Pleistocene deposits (upper glacial aquifer) were as large as 0.007 foot per foot (downward) in the northern part of BNL and were negligible in the southern part. Downward vertical gradients between the lower part of the upper glacial aquifer and the upper part of the Magothy Formation (Magothy aquifer) were about 0.018 foot per foot throughout the site.

Author 1	Author 2	Facility or Agency
Seifert	Greenberg	

Citation

Seifert, G. G. and M. A. Greenberg, 1985. Fence Lake Coal Project, Groundwater Monitoring. Proceedings of a Symposium - Groundwater Contamination and Reclamation, Tucson, AZ, USA, American Water Resources Assoc, Bethesda, MD, USA.

Journal

Title

Fence Lake Coal Project, Groundwater Monitoring.

Document	Year
	(1985

Why	How	What	Where
Monitoring			

Abstract

Author 1	Author 2	Facility or Agency
Shuman	Wicker	

Citation

Shuman, R. and F.W. Wicker. 1986. Intrusion of Reclaimed Uranium Mill Tailing by Prairie Dogs and Ground Squirrels. J. Environ. Qual. 15(1): 21-24.

Journal

J. Environ. Qual. 15(1): 21-24.

Title

Intrusion of Reclaimed Uranium Mill Tailing by Prairie Dogs and Ground Squirrels.

Document	Year
	1986

Why	How	What	Where
Characterization	Ecological		Surface

Abstract

Author 1	Author 2	Facility or Agency
Siegel	Cheng	Hanford

Citation

Siegel, M.D, W.C. Cheng, et al., 2003. Hanford 200 West Area DNAPL Characterization Technology Review. U.S. Department of Energy, Innovative Treatment & Remediation Demonstration Program, ITRD-41735.

Journal

Title

Hanford 200 West Area DNAPL Characterization Technology Review

Document	Year
ITRD-41735.	2003

Why	How	What	Where
Characterization	Geophysical	mixed	Saturated

Abstract

The Innovative Treatment and Remediation Demonstration (ITRD) Program is helping stakeholders for the Hanford site develop a characterization and treatment plan for remediation of soils and groundwater contaminated with carbon tetrachloride (CCl4) in the 200 West Area. Site cleanup of CCl4 is complicated by the presence of a relatively low-permeability layer at a depth of 115 feet, where dense non-aqueous-phase liquid (DNAPL) may have accumulated, and by the great depth to the water table (250 feet). These features, and the presence of radioactive soil contamination within the soil cribs, result in high well installation costs. The selection of areas to characterize and treat and the selection of treatment technology must be integrated into a cost-effective strategy. This plan must satisfy the Environmental Protection Agency (EPA) requirements for the site-wide characterization and treatment plan.
The Hanford site invited ITRD participation in 1999 to support the selection of new remediation technologies for a planned Interim Record of Decision (ROD) review in FY 2000. Early in the evaluation process, it was recognized that definition of the location and estimation of the volume of the DNAPL source was required before treatment technologies could be evaluated. This document summarizes the process and the results of the review of characterization technologies by the Hanford 200 West ITRD Project. The information should be useful in planning future evaluations of characterization technologies for the site. Highlights of the activities for the project are shown in Table 1.

Author 1	Author 2	Facility or Agency
Siegel	Siegel	

Citation

Siegel, S.M., B.Z. Siegel, et al. 1985. Indicator Plant-soil Mercury Patterns in a Mercury Rich Mining Area of British Columbia. Water Air Soil Pollut. 25(1): 73-85.

Journal

Water Air Soil Pollut. 25(1): 73-85.

Title

Indicator Plant-soil Mercury Patterns in a Mercury Rich Mining Area of British Columbia.

Document	Year
	1985

Why	How	What	Where
Characterization	Ecological	plant uptake	Surface

Abstract

Author 1	Author 2	Facility or Agency
Silliman	Mantz	

Citation

Silliman, S. E. and G. Mantz, 2000. Data Related Uncertainties in the Definition of Wellhead Capture Zones. IAHS Publication (International Association of Hydrological Sciences) The 2nd International Symposium on Assessing and Managing Health Risks from Drinking Water Contamination: Approaches and Applications,Sep 7-Sep 10 1998(260): 53-56.

Journal

Title

Data Related Uncertainties in the Definition of Wellhead Capture Zones.

Document	Year
	2000

Why	How	What	Where
Modeling	Uncertainties		

Abstract

The Local Gradient Estimate Technique (LGET) is extended to delineation of capture zones: (a) the LGET is extended to provide a reliable test for measurement errors, and (b) the LGET is also extended to delineation of uncertainty in the geometry and orientation of a capture zone. It is demonstrated that the LGET, in combination with monitoring wells, allows elimination of major measurement errors and estimation of capture zones, including uncertainty, with better performance than that obtained using two other common approaches to capture zone delineation.

Author 1	Author 2	Facility or Agency
Sisson	Schafer	Savannah River Site

Citation

Sisson, J. B., A. L. Schafer, et al., 2000. Vadose Zone Monitoring System for Site Characterization and Transport Modeling. Scientific Basis for Nuclear Waste Management XXIII, Nov 29-Dec 2 1999, Boston, MA, USA.

Journal

Title

Vadose Zone Monitoring System for Site Characterization and Transport Modeling.

Document	Year
	2000

Why	How	What	Where
Monitoring	Devices	mixed	Unsaturated

Abstract

Monitoring the vadose zone below buried waste provides an early warning of contaminate transport toward the groundwater. To quantify the transport mechanisms, vadose zone hydraulic characteristics and the physical variables need to be obtained. We have designed and implemented a Vadose Zone Monitoring System (VZMS) to monitor or sample the 3 state variables of the vadose zone, water potential, water content and chemical concentration. The state variables are monitored using an Advanced Tensiometer (AT), a borehole water content sensoe (BWCS) and a vacuum llysimeter, respectively. This system was installed at the Savannah River Site (SRS) E-Area disposal site, where low level wastes have been disposed of in shallow trenches. The system has operated for several months providing nearly continuous water content and water potential data. The vacuum lysimeters were activated on a quarterly schedule. Installation details and an example data set are presented to illustrate the effectiveness of the VZMS, and demonstrate the utility of the VZMS as an indicator of contaminant transport.

Author 1	Author 2	Facility or Agency
Sisson	Gee	Hanford

Citation

Sisson, J.B., G.W. Gee, et al., 2002. Advances in Tensiometry for Long-Term Monitoring of Soil Water Pressures. Vadose Zone Journal 1:310-315.

Journal

Vadose Zone Journal 1:310-315 (2002)

Title

Advances in Tensiometry for Long-Term Monitoring of Soil Water Pressures

Document	Year
	2002

Why	How	What	Where
Monitoring	Devices	tensiometer	Unsaturated

Abstract

Soil water pressures, measured over space and time, are needed to predict the direction of water flow and chemical transport in the vadose zone. Advanced tensiometers (ATs), which utilize a water-filled porous cup connected directly to a pressure transducer, can be installed at almost any location and depth using standard drilling techniques such as auger drilling, but these methods can significantly disturb the site. For sites where minimal disturbance is desired, alternate approaches for tensiometer placement have been sought. To test installation techniques and performance longevity, advanced tensiometers were placed into the ground at a test site near Richland, WA using two different installation methods, auger drilling and a drive cone push technique. The tensiometers were subsequently monitored for nearly 2 yr without refilling or recalibration. The data indicated that tensiometers placed by the auger technique took several months to equilibrate, while the cone push units came to equilibrium within 24 h following their installation. Soil water pressures always remained above -90 cm pressure head (-90 mbar) at depths >90 cm. At the greatest depth (730 cm), positive then negative pressures were observed as the water table was lowered and the soil drained. The results suggest that for our test conditions (coarse sandy soil, no vegetation), soil water pressures stay well within the tensiometer range and unit gradient conditions persist, indicating a draining profile. Advanced tensiometers, placed either by auger or cone penetrometer, provide a robust and reliable method for long-term monitoring of soil water pressure profiles.

Author 1	Author 2	Facility or Agency
Smallwood	Morrison	

Citation

Smallwood, K.S., M.L. Morrison, and J. Beyea. 1998. Animal Burrowing Attributes Affecting Hazardous Waste Management. Environmental Management 22(6): 831-847.

Journal

Environmental Management 22(6): 831-847.

Title

Animal Burrowing Attributes Affecting Hazardous Waste Management.

Document	Year
	1998

Why	How	What	Where
Characterization	Ecological		Surface

Abstract

Author 1	Author 2	Facility or Agency
Smith	Ketcheson	

Citation

Smith, D. G., D. Ketcheson, et al., 1994. Evaluation, Design, Construction and Monitoring of a Contingency System for Landfill Leachate Management, Glenridge Quarry Landfill Site, St. Catharines, Ontario. Journal of Resource Management and Technology 22(2): 87-95.

Journal

Journal of Resource Management and Technology 22(2): 87-95.

Title

Evaluation, Design, Construction and Monitoring of a Contingency System for Landfill Leachate Management, Glenridge Quarry Landfill Site, St. Catharines, Ontario.

Document	Year
	1994

Why	How	What	Where
Design	Optimization		

Abstract

Author 1	Author 2	Facility or Agency
Spruill	Candela	

Citation

Spruill, T. B. and L. Candela, 1990. Two Approaches to Design of Monitoring Networks. Ground Water 28(3): 430-442.

Journal

Ground Water 28(3): 430-442.

Title

Two Approaches to Design of Monitoring Networks.

Document	Year
	1990

Why	How	What	Where
Design	Optimization	comparison	Saturated

Abstract

Two different approaches to the design of a ground-water-quality monitoring may be appropriate, depending on the type of information desired. First, where the objective is to determine what ground-water-quality characteristics are like in an area (statistical quantification of typical concentrations, as given by the mean or median, or percentage of wells exceeding various use standards), networks can be designed to provide estimates of known reliability using standard parametric and nonparametric statistical techniques. This approach can provide information adequate to perform general water-quality assessments where the intention of the monitoring network is to provide data about general suitability of the water for various uses. Second, where the objective is to maximize areal ground-water-quality information, networks also can be designed using geostatistical techniques, such as kriging. This second approach would be appropriate when information is needed on where particular problem areas may exist.

Both approaches were applied to 1965 chloride data from a deep confined aquifer in the Llobregat delta near Barcelona, Spain. Traditional statistical techniques are demonstrated to design a network that would provide an estimated median chloride concentration. A method is introduced that can be used to determine the sample size necessary to describe any selected quantile with known precision. ON the basis of 120 observations in the 1965 data set, between 13 and 25 wells would be necessary to estimate the median chloride concentration within 40 percent of the true median with 95-percent confidence. Kriging, a geostatistical technique, was applied to the data set to determine the minimum number of wells necessary to include in the network to retain the essential spatial information of the original network. By use of this technique, the original network of 120 wells was reduced by 17.5 percent to 99 wells, while the standard error was increased by only 1 percent.

