BASALT OPERATING PROCEDURE

RESPONSIBLE ORGANIZATION: Site AUTHOR: R. K. Ledgerwood

Approved By	Subject	Classification
	DRILLING	SCIENTIFIC TECHNOLOGIES

1.0 PURPOSE

The overall purpose of drilling and testing boreholes in Columbia River basalts and overlying sediments is to deliver subsurface geologic, hydrologic, and engineering data in support of the Basalt Waste Isolation Project (BWIP). The drilling and testing of small diameter boreholes from the surface is a necessary and economical method for the gathering of this type of data.

This Basalt Operating Procedure (BOP) defines responsibilities, methods, and procedures for all borehole drilling operations conducted from the surface by BWIP personnel.

2.0 APPLICABILITY

This BOP applies to all drilling operations conducted by the Drilling and Testing Group of the Site Department, BWIP, under the provisions of SD-BWI-TP-011, "Drilling and Testing Plan." Contents of this BOP are limited to drilling activities only; testing procedures are covered by separate specific BOPs (see BOP C-2.8).

3.0 DEFINITIONS

3.1 DRILLING

Drilling is defined as the process of cutting a circular hole with a drill or other cutting tool.

Other terms are defined where used in the body.

NOTE: This procedure has been completely revised.

BASALT OPERATING PROCEDURE

4.0. RESPONSIBILITIES

4.1 MANAGER, DRILLING AND TESTING GROUP

The Manager, Drilling and Testing Group, is directly responsible to the Manager, Site Department, for planning, assessment of test priorities, schedules and budgeting, and technical direction of the BWIP drilling and testing program. The Manager also:

(1) Approves or originates borehole Test Specifications and requests for changes or additions to the Test Plan or Test Specifications as applicable.

(2) Procures and administers drilling related subcontracts in support of Borehole Team Leaders.

(3) Provides drill site preparation and services support.

(4) Ensures proper maintenance of Government-owned drilling equipment and provides inventory control of drilling equipment and material (see BOP C-2.11, TBI).

(5) Maintains a staff of qualified drilling and support personnel and assigns personnel to Borehole Teams as required by the Test Plan.

4.2 BOREHOLE TEAM LEADER

Borehole Team Leaders are assigned overall field responsibility for the drilling and testing of each major borehole (or group of related boreholes). The Team Leader reports to the Manager, Drilling and Testing Group, for technical direction. Specific responsibilities are:

(1) Complete borehole drilling/testing on schedule within budget and according to an approved test plan.

(2) Develop detailed borehole specification(s) and schedule(s).

(3) Inform team members of technical requirements and approved changes.

(4) Ensure that activities are properly documented.

(5) Develop and approve field change records to borehole specifications.

(6) Ensure that proper action is taken to correct borehole problems.

(7) Ensure that activities are in accordance with applicable sections of the BOPs.

(8) Direct Borehole Team to complete planned drilling and testing program. Make approvals of team actions as required.

(9) Delegate authority to a team member when not in the field.

(10) Process and approve field data records and other deliverables.

(11) Verify that downhole logging, surveying and other downhole services have been properly run, witnessed and documented.

4.3 TASK USER

Each end function performing a BWIP task that needs field data provides input to preparation and revision of SD-BWI-TP-011, "Drilling and Testing Plan." Tasks users have the following responsibilities:

(1) Assist in preparation of the Borehole Test Specifications by reviewing and providing information to include:

a. Final data needed

- Investigative field boundaries
- Acceptable range of final data
- Level of predictive accuracy required
- Level of predictive confidence achieved
- Need for additional field data
- Source of additional field data.

b. Data analyses planned

c. Field data to be delivered

d. Borehole site selection support

e. Special testing requirements

f. Schedule milestones, interfaces, and constraints.

(2) Interface with borehole team leaders, monitor preparations and field activities, and provide expert assistance when required.

(3) Approve borehole test procedures/specifications (and proposed changes) and EOs releasing field data records.

(4) Verify the traceability of field data through analysis into final data.

(5) Coordinate the preparation of interim and final data objective reports presenting the final data needed.

4.4 DRILLING ENGINEER OR DRILLING SPECIALIST

The Drilling Engineer or Drilling Specialist is assigned to Borehole Teams as required. Specific responsibilities within the provisions of the Test Plan and according to test specifications as applicable are:

(1) Set surface casing and provide cementation in accordance with state and industrial standards. Assure that work is completed as planned. (Surface casing = casing set from ground surface to at least 20 feet depth and cemented in).

(2) Provide drilling progress reports and additional reports of special operations or problems encountered to Project Team Leader.

(3) Provide coverage and supervision of drilling activities as required by test specifications and subcontract management.

(4) Direct drilling activities to overcome hole problems if encountered.

(5) Supervise coring operations to meet test specifications, including the makeup and running of the core barrel and coring technique, such as weight, rotational speed, etc.

(6) Assure the timely delivery of the contractor-supplied, Government-owned equipment.

(7) Supervise fishing operations (fishing = operations for the purpose of retrieving from the well bore sections of pipe, casing or other items which may have become stuck or inadvertently dropped in the hole).

(8) Provide pertinent drilling data such as uses of casing, mud, bits, and other material to be recorded in the SHIFT REPORT OF OPERATIONS. (BOP C-2.5)

4.5 WELL SITE GEOLOGIST

The Well Site Geologist is assigned as required to Borehole Teams. Responsibilities include:

(1) Provide continuous coverage at the well site and maintain all applicable logs and records as required by the Borehole Test Specifications and BOPs.

(2) Assure that core, chips, and special samples are logged, protected, and documented according to applicable BOPs (C-2.3) prior to transfer to permanent storage and that no core, samples or chips are removed without proper written authorization.

4.6 HYDROLOGIST

Hydrologists are assigned as required to Borehole Teams. Responsibilities are:

(1) Perform hydrologic tests and water sampling according to test specifications and BOPs C-2.4, and C-2.8.

(2) Analyze test results and provide field data results to the Project Team Leader as required by test specifications.

(3) Recommend additional tests or sampling as needs are identified.

4.7 HYDROLOGIC TECHNICIAN

Hydrologic Technicians are assigned to support Borehole Teams. Responsibilities are:

- Provide support to field testing as directed by Borehole Team Leaders or Hydrologists.

4.8 INVENTORY TECHNICIAN

The Inventory Technician's responsibilities are:

(1) Provide inventory control of drilling and testing equipment and materials for the Drilling and Testing Group.

(2) Specific inventory procedures are contained in BOP C-2.7, "Storage, Inventory Control, and Usage of Drilling and Testing Equipment and Material."

5.0 SAFETY

Safety requirements, as a minimum, are to be performed in accordance with BOP C-2.3, Section 4.0. Drilling operations, by their nature, contain many hazards to safety. Specific safety cautions are given in applicable procedural steps.

6.0 PROCEDURE

Drilling activities carried out by BWIP personnel are primarily direction, supervision, and documentation of subcontracted drilling rigs, or subcontracted crews operating BWIP-assigned, Government-owned drilling rigs. This BOP addresses those activities. Drilling operations carried out by subcontractor crews are by drilling industry practices and procedures. Operational guideline manuals for drilling industry-recommended practices and procedures are the "Drilling Manual," "Accident Prevention Manual," and the "Diamond Drill Handbook" (See Section 8.0, Applicable Documents). Copies of these manuals are furnished as required to Borehole Team Leaders and Drilling Engineers or Specialists. Applicable sections of these manuals are referenced in the following procedural steps.

BASALT OPERATING PROCEDURE

6.1 PREDRILLING PREPARATION

Prior to rigging up and drilling, select the site is and prepare in accordance with the Test Plan and BOP C-2.1, "Selection and Preparation of Borehole Drilling Sites." Do not commence drilling without completion and approval of an approved environmental checklist and preparation of test specifications.

