Sec 101 -
for memo from
Prichard 9/19/83

Basalt Waste Isolation Project

Advisory Committee on Reactor Safeguards
Subcommittee on Waste Management Program

Richland, Washington
September 8-9, 1983

#00620

AGENDA

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS (ACRS)
SUBCOMMITTEE ON WASTE MANAGEMENT PROGRAM

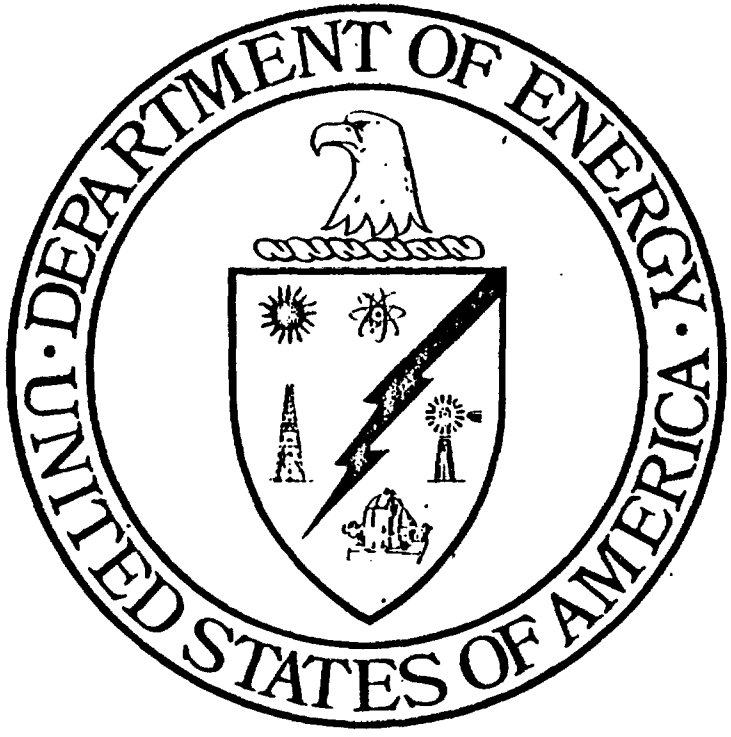
BASALT WASTE ISOLATION PROJECT

THURSDAY, SEPTEMBER 8, 1983

5:00 p.m.	ACRS OPENING REMARKS	D. W. MOELLER
5:15	U.S. DEPARTMENT OF ENERGY INTRODUCTION	O. L. OLSON
5:30	PROGRAM OVERVIEW	J. H. LARUE
5:55	GEOLOGY	S. M. PRICE
6:25	HYDROLOGY	S. M. BAKER
6:55	BREAK	
7:10	GEOENGINEERING AND REPOSITORY DESIGN	D. A. TURNER
8:00	WASTE PACKAGE	M. J. SMITH
8:30	GEOCHEMISTRY	P. F. SALTER
9:00	PERFORMANCE ASSESSMENT	R. G. BACA

FRIDAY, SEPTEMBER 9, 1983

8:00 a.m.	ACRS DISCUSSION
10:00	ADJOURN



BASALT WASTE ISOLATION PROJECT

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
SUBCOMMITTEE ON WASTE MANAGEMENT PROGRAM
RICHLAND, WASHINGTON
SEPTEMBER 8–9, 1983

PROGRAM OVERVIEW

J. H. LARUE

PROGRAM OVERVIEW

- HISTORY/BACKGROUND
- COMMENTS FROM APRIL 1983 ADVISORY COMMITTEE ON REACTOR SAFEGUARDS MEETING
- SITE CHARACTERIZATION REPORT COMMENT RESOLUTION PROCESS
- TOPICAL TECHNICAL MEETINGS TO RESOLVE OPEN ITEMS
- BASALT WASTE ISOLATION PROJECT/U.S. NUCLEAR REGULATORY COMMISSION "COMMUNICATORS"
- DATA RELEASE SYSTEM
- PLANNED INTERACTIONS

HISTORY/BACKGROUND

09/82 NATIONAL ENVIRONMENTAL POLICY ACT OF 1969 ENVIRONMENTAL ASSESSMENT FOR THE EXPLORATORY SHAFT SUBMITTED – FINDING OF NO SIGNIFICANT IMPACT ISSUED

11/82 SITE CHARACTERIZATION REPORT ISSUED TO NRC

01/83 NUCLEAR WASTE POLICY ACT OF 1982 PASSES

- SITING GUIDELINES
- ENVIRONMENTAL ASSESSMENT
- SITE CHARACTERIZATION PLAN
- SCHEDULE

03/83 PUBLIC HEARINGS (ENVIRONMENTAL ASSESSMENT, SITE CHARACTERIZATION REPORT)

04/83 NRC ISSUED DRAFT SITE CHARACTERIZATION ANALYSIS

04/83 ADVISORY COMMITTEE ON REACTOR SAFEGUARDS MEETING – SITE CHARACTERIZATION REPORT

COMMENTS FROM APRIL 1983 ADVISORY COMMITTEE ON REACTOR SAFEGUARDS MEETING

GENERAL COMMENTS

- INCREASE NRC/DOE INTERFACE
- PRIORITIZE DATA REQUESTS
- IMPROVE DATA AVAILABILITY
- NRC SPECIFY SITE CHARACTERIZATION PLAN REVIEW PROCESS
- NRC PRIORITIZE ISSUES

TECHNICAL COMMENTS

- ADDITIONAL DATA NEEDS
- DATA UNCERTAINITY
- SEISMICITY
- ROCK STRENGTH/PERMEABILITY
- REPOSITORY DESIGN
- GEOCHEMISTRY/WASTE PACKAGE

SITE CHARACTERIZATION REPORT
COMMENT RESOLUTION PROCESS

RECEIVE COMMENTS FROM PROGRAM PARTICIPANTS

- NRC – 03/83 (DRAFT SITE CHARACTERIZATION ANALYSIS)
- AFFECTED INDIAN TRIBES/PUBLIC – 03/83 (COMBINED WITH ENVIRONMENTAL ASSESSMENT'S COMMENT PROCESS)
- USGS – 05/83
- STATE – 05/83 (GOLDER REPORT)

ISSUE INTERIM DISPOSITION TABLES

- NRC – 06/83
- USGS – 07/83
- STATE – 09/83 (PLANNED)

CONDUCT MEETINGS TO ATTAIN AGREEMENT ON DISPOSITIONS/OPEN ITEMS

- NRC – 06/83
- USGS – 09/83 (PLANNED)
- STATE – TO BE DETERMINED

SITE CHARACTERIZATION REPORT
COMMENT RESOLUTION PROCESS (CONTINUED)

ISSUE FINAL DISPOSITION TABLES

- NRC – 09/83
- USGS – TO BE DETERMINED
- STATE – TO BE DETERMINED

RESOLVE OPEN ITEMS IN TOPICAL TECHNICAL MEETINGS

TABLE II

GEOCHEMISTRY

ITEM REFERENCE: Chapter 11, page 11-9, items 11 and 12

NRC COMMENT: Rock/water interactions. Dissolved silica can act as a pH buffer through the H_4SiO_4/H_3SiO_4 couple. There are, however, additional pH buffering couples that are found in reference BWIP groundwater (e.g., $HCO_3^-/CO_3^=$, H_2O/OH^-) and that should be evaluated.

STATUS: Agreed

BWIP RESPONSE: Recent results from hydrothermal and theoretical studies which are reported in RHO-BWI-ST-38 P illustrate that silicic acid is the dominant pH buffer in Grande Ronde groundwaters at low temperature. At elevated temperatures (100^o-300^oC) hydroxyl (OH-) and carbonate (CO_3^{2-}) equilibria become important. This will be discussed and evaluated in Chapter 6 of the SCP.

ITEM REFERENCE: Chapter 11, page 11-10, items 1, 2, 3, 6, 7, 8, 9, 10, 11, and 14.

NRC COMMENT: Item 1. Use of baseline geochemical data as a "natural experiment". There should be use of the baseline information which must be gathered during characterization of the prevailing in situ geochemical conditions as a "natural experiment".

STATUS: Open

BWIP RESPONSE: It is not clear if the "natural experiment" refers to "geochemical conditions", "characterization of conditions", or "baseline information". The BWIP will be including in the SCP a discussion of in situ, diagenetic alteration of Columbia River basalts as evidence for expected alteration of basalt after emplacement of nuclear waste. Thus, site characterization data will be used as a "natural analog" for long-term basalt alteration. A discussion of how the natural analog studies will be used to support waste package design will be included in the SCP, Chapter 6. The NRC will provide additional written clarification.

. . . . . .

TOPICAL TECHNICAL MEETINGS TO RESOLVE OPEN ITEMS

DATE	SUBJECT
07/11/83	HYDROLOGY
08/30/83	PERFORMANCE ASSESSMENT
10/83*	UNDERGROUND TESTING
11/83*	WASTE PACKAGE, GEOCHEMISTRY, HYDROCHEMISTRY
12/83*	GEOLOGY AND TECTONICS
01/84*	REPOSITORY AND QUALITY ASSURANCE

*TENTATIVE DATES

BASALT WASTE ISOLATION PROJECT/
U.S. NUCLEAR REGULATORY COMMISSION
"COMMUNICATORS"

AREA	BWIP COMMUNICATOR	NRC CONTACT
GEOCHEMISTRY	P. F. SALTER	P. JUSTUS
GEOLOGY	S. M. PRICE	P. PRESTHOLT
HYDROGEOLOGY	G. S. HUNT	T. VERMA
PERFORMANCE ASSESSMENT	R. T. WILDE	D. FEHRINGER
QUALITY ASSURANCE	M. S. KAROL*	J. GREEVES
REPOSITORY DESIGN	R. J. GIMERA	J. GREEVES
WASTE PACKAGE	M. J. SMITH	M. KNAPP

*DOE

DATA RELEASE SYSTEM

PROVIDE PROGRAM PARTICIPANTS

- NRC
- USGS
- STATE
- AFFECTED INDIAN TRIBES
- PUBLIC AGENCIES
- INTERESTED PARTIES

WITH ACCESS TO

- MONTHLY/ANNUAL DATA INDEX
- RELEASED REPORTS
- TEST PLANS
- APPROVED BASALT OPERATING PROCEDURES
- DESIGN DOCUMENTATION

PLANNED INTERACTIONS

- 08/83 – NRC SITE REPRESENTATIVE AT RICHLAND
- PUBLIC INFORMATION MEETINGS THROUGHOUT WASHINGTON, OREGON, IDAHO
- VARIOUS TOURS CONDUCTED ON SITE
- INCREASED INTERFACE WITH STATE, AFFECTED INDIAN TRIBES, LOCAL GOVERNMENTS, PUBLIC, ETC.

GEOLOGY

S. M. PRICE

SUMMARY OF GEOLOGY CONCERNS

- PRESENT STRATIGRAPHIC DISCONTINUITIES
- PRESENT STRUCTURAL DISCONTINUITIES IN PASCO BASIN
- PROBABILITIES AND NATURE OF NATURAL CHANGES THAT WOULD AFFECT REPOSITORY PERFORMANCE (e.g., TECTONICS AND SEISMICITY)

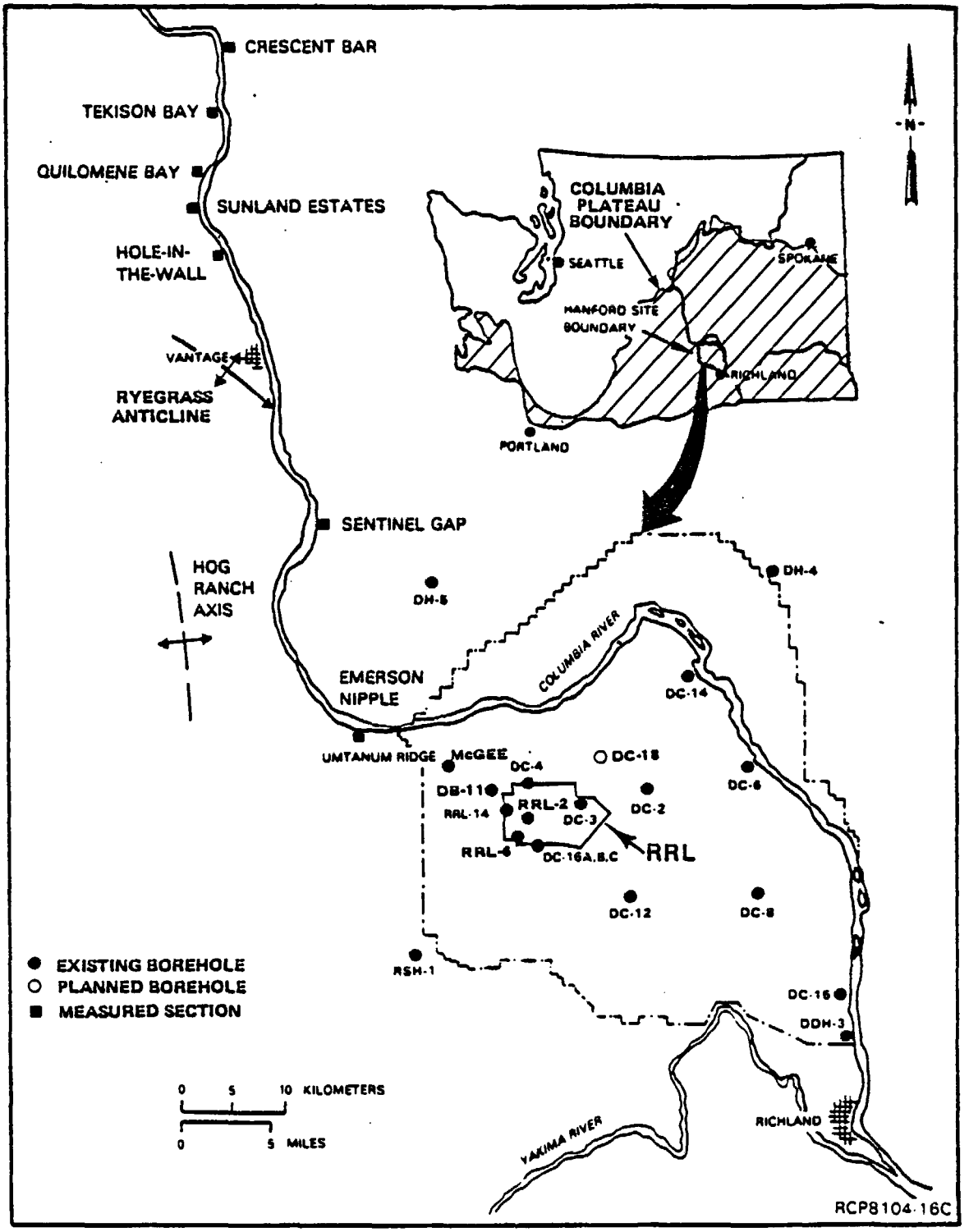
GEOLOGIC STUDIES

CONCERNS / PLANS FOR RESOLUTION	HOST ROCK				TECTONIC			
	STRATIGRAPHIC DISCONTINUITIES	STRUCTURAL DISCONTINUITIES			TECTONICS AND SEISMICITY			
					TECTONIC STABILITY			
		FRACTURE ANALYSIS			DEFORMATION RATE/PATTERN			
	INTRAFLOW STRUCTURES	COOLING	TECTONIC	GEOPHYSICAL ANOMALIES	GEOLOGIC	CONTEMPORARY	TECTONIC MODEL(s)	SEISMIC DESIGN/ CONSTRUCTIBILITY
OUTCROP ANALYSIS	●	●	●	●	●		●	
BOREHOLE STUDIES/TESTING*	●	●	●	●	●	●	●	
LABORATORY ANALYSIS**	●	●	●	●	●			
EXPLORATORY SHAFT**	●	●	●	●		●	●	●
GEOPHYSICAL SURVEYS**							●	
SEISMIC SURVEILLANCE*			●	●		●	●	●
GEODETIC/ LEVELING SURVEYS**						●	●	
CONCEPTUAL MODELING	●	●	●	●	●	●	●	●

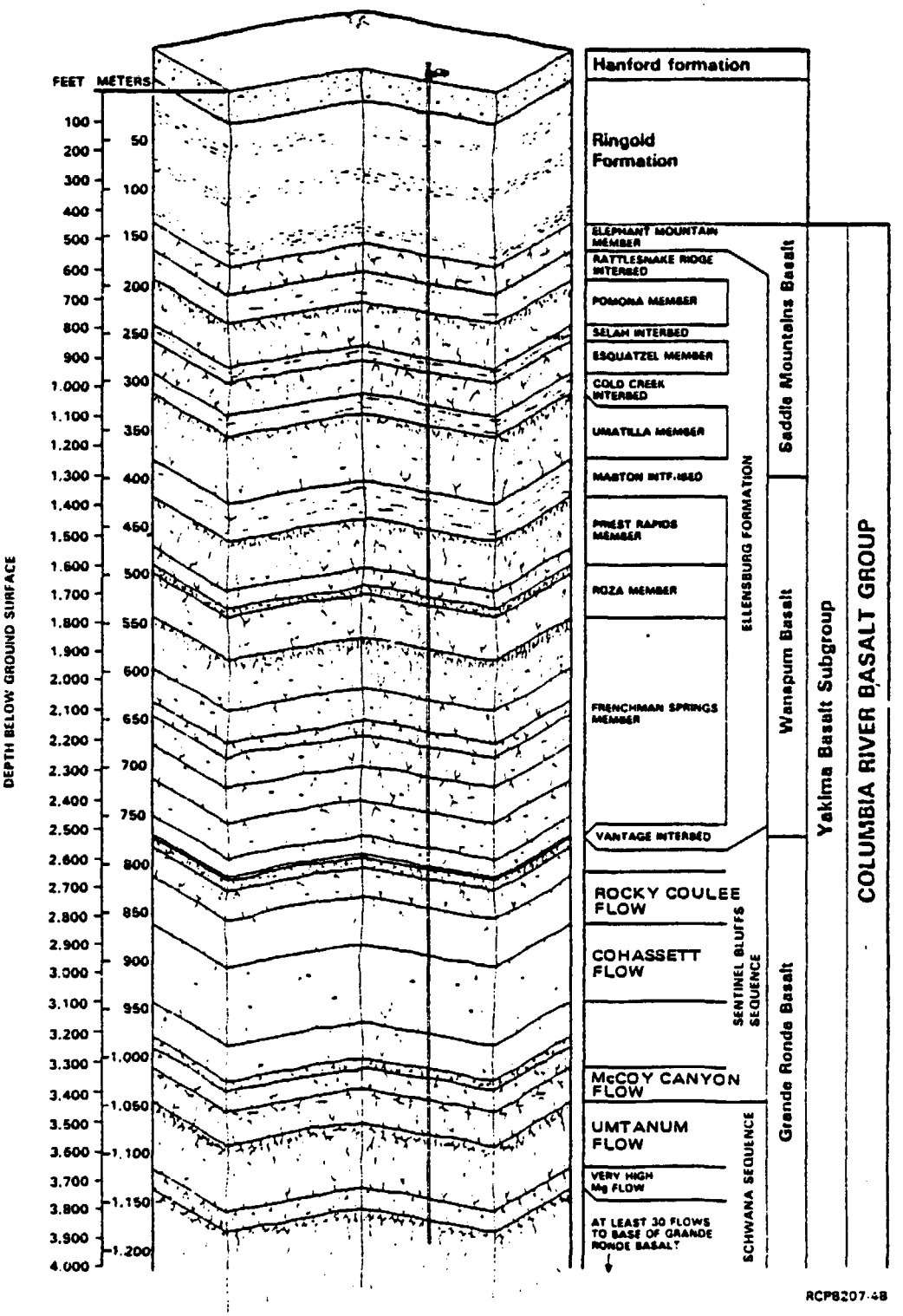
* TEST PLAN COMPLETED

** TEST PLAN IN PROGRESS OR UNDER CONSIDERATION

LOCATION MAP, REFERENCE REPOSITORY LOCATION AND SURROUNDING AREA



REFERENCE REPOSITORY LOCATION STRATIGRAPHY



RCP8207-48

HORIZON IDENTIFICATION STUDY
RANKING MEASURES

PERFORMANCE-RELATED MEASURES

- RADIONUCLIDE RELEASE
- GROUNDWATER TRAVELTIME
- RADIONUCLIDE PLUME DEPTH

CONSTRUCTION-RELATED MEASURES

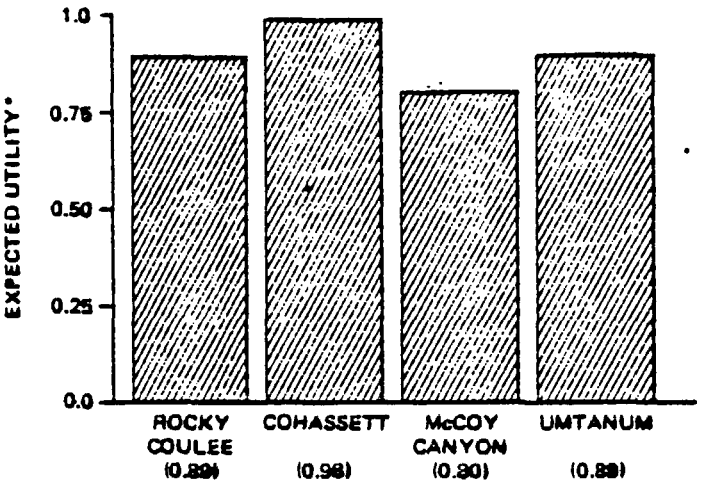
- MEAN INTERIOR THICKNESS
- MINIMUM INTERIOR THICKNESS
- PERCENT VESICULATION

COST-RELATED MEASURES

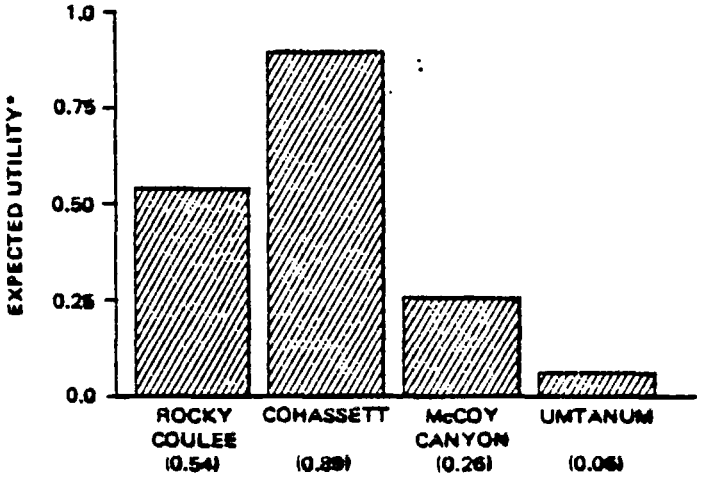
- COST SAVINGS
- SCHEDULE SAVINGS

RANKING RESULTS BASED ON DETERMINISTIC AND PROBABILISTIC EVALUATIONS

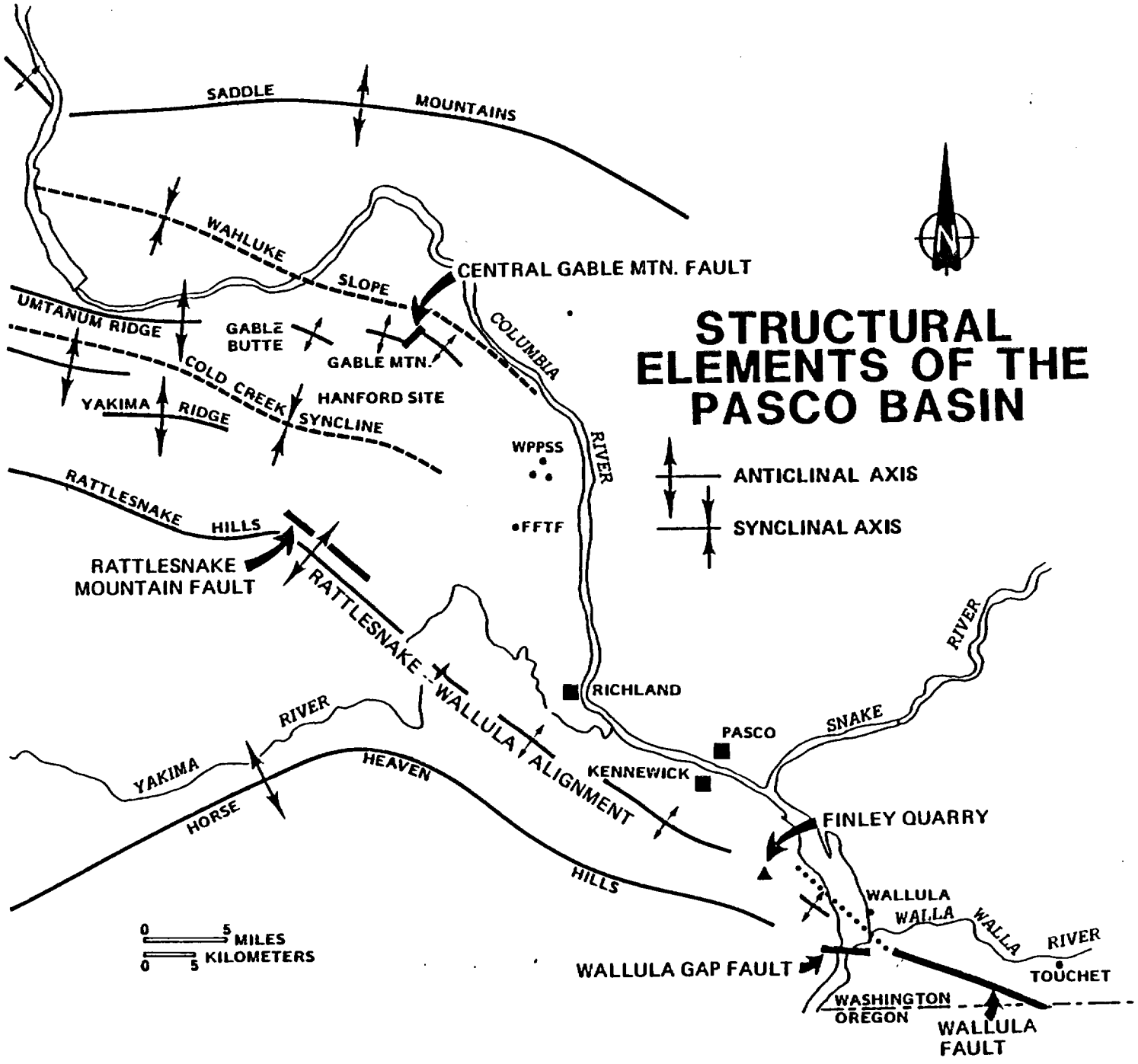
DETERMINISTIC CASE



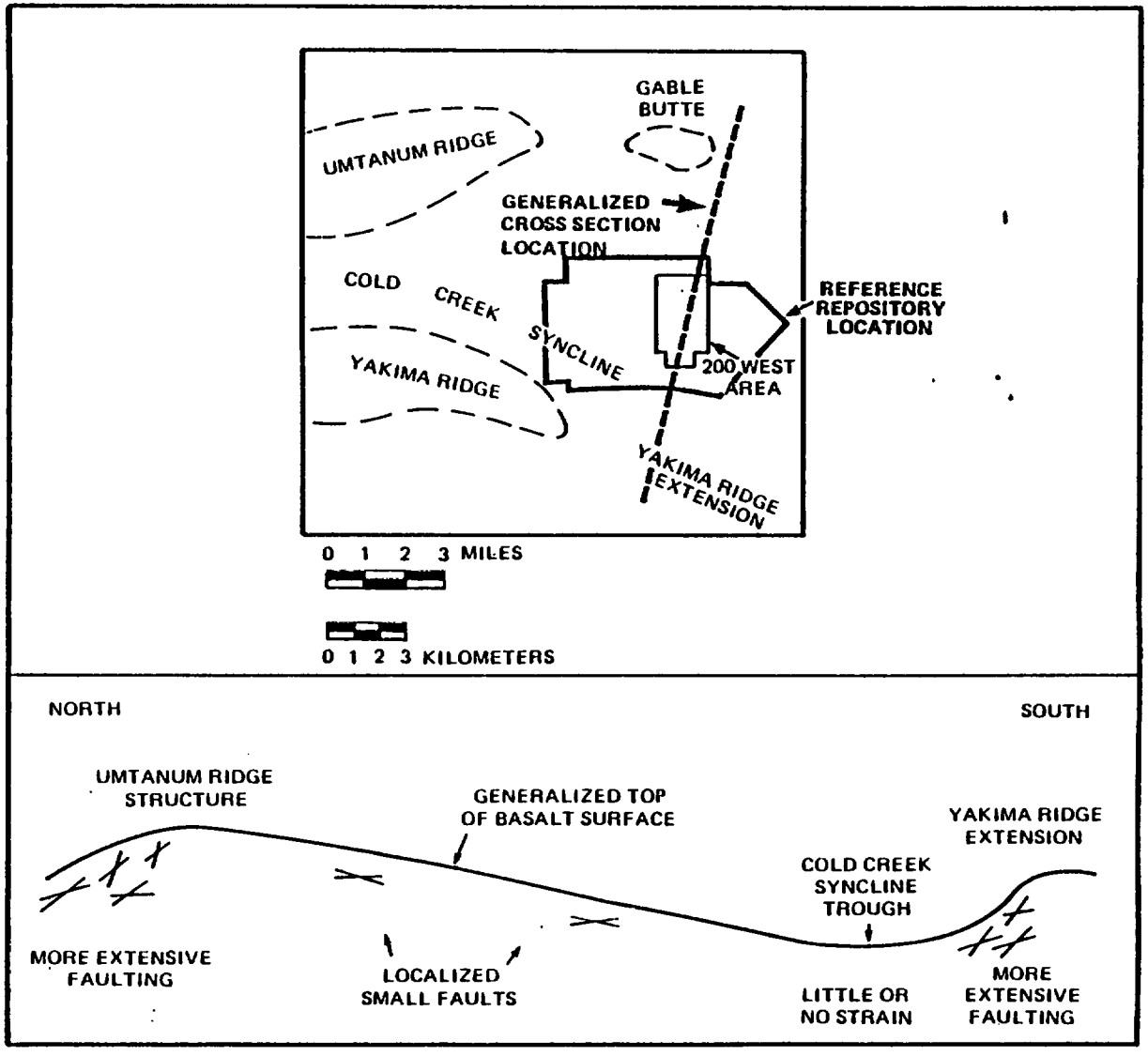
PROBABILISTIC CASE



*UTILITY: *a number that reflects the relative desirability of a candidate horizon.*


SADDLE MOUNTAINS
WAHLUKE SLOPE
CENTRAL GABLE MTN. FAULT
UMTANUM RIDGE
GABLE BUTTE
GABLE MTN.
COLD CREEK SYNCLINE
HANFORD SITE
YAKIMA RIDGE
COLUMBIA RIVER
WPPSS
FFTF
RATTLESNAKE HILLS
RATTLESNAKE MOUNTAIN FAULT
RATTLESNAKE - WALLULA ALIGNMENT
RICHLAND
PASCO
KENNEWICK
SNAKE RIVER
YAKIMA RIVER
HORSE HEAVEN HILLS
FINLEY QUARRY
WALLULA
WALLA WALLA RIVER
TOUCHET
WALLULA GAP FAULT
WASHINGTON
OREGON
WALLULA FAULT
0 5 MILES
0 5 KILOMETERS
N
STRUCTURAL ELEMENTS OF THE PASCO BASIN
ANTICLINAL AXIS
SYNCLINAL AXIS

SCHEMATIC CROSS SECTION, COLD CREEK SYNCLINE



TECTONIC BRECCIA STUDY

STATUS

- GEOLOGIC MAPPING UNDER WAY IN VANTAGE AREA
- SAMPLING APPROACH UNDER DEVELOPMENT
- BRECCIA CLASSIFICATION SCHEME UNDER DEVELOPMENT

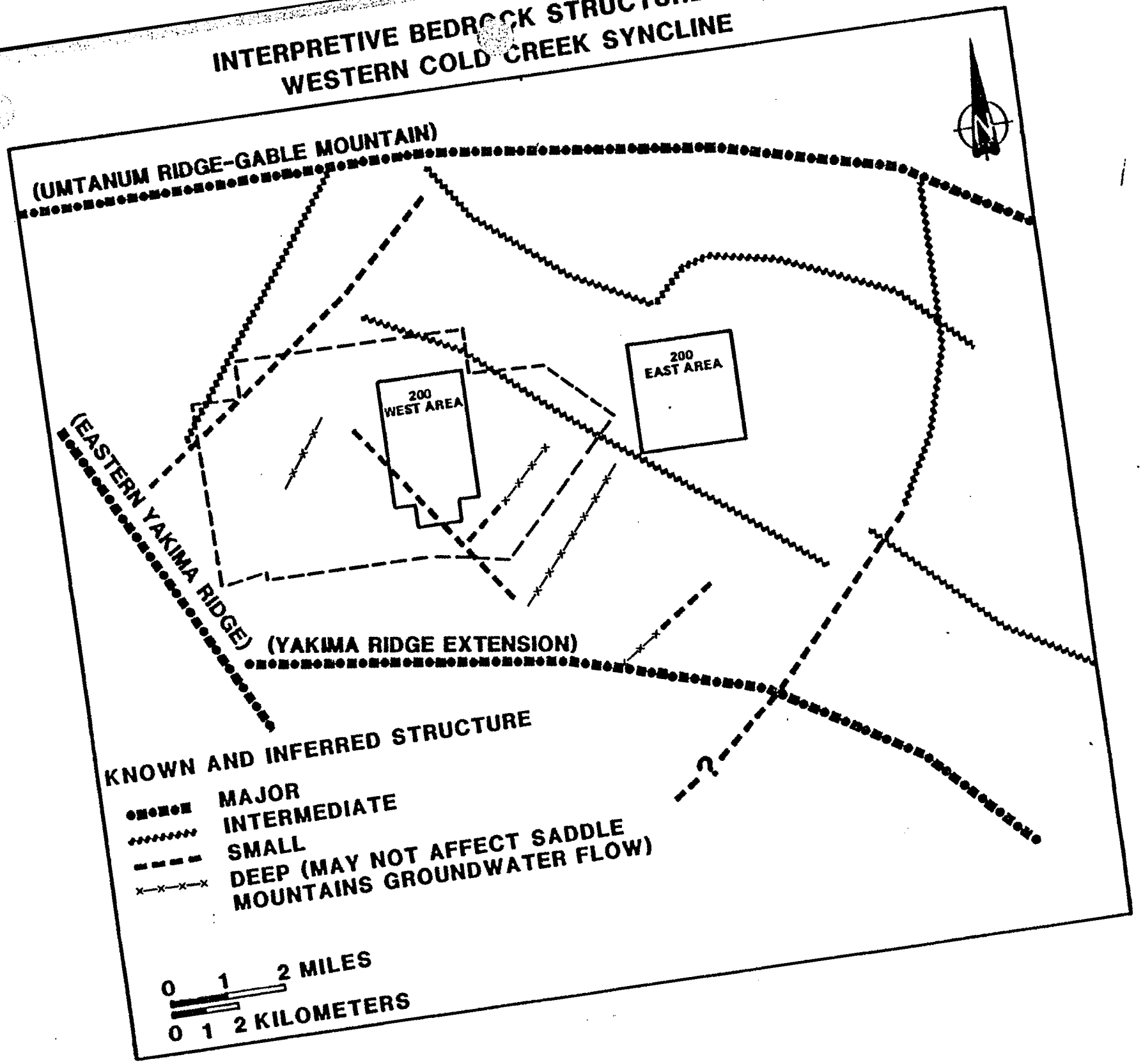
PRELIMINARY FINDINGS

- INCREASED FREQUENCY OF BRECCIA ZONES ALONG THE RYEGRASS MOUNTAIN STRUCTURAL ZONE
- SCATTERED BRECCIA ZONES NOT DIRECTLY RELATED TO STRUCTURES
- POSSIBLE REGIONAL TECTONIC JOINTS

PLANS

- COMPLETION OF GEOLOGIC MAPPING AND ANALYSIS OF BRECCIAS ALONG TRAVERSE LINES
- ANALYSIS OF BRECCIAS IN CORE
- COMPARISON OF VANTAGE AREA AND COLD CREEK SYNCLINE