A comparison of these two approaches indicates that a network designed by use of geostatistical techniques generally will require larger sample sized than networks designed by use of traditional techniques, but the geostatistical techniques can provide data adequate to describe both stochastic and spatial features of water-quality variables. On the basis of results presented in this paper, prediction errors for chloride concentrations in ground water at selected points in the Llobregat delta were as much as 300 percent. Nevertheless, even the modified network of 99 wells would produce statistical estimates adequate for most general water-quality assessments, in addition to retaining the spatial information contained in the original 1965 data set.

Author 1	Author 2	Facility or Agency
Stothoff	Bagtzoglou	Yucca Mountain

Citation

Stothoff, S.A., A.C. Bagtzoglou, et al., 1995. Estimation of Spatial Distribution of Recharge Factors at Yucca Mountain, Nevada, Proceedings, Sixth Annual International High-Level Radioactive Waste Management Conference, pp. 69-71.

Journal

Title

Estimation of Spatial Distribution of Recharge Factors at Yucca Mountain, Nevada

Document	Year
	1995

Why	How	What	Where
Characterization			Structure

Abstract

Author 1	Author 2	Facility or Agency
Surampalli	Banerji	

Citation

Surampalli, R. and S. Banerji, 2002. Long-term Performance Monitoring at Natural Attenuation Site. Practice Periodical of Hazardous, Toxic, and Radioactive Waste Management 6(3): 173-176.

Journal

Practice Periodical of Hazardous, Toxic, and Radioactive Waste Management 6(3): 173-176.

Title

Long-term Performance Monitoring at Natural Attenuation Site.

Document	Year
	2002

Why	How	What	Where
Monitoring	Performance	chemical	Saturated

Abstract

Long-term monitoring is an integral part of the natural attenuation remediation process. It is needed to monitor the migration of a contaminated groundwater plume over time and to evaluate the extent of natural remediation that is occurring. It involves the placement of four types of monitoring wells: up-gradient, side-gradient, impacted source, and down-gradient wells. The monitoring of groundwater samples from these wells should provide information to evaluate if the objectives of the natural attenuation process are being met. The sampling analytical plan depends upon the type of contaminants involved. The frequency of sampling should be sufficient to det3ect in a timely manner any changes in plume contaminant degradation behavior. It should also be flexible enough to make changes, should there be a need. The monitoring program should be continued until the objectives of the natural attenuation process have been met, and possibly longer, if necessary, to ensure that health and environment threats are protected. If during the monitoring process, the plume behavior is found to change for the worse (i.e., plume migration is faster or further than before), a contingency plan should be in place to protect the down-gradient receptors. The contingency plan usually requires an engineered remediation plan to reduce the negative impact of the plume on the down-gradient receptors.

Author 1	Author 2	Facility or Agency
Suter	Luxmore	

Citation

Suter, G.W., R.L. Luxmore, and E.D. Smith. 1993. Compacted soil barriers at abandoned landfill sites are likely to fail in the long term. J. Environ. Qual. 22(2): 217-226.

Journal

J. Environ. Qual. 22(2): 217-226.

Title

Compacted soil barriers at abandoned landfill sites are likely to fail in the long term.

Document	Year
	1993

Why	How	What	Where

Abstract

Author 1	Author 2	Facility or Agency
Swanson	Rohay	Hanford

Citation

Swanson, L.C., V.J. Rohay, et al., 1999. Hydrogeologic Conceptual Model for the Carbon Tetrachloride and Uranium/Technetium Plumes in the 200 West Area: 1994 Through 1999 Update. U.S. Department of Energy, BHI-01311.

Journal

Title

Hydrogeologic Conceptual Model for the Carbon Tetrachloride and Uranium/Technetium Plumes in the 200 West Area: 1994 Through 1999 Update

Document	Year
BHI-01311	1999

Why	How	What	Where
Modeling			Saturated

Abstract

This report updates the hydrogeologic conceptual model for the carbon tetrachloride and uranium/technetium plumes in the 200 West Area of the Hanford Site over the last 5 years (1994 through 1999). During this 5-year period, the Environmental Restoration Contractor (ERC) has been performing interim remedial actions at three operable units to remove the carbon tetrachloride and uranium/technetium contamination from the subsurface. These actions include the following:
- 200-ZP-2 soil vapor extraction system that is designed to remediate carbon tetrachloride in the vadose zone
- 200-ZP-1 extraction treatment injection system that is designed to remediate carbon tetrachloride, trichloroethene, and chloroform in the groundwater
- 200-UP-1 extraction treatment injection system that is designed to remediate the primary contaminants of technetium-99 and uranium and the secondary contaminants of carbon tetrachloride and nitrate in the groundwater.

The data collected during these remedial actions and during other 200 West Area characterization and monitoring activities have resulted in modifications to the understanding of the subsurface system and contaminant distribution.

The objective of this 5-year update is to address the aspects of the hydrogeologic conceptual model related to remediation of the carbon tetrachloride and uranium/technetium plumes.

Author 1	Author 2	Facility or Agency
Thomasson	Wierenga	

Citation

Thomasson, M.J., P.J. Wierenga, 2003. Spatial Variability of the Effective Retardation Factor in an Unsaturated Field Soil. Journal of Hydrology 272, 213-225.

Journal

Journal of Hydrology 272 (2003) 213-225

Title

Spatial Variability of the Effective Retardation Factor in an Unsaturated Field Soil.

Document	Year
	2003

Why	How	What	Where
Characterization	Devices	mixed	Unsaturated

Abstract

A precisely controlled field study was conducted to determine flow and transport of water and bromide through an unsaturated soil. A 50 m X 50 m plot was instrumented with neutron probe access tubes, tensiometers, and solution samplers. Water containing bromide part of the time was applied at a steady flux of 1.85 cm d-1 for 24 days. The average degree of water saturation during water application was about 56%. The Hydrus 1-D model was used to optimize the saturated hydraulic conductivity parameter Ks, and the transport parameters D (dispersion coefficient) and R (used here as a 'bulk retardation coefficient'). The van Genuchten flow parameters THETAr, THETAs, ALPHA, and n were obtained from laboratory measurements on 11 cores taken 1.5 m below the soil surface along a transect through the plot. The estimated field Ks value increased with depth due to higher sand and gravel contents at depth. The mean dispersion coefficient for 13 locations at the 3 m depth was found to be 5.35 cm2 d-1, with a coefficient of variation of 52%. This resulted in a relatively small mean dispersivity value of 0.64 cm. The average R value was 0.63 with a range of 0.45-1.02 at 3 m (CV = 28%). The low R value is indicative of anion exclusion, immobile water, or some other phenomenon difficult to identify from field data. These field data indicate that if a transport model with a bulk retardation factor is used for predicting bromide transport through unsaturated soil a range of retardation values may need to be used. For our soil, the highest R value needed to be at least twice its lowest value.

Author 1	Author 2	Facility or Agency
Thompson		Sandia

Citation
Thompson, B. G. J., 1999. The Role of Performance Assessment in the Regulation of Underground Disposal of Radioactive Wastes; an International Perspective. Helton, J. C. (editor), Anderson, D. R. (editor), Performance assessment for radioactive waste disposal. Risk Analysis, 19 (5), p. 809-846.

Journal
Risk Analysis, 19 (5), p. 809-846.

Title
The Role of Performance Assessment in the Regulation of Underground Disposal of Radioactive Wastes; an International Perspective.

Document	Year
	1999

Why	How	What	Where

Abstract

Author 1	Author 2	Facility or Agency
Thomson		

Citation

Thomson, K.A., 1994. Case Studies of Soil Gas Sampling. In "Handbook of Vadose Zone Characterization and Monitoring". L.G. Wilson, L.G. Everett and S.J. Cullen, editors. CRC Press, Inc.

Journal

Title

Case Studies of Soil Gas Sampling.

Document	Year
	1995

Why	How	What	Where
Monitoring	Devices	wells	Unsaturated

Abstract

The technical acceptance, popularity, accuracy, and use of soil gas survey techniques have increased tremendously over the past five years. Due to the volatile nature of many solvents and fuel hydrocarbons, soil sample analytical results are often inaccurate (not representative) due to loss of volatile organic compounds (VOCs) from samples during sample collection, transport and analysis. In-situ measurement of soil gas samples is often a more accurate means of assessing the presence and extent of VOCs in unsaturated medium-to coarse-grain geologic materials. The volatile nature of many solvents and fuel hydrocarbons has made vapor extraction the preferred remediation technique for soil impacted by these chemicals and, therefore, it is prudent to sample the gas or vapor phase to evaluate remediation progress. This chapter describes the objectives and limitations of soils gas surveying, provides specific investigative methods and procedures, and presents two case studies conducted in Southern California.

Author 1	Author 2	Facility or Agency
Tokunaga	Salve	

Citation

Tokunaga, T. and R. Salve., 1994. Gauge Sensitivity Optimization in Air Pocket Tensiometry: Implications for Deep Vadose Zone Monitoring. Soil Science, Vol 158 No. 6, 389-397.

Journal

Soil Science, Vol 158 No. 6, 389-397

Title

Gauge Sensitivity Optimization in Air Pocket Tensiometry: Implications for Deep Vadose Zone Monitoring.

Document	Year
	1994

Why	How	What	Where
Monitoring	Devices	tensiometer	Unsaturated

Abstract

Potential applications of air pocket type tensiometers in measuring hydraulic head profiles in deep vadose zones are discussed. Advantages of this method include (i) the ability to obtain tensiometer measurements far beyond the approximately 9 m-depth often associated with the limit of conventional tensiometry, (ii) ease of regular gauge calibration, and (iii) low cost. Advantages relative to buried, dedicated pressure transducer tensiometers are gained at the expense of substantial losses in gauge sensitivity, S*. In view of this compromise, an analysis was performed to determine the optimal fractional water-filled length, F, for air pocket tensiometers. It is shown that the critical ration governing the nature of S*-optimization is approximated by (Ð* - Ðo)z*, where Ð* represents the absolute matric head, Ðo is the vapor pressure of water expressed in head units, and z* is the depth of the tensiometer tip. When (Ð* - Ðo)z* > 1, S* is optimized when F à 1. However, when (Ð* - Ðo)z* <1, S* is optimized as F à 0. The central role of (Ð* - Ðo)z* arises from the fact that S* = Pa/Vg, where Pa refers to the absolute pressure of all tensiometer headspace gases excluding water vapor, and Vg refers to the volume of the gas phase within the tensiometer headspace. When (Ð* - Ðo) is less than z*, S* goes to zero because the absolute pressure in the tensiometer headspace approaches the vapor pressure of the tensiometer water (Po) when attempts are made to fill the tensiometer column with liquid water. In the more familiar case of Ð* - Ðo being larger than z*, the dominance of Pa over Po assures that S* increases as the instrument is filled. To test the predicted nature of S*, laboratory experiments were performed on 1.11-6.26, and 11.91 m long tensiometers over a range of values of (Ð* - Ðo) and F sufficient to provide three orders of magnitude variation in S*. Measure S* agreed well with predicted values, and supports the conclusion that response times are minimized with F à 0, in situations where (Ð* - Ðo)/z* <1.

