Evaluating Monitoring Systems and Strategies for the Unsaturated Zone

- Project initiated by USNRC in 1997 to develop an integrated and systematic strategy for monitoring unsaturated zone flow and transport to the underlying water-table aquifer that will confirm nuclear waste and decommissioning site performance.
- Goals of project:
  - To provide early warning of releases of contaminants (e.g., radionuclides) from disposal sites before they reach the facility boundary
  - To design a system that reduces or eliminates active maintenance, and one that emphasizes protection of the facility during potential future replacement of instruments
  - To use strategies that focus on redundant observations of performance measures, reducing the dependency of the program on a single monitoring system

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Definitions

- Definition of monitoring - Code of Federal Regulations, 1990, 10 CFR 61, Subpart A: “Monitoring” means observing and making measurements to provide data to evaluate the performance and characteristics of the disposal site.
- Other definitions:
  - Monitoring program - a set of monitoring strategies, including data collection intervals, analytical methods and data analysis
  - Monitoring strategy - a set of monitoring systems that emphasize a specific concept or philosophy
  - Monitoring system - a system that collects the output of sensors (Dictionary of Science and Technology, Academic Press, 1992)
  - Monitoring instrument - a device or sensor that collects information about the site environs

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Description of Monitoring Philosophies

- Monitoring Trenches – potentially long, wide or narrow trenches into which instruments can be installed. Trenches can be installed at base of disposal site, or near ground surface, but typically is backfilled to prevent preferential flow
- Monitoring Islands – large diameter boreholes drilled vertically into the soil, allowing monitoring instruments to be installed into undisturbed material
- Borehole Monitoring – vertical and/or horizontal boreholes used for monitoring with either fixed or mobile instruments
- Geophysical Monitoring – combination of intrusive and non-intrusive techniques for measuring bulk electrical properties of subsurface material

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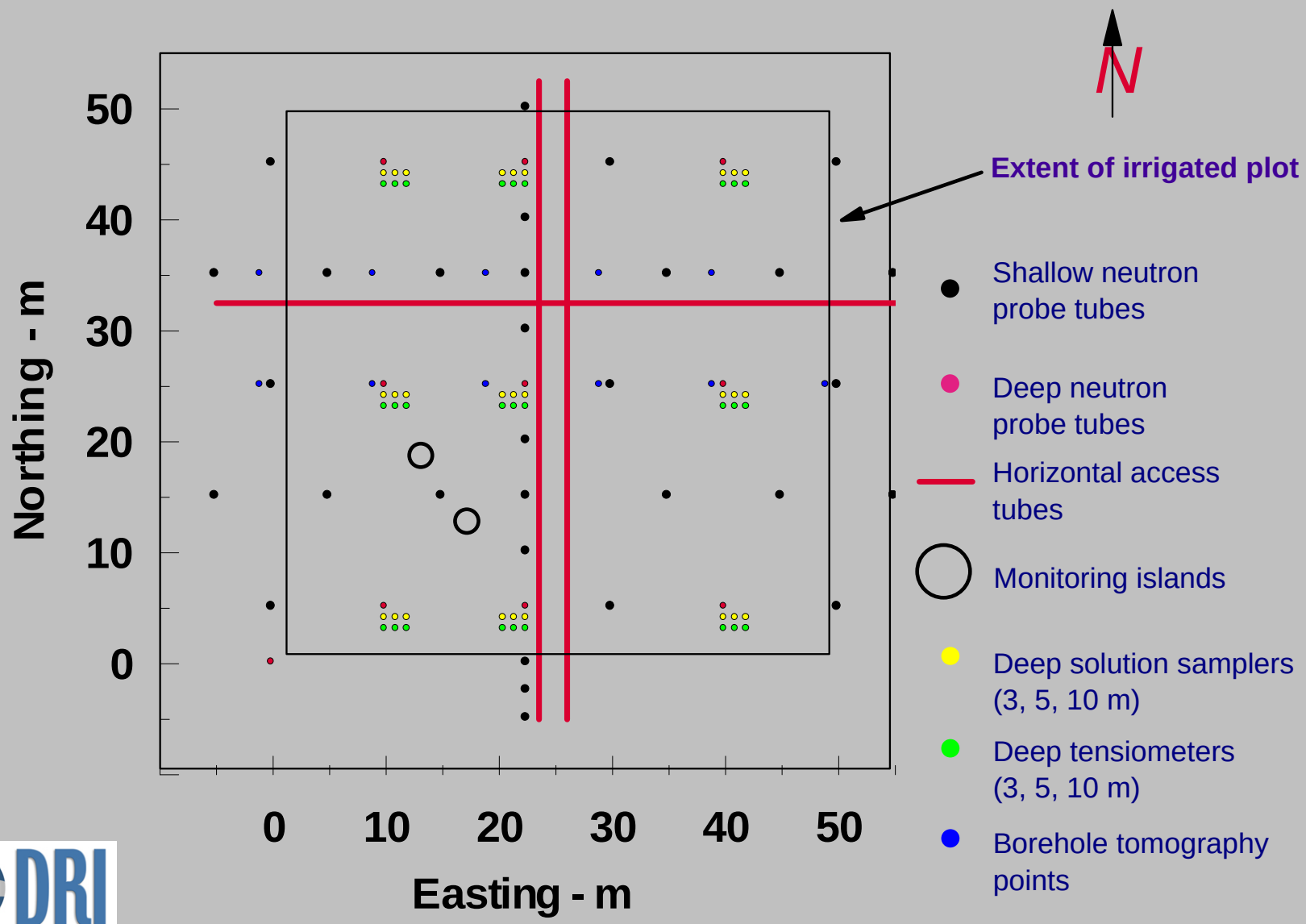
General Site Layout at Maricopa Site