INTERPRETIVE BEDROCK STRUCTURES MAP
WESTERN COLD CREEK SYNCLINE



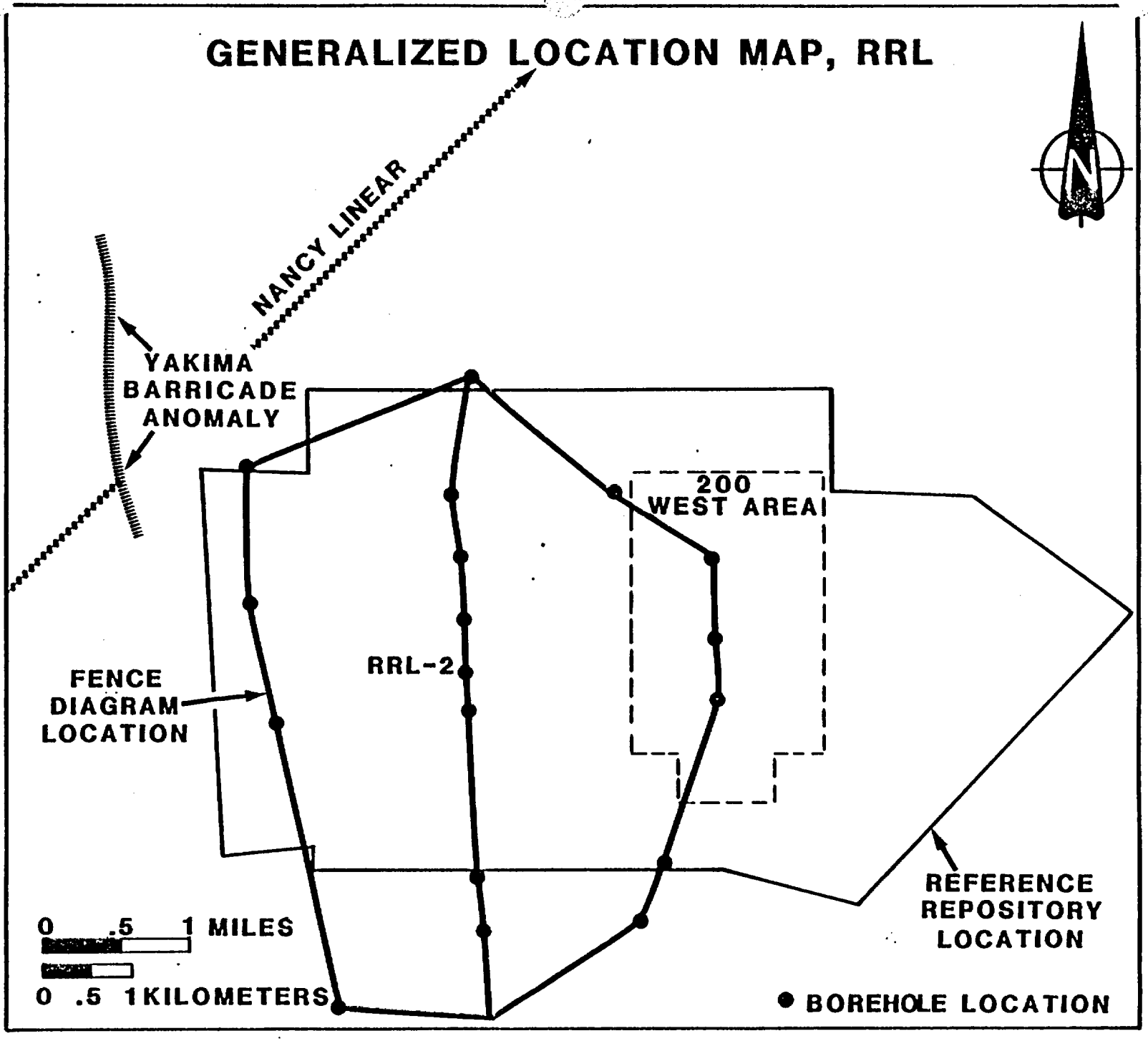
GEOPHYSICAL STUDIES

INTERPRETATION OF GEOPHYSICAL DATA

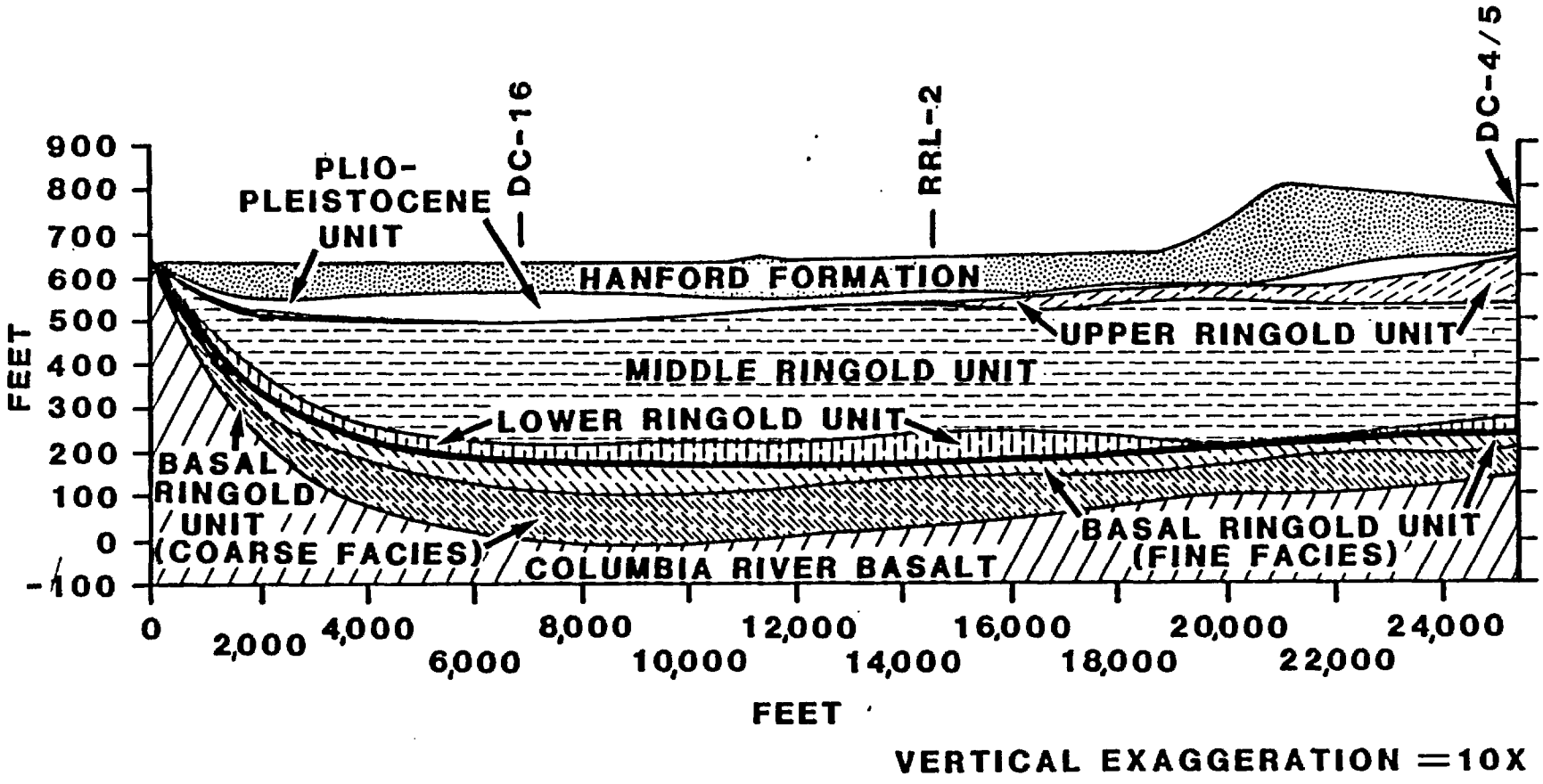
- SEISMIC REFLECTION REPROCESSING (REFERENCE REPOSITORY LOCATION)
- BOREHOLE AND GRIDDED GRAVITY DATA INTEGRATION
- MAGNETOTELLURIC INTERPRETATION REFINEMENT

EVALUATION OF GEOPHYSICAL ANOMALIES

- DEFINITION OF ANOMALY LOCATIONS
- COMPILATION AND INTEGRATION OF GEOLOGIC AND GEOPHYSICAL DATA
- IDENTIFICATION OF ANOMALIES REQUIRING ADDITIONAL STUDY
- EXECUTION OF ADDITIONAL STUDIES


GENERALIZED LOCATION MAP, RRL
N
NANCY LINEAR
YAKIMA
BARRICADE
ANOMALY
200
WEST AREA
RRL-2
FENCE
DIAGRAM
LOCATION
REFERENCE
REPOSITORY
LOCATION
0 .5 1 MILES
0 .5 1KILOMETERS
BOREHOLE LOCATION

GENERALIZED CROSS SECTION OF SUPRABASALT SEDIMENTS WITHIN RRL



VERTICAL EXAGGERATION = 10X

PALEOMAGNETIC ROTATION STUDY

STATUS

- POMONA FLOW (12 MILLION YEARS BEFORE PRESENT) SAMPLED AT 32 SITES IN CENTRAL COLUMBIA PLATEAU

PRELIMINARY FINDINGS

- GREATEST ROTATION ON ANTICLINES; DECREASES INTO SYNCLINES
- ROTATION AMOUNT VARIES ALONG GEOMETRIC SEGMENTS OF ANTICLINES
- CLOCKWISE ROTATION CONSISTENT WITH DEXTRAL SHEAR

PLANS

- SAMPLE ADDITIONAL SITES TO CONFIRM FINDINGS
- ASSESS PATTERN OF DEFORMATION WITH TIME

INSTRUMENTAL SURVEILLANCE

STATUS

- REOCCUPATION OF GEODETIC STATIONS AND LEVELING LINE
- CONTINUED OPERATION OF EXISTING SURFACE NETWORK
- EQUIPMENT ORDERED FOR REFERENCE REPOSITORY LOCATION BOREHOLE NETWORK
- REFINEMENT OF VELOCITY MODEL
- COMPARISON OF SWARM AND NONSWARM EVENTS UNDER WAY

PLANS

- DOCUMENTATION OF GEODETIC AND BASELINE LEVELING SURVEYS
- CONTINUED ASSESSMENT OF SWARM AND NONSWARM EVENTS
- INSTALLATION OF BOREHOLE NETWORK

"CLASSIFICATION" OF TECTONIC MODELS*

- ACTIVE SUBDUCTION
- SUBDUCTED SPREADING CENTER
- BACK ARC REGIME
- MANTLE PLUME, DIAPIR, OR HOT SPOT
- SHEAR BETWEEN PLATES
- MANTLE DIAPIR AND INTERPLATE SHEAR
- MICROPLATE ROTATIONS

*FROM RHO-BW-ST-19 P, PRELIMINARY INTERPRETATION OF THE TECTONIC STABILITY OF THE REFERENCE REPOSITORY LOCATION, COLD CREEK SYNCLINE, HANFORD SITE, MARCH 1983

- all members from BWIP project
- other DOE and consultants.

SEISMIC DESIGN TASK FORCE

STATUS

- PREPARED CHARTER AND DESIGNATED TASK FORCE MEMBERSHIP
- PREPARED "STATUS OF AND SUGGESTIONS FOR BWIP SEISMIC DESIGN," WHICH INCLUDES:
  - SUMMARY OF CONTENTS OF RHO-BW-ST-19 P
  - SUMMARY OF SEISMIC DESIGN CONSIDERATIONS FOR WNP-2 AND SKAGIT HANFORD NUCLEAR POWERPLANTS
  - SUGGESTIONS FOR SEISMIC DESIGN

PLANS

- CONSULTANT REVIEW AND EVALUATION

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* does not include input for performance assessment

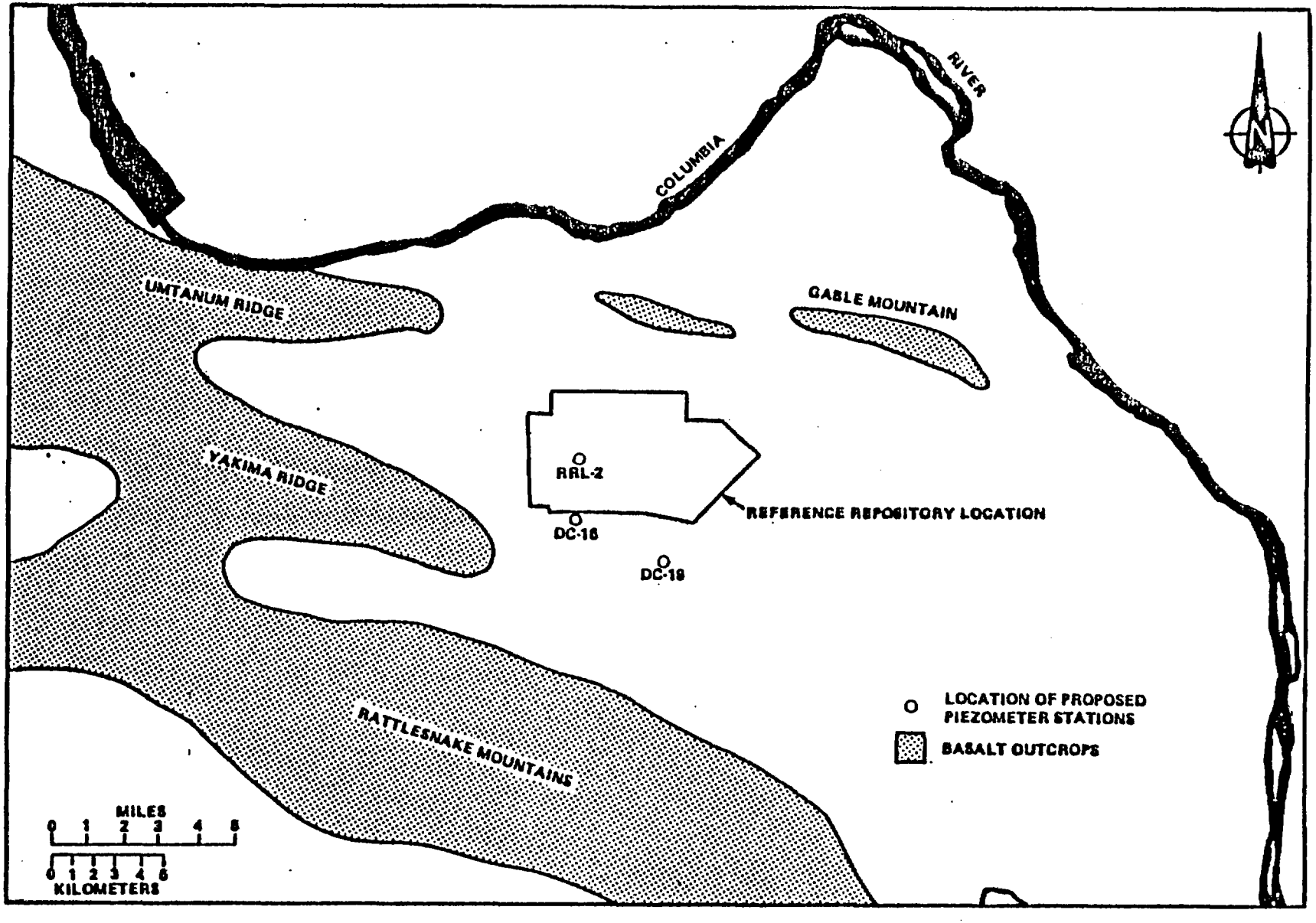
HYDROLOGY

S. M. BAKER

GENERAL CONCERNS ABOUT GROUNDWATER FLOW SYSTEM

- LACK OF DATA–TO SUPPORT UNDERSTANDING OF CONCEPTUAL GROUND-WATER FLOW SYSTEM
- COMPREHENSIVE EVALUATION OF DATA–INTEGRATION OF A BROAD BASE OF GEOLOGICAL, GEOPHYSICAL, GEOCHEMICAL, AND HYDROLOGICAL DATA IN SUPPORT OF UNDERSTANDING THE GROUNDWATER FLOW SYSTEM
- REPRESENTATIVENESS OF DATA–TO ASSURE THAT HYDROLOGICAL DATA ARE REPRESENTATIVE OF THE FLOW SYSTEM (TIME AND SCALE)
- CREDIBILITY OF PROGRAM–TO ASSURE THAT THE SCOPE OF THE HYDROLOGY PROGRAM IS ADEQUATE, THAT THE DATA ARE REPORTED IN AN ACCURATE AND TIMELY FASHION, AND THAT THE INVESTIGATORS ARE IMPARTIAL AND OBJECTIVE

PROPOSED PIEZOMETER STATIONS



USGS/PNL/ROCKWELL*
PLAN TO RESOLVE DIFFERENCES

- CONDUCT REGIONAL HYDROLOGY STUDIES
- CONSOLIDATE BOUNDARY CONDITIONS
- ATTAIN CONCENSUS ON A PRELIMINARY DATA BASE
- DEVELOP CALIBRATED MODEL OF PASCO BASIN
- SELECT AND DOCUMENT A BENCH MARK MODEL
- DESIGN A SERIES OF BENCH MARK PROBLEMS
- UPDATE AND REFINE MODEL

obtained concensus on a preliminary data base for calibrating a regional groundwater model

what scale?

*U.S. GEOLOGICAL SURVEY/PACIFIC NORTHWEST LABORATORY/ROCKWELL HANFORD OPERATIONS

HYDROLOGIC CHARACTERIZATION PLAN ELEMENTS

OBJECTIVES	REQUIRED ACTIVITIES	DATA NEEDS	FACILITIES
COLLECT ADDITIONAL DATA REQUIRED FOR HYDROLOGIC CHARACTERIZATION OF THE REFERENCE REPOSITORY LOCATION WHILE ADDRESSING CONCERNS RAISED	PIEZOMETRIC BASELINE LARGE-SCALE HYDRAULIC TESTING CONTINUE SMALL-SCALE TESTING	• HEAD DATA VALIDATION • ESTABLISHMENT OF MODEL BOUNDARY CONDITIONS • DETERMINATION OF PRE-EMPLACEMENT TRAVEL-TIMES • REPRESENTATIVENESS OF DATA (REPOSITORY SCALE) • FLOW SYSTEM EVALUATION (FOUR-DIMENSIONAL)	PIEZOMETRIC NETWORK DC-19, DC-20, DC-22, RRL-14, RRL-2A, 699-57-83 MISCELLANEOUS OBSERVATION POINTS DB-11, DB-12, DB-14, DC-16, DC-4/5, RRL-6 LARGE-SCALE PUMPING NETWORK RRL-2B, DC-16, DC-20, DC-22 SMALL-SCALE TESTING DC-18, MCGEE, DC-16, DC-4/5, DC-7/8

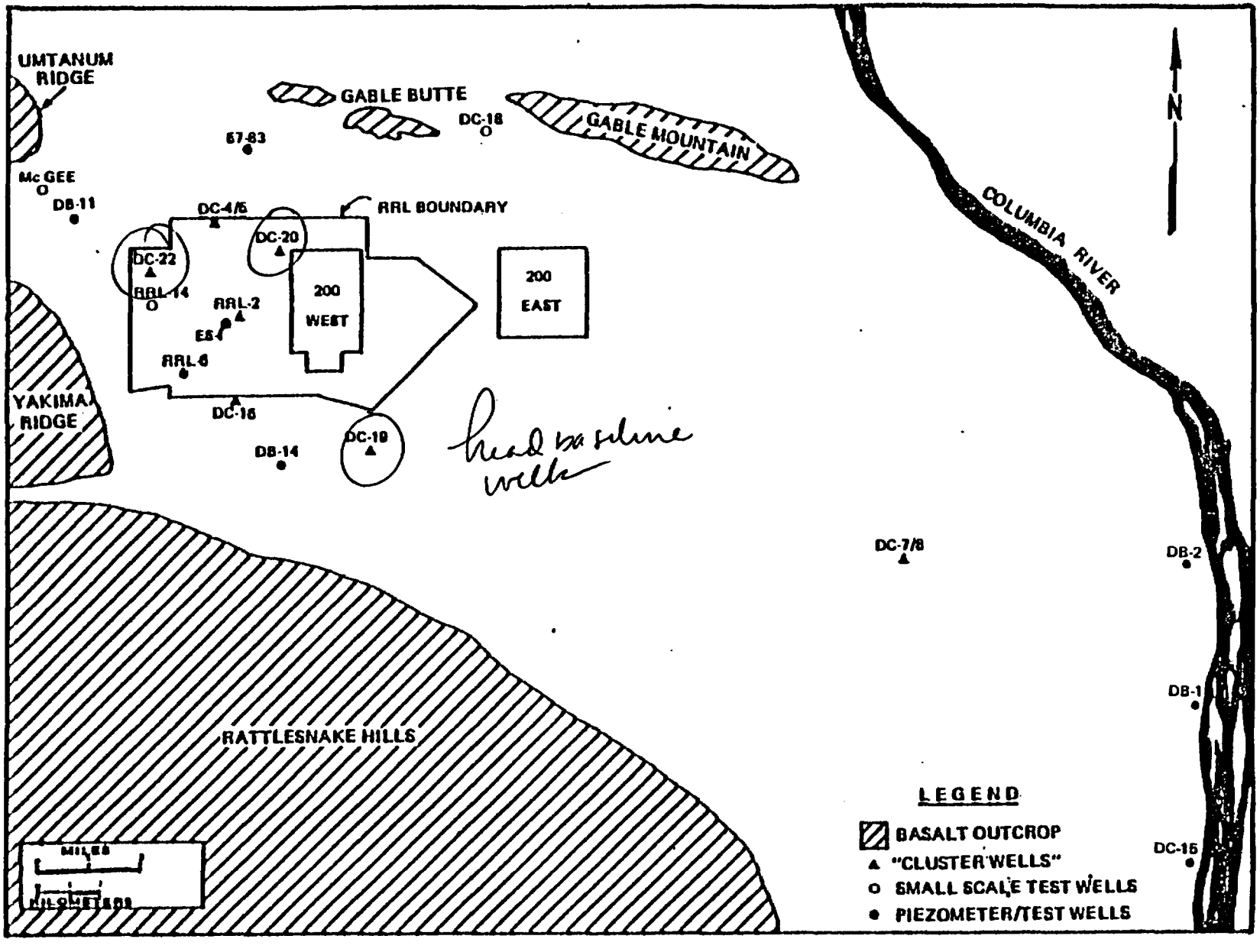
MAJOR ACTIVITIES REQUIRED FOR HYDROLOGIC CHARACTERIZATION

- PIEZOMETER BASELINE (DC–19, DC–20, DC–22, RRL–14, RRL–2)
  - INVESTIGATE VALIDITY OF HEAD DATA
  - DETERMINE MODEL BOUNDARY CONDITIONS
  - SUPPORT PREEMPLACEMENT TRAVELTIME DETERMINATION
  - INSTALL MULTIPORT SYSTEMS IN RRL–14 AND RRL–2
- LARGE–SCALE MULTIPLE WELL AQUIFER TESTING (DC–16, DC–19, DC–20, DC–22)
  - EVALUATE REPRESENTATIVENESS OF DATA (INCLUDES VALIDITY OF TESTING)
  - EVALUATE HYDROLOGIC SIGNIFICANCE OF STRUCTURES
  - INVESTIGATE VERTICAL CONDUCTIVITY RELATIONSHIPS
- SMALL–SCALE HYDRAULIC TESTING (SINGLE AND MULTIPLE WELL)
  - MEASURE HYDRAULIC PROPERTIES
  - COLLECT HYDROCHEMICAL DATA (DC–18)
  - CONTINUE SPECIAL TESTING (MUD EFFECTS, DYNAMIC LOGGING)
- GROUNDWATER MONITORING
- GEOCHEMICAL ANALYSES
  - CONTINUE HYDROCHEMICAL SAMPLING
  - CONTINUE ISOTOPIC ANALYSES
  - EXPAND SOLIDS CHARACTERIZATION
  - INITIATE GEOCHEMICAL MODELING
  - CONTINUE FIELD TESTING (TRACER TESTS)

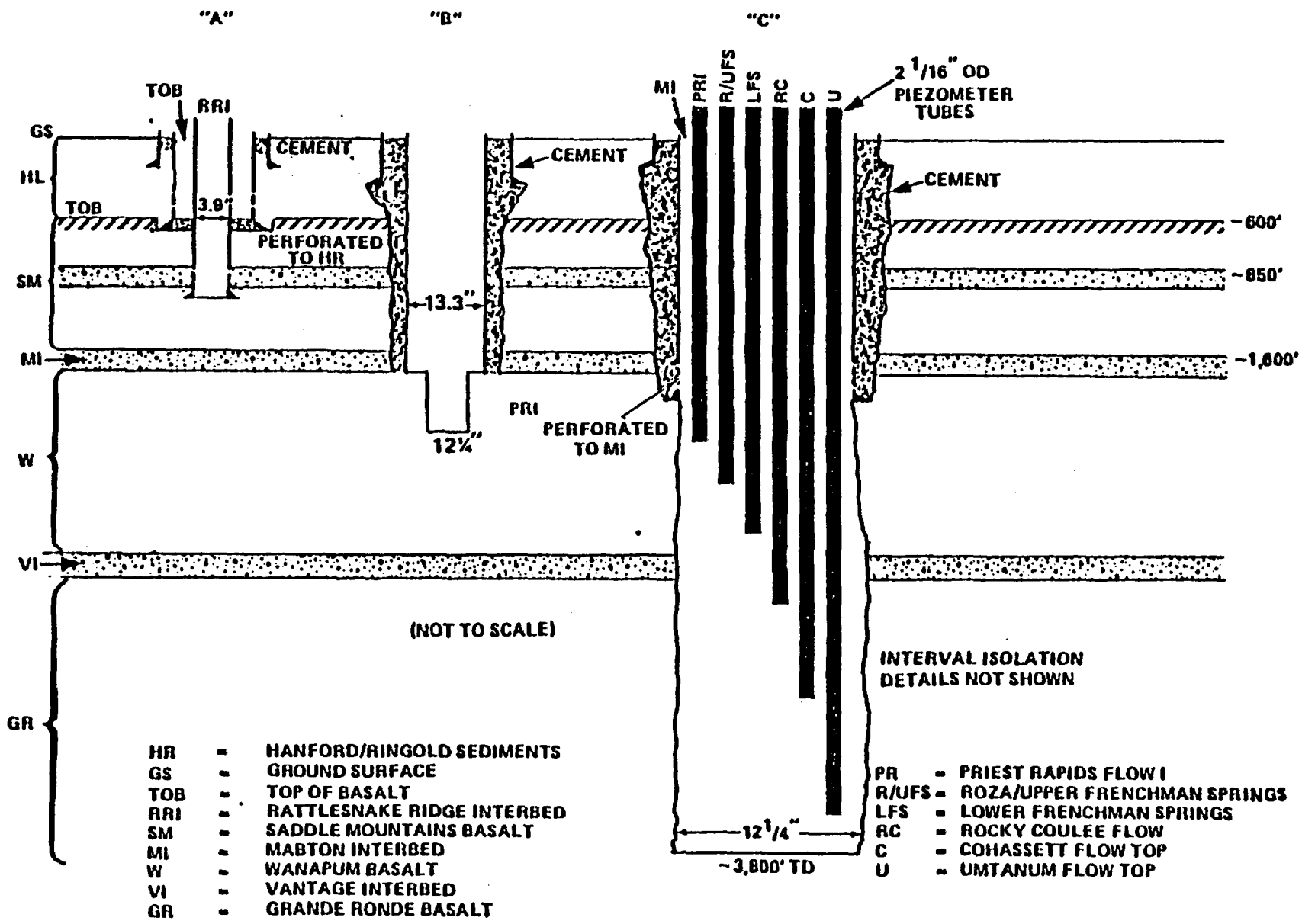
NEW FACILITIES

- THREE DEDICATED PIEZOMETER SITES (DC–19, DC–20, DC–22)
- INSTRUMENTATION OF RRL–2 AND RRL–14
- CONTINUOUS MONITORING WITHIN NINE HYDROSTRATIGRAPHIC UNITS ACROSS THE REFERENCE REPOSITORY LOCATION
- USE OF NESTED AND SINGLE STANDPIPE PIEZOMETERS AT EACH SITE

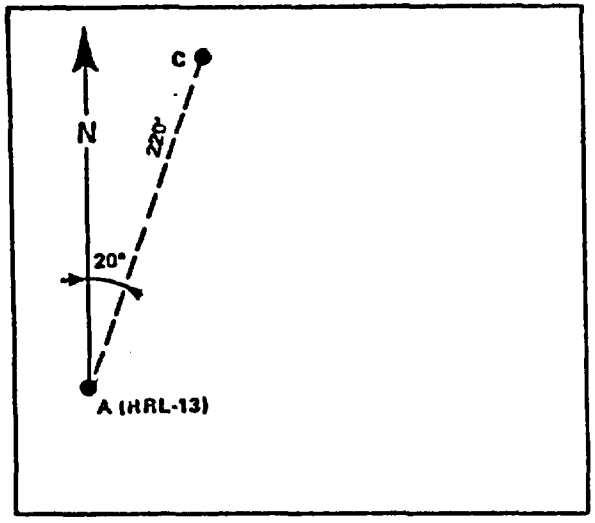
ACTIVE AND PLANNED WELL LOCATIONS



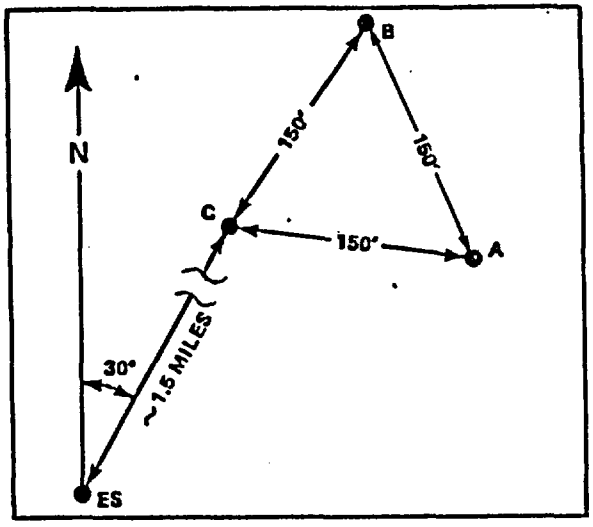
SCHEMATIC OF PROPOSED
PIEZOMETER CLUSTER DESIGN (PRELIMINARY)



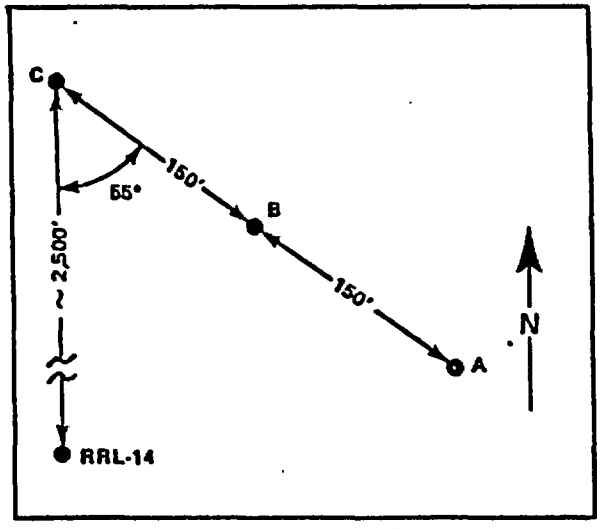
PLAN VIEW ILLUSTRATING THE RELATIONSHIP OF BOREHOLES AT EACH CLUSTER SITE



DC-19 CONFIGURATION

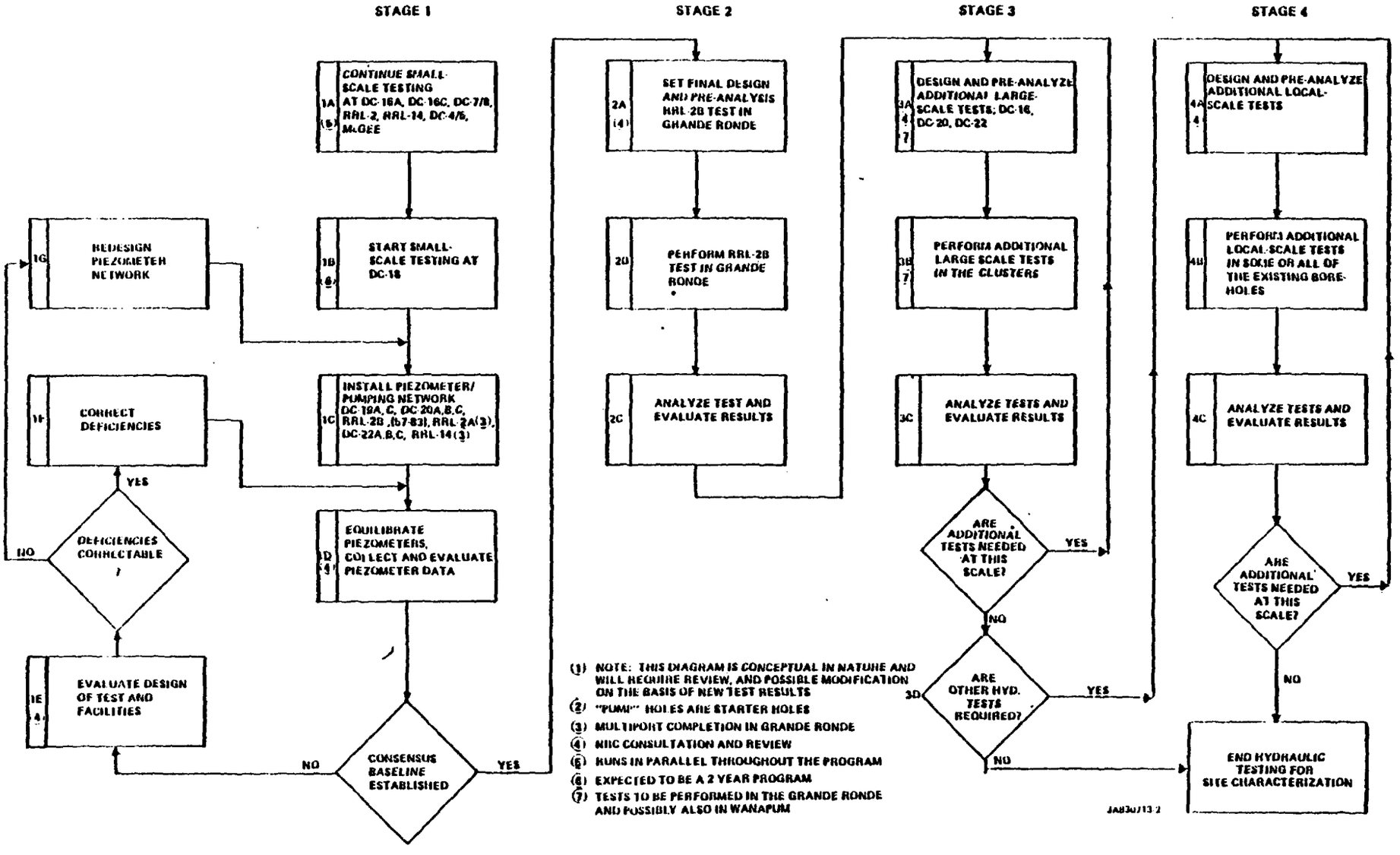


DC-20 CONFIGURATION

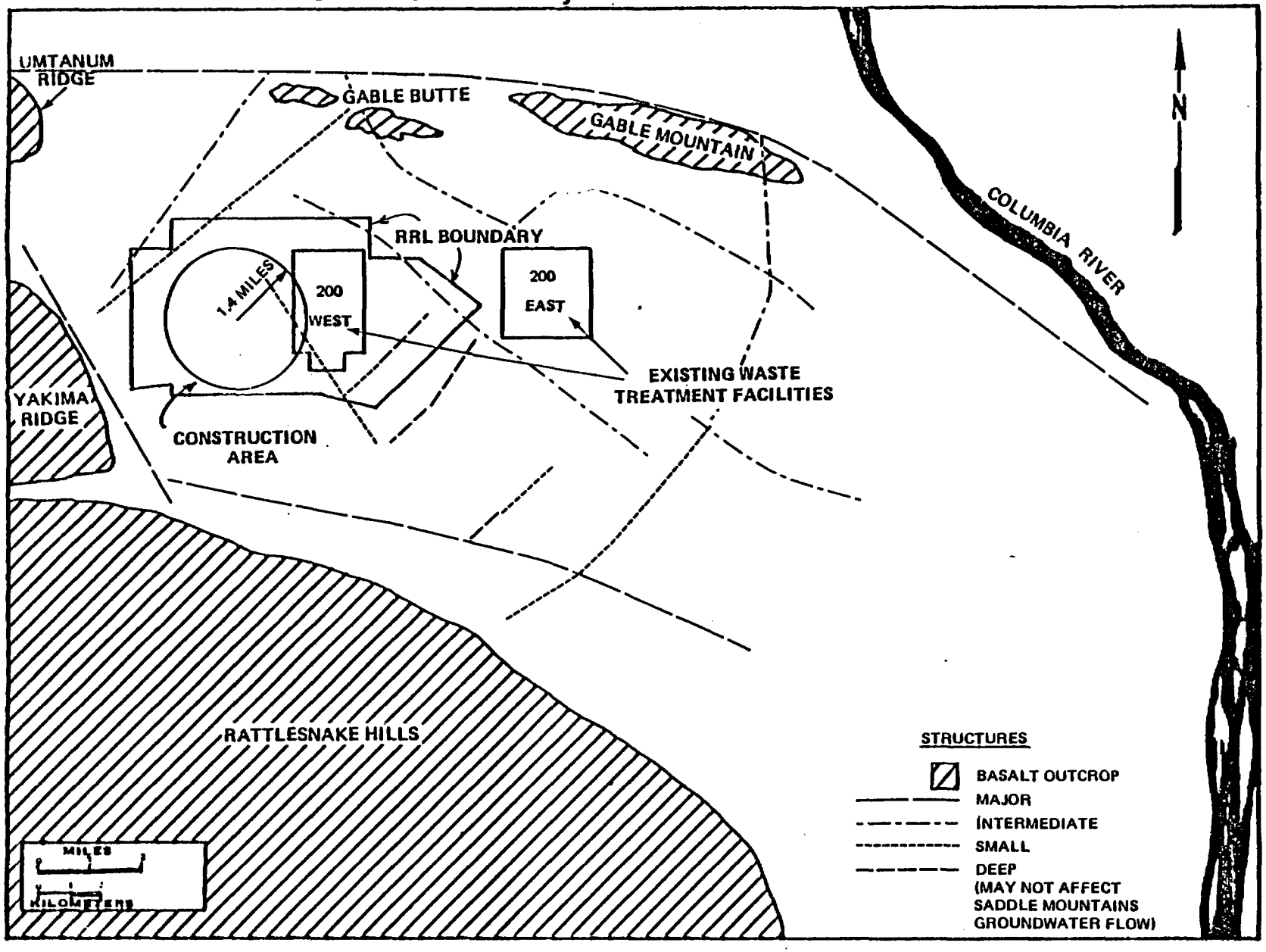


DC-22 CONFIGURATION

LOGIC DIAGRAM FOR BWIP BOREHOLE: HYDROLOGIC TEST STRATEGY (1)