Author 1	Author 2	Facility or Agency
Toran	Sjoreen	ORNL

Citation

Toran, L., Sjoreen, A., Dreier, R.B., Modeling of a density-dependent contaminant plume located in a regional discharge area on the Oak Ridge Reservation. Anonymous, Geological Society of America, 1993 annual meeting, Abstracts with Programs - Geological Society of America, 25 (6), p. 246, 1993. Meeting: Geological Society of America, 1993 annual

Journal

Title

Modeling of a density-dependent contaminant plume located in a regional discharge area on the Oak Ridge Reservation

Document	Year
	1993

Why	How	What	Where
Modeling			Saturated

Abstract

Author 1	Author 2	Facility or Agency
Turner		

Citation
Turner, D.R., 1991. Effects of Variable Hydrologic Saturation on Sorption Modeling for High-Level Waste Performance Assessment: A Literature Review. CNWRA 91-016.

Journal

Title
Effects of Variable Hydrologic Saturation on Sorption Modeling for High-Level Waste Performance Assessment: A Literature Review

Document	Year
CNWRA 91-016	1991

Why	How	What	Where
Modeling	Geochemical		Unsaturated

Abstract

Author 1	Author 2	Facility or Agency
Vasarhelyi	Csige	

Citation

Vasarhelyi, A., I. Csige, et al., 1997. Spatial Distribution of Radon Content of Soil-Gas and Well-Waters Measured with Etched Track Radon Monitors. Proceedings of the 1996 18th International Conference on Nuclear Tracks in Solids, Sep 1-5 1996 28(1-6): 685-690.

Journal

Title

Spatial Distribution of Radon Content of Soil-Gas and Well-Waters Measured with Etched Track Radon Monitors.

Document	Year
	1997

Why	How	What	Where
Monitoring	Devices	radiometric	Saturated

Abstract

We have measured the spatial distribution of radon content of ground-water and of soil-gas in Matraderecske village (Hungary) using etched track type radon monitors. The applicability of the used in-situ method to measure radon content of ground-water is tested and discussed. Regression analysis between ground-water radon level, soil-gas radon content and other parameters, such as temperature, pH level and the electric conductivity of water revealed no significant linear correlation between any pair of the above parameters. Surface maps of radon activity levels in soil and in ground-water were computed and compared to each other and to geological structure of the area.

Author 1	Author 2	Facility or Agency
Vo-Dinh		

Citation

Vo-Dinh, T., 1995. Environmental Monitoring and Hazardous Waste Site Remediation. Environmental Monitoring and Hazardous Waste Site Remediation, Jun 19-21 1995, Munich, Ger.

Journal

Title

Environmental Monitoring and Hazardous Waste Site Remediation

Document	Year
	1995

Why	How	What	Where
Monitoring			

Abstract

Author 1	Author 2	Facility or Agency
Vroblesky	Hyde	

Citation

Vroblesky, D.A. and W. T. Hyde, 1997. Diffusion Samplers as an Inexpensive Approach to Monitoring VOCs in Ground Water. Ground Water Monitoring and Remediation, 177-184.

Journal

Ground Water Monitoring and Remediation, 177-184.

Title

Diffusion Samplers as an Inexpensive Approach to Monitoring VOCs in Ground Water.

Document	Year
	1997

Why	How	What	Where
Monitoring	Devices	samplers	Saturated

Abstract

Diffusion samplers installed in observation wells were found to be capable of yielding representative water samples for chlorinated volatile organic compounds. The samplers consisted of polyethylene bags containing deionized water and relied on diffusion of chlorinated volatile organic compounds through the polyethylene membrane. The known ability of polyethylene to transmit other volatile compounds, such as benzene and toluene, indicates that the samplers can be used for a variety of volatile organic compounds. In wells at the study area, the volatile organic compound concentrations in water samples obtained using the samplers without prior purging were similar to concentrations in water samples obtained from the respective wells using traditional purging and sampling approaches. The low cost associated with this approach makes it a viable option for monitoring large observation-well networks for volatile organic compounds.

Author 1	Author 2	Facility or Agency
Wadey	Shaw	

Citation

Wadey, P., G. Shaw, et al., 2001. Radionuclide Transport Above a Near-Surface Water Table: III. Soil Migration and Crop Uptake of Three Gamma-Emitting Radionuclides, 1990 to 1993. J. Environ. Qual. 30:1341- 1353.

Journal

J. Environ. Qual. 30:1341- 1353

Title

Radionuclide Transport above a Near-Surface Water Table: III. Soil Migration and Crop Uptake of Three Gamma-Emitting Radionuclides, 1990 to 1993

Document	Year
	2001

Why	How	What	Where
Characterization	Geochemical	crop uptake	Surface

Abstract

This paper summarizes the vertical distributions of 22Na, 137Cs, and 60Co above controlled water tables in deep and shallow lysimeters during a four-year experiment. The activity concentration profiles were all determined at the time of harvest of a winter wheat (Triticum aestivum L. cv. Pastiche) crop. Activity concentrations in different crop tissues were determined and crop uptake expressed as both an inventory ratio (IR) and a transfer factor (TFw), weighted to account for root and radionuclide distributions within the soil profile. Experimental variates were subjected to analysis of variance to determine the single and combined effects of the soil depth and the year of the experiment on the results obtained. Each radionuclide showed significant variations in activity concentration with soil depth, but the significance of these variations from year to year was dependent on radionuclide. A distinction in the behavior of weakly sorbed (22Na) and more highly sorbed (137Cs and 60Co) radionuclides was observed. The former exhibited significant variations in its distribution in the soil profile from year-to-year whereas the latter did not. Relatively high TFw values for 22Na were maintained throughout the experiment, whereas for 137Cs and 60Co, the highest TFw values were recorded in 1990 followed by a significant decline in 1991, with TFw remaining low in 1992 and 1993. The TFw values were, in general, significantly higher for deep lysimeters than for shallow lysimeters. This is thought to provide evidence of enhanced radionuclide absorption by the relatively small fraction of roots in the vicinity of the deeper water table.

Author 1	Author 2	Facility or Agency
Wagner		

Citation

Wagner, B. J., 1999. Evaluating Data Worth for Ground-Water Management Under Uncertainty. J. Water Resources Planning and Management 125(5): 281-288.

Journal

J. Water Resources Planning and Management 125(5): 281-288

Title

Evaluating Data Worth for Ground-water Management Under Uncertainty.

Document	Year
	1999

Why	How	What	Where
DQO	Uncertainties		Saturated

Abstract

A decision framework is presented for assessing the value of ground-water sampling within the context of ground-water management under uncertainty. The framework couples two optimization models - a chance-constrained ground-water management model and an integer-programming sampling network design model - to identify optimal pumping and sampling strategies. The methodology consists of four steps: (1) The optimal ground-water management strategy for the present level of model uncertainty is determined using the chance-constrained management model; (2) for a specified data collection budget, the monitoring network design model identifies, prior to data collection, the sampling strategy that will minimize model uncertainty; (3) the optimal ground-water management strategy is recalculated on the basis of the projected model uncertainty after sampling; and (4) the worth of the monitoring strategy is assessed by comparing the value of the sample information - i.e., the projected reduction in management costs - with the cost of data collection. Steps 2-4 are repeated for a series of data collection budgets, producing a suite of management/monitoring alternatives, from which the best alternative can be selected. A hypothetical example demonstrates the methodology's ability to identify the ground-water sampling strategy with greatest net economic benefit for ground-water management.

Author 1	Author 2	Facility or Agency
Walker	Nashold	Argonne

Citation

Walker, J.L., B.W. Nashold, et al., Carbon Tetrachloride in Vegetation and its Application Expedited Site Characterization.

Journal

Title

Carbon Tetrachloride in Vegetation and its Application Expedited Site Characterization

Document	Year

Why	How	What	Where
Characterization	Geochemical	plant uptake	Surface

Abstract

The use of vegetation analyses to outline areas of near-surface enrichment with metals and organic compounds was pioneered by the mining and petroleum industries. Research and development (R&D) on environmental applications is focusing on the ability of vegetation to remediate soils. Certain contaminants are taken up by plants and either stored in the plant tissue for easy harvesting and removal or changed into products that are not a health concern. In the development of its Expedited Site Characterization (ESC) methodology, our group at Argonne has focused its R&D on the application of vegetation analyses to detect subsurface contamination in vadose zone soils. We have developed the technology to locate past spills or leaks of carbon tetrachloride that penetrated the vadose zone and contaminated underlying drinking water supplies. Vegetation analysis is attractive as a first-step exploratory technique because it is noninvasive, rapid, and inexpensive. The technique requires collection of a uniform, constant sample type and an analytical method with a low detection limit and high-quality results.

Author 1	Author 2	Facility or Agency
Walther	Bitea	

Citation

Walther, C., C. Bitea, et al., 2002. Laser Induced Breakdown Detection for the Assessment of Colloid Mediated Radionuclide Migration. Nuclear Instruments and Methods in Physics Research, Section B: Beam Interactions with Materials and Atoms 195(3-4): 374-388.

Journal

Nuclear Instr. and Methods in Physics Res., B 195(3-4): 374-388.

Title

Laser Induced Breakdown Detection for the Assessment of Colloid Mediated Radionuclide Migration.

Document	Year
	2002

Why	How	What	Where
Monitoring	Sensors	optical	Saturated

Abstract

Colloids play an important role in the transport of pollutants in the environment Harmful substances can undergo transport over large distances if bound to colloids in aqueous surrounding. One important example is the migration of Pu(IV) at unexpectedly high rates over several miles at a Nevada nuclear detonation test site. For long term safety assessments of radioactive waste repositories, it is hence crucial to know about the amount, size distribution and chemical composition of colloids in the ground water. Standard methods (e.g. light scattering) can be applied for high concentrations and large sizes of particles. Colloids smaller than 50nm, however, are detected with very low efficiency. Laser induced breakdown detection (LIBD) can fill this gap. A new instrumentation is presented, which as compared to previous instruments, opens up a much wider operational dynamic range, now covering three orders of magnitude in size (5-1000 nm) and seven orders of magnitude in particle concentration (1 ppt - several ppm). The technique is based on plasma formation on colloidal particles inside the focus of a pulsed laser. The plasma plume is detected by three-dimensional optical observations and by means of its shock wave with a piezo-detector. For mathematical modelling, Gaussian TEM00 mode has been achieved in the focus of a LIBD apparatus and great care has been taken to guarantee long-term stability of the optical parameters. Automated control of the laser pulse energy and beam shape is introduced to allow routine reproducible measurement. The apparatus combines acoustic detection with three-dimensional optical monitoring of the focal region with two CCD cameras placed perpendicular to each other in order to gain additional size information. The breakdown events are systematically characterized with respect to the number density and size of aquatic colloids as a function of the laser pulse energy. Whereas the threshold energy (irradiance) only depends on the colloid size, the breakdown probability at higher pulse energies is a direct function of the number density of colloids. A correlation of the two facts allows the speciation of the colloidal size distribution.

