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U.S. Nuclear Regulatory Commission
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Subject: Programmatic Review of a Presentation for the 7th International Conference on Probabilistic Safety Assessment and Management (PSAM 7) titled "Role of Component Sensitivity Analysis in the Risk Assessment of a Large and Complex System" in Berlin, Germany on June 14–18, 2004

Dear Mrs. DeMarco:

The enclosed presentation will be given at the 7th International Conference on Probabilistic Safety Assessment and Management (PSAM7) in Berlin, Germany on June 14–18, 2004. The presentation is "Role of Component Sensitivity Analysis in the Risk Assessment of a Large and Complex System by Sitakanta Mohanty, Budhi Sagar, Ron Janetzke, Gordon Wittmeyer, and Wes Patrick. This presentation is based on a paper previously reviewed and approved by NRC in November 2003. The paper used information reported in the TPA 4.1 Sensitivity Analyses Report.

The paper presents a component-level sensitivity analysis method that provides a powerful tool for understanding the behavior of large and complex systems. This method produces easy-to-understand results that can explain the performance of a system clearly at the component level rather than parameter by parameter.

Please contact me at (210) 522-5252 if you have any questions regarding these papers.

Sincerely yours,

Budhi Sagar
Technical Director

Enclosures

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Role of Component Sensitivity Analysis in the Risk Assessment of a Large and Complex System

by

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Presented at the

PSAM 7/ESREL'04 Conference

Berlin, Germany

June 14-18, 2004

Outline

- Background
- Objective
- Component Sensitivity Analysis Method
- Example Problem
- Results
- Conclusions

Background

- Risk Assessment models for large, complex systems are simplified representations that embody physical features and simulate many coupled processes with uncertainties
- Model sensitivity analyses can be used to identify system attributes contributing most to risk
- A measure of sensitivity is the change in model behavior caused by potential changes in model attributes
- All model attributes cannot be simplified to the same degree in a model
- Therefore, several different types of sensitivity analyses may be needed to adequately and consistently identify factors driving system risk/performance

Objective

- Describe an analytical approach for estimating the sensitivity of a model of a complex system to changes in a subsystem or a component of that system

Component Sensitivity Analysis

- The component or subsystem is an element of the system with some performance value
- System response sensitivity to change in component functionality

$$Sensitivity = (\Delta y / y_r) / (\Delta c / c_r)$$

$$\Delta y = y_r - y_s$$

$$\Delta c = c_r - c_s$$

y: performance metric
r: reference
s: sensitivity case
c: component

- For the complete loss or gain of function of a component

$$\Delta c / c_r = 1 \ or \ -1$$

Component Sensitivity Analysis (cont'd)

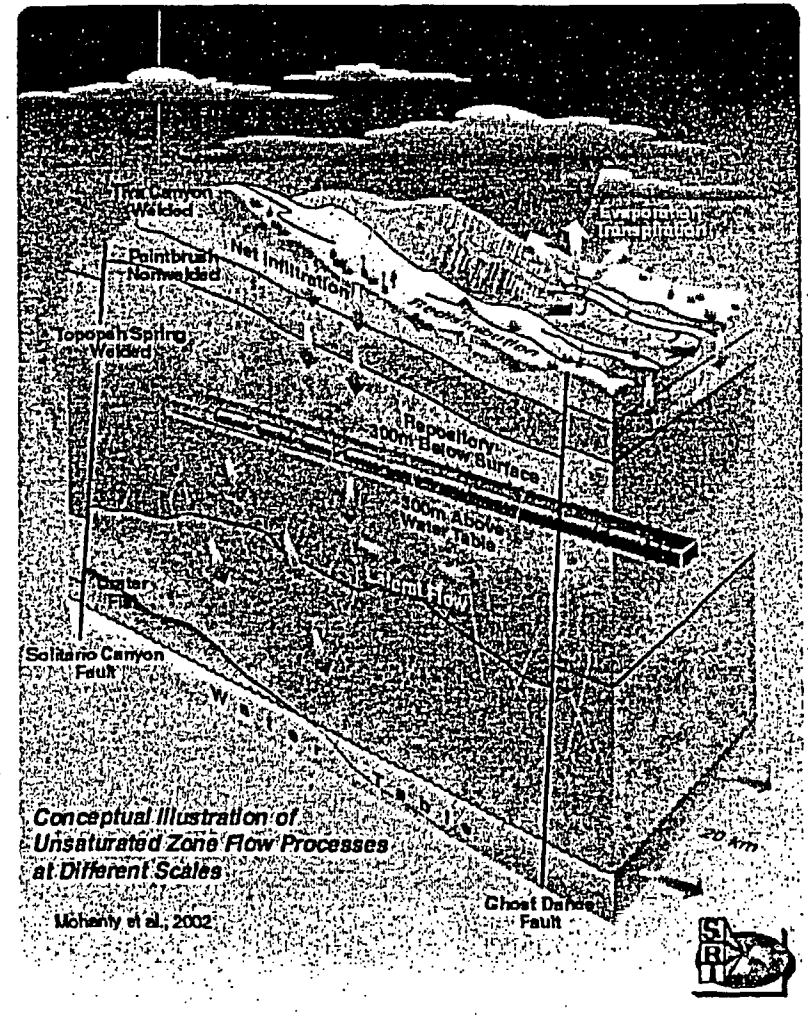
- Reference case: base case
- Sensitivity case: performance assessment is calculated by suppressing the function(s) of a system component or combination of components to a specified level
- System component functionality suppression is specified by
  - Selecting an appropriate alternative conceptual model
  - Appropriately modifying model parameters