KNOWN AND INFERRED STRUCTURES, EXISTING FACILITIES, AND CONSTRUCTION AREA



GEOENGINEERING AND REPOSITORY DESIGN

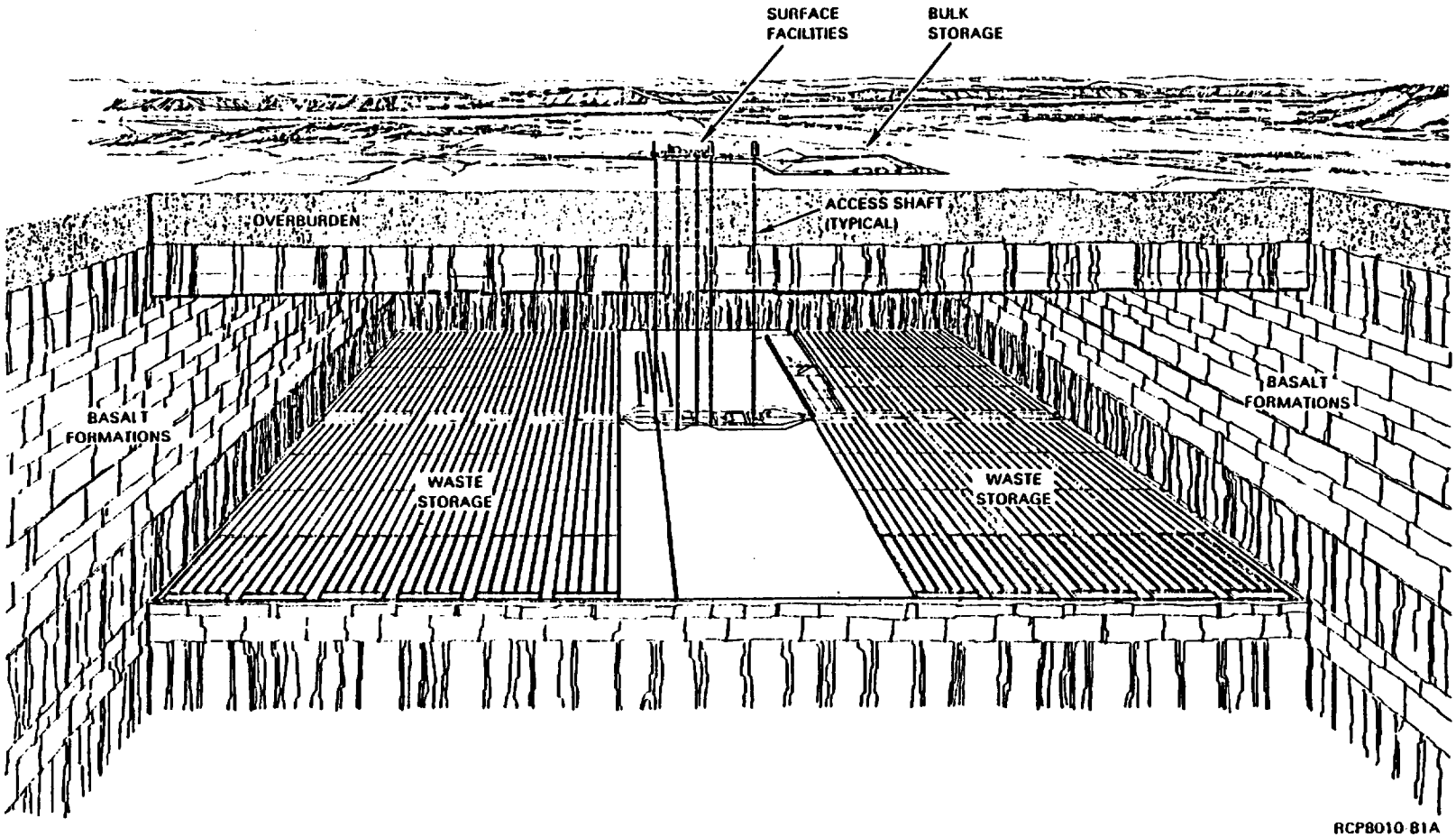
D. A. TURNER

COMMENTS ON GEOENGINEERING AND REPOSITORY DESIGN PORTIONS OF THE SITE CHARACTERIZATION REPORT

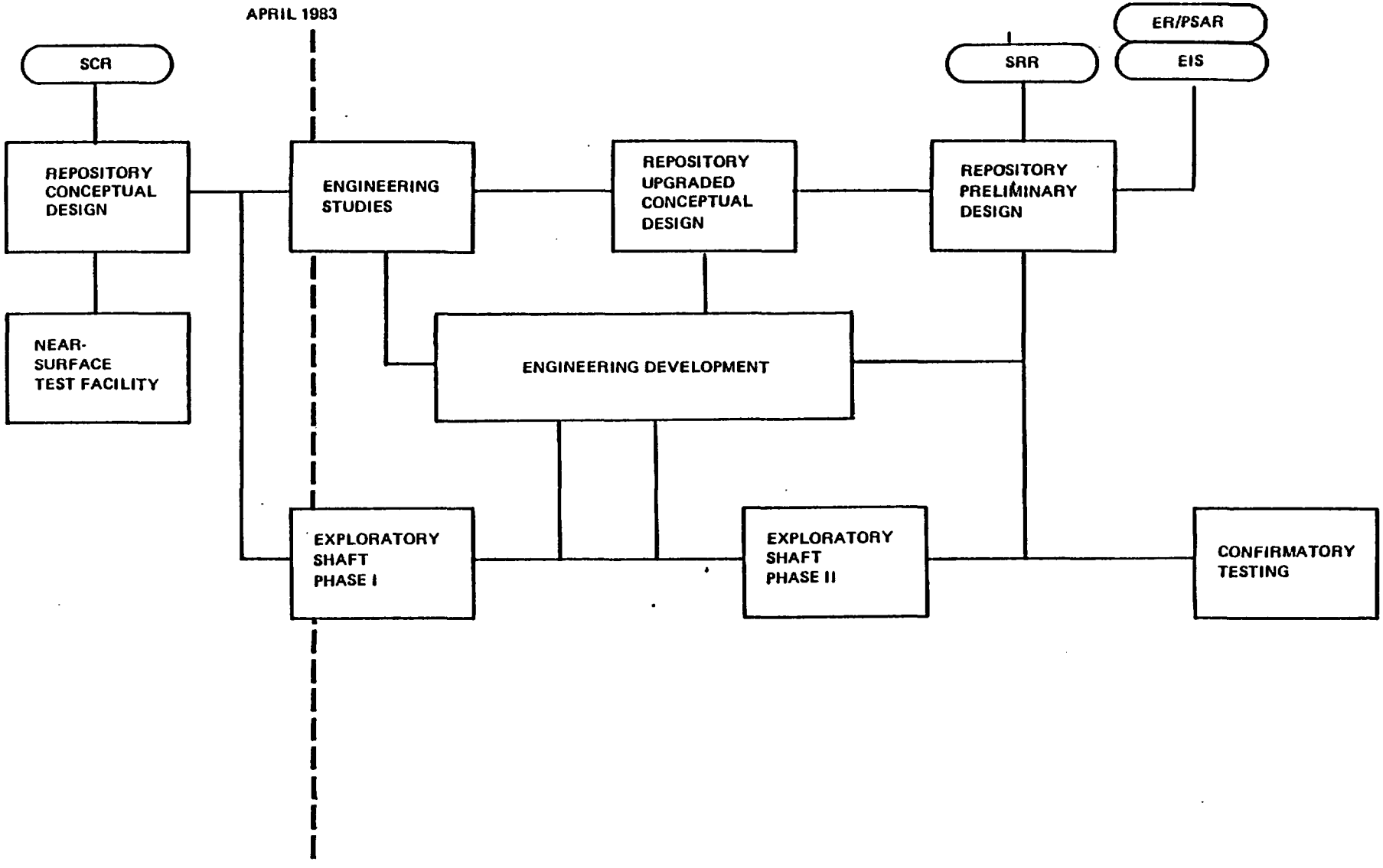
PRESENTATION FORMAT

- APRIL 1983 ACRS PRESENTATION ADDRESSED NRC COMMENTS
- THIS PRESENTATION FOCUSES ON COMMENTS FROM ORGANIZATIONS OTHER THAN NRC (USGS, STATE OF WASHINGTON)
- THIS PRESENTATION COVERS:
  - COMMENT HIGHLIGHTS FOR SEVERAL TOPICAL CATEGORIES
  - BWIP RESPONSES, IN TERMS OF PROGRAM OR PLANNING CHANGES (IN MOST CASES, REEMPHASIS OF PREVIOUS PLANS)

REPOSITORY CUTAWAY



REPOSITORY ENGINEERING LOGIC

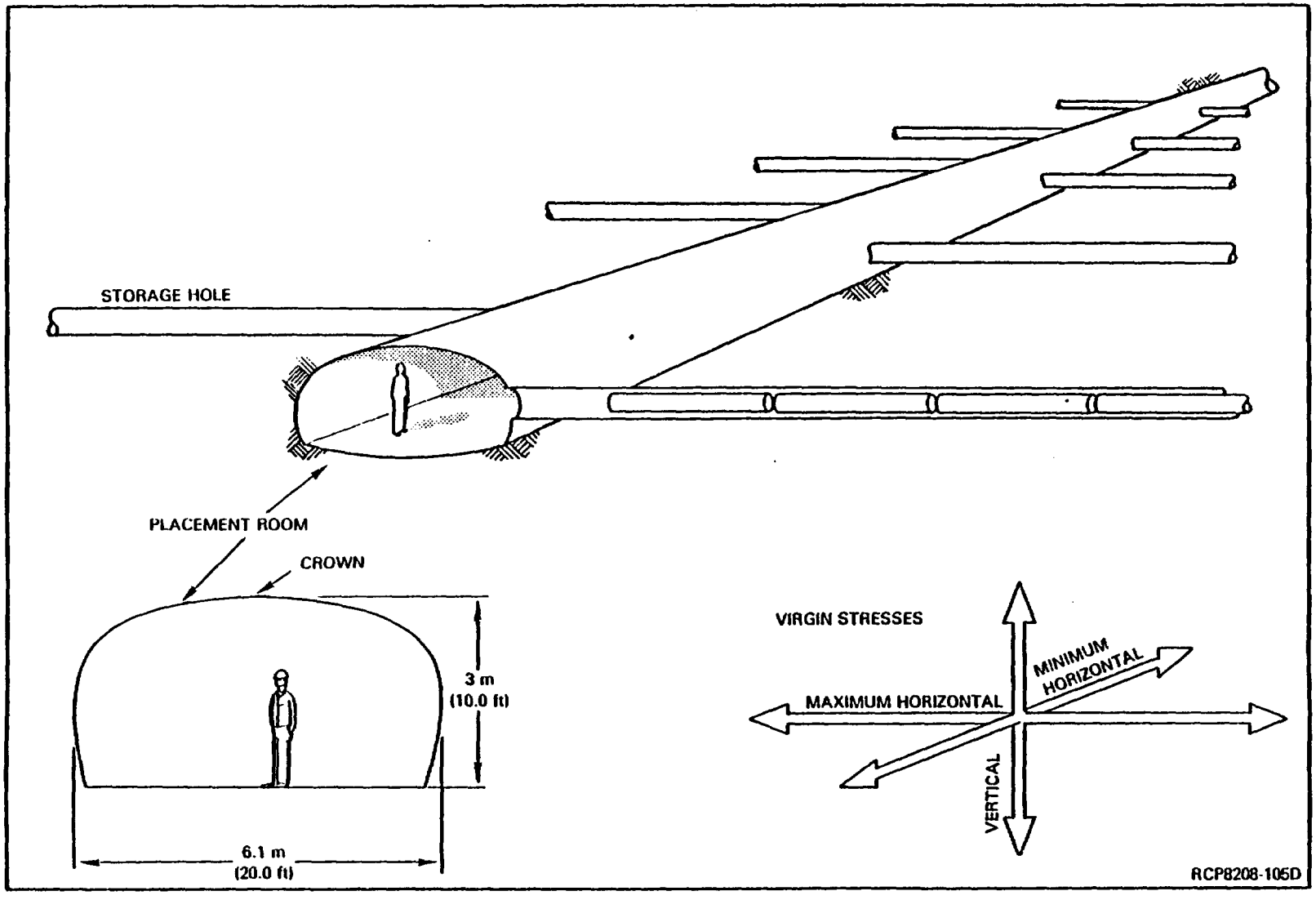


COMMENTS ON GEOENGINEERING AND REPOSITORY DESIGN PORTIONS OF THE SITE CHARACTERIZATION REPORT

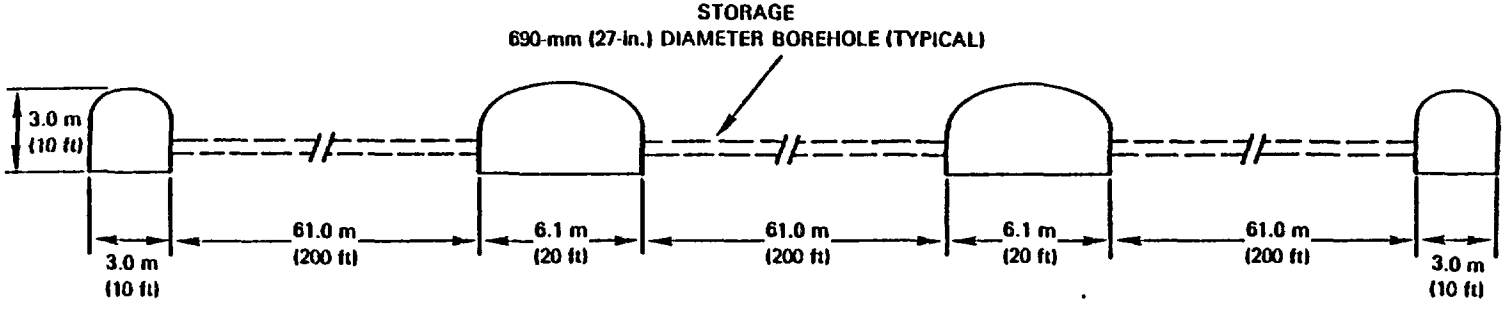
COMMENT HIGHLIGHTS--GEOENGINEERING DATA BASE

- GEOENGINEERING DATA BASE NEEDS TO BE EXPANDED IN THE AREAS OF:
  - IN SITU STRESS
  - ROCK MATERIAL PROPERTIES
  - ROCK MASS PROPERTIES
- SCOPE OF TESTS PLANNED FOR EXPLORATORY SHAFT IS INADEQUATE

ORIENTATION OF ROCK STRESSES AND EXCAVATIONS



WASTE STORAGE PANEL CROSS SECTIONS

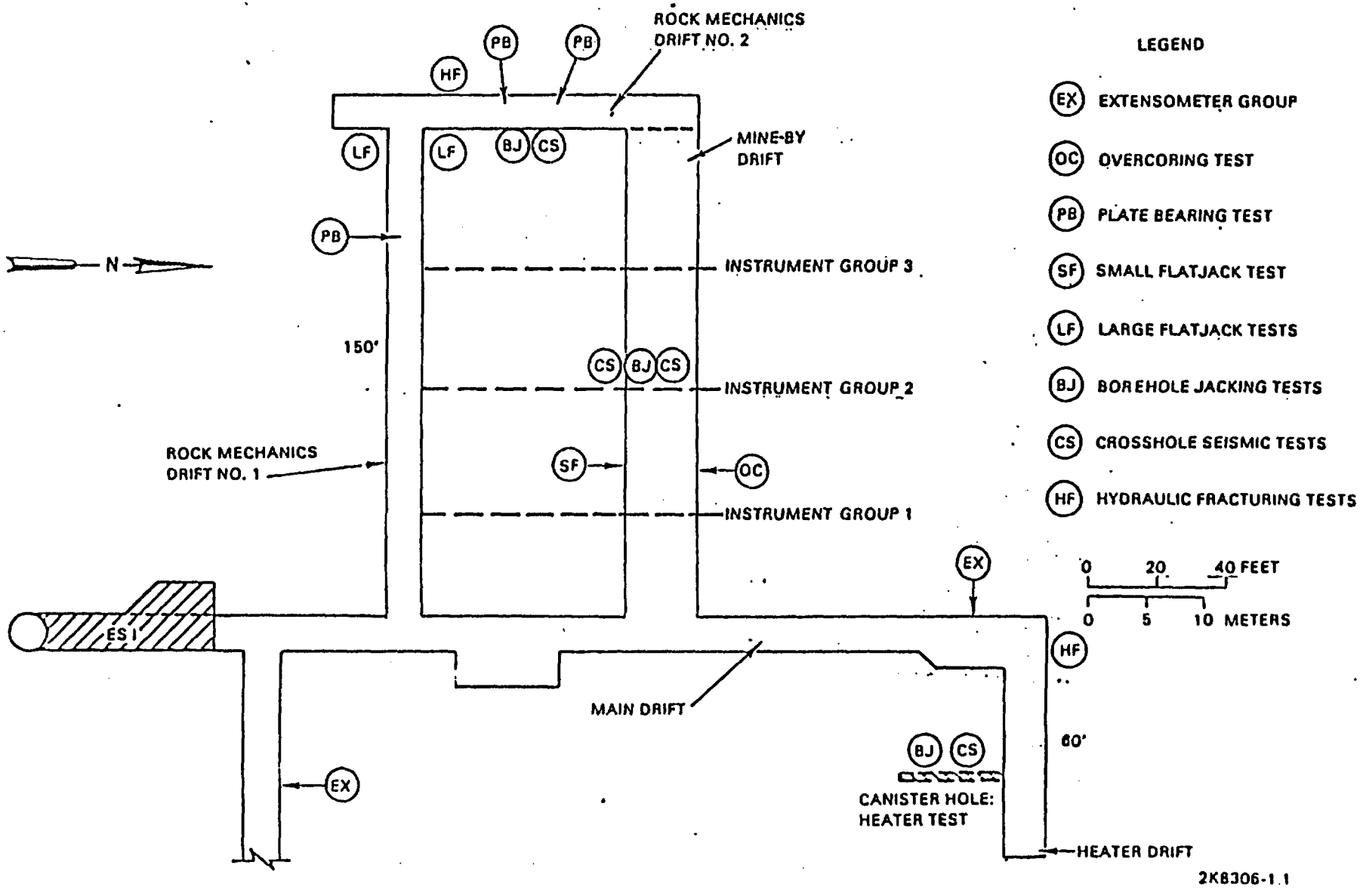


RCP8209-119

COMMENTS ON GEOENGINEERING AND REPOSITORY DESIGN PORTIONS OF THE SITE CHARACTERIZATION REPORT

BWIP RESPONSE--GEOENGINEERING DATA BASE

- ENGINEERING STUDY TO IDENTIFY GEOENGINEERING DATA AND INSTRUMENTATION DEVELOPMENT NEEDS HAS BEEN INITIATED
- EXPLORATORY SHAFT TEST PLANNING IS BEING UPGRADED


ROCK MECHANICS
DRIFT NO. 2
PB
PB
HF
LF
LF
BJ
CS
MINE-BY
DRIFT
PB
N
INSTRUMENT GROUP 3
150'
CS
BJ
CS
INSTRUMENT GROUP 2
ROCK MECHANICS
DRIFT NO. 1
SF
OC
INSTRUMENT GROUP 1
EX
ES 1
HF
MAIN DRIFT
60'
BJ
CS
CANISTER HOLE:
HEATER TEST
EX
HEATER DRIFT
LEGEND
EX EXTENSOMETER GROUP
OC OVERCORING TEST
PB PLATE BEARING TEST
SF SMALL FLATJACK TEST
LF LARGE FLATJACK TESTS
BJ BOREHOLE JACKING TESTS
CS CROSSHOLE SEISMIC TESTS
HF HYDRAULIC FRACTURING TESTS
0 20 40 FEET
0 5 10 METERS
2K8306-1.1

COMMENTS ON GEOENGINEERING AND REPOSITORY DESIGN PORTIONS OF THE SITE CHARACTERIZATION REPORT

COMMENT HIGHLIGHTS--OPENING STABILITY

- DESIGN IMPACT OF STRESS RATIO GREATER THAN 2:1 NEEDS EVALUATION
- IN SITU TESTING TO ASSESS ROOM STABILITY CONCERNS NEEDS BETTER DEFINITION
- RELATIONSHIPS BETWEEN ROOM SHAPE AND ORIENTATION AND ROOM STABILITY NEED MORE RIGOROUS ANALYSES

COMMENTS ON GEOENGINEERING AND REPOSITORY DESIGN PORTIONS OF THE SITE CHARACTERIZATION REPORT

BWIP RESPONSE--OPENING STABILITY

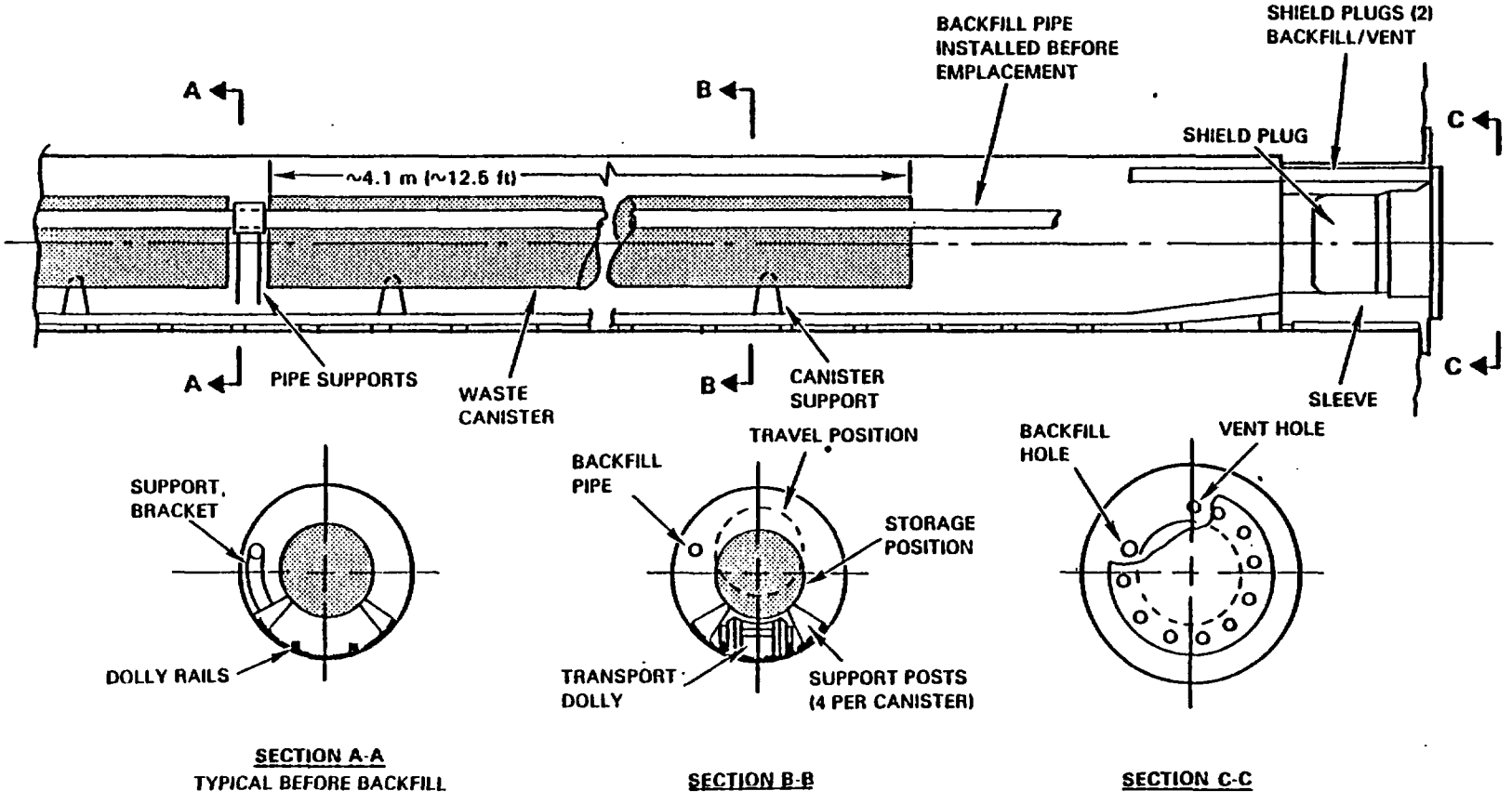
- SENSITIVITY STUDIES AND NONLINEAR STRESS ANALYSES WILL BE CONDUCTED TO EVALUATE DESIGN IMPACTS OF ROOM SHAPE AND ORIENTATION, HIGH ROCK STRESS RATIO, AND OTHER GEOTECHNICAL PARAMETERS
- IN SITU TESTING NEEDS, INCLUDING THOSE RELATED TO ROOM STABILITY, ARE BEING REEVALUATED

COMMENTS ON GEOENGINEERING AND REPOSITORY DESIGN PORTIONS OF THE SITE CHARACTERIZATION REPORT

COMMENT HIGHLIGHTS--WASTE EMPLACEMENT CONCEPT

- CANISTER RETRIEVAL METHODS UNDER POTENTIAL ADVERSE CONDITIONS ARE NOT ADEQUATELY DEFINED
- POTENTIAL IMPACTS OF EMPLACEMENT CONCEPT ON CANISTER INTEGRITY NEED THOROUGH EVALUATION
- EFFECTIVENESS OF CANISTER BACKFILL PLACEMENT METHODS IS QUESTIONABLE

WASTE CANISTER IN HORIZONTAL STORAGE BOREHOLE



SECTION A-A
TYPICAL BEFORE BACKFILL

SECTION B-B

SECTION C-C

RCP8205-44

COMMENTS ON GEOENGINEERING AND REPOSITORY DESIGN PORTIONS OF THE SITE CHARACTERIZATION REPORT

BWIP RESPONSE--WASTE EMPLACEMENT CONCEPT

- **ENGINEERING STUDY HAS BEEN INITIATED TO REEVALUATE WASTE EMPLACEMENT CONCEPTS, WITH EMPHASIS ON RETRIEVABILITY AND RELATED CONCERNS**
- **DEVELOPMENT TEST PLANNING TO DEMONSTRATE WASTE EMPLACEMENT CONSTRUCTION AND OPERATIONS HAS BEEN INITIATED**

most likely go away from very long borehole

COMMENTS ON GEOENGINEERING AND REPOSITORY DESIGN PORTIONS OF THE SITE CHARACTERIZATION REPORT

COMMENT HIGHLIGHTS--CONSTRUCTIBILITY

- **CONSTRUCTIBILITY OF LONG HORIZONTAL EMPLACEMENT HOLES AND EFFECTIVENESS OF MECHANICAL DRIFT EXCAVATORS NEED MORE THOROUGH EVALUATION**
- **UNDERGROUND EXPLORATION AND CONTINGENCY PLANS DURING CONSTRUCTION ARE INADEQUATELY COVERED**
- **STABILITY OF LESS COMPETENT ROCK ZONES DURING SHAFT CONSTRUCTION IS INADEQUATELY ADDRESSED**

COMMENTS ON GEOENGINEERING AND REPOSITORY DESIGN PORTIONS OF THE SITE CHARACTERIZATION REPORT

BWIP RESPONSE--CONSTRUCTIBILITY

- ENGINEERING STUDIES IN PROGRESS ARE REEVALUATING CONSTRUCTIBILITY OF WASTE EMPLACEMENT CONCEPTS, DRIFTS USING MECHANICAL EXCAVATORS, AND SHAFTS AND SHAFT LINERS
- DEVELOPMENT TEST PLANNING TO DEMONSTRATE CONSTRUCTIBILITY CONCERNS HAS BEEN INITIATED
- UNDERGROUND EXPLORATION AND CONTINGENCY PLANS DURING CONSTRUCTION ARE INCLUDED AS FUTURE ENGINEERING STUDY TOPICS

COMMENTS ON GEOENGINEERING AND REPOSITORY DESIGN PORTIONS OF THE SITE CHARACTERIZATION REPORT

COMMENT HIGHLIGHTS--REPOSITORY SEALS

- **DESIGN BASES, DESIGN, CONSTRUCTION, AND PERFORMANCE FOR SEALS ARE NOT ADEQUATELY DEFINED**
- **THE HYDROLOGIC CONDITIONS THAT SEALS MUST WITHSTAND NEED BETTER DEFINITION**
- **METHODS FOR ASSURING LONG-TERM EFFECTIVENESS OF SEAL MATERIALS NEED TO BE ADDRESSED**

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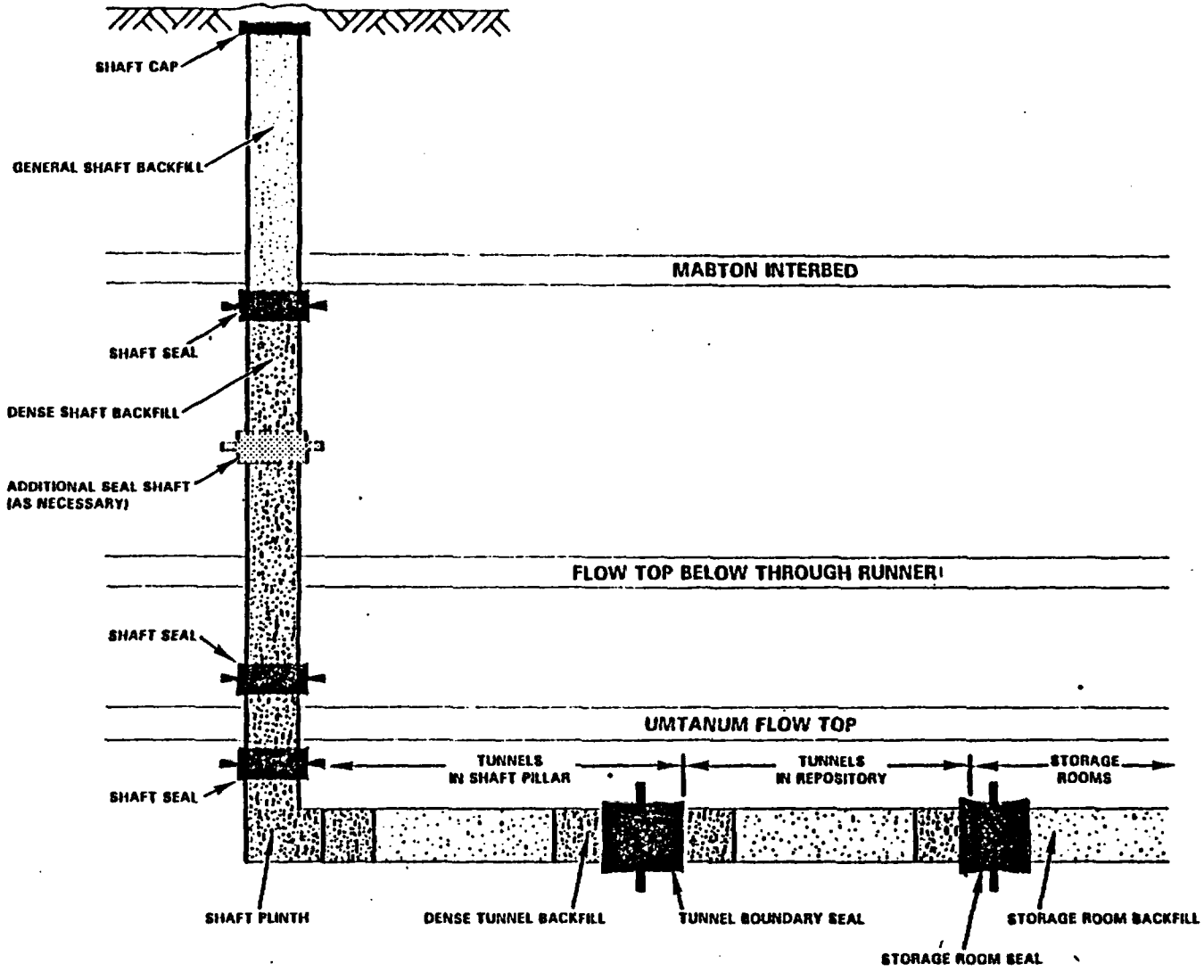
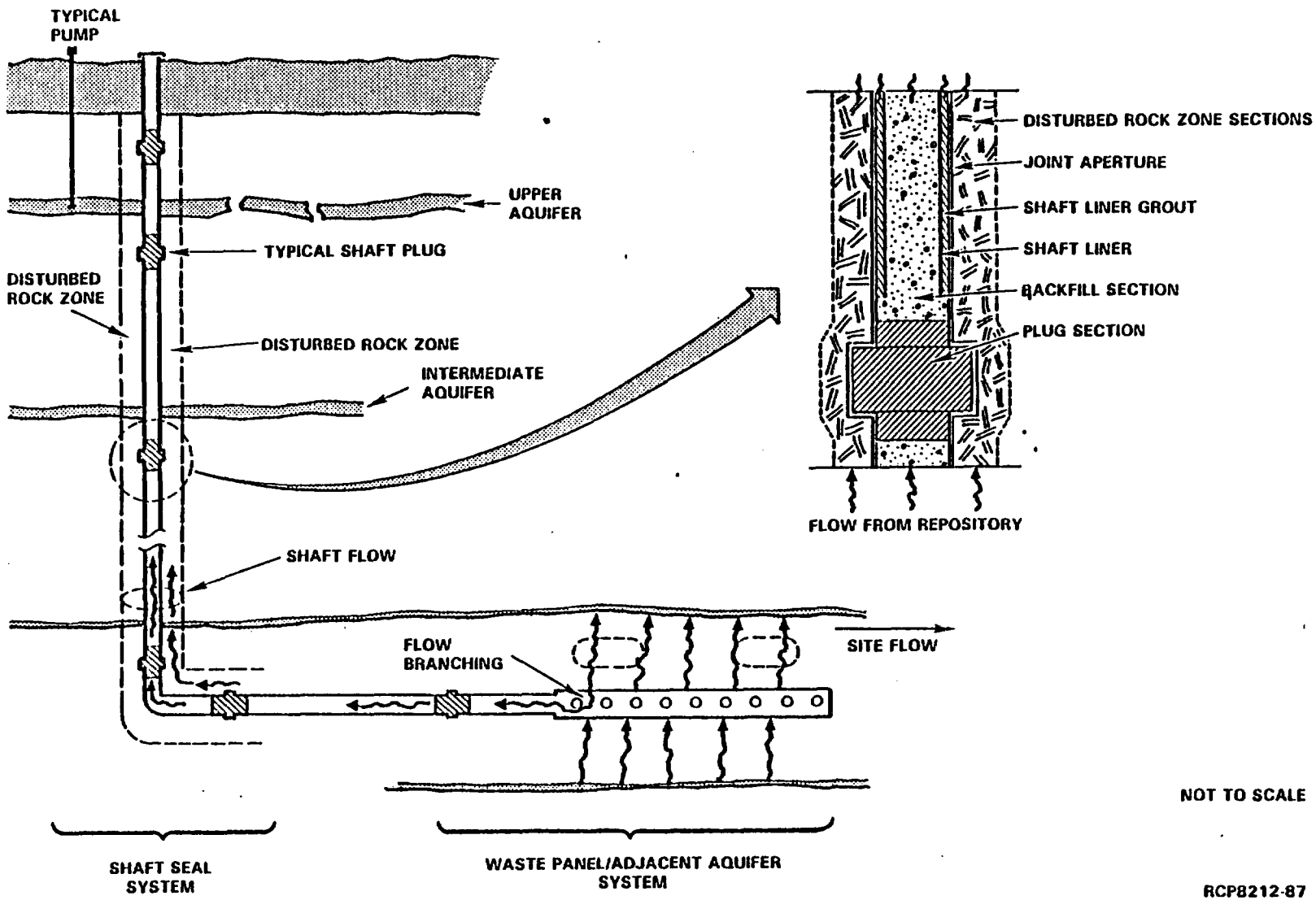
BASIC COMPONENTS FOR SHAFT AND TUNNEL SEALS IN BASALT



