Uncertainty of A Remediation Cost: A Demonstration of the NLH Technique in the analysis of uncertainty of objective value in model application

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Problem Definition (1)

- Uncertainty in objective value, such as performance measures, is more important than uncertainties in model parameters in decision making
- Uncertainty in objective value come from model parameters and objective function uncertainties.
- Objective function often subject to timely modification

Problem Definition (2)

- Analysis of model parameter uncertainties is tedious and should be done before decision-making
- Managers need a tool for fast responses to questions on confidence levels among alternatives subject to modified priorities

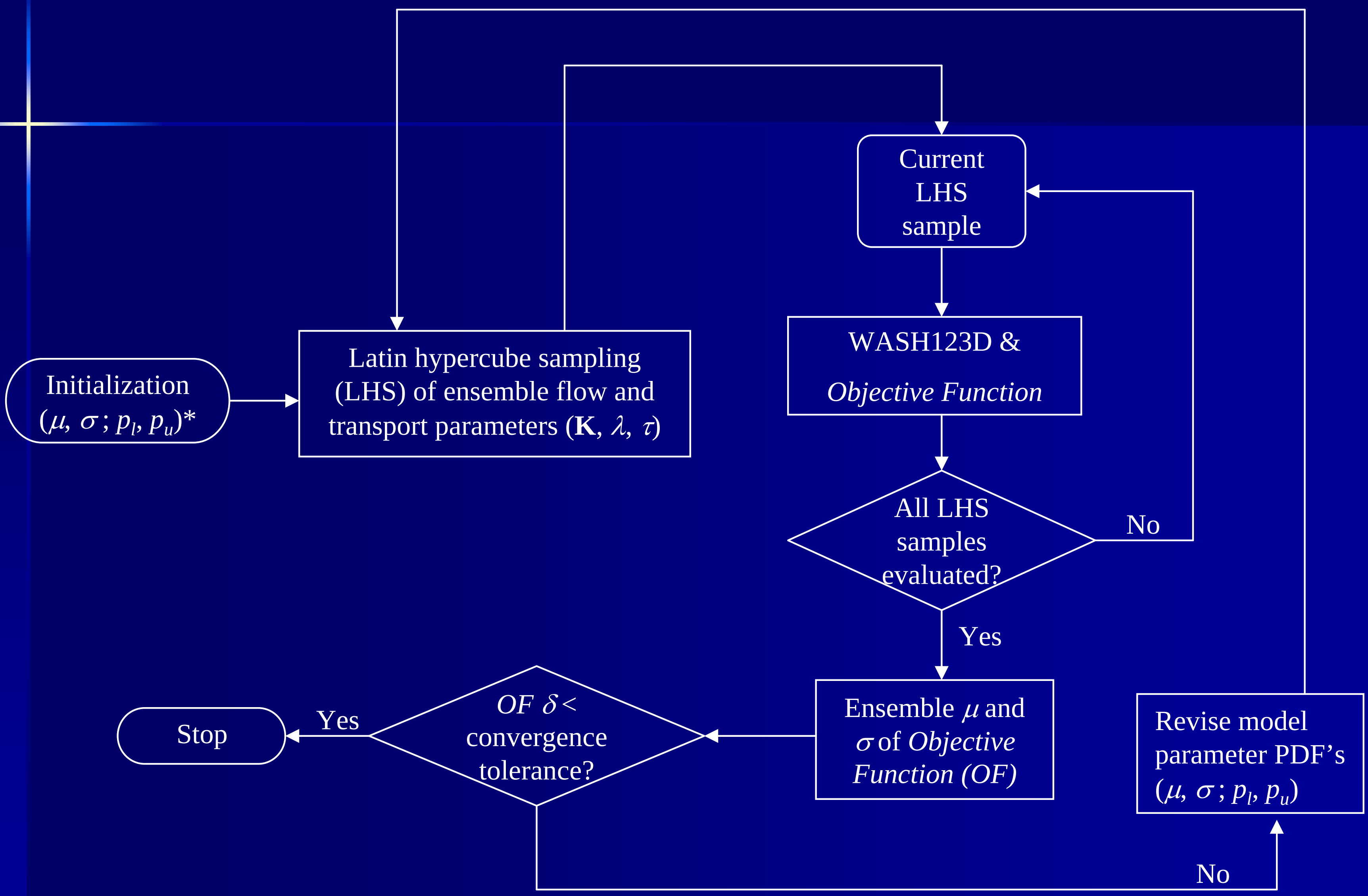
Demonstration Objectives

- Inherent uncertainties in parameters of established models induce uncertainties in performance measures (objective value)
- The Nested Latin-hypercube (NLH) is a general tool, albeit brute force, to obtain uncertainty information
- Uncertainty analysis of model applications can help to quantify the confidence level of a project success

