

**U.S. DEPARTMENT OF ENERGY
OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT**

**PRESENTATION TO
THE NUCLEAR WASTE TECHNICAL REVIEW BOARD**

**SUBJECT: PERFORMANCE ASSESSMENT
OF YUCCA MOUNTAIN IN
SUPPORT OF THE COMPARATIVE
SITE ANALYSIS**

PRESENTER: DR. PAUL GNIRK

**PRESENTER'S TITLE
AND ORGANIZATION: PRINCIPAL CONSULTANT
RE/SPEC INC.**

**PRESENTER'S
TELEPHONE NUMBER: (505) 293-2000**

MAY 16-17, 1989

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INTRODUCTION

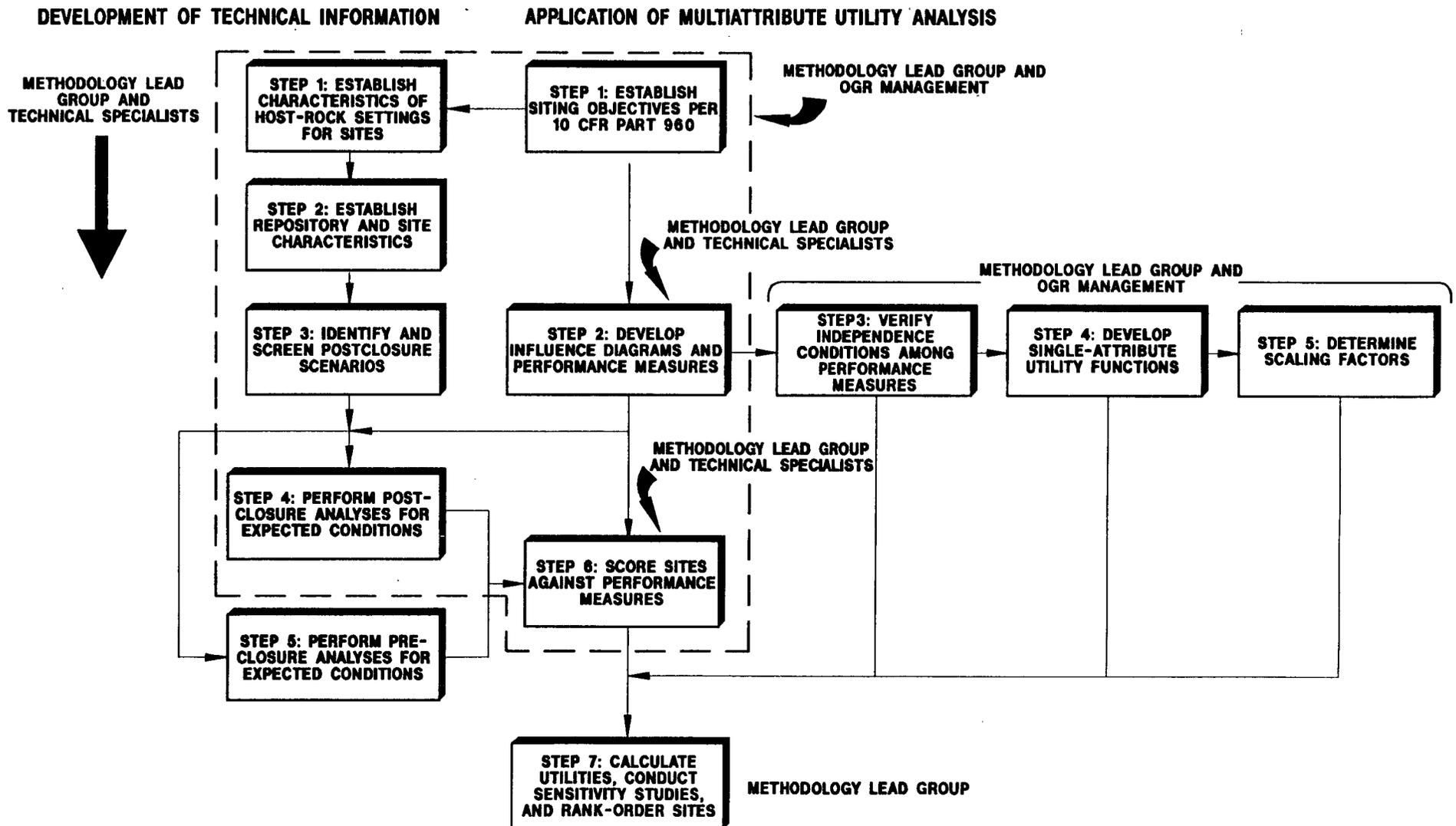
- **FROM SEPT. 1985 - MAY 1986, DOE CONDUCTED A COMPARATIVE EVALUATION OF 5 REPOSITORY SITES BY MULTIATTRIBUTE UTILITY ANALYSIS (DECISION-AIDING METHODOLOGY)**
- **PURPOSE OF COMPARATIVE EVALUATION WAS TO AID DOE IN THE SELECTION OF THREE SITES FOR CHARACTERIZATION FOR DEVELOPMENT AS THE FIRST REPOSITORY**
- **AFTER REVIEWING THE APPLICATION OF THE DECISION-AIDING METHODOLOGY ON THREE SEPARATE OCCASIONS, THE NAS-BOARD OF RADIOACTIVE WASTE MANAGEMENT ENDORSED THE APPLICATION IN A LETTER FROM FRANK PARKER TO BEN RUSCHE IN APRIL 1986**

INTRODUCTION

(CONTINUED)