NOT TO SCALE

RCP8212-41

SCOPE AND LEVEL OF DETAIL REQUIRED IN FLOW MODELING FOR REPOSITORY SEAL DESIGN



COMMENTS ON GEOENGINEERING AND REPOSITORY DESIGN PORTIONS OF THE SITE CHARACTERIZATION REPORT

BWIP RESPONSE--REPOSITORY SEALS

- ONGOING AND PLANNED HYDROLOGIC STUDIES WILL PROVIDE INPUT TO SEAL DEVELOPMENT PROGRAM
- ADDITIONAL DEFINITION OF SEAL PERFORMANCE REQUIREMENTS IS BEING PREPARED AS BASES FOR SEAL DESIGN
- PLANNING FOR SEAL MATERIAL TESTING (LABORATORY, PERHAPS IN SITU) IS BEING DEVELOPED; ACCELERATED METHODS WILL BE CONSIDERED

COMMENTS ON GEOENGINEERING AND REPOSITORY DESIGN PORTIONS OF THE SITE CHARACTERIZATION REPORT

COMMENT HIGHLIGHTS--DESIGN PROCESS

- DETAILED DESCRIPTION OF DESIGN PROCESS (FUTURE DESIGN DECISIONS) IS NEEDED
- DESIGN SHOULD BE BASED ON EXPECTED RANGES OF GEOLOGIC CONDITIONS RATHER THAN SINGLE VALUES
- FACTORS THAT DETERMINE OPTIMUM SHAFT LOCATIONS SHOULD BE DEFINED
- WASTE CONTAINMENT BARRIERS AND SHIELDING REQUIREMENT TO PROTECT OPERATING PERSONNEL SHOULD BE DEFINED FOR EACH POINT IN THE PROCESS
- TEMPERATURE EFFECTS ON STABILITY OF FRACTURE INFILLING MINERALS ARE OF CONCERN
- ROOF SUPPORT METHODS (SHOTCRETE) COULD IMPAIR MEASUREMENT OF ROCK MASS PROPERTY CHANGES

COMMENTS ON GEOENGINEERING AND REPOSITORY DESIGN PORTIONS OF THE SITE CHARACTERIZATION REPORT

BWIP RESPONSE--DESIGN PROCESS

- ENGINEERING DESIGN PLANNING IS CURRENTLY BEING REFINED
- ENGINEERING STUDY PLANNED FOR FY 1984 WILL REEVALUATE FUNCTIONAL DESIGN CRITERIA
- SEPARATE ENGINEERING STUDIES WILL ADDRESS MAJOR DESIGN DECISIONS
- SPECIFIC DESIGN COMMENTS WILL BE FACTORED INTO THE ENGINEERING STUDY PROCESS

WASTE PACKAGE

M. J. SMITH

SUMMARY

- GENERALIZED LIST OF NRC AND OTHERS' CONCERNS
- PROGRAM STATUS WITH RESPECT TO CONCERNS
  - CANISTER TESTING
  - BACKFILL TESTING
  - WASTE FORM/SOLUBILITY PERFORMANCE REQUIREMENTS
  - WASTE/BARRIER/ROCK INTERACTIONS TESTING
  - WASTE PACKAGE DESIGN/ENGINEERING STUDIES
  - FIELD AND ENGINEERING TESTING

U.S. NUCLEAR REGULATORY COMMISSION CONCERNS – WASTE PACKAGE

CANISTER

- PITTING CHARACTERISTICS OF LOW–CARBON STEEL AND WELDMENTS SHOULD BE INVESTIGATED USING ACCELERATED TESTS IN PRESENCE OF BACKFILL
- STRESS CORROSION CRACKING OF LOW–CARBON STEEL AND WELDMENTS DUE TO CARBONATE ION AND HYDROGEN EMBRITTLEMENT DUE TO RADIOLYSIS PRODUCTS SHOULD BE INVESTIGATED
- USE OF BENTONITE/BASALT BACKFILL MAY ENCOURAGE PITTING CORROSION
- LONG–TERM AUTOCLAVE CORROSION TESTS (UP TO 20 YEARS) NEEDED

PACKING MATERIAL

- HYDRAULIC CONDUCTIVITY OF BACKFILL SHOULD BE MEASURED UNDER REPOSITORY CONDITIONS
- FEASIBILITY OF PNEUMATICALLY EMPLACING BACKFILL MUST BE ADDRESSED
- EFFECT OF K + FROM BASALT HYDROTHERMAL REACTIONS ON BACKFILL ALTERATION NEEDS TO BE EXAMINED
- BWIP PROGRAM DOES NOT ADDRESS RADIONUCLIDE TRANSPORT PROPERTIES OF BACKFILL

U.S. NUCLEAR REGULATORY COMMISSION CONCERNS – WASTE PACKAGE
(CONTINUED)

DESIGN/ENGINEERING STUDIES/PERFORMANCE ANALYSIS

- A COMPREHENSIVE PROGRAM TO DETERMINE THE STRESS STATE OF WASTE PACKAGE AND ITS EFFECT ON THE CANISTER IS NEEDED
- RELIABILITY OBJECTIVES FOR THE WASTE PACKAGE NEED TO BE ESTABLISHED
- WATER FLOW RATES THROUGH A WASTE PACKAGE SHOULD BE EVALUATED.
- HORIZONTAL BOREHOLE WASTE PACKAGE IS NOT RELIABLE ENOUGH TO MEET NRC CONTAINMENT REQUIREMENT DUE TO EXCESSIVE PITTING CORROSION

MATERIALS TESTING

- RADIATION EFFECTS ON SOLUBILITY NEED EVALUATION
- HIGH TEMPERATURE LIMITS FOR GLASS ARE INCONSISTENT WITH A LONG DESIGN LIFE FOR WASTE PACKAGE
- BWIP PROGRAM DOES NOT INCLUDE PLANS FOR DETERMINING THE EFFECTS OF pH, Eh, COLLOIDS, COMPLEXATION, AGING, SOLUBILITY, FLOW, AND OTHER BARRIER MATERIALS ON WASTE FORM AND WASTE PACKAGE RELEASE RATES

STATUS SUMMARY WITH RESPECT TO CONCERNS

COMPLETED

- PRELIMINARY WASTE ACCEPTANCE REQUIREMENTS FOR SPENT FUEL, COMMERCIAL HIGH-LEVEL WASTE AND DEFENSE HIGH-LEVEL WASTE
- HOT CELL FACILITY AND EQUIPMENT INSTALLATION FOR HYDROTHERMAL TESTING OF WASTE/BARRIER/ROCK INTERACTIONS WITH FULLY RADIOACTIVE WASTE FORMS
- STATIC TESTING OF TRACER DOPED (^{99}Tc) COMMERCIAL HIGH-LEVEL WASTE GLASS AT 200°C IN BASALT GROUNDWATER
- EQUIPMENT INSTALLATION FOR BACKFILL PROCESS DEVELOPMENT ENGINEERING TEST
- REPLANNING OF ADVANCED CONCEPTUAL DESIGN DEVELOPMENT PROGRAM TO ADDRESS NRC STAFF CONCERNS.

IN PROGRESS

- PREPARATION OF WASTE PACKAGE ADVANCED CONCEPTUAL DESIGN REQUIREMENTS
- STARTUP OF WASTE/BARRIER/ROCK INTERACTIONS TESTING WITH FULLY RADIOACTIVE WASTE FORMS
- STATIC TESTING OF ^{237}Np AND ^{239}Pu DOPED COMMERCIAL HIGH-LEVEL WASTE GLASS UNDER REPOSITORY SPECIFIC CONDITIONS
- STARTUP OF BACKFILL PROCESS DEVELOPMENT ENGINEERING TEST
- DEVELOPMENT OF RELIABILITY APPROACH FOR WASTE PACKAGE DESIGN
- UPDATE OF BARRIER MATERIALS TEST PLAN TO ADDRESS NRC STAFF CONCERNS ABOUT RELIABILITY TESTING.

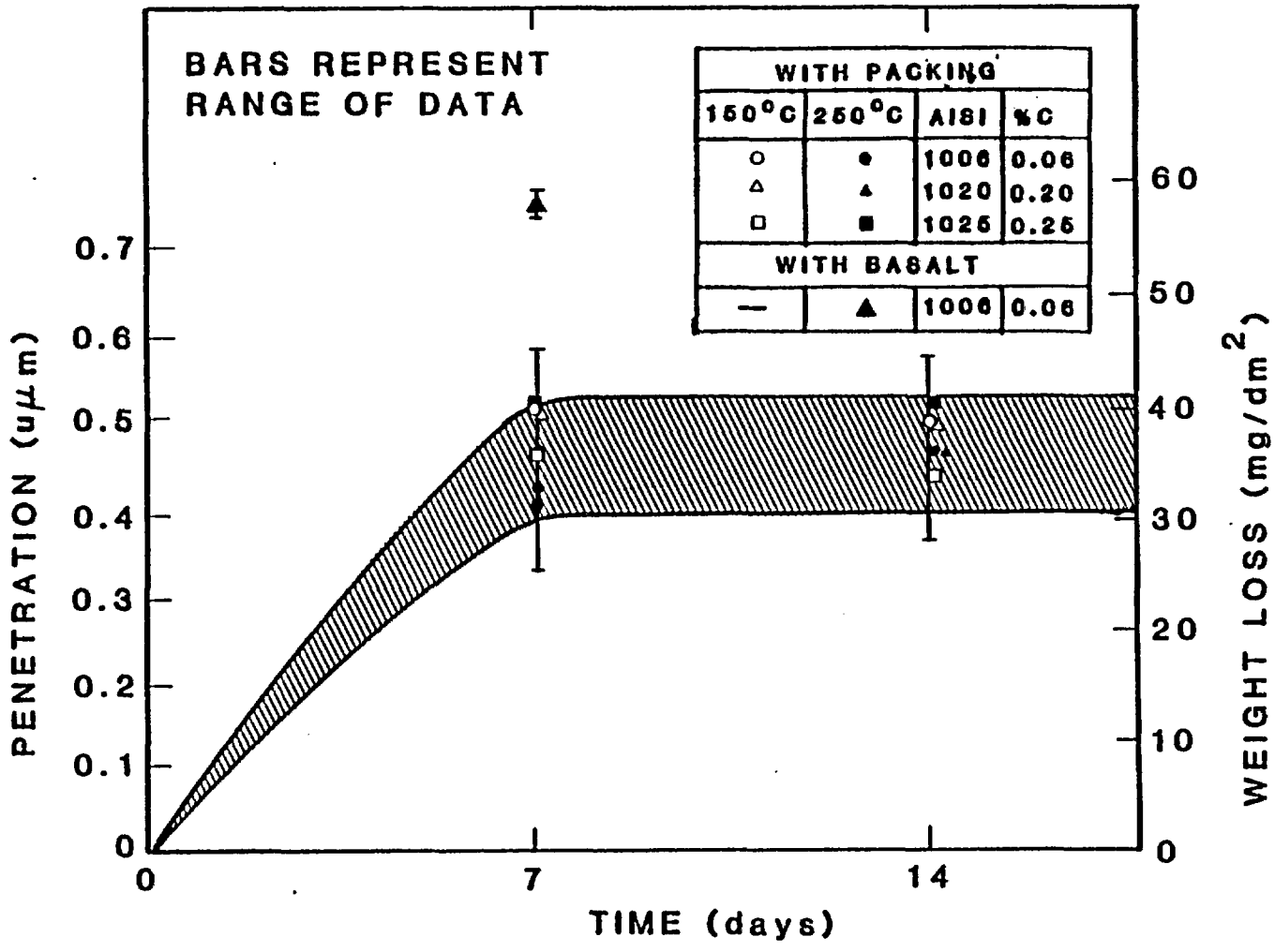
BWIP CANISTER CORROSION TESTING

RECENT LOW–CARBON STEEL CORROSION TEST RESULTS

- CORROSION INDEPENDENT OF CARBON CONTENT (0.06% to 0.25% C)
- STRONGLY ADHERENT IRON–RICH CLAY FORMS AT T > 150°C, WHICH REDUCES CORROSION RATE
- GROUNDWATER CHEMISTRY EFFECTS ARE INSIGNIFICANT COMPARED TO TEMPERATURE EFFECT ON CORROSION
- GAMMA RADIATION (3×10^5 rad/hr) ENHANCES CORROSION TWO– TO THREEFOLD (PEAK COMMERCIAL HIGH–LEVEL WASTE CANISTER SURFACE EXPOSURE RATE $= 7 \times 10^3$ rad/hr).

EFFECT OF CARBON CONTENT ON LOW-CARBON STEEL CORROSION

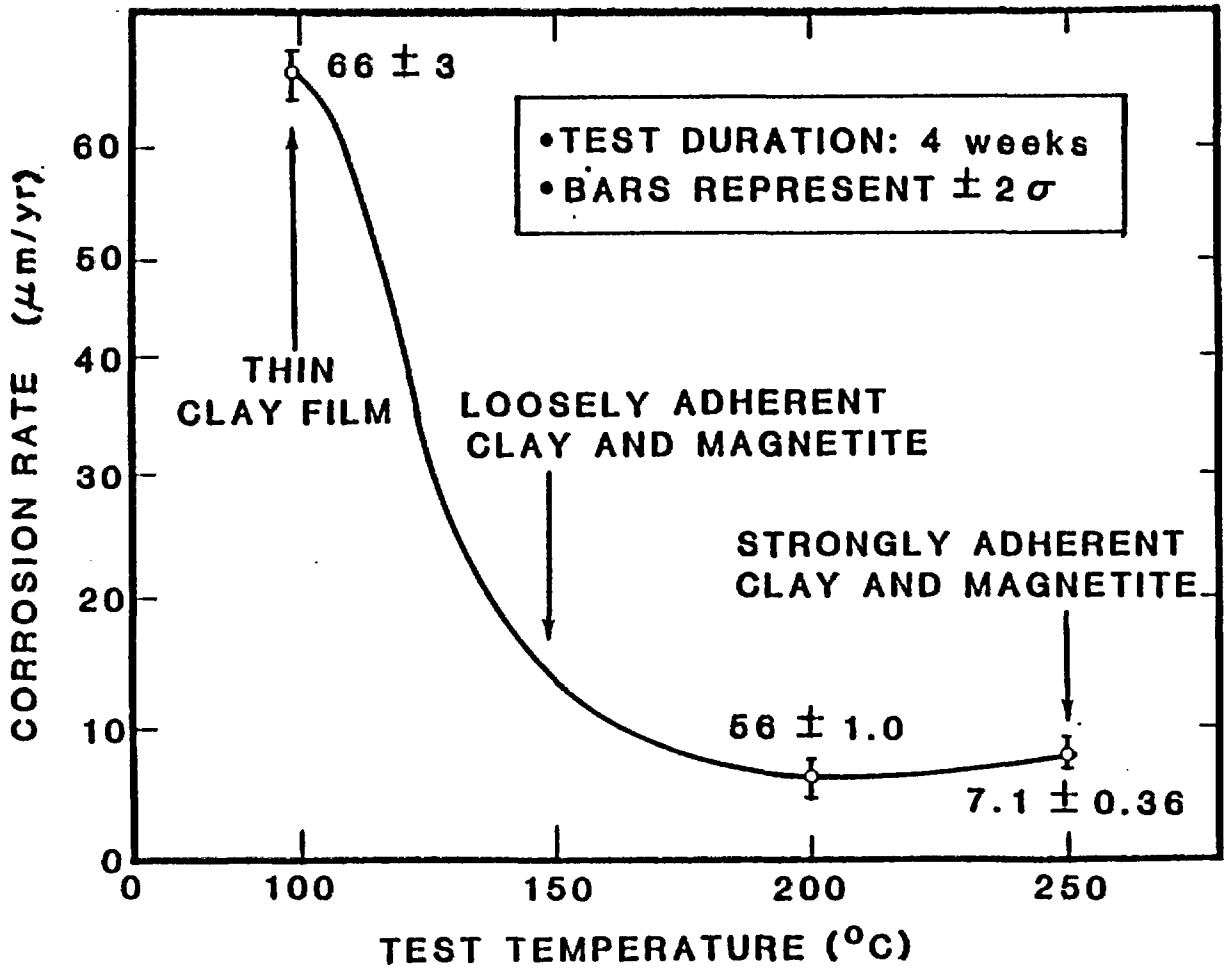
UNDER ANOXIC CONDITIONS (ARGON SPARGE) IN HANFORD GROUNDWATER



WP8308-133A

TEMPERATURE DEPENDENCE OF LOW-CARBON STEEL CORROSION

UNDER ANOXIC CONDITIONS (ARGON SPARGE)
IN HANFORD GROUNDWATER WITH PACKING



WP8308-132

GROUNDWATER CHEMISTRY EFFECTS

ON LOW-CARBON STEEL CORROSION IN CONTACT WITH PACKING MATERIAL (4-WEEK TEST DATA)

TEST TEMPERATURE	100°C	250°C
RANGE OF RESULTS OBSERVED OVER CONCENTRATION RANGES TESTED	21.6 to 68.6 μm/yr	6.8 to 10.2 μm/yr

PLACKETT-BURMAN TEST DESIGN

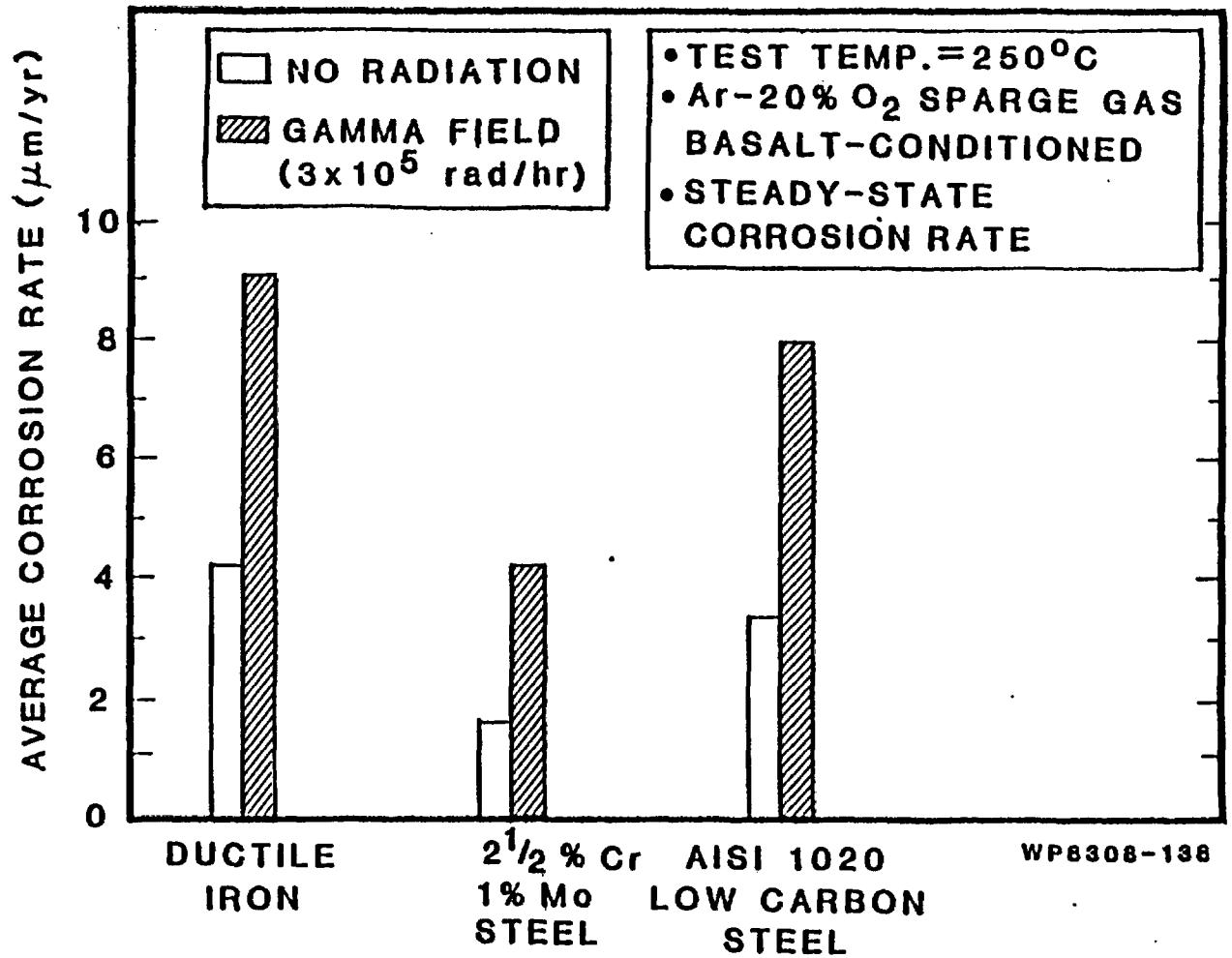
ANION	TEST CONCENTRATION RANGE (mg/L)	EXPECTED ANION * CONCENTRATION (mg/L)
Cl^-	780	405
F^-	100	20
CO_3^{2-}	120	115
SO_4^{2-}	576	4

WP8308-134A

*COHASSETT FLOW RRL-2

EFFECT OF GAMMA RADIATION ON FERROUS ALLOYS

(5- to 17-MONTH TESTS)



BACKFILL MATERIALS TESTING AND WASTE FORM/SOLUBILITY PERFORMANCE REQUIREMENTS

CRUSHED BASALT AND SODIUM BENTONITE HYDROTHERMAL STABILITY TESTS

- UP TO ONE YEAR EXPERIMENTS COMPLETED AT 300° AND 150°C IN HANFORD GROUNDWATER
- EXPERIMENTAL SYSTEMS WERE BENTONITE/WATER AND BASALT/BENTONITE/ WATER
- SOLUTIONS ANALYZED AS A FUNCTION OF TIME AND SOLID RUN PRODUCTS CHARACTERIZED (XRD, SEM, STEM)

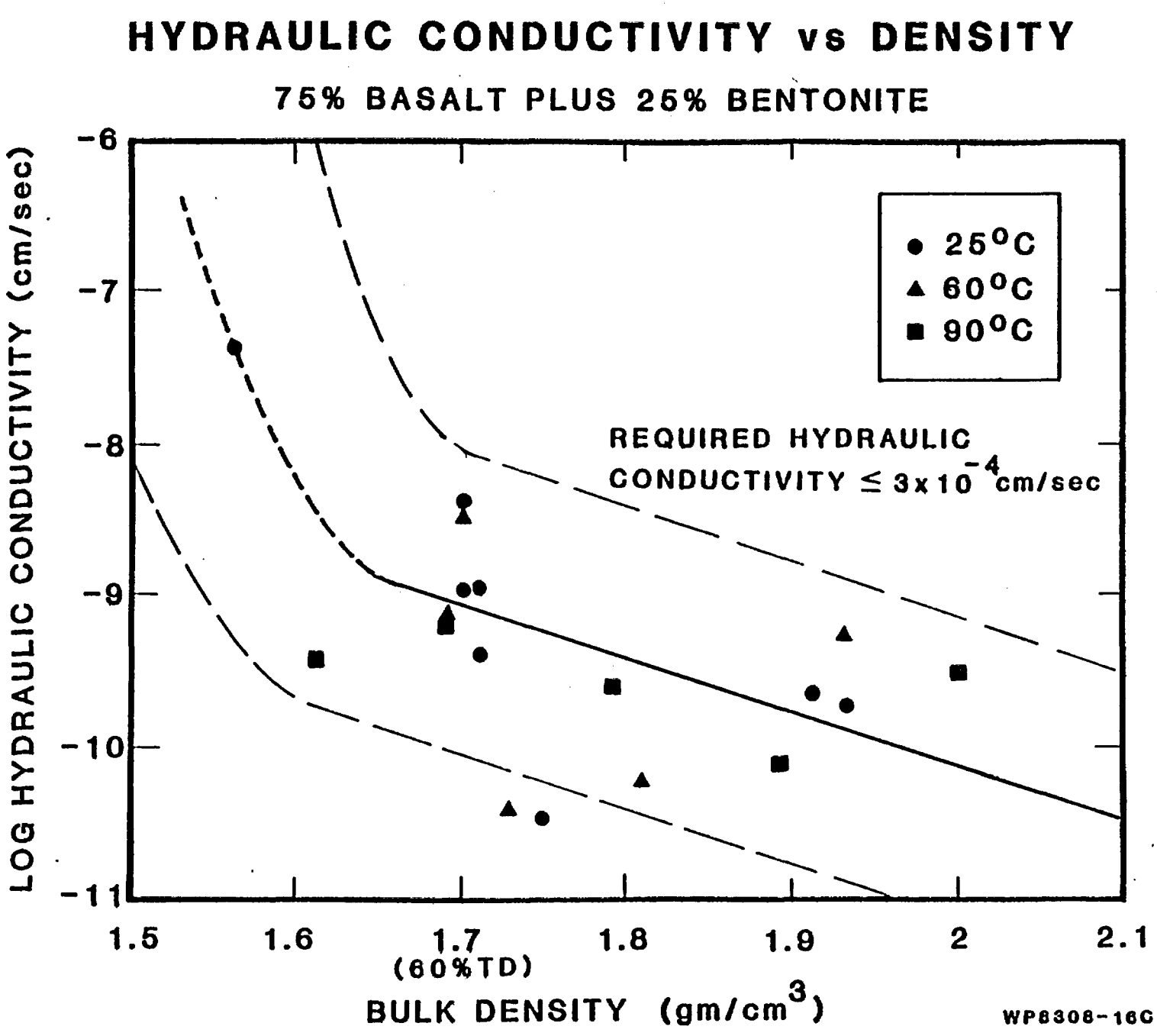
CRUSHED BASALT AND SODIUM BENTONITE HYDROTHERMAL STABILITY

MAJOR FINDINGS

- EXTENSIVE CHEMICAL REACTION OF BASALT AT 300°C BUT ESSENTIALLY NONE AT 150°C
- MAJOR BASALT REACTION IS GLASS ALTERING TO Fe–SMECTITE, ZEOLITES, QUARTZ ± CRISTOBALITE
- LIMITED BREAKDOWN OF BENTONITE TO ALBITE AND QUARTZ AT 300°C
- LIMITED K AND Fe SUBSTITUTION FOR Na IN BENTONITE POSSIBLE. FORMATION OF MIXED LAYER K AND Na SMECTITE AND/OR ILLITE/SMECTITE AT 300°C ONLY

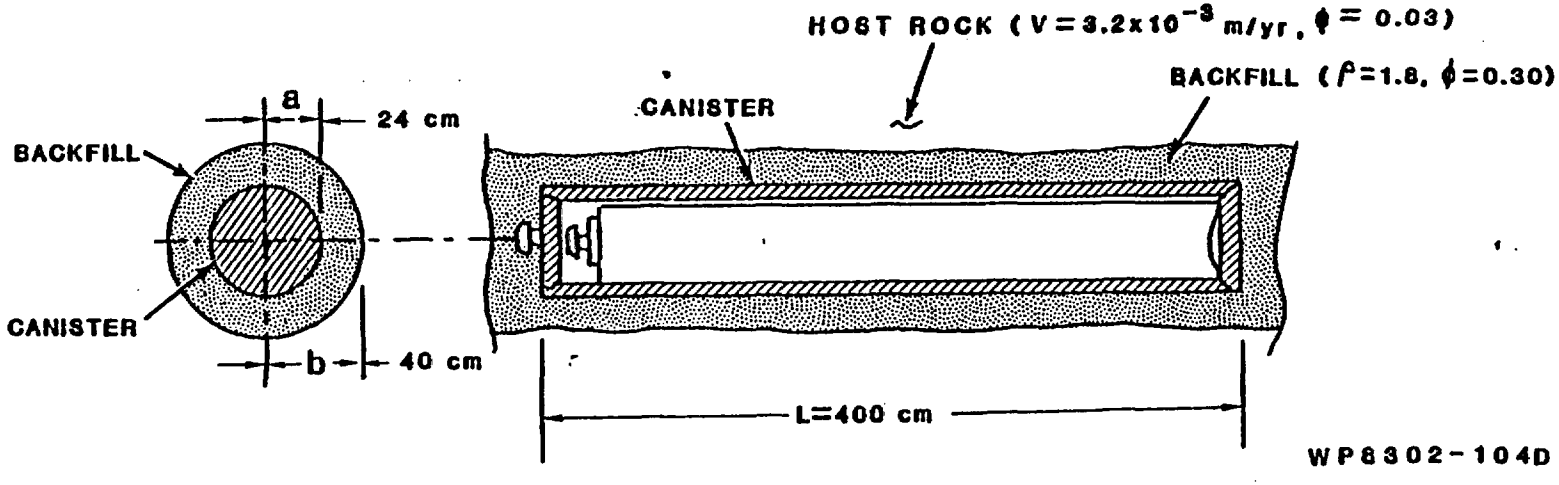
INTERPRETATION

- BASALT GLASS ALTERATION EXPECTED TO ENHANCE PACKING MATERIAL PERFORMANCE WITH TIME BY REDUCING PERMEABILITY AND POROSITY AND ENHANCING SORPTION
- BENTONITE CONVERSION TO ILLITE APPEARS MINOR BECAUSE OF (1) LIMITED K SUPPLY IN BASALT (2) COMPETITION FOR K AMONG OTHER ALTERATION PHASES, AND (3) SLOW RATE OF CONVERSION AT EXPECTED HYDROTHERMAL TEMPERATURES (150°C)


HYDRAULIC CONDUCTIVITY vs DENSITY
75% BASALT PLUS 25% BENTONITE
LOG HYDRAULIC CONDUCTIVITY (cm/sec)
-6
-7
-8
-9
-10
-11
25°C
60°C
90°C
REQUIRED HYDRAULIC
CONDUCTIVITY ≤ 3x10⁻⁴ cm/sec
1.5
1.6
1.7
(60%TD)
1.8
1.9
2
2.1
BULK DENSITY (gm/cm³)
WP8308-16C

RADIONUCLIDE RELEASE ESTIMATES

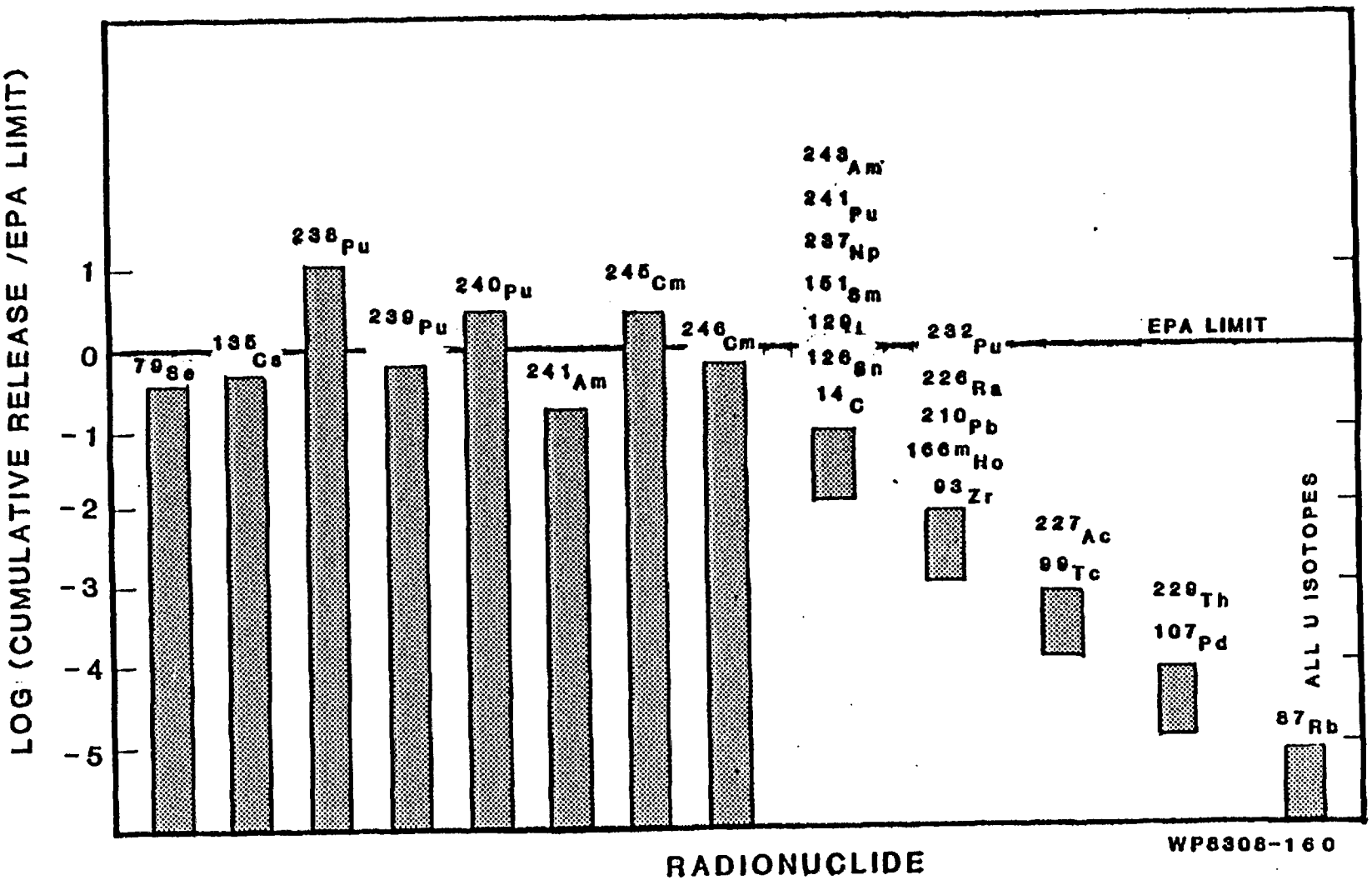
- ASSUMPTIONS
  - 100-YEAR-OLD SPENT FUEL OR COMMERCIAL HIGH-LEVEL WASTE
  - TRANSPORT THROUGH PACKING MATERIAL DIFFUSION CONTROLLED STARTING AT 100 YEARS
  - RADIAL TRANSPORT THROUGH A POROUS CYLINDER
  - RADIONUCLIDE DECAY NEGLECTED
  - NO WASTE FORM PERFORMANCE
  - FIXED CONCENTRATIONS (SOLUBILITY LIMITS) MAINTAINED AT THE WASTE FORM-PACKING MATERIAL INTERFACE.