Tasks

- Select a calibrated model – an aquifer pollution clean-up model using WASH123D is selected
- Apply the NLH technique to the model to collect samples of the pump-and-treat operation with variable model parameters
- Find the distribution of the operation costs

A Nested Latin-Hypercube Technique



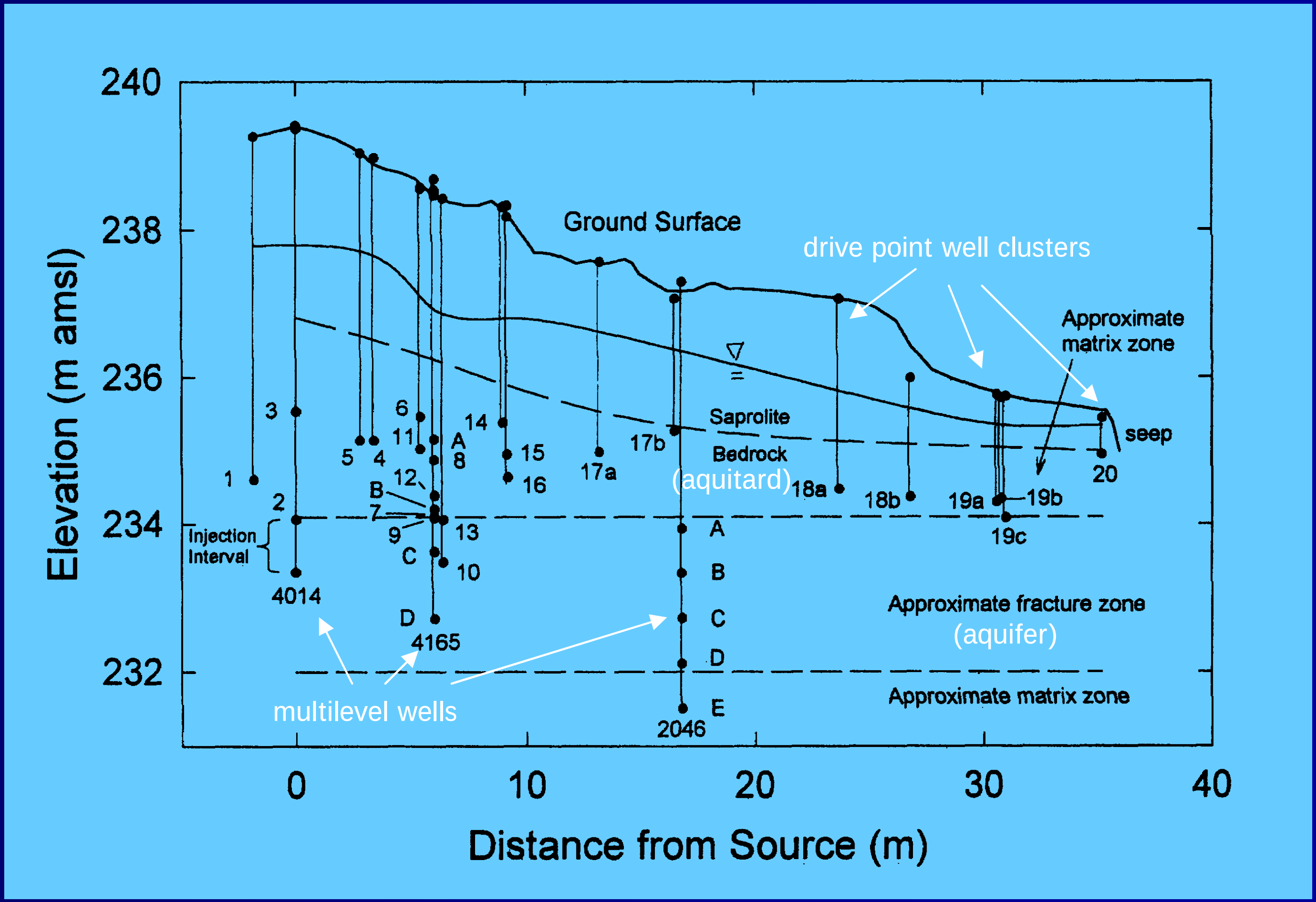
*μ = mean, σ = standard deviation, δ = coefficient of variation, p_l = low bound of a model parameter, p_u = upper bound of a model parameter, **K** = hydraulic conductivity tensor, λ = dispersivity, and τ = tortuosity.