Author 1	Author 2	Facility or Agency
Wang	Williams	

Citation

C-P. Wang, R.E. Williams, 1984. Aquifer Testing, Mathematical Modeling and Regulatory Risk, Ground Water 22 (3), 285-296.

Journal

Ground Water, Vol. 22 No. 3, 285-296,1984.

Title

Aquifer Testing, Mathematical Modeling and Regulatory Risk,

Document	Year
	1984

Why	How	What	Where
Modeling			Saturated

Abstract

Mathematical modeling founded on a strong field data base can be a valuable tool for the analysis of groundwater contamination problems. The purposes of this paper are threefold: (1) we demonstrate the dilemma of a knowledgeable ground-water quality regulator whose regulatory decision-making process is confronted with the output of a mathematical model that is based on very limited field test data; (2) we demonstrate a method available to a knowledgeable regulator for assessing approximately a range of possible performances of a contaminated ground-water recovery well field using a range of input data derived from a very limited data base; and (3) we present a strong case for presenting mathematical model outputs as ranges of values rather than as unique solutions. A range is determined by an examination of the level of sophistication of the field data base. Our experience with 12 field sites wherein ground-water contamination has occurred has led us to conclude that field data are seldom, if ever, adequate to defend a unique solution from a mathematical model. Regulatory decisions generally can be reduced to a minimization of risks based on the smallest range of model outputs that can be defended on the basis of the field data base. The more limited the field data base, the greater must be the range of defensible model outputs, and consequently, the greater the risk inherent in subsequent regulatory decisions. The knowledgeable regulator can assess the risks in the regulatory decision-making process only if he is able to assess the extent to which the field data base for the mathematical model output reflects state-of-the-art data collection and analysis technologies and methodologies. If an applicant for a permit or license submits a less than adequate data base and concomitantly a broad range of defensible model outputs, he inherently requests that the knowledgeable regulator accept a risk greater than that required if adequate aquifer testing techniques had been employed.

Author 1	Author 2	Facility or Agency
Ward	Clement	

Citation
Ward, A.L, W.P. Clement, et al., Penetrating Radar to Monitoring Soil-Water Storage in a Prototype Surface Barrier.

Journal

Title

Document	Year

Why	How	What	Where
Monitoring	Geophysical	GPR	Structure

Abstract

Author 1	Author 2	Facility or Agency
Ward	Caldwell	

Citation

Ward, A. L., T. G. Caldwell, et al., 2002. A Vadose Zone Water Fluxmeter With Divergence Control. Water Resources Research 38(8): 161-1617.

Journal

Water Resources Research 38(8): 161-1617.

Title

A Vadose Zone Water Fluxmeter With Divergence Control.

Document	Year
	2002

Why	How	What	Where
Characterization	Devices		Unsaturated

Abstract

Unsaturated water flux densities are needed to quantify water and contaminant transfer within the vadose zone. However, water flux densities are seldom measured directly and often are predicted with uncertainties of an order or magnitude or more. A water fluxmeter was designed, constructed, and tested to directly measure drainage fluxes in field soils. The fluxmeter was designed to minimize divergence. It concentrates flow into a narrow sensing region filled with a fiberglass wick. The wick applies suction, proportional to its length, and passively drains the meter. The meter can be installed in an augured borehole at almost any depth below the root zone. Water flux through the meter is measured with a self-calibrating tipping bucket, with a sensitivity of [similar to] 4 mL tip⁻¹. For our meter this is equivalent to detection limit of [similar to] 0.1 mm. Passivewick devices previously have not properly corrected for flow divergence. Laboratory measurements supported predictions of a two-dimensional (2-D) numerical model, which showed that control of the collector height H and knowledge of soil hydraulic properties are required for improving divergence control, particularly at fluxes below 1000 mm yr⁻¹. The water fluxmeter is simple in concept, is inexpensive, and has the capability of providing continuous and reliable monitoring of unsaturated water fluxes ranging from less than 1 mm yr⁻¹ to more than 1000 mm yr⁻¹.

Author 1	Author 2	Facility or Agency
Warren	Delavault	

Citation

Warren, H. V. and R. E. Delavault, 1962. Lead in some food crops and trees. J. Sci. Food Agric., 13: 96-98.

Journal

J. Sci. Food Agric., 13: 96-98.

Title

Lead in some food crops and trees.

Document	Year
	1962

Why	How	What	Where
Characterization	Ecological	plant uptake	Surface

Abstract

Author 1	Author 2	Facility or Agency
Washburn	Edelmann	

Citation

Washburn, S. T. and K. G. Edelmann, 1999. Development of Risk-based Remediation Strategies. Practice Periodical of Hazardous, Toxic, and Radioactive Waste Management 3(2): 77-82.

Journal

Practice Periodical of Hazardous, Toxic, and Radioactive Waste Management 3(2): 77-82.

Title

Development of Risk-based Remediation Strategies.

Document	Year
	1999

Why	How	What	Where
Design			

Abstract

Author 1	Author 2	Facility or Agency
Watts	Janin	

Citation

Watts, L., S. Janin, et al., 1996. Methodology for Estimating Predictive Uncertainty in Groundwater Contaminant Modeling Using the Hydrogeochemical Transport Code, TRAFFIC. Proceedings of the ModelCARE'96 Conference, Sep 24-26 1996, Golden, CO, USA

Journal

Title

Methodology for Estimating Predictive Uncertainty in Groundwater Contaminant Modeling Using the Hydrogeochemical Transport Code, TRAFFIC.

Document	Year
	1996

Why	How	What	Where
Modeling	Uncertainties	statistics	Saturated

Abstract

Model predictions are uncertain due to the incompleteness of our knowledge and representation of real systems. Further, a best-fit model calibration leading to a single averaged model prediction, even with some sensitivity analysis, may suggest an unjustified and misleading degree of accuracy. Instead, we consider a number of alternate reasonable model calibrations. Latin hypercube sampling is used to sample efficiently for groundwater flow and/or transport parameter valued from specified probability density functions. In combination with this uncertainty methodology we utilize TRAFFIC, a three-dimensional finite element code for groundwater contaminant TRAnsport and Fluid Flow Including geoChemistry, developed and verified by BFNL. For each set of sampled parameters, a groundwater flow solution is determined; the results are compared with monitoring data and a measure of reasonableness, or likelihood, assigned to that velocity field. Contaminant transport realizations are then performed to provide, e.g. upper and lower confidence intervals on the mean prediction of groundwater concentrations against time at observation points. An application of this methodology to investigate the consequences of uncertainty in hydraulic conductivity and in Kd on contaminant migration from a hypothetical site is provided. The parameter uncertainty is here addressed via a zonation approach wherein the model domain is subdivided into a number of zones and in each zone the uncertain parameter is assumed to be constant. The methodology provides a tool to aid decision-making, to prioritize aspects of site characterization, and to demonstrate compliance with regulatory criteria.

Author 1	Author 2	Facility or Agency
Waugh	Bullard	

Citation

Waugh, J., T. Bullard, et al., 2002. Characterization of the Environmental Envelope for the Design of Long-Term Covers. Three -Part Project Summary. SCFA Mid-year Review, Salt Lake City, UT.

Journal

Title

Characterization of the Environmental Envelope for the Design of Long-Term Covers.

Document	Year
	2002

Why	How	What	Where
Design	Performance	barrier	Unsaturated

Abstract

Author 1	Author 2	Facility or Agency
Waugh		

Citation

Waugh, W.J. 1997. Ecology of Uranium Mill Tailing Covers. In: Landfill capping in the semi-arid West: problems, perspectives and solutions. Environmental Science Research Foundation, Idaho. Pp. 199-212.

Journal

Title

Ecology of Uranium Mill Tailing Covers.

Document	Year
	1997

Why	How	What	Where
	Ecological		

Abstract

Author 1	Author 2	Facility or Agency
Webb	Conrad	

Citation

Webb, E. K., S. H. Conrad, et al., 1996. Iterative, Probabilistic Environmental Decision Analysis Approach. Proceedings of the 1995 7th Risk-Based Decision Making in Water Resources,Oct 8-13 1995, Santa Barbara,CA,USA.

Journal

Title

Iterative, Probabilistic Environmental Decision Analysis Approach.

Document	Year
	1996

Why	How	What	Where
Design	Performance		

Abstract

In order to provide a more cost-effective and open decision-making process for evaluating the safety of contaminated sites or proposed waste-management facilities, for selecting appropriate remedial activities, and for optimizing data collection and monitoring, Sandia National Laboratories is promoting a decision framework based on a form of probabilistic performance assessment. This framework is iterative and probabilistic, allowing a connection between performance analysis and data collection. Additionally, the framework focuses all activities on addressing the specified performance criteria, quantifies uncertainty in the decision, uses process-based simulation techniques, and most importantly provides a platform where the process of assessing decision alternatives is transparent to all, and thus supports multi-party decision making.

Author 1	Author 2	Facility or Agency
West		INEEL

Citation

West, W., 2002. Raw Data Report and Meeting Record from the Vadose Zone/Groundwater Uncertainties Prioritization Meeting. U.S. Department of Energy, INEEL/EXT- 02- 00529.

Journal

Title

Raw Data Report and Meeting Record from the Vadose Zone/Groundwater Uncertainties Prioritization Meeting

Document	Year
INEEL/EXT- 02- 00529	2002

Why	How	What	Where
Monitoring	Performance	mixed	Unsaturated

Abstract

The purpose of this document is to document and present the results of a Value Engineering Session held in Idaho Falls, Idaho on April 2 & 3, 2002 to prioritize vadose zone and groundwater uncertainties. These uncertainties were developed as part of the INEEL Vadose Zone/Groundwater Roadmapping task of the Water Integration Project. The uncertainties were developed over a two-year period by scientists and engineers knowledgeable in the areas of geosciences, flow and transport modeling, source term issues, and surface and groundwater issues. These uncertainties represent gaps in knowledge and capabilities for the vadose zone and groundwater at the INEEL. There were 25 uncertainties developed by utilizing the uncertainties from the document, "Uncertain Predictions of Contaminant Behavior at INEEL: A Roadmap for Addressing Current Limitations through Vadose Zone Studies, INEEL/EXT-2001-552, Draft, September 2001", and from an uncertainties validation meeting held in March 2002.