CUMULATIVE RELEASE vs EPA LIMITS

FROM SPENT FUEL WASTE PACKAGES USING CONSERVATIVE SOLUBILITIES

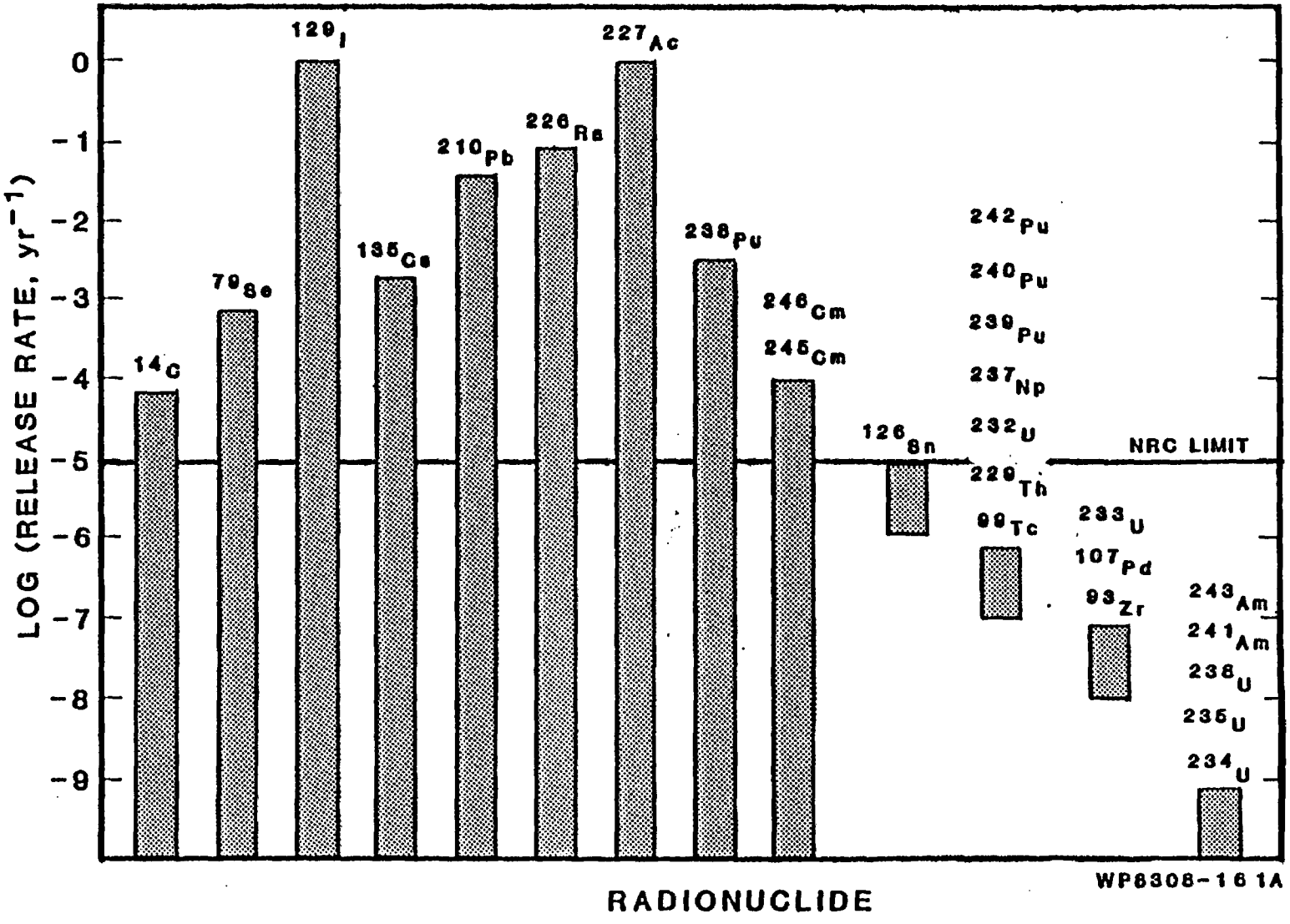
(NO WASTE FORM PERFORMANCE)



FRACTIONAL RADIONUCLIDE RELEASE RATES

FROM SPENT FUEL WASTE PACKAGE USING CONSERVATIVE SOLUBILITIES

(NO WASTE FORM PERFORMANCE)



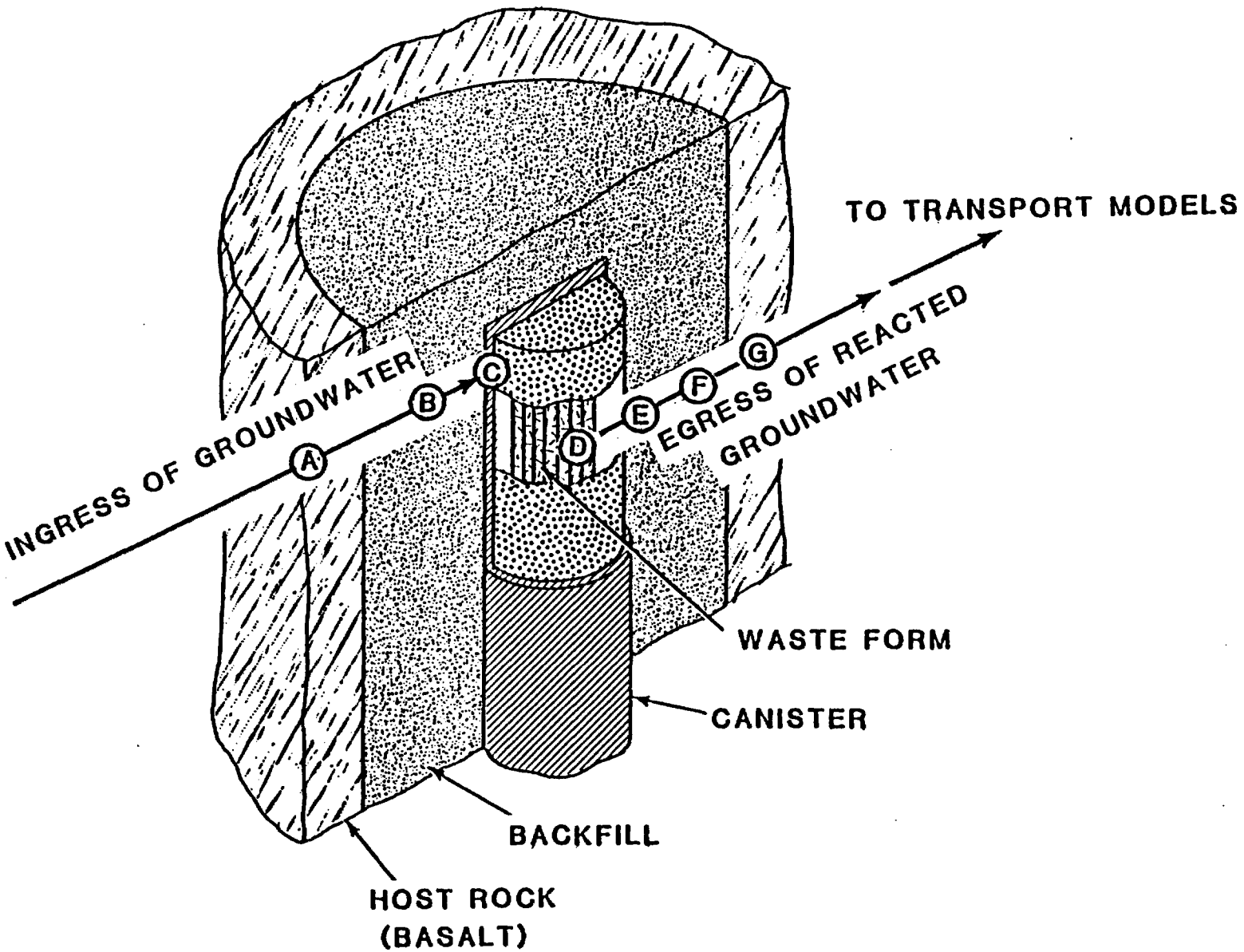
SUMMARY OF SOLUBILITY LIMITS REQUIRED IN THE WASTE PACKAGE PACKING MATERIAL

NUCLIDE	CONCENTRATION (M)*	
	SPENT FUEL	COMMERCIAL HIGH-LEVEL WASTE
^{14}C	7.3E – 4	–
^{79}Se	7.7E – 5	7.7E – 5
^{135}Cs	3.4E – 4	3.4E – 4
^{238}Pu	5.0E – 8	5.0E – 8
^{240}Pu	5.0E – 8	5.0E – 8
^{241}Am	5.0E –10	8.0E –10
^{245}Cm	3.0E – 8	5.0E – 8
^{246}Cm	3.0E – 8	5.0E – 8

*CONCENTRATIONS ARE THOSE REQUIRED TO LIMIT INDIVIDUAL RADIONUCLIDE RELEASE TO 0.1 EPA LIMIT AND TO NRC 10^{-5} RELEASE RATE.

WASTE/BARRIER/ROCK INTERACTIONS TESTING

HYDROTHERMAL INTERACTIONS RESULTING FROM GROUNDWATER FLOW THROUGH A WASTE PACKAGE



WP8308-99

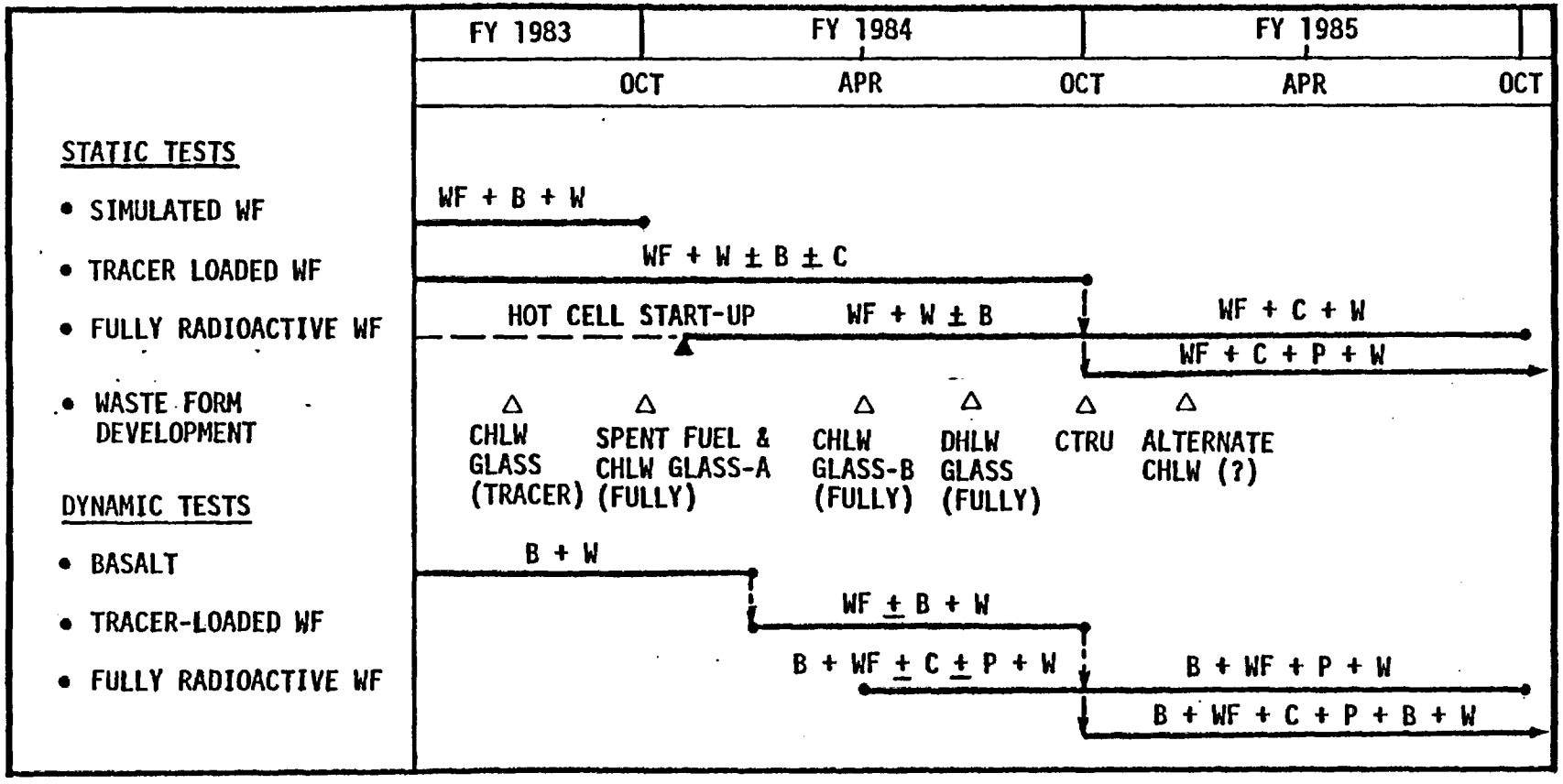
WASTE/BARRIER/ROCK INTERACTION TEST DATA UTILIZATION

LONG-TERM (SLOW-RELEASE) PERFORMANCE

TEST	PERFORMANCE ANALYSIS	DESIGN
D. WASTE-WATER$_{(C)}$	• WF RELEASE RATE UNDER REPOSITORY CONDITIONS • SOLUBILITY/STEADY-STATE CONCENTRATION • SECONDARY ALTERATION SOLIDS	•DETERMINE NEED FOR OTHER BARRIERS •QUANTIFY WF PERFORMANCE •RADIOLYSIS EFFECTS OF WATER
E. WASTE-CANISTER-WATER$_{(D)}$	• EFFECT OF CANISTER MATERIAL ON WASTE FORM RELEASE RATE (REDOX/FE-OXIDE COLLOIDS) • SOLUBILITY/STEADY-STATE CONCENTRATIONS	•DETERMINE NEED FOR OTHER BARRIERS •CONFIRM COMPATIBILITY OF CANISTER WITH WASTE FORM •DEFINE RADIONUCLIDES REQUIRING PACKING PERFORMANCE
F. WASTE-CANISTER-PACKING-WATER$_{(E)}$	• EFFECT OF PACKING ON RADIONUCLIDE SOLUBILITY IN WASTE PACKAGE • MEASURE RADIONUCLIDE RELEASE RATES FROM WASTE PACKAGE	•CONFIRM DESIGN MEETS RELEASE RATE CRITERIA •CONFIRM COMPATIBILITY OF WP MATERIALS •IDENTIFY RADIONUCLIDES REQUIRING TAILORING OF PACKING MATERIAL
G. WASTE-BASALT-WATER$_{(F)}$	• EFFECT OF BASALT ON RADIONUCLIDE SOLUBILITY • EVALUATE RADIONUCLIDE TRANSPORT IN DISTURBED ZONE • PROVIDE SOURCE TERM FOR FAR-FIELD TRANSPORT MODELING	• DETERMINE NEED FOR BASALT IN PACKING MATERIAL • ESTABLISH EXTENT OF EH CONTROL BY BASALT

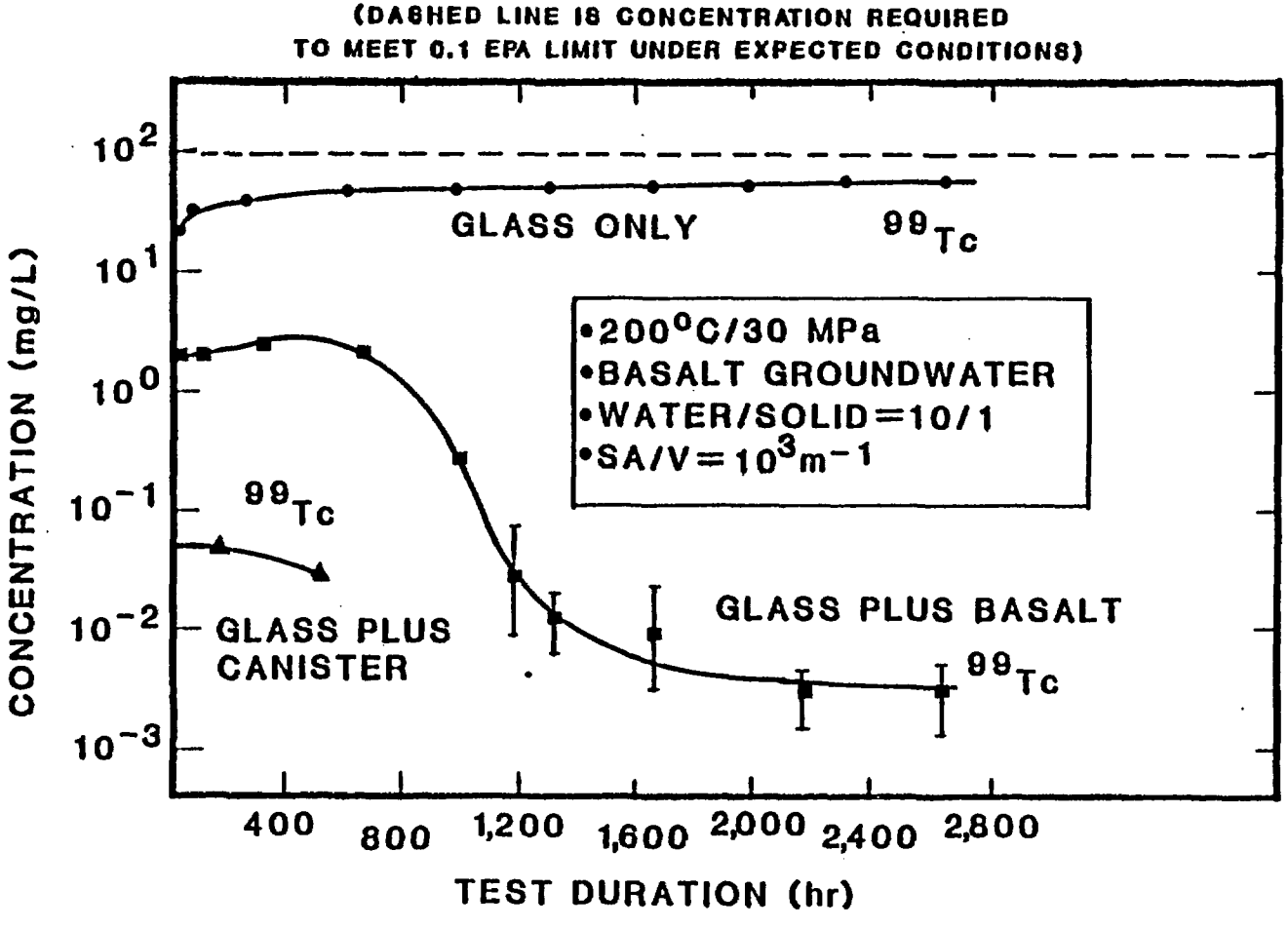
WP8306-166

SCHEDULE FOR
BASALT WASTE ISOLATION PROJECT
WASTE/BARRIER/ROCK INTERACTION STUDIES



WP8308-164

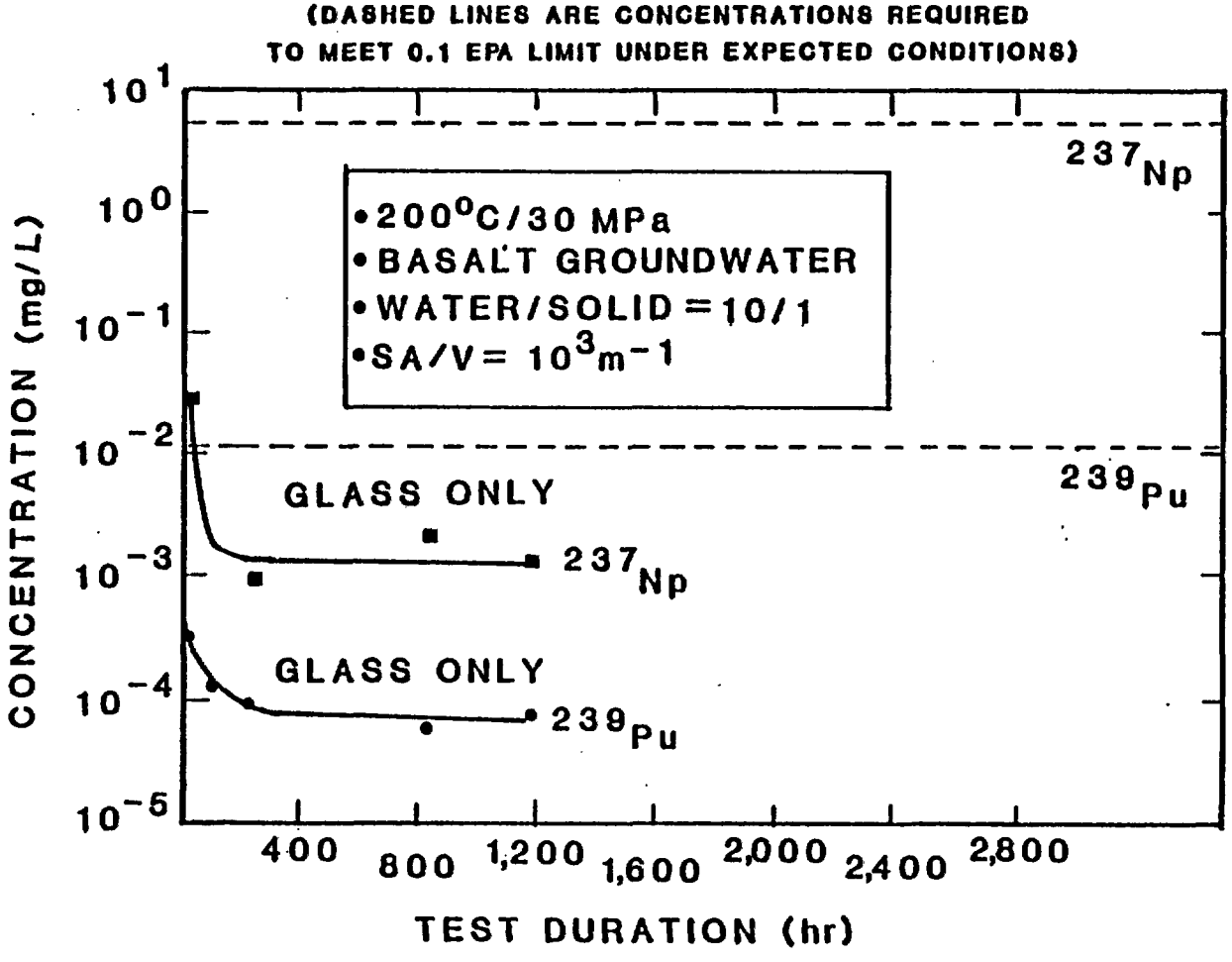
STEADY-STATE CONCENTRATIONS
OF KEY RADIONUCLIDES FOR CHLW (76-68) GLASS



WP8306-163A

STEADY-STATE CONCENTRATIONS

OF KEY RADIONUCLIDES FOR CHLW (76-68) GLASS



WP8306-162A

WASTE PACKAGE DESIGN/ENGINEERING STUDIES
AND
ENGINEERING TESTING

WASTE PACKAGE CONFIGURATION ALTERNATIVES STUDY

PURPOSE

- IDENTIFY AND EVALUATE ALTERNATIVE WASTE PACKAGE CONFIGURATIONS FOR USE IN ADVANCED CONCEPTUAL DESIGN

SUBCONTRACTOR

- WESTINGHOUSE – WASTE TECHNOLOGY SERVICES DIVISION

WASTE PACKAGE CONFIGURATION ALTERNATIVES
STUDY SELECTION CRITERIA

PERFORMANCE

- OPERATIONS PERIOD
- SAFE HANDLING
- IDENTIFICATION
- RETRIEVAL
- CRITICALITY
- POST–CLOSURE PERIOD
- CONTAINMENT
- CRITICALITY

COST

- MATERIALS
- FABRICATION
- HANDLING
- STORAGE
- EMPLACEMENT
- RETRIEVAL
- MONITORING

DEVELOPMENT PROGRAMS REQUIRED

- RISK TO SCHEDULE
- PROGRAM CHARACTERISTICS

PROGRAM COMPATIBILITY

- DESIGN ACCEPTABILITY
- LICENSABILITY

ALTERNATIVES FOR MAJOR FEATURES

WASTE MATRIX

- SPENT FUEL PELLETS (IN WHOLE FUEL ASSEMBLIES)
- SPENT FUEL PELLETS (IN CONSOLIDATED BUNDLES OF FUEL RODS)
- BOROSILICATE GLASS MONOLITH
- CERAMIC MONOLITH
- CERAMIC PELLETS OR SPHERES
- BOROSILICATE GLASS PELLETS OR SPHERES MIXED WITH CRUSHED BASALT AND BENTONITE

CONTAINER

- ZIRCALLOY CLADDING (APPLIES TO SPENT FUEL ONLY)
- STAINLESS STEEL VESSEL (APPLIES TO GLASS AND CERAMICS ONLY)
- NONE (APPLIES TO GLASS AND CERAMICS ONLY)

CANISTER (PROVIDES 1,000-YEAR CONTAINMENT)

- CARBON STEEL CYLINDRICAL VESSEL
- CARBON STEEL CYLINDRICAL PIPE
- CARBON STEEL RECTANGULAR VESSEL
- CARBON STEEL BINS
- LOW CHROMIUM, FERRITIC ALLOY STEEL CYLINDRICAL VESSEL
- CAST IRON OR STEEL VESSEL

ALTERNATIVES FOR MAJOR FEATURES (CONTINUED)

PACKING

- CRUSHED BASALT AND BENTONITE BULK MATERIAL
- CRUSHED BASALT AND BENTONITE PRESSED BLOCK FORM
- PACKAGED CRUSHED BASALT AND BENTONITE
- CRUSHED BASALT
- NONE

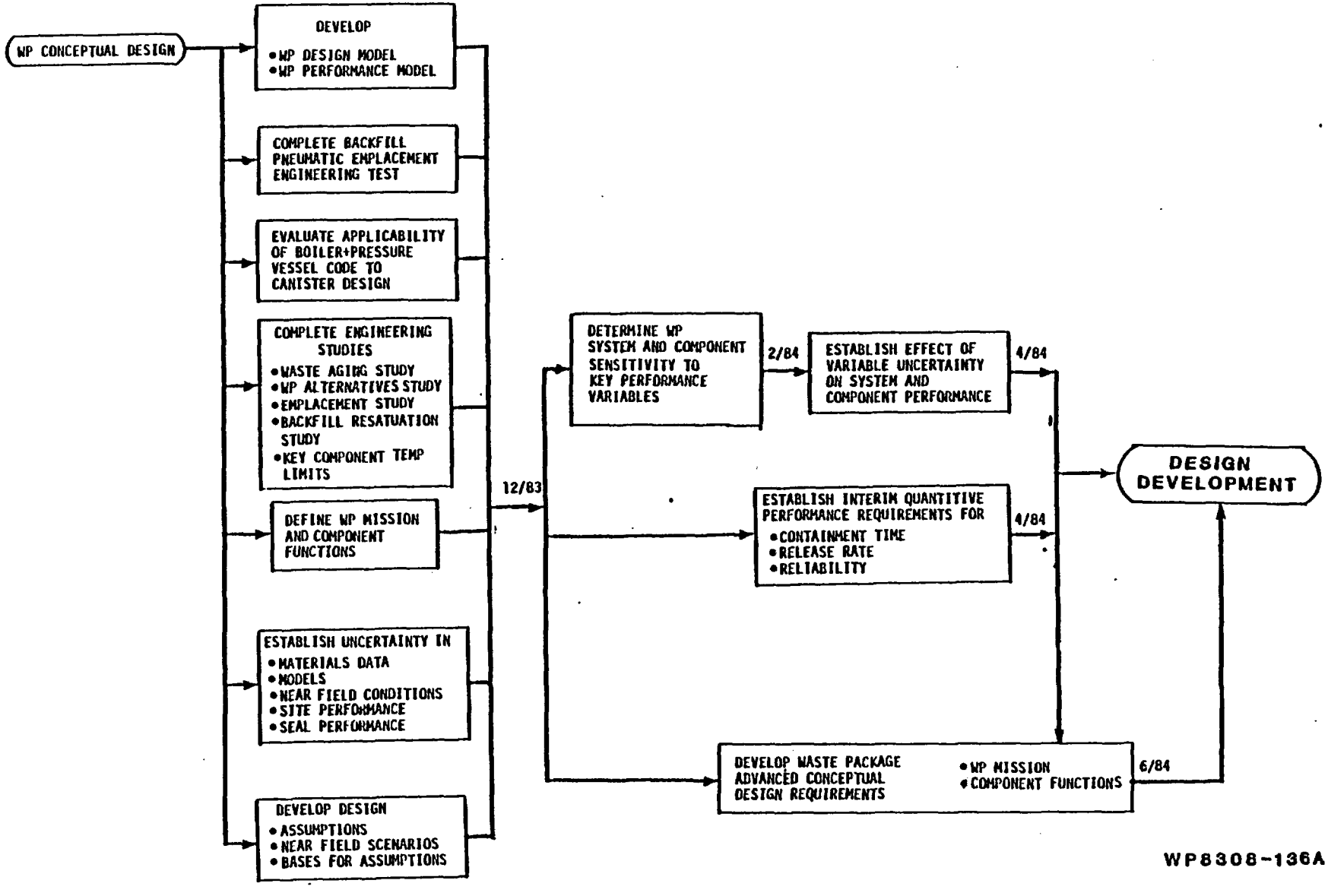
EMPLACEMENT

- VERTICAL
- HORIZONTAL IN-TUNNEL
- LONG HORIZONTAL BOREHOLE
- LINED LONG HORIZONTAL BOREHOLE
- SHORT HORIZONTAL BOREHOLE
- ALCOVE
- TRENCH