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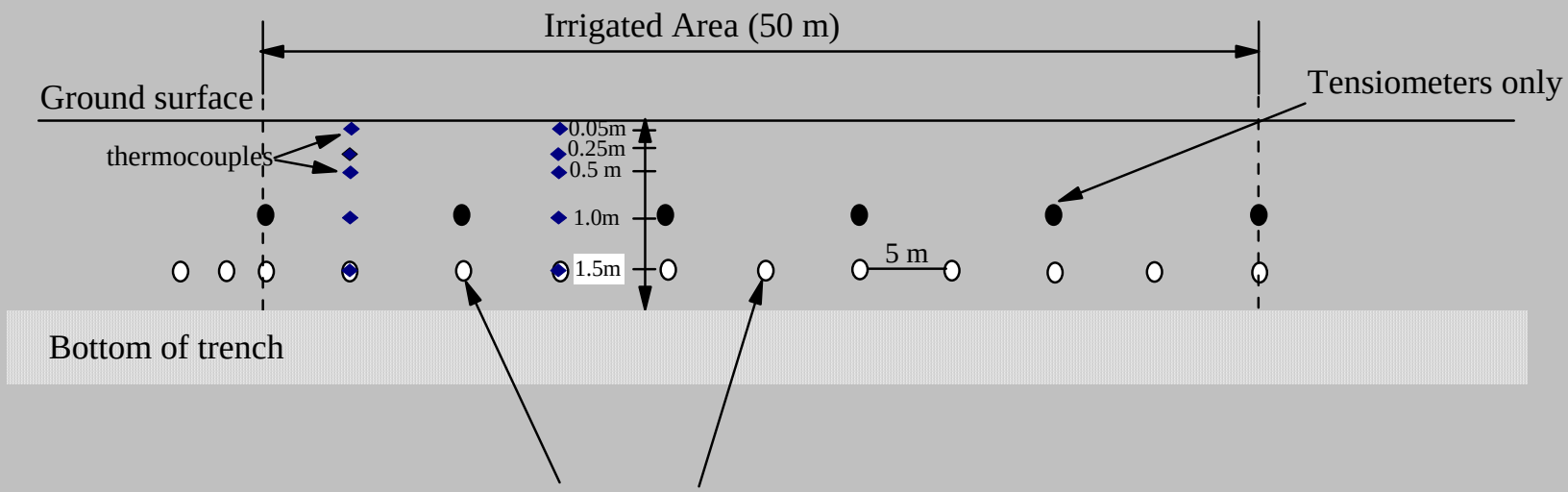
Monitoring Trenches



Monitoring locations containing each device listed in box.