6.1.1 Rigging Up

"Rigging up" is the process of getting the rig ready for drilling before drilling can proceed. The Borehole Team Leader is responsible for assuring that all safety standards and requirements have been met after rigging up and prior to drilling. A formal safety inspection and review is to be made and documented in the SHIFT REPORT OF OPERATIONS.

6.1.2 Guy Lines

All drilling rigs with masts in excess of 30 feet are to be guyed in accordance with manufacturer's recommendations.

6.2 DRILLING

Drilling activities are detailed in applicable drill and test specifications. Required changes in drilling methods or schedules originate from or are approved by the Borehole Team Leader and documented by Change Engineering Orders (CEOs) (BOP B-21, TBI). The Drilling Engineer or Specialist directs drilling so as to achieve maximum penetration and minimum material use within the provision of the test specifications. Make immediate notification of off-standard hole conditions to the Project Team Leader or the Drilling and Testing Group manager.

NOTE: Safety is the primary consideration in drilling; hole integrity is next. Plan and conduct all drilling operations to assure safe and efficient operation.

6.2.1 Drilling Documentation

Document all drilling-related activities in a SHIFT REPORT OF OPERATIONS, (BOP C-2.5).

BASALT OPERATING PROCEDURE

6.3 CASING

The Borehole Team Leader directs/approves the following actions during casing operations: (Reference; DRILLING MANUAL, Sections B-Tubular Steel Goods, E-Pipe Handling Equipment, and U-General Information).

6.3.1 Test Specification

Set casing to the depth specified using materials detailed in borehole test specifications. Any change to these specifications requires a CEO and revision of those specifications.

6.3.2 Casing Location

Provide casing and auxiliary equipment such as cementing shoes, float collars, stage collars, and centralizers on location when needed, properly protected, stored, and arranged for running.

6.3.3 Casing Tally

Inspect casing to assure conformity with specifications. Individually measure and tally every casing joint run. Enter a record of casing inspection and the casing tally in the SHIFT REPORT OF OPERATIONS (BOP C-2.5).

6.4 CEMENTING

Cementing operations may be necessary in a borehole to grout casing, repair caving or lost circulation zones, or to plug back the hole. Perform all such operations in conformance with test specifications or by CEO. Do not plug borehole back unless explicitly directed in borehole test specifications. The Borehole Team Leader directs/approves the following actions during cementing operations: (Reference: DRILLING MANUAL, Section T - Cementing).

(1) Material and Equipment - Assure that cementing crews, cement, cementing equipment, necessary tanks, water pumps, or other means of supplying mixing and displacement water are available.

(2) Test Specifications - Assure that cementing operations conform to the test specifications. Compare cement rise for each stage with planned rise for the amount of cement and determine reasons for any deviation. Suspend operations if there is danger of casing burst, collapse, flash set or other problem.

(3) Documentation - Record all pertinent data such as starting and ending time, pump pressures and rates, fluid levels, tagged tops of cement, logged tops of cement, and amounts of cement used. Record all information in the SHIFT REPORT OF OPERATIONS.

6.5 HOLE COMPLETION

Drilling may stop and the drilling rig directed to demobilize under the following conditions:

(1) Hole Abandonment, Not Completed to Specifications - Must originate as a recommended CEO from the Borehole Team Leader, have the concurrence of the Manager, Drilling and Testing Group, and approval of the Director, BWIP or his authorized designee.

(2) Hole Completed to Test Specifications - Recommended by the Borehole Team Leader and approved by the Manager, Drilling and Testing Group.

(3) Convenience of Government - Must be initiated by the Manager, Drilling and Testing Group, and approved by the Project Director or his authorized designee.

6.6 SITE RESTORATION

Accomplish site restoration in accordance with BOP C-2.1, and any applicable provisions of individual borehole specifications and excavation permits.

7.0 QUALITY ASSURANCE

Perform Quality Assurance requirements in accordance with BOP C-1.2, Section 6.0.

BASALT OPERATING PROCEDURE

7.1 DOCUMENTATION

Primary documentation of drilling needs and operational procedures are contained in SD-BWI-TP-011, "Drilling and Testing Plan," and in applicable test specifications for individual test projects. These documents are released through the BWIP Engineering Release system.

Document drilling operations by completion of form BC-6200-072 (N-3-79), SHIFT REPORT OF OPERATIONS, in accordance with BOP C-2.5.

8.0 APPLICABLE DOCUMENTS

RHO-BWI-MA-4, Basalt Operating Procedures (BOP) Manual
BOP B-21, "Change Engineering Orders," (TBI)

BOP C-1.2, "Field Work"
BOP C-2.1, "Selection and Preparation of Borehole Drilling Sites"
BOP C-2.3, "Basalt Core Logging, Protection, and Treatment"
BOP C-2.4, "Groundwater Sampling and Analysis"
BOP C-2.5, "Preparation of Shift Report of Operations"
BOP C-2.7, "Storage, Inventory Control, and Usage of Drilling and Testing Equipment and Material"
BOP C-2.8, "General Hydrologic Field Testing Procedures"
BOP C-2.11, "Drilling Equipment Maintenance" (TBI)

BOP D-6, "Test Program Documentation"

SD-BWI-TP-011, "Drilling and Testing Plan"

Drilling Manual, International Association of Drilling Contractors, Houston, Texas.

Accident Prevention Manual, International Association of Drilling Contractors, Houston, Texas.

Diamond Drill Handbook, J. K. Smit Co., September 1980.

State of Washington, Department of Ecology, "Minimum Standards for Construction and Maintenance of Water Wells," DOE 73-049, Olympia, Washington, May 30, 1973.

BASALT OPERATING PROCEDURE

RESPONSIBLE ORGANIZATION: Site AUTHORS: R. L. Jackson, L. S. Leonhart

Approved By	Subject	Classification
	GENERAL HYDROLOGIC FIELD TESTING PROCEDURES	SCIENTIFIC TECHNOLOGIES

1.0 OBJECTIVE

This procedure implements ANSI/ASME Standard NQA-1-1979 Basic Requirement 11 and Supplement 11S-1 for "Test Control," and Basic Requirement 12 and Supplement 12S-1 for "Control of Measuring and Test Equipment," in support of the Basalt Waste Isolation Project (BWIP) general hydrologic field testing procedures.

1.1 INTRODUCTION

Hydrologic tests are performed in boreholes to determine hydrologic properties and to obtain water samples from a selected geologic horizon. Results are documented and used to develop conceptual and numerical models of the groundwater flow system. This BOP describes hydrologic testing procedures applied to determine the hydraulic properties of a selected test horizon (Appendices A-H). Figure 1 is a flow chart summarizing the hydrologic testing procedure in a borehole. General procedures for field collection of groundwater samples are described in BOP C-2.4.

1.2 APPLICABILITY

These procedures apply to determining hydrologic properties and hydrochemistry by Basalt Waste Isolation Project (BWIP) personnel and to subcontractors and consultants to the extent specified in applicable procurement/contract documents.

2.0 RESPONSIBILITIES

2.1 HYDROLOGIC TESTING PERSONNEL

Responsibilities for hydrologic testing personnel are described in BOP C-2.2, Section 5.2, "Drilling."

2.2 FIELD NOTES

The field hydrologist is responsible for recording testing information in the format found in Appendix A and controlled Laboratory Notebooks or data forms information specified in BOP C-1.2, Section 6.2, "Field Notes." In addition, the hydrologist is responsible to:

(1) Record daily field hydrological testing activities

(2) Record hydrologic data on appropriate data forms as described in the appendices to this BOP

(3) Record the name of the person who obtained the measurement.