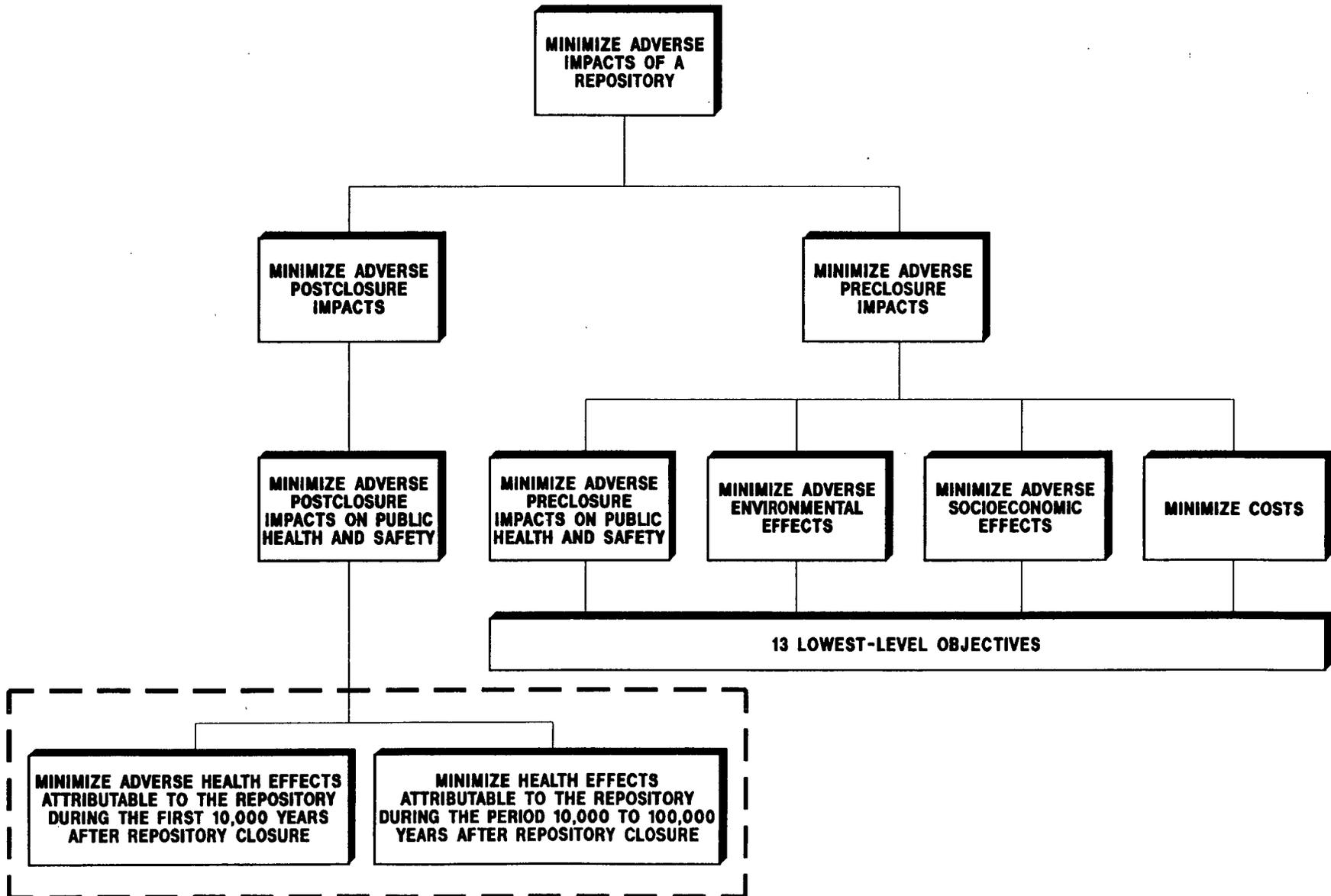
- **IN LATE MAY 1986, DOE SELECTED THREE SITES, INCLUDING THE YUCCA MOUNTAIN SITE, FOR DETAILED CHARACTERIZATION**
- **IN DECEMBER 1987, CONGRESSIONAL LEGISLATION DECREED THAT ONLY THE YUCCA MOUNTAIN SITE WOULD BE CHARACTERIZED**
- **THIS PRESENTATION WILL FOCUS ON THE POSTCLOSURE PERFORMANCE ASSESSMENT OF THE YUCCA MOUNTAIN SITE THAT WAS CONDUCTED IN SUPPORT OF THE DECISION METHODOLOGY APPLICATION, AND NOT ON THE COMPARATIVE EVALUATION ITSELF**

GENERAL FLOW OF ACTIVITIES AND DIVISION OF RESPONSIBILITIES FOR IMPLEMENTATION OF COMPARATIVE SITE EVALUATION (DOE/RW-0074)