Component Sensitivity Analysis Types

- Component sensitivity analyses conducted with an exhaustive combination of components
- These combinations are parsed into smaller groups
  - Single repository component suppressed (One-Off Component Sensitivity Analysis)
  - Single repository component added to a system in which all repository components have been suppressed (One-On Component Sensitivity Analysis)
  - Repository components added cumulatively to a completely suppressed system (Cumulative One-On Component Sensitivity Analysis)
  - Component Combination Sensitivity Analysis

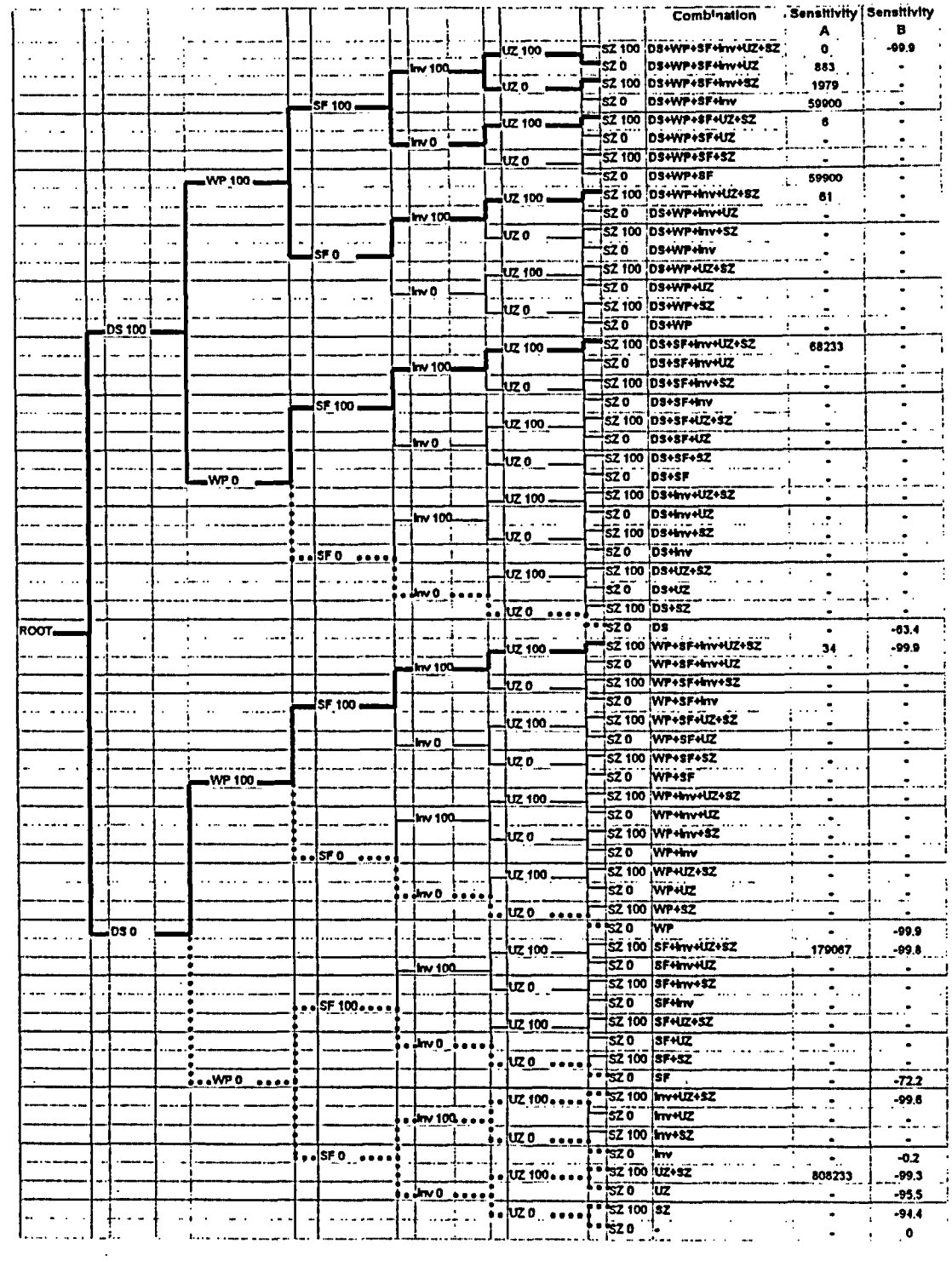
Example Problem

- Total-system Performance Assessment (TPA) model for analyzing a potential repository at Yucca Mountain
- Repository system divided into components: (1) drip shield, (2) waste package, (3) spent nuclear fuel, (4) invert, (5) unsaturated zone above and below the repository, (6) saturated zone below the repository
- TPA system model has 12 alternative conceptual models and 950 parameters (330 are sampled)
- The base case and each sensitivity case are 100-realization Monte Carlo runs