Demonstration Site: ORNL WAG 5* - a fractured-rock site

*Oak Ridge National Laboratory, Waste Area Grouping 5

Instrument Transect of ORNL WAG 5

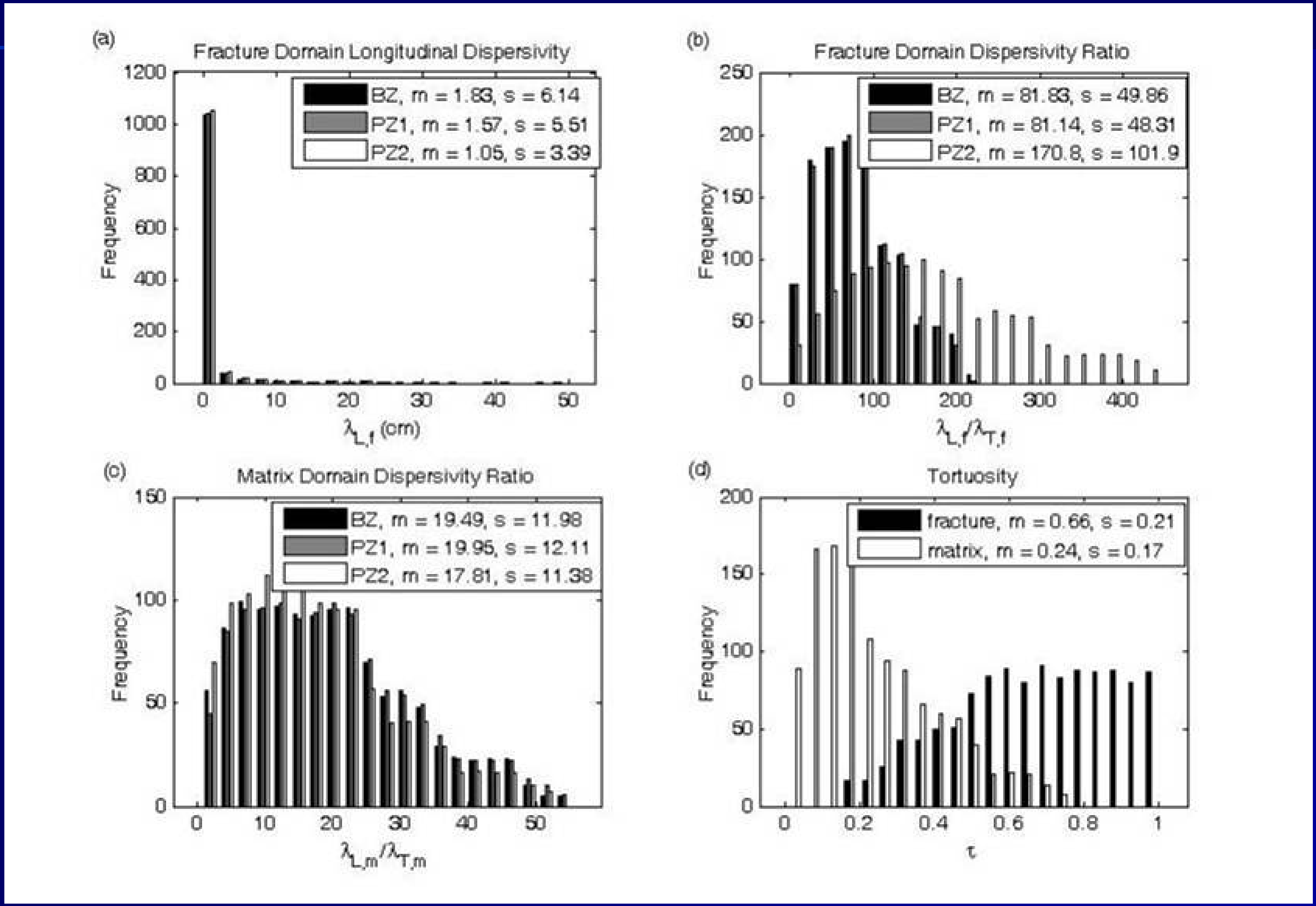
- Three multilevel wells and 20 drive point well clusters
- Br, Ne, He tracer injection to characterize groundwater dynamics and pollutant transport (Jardine et al., 1999, WRR)
- Field observations used to calibrate a fractured-rock flow and solute transport model (Gwo et al., 2005, JCH).