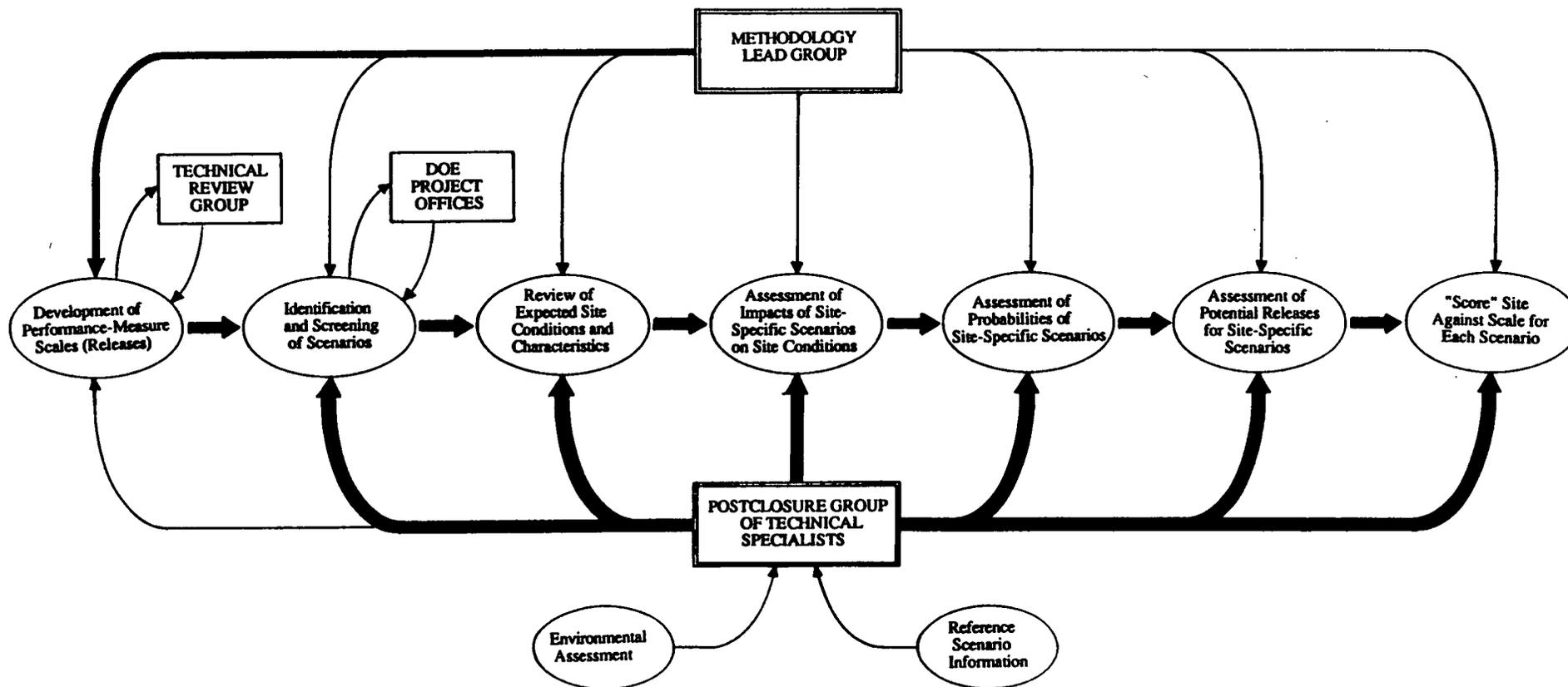
**OBJECTIVES HIERARCHY FOR GEOLOGIC DISPOSAL
(DOE/RW-0074)**

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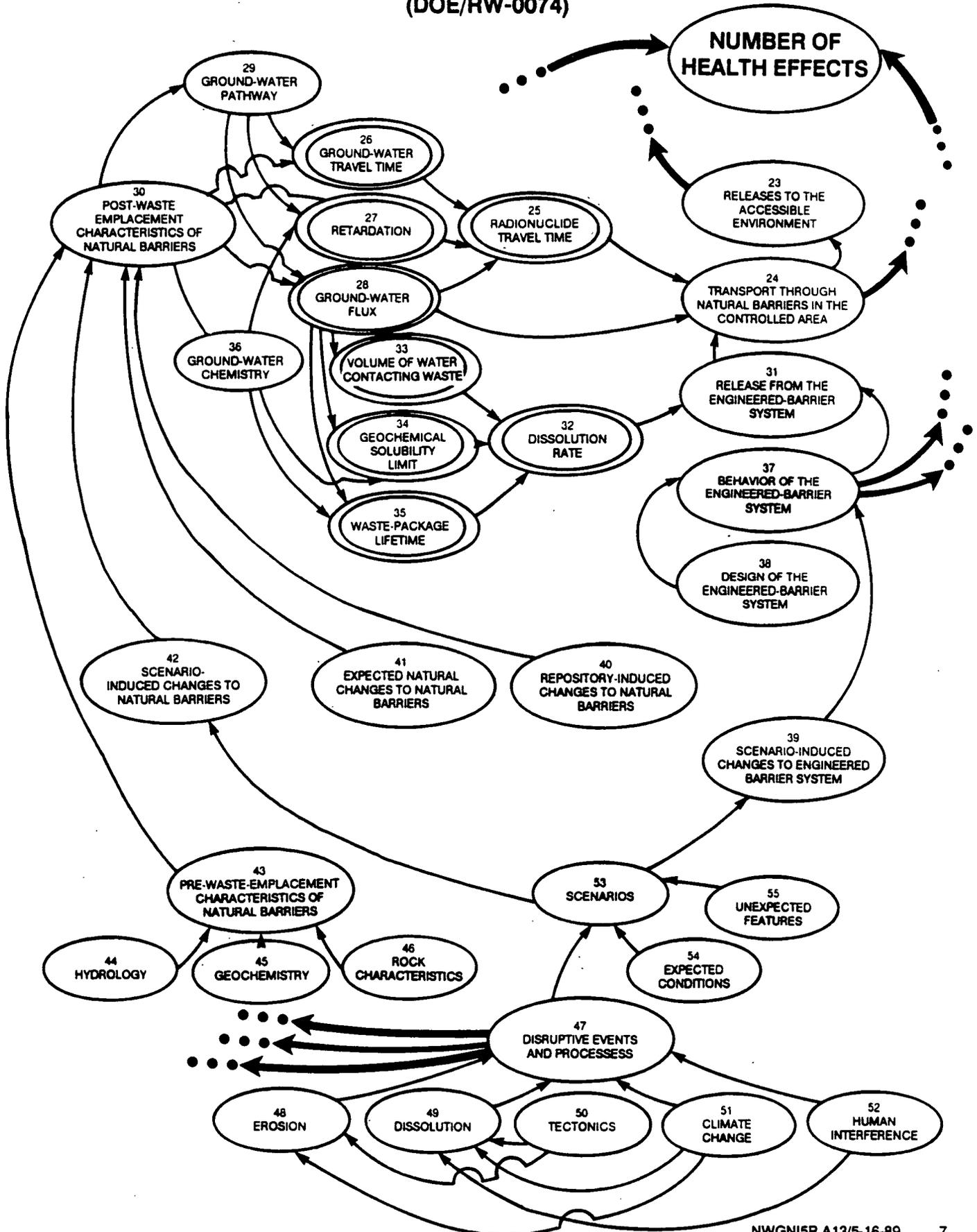
PROCESS FOR "SCORING" YUCCA MOUNTAIN SITE AGAINST POSTCLOSURE PERFORMANCE MEASURES

(DOE/RW-0074)



FACTORS THAT INFLUENCE NUMBER OF POSTCLOSURE HEALTH EFFECTS

(DOE/RW-0074)



POST-WASTE-EMPLACEMENT PERFORMANCE FACTORS FOR SITE

● RADIONUCLIDE RELEASE FROM ENGINEERED BARRIER SYSTEM

— MEASURE OF AMOUNT OF RADIONUCLIDES DISSOLVED INTO GROUND WATER DURING A SPECIFIED TIME PERIOD, BASED ON GROUND-WATER FLOW AND GROUND-WATER CHEMISTRY

$$— F = \sum \frac{QC_i}{RL_i}$$

WHERE:

Q = TOTAL VOLUME OF GROUND WATER CONTACTING WASTE (CUBIC METERS PER 1,000 MTHM)

C_i = MAXIMUM CONCENTRATION OF EACH KEY RADIONUCLIDE BASED ON SOLUBILITY, INVENTORY, ETC. (CURIES PER 1,000 MTHM)

RL_i = RELEASE LIMIT FOR EACH RADIONUCLIDE BASED ON TABLE 1 OF APPENDIX A OF 40 CFR PART 191 (CURIES PER 1,000 MTHM)

POST-WASTE-EMPLACEMENT PERFORMANCE FACTORS FOR SITE

(CONTINUED)

● RADIONUCLIDE TRANSPORT THROUGH NATURAL BARRIERS

—— MEASURE OF TRAVEL TIME OF KEY RADIONUCLIDES THROUGH NATURAL BARRIERS FROM ENGINEERED BARRIER SYSTEM TO ACCESSIBLE ENVIRONMENT, BASED ON CHEMICAL AND PHYSICAL RETARDATION CHARACTERISTICS OF ROCK AND GROUND-WATER TRAVEL TIME