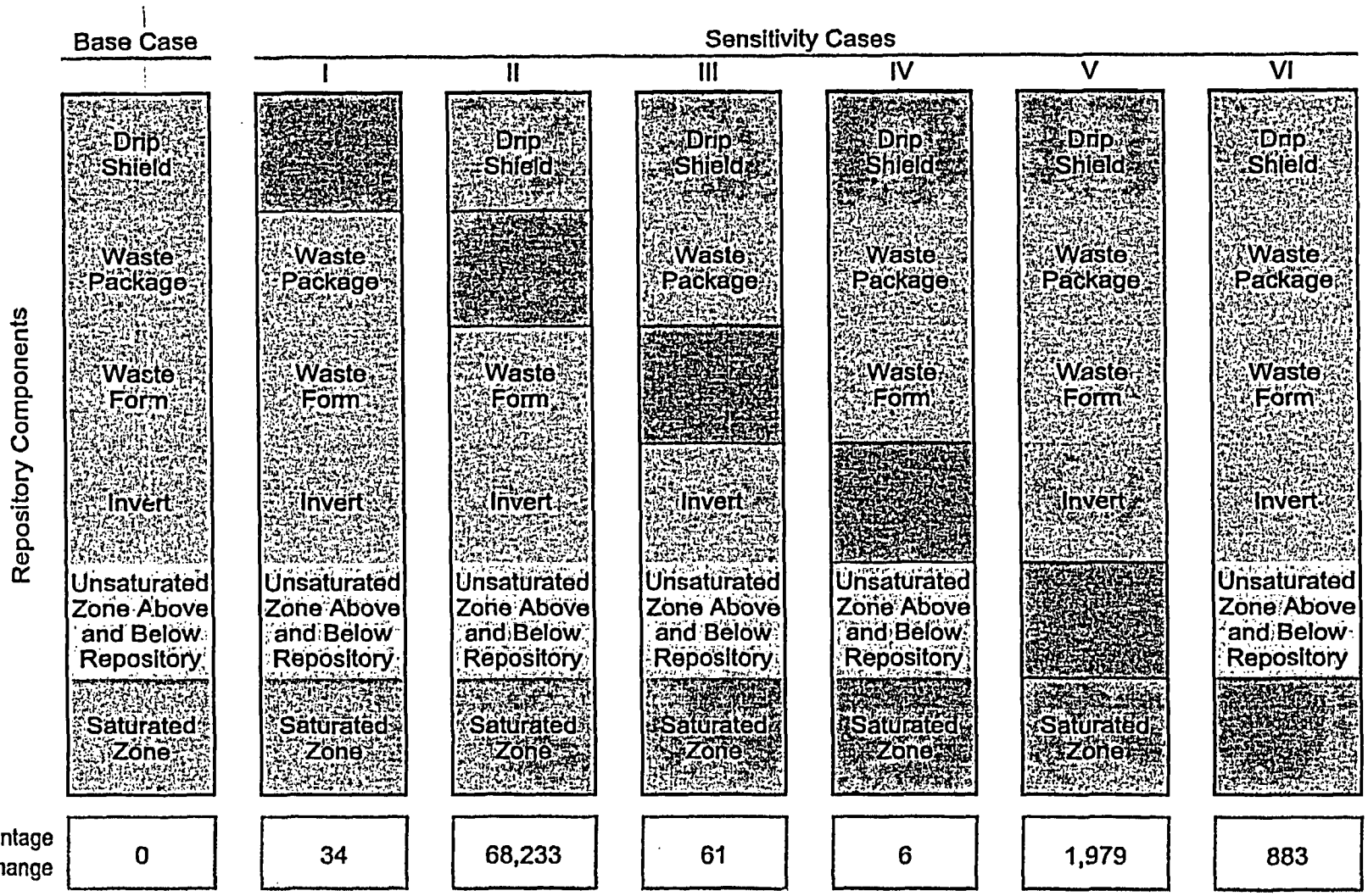
Exhaustive Combinations

- Exhaustive combinations of component sensitivity analysis cases for six components (2^6 or 64)
- Thick solid lines and dotted lines represent one-off and one-on analysis cases, respectively