3.0 SAFETY

Observe safety requirements in accordance with BOP C-1.2, Section 4.0.

4.0 DEFINITIONS

Definitions are given in text where used.

5.0 REQUIREMENTS

The following appendices contain the requirements for hydrologic testing:

Appendix A. Hydrologic Formation Development Procedures

Appendix B. Constant Discharge Test - Air-lift Method

Appendix C. Constant Discharge Test - Constant Rate Pumping Method

Appendix D. Constant Drawdown Test

Appendix E. Instantaneous Slug Withdrawal/Injection Test

Appendix F. Instantaneous Pulse Withdrawal/Injection Test

Appendix G. Constant Head Injection Test

Appendix H. Tracer Test

The basic hydrologic parameters obtained directly from the various types of test are summarized in Table 1.

TABLE 1. Hydrologic Parameters.

Test Type	Transmissivity	Storage Coefficient	Effective Porosity	Dispersivity
Air lift	x	Estimated	-	-
Constant rate pumping	x	Estimated	-	-
Constant drawndown	x	Estimated	-	-
Instantaneous Slug withdrawal injection	x	Estimated	-	-
Instanteous pulse withdrawal injection	x	Estimated	-	-
Constant head injection test	x	-	-	-
Tracer test	-	-	X	X

6.0 QUALITY ASSURANCE

Quality Assurance requirements are described in BOP C-1.1, Section 4.0. Standards for qualification of this procedure and appendices are listed in Section 7.0 (below). Calibration of test equipment is to be performed in accordance with BOP C-1.3 and ANSI/ASME NQA-1-1979, Basic Requirement 12 and 12S-1.

BASALT OPERATING PROCEDURE

7.0 APPLICABLE DOCUMENTS

Texts and Journals

Bredehoeft, J. D., Papadopulos, S. S., 1980, A Method for Determining the Hydraulic Properties of Tight Formations, Water Resources Research, V. 16, n. 1, pp. 233-238.

Cooper, H. H. Jr., Bredeheoft, J. D., Papadopulos, S. S., 1967, Response of a Finite-Diameter Well to an Instantaneous Charge of Water, Water Resources Research, V. 3, n. 1, pp. 263-269.

Cooper, H. H. Jr., Jacob, C. E., 1946, A Generalized Graphical Method for Evaluating Formation Constants and Summarzing Well Field History, Am. Geophys. Union Trans., V. 27, pp. 526-534.

Davis, S. N., Thompson, G. M., Bently, H. W., Stiles, G., 1980, Ground-Water Tracers - A Short Review, Ground Water, V. 18, n. 1, pp. 14-23.

Earlougher, R. C., 1977, Advances in Well Test Analysis, Society of Petroleum Engineers of AIME, 2nd Edition, Monograph Series, pp. 264.

Ferris, J. G., Knowles, D. B., Brown, R. H., Stallman, R. C., 1962, Theory of Aquifer Tests, U.S. Geological Survey Water-Supply Paper 1536-E, p. 174.

Gelhar, L. W., Collins, M. A., 1971, General Analysis of Longitudinal Dispersion in Nonuniform Flow, Water Resources Research, V. 7, n. 6, pp. 1511-1521.

Gelhar, L. W., 1982, "Analysis of Two-Well Tracer Tests with a Pulse Input," SD-BWI-TI-023, (draft).

Grove, D. B., Beetem, W. A., 1970, Porosity and Dispersion Constant Calculations for a Fractured Carbonate Aquifer Using the Two Well Tracer Method, Water Resources Research, V. 7, n. 1, pp. 128-134.

Jacob, C. E., Lohman, S. W., 1952, Non-Steady Flow to a Well of Constant Drawdown in an Extensive Aquifer, Am. Geophys. Union Trans., V. 33, pp. 559-569.

Lohman, S. W., 1972, Groundwater Hydraulics, U.S. Geological Survey Professional Paper 708, pp. 70.

Papadopulos, S. S., Bredehoeft, J. D., Cooper, H. H., Jr., 1973, Analysis of Slug Test Data, Water Resources Research, V. 9, n. 4, pp. 1087-1089.

Pickens, F. F., Jackson, R. E., Inch, K. J., Merritt, W. F., 1980, Field Measurements of Distribution Coefficients Using a Radial Injection Dual-Tracer Test, Atomic Energy of Canada, LTD, Report No. TR-133, Chalk River, Ont.

Ramey, H. J., Jr., Agarawal, R. G., Martin, I., 1975, Analysis of Slug Test or SDT Flow Period Data, J. Canadian Pet. Tech., July-Septenber, pp. 37-42.

Sauty, J. P., 1978, Interpretation of Tracer Tests by Means of Type Curves; Application to Uniform and Radial Flow in Proceedings of the Invitation Well Testing Symposium, U.S. Dept. of Energy, Washington, D.C.

Theis, C. V., 1935, The Relation Between the Lowering of the Piezometric Surface and the Rate and Duration of Discharge at a Well Using Groundwater Storage, Am. Geophys. Union Trans., V. 16, pp. 519-524.

U.S. Bureau of Reclamation, 1963, Earth Manual, 1st ed., U.S. Government Printing Office, Washington, D.C.

U.S. Geological Survey, Techniques of Water Resources Investigations

- o "Methods of Measuring Water Levels in Deep Weels," Book 8, Chapter A1, 23 p.
- o "Aquifer - Test Design, Observation, and Data Analysis," Book 3, Chapter B1, 26 p.
- o "Water Temperature - Influential Factors, Field Measurement, and Data Presentative," Book 1, Chapter D1, 65 p.
- o "Application of Borehole Geophysics to Water Resources Investigations," Book 2, Chapter E1, 116 p.

Van Der Kamp, G., 1976, Determining Aquifer Transmissivity by Means of Well Response Tests: The Underdamped Case, Water Resources Research, V. 12, n. 1, pp. 71-77.

Welhan, J. A., 1979, A Review of Isotope Methods for Mapping Deep Groundwater Flow Systems in Fracture Crystalline Media, Atomic Energy of Canada, LTD, Report no. TR-14, Pinawa, Man.

Zeigler, Timothy W., 1976, Determination of Rock Mass Permeability: U.S. Army Engineer Waterways Experiment Station, Technical Report S-76-2, Vicksburg, Miss.

BASALT OPERATING PROCEDURE

Manuals and Standards

RHO-BWI-MA-4, Basalt Operating Procedures (BOP) Manual

- BOP C-1.1, "Preparation and Issue of Basalt Operating Procedures for Hydrology and Geoscience Investigations"
- BOP C-1.2, "Field Work"
- BOP C-1.3, "Instrument Calibration"
- BOP C-1.4, "Peer Review"
- BOP C-2.2, "Drilling"
- BOP C-2.4, "Groundwater Sampling and Analysis"

ANSI/ASME Standard NQA-1-1979, Quality Assurance program Requirements for Nuclear Power Plants

- Basic Requirement II and Supplementary Requirement 11S-1, "Test Control"
- Basic Requirement 12 and Supplementary 12S--1, "Control of Measuring and Test Equipment"