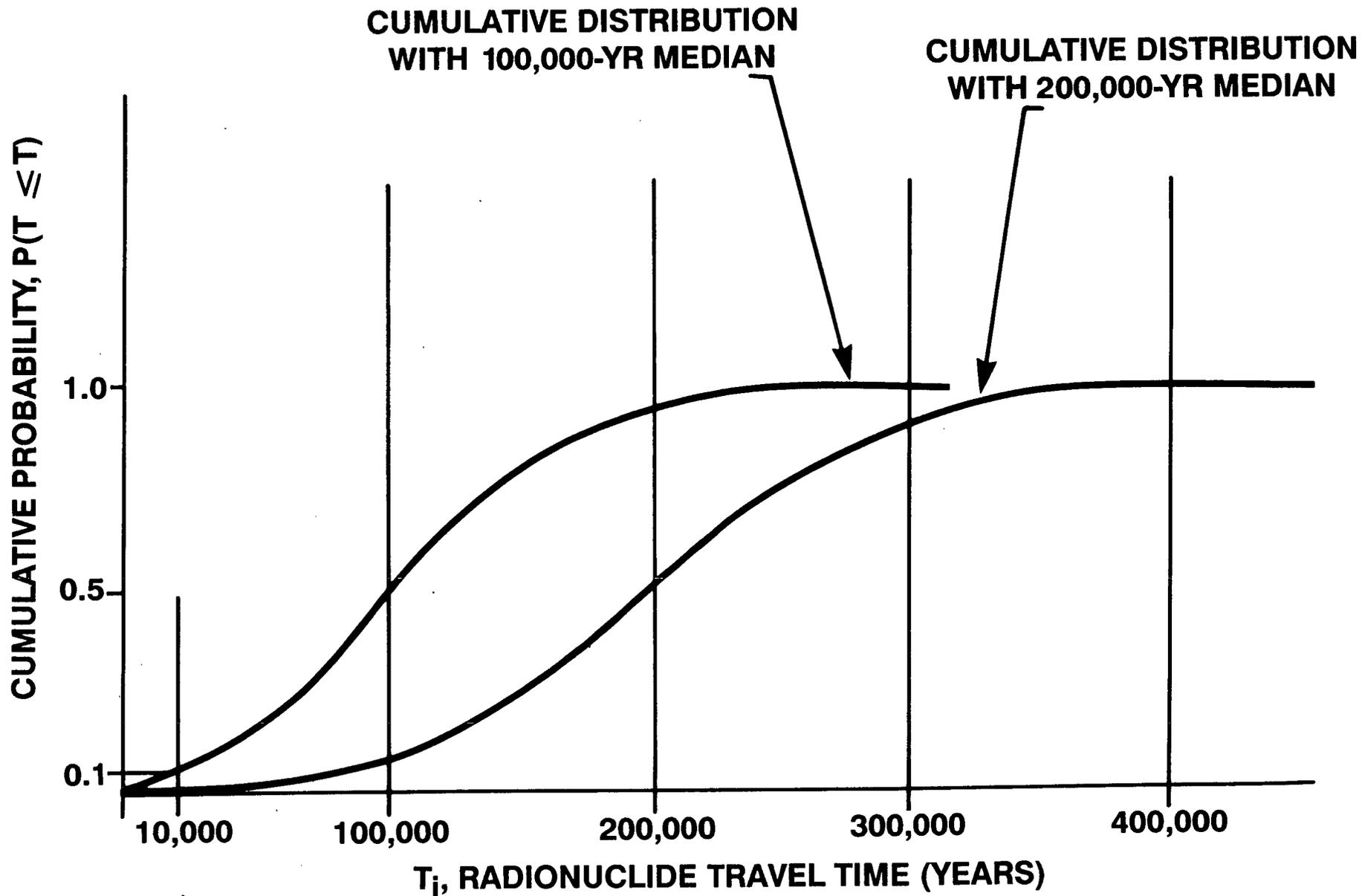
—— $T_i = R_i T$

WHERE:

R_i = RETARDATION FACTOR FOR KEY RADIONUCLIDES
(DIMENSIONLESS)

T = GROUND-WATER TRAVEL FROM ENGINEERED
BARRIER SYSTEM TO ACCESSIBLE ENVIRONMENT
(YEARS)

ILLUSTRATION OF RELATIONSHIP BETWEEN MEDIAN RADIONUCLIDE TRAVEL TIME AND FRACTION OF RELEASED RADIONUCLIDES REACHING ACCESSIBLE ENVIRONMENT