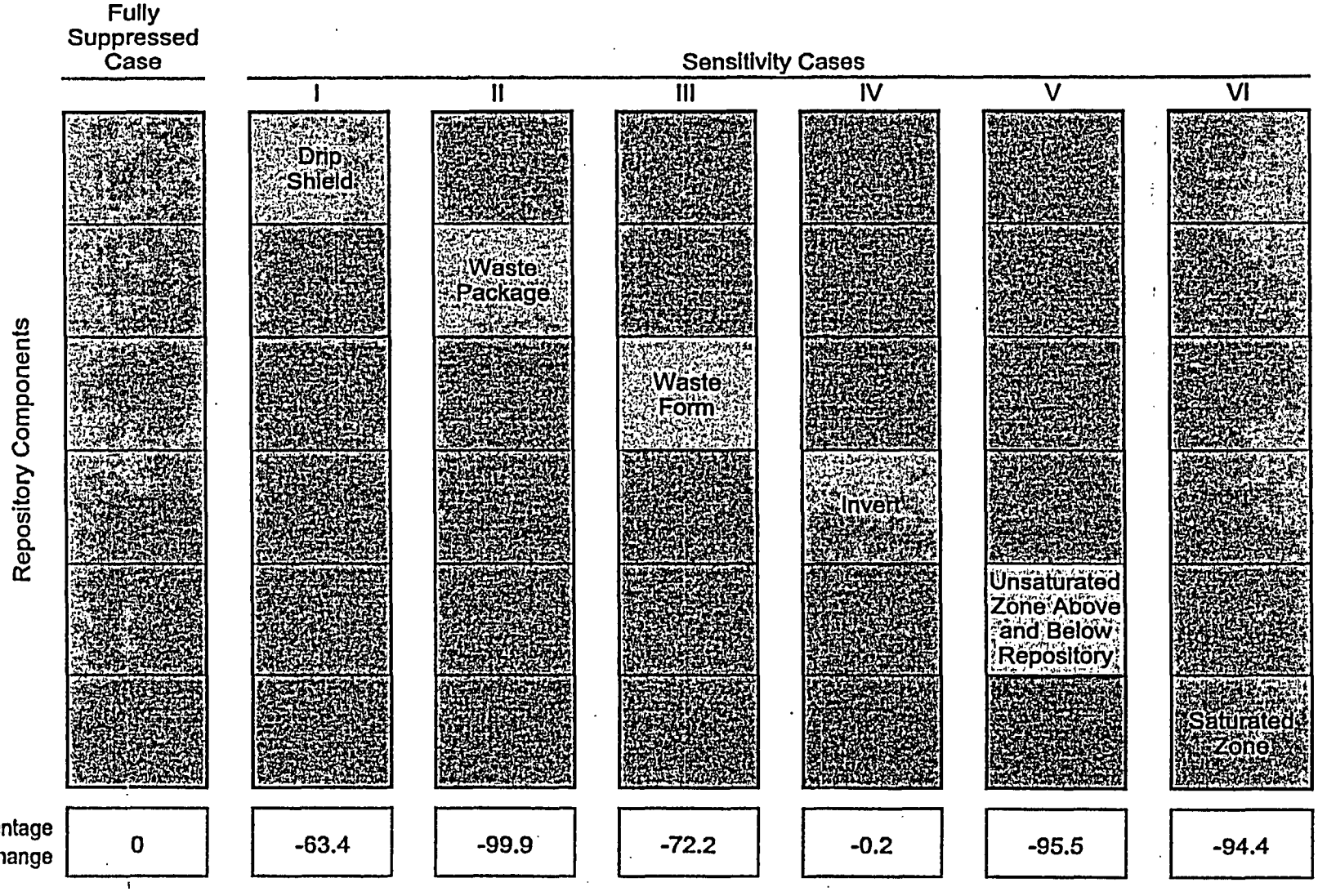


Combination	Sensitivity A	Sensitivity B
DS+WP+SF+Inv+UZ+SZ	0	-99.9
DS+WP+SF+Inv+UZ	883	-
DS+WP+SF+Inv+SZ	1979	-
DS+WP+SF+Inv	59900	-
DS+WP+SF+UZ+SZ	6	-
DS+WP+SF+UZ	-	-
DS+WP+SF+SZ	-	-
DS+WP+SF	59900	-
DS+WP+Inv+UZ+SZ	61	-
DS+WP+Inv+UZ	-	-
DS+WP+Inv+SZ	-	-
DS+WP+Inv	-	-
DS+WP+UZ+SZ	-	-
DS+WP+UZ	-	-
DS+WP+SZ	-	-
DS+WP	-	-
DS+SF+Inv+UZ+SZ	68233	-
DS+SF+Inv+UZ	-	-
DS+SF+Inv+SZ	-	-
DS+SF+Inv	-	-
DS+SF+UZ+SZ	-	-
DS+SF+UZ	-	-
DS+SF+SZ	-	-
DS+SF	-	-
DS+Inv+UZ+SZ	-	-