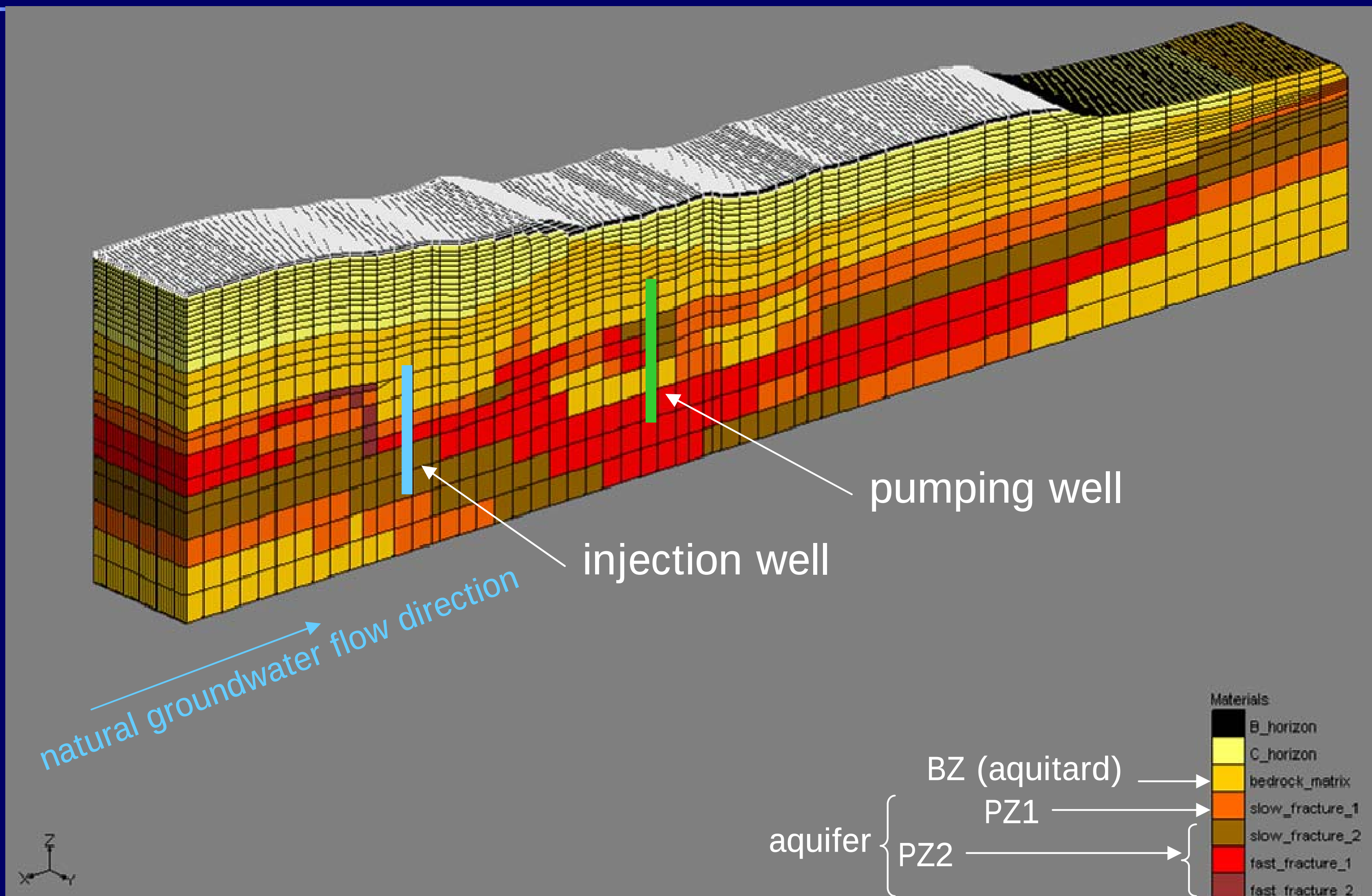
Empirical PDFs from Model Calibration

- three flow zones, BZ, PZ1 and PZ2