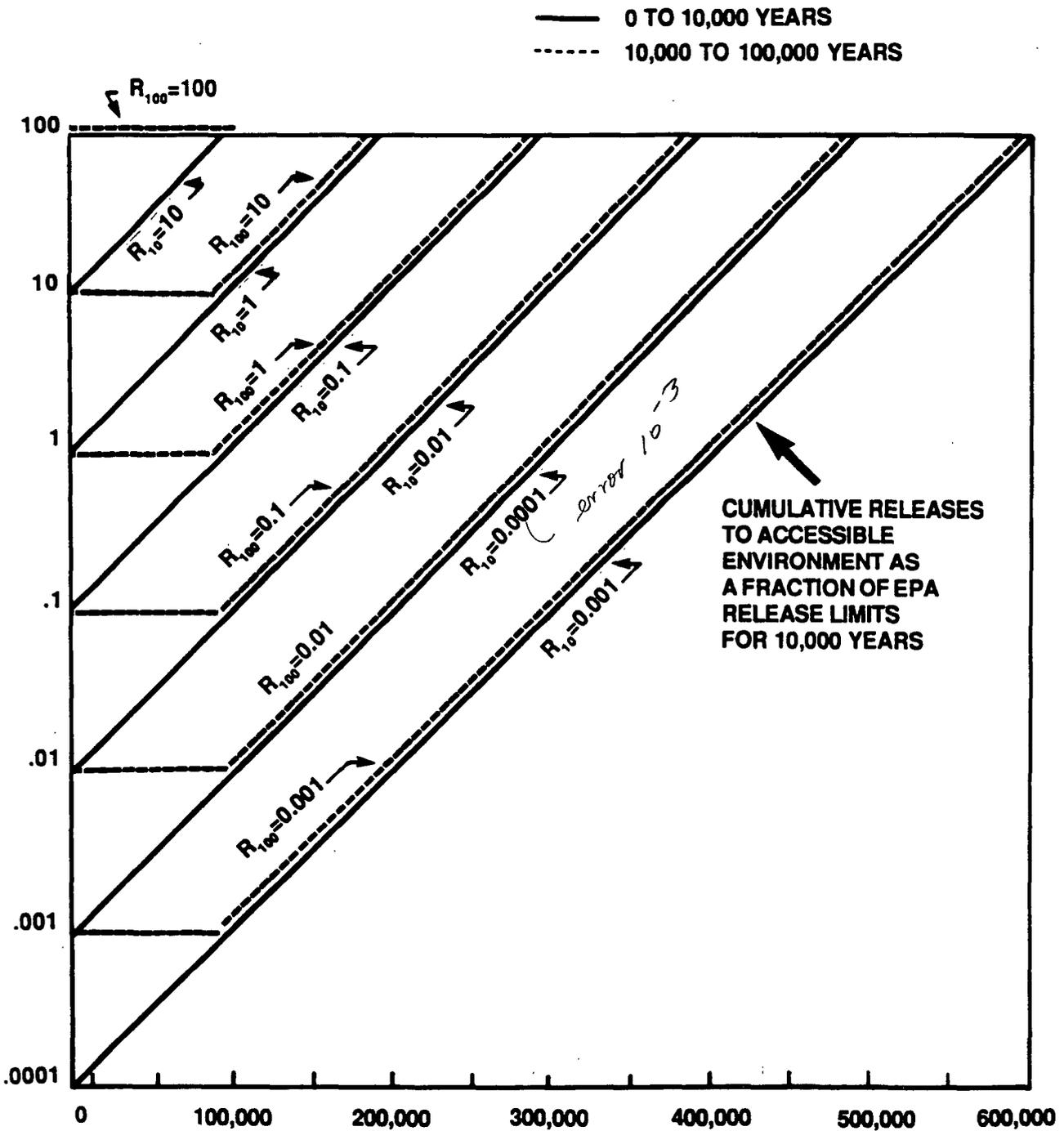


**RELATIONSHIPS TO AID JUDGMENTAL ESTIMATION OF
CUMULATIVE RELEASES TO THE ACCESSIBLE ENVIRONMENT
DURING THE FIRST 10,000 YEARS AFTER REPOSITORY
CLOSURE (DOE/RW-0074)**

EXAMPLE COMBINATION OF SITE CHARACTERISTICS								
		WASTE FORM DISSOLUTION			KEY RADIONUCLIDE TRAVEL TIME			ESTIMATED RELEASES
CUMULA- TIVE RELEASES	SCORE	VOLUMETRIC GW FLOW RATE	INHIBITING GEOCHEM- ISTRY	EST. % OF EPA RE- LEASE LIMITS	GW TRAVEL TIME	RETARDATION CAPABILITY	EST. TIME IN YEARS	
0.0001	10	EXTREMELY LOW	EXCELLENT	<1	EXTREMELY LONG	EXTREMELY FAVORABLE	200,000	INSIGNIFICANT
0.001	8	EXTREMELY LOW	VERY GOOD	~3	EXTREMELY LONG	EXTREMELY FAVORABLE	150,000	EXTREMELY SMALL
0.01	6	VERY LOW	GOOD	~10	VERY LONG	VERY FAVORABLE	100,000	VERY SMALL
0.1	4	LOW	GOOD	~30	LONG	FAVORABLE	50,000	SMALL
1	2	HIGH	POOR	~100	MODERATE	MODERATE	<10,000	SIGNIFICANT
10	0	EXTREMELY HIGH	VERY POOR	~1,000	SHORT	LITTLE	<3,000	EXTREMELY SIGNIFICANT

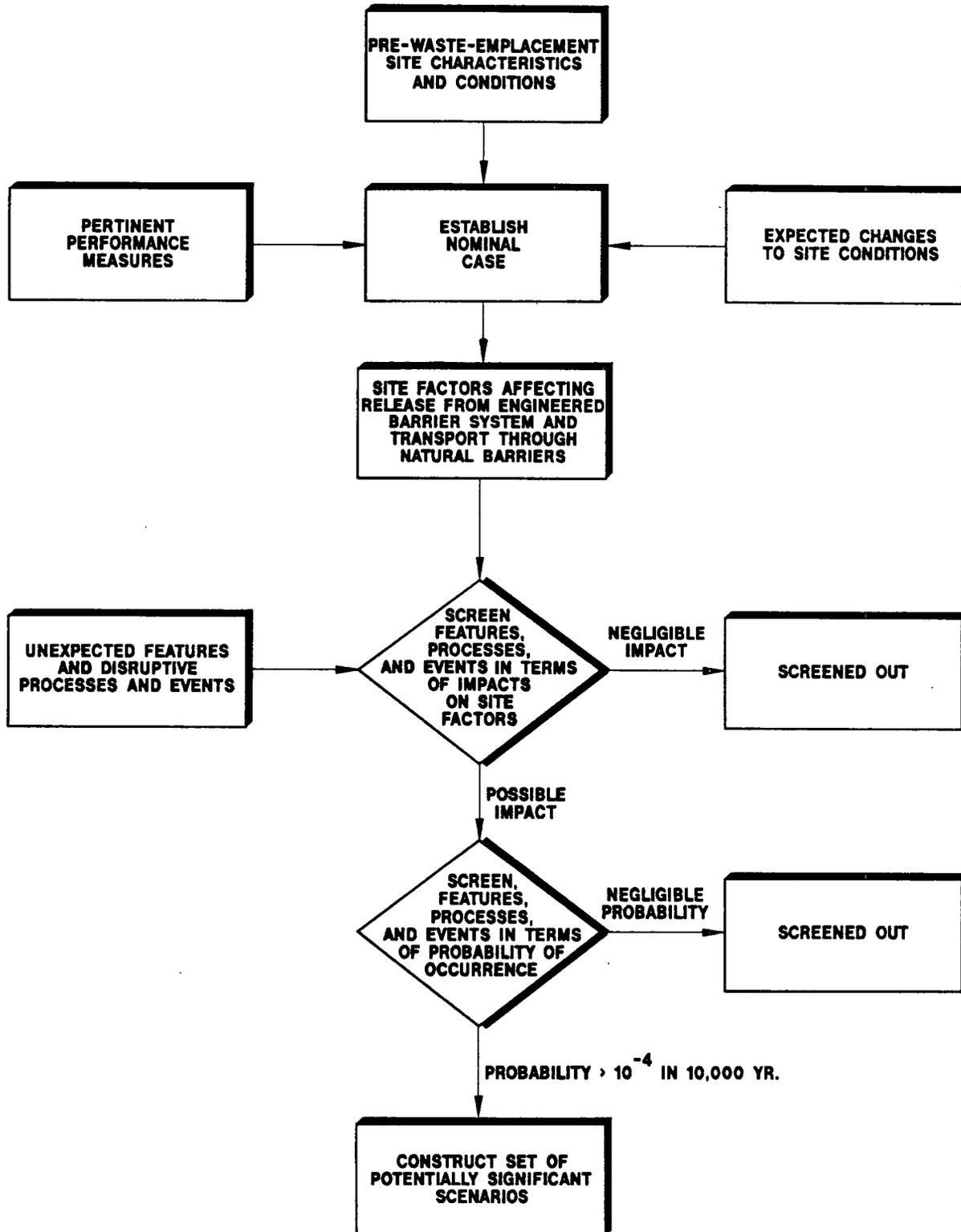
RELEASES TO THE ACCESSIBLE ENVIRONMENT (DOE/RW-0074)