BASALT OPERATING PROCEDURE

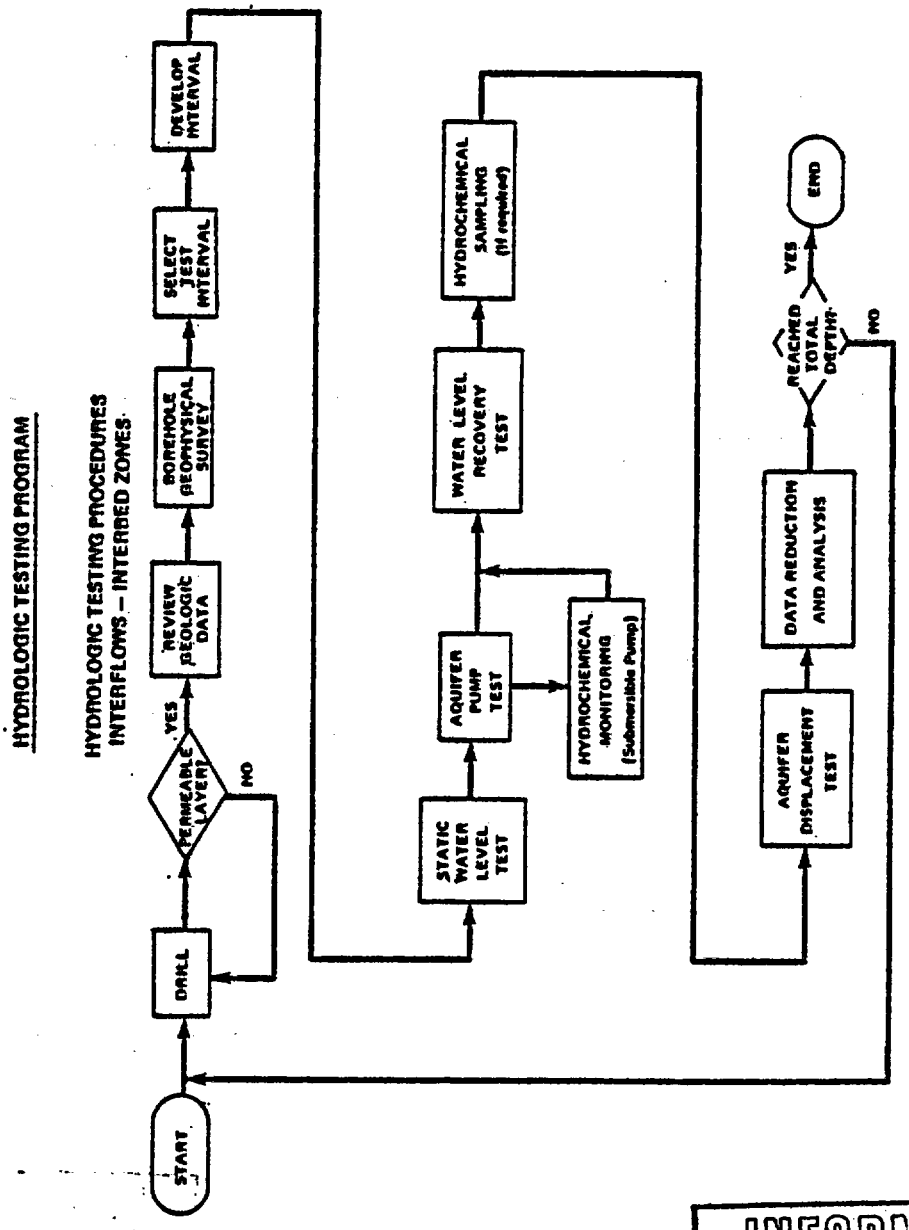

FIGURE 1. Flow Chart Showing Generalized Hydrologic Testing Procedures.

Date Issued	Supersedes Issue Dated	To Be Reviewed By	Page	No.
JUNE 1982	NOV 1980	ANNUALLY	7 of 17	C-2.8

BASALT OPERATING PROCEDURE

BWIP HYDROLOGIC TEST INFORMATION

BOREHOLE _____ HANFORD COORDINATES _____

TEST TYPE _____ TEST DATE _____

TEST INTERVAL _____ DEPTH INTERVAL _____

PACKER SETTING _____ HOLE DEPTH _____

HOLE DIAMETER _____

EQUIPMENT

FLOW METER _____ WEIR _____

THERMOMETER _____ ELECTRIC SOUNDER _____

STEEL TAPE _____ PRESSURE TRANSDUCER _____

TRANSDUCER COMPUTER _____ PRESSURE GAUGE _____

PRINTER _____ PUMP TYPE _____ PUMP SETTING _____

MEASUREMENT DATUM

CONTROL DATUM _____ ELEVATION _____

ELECTRIC SOUNDER MEASUREMENT DATUM _____

STEEL TAPE MEASUREMENT DATUM _____

PRESSURE TRANSDUCER MEASUREMENT DATUM _____

OTHER _____

WELL-HEAD SKETCH

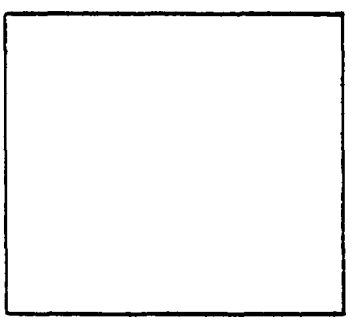

FIGURE 2. BWIP Hydrologic Test Information Sheet.

BASALT OPERATING PROCEDURE

DRAWDOWN PUMPING TEST DATA SHEET Page ___ of ___

BOREHOLE _____ TEST INTERVAL _____

TEST TYPE _____ DEPTH INTERVAL _____

DATE	TIME IN HOURS	TIME, T, SINCE PUMP STARTED—MINUTES	WATER LEVEL DATA: DEPTH TO WATER BELOW MEASURING POINT (FEET)	WATER LEVEL DATA	DISCHARGE MEASUREMENTS: FLOW CUMULATOR, GALLONS	FLOW DURING INTERVAL, GALLONS	INTERVAL FLOW RATE, Q (GPM)	FLOW WEIR IN	FLOW RATE GPM	TEMPERATURE °C	REMARKS	MEASURED BY

SITE HYDROLOGIST: _____

FIGURE 3. Constant Discharge - Drawdown Pumping Test Data Sheet.

BASALT OPERATING PROCEDURE

RECOVERY PUMPING TEST DATA SHEET

Page ____ of ____

BOREHOLE _____ TEST INTERVAL _____

TEST TYPE _____ DEPTH INTERVAL _____

DATE	TIME IN HOURS	TIME, T, SINCE PUMP STARTED MINUTES	TIME, T', SINCE PUMP STOPPED-MINUTES	RATIO T/T'	ABOVE STRADDLE ZONE		STRADDLE ZONE			REMARKS	MEASURED BY
					DEPTH TO WATER BELOW MEASURING POINT (FEET)		DEPTH TO WATER BELOW MEASURING POINT (FEET)	PRESSURE TRANSDUCER, PSI			

SITE HYDROLOGIST: _____

FIGURE 4. Constant Discharge - Recovery Pumping Test Data Sheet.