- two pore domains, fracture and matrix



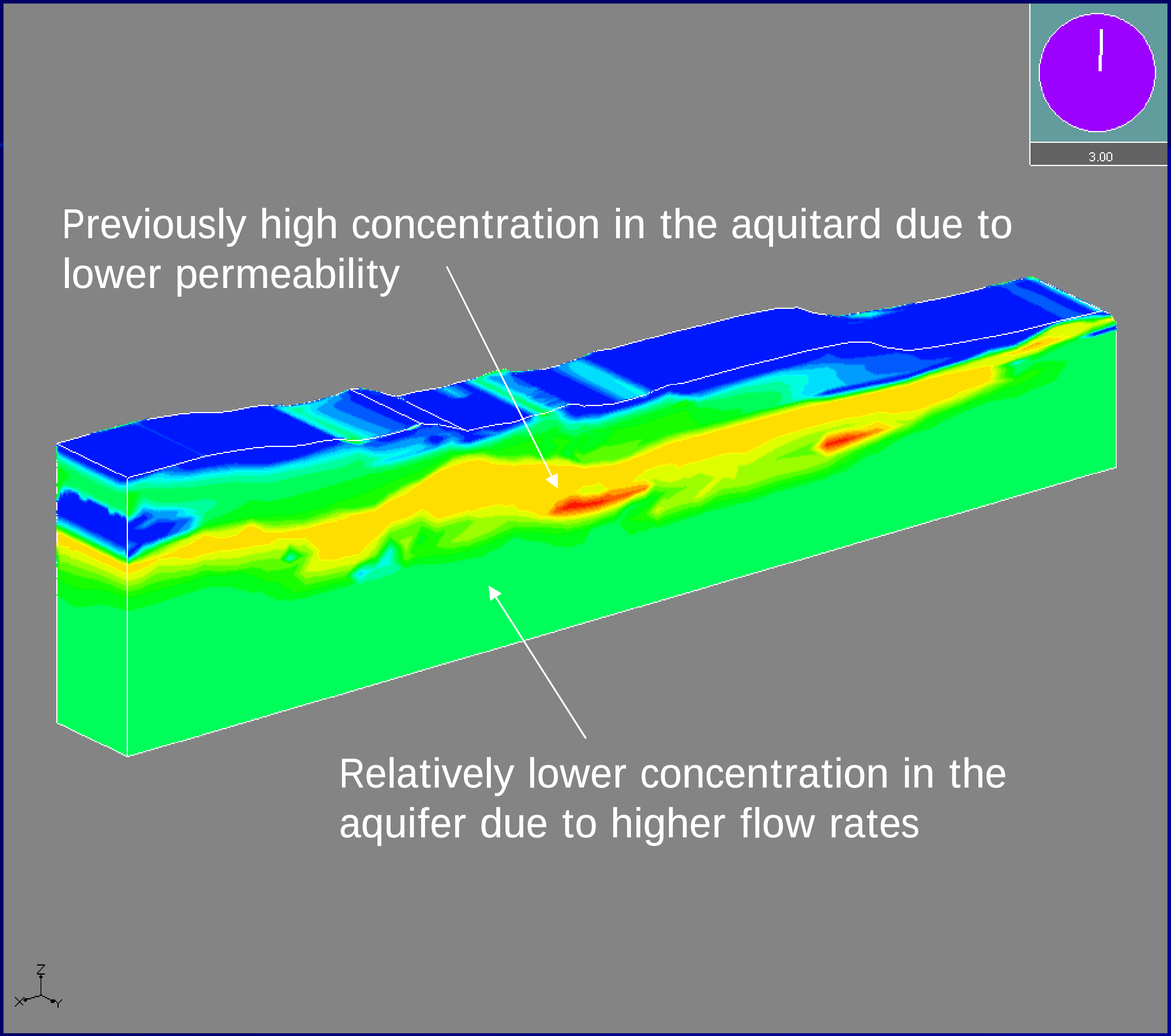
A WASH123D Aquifer/Aquitard Model of ORNL WAG 5