FRACTION OF RADIONUCLIDES DISSOLVED IN GROUND WATER
 AS MULTIPLE OF EPA RELEASE LIMITS FOR 10,000 YEARS



T_i -- MEDIAN TRAVEL TIME OF KEY RADIONUCLIDES FROM EBS TO ACCESSIBLE ENVIRONMENT (YEARS)

GENERAL STEPS IN THE SCREENING AND DEVELOPMENT OF SCENARIOS (DOE/RW-0074)



PHENOMENA THAT ARE POTENTIALLY RELEVANT TO RELEASE SCENARIOS (DOE/RW-0074)

EXPECTED CONDITIONS

- **BRINE-INCLUSION
MIGRATION**
- **BUOYANCY AND
CONVECTIVE CELLS**
- **CHANGES IN ROCK
CHARACTERISTICS**
- **CLIMATE CHANGES**
- **CORROSION**
- **DIAGENESIS**
- **GEOCHEMICAL
CHANGES**
- **GEOHYDROLOGY
CHANGES**
- **LOCALIZED ROCK
FRACTURING**
- **SEA-LEVEL CHANGES**
- **THERMAL EFFECTS**
- **THERMOMECHANICAL
EFFECTS**

UNEXPECTED FEATURES

- **EXTREME CHANGES IN ROCK
CHARACTERISTICS, GEO-
HYDROLOGY, OR GEO-
CHEMISTRY, INDUCED
BY EXCAVATION OR HEAT
GENERATED BY WASTE**
- **UNDETECTED FEATURES,
SUCH AS FAULTS,
SHEAR ZONES,
BRECCIA PIPES,
DIKES, GAS POCKETS,
BOREHOLES**

PHENOMENA THAT ARE POTENTIALLY RELEVANT TO RELEASE SCENARIOS (DOE/RW-0074)

(CONTINUED)

DISRUPTIVE PROCESSES AND EVENTS

- BRINE POCKETS
- DEPOSITION
- DIAPIRISM
- DISSOLUTION
- EPEIROGENY
- EROSION
- METEORITE IMPACT
- SEVERE-WEATHER
PHENOMENA
- SURFACE-WATER
CHANGES
- TECTONIC ACTIVITY
 - FAULTING
 - MAGMATIC ACTIVITY
- HUMAN INTERFERENCE
 - DRILLING
 - GROUND-WATER WITHDRAWAL
 - INJECTION
 - IRRIGATION
 - MILITARY ACTIVITIES
 - MINING
 - RECHARGE
 - UNDERGROUND STORAGE
- PREMATURE FAILURE OF WASTE
PACKAGES
- INCOMPLETE SEALING OF THE SHAFTS
AND THE REPOSITORY

POSTCLOSURE SCENARIOS FOR THE YUCCA MOUNTAIN SITE (DOE/RW-0074)

SCENARIO	PROBABILITY (in 10,000 yrs)	EXPECTED CONSEQUENCES
EXPECTED CONDITIONS UNEXPECTED FEATURES EXTRUSIVE MAGMATIC EVENT DURING FIRST 500 YEARS EXTRUSIVE MAGMATIC EVENT AFTER FIRST 500 YEARS	0.8 TO 1 10⁻¹⁰ TO 0.2 10⁻¹⁰ TO 10⁻⁶ 10⁻¹⁰ TO 10⁻⁴	<i>To be determined</i> TBD TBD TBD TBD
REPOSITORY-INDUCED DISSOLUTION OF HOST ROCK ADVANCE OF A DISSOLUTION FRONT LARGE FAULT MOVEMENT INSIDE CONTROLLED AREA BUT OUTSIDE REPOSITORY LARGE-FAULT MOVEMENT WITHIN REPOSITORY SMALL-FAULT MOVEMENT INSIDE CONTROLLED AREA BUT OUTSIDE REPOSITORY SMALL-FAULT MOVEMENT WITHIN REPOSITORY LARGE-FAULT MOVEMENT OUTSIDE CONTROLLED AREA INTRUSIVE MAGMATIC EVENT LARGE-SCALE EXPLORATORY DRILLING SMALL-SCALE EXPLORATORY DRILLING FAILURE OF SHAFT AND REPOSITORY SEALS	NOT CREDIBLE NOT CREDIBLE — NOT CREDIBLE — — — NOT CREDIBLE <<10⁻⁴ — —	— — NOT SIGNIFICANT — NOT SIGNIFICANT NOT SIGNIFICANT NOT SIGNIFICANT NOT SIGNIFICANT — — NOT SIGNIFICANT NOT SIGNIFICANT

SOLUBILITY FACTORS FOR SPENT FUEL IN THE SUBSURFACE ENVIRONMENT AT THE YUCCA MOUNTAIN SITE (DOE/RW-0074)

RADIONUCLIDE	SOLUBILITY LIMIT (PPM)
C-14, Tc-99, I-129 Cs-135	LARGE
Np-237, Sr-90 WASTEFORM (UO ₂) Ra-226	MODERATE TO SMALL (<1,000 TO 1)
Pu-238, Pu-239, Pu-240, Pu-241, Pu-242, Am-241, Am-242, Am-243, Sn-126	VERY SMALL (<1)

TIME PERIOD (YEARS)	FRACTIONAL RELEASE (PER m ³ OF gw PER 1,000 MTHM)
0 TO 1,000	5.3 X 10 ⁻⁴
1,000 TO 10,000	2.2 X 10 ⁻⁴
10,000 TO 100,000	9.4 X 10 ⁻⁶

SITE CHARACTERISTICS AND PERFORMANCE FACTORS FOR EXPECTED CONDITIONS AT YUCCA MOUNTAIN (DOE/RW-0074)

PARAMETER	RANGE OF PARAMETER VALUES	
	0 TO 10,000 YEARS	10,000 TO 100,000 YEARS
Q - VOLUME OF WATER AVAILABLE FOR DISSOLUTION OF WASTE (m³/1,000 MTHM) $\sum \frac{C_i}{RL_i}$ (1,000 MTHM/m ³) <i>Metric tons Heavy Metal</i>	0 TO 44,000	0 TO 400,000
	2.2X10 ⁻⁸ TO 2.2X10 ⁻⁴	9.4X10 ⁻¹⁰ TO 9.4X10 ⁻⁶
F - RADIONUCLIDE RELEASE FROM ENGINEERED BARRIER SYSTEM*	0.001 TO 9.7	0.0001 TO 3.8
T - MEDIAN GROUND-WATER TRAVEL TIME (YEARS)	42,000 TO 200,000	42,000 TO 200,000
R - RETARDATION FACTOR	100 TO 1,000	100 TO 1,000
T_i - MEDIAN RADIONUCLIDE TRAVEL TIME (YEARS)	4.3X10 ⁶ TO 2X10 ⁸	> 4.3X10 ⁶
WASTE PACKAGE LIFETIME (YEARS)	3,000 TO 30,000	