FY .984-1985

BWIP WASTE PACKAGE

ADVANCED CONCEPTUAL DESIGN ENGINEERING STUDIES

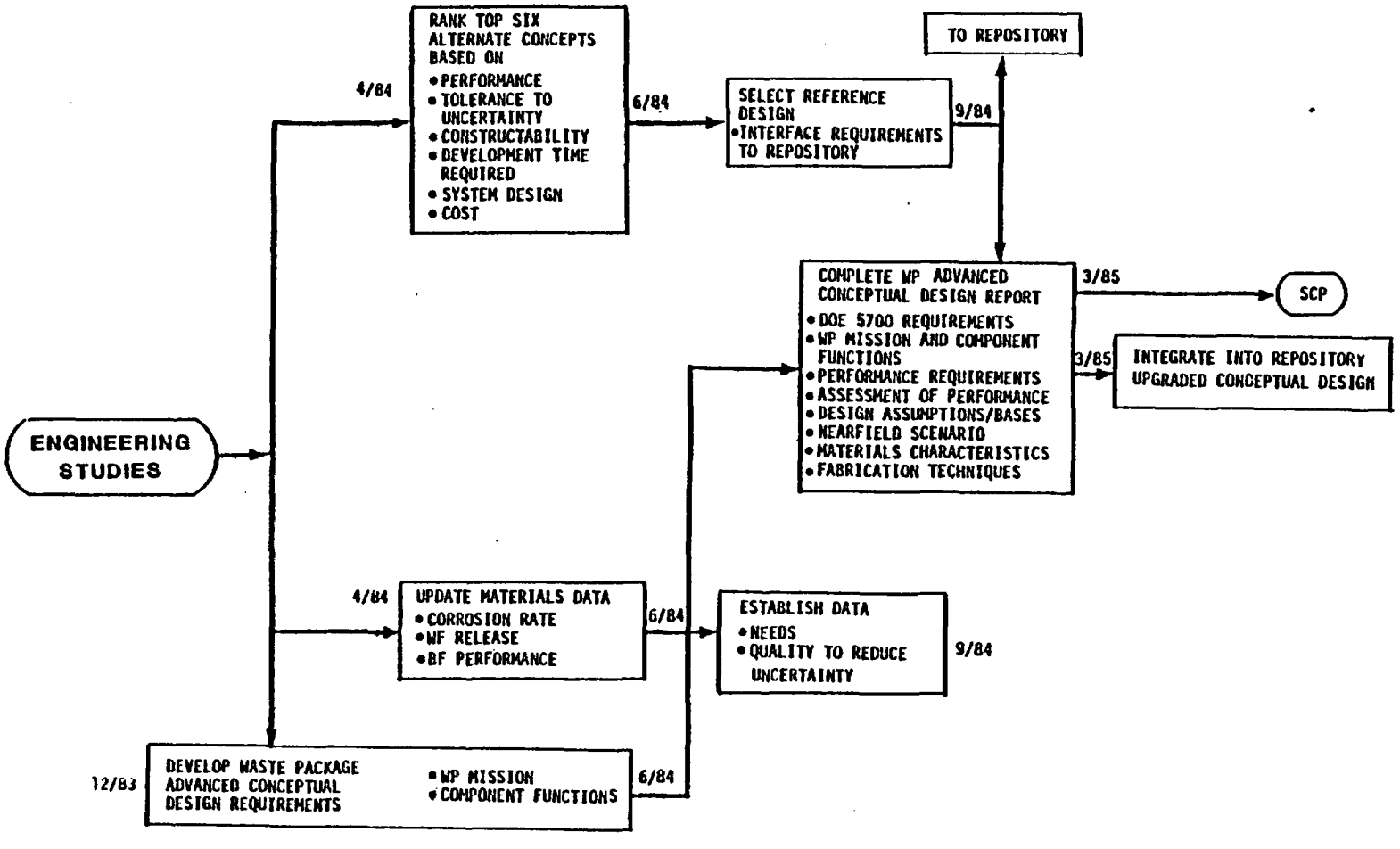


WP8308-136A

FY 1984-1985

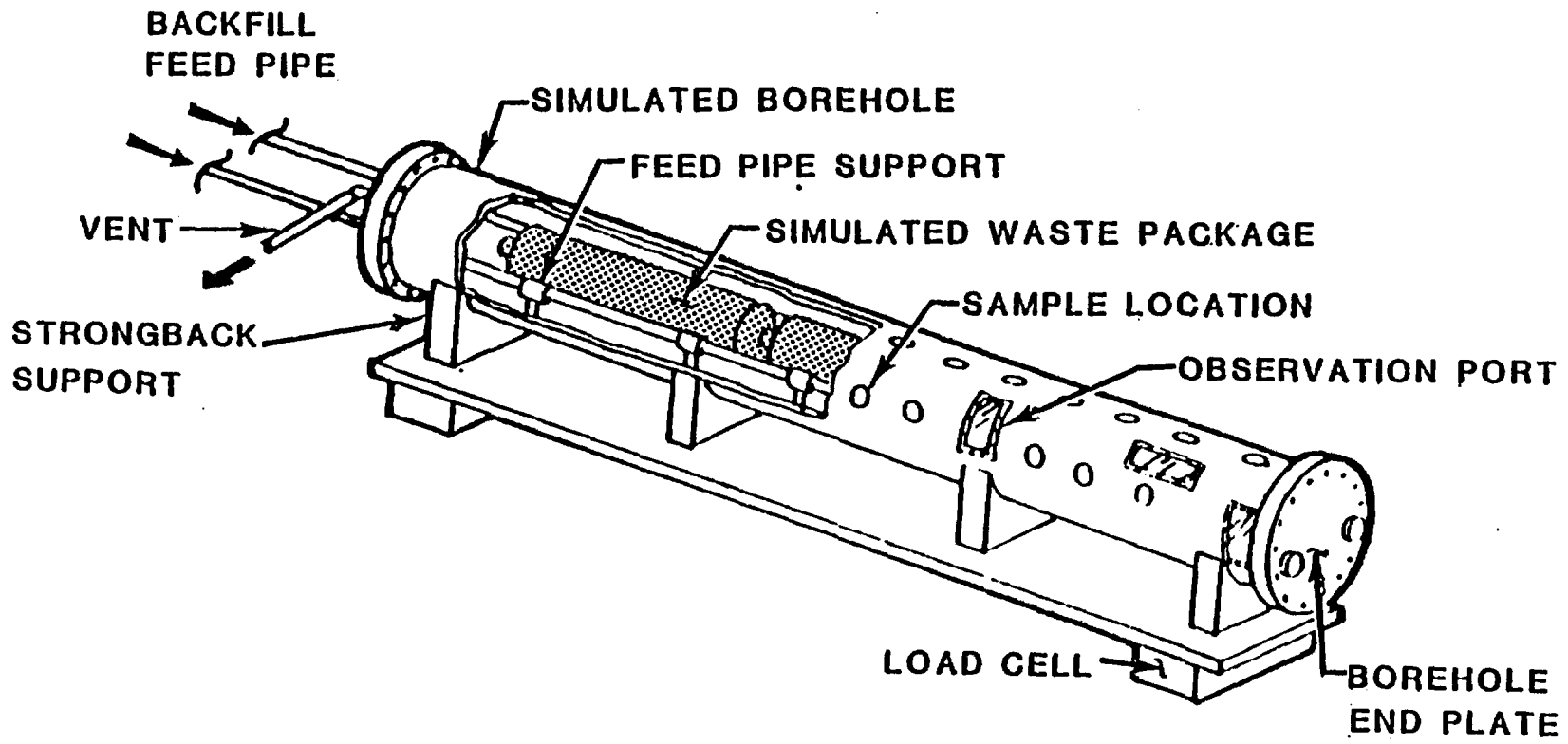
BWIP WASTE PACKAGE

ADVANCED CONCEPTUAL DESIGN DEVELOPMENT

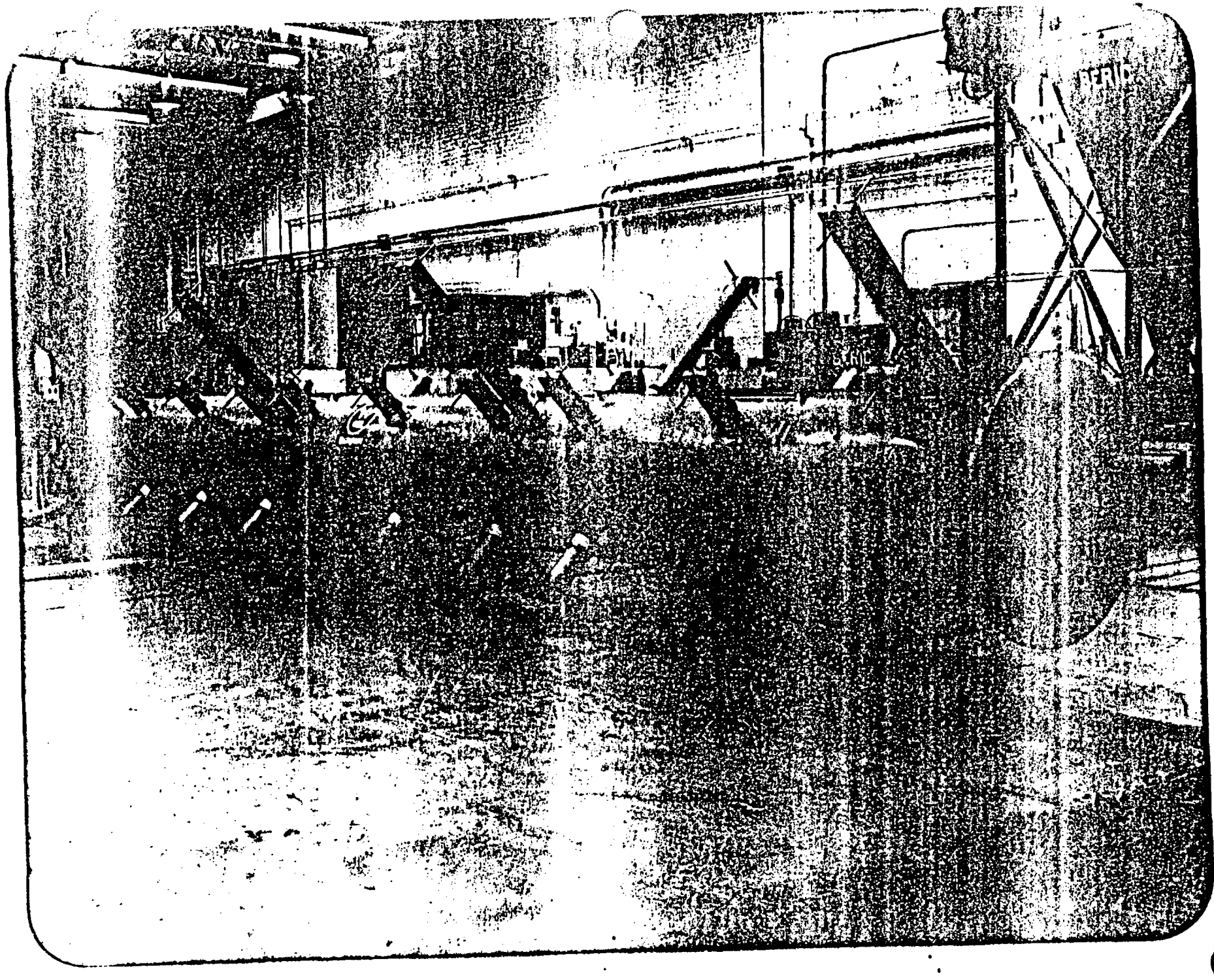


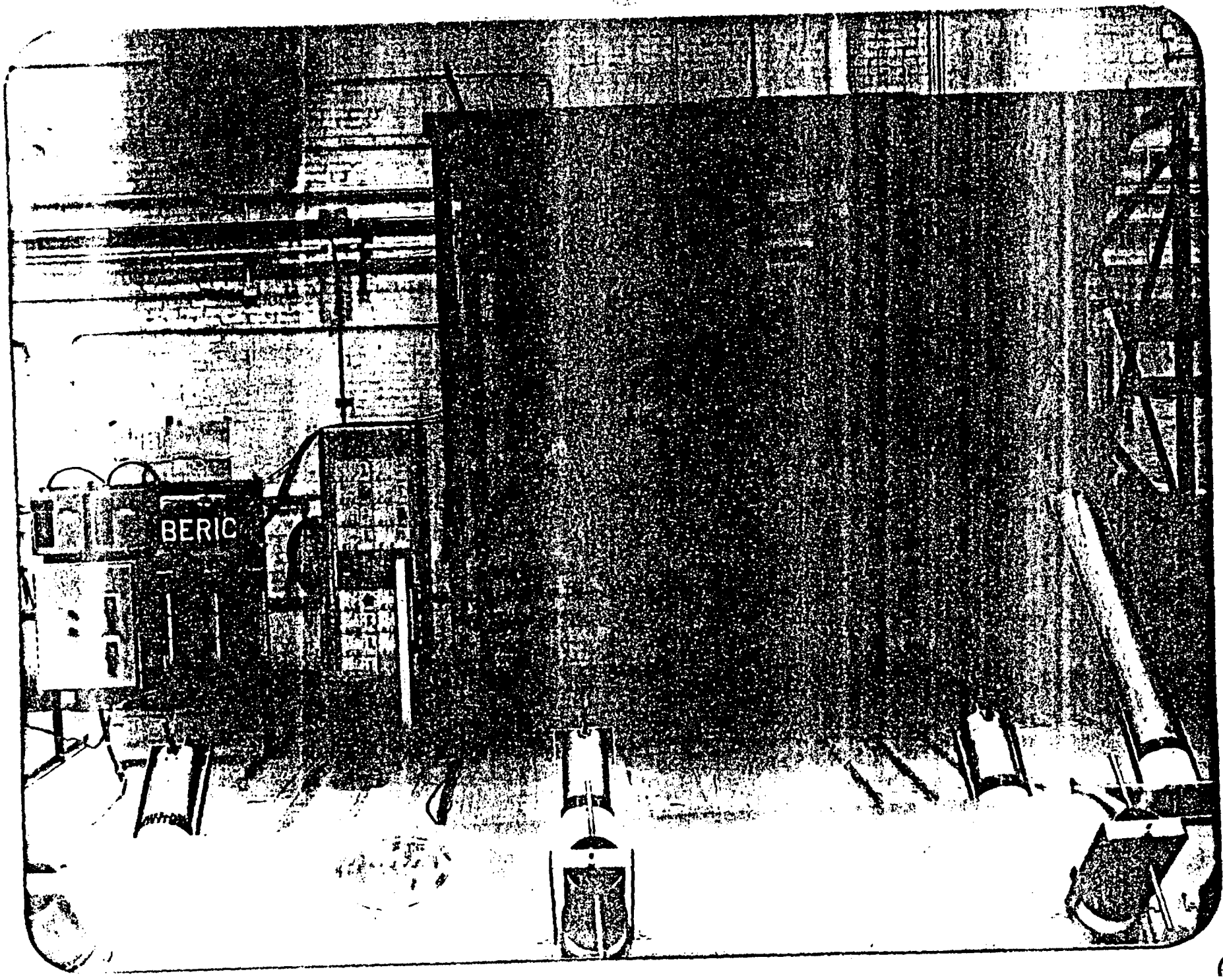
WP8306-137A

WASTE PACKAGE BACKFILL PROCESS DEVELOPMENT TEST



WP8303-69

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SUMMARY

- WASTE PACKAGE ADVANCED CONCEPTUAL DESIGN PROGRAM RELANNED TO INCLUDE RESULTS OF 08/03/83 INTERFACE MEETING WITH NRC STAFF
- GROUNDWATER CHEMISTRY EFFECTS ON LOW-CARBON STEEL CORROSION APPEAR TO BE INSIGNIFICANT IN COMPARISON TO TEMPERATURE EFFECTS
- GAMMA RADIATION ENHANCES LOW-CARBON STEEL CORROSION RATE TWOFOLD AT HIGH FLUID VELOCITIES (35 mL/hr) AND IN AN INTENSE RADIATION FIELD
- PACKING MATERIAL HYDRAULIC CONDUCTIVITIES AT 25° TO 90°C APPEAR TO BE INSENSITIVE TO EMPLACEMENT DENSITIES GREATER THAN 1.6
- RELEASE RATES FROM ^{99}Tc, ^{239}Pu, AND ^{237}Np DOPED COMMERCIAL HIGH-LEVEL WASTE GLASS UNDER REPOSITORY CONDITIONS APPEAR TO BE ADEQUATE TO MEET REGULATORY REQUIREMENTS
- ALTERNATIVES TO THE BWIP WASTE PACKAGE LONG-HOLE STORAGE CONCEPT ARE BEING EVALUATED AS PART OF ENGINEERING STUDIES IN PROGRESS
- RELIABILITY PROGRAM FOR WASTE PACKAGE DESIGN BEING DEVELOPED
- FULL-SCALE PNEUMATIC BACKFILLING ENGINEERING TEST IN PROGRESS

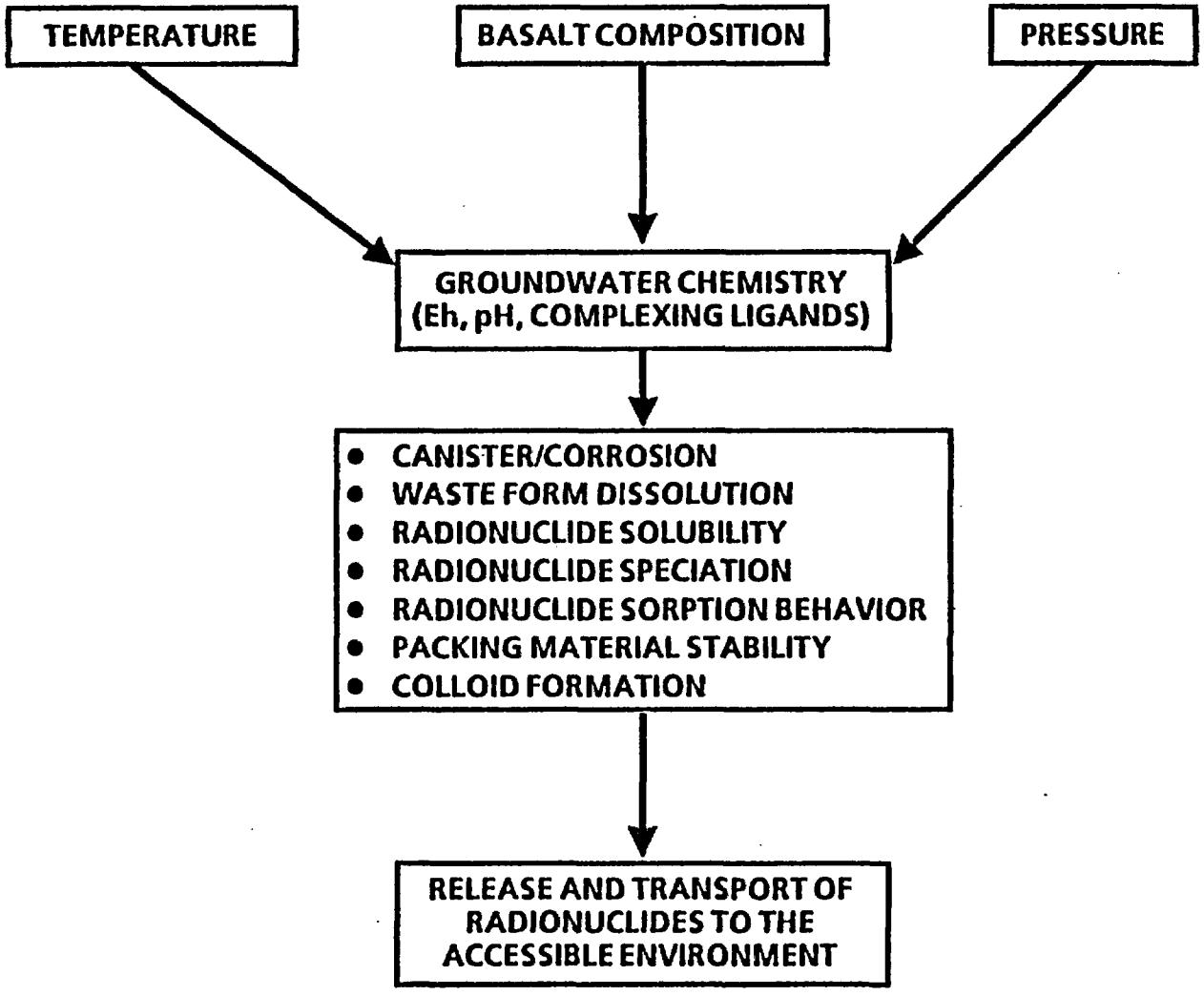
GEOCHEMISTRY

P. F. SALTER

PRESENTATION SUMMARY

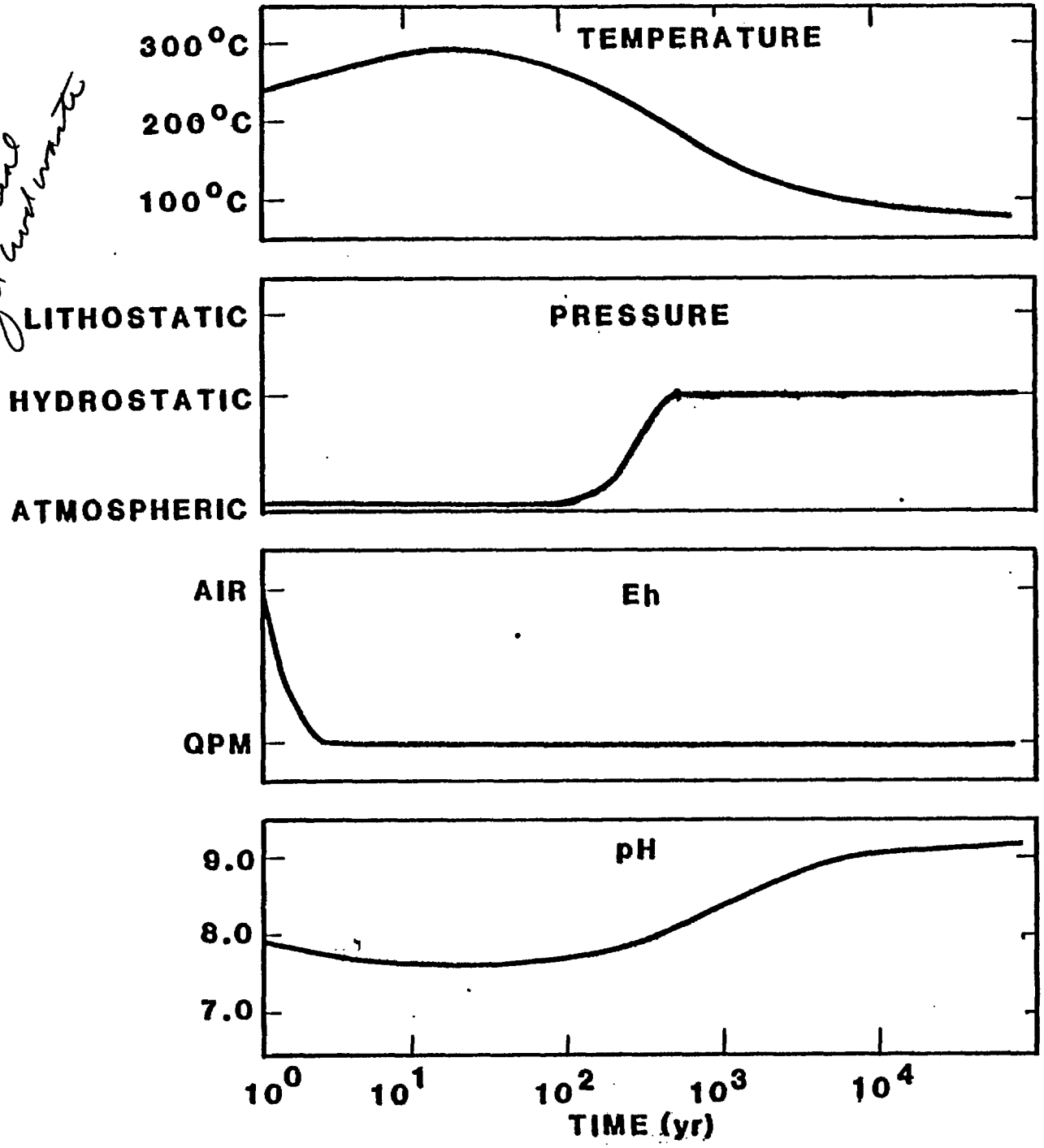
- PROGRAM OBJECTIVE
- ROLE OF GEOCHEMISTRY IN THE PROJECT
- GENERALIZED LIST OF NRC AND OTHERS' CONCERNS
- PLANS FOR RESOLUTION OF GEOCHEMISTRY CONCERNS
- PROGRAM STATUS WITH RESPECT TO CONCERNS
  - PREVAILING Eh CONDITIONS
  - RADIONUCLIDE SOLUBILITY
  - RADIONUCLIDE SORPTION
  - COLLOID FORMATION AND TRANSPORT
  - RADIOLYSIS OF GROUNDWATER

IMPORTANT GEOCHEMICAL PARAMETERS FOR A NUCLEAR WASTE REPOSITORY IN BASALT



PREDICTED VARIATION OF GEOCHEMICAL PARAMETERS WITH TIME

Based on 10 generalized oxidizing high salt waste



WP8211-14C

GENERALIZED LIST OF CONCERNS: GEOCHEMISTRY

- VALIDATION/VERIFICATION OF PREDICTED REDOX CONDITIONS IN THE CANDIDATE HORIZONS IS NEEDED
- DEMONSTRATION OF REDOX BUFFERING CAPACITY OF BASALT IS NEEDED
- VERIFICATION OF RADIONUCLIDE SOLUBILITY ESTIMATES IS NEEDED AND EFFECTS OF RADIATION, COMPLEXATION, AND WASTE PACKAGE COMPONENTS/EMPLACEMENT ON SOLUBILITY MUST BE EVALUATED
- COLLOIDAL TRANSPORT OF RADIONUCLIDES MUST BE EVALUATED
- RADIONUCLIDE SORPTION BEHAVIOR MUST BE EVALUATED WITH RESPECT TO SPECIATION EFFECTS, FLOW RATE EFFECTS, REVERSIBILITY, THE EFFECT OF WASTE PACKAGE COMPONENTS/EMPLACEMENT AND THE USE OF ISOTHERMS VERSUS Kd VALUES FOR PACKING MATERIALS, BACKFILL MATERIALS, BASALT, FRACTURE MINERALIZATION, AND BASALT FLOW TOPS AND INTERBEDS
- SUFFICIENT CHARACTERIZATION OF FRACTURE MINERALIZATION, BASALT FLOW TOPS, AND BASALT INTERBEDS TO EVALUATE HYDROTHERMAL STABILITY/ALTERATION OF FRACTURE FILLINGS, TO EVALUATE Eh CONTROL MECHANISMS, AND TO EVALUATE RADIONUCLIDE SORPTION CAPACITY IS NEEDED
- UNCERTAINTIES IN LONG-TERM PREDICTIBILITY OF THE GEOCHEMICAL ENVIRONMENT MUST BE EVALUATED

PLANS FOR RESOLUTION OF U.S. NUCLEAR REGULATORY COMMISSION GEOCHEMISTRY CONCERNS

RESOLUTION / ISSUE	EMPLACEMENT ENVIRONMENT CHARACTERIZATION				BARRIER MATERIALS TESTING			DRILLING AND TESTING
	ROCK	GROUNDWATER	WATER/ ROCK REACTIONS	T,P	SOLUBILITY TESTING	SORPTION TESTING	WASTE/ BARRIER/ ROCK REACTIONS	FIELD TESTS
Eh CONDITIONS	X			X			X	X
Eh BUFFERING CAPACITY	X	X	X	X			X	
RADIONUCLIDE SOLUBILITY VERIFICATION		X		X	X		X	
RADIONUCLIDE SORPTION BEHAVIOR	X	X		X		X		X
COLLOID FORMATION AND TRANSPORT		X	X		X	X	X	
FRACTURE FILLING STABILITY			X	X				X
RADIATION EFFECTS		X	X		X		X	
LONG-TERM BEHAVIOR			X	X			X	X

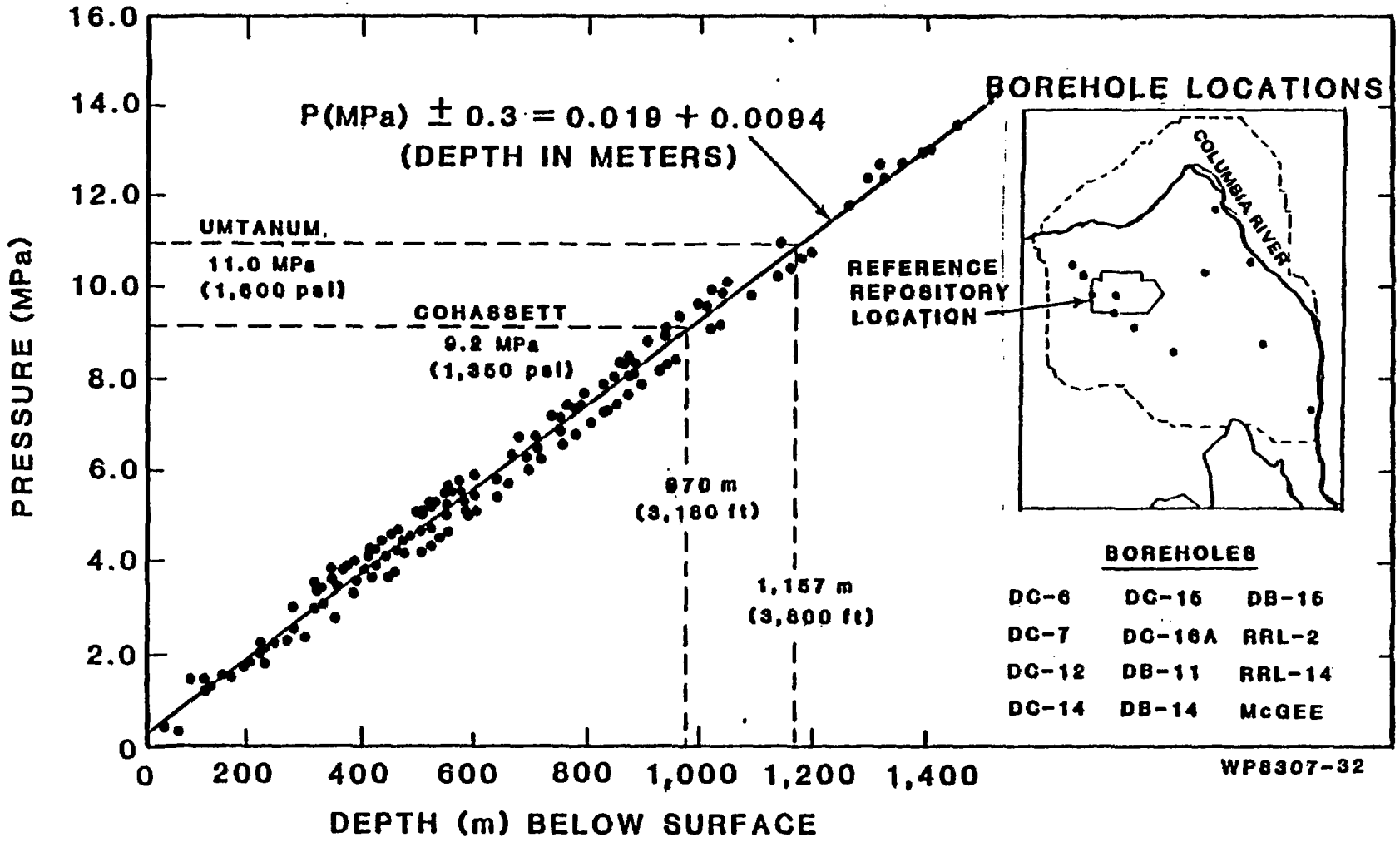
WP8308-175

PROGRAM STATUS WITH RESPECT TO CONCERNS: SUMMARY

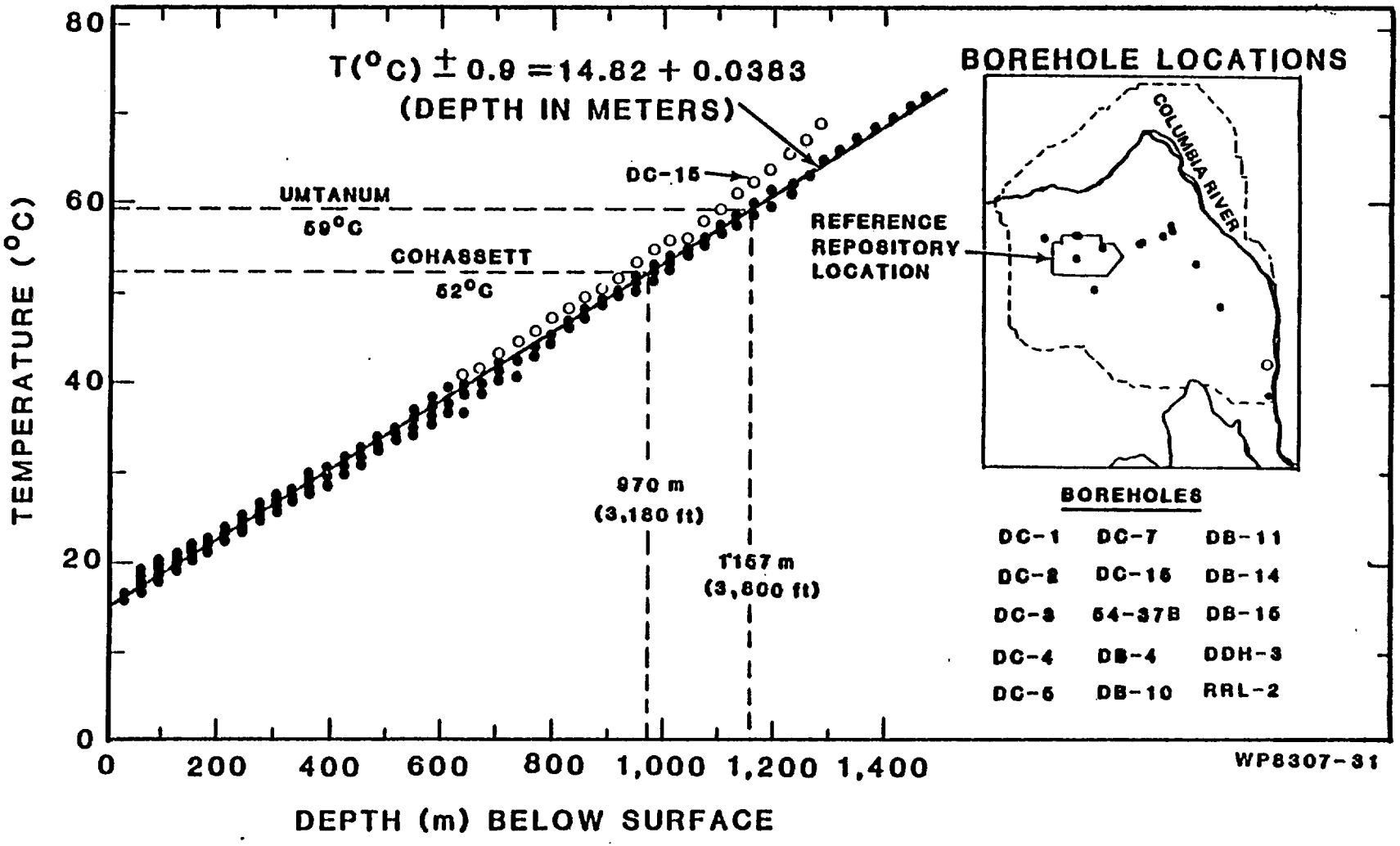
IN PROGRESS

- DEVELOPMENT OF HIGH-TEMPERATURE LABORATORY Eh-pH MEASURING TECHNIQUES
- BASALT OXYGEN BUFFERING CAPACITY TESTING
- SOLUBILITY DETERMINATIONS OF KEY RADIONUCLIDES
- INVESTIGATIONS OF RADIONUCLIDE TRANSPORT BY SILICA COLLOIDS
- RADIATION EFFECTS TESTING OF BASALT GROUNDWATER
- SORPTION ISOTHERM DETERMINATIONS
- SORPTION HYSTERESIS EVALUATIONS
- FRACTURE MINERALIZATION AND BASALT MESOSTASIS CHARACTERIZATION
- HYDROTHERMAL WATER-ROCK REACTIONS TESTING

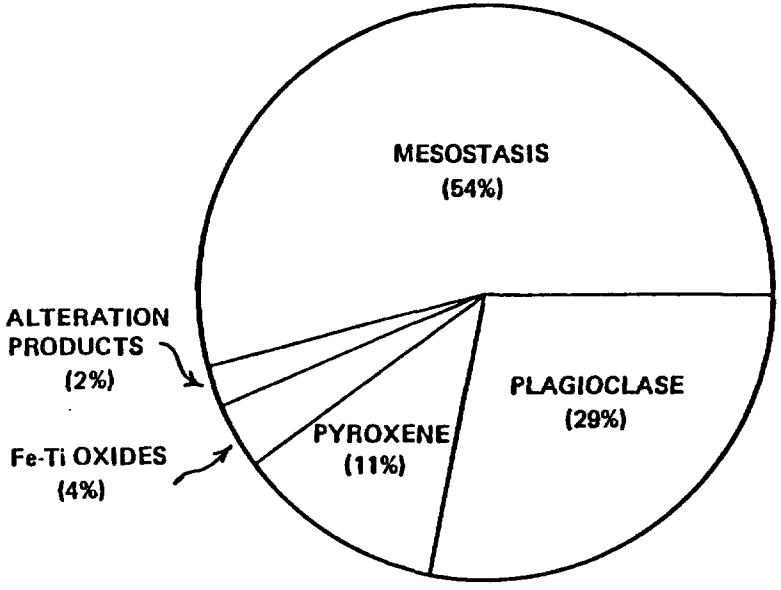
PRESSURE vs DEPTH IN SELECTED BOREHOLES ON THE HANFORD SITE



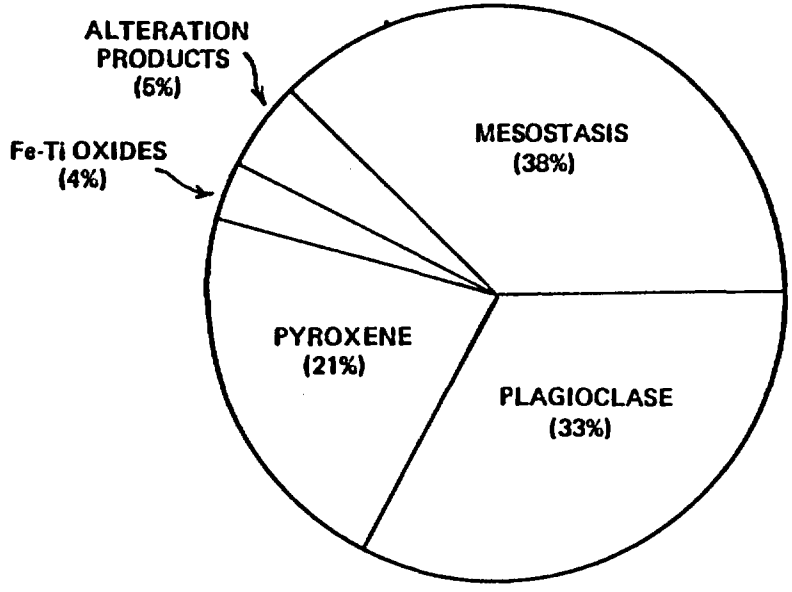
MEASURED FLUID TEMPERATURE vs DEPTH IN SELECTED BOREHOLES ON THE HANFORD SITE



PETROLOGIC COMPOSITION OF UMTANUM AND COHASSETT BASALTS (WEIGHT PERCENTAGE)



UMTANUM BASALT

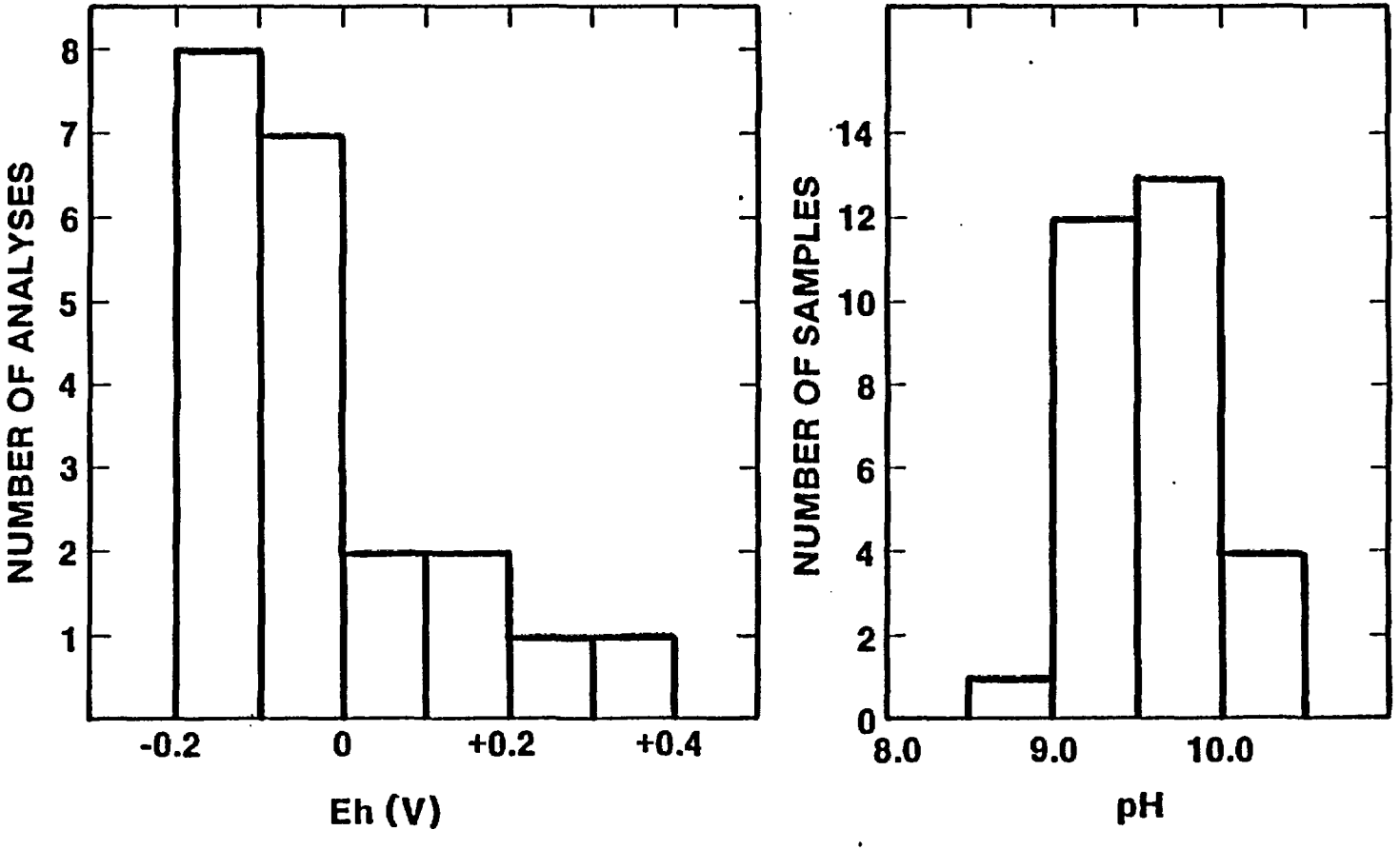


COHASSETT BASALT

GRANDE RONDE GROUNDWATER COMPOSITION

CONSTITUENT	REFERENCE REPOSITORY LOCATION (mg/L)	OUTSIDE THE REFERENCE REPOSITORY LOCATION (mg/L)
Na^+	337	358
K^+	13.8	3.4
Ca^{2+}	2.2	2.8
Mg^{2+}	<0.1	<0.1
Cl^-	405	312
SO_4^{2-}	4.2	173
F^-	20.0	33.4
$Si(HSiO_4^-)$	44.6 (64)	35.6 (69)
HCO_3^-	98	44
$CO_3^=$	17	11
pH	9.7	9.8
Dissolved Gases	615 (98% CH_4)	N.A.