Total Number of Devices In Trench Transect

Thermocouple Psychrometer	13
TDR Probe	13
Tensiometer	19
Heat Dissipation Sensor	13
Stainless Steel Solution Sampler	13
Ceramic Solution Sampler	13
Thermocouples	10

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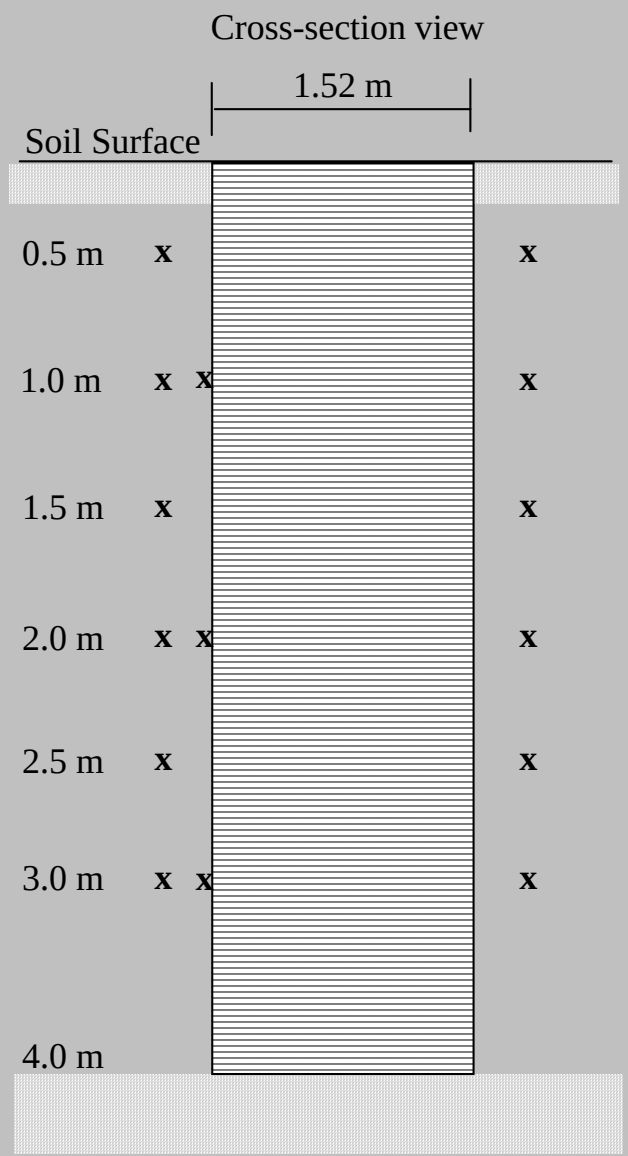
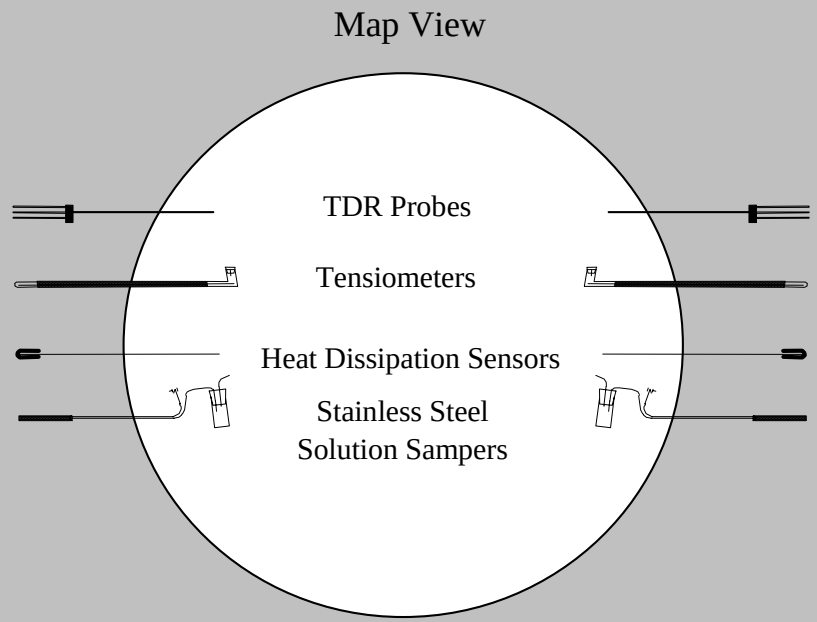
Monitoring Islands





Number of devices in each island

Tensiometer	15
TDR Probe	15
Heat Dissipation Probe	15
Stainless Steel Solution Sampler	15