* MULTIPLE OF EPA RELEASE LIMITS FOR 10,000 YEARS

ESTIMATED RADIONUCLIDE RELEASES TO ACCESSIBLE ENVIRONMENT FROM YUCCA MOUNTAIN REPOSITORY (DOE/RW-0074)

*soluble only
NOT volatile*

SCENARIO	JUDGEMENT	PROBABILITY	RADIONUCLIDE RELEASES *	
			0 TO 10,000 YEARS	10,000 TO 100,000 YEARS
EXPECTED CONDITIONS	HIGH BEST JUDGEMENT LOW	~1 0.98 0.80	0.0001 0.0001 0.032	0.001 0.0032 0.32
<u>UN</u> EXPECTED FEATURES	HIGH BEST JUDGEMENT LOW	10 ⁻¹⁰ 0.019 0.20	0.0001 0.001 1	0.001 0.01 10
EXTRUSIVE MAGMATIC EVENT DURING FIRST 500 YEARS	HIGH BEST JUDGEMENT LOW	10 ⁻¹⁰ 5X10 ⁻⁸ 5X10 ⁻⁶	0.0032 1 10	0.0032 0.032 3.2
EXTRUSIVE MAGMATIC EVENT AFTER FIRST 500 YEARS	HIGH BEST JUDGEMENT LOW	10 ⁻¹⁰ 10 ⁻⁶ 10 ⁻⁴	0.0032 0.32 10	0.001 0.032 10

* MULTIPLE OF EPA RELEASE LIMITS FOR 10,000 YEARS

SUMMARY OF ESTIMATED RADIONUCLIDE RELEASES TO ACCESSIBLE ENVIRONMENT FROM REPOSITORY AT THE YUCCA MOUNTAIN SITE

REFERENCE	SITE CONDITIONS	FRACTIONAL RELEASE RATE FROM EBS (PER YEAR)	RADIONUCLIDE RELEASES *	
			0 TO 10,000 YEARS	0 TO 100,000 YEARS
MULTIATTRIBUTE UTILITY ANALYSIS OF NOMINATED SITES (DOE/RW-0074)	EXPECTED CONDITIONS HIGH BEST JUDGEMENT LOW	10^{-10} TO 10^{-3}	10^{-4} 10^{-4} 0.032	1.1×10^{-3} 3.3×10^{-5} 0.35
	ALL SCENARIOS (RELEASES WEIGHTED BY PROBABILITIES) HIGH BEST JUDGEMENT LOW	10^{-10} TO 10^{-3}	10^{-4} 1.2×10^{-4} 0.23	1.1×10^{-3} 3.4×10^{-3} 0.35
ENVIRONMENTAL ASSESSMENT FOR YUCCA MOUNTAIN SITE (DOE/RW-0073)	REFERENCE CASE (EXPECTED CONDITIONS WITH UPPER BOUND FLUX OF 5×10^{-4} M ³ /M ² -yr)	2.5×10^{-9}	$< 10^{-7}$	1.4×10^{-3}
	PERFORMANCE-LIMITS CASE (EX- PECTED CONDITIONS, BUT WITH SHORT WASTE-PACKAGE LIFETIME AND HIGH RELEASE RATES CON- SIDERED NOT REALISTIC)	10^{-6} 10^{-5} 10^{-4}	$< 2 \times 10^{-6}$ $< 2 \times 10^{-5}$ $< 2 \times 10^{-4}$	2.7×10^{-3} 2.7×10^{-2} 0.23

* MULTIPLE OF EPA RELEASE LIMITS FOR 10,000 YEARS

CONCLUSIONS

- **ORDERLY AND DOCUMENTED PROCESS, USING A GROUP OF TECHNICAL SPECIALISTS, WAS ORGANIZED AND IMPLEMENTED TO:**
 - IDENTIFY AND SCREEN DISRUPTIVE SCENARIOS ON BASIS OF EXPECTED IMPACT AND PROBABILITY OF OCCURRENCE
 - ESTIMATE RADIONUCLIDE RELEASES TO THE ACCESSIBLE ENVIRONMENT ON BASIS OF SITE CHARACTERISTICS (PERFORMANCE FACTORS)

- **RESULTS OF THE PROCESS INDICATED THAT:**
 - THE RELEASES ARE PROJECTED TO BE VERY SMALL AND WELL WITHIN THE EPA LIMITS FOR 10,000 YEARS
 - THE SCENARIO OF "UNEXPECTED FEATURES" WAS FOUND TO HAVE THE HIGHEST PROBABILITY OF OCCURRENCE AMONG THE SET OF SCENARIOS CONSIDERED DISRUPTIVE
 - THE RELEASES BOUNDED THOSE REPORTED IN THE ENVIRONMENTAL ASSESSMENT FOR THE YUCCA MOUNTAIN SITE

APPENDIX

CORRESPONDENCE BETWEEN THE SITE SCORING SCALE AND THE PERFORMANCE MEASURE FOR THE 10,000-YEAR POST CLOSURE SITING OBJECTIVE (DOE/RW-0074)