Twenty-four people participated in the Value Engineer Session to prioritize the uncertainties. These twenty-four represented public stakeholders, federal and state regulators, INEEL State Oversight, the United States Geological Survey, DOE Headquarters, DOE-ID, and BBWI. They had a wide range of backgrounds including concerned public, INEEL Operations, geoscience research, flow and transport modeling, geochemistry, contaminant experts, applied geosciences, agriculture, academia, and project management. These 25 people spent the two days discussing the uncertainties, developing criteria to be used in the prioritization, and prioritizing the uncertainties. All raw data and the happenings of the two days are presented in this document. The results of this ranking will be used to develop science strategies for integrating research and technology development and long term monitoring projects at the INEEL to more effectively achieve programmatic goals.

Author 1	Author 2	Facility or Agency
Whelan	McDonald	

Citation

Whelan, G., J. P. McDonald, et al., 1999. Benchmarking of the Saturated-Zone Module Associated with Three Risk Assessment Models: RESRAD, MMSOILS, and MEPAS. Environmental Engineering Science 16(1): 67-80.

Journal

Environmental Engineering Science 16(1): 67-80.

Title

Benchmarking of the Saturated-Zone Module Associated with Three Risk Assessment Models: RESRAD, MMSOILS, and MEPAS.

Document	Year
	1999

Why	How	What	Where
Modeling	Ground-Water		Saturated

Abstract

A comprehensive benchmarking is being performed between three multimedia risk assessment models: RESRAD, MMSOILS, and MEPAS. Each multimedia model is comprised of a suite of modules (e.g., groundwater, air, surface water, exposure, and risk/hazard), all of which can impact the estimation of the human health risk. As a component of the comprehensive benchmarking exercise, the saturated-zone modules of each model were applied to an environmental release scenario, where uranium-234 was released from the waste site to a saturated zone. Uranium-234 time-varying emission rates exiting from the source and concentrations at three downgradient locations (0, 150, and 1500 m) are compared for each multimedia model. Time-varying concentrations for uranium-234 decay products (e.g., thorium-230, radium-226, and lead-210) at the 1500-m location are also presented. Different results reported for RESRAD, MMSOILS, and MEPAS are solely due to the assumptions and mathematical constructs inherently built into each model, thereby impacting the potential risks predicted by each model. Although many differences were identified between the models, differences that impacted these benchmarking results the most are as follows: (1) RESRAD transports its contaminants by pure translation, and MMSOILS and MEPAS solve the one-dimensional advective, three-dimensional dispersive equation. (2) Due to the manner in which the retardation factor is defined, RESRAD contaminant velocities will always be faster than MMSOILS or MEPAS for long-lived contaminants. (3) RESRAD uses a dilution factor to account for a withdrawal well; MMSOILS and MEPAS were designed to calculate in situ concentrations at a receptor location. (4) RESRAD allows for decay products to travel at different velocities, while MEPAS assumes the decay products travel at the same speed as their parents. MMSOILS does not account for decay products and assumes degradation/decay only in the aqueous phase.

Author 1	Author 2	Facility or Agency
White		Hanford

Citation

White, J., 2001. Environmental Control Plan for Groundwater Well Services. U.S. Department of Energy, Report BHI-01407.

Journal

Title

Environmental Control Plan for Groundwater Well Services.

Document	Year
BHI-01407	2001

Why	How	What	Where

Abstract

This environmental control plan (ECP) is applicable to groundwater well services and related activities across the entire Hanford Site. Well services and related activities include well or aquifer sampling tube installation; groundwater well or aquifer sampling tube development; groundwater, aquifer sampling tube, and seep sampling; aquifer testing; well maintenance and decommissioning; and water-level measurements and other in situ measurements. These activities support three programs, which include the Resource Conservation and Recovery Act of 1976 (RCRA), the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), and the Atomic Energy Act, commonly referred to as the U.S. Department of Energy, Richland Operations Office (RL), site surveillance.

Integration of the groundwater well services is the responsibility of Bechtel Hanford, Inc. (BHI). BHI will ensure that subcontractors conduct work consistent with Environmental Restoration Contractor (ERC) procedures and this ECP, as appropriate.

The purpose of this ECP is to identify environmental requirements for groundwater well services and related activities. This ECP is a compilation of existing environmental and regulatory requirements applicable to well service activities that are identified in regulations and BHI documents and procedures. This ECP is intended to provide summary-level information to assist personnel assigned to the Groundwater/Vadose Zone Integration Project. As this ECP provides only an overview, the source documents (i.e., BHI procedures, subcontracts) should be consulted for detailed information regarding the requirements. If discrepancies arise between this ECP and the source documents, contact the Project Environmental Lead (PEL) and the Field Environmental Coordinator. The Field Environmental Coordinator is responsible for field implementation of this ECP.

Author 1	Author 2	Facility or Agency
White	Zegelin	

Citation

White, I. and S.J. Zegelin, 1994. Electric and Dielectric Methods for Monitoring Soil-Water Content. In "Handbook of Vadose Zone Characterization and Monitoring". L.G. Wilson, L.G. Everett and S.J. Cullen, editors. CRC Press, Inc.

Journal

Title

Electric and Dielectric Methods for Monitoring Soil-Water Content.

Document	Year
	1995

Why	How	What	Where
Monitoring	Devices	probes	Unsaturated

Abstract

Information on the temporal and spatial variations of the water content of soil and other porous materials is central to understanding and managing a host of hydrologic, environmental, meteorological, agricultural, engineering, and industrial processes. It has long been recognized that reliable, robust, and automated techniques for the in situ monitoring of soil-water content in these varied processes can be extremely useful, if not essential. Over the past 70 years this recognition has fostered the investment of a considerable amount of ingenuity in developing such techniques.

It is, of course, naïve to expect that a single technique will emerge which will satisfy all diverse needs for water content measurement. Rather, the selection of an appropriate technique or suite of techniques will depend on the specific application and the perceived strengths and weaknesses of the technique. It should also be appreciated that, while a knowledge of water content is adequate for many water balance studies, it may be insufficient for applications in which soil-water dynamics are required. There, it is the spatial gradient of the energy state of water in the material that determines flow, not the gradient of water content. To characterize soil-water flow the distribution of the soil-water potential is usually required as well.

The accepted standard technique for measuring the water content of porous materials involves oven drying a sample of the material at a prescribed temperature and sometimes for a prescribed time (Gardner, 1986). This inevitably involves destructive sampling. It is also time consuming and it therefore not well suited to in situ monitoring over extended periods or when “on-line” measurements are needed. For such instances indirect methods are needed.

...

In this chapter we review electric and dielectric techniques for determining soil-water content. We describe the principles underpinning the technique and examine critically their strengths and weaknesses. Electrical conductance and dielectric techniques are discussed. We include electrical conductivity, electromagnetic induction, moisture blocks, capacitance, time domain reflectometry (TDR), and microwave and radar techniques in our examination.

Author 1	Author 2	Facility or Agency
White	Ferns	NRC

Citation

White, G.J., T.W. Ferns, et al., 1990. Low-Level Radioactive Waste Disposal Facility Closure. Part I: Long-Term Environmental Conditions Affecting Low-Level Waste Disposal Site Performance; Part II: Performance Monitoring to Support Regulatory Decisions. U.S. Nuclear Regulatory Commission, NUREG/CR-5615, EGG-2604.

Journal

Title

Low-Level Radioactive Waste Disposal Facility Closure.

Document	Year
NUREG/CR-5615	1990

Why	How	What	Where

Abstract

Part I: Part I of this report describes and evaluates potential impacts associated with changes in environmental conditions on a low-level radioactive waste disposal site over a long period of time. Ecological processes are discussed and baselines are established consistent with their potential for causing a significant impact to a low-level radioactive waste facility. A variety of factors that might disrupt or act on long-term predictions are evaluated including biological, chemical, and physical phenomena of both natural and anthropogenic origin. These factors are then applied to six existing, yet very different, low-level radioactive waste sites. A summary and recommendations for future site characterization and monitoring activities is given for application to potential and existing sites.

Part II: Part II of this report contains guidance on the design and implementation of a performance monitoring program for low-level radioactive waste disposal facilities. A monitoring program is described and will continue to isolate the waste by remaining structurally stable. Monitoring techniques and instruments are discussed relative to their ability to measure (a) parameters directly related to water movement through engineered barriers, (b) parameters directly related to the structural stability of engineered barriers, and (c) parameters that characterize external or internal conditions that may cause physical changes leading to enhanced water movement or compromises in stability. Data interpretation leading to decisions concerning facility closure is discussed.

Author 1	Author 2	Facility or Agency
White		

Citation
White,

Journal

Title

Document	Year
NUREG/CR-5615	1990

Why	How	What	Where

Abstract

Author 1	Author 2	Facility or Agency
Wierenga	Young	

Citation

Wierenga, P.J., M.H. Young, et al., 1992. Soil Characteristic Methods for Unsaturated Low-Level Waste Sites. U.S. Nuclear Regulatory Commission Report. NUREG/CR-5988.

Journal

Title

Soil Characterization Methods for Unsaturated Low-Level Waste Sites

Document	Year
NUREG/CR-5988	1992

Why	How	What	Where
Design	Performance		Unsaturated

Abstract

To support a license application for the disposal of low-level radioactive waste (LLW), applicants must characterize the unsaturated zone. This requires an integrated plan to be developed for sampling and analyzing the soil horizons for physical hydraulic properties. This document provides a strategy for developing this characterization plan. It describes principles of contaminant flow and transport, site characterization and monitoring strategies, and data management. It also discusses methods and practices that are currently used to monitor properties and conditions in the soil profile, how these properties influence water and waste migration, and why they are important to the license application. The methods part of the document is divided into sections on laboratory and field-based properties, then further subdivided into the description of methods for determining 18 physical, flow, and transport properties. Because of the availability of detailed procedures in many texts and journal articles, the reader is often directed for details to the available literature. References are made to experiments performed at the Las Cruces Trench site, New Mexico, that support LLW site characterization activities. A major contribution form the Las Cruces study is the experience gained in handling data sets for site characterization and the subsequent use of these data sets in modeling studies.

Author 1	Author 2	Facility or Agency
Williams		

Citation

Williams, M.A., 1994. Discussion of 'Vadose Zone Monitoring with the Neutron Moisture Probe'. In "Handbook of Vadose Zone Characterization and Monitoring". L.G. Wilson, L.G. Everett and S.J. Cullen, editors. CRC Press, Inc.

Journal

Title

Discussion of 'Vadose Zone Monitoring with the Neutron Moisture Probe'.