BASALT OPERATING PROCEDURE

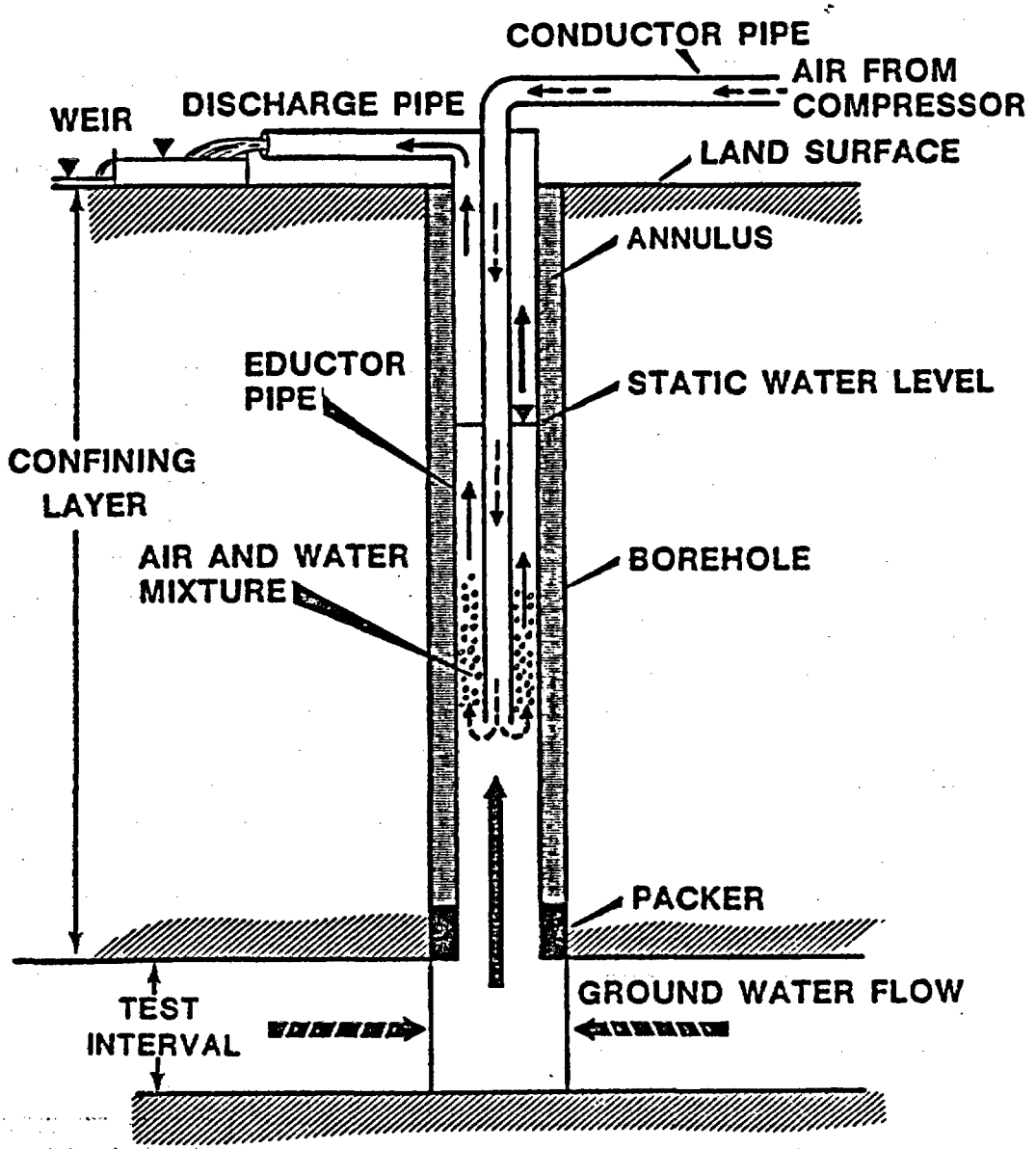

FIGURE 5. Air-Lift Pumping and Isolation Packer Arrangement.

BASALT OPERATING PROCEDURE

Page ___ of ___

CONSTANT DRAWDOWN TEST DATA SHEET

BOREHOLE _____ TEST INTERVAL _____ DEPTH INTERVAL _____

RADIUS OF WELL (r_w) _____ CONSTANT DRAWDOWN (s_w) _____

DATE	TIME IN HOURS	TIME, T, SINCE PUMP STARTED-MINUTES	t/r_w^2 (min/ft^2)		DISCHARGE MEASUREMENTS: FLOW CUMULATOR, GALLONS	FLOW DURING INTERVAL, GALLONS	INTERVAL FLOW RATE, Q (GPM)	s_w/Q (ft-min/gal)	TEMPERATURE °C	REMARKS	MEASURED BY

SITE HYDROLOGIST: _____

FIGURE 6. Constant Drawdown Data Sheet.

BASALT OPERATING PROCEDURE

Page _____ of _____

INSTANTANEOUS SLUG TEST DATA SHEET

BOREHOLE _____ TIME _____

TEST INTERVAL _____ DEPTH INTERVAL _____

DEPTH TO WATER _____ DEPTH TO TRANSDUCER _____

DATE _____ MEASURED BY _____

SLUG VOLUME _____ BAROMETER READING (Beginning) _____ (End) _____

TIME		PRESSURE TRANS. READING		TIME		PRESSURE TRANS. READING		TIME		PRESSURE TRANS. READING	
ACTUAL	ELAPSED (Sec)	Psi		ACTUAL	ELAPSED (Sec)	Psi		ACTUAL	ELAPSED (Sec)	Psi	

SITE HYDROLOGIST: _____

FIGURE 7. Instantaneous Slug Test Data Sheet.

BASALT OPERATING PROCEDURE

INSTANTANEOUS PULSE TEST DATA SHEET

BOREHOLE _____ TIME _____ DATE _____

TEST INTERVAL _____ DEPTH INTERVAL _____

DEPTH TO TRANSDUCER _____ INITIAL PRESSURE (Pi) _____

MAXIMUM PULSE PRESSURE (Po) _____

TIME		PRESSURE TRANSDUCER READING		TIME		PRESSURE TRANSDUCER READING		TIME		PRESSURE TRANSDUCER READING	
ACTUAL	ELAPSED TIME (Sec)	Psi		ACTUAL	ELAPSED TIME (Sec)	Psi		ACTUAL	ELAPSED TIME (Sec)	Psi	

SITE HYDROLOGIST _____

FIGURE 8. Instantaneous Pulse Test Data Sheet.

BASALT OPERATING PROCEDURE

CONSTANT HEAD INJECTION TEST DATA SHEET

BOREHOLE _____ TIME _____ DATE _____

TEST INTERVAL _____ DEPTH INTERVAL _____

STATIC WATER LEVEL _____ TRANSDUCER SETTING _____

FLOW MEASURING INSTRUMENT _____ INITIAL PRESSURE (Pi) _____

TIME		PRESSURE READING psia		FLOW MEASUREMENT		TIME		PRESSURE READING psia		FLOW MEASUREMENT	
OBSERVED (Hrs)	SINCE TEST STARTED (Secs)	P_w	$P_w - P_i$			OBSERVED (Hrs)	SINCE TEST STARTED (Secs)	P_w	$P_w - P_i$		

SITE HYDROLOGIST _____

FIGURE 9. Constant Head Injection Test Data Sheet.