DS+Inv+UZ	-	-
DS+Inv+SZ	-	-
DS+Inv	-	-
DS+UZ+SZ	-	-
DS+UZ	-	-
DS+SZ	-	-
DS	-	-63.4
WP+SF+Inv+UZ+SZ	34	-99.9
WP+SF+Inv+UZ	-	-
WP+SF+Inv+SZ	-	-
WP+SF+Inv	-	-
WP+SF+UZ+SZ	-	-
WP+SF+UZ	-	-
WP+SF+SZ	-	-
WP+SF	-	-
WP+Inv+UZ+SZ	-	-
WP+Inv+UZ	-	-
WP+Inv+SZ	-	-
WP+Inv	-	-
WP+UZ+SZ	-	-
WP+UZ	-	-
WP+SZ	-	-
WP	-	-99.9
SF+Inv+UZ+SZ	179067	-99.8
SF+Inv+UZ	-	-
SF+Inv+SZ	-	-
SF+Inv	-	-
SF+UZ+SZ	-	-
SF+UZ	-	-
SF+SZ	-	-
SF	-	-72.2
Inv+UZ+SZ	-	-99.6
Inv+UZ	-	-
Inv+SZ	-	-
Inv	-	-0.2
UZ+SZ	808233	-99.3
UZ	-	-95.5
SZ	-	-94.4
-	-	0