Document	Year
	1995

Why	How	What	Where
Monitoring	Devices	probe	Unsaturated

Abstract

This chapter will clarify information incorrectly presented by Kramer et al., 1992, concerning the Soil Flushing Project (Case 2). In addition, the practical application of neutron monitoring and the monitoring tube design used at our client's facility will be discussed.

The article incorrectly states that the top 20 feet of soil will be excavated and removed. However, remedial alternatives concerning the top 20 feet have not yet been selected and will be addressed at a later time. The article also states that a vertical injection well was screened from 20 to 80 feet below land surface (bls). Actually, the pilot study injection wells were screened from 20 to 70 feet bls. Because the ground-water surface was at approximately 80 to 82 feet bls, the intention was to avoid direct interconnection between ground water and flushing water until the flushing water had moved laterally for some distance. The monitoring tube spacing is stated incorrectly in the text and on Figures 7 and 8. Monitoring tubes were spaced at 5, 10, and 20 feet from the injection well. Three additional monitoring tubes were located at approximately 26, 52, and 70 feet from the injection well.

Author 1	Author 2	Facility or Agency
Wilson	Dorrance	

Citation

Wilson, L.G., D.W. Dorrance, 1994. In Situ Pore-Liquid Sampling in Saturated Regions of the Vadose Zone. In "Handbook of Vadose Zone Characterization and Monitoring". L.G. Wilson, L.G. Everett and S.J. Cullen, editors. CRC Press, Inc.

Journal

Title

In Situ Pore-Liquid Sampling in Saturated Regions of the Vadose Zone.

Document	Year
	1995

Why	How	What	Where
Monitoring	Devices	wells	Saturated

Abstract

Saturated regions may occur in the vadose zone as perched ground water and possibly as water-table mounds. Perched ground water develops at the interface between regions of varying hydraulic conductivity, e.g., a coarse zone overlying a finer-textured zone (Everett et al., 1984, Wilson and Schmidt, 1979), while water-table mounds develop above a regional water table. Perched systems are underlain by unsaturated sediments. Figure 31.1 shows the growth of perched ground water and a water-table mound in stratified alluvium during a recharge event in the Santa Cruz River, an ephemeral stream near Tucson, Arizona (Wilson and Schmidt, 1979). The two regions were separated by an unsaturated transmission zone which remained at a water content sufficient to transmit vertical leakage from the perched system into the water table mound. Piezometers in both regions manifested positive pressures, yielding water samples. Elsewhere in this book, Schmidt discusses perched ground-water systems in more detail.

Sampling liquid from perched systems or mounds is attractive because liquid is collected over a large area. Such integrated samples are more representative of areal conditions than suction samples (Wilson and Schmidt, 1979). In addition, larger sample volumes can be collected than with suction samplers.

Perched water systems and mounds can be difficult to find and delineate. Possible methods fro locating saturated regions in the vadose zone include nuclear logging (Poeter, 1988) and video logging of existing wells. Perched systems tend to be ephemeral; therefore, suction samplers are sometimes required as a backup. As with all samplers, potential chemical interactions between sampler materials and the constituents of interest should be considered (Dunlap, 1977).

Following are the methods for sampling perched ground water discussed in this section:
- point samplers
- multi-level samplers
- wells
- cascading water samplers
- drainage systems

Except for cascading water samplers and possibly drainage samplers, these methods are commonly used for monitoring ground water and aquifers.

Author 1	Author 2	Facility or Agency
Wilson	Glass	EMSP

Citation

Wilson, J., R. Glass, et al., Permeameters for in situ Characterization of Unsaturated Heterogeneous Permeability.

Journal

Title

Permeameters for in situ Characterization of Unsaturated Heterogeneous Permeability.

Document	Year

Why	How	What	Where
Characterization	Devices	probe	Unsaturated

Abstract

Thick unsaturated zones underlie many Department of Energy (DOE) landfills, industrial areas, and waste storage sites in the western United States and are the primary pathway for contaminants to migrate into underlying aquifers. The spatial variability of unsaturated hydraulic properties in these heterogeneous geologic materials directly influences the movement of water and non-aqueous phase liquids (NAPLs). Poor characterization of heterogeneity may lead to ineffective remedial designs and increased risk, requiring subsequent additional remedial actions at increased cost and time. Remedial design can be improved using probabilistic risk-based decisions analysis, which requires a large number of hydraulic property observations. Laboratory methods for estimating the unsaturated permeability are expensive, time-consuming and may not yield results representative of heterogeneous field conditions. Simple and rapid field methods for estimating in situ unsaturated permeability are appealing and potentially cost-effective.

The primary objective of our EMSP research is to design, develop, and test new permeameters for use in spatial variability studies. We have established a series of permeameter design criteria, including: 1) measurements should be relatively rapid, 2) the total cost per data point should be low, 3) results would accurately reflect the variation of unsaturated hydraulic properties between sampled locations, 4) the volume sampled (measurement support) would be small, and 5) useful range would be relevant to the range of soil moisture conditions encountered at DOE sites.

Author 1	Author 2	Facility or Agency
Wilson	Dorrance	

Citation

Wilson, L.G., D.W. Dorrance, et al., 1994. In Situ Pore-Liquid Sampling in the Vadose Zone. In "Handbook of Vadose Zone Characterization and Monitoring". L.G. Wilson, L.G. Everett and S.J. Cullen, editors. CRC Press, Inc.

Journal

Title

In Situ Pore-Liquid Sampling in the Vadose Zone.

Document	Year
	1995

Why	How	What	Where
Monitoring	Devices	mixed	Unsaturated

Abstract

Reasons for sampling pore-liquids in the vadose zone include determining contaminant concentration/mass trends in time and depth, detection of contaminants, and tracing ontaminant flow paths (Starr et al., 1991). Pore-liquid samples can be obtained either by direct, in situ methods (e.g., tile lines, pan lysimeters, and wells, for saturated regions, and suction samplers for unsaturated regions), or by indirect methods, e.g., soil core samples. A major difference between these two approaches is that core sampling methods are destructive, i.e., repetitive samples cannot be obtained from the same location. More importantly, as pointed out by Dorrance et al. (1991), the two techniques do not sample the same types of liquid. In situ samplers generally sample pore-liquids held under tensions below about 60 kilopascals (kPa) *** (Everett and McMillion, 985). In contrast, pore-liquids extracted from soil cores include liquids held at tensions far in excess of 60 kPa. Extraction under several bars of (equivalent) tension may strip off cations preferentially sorbed in electrical double layers, sorbed organic compounds, and native soil components. These ions may or may not be present in the same concentrations in samples obtained by in situ pore-liquid samplers. Thus, Zabowski and Ugolini (1990) found solute concentrations in liquids obtained by centrifuging core samples were frequently higher than those from suction samplers. They concluded that solutions from suction samplers are more representative of solute movement than core-derived samples.

Brown et al, (1990) evaluated the effectiveness of soil-core versus soil-pore water samplers for detecting the movement of organic constituents from land-treated industrial wastes. Based on t his study, they advised using both soil-core sampling and soil-pore liquid sampling to effectively detect the movement of a wide spectrum of organic chemicals. If sampling for known organic chemicals, they suggested using values of the organic carbon partition coefficient (Koc) of the chemicals as a means of choosing the sampling method. Specifically, soil pore-liquid sampling is the method of choice for detecting those N-alkanes with log Koc values less than (<) 4.4; polynuclear aromatics <3; chlorophenols (mono-, di-, and tri-) <4; nitrophenols (mono-, di-) , 2.3; and aromatics <3.3. N-alkanes with log Koc values between 4.8 and 6.2 are detected equally well with either method. Otherwise, soil-core sampling is recommended for these chemicals when their log Koc values are greater than those listed.

Author 1	Author 2	Facility or Agency
Winsor	Wicker	

Citation

Winsor, T.F. and F.W. Wicker, 1980. Pocket Gophers and Redistribution of Plutonium in Soil. Health Physics 39: 257-262.

Journal

Health Physics 39: 257-262.

Title

Pocket Gophers and Redistribution of Plutonium in Soil.

Document	Year
	1980

Why	How	What	Where
Characterization	Ecological		Surface

Abstract

Author 1	Author 2	Facility or Agency
Wittmeyer	Ferrill	

Citation

Wittmeyer, G.W. and D.A. Ferrill, 1994. Effects of Contemporary Regional Stress on the Anisotropy of Transmissivity in Fractured Rock Aquifers, EOS, Transactions, American Geophysical Union, Vol. 75, No. 44, pp. 258.

Journal

American Geophysical Union, Vol. 75, No. 44, pp. 258

Title

Effects of Contemporary Regional Stress on the Anisotropy of Transmissivity in Fractured Rock Aquifers

Document	Year
	1994

Why	How	What	Where
Modeling	Ground-Water		Saturated

Abstract

Author 1	Author 2	Facility or Agency
Wittmeyer	Turner	

Citation

Wittmeyer, G.W. and D.R. Turner, 1995. Conceptual and Mathematical Models of the Death Valley Regional Groundwater Flow System.Center for Nuclear Waste Regulatory Analyses. San Antonio, TX. CNWRA 95 019.

Journal

Title

Conceptual and Mathematical Models of the Death Valley Regional Groundwater Flow System

Document	Year
CNWRA 95 019	1995

Why	How	What	Where
Modeling	Ground-Water		Saturated

Abstract

Author 1	Author 2	Facility or Agency
Woldt	Bogardi	

Citation

Woldt, W. and I. Bogardi, 1992. Ground Water Monitoring Network Design Using Multiple Criteria Decision Making and Geostatistics. Water Resources Bulletin 28(1): 45-62.

Journal

Water Resources Bulletin 28(1): 45-62.

Title

Ground Water Monitoring Network Design Using Multiple Criteria Decision Making and Geostatistics

Document	Year
	1992

Why	How	What	Where
Design	Optimization	geostatistics	Saturated

Abstract

A multi-criteria approach to ground water quality monitoring network design is developed. The methodology combines multi-criteria decision making (MCDM) and modifications of geostatistical variance reduction analysis. Composite programming, a distance based optimization algorithm that employs a hierarchial structure, is used for the MCDM component of the design methodology. The methodology is useful for identifying the preferred combination of direct borehole and indirect geoelectric data. It also permits the use of prior information during initial stages of network development. Multi-variate kriging is employed to evaluate network performance using the combination of direct borehole data and indirect geoelectric data. Weighted measures of estimation variance are used as primary measures of performance, with the reduction in estimation variance being computed by the fictitious point method. Case study results demonstrate that the network design methodology can be used in both early and late phases of network development. It also leads to selection of the preferred combination and spatial orientation of direct and indirect data sources while considering cost-effectiveness and performance of alternative designs.