HISTOGRAMS OF MEASURED pH AND Eh IN GRANDE RONDE GROUNDWATERS



WP8303-84

MEASURED VS CALCULATED Eh VALUES FOR THE GRANDE RONDE GEOHYDROLOGIC SYSTEM

- CONSIDERABLE UNCERTAINTY IN THE MEASURED VALUES
  - CONTAMINATION OF WATER WITH OXYGEN DURING SAMPLING
  - UNCERTAINTY IN RESPONSE OF PLATINUM ELECTRODE USED TO MEASURE Eh
    - SENSITIVE TO CONCENTRATION OF MEASURED REDOX COUPLE
    - ASSUMES REVERSIBLE REACTION AT THE ELECTRODE (WELL-POISED SYSTEM)
    - KINETIC AND MIXED POTENTIAL LIMITS TO MEASUREMENTS
    - ADSORPTION OF TRACE IMPURITIES ON THE ELECTRODE SURFACE
- THEREFORE, UTILIZE AN INDIRECT APPROACH TO BOUNDING EXPECTED Eh VALUE BY COUPLING AVAILABLE THERMODYNAMIC DATA WITH OBSERVATIONS AND MEASUREMENTS OF REDOX SENSITIVE SYSTEMS
  - ALTERATION MINERAL ASSEMBLAGES
  - SOLUTION REDOX INDICATORS

EVIDENCE FOR PROPOSED Eh CONDITIONS IN THE GRANDE RONDE BASALT

DISSOLVED GAS COMPOSITIONS

- CO_2/CH_4 APPROXIMATELY 0.2

  Eh APPROXIMATELY –0.49 V

Strendler
"not possible in equilibrium"

AQUEOUS SULFATE EQUILIBRIUM

- SO_4^{2-}/HS^- APPROXIMATELY 2×10^6

  Eh APPROXIMATLEY –0.42 V

not within analytical bounds

AQUEOUS ARSENIC EQUILIBRIUM

- As(III)/As(V) >7.3 AT 257 HOURS (T = 300°C)

  Eh APPROXIMATELY –0.40 V

MINERALOGICAL

- NO HEMATITE (Fe_2O_3) FOUND

  Eh <–0.35 V

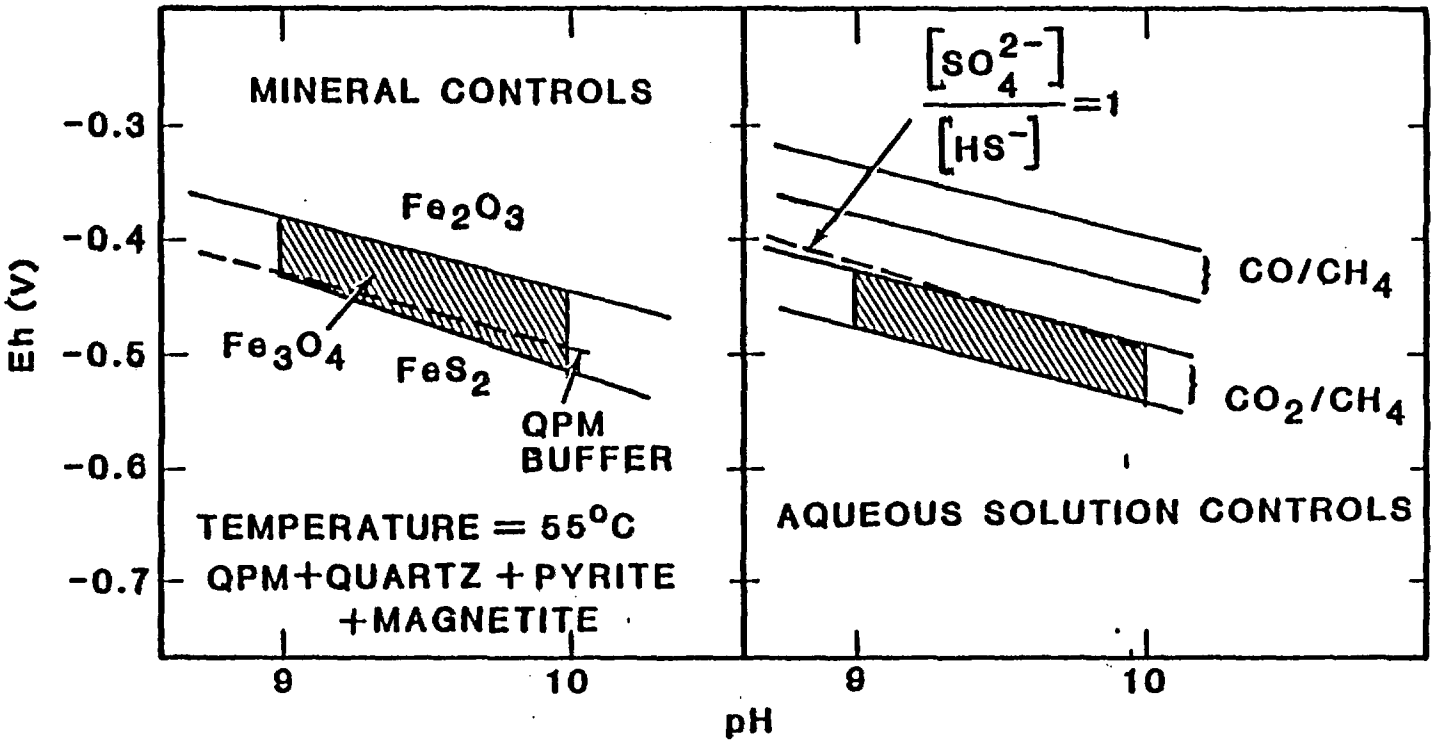
analytical method?

- PYRITE (FeS_2) AND MAGNETITE (Fe_3O_4) FOUND

  Eh APPROXIMATELY –0.45 V

Strendler agrees probably not reducing; doesn't bring argument.

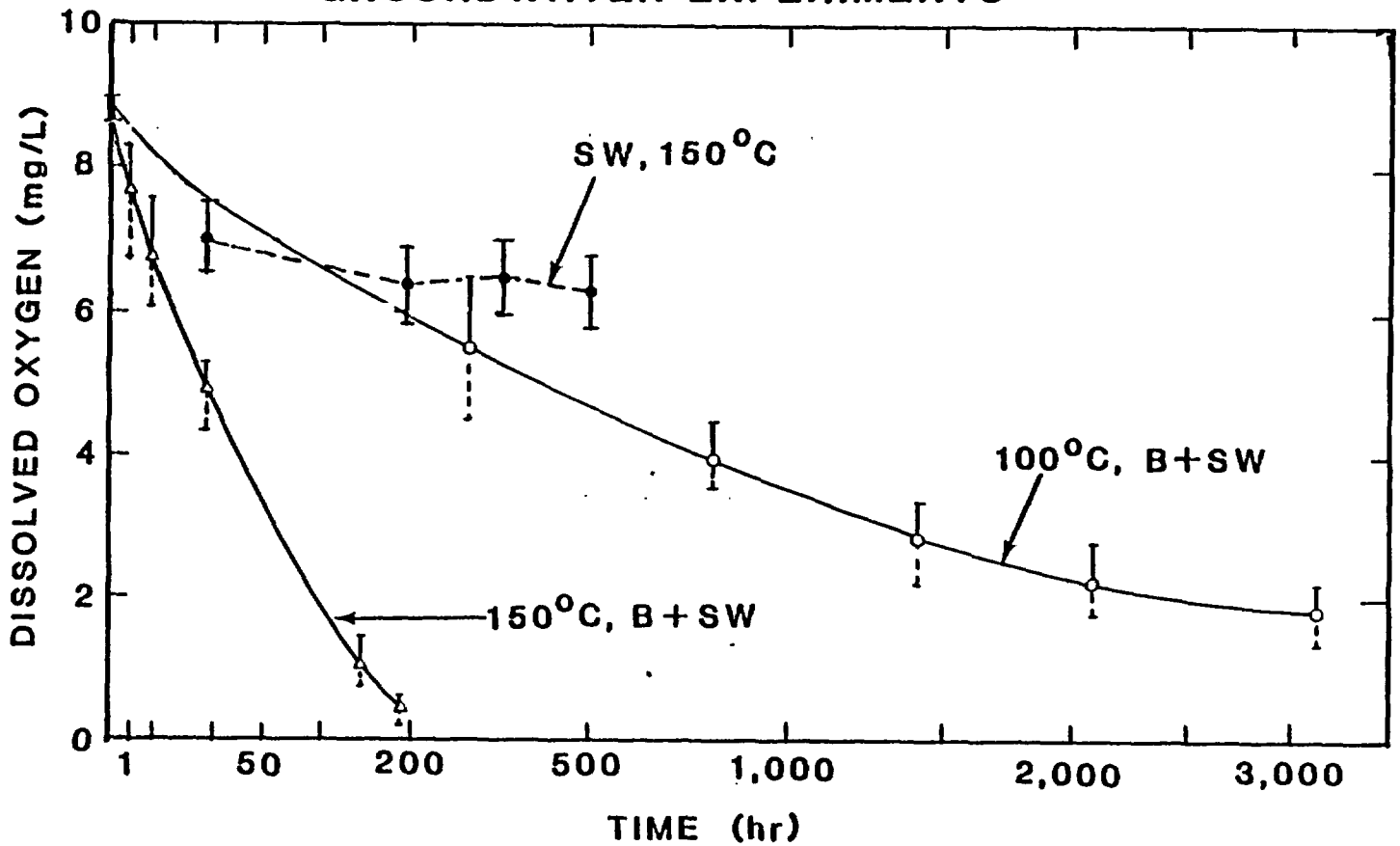
Eh-pH DIAGRAMS FOR GRANDE RONDE BASALT



WP8308-3A

DISSOLVED OXYGEN CONSUMPTION DATA

FROM BASALT-SYNTHETIC GRANDE RONDE GROUNDWATER EXPERIMENTS



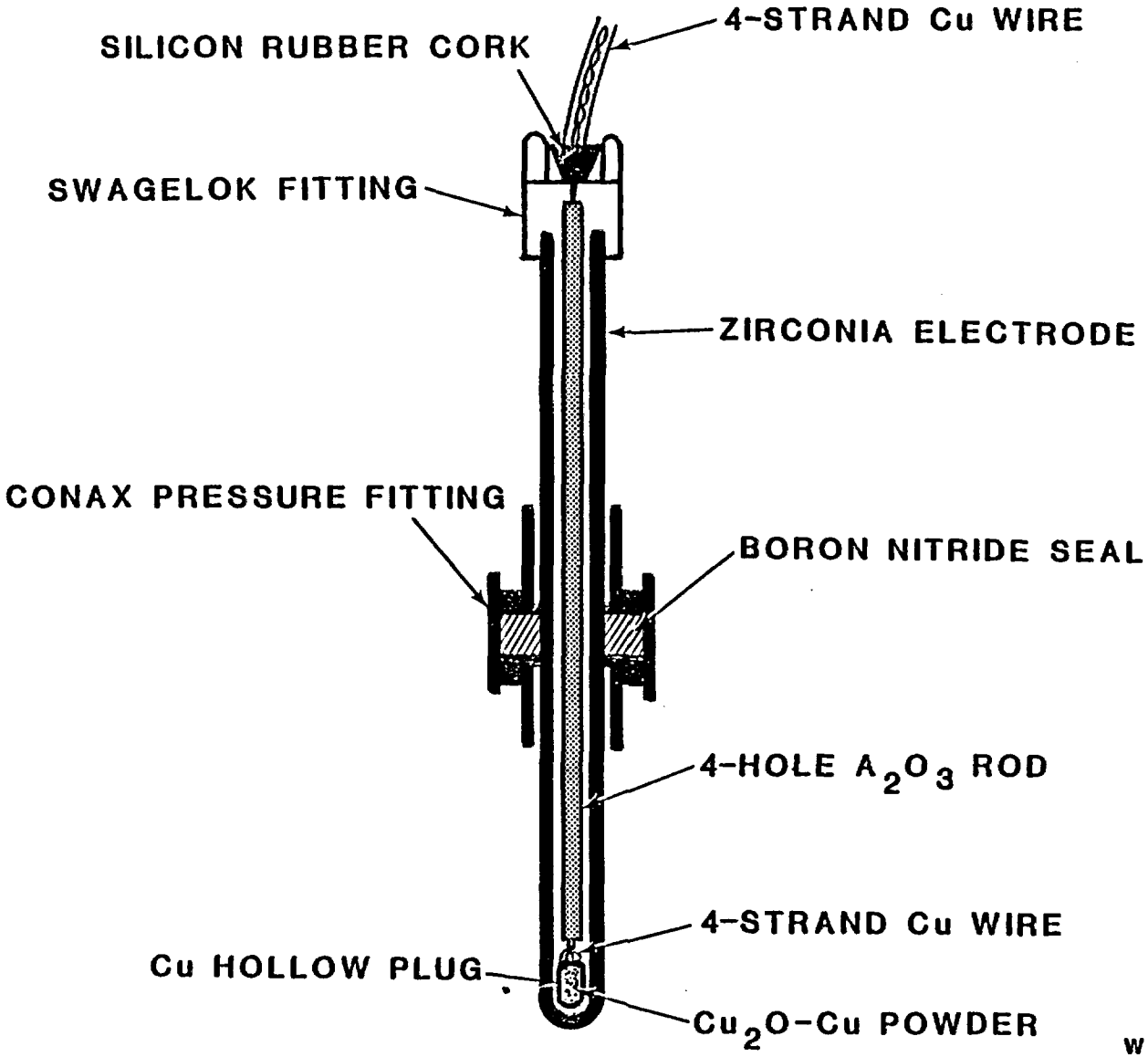
WP8302-39C

SENSOR SYSTEMS UNDER DEVELOPMENT

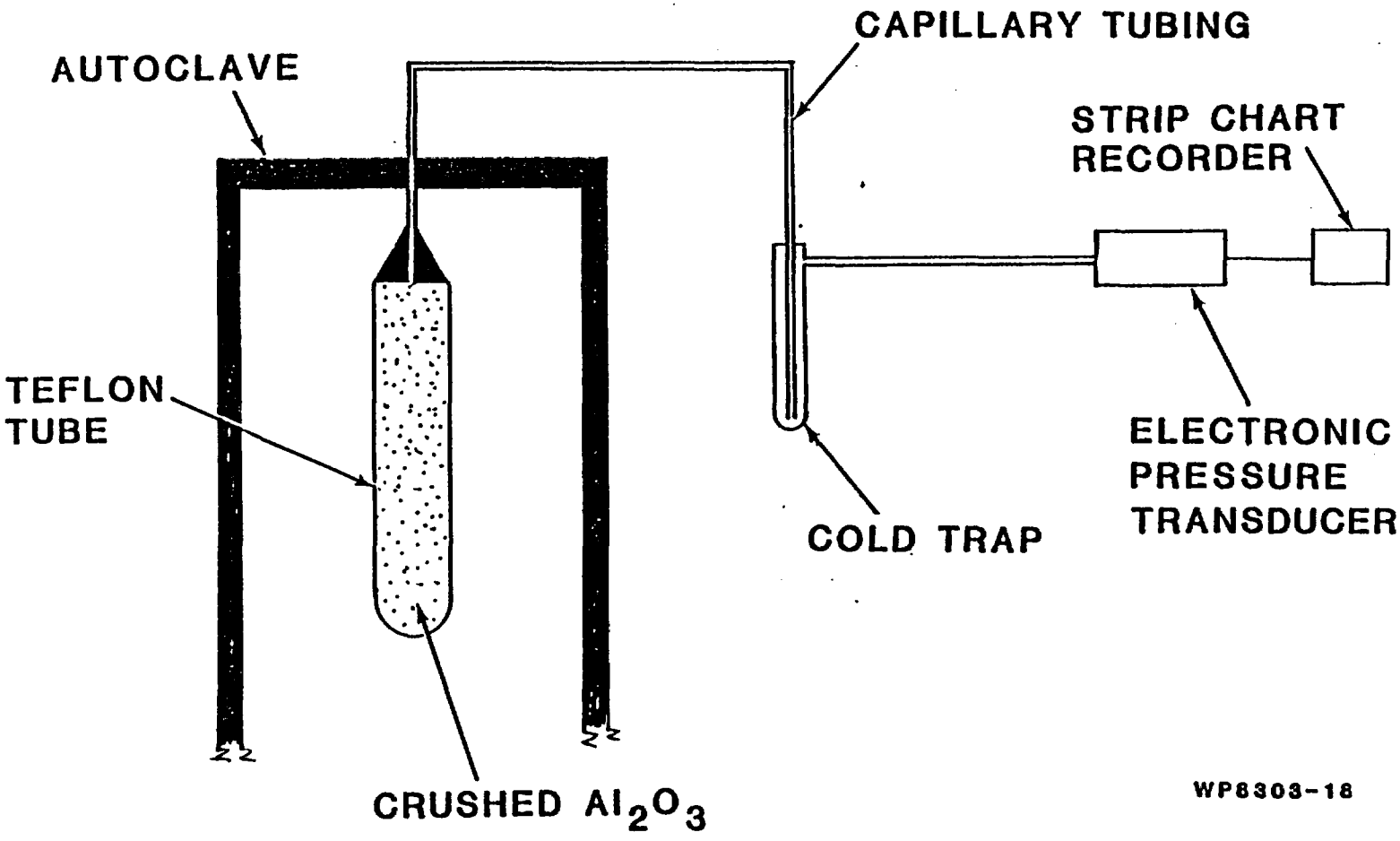
- TEFLON HYDROGEN DIFFUSION MEMBRANE
- ZIRCONIA pH ELECTRODE
- Eh ELECTRODE
- REFERENCE ELECTRODE
- REDOX SENSITIVE COUPLES
- REDOX SENSITIVE DYES

ZIRCONIA pH ELECTRODE

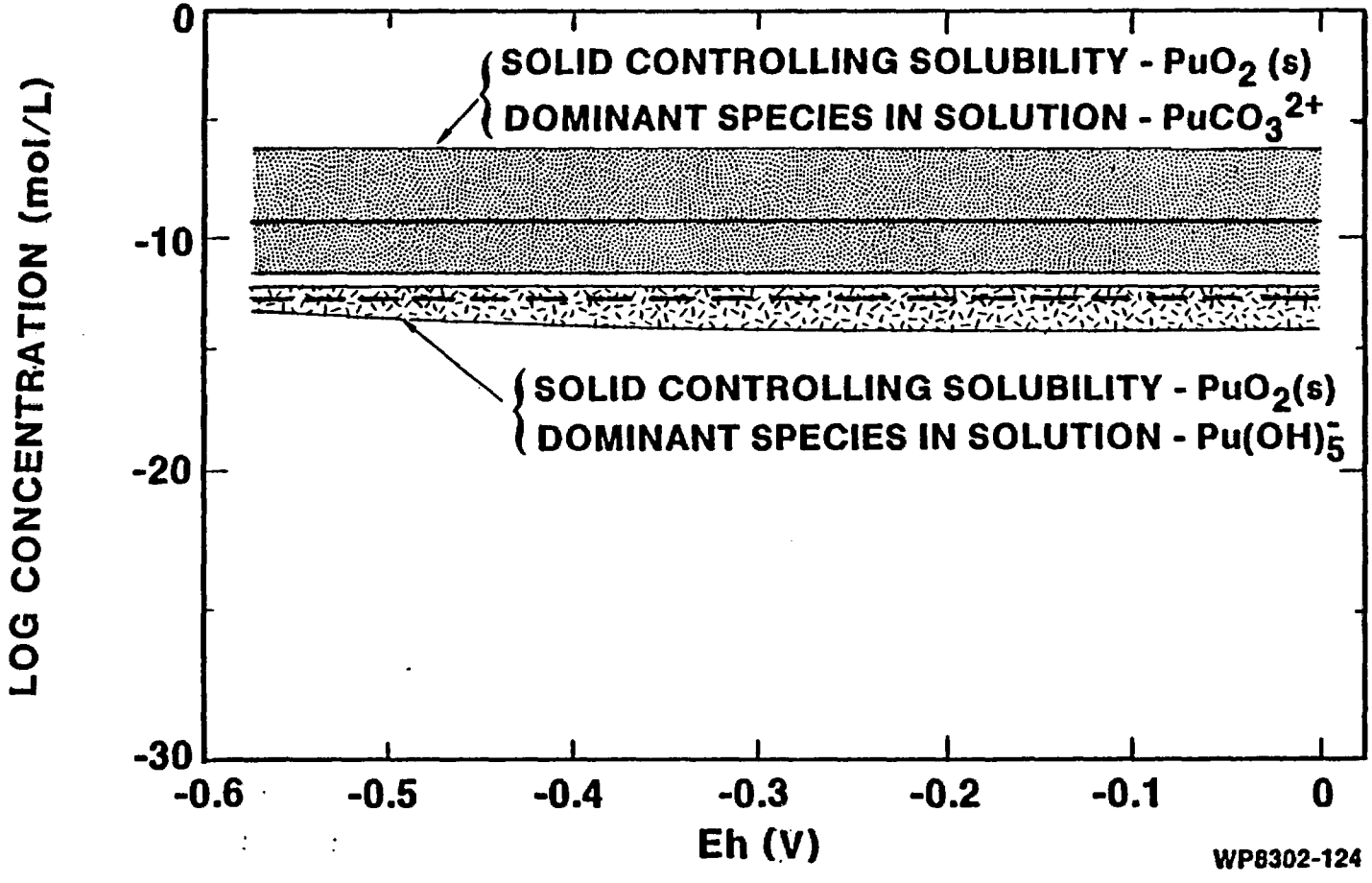
TEMPLE UNIVERSITY DESIGN



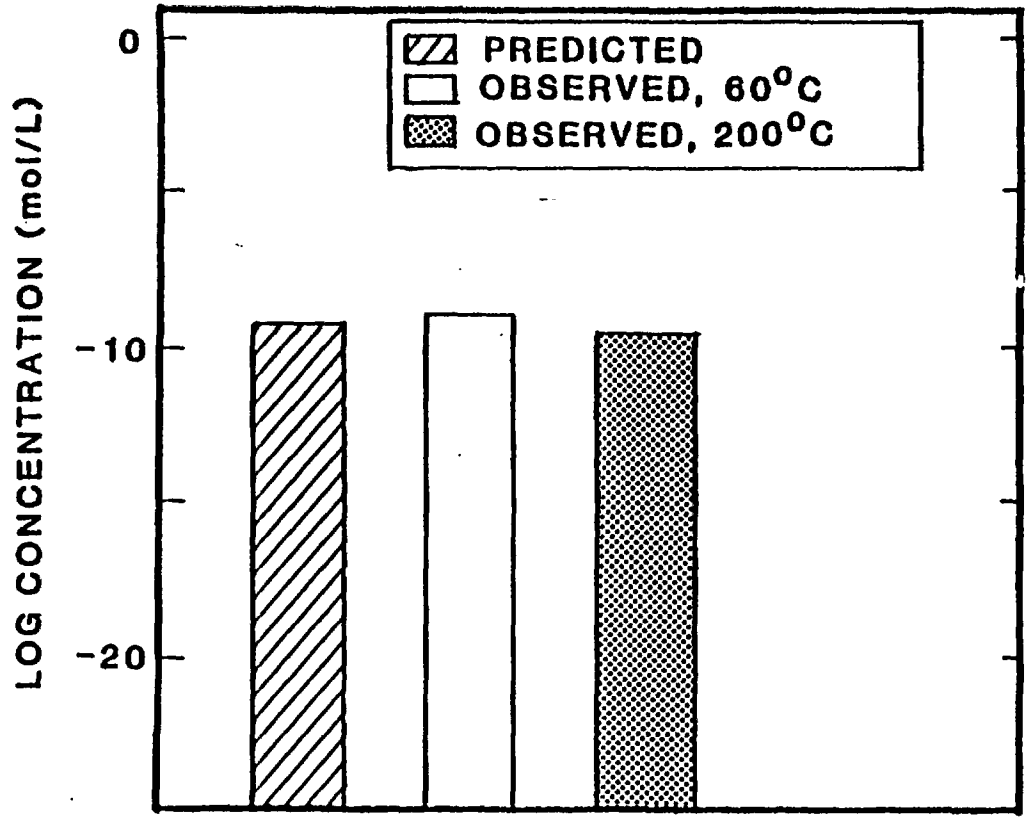
TEFLON HYDROGEN DIFFUSION MEMBRANE SCHEMATIC



SOLUBILITY OF PLUTONIUM AS A FUNCTION OF Eh AT 25° C

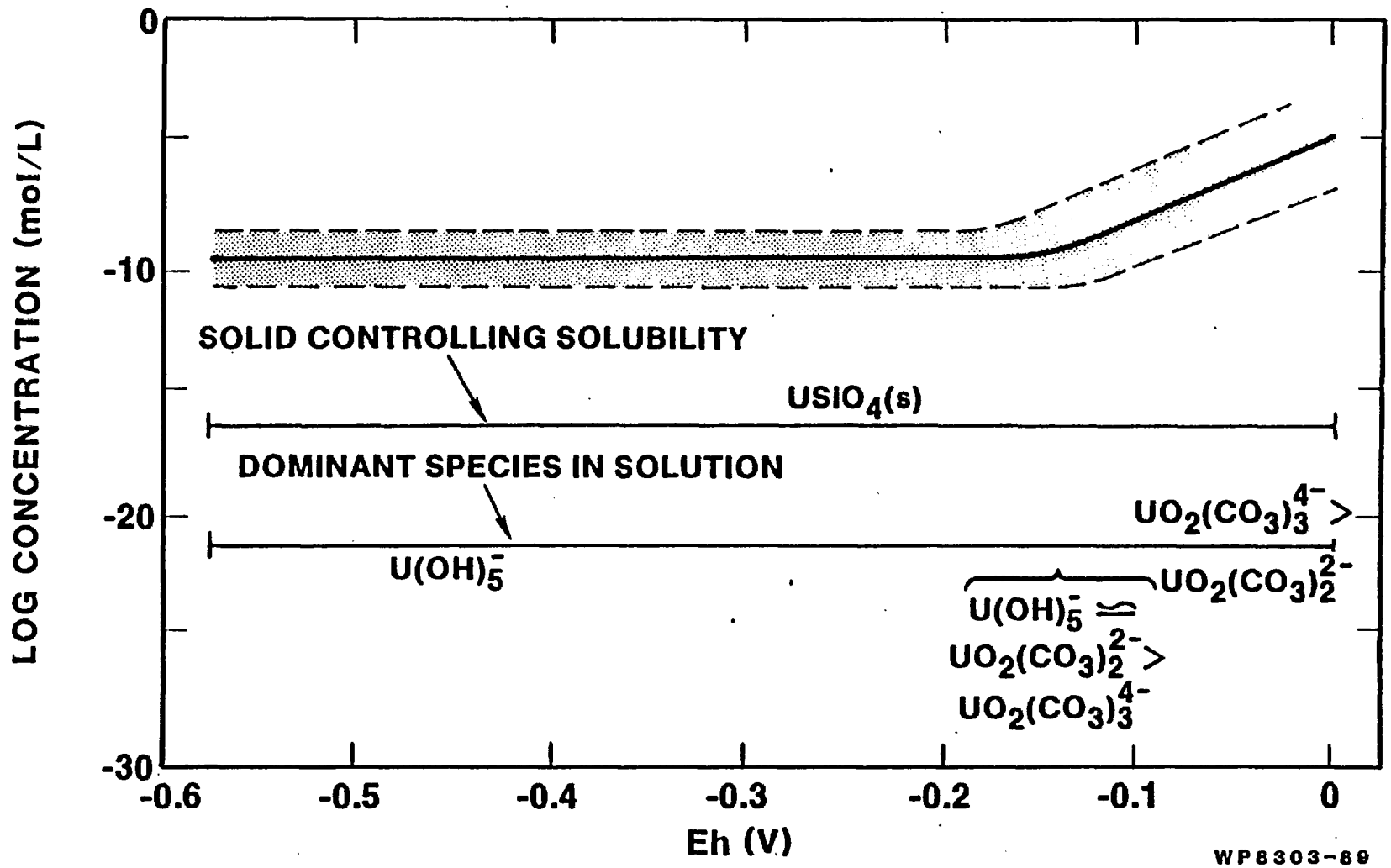


PREDICTED vs OBSERVED SOLUBILITY OF PLUTONIUM

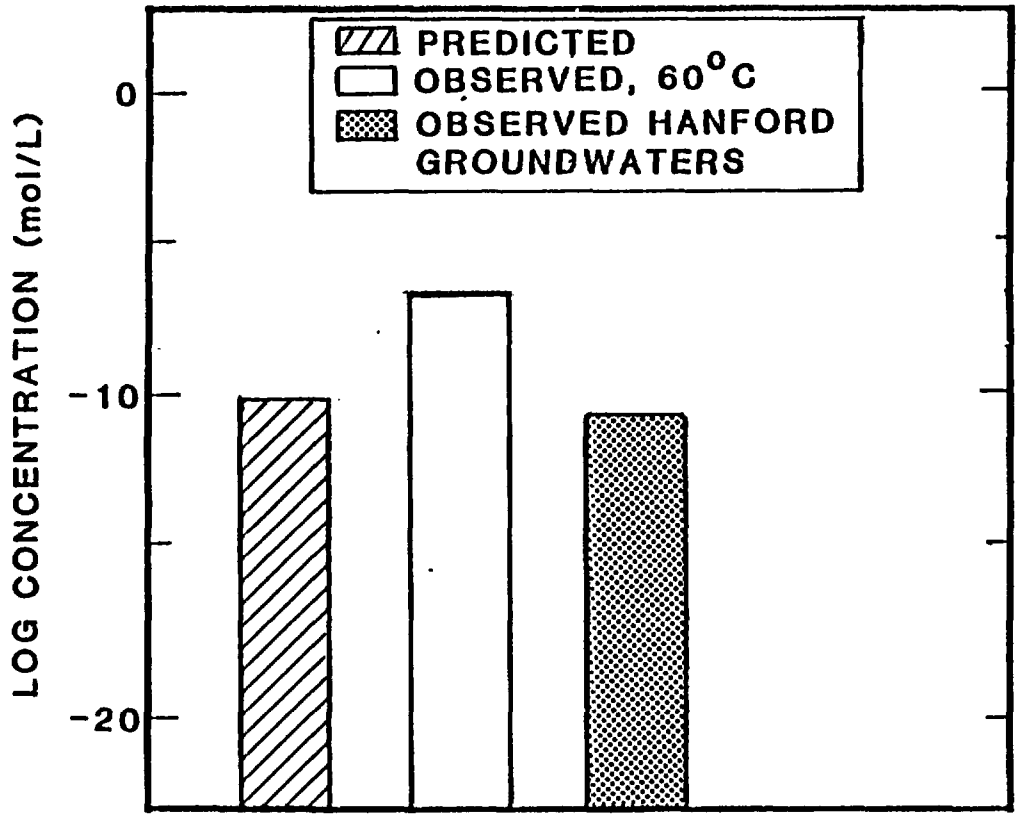


WP8308-171

SOLUBILITY OF URANIUM AS A FUNCTION OF Eh AT 25° C



PREDICTED vs OBSERVED SOLUBILITY OF URANIUM

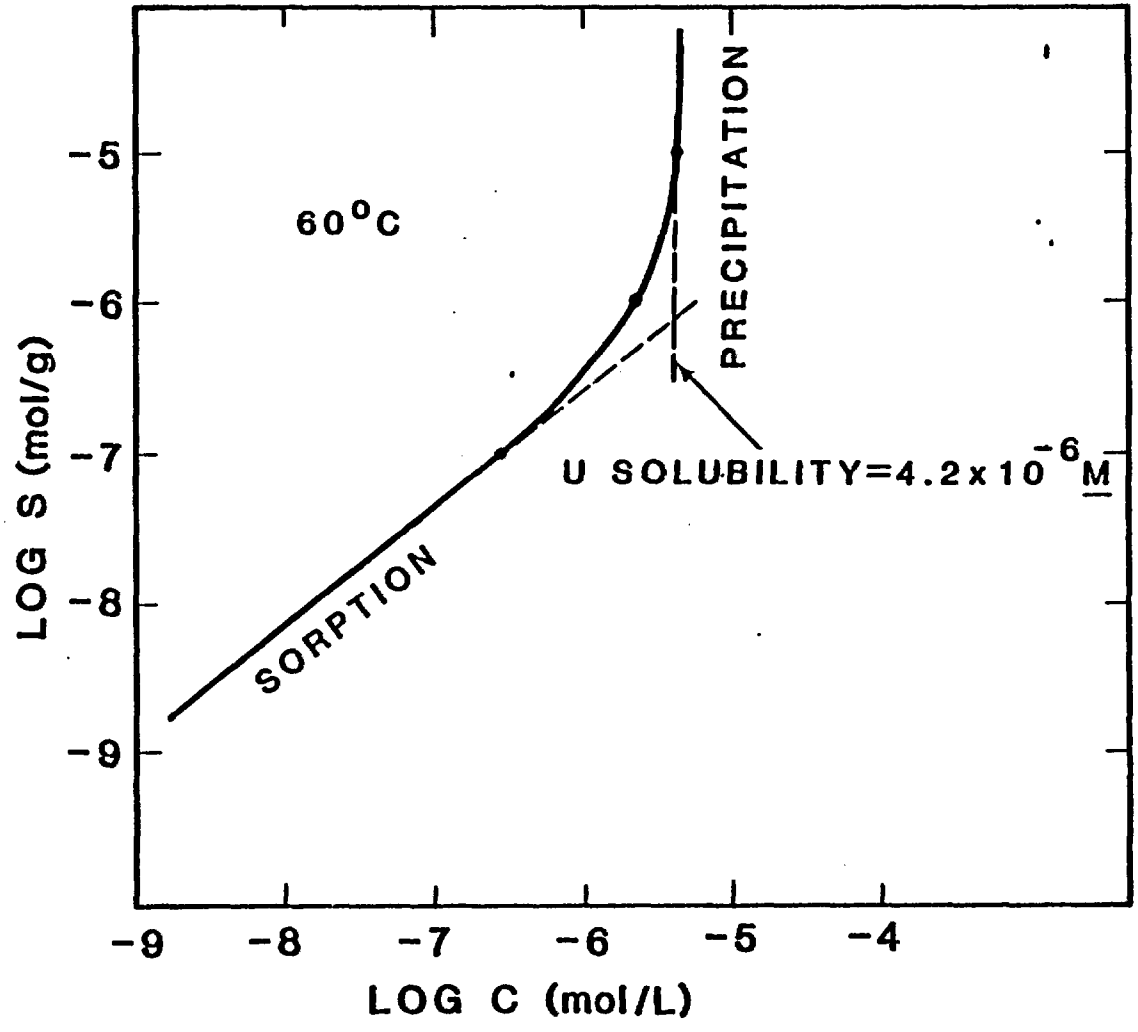


WP8308-172

URANIUM SORPTION ISOTHERM SHOWING PRECIPITATION

URANIUM SORPTION ON UMTANUM BASALT FROM SYNTHETIC GRANDE RONDE GROUNDWATER

(REDUCING CONDITIONS)



WP8303-66

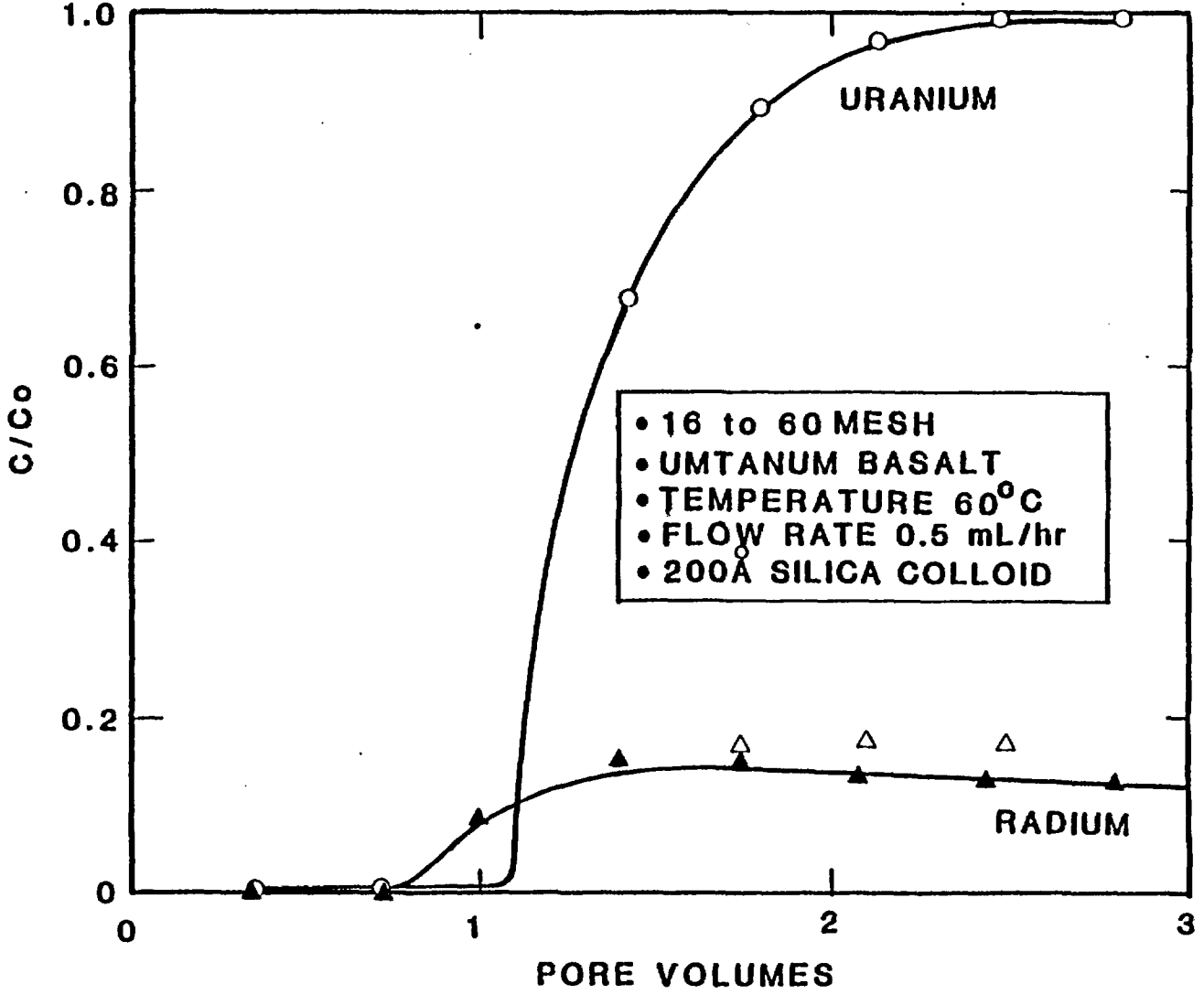
REVERSIBILITY OF RADIONUCLIDE SORPTION ON MABTON INTERBED AT 60°C

ISOTOPE	REDOX	% SORBED		REVERSIBILITY
		AFTER 1 EQUILIBRIUM	AFTER 10 EQUILIBRIUM	
Se	OXIDIZING	7	<1	REVERSIBLE
Se	REDUCING	53	46	SLIGHTLY REVERSIBLE
Tc	OXIDIZING	0	0	DOES NOT SORB
Tc	REDUCING	61	55	IRREVERSIBLE
Np	OXIDIZING	68	5	NEARLY REVERSIBLE
Np	REDUCING	98	97	IRREVERSIBLE
U	OXIDIZING	91	78	SLIGHTLY REVERSIBLE
U	REDUCING	99	98	IRREVERSIBLE
Ra	REDUCING	98	88	SLIGHTLY REVERSIBLE