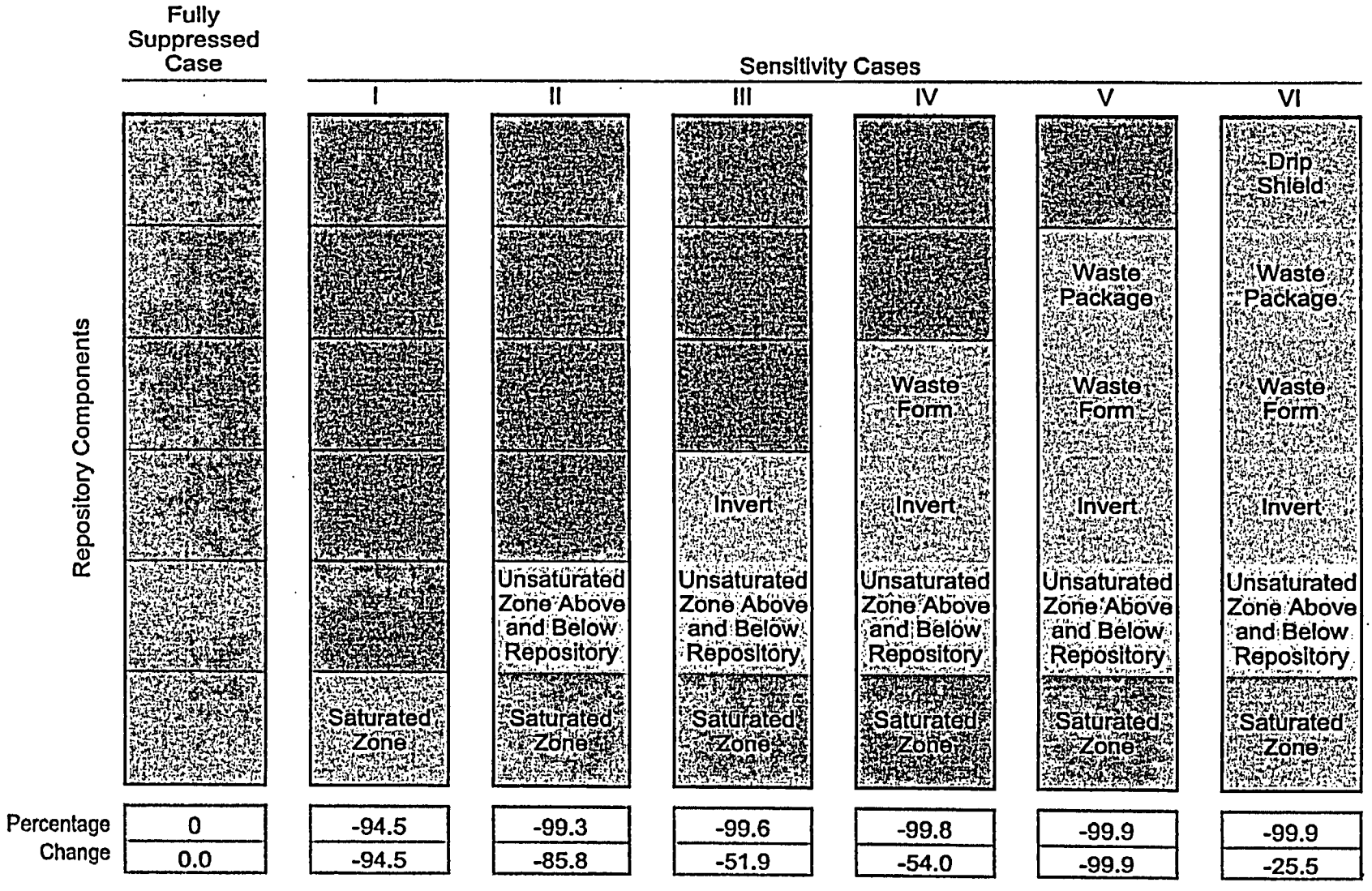
One-Off Sensitivity Analysis



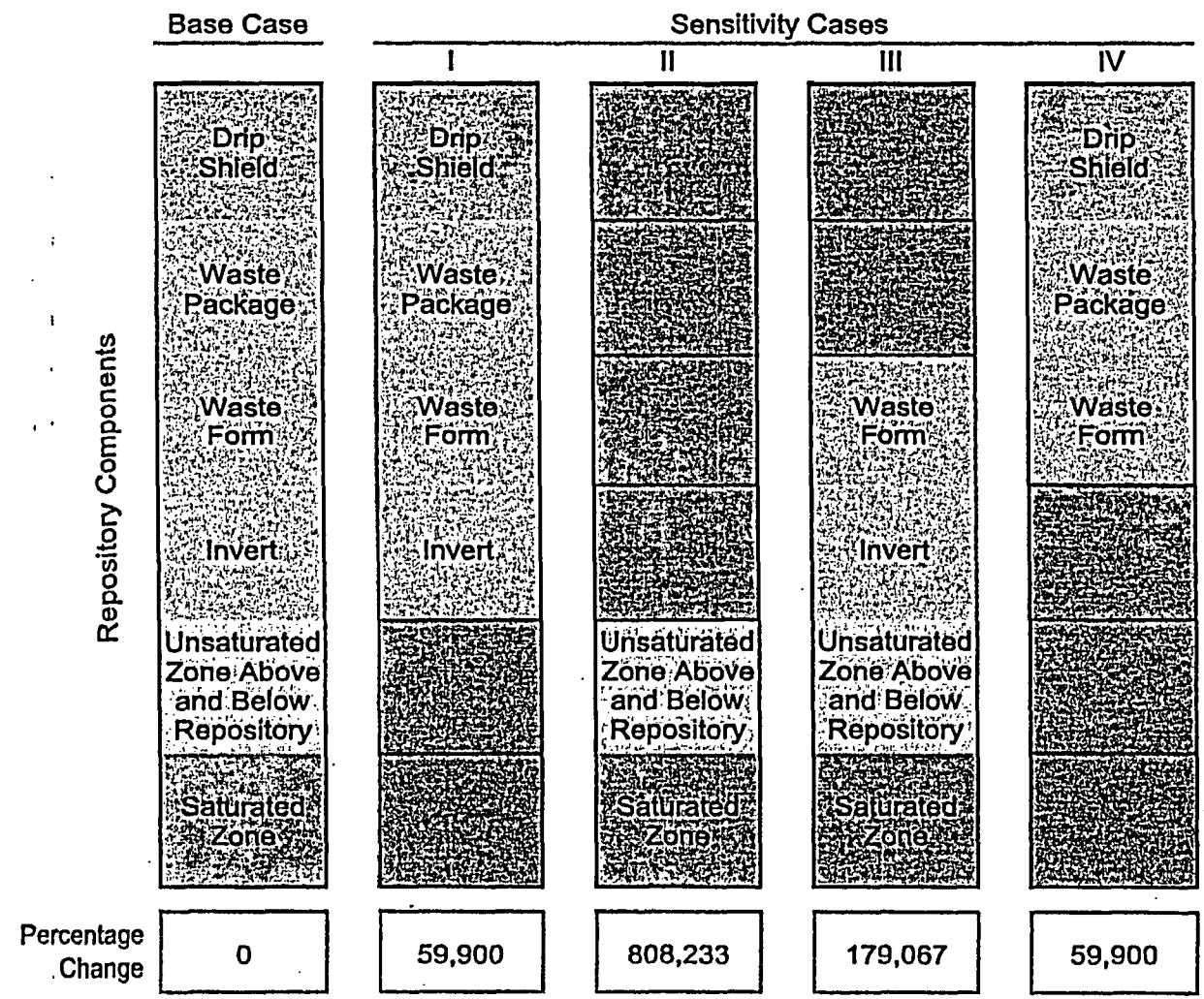
One-On Sensitivity Analysis



Cumulative One-On Component Sensitivity Analysis



Component Combination Sensitivity Analysis



Conclusions

- Component sensitivity analyses provide information about the potential contribution to repository performance of individual or subsets of repository subsystems
- Example showed how the method could be used to identify and rank influential repository components
- Suppression of components unmasked interesting interactions
- Component sensitivity analysis provides a powerful tool for understanding system behavior that complements methods traditionally used in risk assessment
- For highly uncertain complex system models, component sensitivity analysis can elucidate how the system might perform if modeling assumptions are incorrect

Acknowledgments

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Back-up slide

Example: Waste Package component suppressed