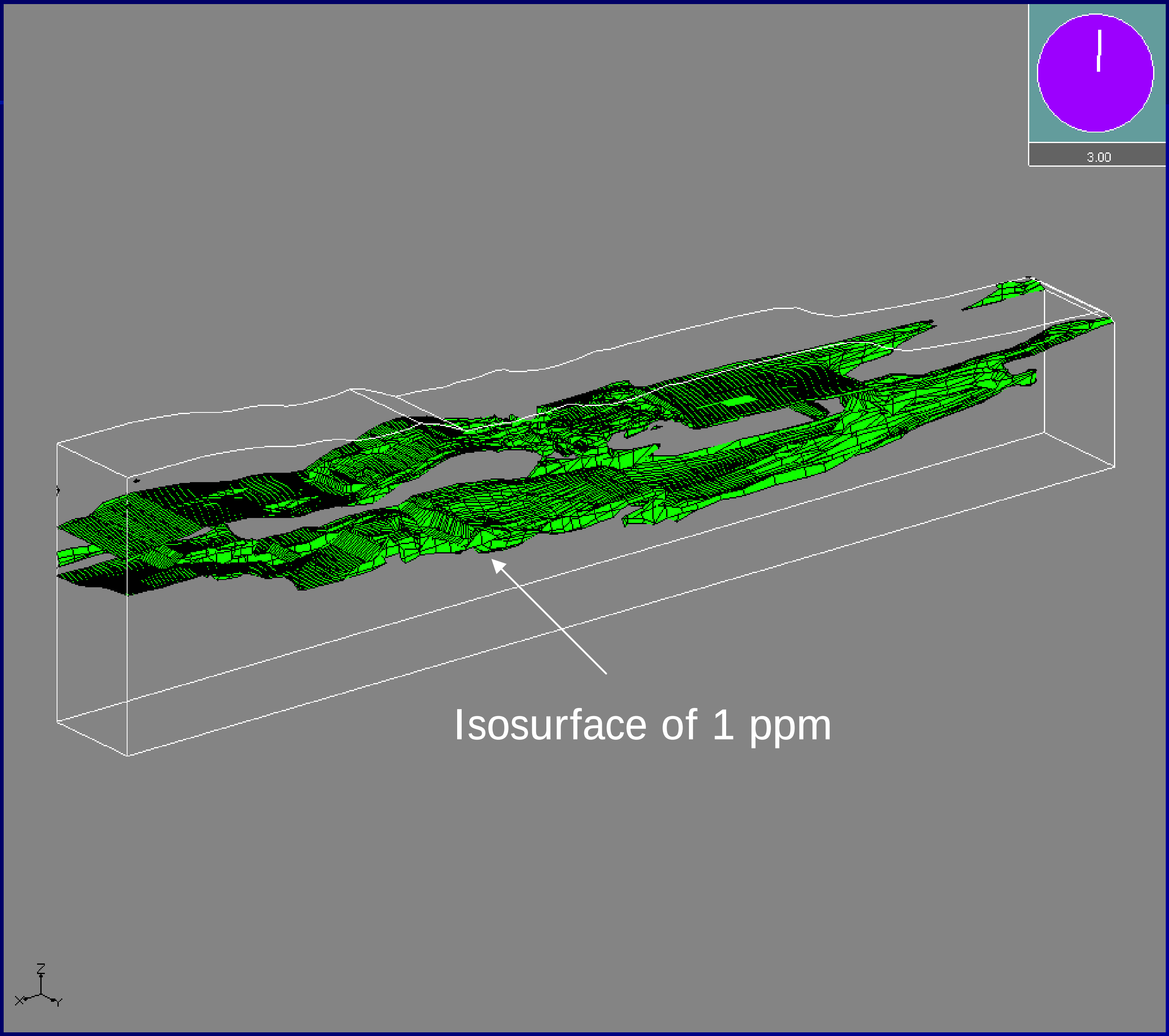
Modeling Assumptions

- The pollutant does not react with rock matrix.
- Only one single pumping-injection dipole is used for the remediation operation and pumping rate is equal to injection rate.
- The pumping and injection rate PDF is assumed uniformly distributed. Model parameter PDFs are taken as they are from the calibration.