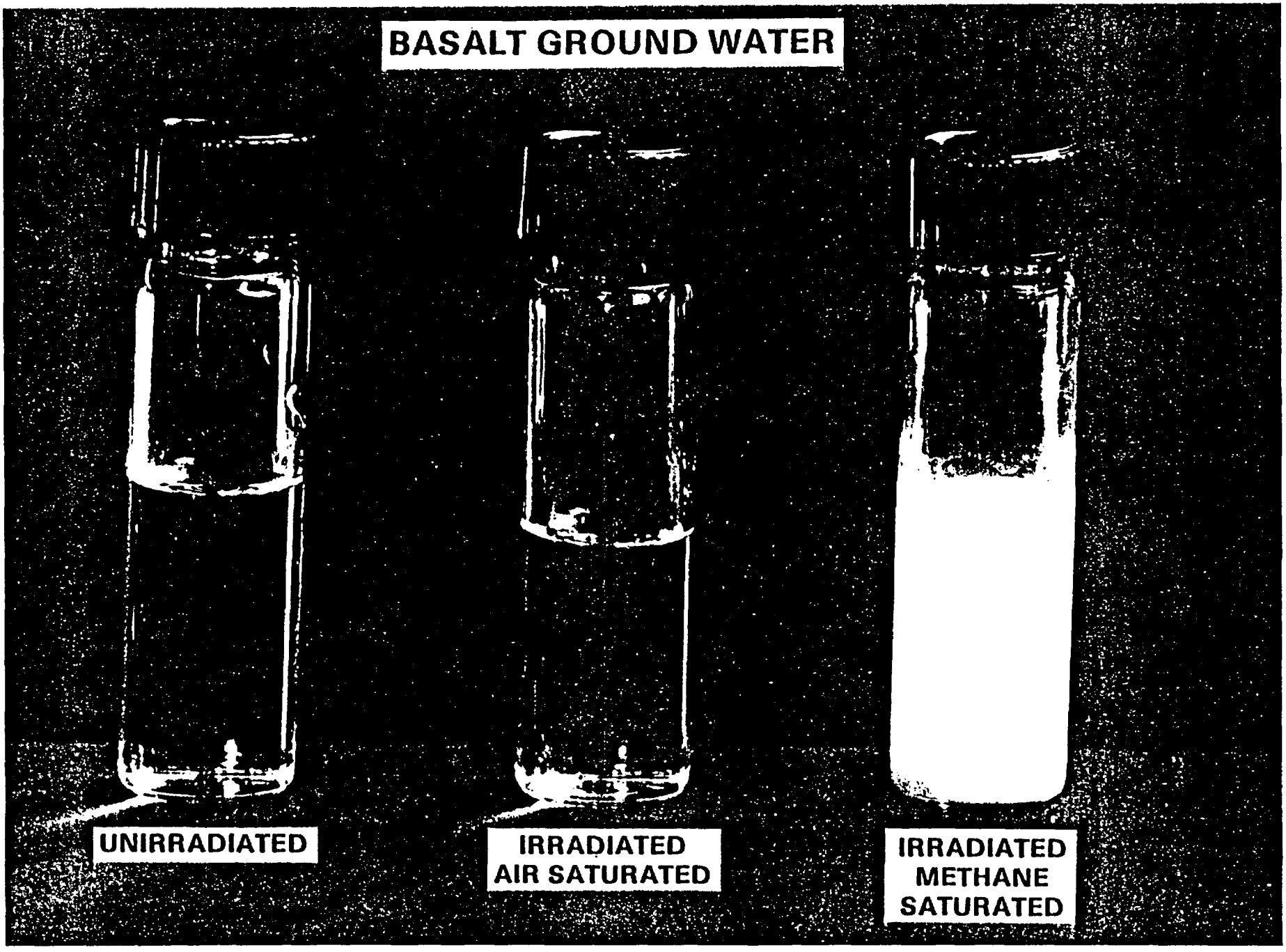
WP8302-35

PSEUDOCOLLOID SORPTION BREAKTHROUGH CURVE

(OXIDIZING CONDITIONS)



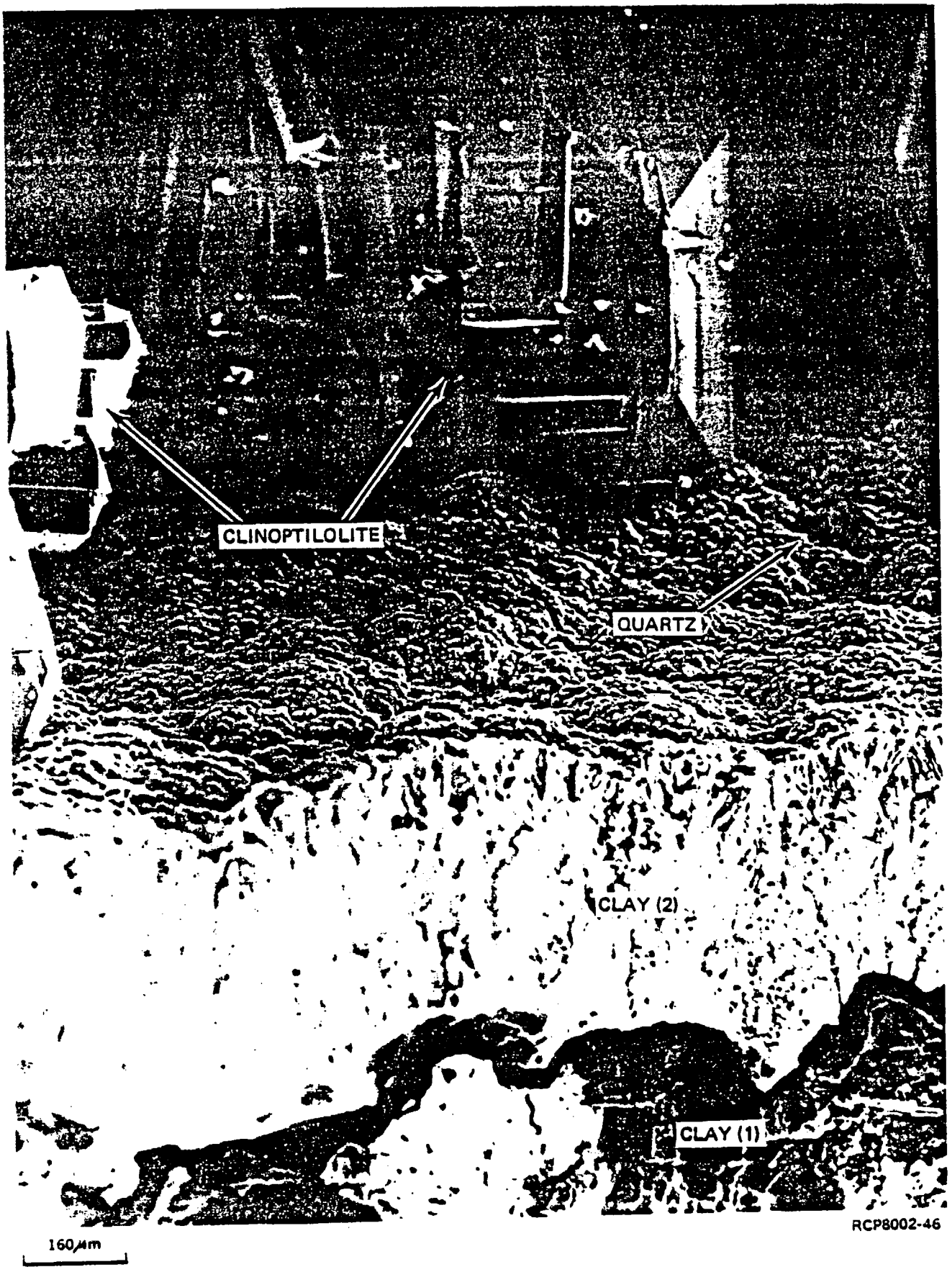
WP8308-118A


BASALT GROUND WATER
UNIRRADIATED
IRRADIATED
AIR SATURATED
IRRADIATED
METHANE
SATURATED

TEST CONDITIONS AND RESULTS FOR RADIOLYSIS OF BASALT GROUNDWATER

	TEST 1		TEST 2	
IRRADIATION TEMPERATURE	75°C		65°C	
DOSE RATE	5.7×10^6 rad/hr		1.5×10^6 rad/hr	
TOTAL DOSE	3.5×10^9 rad		4.7×10^8 rad	
	GAS COMPOSITION AND PRESSURE			
	INITIAL	FINAL	INITIAL	FINAL
HYDROGEN	AIR	66.0%	--	29.8%
METHANE		--	93.2%	59.6%
NITROGEN		29.2%	4.0%	4.2%
OXYGEN		0.5%	--	--
ARGON			2.8%	2.3%
CARBON DIOXIDE		4.5%	--	--
ETHANE		--	--	1%
PROPANE		--	--	0.2%
2, 2 DIMETHYLPROPANE		--	--	3%
2, 2 DIMETHYLBUTANE		--	--	TRACE
PRESSURE (atm)	1.2*	2.6*	42.0*	42.0*

ALL PRESSURES ARE GIVEN AT THE IRRADIATION TEMPERATURE


CLINOPTILOLITE
QUARTZ
CLAY (2)
CLAY (1)
RCP8002-46
160 µm

PERFORMANCE ASSESSMENT

R. G. BACA

PRESENTATION OUTLINE

- INTRODUCTION
- SCENARIO ANALYSIS STUDY
- PLANNED STUDIES

INTRODUCTION

PERFORMANCE ASSESSMENT

long time and space scales

DEFINITION

PERFORMANCE ASSESSMENT IS A SYSTEMATIC EVALUATION PROCESS BY WHICH WE ESTIMATE HOW WELL THE REPOSITORY SYSTEM AND ITS SUBSYSTEMS ISOLATE THE NUCLEAR WASTE

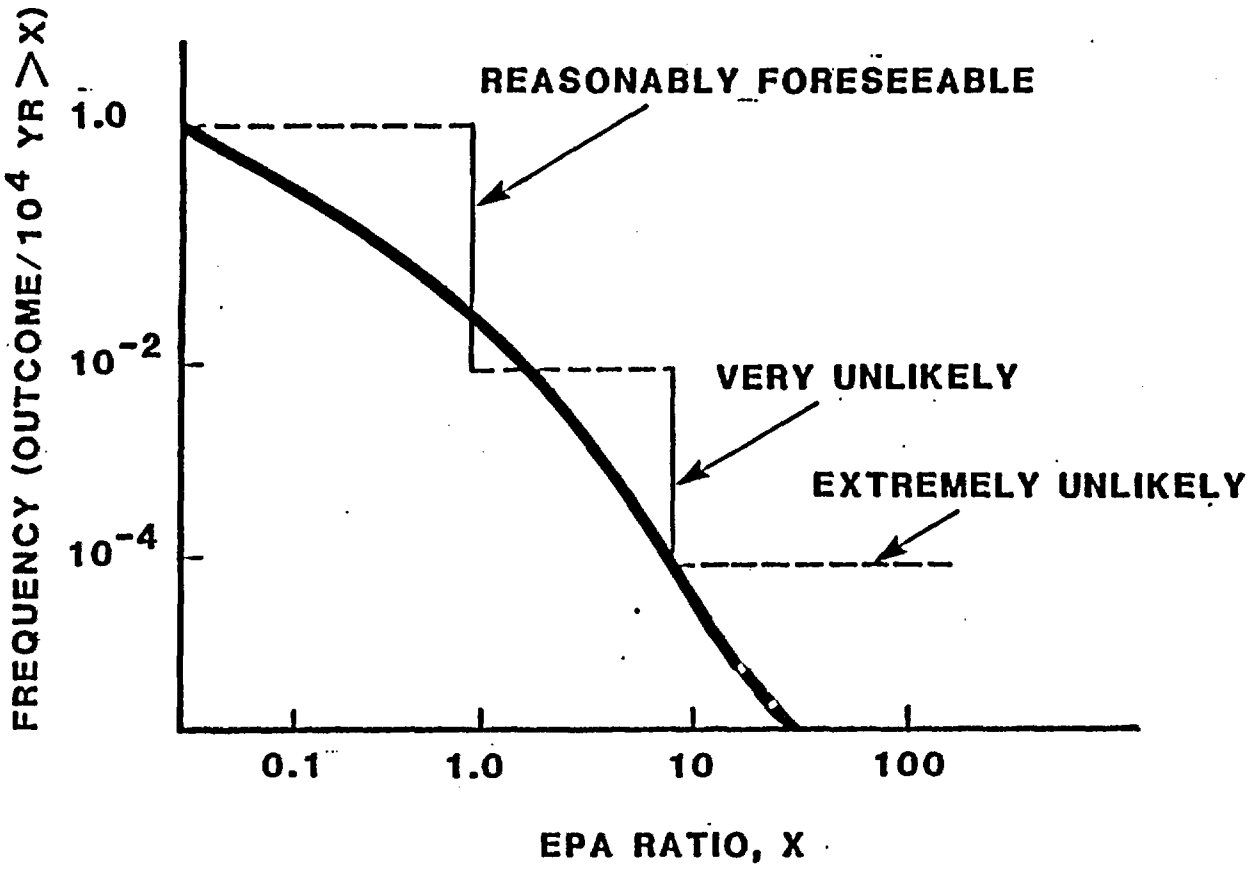
ROLE

- GUIDE DATA COLLECTION EFFORTS
- SUPPORT DESIGN OF THE REPOSITORY SYSTEM
- PROVIDE BASIS FOR EVALUATING SYSTEM COMPLIANCE WITH APPLICABLE STANDARDS

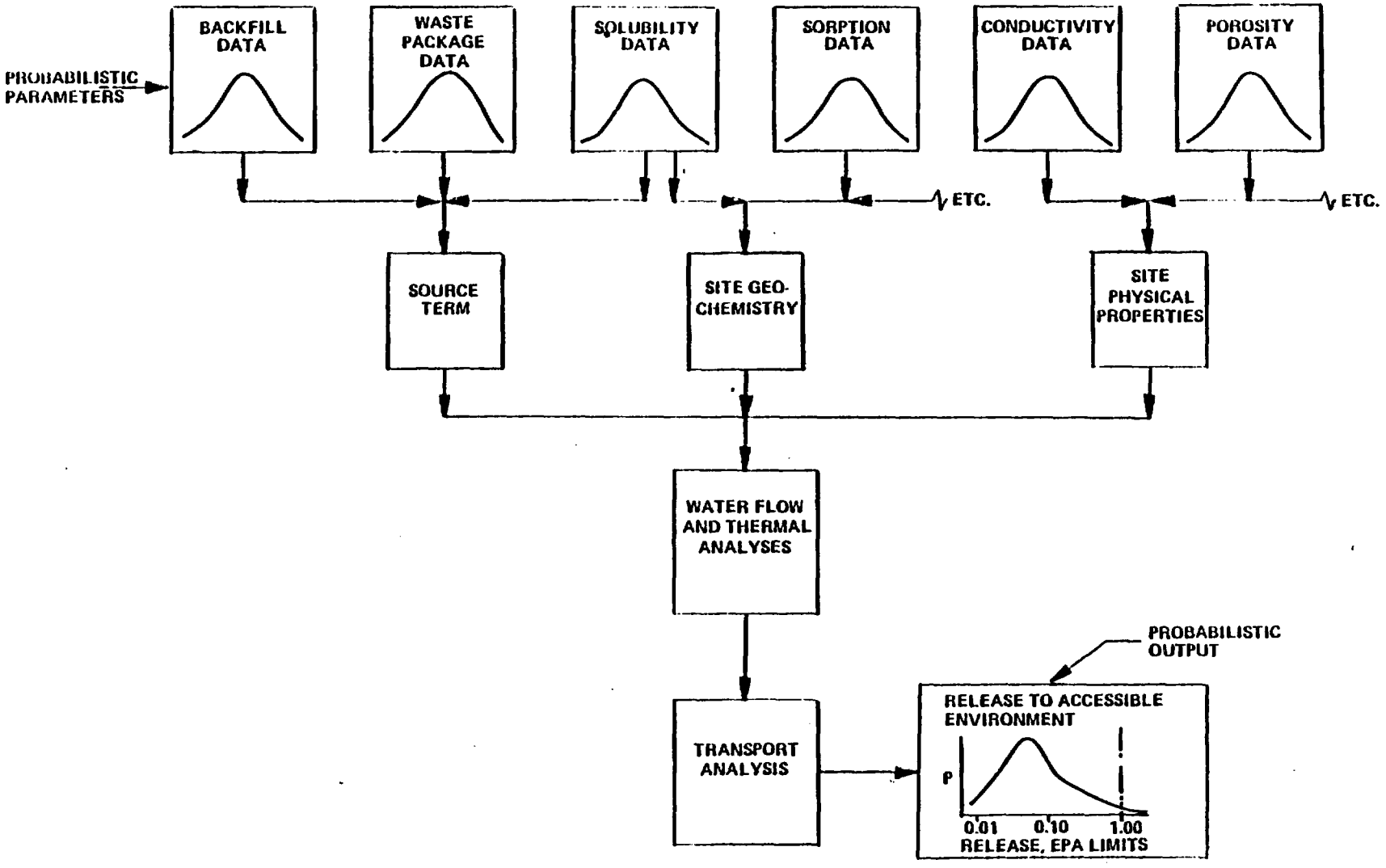
REQUIREMENTS OF DRAFT U.S. ENVIRONMENTAL PROTECTION AGENCY STANDARD (40 CFR 191)

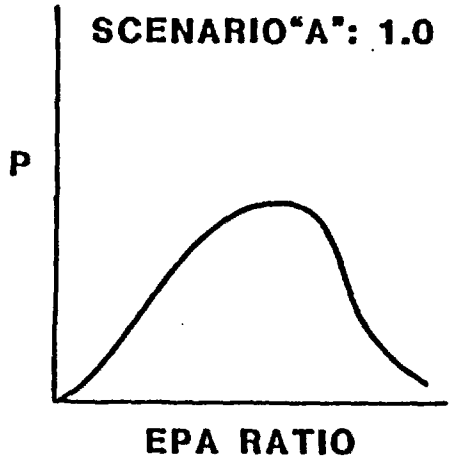
- RISK ASSESSMENT
- SCENARIO ANALYSIS
- TABLE 2 RELEASE LIMITS

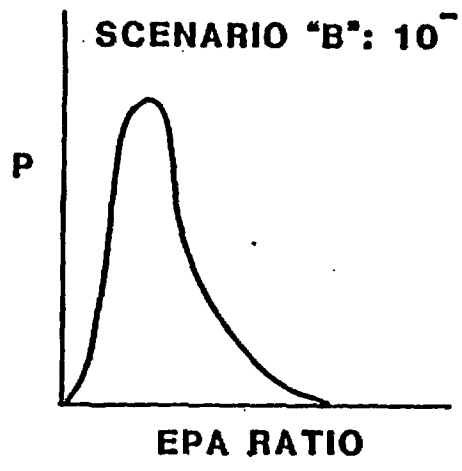
U.S. EPA STANDARD AS A "RISK CURVE"

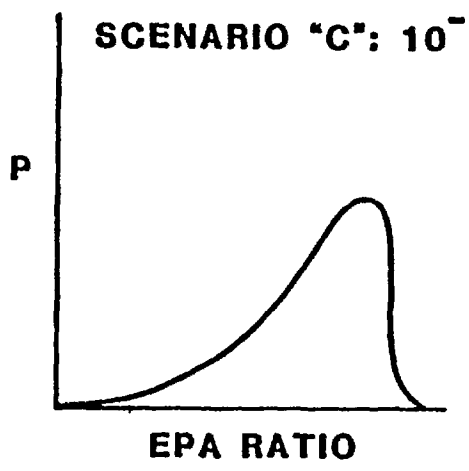


PROBABILISTIC ANALYSIS

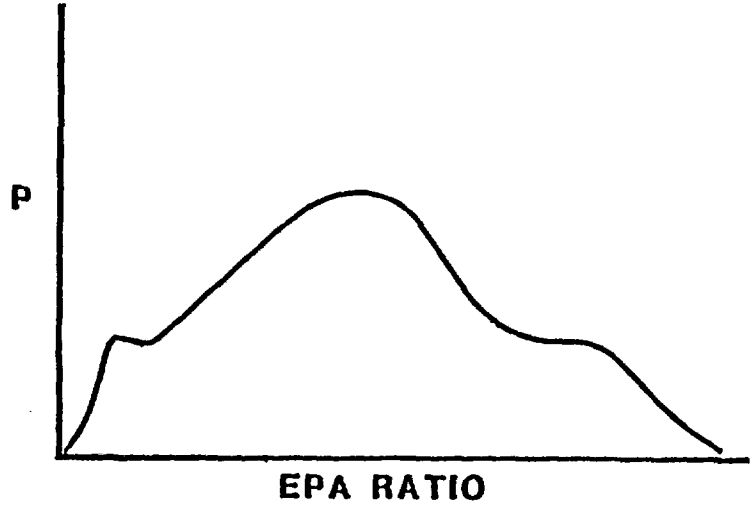




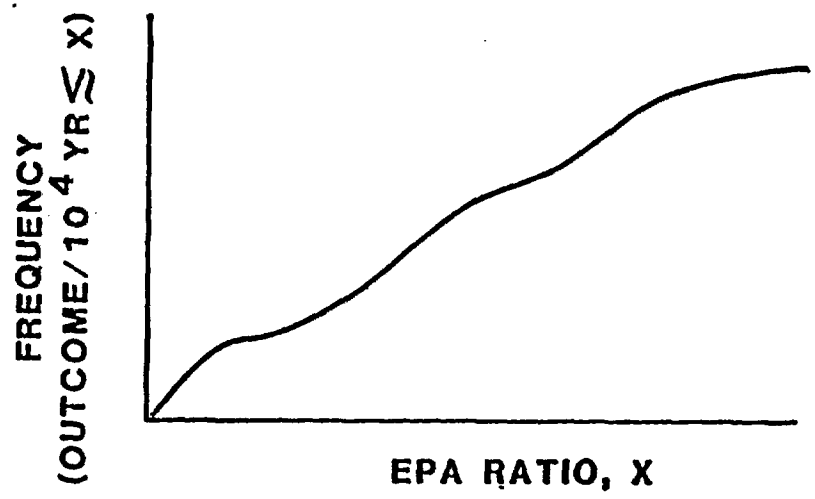




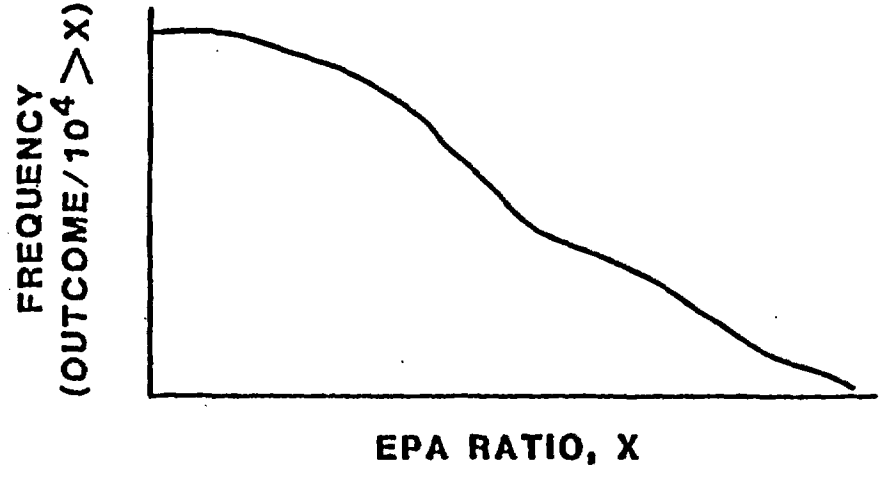
PROBABILITY DENSITY FUNCTION FOR ALL SCENARIOS



INTEGRATING THE PREVIOUS CURVE GIVES:



NEXT, CALCULATE THE COMPLEMENTARY CUMULATIVE DISTRIBUTION FUNCTION



SEQUENTIAL STEPS OF SCENARIO ANALYSIS

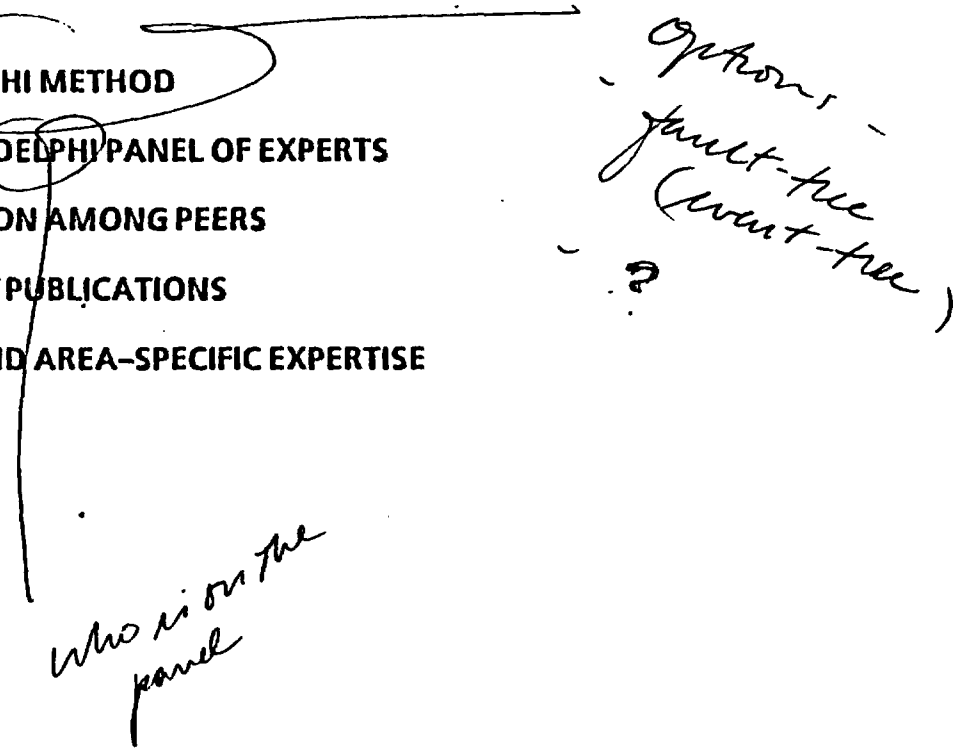
1. DEVELOP LIST OF CREDIBLE SITE-SPECIFIC EVENTS (SCENARIOS)
2. APPLY METHODOLOGY FOR SYSTEMATIC SELECTION OF SCENARIOS
3. ASSESS THE OCCURRENCE PROBABILITY AND LIKELY ADVERSITY OF CONSEQUENCE
4. SELECT SCENARIOS TO BE CHARACTERIZED AND EVALUATED
5. DETERMINE SPECIFIC PARAMETERS REQUIRED FOR CHARACTERIZATION OF SCENARIOS
6. COLLECT AND ANALYZE ADDITIONAL PARAMETRIC DATA
7. DEVELOP DETAILED DESCRIPTION OF SCENARIOS USING SITE-SPECIFIC PARAMETRIC DATA
8. PERFORM CONSEQUENCE ANALYSES (i.e., ANALYSIS OF RADIONUCLIDE TRANSPORT TO THE ACCESSIBLE ENVIRONMENT)
9. QUANTIFY REPOSITORY PERFORMANCE UNDER SCENARIO CONDITIONS AND COMPARE TO REGULATORY STANDARDS

APPROACH

TECHNIQUE: DELPHI METHOD

ANALYSIS TOOL: DELPHI PANEL OF EXPERTS

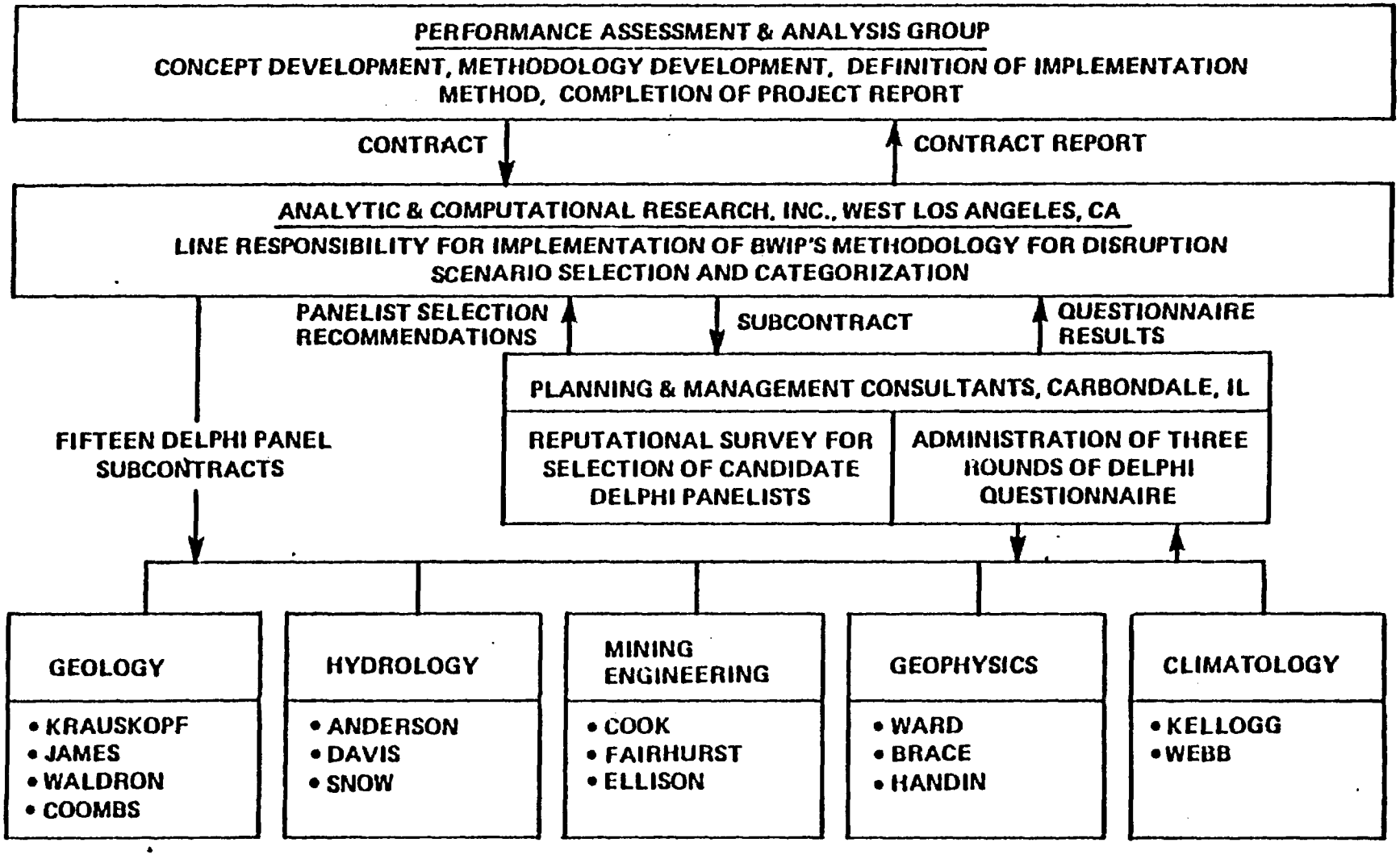
- REPUTATION AMONG PEERS
- RELEVANT PUBLICATIONS
- ISSUE– AND AREA–SPECIFIC EXPERTISE



RATIONALE FOR DELPHI METHODOLOGY SELECTION

- CLEARLY COMPATIBLE WITH DEGREE OF DATA RELIABILITY AND GENERAL UNDERSTANDING OF GEOLOGIC PROCESSES AND THEIR PREDICTABILITY
- PERMITS OBTAINING AN UNBIASED CONSENSUS OF EXPERT OPINION BY ANONYMOUS BUT AUDITABLE MEANS
- DIRECT APPROACH TO DEVELOPING REQUIRED GEOLOGIC AND HYDROLOGIC SUBMODEL CHARACTERIZATIONS FOR USE IN QUANTITATIVE MODELING OF POTENTIAL RELEASES
- CURRENT NRC AND EPA GUIDELINES FORM A FRAMEWORK FOR APPROACHING DISRUPTION SCENARIO ANALYSIS SUITABLE FOR A DELPHI METHODOLOGY
- WIDESPREAD ACCEPTANCE BY THE PUBLIC AND BY SCIENTIFIC COMMUNITIES FOR GUIDANCE ON QUESTIONS IN THE ARENA OF PUBLIC POLICY
- CAN BE STRUCTURED TO MINIMIZE WEAKNESSES ARISING FROM DISAGREEMENTS

ADMINISTRATIVE ORGANIZATION AND RESPONSIBILITIES



SCOPE OF ANALYSIS

- FORTY–FIVE POTENTIAL DISRUPTIONS
- FIVE PROBABILITY OCCURRENCE CATEGORIES
- FOUR FAMILIES OF DISRUPTIONS

FAMILIES OF DISRUPTIONS

- SITE CHARACTERIZATION
- NATURAL SYSTEMS DYNAMICS
- CONSTRUCTION AND OPERATION
- HUMAN ACTIVITIES

OCCURRENCE PROBABILITY CATEGORIES

- REASONABLY FORESEEABLE ($P > 10^{-2}$)
  - ANTICIPATED
  - UNANTICIPATED
- VERY UNLIKELY ($10^{-4} \leq P \leq 10^{-2}$)
  - ANTICIPATED
  - UNANTICIPATED
- EXTREMELY UNLIKELY ($P < 10^{-4}$)

TASKS TO BE COMPLETED

TASK 1. CLASSIFY THE DISRUPTIONS BY THE PROBABILITY OF OCCURRENCE

TASK 2. SELECT DISRUPTION OF MOST CONCERN IN EACH DISRUPTION FAMILY IN EACH PROBABILITY CATEGORY

TASK 3. SELECT DISRUPTION OF MOST CONCERN FROM ALL FAMILIES IN EACH PROBABILITY CATEGORY

RESULTS – TASK 1

- THERE WERE 45 DISRUPTIONS IN ALL
- BETTER THAN 75% AGREEMENT ON CLASSIFYING 26 OF THESE
- CONSENSUS OF CLASSIFYING 9 DISRUPTIONS

complete

RESULTS – TASK 2

REASONABLY FORESEEABLE

- K–ESTIMATION UNCERTAINTY GREATER THAN ONE ORDER OF MAGNITUDE (12:2:1)
- SEISMICITY 6.7 WITH FAULTING (7:6:2)
- ESTIMATION UNCERTAINTY GREATER THAN 50% IN HOST ROCK FRACTURING (8:3:4)
- NUCLEAR FUEL RECOVERY BY MINING (10:5:0)

VERY UNLIKELY

- UNDETECTED FLOW BRECCIA GREATER THAN 1/2 MILE (9:4:2)
- CHANGE IN TRANSPORT PROPERTIES CAUSING DECREASE IN GROUNDWATER TRAVELTIME GREATER THAN 50% (10:3:2)

EXTREMELY UNLIKELY

- CRITICALITY (6:0:9)

RESULTS – TASK 3

REASONABLY FORESEEABLE

- **K–ESTIMATION UNCERTAINTY GREATER THAN ONE ORDER OF MAGNITUDE (10:4:1)**

VERY UNLIKELY

- **UNDETECTED FLOW BRECCIA GREATER THAN 1/2 MILE (7:6:2)**

VERY UNLIKELY – UNANTICIPATED

- **CHANGE IN TRANSPORT PROPERTIES DECREASING THE GROUNDWATER TRAVELTIME BY 50% (9:3:3)**

PLANNED STUDIES

- SCENARIO CHARACTERIZATION
- SUBSYSTEM PERFORMANCE ALLOCATION
- GROUNDWATER FLOW MODELING
- CODE TESTING AND DOCUMENTATION