Author 1	Author 2	Facility or Agency
Wolka		

Citation

Wolka, K. K., 1997. Emerging Ideas: Site-specific Benefit-cost Analysis for Environmental Remediation Projects. Practice Periodical of Hazardous, Toxic, and Radioactive Waste Management 1(2): 47-49.

Journal

Practice Periodical of Hazardous, Toxic, and Radioactive Waste Management 1(2): 47-49.

Title

Emerging Ideas: Site-specific Benefit-cost Analysis for Environmental Remediation Projects.

Document	Year
	1997

Why	How	What	Where
Design	Optimization		

Abstract

Author 1	Author 2	Facility or Agency
Wolkenhauer	Edmunds	

Citation

Wolkenhauer, O. and J. Edmunds, 1997. Dynamic Systems Reliability Evaluation Using Uncertainty Techniques for Performance Monitoring. IEE Proceedings: Control Theory and Applications 144(1): 103-108.

Journal

Title

Dynamic Systems Reliability Evaluation Using Uncertainty Techniques for Performance Monitoring.

Document	Year
	1997

Why	How	What	Where
Design	Performance		

Abstract

The authors suggest the use of fuzzy measures and fuzzy integrals in evaluating the reliability of control systems by approximating an experts view on a complex system when assessing the performance. The class of systems considered have structural complexity exhibiting a closed-form model of the underlying process. The approach may be described in three parts where in the first stage a rule-based classifier (`spy') extracts `states of performance' from the process. It is shown that the rule-premise resembles a possibility based control chart and that the possibilistic version, embedded in a rule-based system, offers a comprehensive man-process interface while having a similar or slightly improved speed of detection. The reliability can be quantified based on a finite set of abstract states over which a certainty measure is defined. A prediction for a specified reliability interval of time is done by using a qualitative model akin to Markov stochastic processes and consequently decisions are made to alter the system structure. This framework allows distinct classes of uncertainty to be considered.

Author 1	Author 2	Facility or Agency
Wood		INEEL

Citation

Wood, T. R., 1990. Impact of Surface Water Recharge on the Design of a Groundwater Monitoring System for the Radioactive Waste Management Complex. Idaho National Engineering Laboratory. Proceedings of the 1990 Annual Symposium on Engineering Geology & Geotechnical Engineering, April 1990, Pocatello, ID, USA.

Journal

Title

Impact of Surface Water Recharge on the Design of a Groundwater Monitoring System for the Radioactive Waste Management Complex. Idaho National Engineering Laboratory.

Document	Year
	I990

Why	How	What	Where
Modeling	Uncertainties		Saturated

Abstract

Recent hydrogeologic studies have been initiated to characterize the hydrogeologic conditions at the Radioactive Waste Management Complex (RWMC) at the Idaho National Engineering Laboratory (INEL). Measured water levels in wells penetrating the Snake River Plain aquifer near the RWMC and the corresponding direction of flow show change over time. This change is related to water table mounding caused by recharge from excess water diverted from the Big Lost River for flood protection during high flows. Water levels in most wells near the RWMC rise on the order of 10 ft (3 m) in response to recharge, with water in one well rising over 60 ft (18 m). Recharge changes the normal south-southwest direction of flow to the east. Design of the proposed groundwater monitoring network for the RWMC must account for the variable directions of groundwater flow.

Author 1	Author 2	Facility or Agency
Wood	Bates	INEEL

Citation

Wood, T.R., D. Bates, et al., 2000. Deficiencies in Vadose Zone Understanding at the Idaho National Engineering and Environmental Laboratory.

Journal

Title

Deficiencies in Vadose Zone Understanding at the Idaho National Engineering and Environmental Laboratory

Document	Year
INEEL/EXT-99-00984	2000

Why	How	What	Where
Characterization	Uncertainties		Unsaturated

Abstract

Subsurface contamination in the vadose zone, that portion of the subsurface pathway between land surface and an underlying aquifer, poses environmental problems at the Idaho National Engineering and Environmental Laboratory (INEEL) in eastern Idaho and across the U.S. Department of Energy complex. Assessing potential adverse impacts from these contaminated sites requires an understanding of the mechanisms controlling contaminant transport. Currently, vadose zone experts at the INEEL cannot with confidence predict the movement of water and contaminants in the complex, heterogeneous, fractured subsurface at the INEEL, especially within the vadose zone.

In the draft version (Revision 1) of the Vadose Zone Deficiencies document, deficiencies in scientific understanding of flow and transport processes in the vadose zone at the INEEL were identified and grouped into 13 categories and recommendations were provided to address each of the deficiencies. The draft document provided the basis for an INEEL Vadose Zone Workshop that was conducted October 20 and 21, 1999, in Idaho Falls, Idaho. The workshop was conducted to group and rank the previously identified deficiencies and for the subsequent development of science plans to address the deficiencies that limit reliable predictions of water and contaminant movement in the subsurface.

The workshop participants, comprising INEEL and scientists and project managers and non-INEEL scientists knowledgeable about the vadose zone, developed science- and technology-based recommendations derived through a series of technical sessions at the workshop. In this document, the final version of the Vadose Zone Deficiencies document, the draft document has been incorporated, largely intact, as well as the results from the workshop. The workshop participants grouped the deficiencies in vadose zone understanding at the INEEL into seven categories. These seven categories will be the focus areas of five science plans that are being developed to address the deficiencies. This document lays the foundation for the INEEL Site-wide vadose zone roadmap.

Author 1	Author 2	Facility or Agency
Yanagihara	Shiraishi	

Citation

Yanagihara, S., K. Shiraishi, et al., 1997. Systems Engineering Approach to Planning and Evaluation of Nuclear Power Plant Decommissioning. Proceedings of the 1997 5th International Conference on Nuclear Engineering, ICONE5,May 25-29 1997, Nice, Fr, ASME,New York,NY,USA.

Journal

Title

Systems Engineering Approach to Planning and Evaluation of Nuclear Power Plant Decommissioning.

Document	Year
	1997

Why	How	What	Where
Design			

Abstract

Author 1	Author 2	Facility or Agency
Yang	LaBrecque	Socorro

Citation

Yang, X., D. LaBrecque, et. al., 2000. Estimation of 3-D Moisture Content Using ERT Data at the Socorro-Tech Vadose Zone Facility. Proceedings of the Symposium on the Application of Geophysics to Engineering and Environmental Problems, Feb. 20-24, 2000, Arlington, VA.

Journal

Title

Estimation of 3-D Moisture Content Using ERT Data at the Socorro-Tech Vadose Zone Facility.

Document	Year
	2000

Why	How	What	Where
Monitoring	Geophysical	electricial resistivity tomograp	Unsaturated

Abstract

We developed a novel cokriging approach to convert electrical conductivity derived from three-dimensional (3-D) electricial resistivity tomography (ERT) data and neutron-derived moisture content into a 3-D moisture content distribution. This provided a complete picture about the water movement in an infiltration experiment at the Socorro-Tech vadose zone (STVZ) facility in Socorro, New Mexico.

3-D hydrological monitoring is extremely expensive due to the number of boreholes required to accurately image the area. ERT, however, is a fast and inexpensive technique designed to estimate the 3-D moisture content distribution and monitor an advancing wetting front. A vadose zone field site was built to test both hydrological and geophysical techniques for vadose zone monitoring. Thirteen neutron boreholes were installed at the site for direct measurements of moisture content and eight vertical electrode arrays were installed for ERT measurements.

Cokriging results indicated that 3-D electrical conductivity data together with neutron-derived moisture contents provided an excellent estimate of the 3-D moisture content distribution. The effect of the number of neutron wells used for the cokriging was investigated to determine the optimum results for the least input. We found that a neutron well in the center of ERT mesh where no VEA exists played an indispensable role in cokriging estimates. The center neutron well along with the ERT data provided a fairly good result for limited amount of data used. The results suggest that cokriging of ERT and neutron data is a fast and effective technique for obtaining the 3-D in-situ moisture content distribution and for 3-D monitoring of an advancing wetting front.

Author 1	Author 2	Facility or Agency
Yeh	Guzman-Guzman	

Citation

Yeh, T.-C. J. and A. Guzman-Guzman, 1994. Tensiometry. In "Handbook of Vadose Zone Characterization and Monitoring". L.G. Wilson, L.G. Everett and S.J. Cullen, editors. CRC Press, Inc.

Journal

Title

Tensiometry.

Document	Year
	1995

Why	How	What	Where
Monitoring	Devices	tensiometer	Unsaturated

Abstract

Movement of water in the vadose zone (i.e., the variably saturated zone above the regional ground-water table) is of considerable interest in studies of landfill and hazardous waste sites, ground-water recharge investigations, irrigation management, and civil engineering projecs. Many of these studies have relied on soil water content measurements which are useful for many purposes. However, evaluation of the energy status of the soil water in the vadose zone is necessary for defining the direction of water and contaminant movement, and studying the soil-water-plant relationship.

Author 1	Author 2	Facility or Agency
Yeh	Simunek	

Citation

Yeh, T-C. J., J. Simunek, 2002. Stochastic Fusion of Information for Characterizing and Monitoring the Vadose Zone. Vadose Zone Journal 1:207-221.

Journal

Vadose Zone Journal 1:207-221 (2002

Title

Stochastic Fusion of Information for Characterizing and Monitoring the Vadose Zone

Document	Year
	2002

Why	How	What	Where
Modeling			Unsaturated

Abstract

Inverse problems for hydrological processes in the vadose zone are often perceived as being ill posed and intractable. Consequently, solutions to the inverse problems are frequently subject to skepticism. In this paper, we examine the necessary and sufficient conditions for the inverse problems to be well posed and discuss difficulties associated with solving the inverse problems. We subsequently explain the need for a stochastic conceptualization of inverse problems of the vadose zone. Principles of geostatistically based inverse approaches, which rely on stochastic concepts, are then illustrated, including cokriging, a sequential linear estimator, and a successive linear estimator. We then discuss applications involved in the approaches to classical vadose zone inversion problems (using observed pressure heads, moisture contents, concentrations, and arrival times), hydraulic tomography, and electrical resistivity tomography for vadose zone characterization and monitoring. Finally, we present a stochastic information fusion technology that assimilates information from both unsaturated hydraulic tomography and electrical resistivity tomography. Preliminary results suggest that this fusion technology is a promising tool for effectively characterizing heterogeneity, monitoring processes in the vadose zone, and quantifying uncertainties associated with vadose zone characterization and monitoring.

Author 1	Author 2	Facility or Agency
Yoder	Wilkerson	

Citation

Rainwater, N.R., R.E. Yoder, et al., 1998. Automatic Sampling of Perched Water from Vadose Zone Shallow Wells. Applied Engineering in Agriculture, 14 (4) 399-406.

Journal

Applied Engineering in Agriculture, 14 (4) 399-406.