BASALT OPERATING PROCEDURE

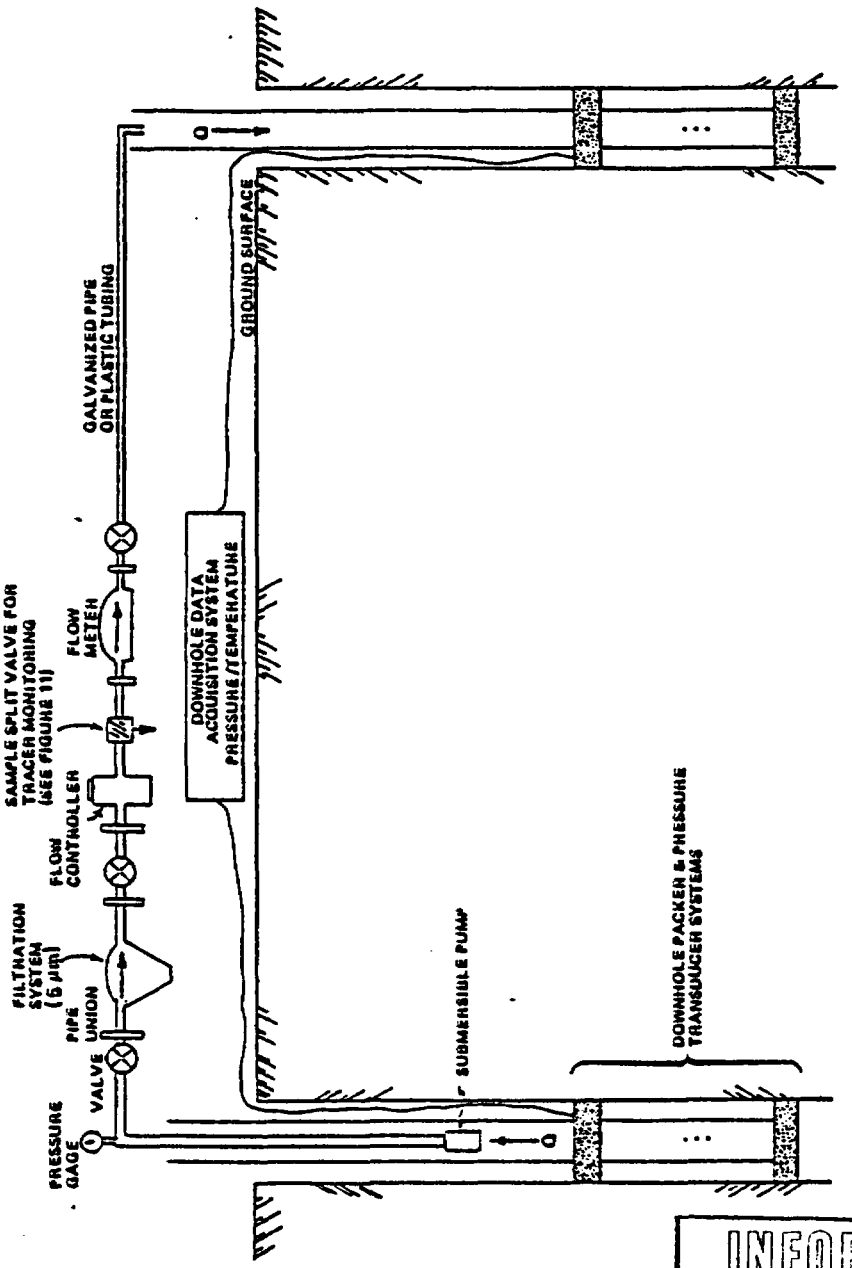

FIGURE 10. Cross-Sectional Schematic of Dual-Borehole Recirculating Tracer Test Equipment Configuration.

BASALT OPERATING PROCEDURE

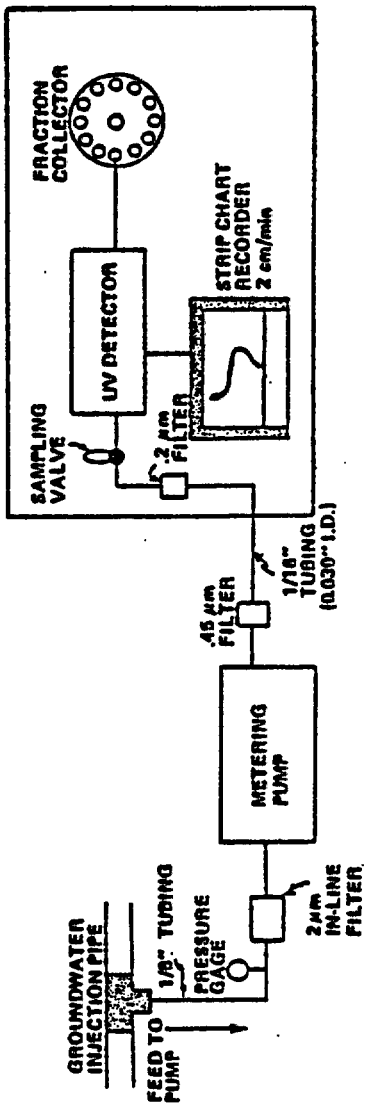

FIGURE 11. Typical Schematic of a Continuous Monitoring Apparatus (Using a UV Absorption Detector as an Example) for a Dual-Borehole Recirculating Tracer Test.

INFORMATION COPY

THIS COPY WILL NOT BE REPLACED AND MAY BE CHANGED WITHOUT NOTICE

Date Issued	Supersedes Issue Dated	To Be Reviewed By	Page	No.
JUNE 1982	NOV 1980	ANNUALLY	17 of 17	C-2.8

BASALT OPERATING PROCEDURE

APPENDIX A

HYDROLOGIC FORMATION DEVELOPMENT PROCEDURES

1.0 INTRODUCTION

The purpose of formational development is to remove drilling fluid from the borehole prior to conducting hydrologic tests. In addition, development is required to help break down the mud cake on the borehole wall, liquify jelled mud, and draw in other fines that have penetrated the formation. Such development of formation is accomplished by using the air-lift pumping method, described below in Section 3.0.

2.0 SAFETY

Observe safety reqirements in accordance with BOP C-1.2, Section 4.0.

3.0 PROCEDURES

The procedures and equipment necessary to develop the test horizon prior to hydrologic testing are described below:

3.1 EQUIPMENT

(1) Calibrate water-level equipment and discharge flow measuring devices in general accordance with U.S. Geological Survey - Techniques of Water Resources Investigations, "Methods of Measuring Water Levels in Deep Wells."

(2) Provide an uphole annulus velocity in the air compressor of 1,000 to 2,000 feet per minute at a pressure of 125 psig. Initially submerge the conductor pipe at least 150 feet below static conditions.

(3) Use calibrated thermometers with appropriate scale and temperature ranges, in general accordance with U.S. Geological Survey - Techniques of Water Resources Investigations, "Water Temperature - Influential Factors, Field Measurement, and Data Presentation."

(4) Use calibrated sensitive pressure transducers verified with electric waste level indicators and steel tape measurement where applicable.

3.2 METHOD

The following procedure applies to developing the test horizon by air-lifting:

1. Isolate test interval by using packer(s).

2. Conduct air-lifting pumping until drilling fluid is removed from the borehole and clear water is discharging at the well head.

3. After air-lifting pumping stops, obtain water-level recovery measurements to determine static head.

3.3 RECORDS OF MEASUREMENTS

1. Record general hydrologic information, equipment, and measurement data on BWIP Hydrologic Information form, Figure 2.

(2) During pumping, record pertinent measurements such as the discharge rate on the hydrologic test form, Constant Discharge - Drawdown Pumping Test Data, Figure 3. Record other pertinent observations such as fluid characteristics in the remark column.

(3) After air-lift pumping stops, obtain recovery water level measurements until static conditions have been reached. Record these measurements on hydrologic form, Constant Discharge - Recovery Pumping Test Data, Figure 4.

4.0 FINAL RESULTS

The preliminary air-lift testing as described above applied to developing the horizon prior to conducting long-term pumping tests to obtain water samples and other hydrologic data. Data obtained during development pumping, however, provides preliminary information on the hydrologic characteristics and hydraulic head in the selected test horizon.

BASALT OPERATING PROCEDURE

APPENDIX B

CONSTANT DISCHARGE TEST-AIR LIFT PUMPING METHOD

1.0 INTRODUCTION

The objective of air-lift pumping is to determine hydraulic properties and to obtain groundwater samples for preliminary hydrochemical characterization of the test horizon. The procedures for conducting a constant discharge test using the air-lift method are described below in Section 3.0.

2.0 SAFETY

Observe safety requirements in accordance with BOP C-1.2, Section 4.0.

3.0 PROCEDURES

3.1 EQUIPMENT

Equipment used is in general accordance with Appendix A. Figure 5 shows the air-lift pumping and isolation packer arrangement.

3.2 METHOD

The following procedures apply to conducting an air-lift test:

(1) Start test after the static head has been determined following hydrologic development as discussed in Appendix A.