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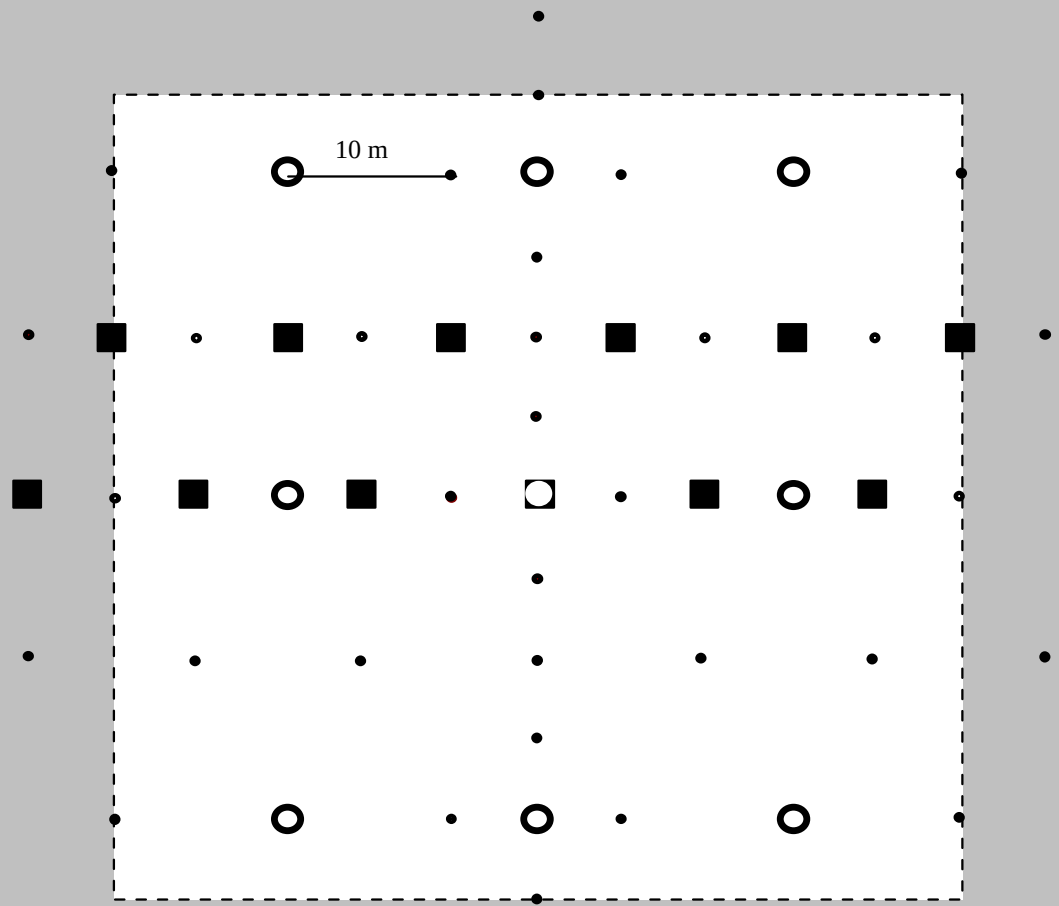
Borehole/Geophysics Monitoring



Legend:

- shallow access tube - 34
- deep access tube - 9
- ERBT borehole - 12

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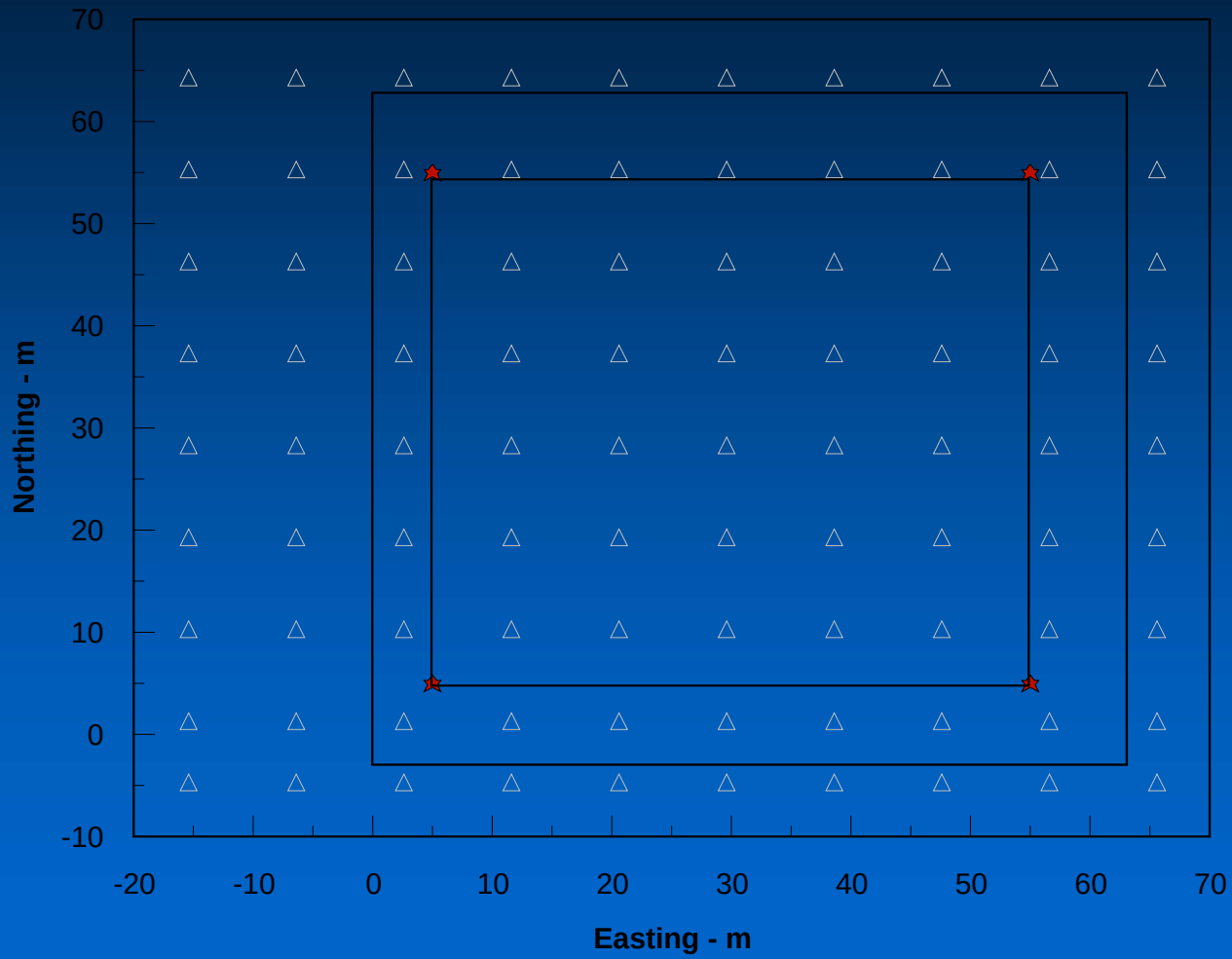
Geophysics (EM) Monitoring



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Experimental Design

	Experiment 1	Experiment 2	Experiments Total
	Water	Water	
Start Date:	4/28/97	12/3/97	
End Date:	5/21/97	1/5/98	
Duration:	24 days	34 days	58 days
Application Rate:	1.85 cm/d	1.97 cm/d	
Depth Applied:	44.4 cm	64.8 cm	109.2 cm
	Bromide	Total Conductivity Salts	
Start Date:	4/28/97	12/3/97	
End Date:	5/11/97	12/9/97	
Duration:	14 days	7 days	
Application Rate:	31.6 ppm	2.2 dS/m	
Depth Applied:	26 cm	14 cm	

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General Observations

- Borehole Monitoring strategy provided many measurement points, but collection frequency was relatively low, especially when using mobile instruments.
- Monitoring Trench allowed for automated data collection, but depth resolution was low
- Monitoring Islands allowed for good depth resolution; though installing numerous islands increased spatial resolution, they cost increase was too large for project.
- Geophysical method provided good spatial coverage, but conversion to soil water conditions was not trivial (required lots of calibration points in our heterogeneous site).

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Some Related References

- Young, M.H., P.J. Wierenga, A.W. Warrick, L.L. Hofmann, S.A. Musil, M. Yao, C. Mai, B.R. Scanlon. 1999. Results of field studies at the Maricopa Environmental Monitoring Site, Arizona. NUREG/CR-5694, U.S. Nuclear Regulatory Commission, Washington, DC.
- Young, M.H., A.W. Warrick, P.J. Wierenga, L.L. Hofmann, S.A. Musil, 1999. Comparing monitoring strategies at the Maricopa site, Arizona. NUREG/CR-5698, U.S. Nuclear Regulatory Commission, Washington, DC.
- Young, M.H., P.J. Wierenga, A.W. Warrick, L.L. Hofmann, S.A. Musil, B.R. Scanlon, T.J. Nicholson. 1996. Field testing plan for unsaturated zone monitoring and field studies. NUREG/CR-6462, U.S. Nuclear Regulatory Commission, Washington, DC.

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