Title

Automatic Sampling of Perched Water from Vadose Zone Shallow Wells.

Document	Year
	1998

Why	How	What	Where
Monitoring			Unsaturated

Abstract

Author 1	Author 2	Facility or Agency
Young	Warrick	Maricopa

Citation

Young, M.H., Warrick, A.W., et al., 1999. Comparing Monitoring Strategies at the Maricopa Environmental Monitoring Site, Arizona. U.S. Nuclear Regulatory Commission Report. NUREG/CR-5698.

Journal

Title

Comparing Monitoring Strategies at the Maricopa Environmental Monitoring Site, Arizona.

Document	Year
NUREG/CR-5698	1999

Why	How	What	Where
Monitoring		comparison	

Abstract

The purpose of this document is to discuss the alternative monitoring strategies used during field experiments at the Maricopa Environmental Monitoring site, Maricopa, AZ. The strategies used at Maricopa were selected so that they could potentially be incorporated into monitoring programs at Low Level Waste disposal facilities. Although the evaluation of the strategies was mostly qualitative in nature, they were supported by data collected during two, field-scale infiltration experiments. The results of the field experiments with respect to water movement and tracer migration were presented in a companion NUREG report (NUREG/CR-5694). The emphasis was on monitoring in the vadose zone.

This document describes and compares four monitoring strategies that were implemented at the Maricopa site. They were designated as Monitoring Trenches, Monitoring Islands, Borehole Monitoring, and Geophysical Monitoring. The strengths and weaknesses of each strategy were described with respect to installation, maintenance and replacement of monitoring systems and instruments. Monitoring Trenches and Islands provide excellent opportunities for specific placement of monitoring instruments, with the possibility of direct observation of undisturbed soil material. Borehole Monitoring is more flexible with respect to depth of installation than the other three strategies. Maintenance of monitoring instruments in the Monitoring Trenches and Borehole Monitoring is not always possible because instruments are often backfilled in place. Some techniques used to support the Geophysical Monitoring strategy (e.g., electroresistive borehole tomography) suffer from the same infeasibility. Instrument maintenance in the Monitoring Islands is easier if the island is not backfilled. Limiting access to undisturbed soil, especially with respect to the Monitoring Trenches and Borehole Monitoring strategies, will also make instrument replacement more difficult. Portability of surface geophysical instruments used during the infiltration experiments removes several restrictions on maintenance and replacement.

The document also presents the concept of primary performance measures (e.g., water content, water tension and solute concentration), each of which directly influences water movement and contaminant migration from disposal sites. The majority of commercially available monitoring instruments measure secondary performance measures, which are soil water conditions that are converted to primary measures using calibration curves. Unfortunately, each instrument has different operational limitations and sensitivities, which depend on the soil water environment. Therefore, it is recommended to use multiple instruments whose data convert to the same primary performance measures. This should improve the confidence that changes in soil water conditions are real and not affected by the monitoring systems themselves.

Author 1	Author 2	Facility or Agency
Young	Wierenga	Maricopa

Citation

Young, M.H., P.J. Wierenga, A.W. Warrick, L.L. Hofmann, S.A. Musil, M. Yao, C.J. Mai, Z. Zou, and B.R. Scanlon. 1999. Results of Field Studies at the Maricopa Environmental Monitoring Site, Arizona. U.S. Nuclear Regulatory Commission Report. NUREG/CR-5694.

Journal

Title

Results of Field Studies at the Maricopa Environmental Monitoring Site, Arizona.

Document	Year
NUREG/CR-5694	1999

Why	How	What	Where
Monitoring			

Abstract

The purpose of this study was to evaluate issues related to alternative monitoring strategies for sites containing low level radioactive wastes. The study consisted of a theoretical evaluation of monitoring strategies and field studies. This NUREG reports on the field activities and the results of the field experiments.

A field site, located at the Maricopa Agricultural Center (Maricopa, AZ) was designed for conducting controlled water flow and solute transport studies, and for testing the strengths and weaknesses of four monitoring strategies designated as 1) Monitoring Trench, 2) Monitoring Island, 3) Borehole Monitoring, and 4) Geophysical Monitoring. Field instrumentation was extensive, and designed to support alternative monitoring strategies. Two experiments were conducted at the site covering the time frame from Spring 1997 through Summer 1998. During Experiment 1, water was applied at an average flux of 1.85 cm/d to the 50 m by 50 m field plot for 24 days, with bromide tracer added for the first 15 days. The water application period was followed by a redistribution period of 69 days. During Experiment 2, water was applied at an average rate of 1.97 cm/d for 33 days with a redistribution period of 177 days. Field experiments ended officially on July 1, 1998.

Water movement across the plot was spatially variable during Experiment 1, due mostly to variability in the initial water content, and thus, the soil's hydraulic properties. The results of intrusive and non-intrusive instruments showed that 1) water movement in the western portion of the site was faster than the eastern portion; 2) a zone of more rapid water flow was observed near the northern and central areas of the plot, as confirmed using several types of instruments; and 3) the variability of water movement, as measured using a neutron probe, decreased with increasing depth. During Experiment 2, spatial variability of water movement was significantly reduced in surface soils (< 1.5 m), from a CV = 41.8% to 4.7 % between Experiments 1 and 2, respectively. The reduced variability was observed because of the flux-controlled water application led to more uniform hydraulic property fields, and thus, more uniform water movement. Most of the monitoring systems performed well during the field experiments. Though some data were lost (of considered unreliable) due to electrical problems with the AC power supply and corrosion of electrical connections, an extensive data set was compiled and found useful for comparing monitoring strategies.

Author 1	Author 2	Facility or Agency
Young	Stirewalt	

Citation

Young, S.R., G.L. Stirewalt, et al., 1991. Computer-Assisted Geometric and Kinematic Analysis of Subsurface Faulting in the Vicinity of Yucca Mountain, Nevada, Using Balanced Geologic Cross-Sections. Proceedings of the Second International Conference on High-Level Radioactive Waste Management, American Nuclear Society, La Grange Park, Illinois, Vol. 1, pp.

Journal

Title

Computer-Assisted Geometric and Kinematic Analysis of Subsurface Faulting in the Vicinity of Yucca Mountain, Nevada, Using Balanced Geologic Cross-Sections.

Document	Year
	1991

Why	How	What	Where
Modeling	Geological		Structure

Abstract

Author 1	Author 2	Facility or Agency
Zachara		

Citation

Zachara, J.M, J. K. Fredrickson, et al., 2001. Biogeochemical Processes Controlling Metal Ion Fluxes From FE(III) Oxides During Reductive Phase Transformations. Eleventh Annual V. M. Goldschmidt Conference.

Journal

Title

Biogeochemical Processes Controlling Metal Ion Fluxes From FE(III) Oxides During Reductive Phase Transformations.

Document	Year
	2001

Why	How	What	Where
Characterization			

Abstract

Poorly crystalline Fe(III) oxides are common secondary weathering products found in soil subsurface, and geologic materials. They function as sorbents for contaminants and nutrients, act as redox and proton buffering phases for porewater, and are precursors for the formation of crystalline Fe(III) oxides (goethite, hematite). Dissimilatory iron reducing bacteria (DIRB) can utilize poorly crystalline Fe(III) oxides as electron acceptors under reducing condition leading to phase transformations of the oxide and complex, poorly understood geochemical behavior for associated (adsorbed, coprecipitated) minor ions.

Author 1	Author 2	Facility or Agency
Zhu	Mohanty	

Citation

Zhu, and S. Mohanty, 2002. Spatial Averaging of van Genuchten Hydraulic Parameters for Steady-State Flow in Heterogeneous Soils: A Numerical Study. Vadose Zone Journal 1:261- 272

Journal

Vadose Zone Journal 1:261- 272

Title

Spatial Averaging of van Genuchten Hydraulic Parameters for Steady-State Flow in Heterogeneous Soils: A Numerical Study

Document	Year
	2002

Why	How	What	Where
Modeling	Uncertainties		Unsaturated

Abstract

For meso- or regional-scale Soil-Vegetation-Atmosphere Transfer (SVAT) schemes in hydroclimatic models, pixel dimensions may range from several hundred square meters to several hundred square kilometers. Pixel-scale soil hydraulic parameters and their accuracy are critical for the success of hydroclimatic and soil hydrologic models. This study tries to answer a major question: What will be the effective and average hydraulic properties for the entire pixel (or footprint of a remote sensor) consisting of several textures if the soil hydraulic properties can be estimated for each individual texture? In this study, we examined the impact of areal heterogeneity in soil hydraulic parameters on soil ensemble behavior for steady-state evaporation and infiltration. Using the widely used van Genuchten model and hydraulic parameter statistics obtained from neural network-based pedotransfer functions (PTFs) for various soil textural classes, we address the impact of areal hydraulic property heterogeneity on ensemble behavior for uncertainty in steady-state vertical flow in large-scale heterogeneous fields. The various averaging schemes of van Genuchten parameters
are compared with "effective parameters" calculated by conceptualizing the areally heterogeneous soil formation as an equivalent homogeneous medium that will discharge approximately the same amount of ensemble flux of the eterogeneous soil. The impact of boundary conditions and parameter correlation on the effective parameters, as well as the accuracy and uncertainty of the averaging schemes for the hydraulic parameters, are investigated and discussed.
In light of our results, we suggest the following guidelines for van Genuchten hydraulic parameter averaging: arithmetic means for Ks and n, a value between arithmetic and geometric means for alpah when Ks and alpha are highly correlated, and a value between geometric and harmonic means for alpha when Ks and alpha are poorly correlated.

Author 1	Author 2	Facility or Agency
Zohdy	Eaton	

Citation

Zohdy, A.A.R., G.P. Eaton, et al., 1984. Techniques of Water Resources Investigations of the United States Geological Survey, Chapter D1: Application of Surface Geophysics to Ground-Water Investigations. U.S. Govt. Printing Office, Washington, DC.

Journal

Title

Techniques of Water Resources Investigations of the United States Geological Survey, Chapter D1: Application of Surface Geophysics to Ground-Water Investigations.

Document	Year
	1984

Why	How	What	Where

Abstract

This manual reviews the standard methods of surface geophysics applicable to ground-water investigations. It covers electrical methods, seismic and gravity methods, and magnetic methods.

The general physical principles underlying each method and its capabilities and limitations are described. Possibilities for non-uniqueness of interpretation of geophysical results are noted. Examples of actual use of the methods are given to illustrate applications and interpretation in selected geohydrologic environments.

The objective of the manual is to provide the hydrogeologist with a sufficient understanding of the capabilities, limitations, and relative cost of geophysical methods to make sound decisions as to when use of these methods is desirable. The manual also provides enough information for the hydrogeologist to work with a geophysicist in designing geophysical surveys that differentiate significant hydrogeologic changes.