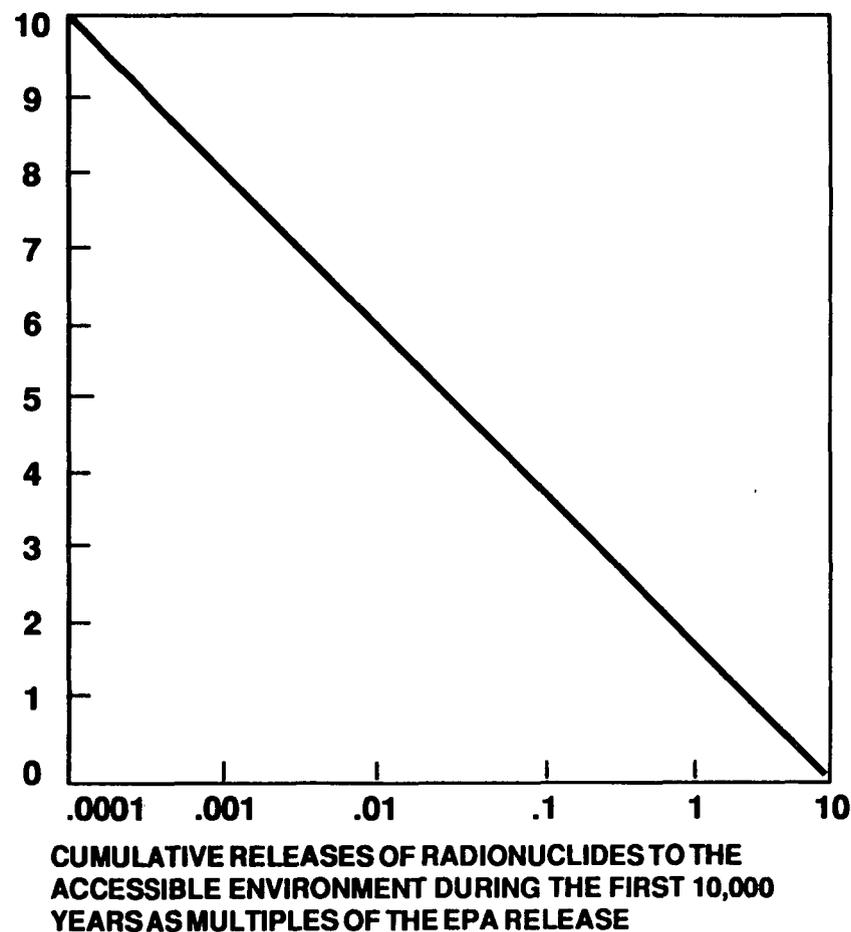
OBJECTIVE:

MINIMIZE THE TOTAL NUMBER OF HEALTH EFFECTS ATTRIBUTABLE TO THE REPOSITORY DURING THE FIRST 10,000 YEARS AFTER CLOSURE

PERFORMANCE MEASURE:

CUMULATIVE RELEASES OF RADIONUCLIDES TO THE ACCESSIBLE ENVIRONMENT

SITE SCORING SCALE



SITE CONDITIONS AND CHARACTERISTICS AFFECTING REPOSITORY-PERFORMANCE FACTORS (DOE/RW-0074)

CONDITIONS AFFECTING WASTE-PACKAGE LIFETIME

- **THERMAL CONDITIONS**
- **MECHANICAL CONDITIONS (THERMOMECHANICAL STRESSES, GROUND MOVEMENT)**
- **VOLUME OF, AND REPLACEMENT RATE FOR, FLUIDS NEAR WASTE PACKAGE**
- **CORROSION RATE**

LOCAL FLUID CONDITIONS AFFECTING THE RATE OF RELEASE FROM THE ENGINEERED-BARRIER SYSTEM

- **GROUND-WATER FLUX THROUGH THE HOST ROCK OR SEEPAGE INTO REPOSITORY**
- **NUMBER OF PACKAGES EXPOSED TO WATER**

LOCAL CHEMICAL CONDITIONS AFFECTING THE RATE OF RELEASE FROM THE ENGINEERED-BARRIER SYSTEM

- **RADIONUCLIDE SOLUBILITY**
- **WASTE-FORM DISSOLUTION RATE**
- **THERMAL EFFECTS ON LEACH RATES AND LOCAL CHEMICAL CONDITIONS**

PARTICIPANTS IN POSTCLOSURE PERFORMANCE ASSESSMENT FOR COMPARATIVE SITE EVALUATION (DOE/RW-0074)

METHODOLOGY LEAD GROUP

GEOLOGIC DISPOSAL

TOM LONGO* (DOE-OGR)
PAUL GNIRK (RE/SPEC)

21 YEARS OF COMBINED
EXPERIENCE IN GEOLOGIC
DISPOSAL OF RADIOACTIVE WASTES

DECISION ANALYSIS

LEE MERKHOFFER
(APPLIED DECISION ANALYSIS)
RALPH KEENEY**
(UNIV. SOUTHERN CALIFORNIA)

29 YEARS OF COMBINED
EXPERIENCE IN DECISION
ANALYSIS AND RISK ASSESSMENT

* MLG LEAD

** JAN. - APRIL 1986

AD HOC TECHNICAL ADVISORY GROUP

FELTON BINGHAM
(SANDIAL NATIONAL LABORATORY)
JAMES CAMPBELL
(INTERA TECH.)

BUDI SAGAR
(ROCKWELL-HERFORD OPS.)
WENDALL WEART
(SANDIAL NATIONAL LABORATORY)

31 YEARS OF COMBINED EXPERIENCE IN GEOLOGIC DISPOSAL
OF RADIOACTIVE WASTES, INCLUDING PERFORMANCE ASSESSMENT

POST CLOSURE TECHNICAL SPECIALISTS

ALLEN JELACIC*** (DOE-OGR)

JEFF KIMBALL (WESTON)

JAY RHODERICK (DOE-OGR)

SAM PANNO (WESTON)

GLEN FAULKNER (USGS-DOE-OGR)

MARTHA PENDLETON (WESTON)

KENNETH CZYSCINSKI (WESTON)

LARRY RICKERTSEN (WESTON)

WILLIAM HEWITT (WESTON)

DAVID SIEFKEN (WESTON)

ROBERT JACKSON (WESTON)

ROBERT JACKSON (WESTON)

62 YEARS OF COMBINED EXPERIENCE IN GEOLOGIC DISPOSAL OF RADIOACTIVE WASTES,
PLUS 26 YEARS OF COMBINED EXPERIENCE IN GEOLOGY, GEOPHYSICS, HYDROLOGY,
GEOCHEMISTRY, GEOTECHNICAL ENGINEERING, SAFETY ASSESSMENT, AND NUMERICAL
MODELING

*** LEAD

SITE CONDITIONS AND CHARACTERISTICS AFFECTING REPOSITORY- PERFORMANCE FACTORS (DOE/RW-0074)

CONDITIONS AFFECTING GROUND-WATER MOVEMENT TO ACCESSIBLE ENVIRONMENT

- **ROCK CHARACTERISTICS THAT DETERMINE
GROUND-WATER PATHWAYS**
- **HYDRAULIC PROPERTIES**
- **HEAD GRADIENTS**
- **UNSATURATED FLOW CHARACTERISTICS**
- **CONSTRAINTS DUE TO REGIONAL FLOW CONDITIONS**

CONDITIONS AFFECTING RETARDATION

- **SORPTION**
- **PRECIPITATION**
- **PHYSICAL RETARDATION**
- **DISPERSION**

OTHER CONDITIONS AFFECTING RADIONUCLIDE- TRAVEL TIME

- **DIFFUSION TRANSPORT**
- **TRANSPORT OF GASES**