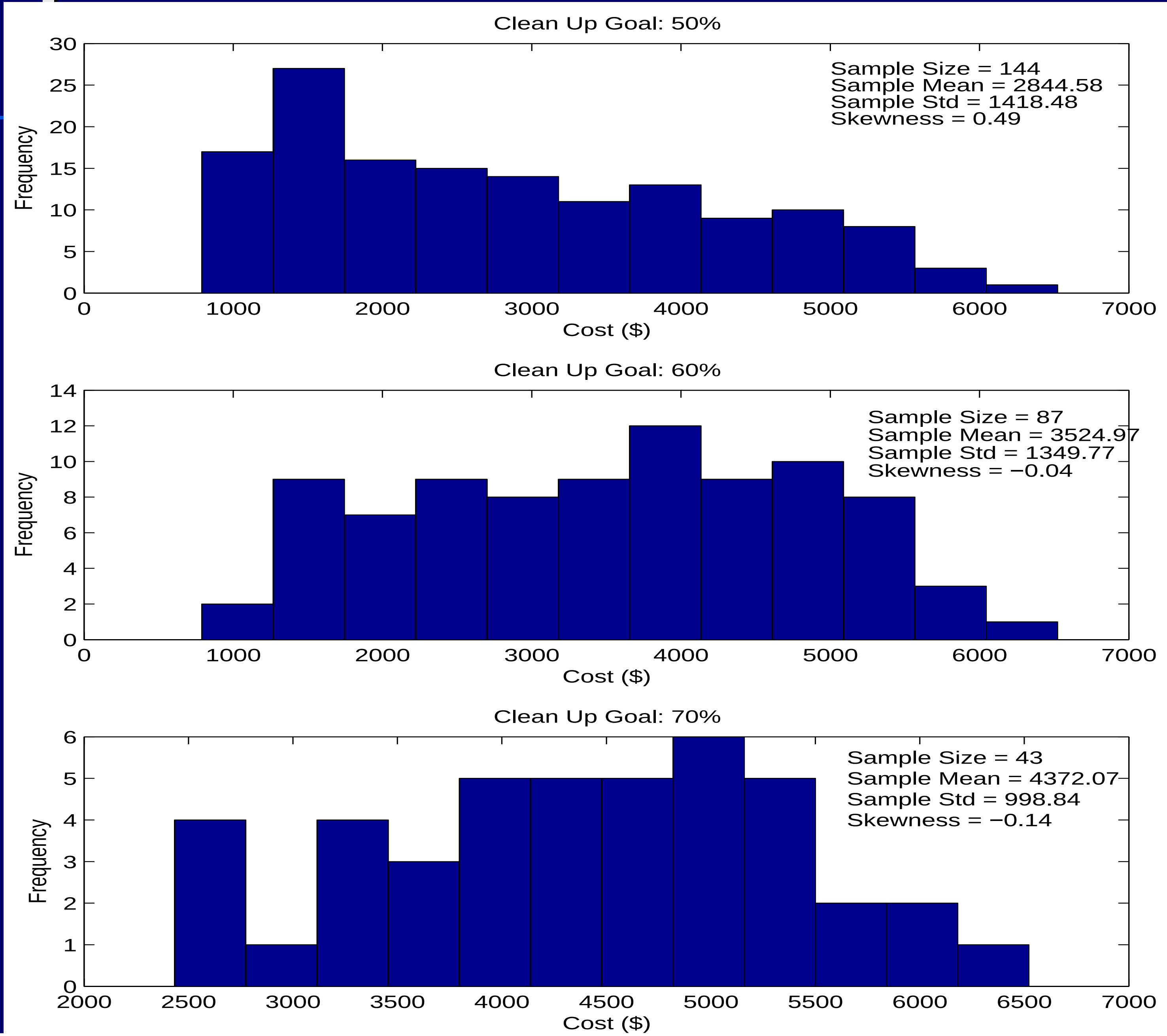
Clean-up of the Aquifer



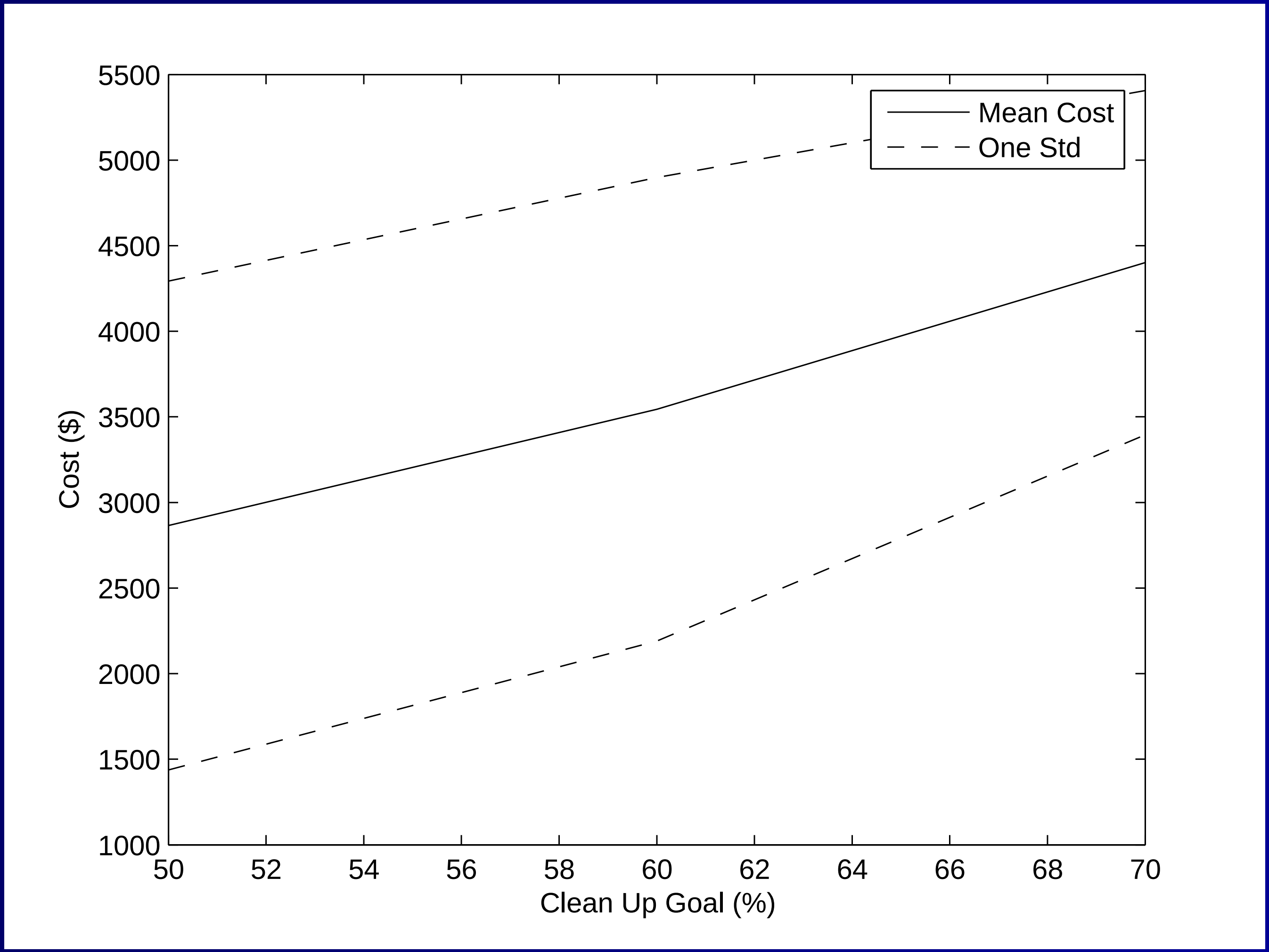
Residual Pollutant in Aquitard
(91% Removal Efficiency in 720 hr)



Empirical PDFs of Pump-and-Treat Aquifer Remediation Cost



Clean-up Cost vs. Clean-up Goal



Assumed Cost Formulae

- Cost of pumping and injection: $0.028/$m^3$, using estimated electricity cost of 9.20 ¢/kWh.
- Cost of water treatment: $1.32/$m^3$
- Well installation and maintenance, supplies, and other fixed costs are NOT included in the previous two figures.
- A huge penalty is applied to realizations that do not pass the clean-up goal thresholds. These realizations are removed before the cost PDFs are derived.

Summary and Conclusion

- A NLH technique was used to determine the cost of remediating a fractured-rock aquifer/aquitard contaminated with a pollutant.
- A small amount of residual pollutant was found to remain in the aquitard after 30 days of pump-and-treat operation.
- The NLH sampling can be applied to any model, even without source code, but is computer-intensive

Summary and Conclusion

- Empirical PDFs of remediation cost were developed using the PDFs of model parameters, a range of pumping rates and WASH123D simulations.
- Higher cost is associated with higher percentage of desired pollutant removal and slightly narrower cost confidence intervals.
- Uncertainty information of objective value (performance measure) is directly useful in decision-making.

Next

- Take advantages of parallel computation.
- Continually synthesize the distribution of objective value during the long sampling for fast responses to management questions.
- Identify critical model parameters with respect to performance measures.