(2) Conduct the test for 24 or more hours at a constant discharge or until sufficient hydrologic data are obtained to discontinue pumping as recommended by the supervising hydrologist.

(3) Terminate pumping as recommended by the supervising hydrologist.

(4) Monitor water levels following termination of pumping to determine static head.

BASALT OPERATING PROCEDURE

3.3 RECORD OF MEASUREMENTS

(1) Record general hydrologic information, equipment, and measurement data on BWIP Hydrologic Information form, Figure 2.

(2) During pumping, record pertinent measurements such as water level, temperature, and discharge rate on the hydrologic test form, Constant Discharge - Drawdown Pumping Test Data, Figure 3. Record other pertinent observations such as fluid characteristics in the remarks column.

(3) Monitor water-level measurements obtained in the annulus for geologic horizons above the packer and recorded during hydrologic testing to assess proper packer setting and vertical leakage. In some cases, the geometry of the borehole equipment (rods and casing) may prohibit annulus water-level measurement. If this condition exists, it should be documented in the field notebook.

(4) Record recovery water-level data on hydrologic form, Constant Discharge - Recovery Pumping Test Data, shown in Figure 4.

4.0 DATA ANALYSIS

The results of the air-lift pumping test provides information on static hydraulic head, hydraulic conductivity, and preliminary hydrochemistry in the selected interval.

Obtain static head prior to pumping and also following the constant rate air-lift test.

Transmissivity and storavity are determined by analyzing the drawdown (if available) and the recovery data of the air-lift pumping test using the straight-line method (Cooper and Jacob, 1946) and the Theis method (1935).

Equivalent hydraulic conductivity (K) is computed from the equation: $K=T/m$ where T equals transmissivity, and m equals effective equivalent thickness.

Perform field collection and analysis of water samples in accordance with BOP C-2.4.

BASALT OPERATING PROCEDURE

APPENDIX C

CONSTANT DISCHARGE TEST - CONSTANT RATE PUMPING METHOD

1.0 INTRODUCTION

Pumping test procedures are similar to the air-lift test as described in Appendix B except that an electric-powered submersible or line-shaft turbine pump is used to pump water from the borehole. The constant rate pumping test is conducted following the long-term air-lift test. The constant rate pumping test is required to obtain groundwater samples for complete hydrochemical analysis and supplementary hydrologic data. Testing procedures are described below in Section 3.0.

2.0 SAFETY

Observe safety requirements in accordance with BOP C-1.2, Section 4.0.

3.0 PROCEDURES

3.1 EQUIPMENT

Use equipment in accordance with Appendix B, except use a submersible or line-shaft turbine pump to withdraw water from the borehole at a constant discharge rate throughout the pumping period. In addition, use a submersible pump with a diameter to fit inside at least 2-7/8-inch-ID casing to a depth of about 200 feet below the static head.

3.2 METHOD

The following procedures apply to conducting a constant discharge rate pumping test:

(1) Start this pumping test after the static head conditions have been reached, following the air-lift test discussed in Appendix B.

(2) Pump groundwater from the test interval at a constant discharge rate for 24 or more hours or until sufficient hydrologic data have been obtained to discontinue pumping as determined by the supervising hydrologist or site representative.

(3) Collect water samples during the test period as determined by the supervising hydrologist or site representative for preliminary hydrochemical analysis. Collect water samples in the field in accordance with BOP C-2.4.

(4) Terminate the test at a time determined by the supervising hydrologist or site representative following groundwater sampling for complete hydrochemical and isotopic analysis.

(5) Monitor recovery water levels following termination of pumping to determine static head.

3.3 RECORD OF MEASUREMENT

(1) Record general hydrologic information, equipment, and measurement data on BWIP Hydrologic Information form, Figure 2.

(2) During pumping, record pertinent measurements such as water level, temperature, and discharge rate on the hydrologic test form, Constant Discharge - Drawdown Pumping Test Data form, Figure 3. Record other pertiment observations such as fluid characteristics and water sample collection data in the remarks column.

(3) Monitor and record water-level measurements above the packer during hydrologic testing to assess proper packer setting and vertical leakage.

(4) Record recovery water-level data on hydrologic form, Constant Discharge-Recovery Pumping Test Data, shown in Figure 4.

4.0 DATA ANALYSIS

The results of this pumping test provide corroborative information on hydraulic head and hydrologic characteristics, and define completely the hydrochemistry in the test horizon. The data are analyzed in accordance with Appendix B.

BASALT OPERATING PROCEDURE

APPENDIX D

CONSTANT DRAWDOWN TEST

1.0 INTRODUCTION

This test is performed when artesian flowing conditions are encountered in the test horizon. The primary purpose of this test is to obtain hydraulic properties of the test interval. The procedures for conducting a constant drawdown test are described below in Section 3.0.

2.0 SAFETY

Observe safety requirements in accordance with RHO-BWI-MA-4, BOP C-1.2, Section 4.0.

3.0 PROCEDURES

3.1 EQUIPMENT

(1) Appropriate shut-in tools to close in the artesian flow and packers to isolate the test interval.

(2) Calibrated sensitive pressure gauges, pressure transducers, and associated monitoring equipment.

(3) Calibrated discharge flow measuring devices in general accordance with U. S. Geologic Survey - Techniques of Water Resources Investigations, "Aquifer - Test Design, Observation, and Data Analysis."

3.2 PROCEDURES

(1) Develop formation following procedures described in Appendix A.

(2) Allow static conditions to be reached following developmental pumping procedures.

(3) Open shut-in valve and monitor discharge rates, discharge temperatures, and obtain groundwater samples as required by supervising hydrologist.

(4) Close shut-in valve after sufficient hydrologic data are obtained as determined by the supervising hydrologist.

(5) Monitor recovery pressures following termination of flow period to determine static head and hydraulic properties for the test interval.

3.3 RECORD OF MEASUREMENTS

(1) Record general hydrologic information, equipment, and measurement data on BWIP Hydrologic Information form, Figure 2.

(2) When the well is flowing, record pertinent measurements such as temperature and discharge rate on the hydrologic test form, Constant Drawdown Test Data, Figure 6. Record other pertinent observations such as fluid characteristics and water sampling record in the remarks column.

(3) Monitor water-level measurements above the packer and record during hydrologic testing to assess proper packer seats and/or vertical leakage.

(4) Record recovery water-level measurement on hydrologic form, Constant Discharge-Recovery Pumping Test Data, Figure 4.

(5) Collect water samples in the field in accordance with BOP C-2.4.

4.0 DATA ANALYSIS

The results of the constant rate pumping test provide information on static hydraulic head, hydraulic properties, and hydrochemistry for the selected test interval.

Static head can be determined by allowing the pressure to stabilize prior to or following test pumping.

BASALT OPERATING PROCEDURE

The transmissivity and storativity are determined by analyzing discharge-rate data during the test period using analytical solutions by Jacob and Lohman (1952). Estimates of transmissivity determined from the discharge data should be corroborated by analyzing the recovery data after shutting-in the borehole. Recovery data can be analyzed using the straight-line solution of Theis (1935).

The equivalent hydraulic conductivity (K) is computed from the equation; K=T/m; where T equals transmissivity, and m equals effective equivalent thickness.

Collect water samples in accordance with BOP C-2.4.

BASALT OPERATING PROCEDURE

APPENDIX E
INSTANTANEOUS SLUG WITHDRAWAL/INJECTION TEST

1.0 INTRODUCTION

The instantaneous slug withdrawal and injection tests are conducted by inducing an instantaneous reduction or increase in hydraulic head within the tested zone followed by observation of the associated hydraulic response. The purpose of these tests is to provide corraborative data on the hydrologic characteristics of the test interval. These tests are conducted, in general, after all other hydrologic tests have been performed in the selected horizon. The procedures for conducting instantaneous slug withdrawal/injection tests are described below in Section 3.0.

2.0 SAFETY

Safety requirements are to be in accordance with BOP C-1.2, Section 4.0.

3.0 PROCEDURES

The procedures for conducting slug withdrawal/injection tests are described below.

3.1 EQUIPMENT

(1) Packer element(s) to isolate test interval.

(2) Calibrated, sensitive pressure transducers and recording equipment to monitor pressure changes and verified with electric water-level indicator or steel tape devices.

3.2 METHOD

(1) Allow the hydraulic head to reach equilibrium or establish head trends prior to conducting tests.

(2) Instantaneously withdraw or inject a slug of known volume to induce a pressure differential between the formation and the fluid level in the tubing.

(3) Monitor recovery pressure responses following instantaneous injection or withdrawal.

3.3 RECORD OF MEASUREMENTS

(1) Record general hydrologic information, equipment, and measurement data on BWIP Hydrologic Information form, Figure 2.

(2) Monitor pressure measurements with calibrated and sensitive pressure transducers. Note these measurements will be recorded on hydrologic form, Instantaneous Slug Test Data Sheet, shown in Figure 7. Verify pressure transducer measurements in the field by taking measurements on a selected basis with a calibrated pressure gauge or known atmospheric pressure reading.

4.0 DATA ANALYSIS

Slug/withdrawal testing data are obtained to determine transmissivity and storativity using analytical solutions by Cooper, et al., (1967) and Van der Kamp (1976).

The equivalent hydraulic conductivity (K) is computed from the empirical equation K=T/m; where T equals transmissivity, and m equals effective equivalent thickness.

BASALT OPERATING PROCEDURE

APPENDIX F

INSTANTANEOUS PULSE WITHDRAWAL/INJECTION TEST

1.0 INTRODUCTION

The pulse withdrawal/injection test is conducted by instantaneously overpressurizing or underpressurizing the interval under closed-in conditions. The pressure-recovery data are analyzed to determine the hydrologic characteristics of the test interval. Pulse tests are performed in zones of very low hydraulic conductivity.

2.0 SAFETY

Observe safety requirements in accordance with BOP C-1.2, Section 4.0.

3.0 PROCEDURES

3.1 EQUIPMENT

(1) Packer element(s) to isolate test interval,

(2) Calibrated, sensitive pressure transducers and recording equipment to monitor pressure changes.

3.2 PROCEDURES

The surface shut-in valves and surface pressure transducers are used for overpressurized pulse testing, perform the following procedures:

(1) Fill standpipe with water to top of tubing

(2) Determine baseline pressure decay

(3) Instantaneously pressurize system with an additional amount of water

(4) Close surface shut-in valves

(5) Monitor decay of pressure until 80% of pressure pulse has decayed.

If a downhole shut-in valve and downhole pressure transducers are used for either the overpressurized (injection) or underpressurized (withdrawal) pulse test, perform the following procedures:

(1) Allow downhole pressure to reach equilibrium conditions or establish pretest pressure trends prior to conducting tests.

(2) With shut-in tool closed, withdraw or fill standpipe with water to create a pressure differential of no greater than 100 psi.

(3) Instantaneously open and close downhole shut-in tool.

(4) Monitor overpressurized or underpressurized pulse to static pressure.

3.3 RECORD OF MEASUREMENTS

(1) Record general hydrologic information, equipment, and measurement data on BWIP Hydrologic Information Form, Figure 1.

(2) Monitor pressure measurements with calibrated and sensitive pressure transducers. Note pressure readings on hydrologic form, Instantaneous Pulse Data Sheet, Figure 8 or have pressure data printouts attached to the hydrologic form.

4.0 DATA ANALYSIS

Pulse withdrawal/injection tests are performed to determine transmissivity and storativity using the type curves of Cooper, et al., (1967), Papadopulos et al., (1973), Bredehoeft and Papadopulos (1980), and Ramey et al., (1975).

The equivalent hydraulic conductivity (K) is computed from the equation $K = T/m$; where T equals transmissivity and m equals effective equivalent thickness.

BASALT OPERATING PROCEDURE

APPENDIX G

CONSTANT HEAD INJECTION TEST

1.0 INTRODUCTION

The constant head injection test consists of monitoring the injection rate of water into the test interval under constant pressure head conditions. The purpose of this test is to provide corroborative data on the hydrologic characteristics of the test interval. A constant head injection test is conducted primarily in formations of low to moderate hydraulic conductivity.

2.0 SAFETY

Perform safety practices in accordance with BOP C-1.2, Section 4.0.

3.0 PROCEDURES

3.1 EQUIPMENT

(1) Packer element(s) to isolate test interval

(2) Calibrated and sensitive pressure transducers

(3) Calibrated flow measuring devices.

3.2 PROCEDURES

(1) After the interval is flushed with clean water and packer(s) installed, fill standpipe to top of tubing.

(2) Pressurize interval to desired value and maintain pressure until rate of flow has reached steady-state conditions.

(3) Repeat step 2 at increasing pressures for three to five incremental values. (Note: Limit the water injection pressure to a value which does not hydraulically fracture the formation.

within and adjacent to the test interval. At depths greater than 250 feet, the maximum differential pressure should not exceed 100 psi).

(4) Monitor the flow injection rate and pressures during injection period.

3.3 RECORD OF MEASUREMENTS

(1) Record general hydrologic information, equipment, and measurement data on BWIP Hydrologic Information form, Figure 2.

(2) Monitor pressure reading and flow rates with calibrated sensitive devices. Note these measurements on the hydrologic form, Constant Head Injection Test, Figure 9.

4.0 DATA ANALYSIS

Constant head injection tests are performed to determine the equivalent hydraulic conductivity for the test interval. Equivalent hydraulic conductivity is determined by using equations summarized by Zeigler (1976).

Transmissivity (T) is computed from the equation $T = Km$; where K equals equivalent hydraulic conductivity and m equals effective equivalent thickness.

Where injection rates vary with time under constant pressure, transmissivity can be determined by the straight-line method described by Jacob and Lehman (1952).

BASALT OPERATING PROCEDURE

APPENDIX H

DUAL-BOREHOLE RECIRCULATING TRACER TEST

1.0 INTRODUCTION

The dual-borehole recirculating tracer test is a generally accepted method for determining effective porosities and dispersivities in situ. The applicability of the test is generally limited to horizons having high to moderate transmissivities. The test involves pulse-tracer injection and recirculation within a steady-state flow field established between two adjacent boreholes. General procedures involved with the test are provided in Section 3.0.

2.0 SAFETY

Observe safety requrements applicable to this procedure in accordance with BOP C-1.2, Section 4.0.

3.0 DESIGN

Many generic options are available with respect to tracer selection (e.g., Davis, et al., 1980). This procedure describes general analytical and monitoring requirements for any tracer used with the field equipment. Additional detail is provided by means of the specific thiocyanate (SCN^-) tracer example. No significant change to the procedure pertaining to hydraulics is anticipated as a result of alternative tracer selection.

Procedures for the dual-borehole recirculating tracer test involve three components:

(1) Hydraulics

(2) Analysis and monitoring

(3) Data analysis.

These components are integrated within the paragraphs below.

BASALT OPERATING PROCEDURE

3.1 EQUIPMENT

A schematic cross-sectional drawing of the dual-borehole recirculating tracer test field set-up, exclusive of the monitoring apparatus, is shown in Figure 10.

3.1.1 Downhole Isolation Equipment

(1) Dual packer system to isolate the test interval

(2) Calibrated sensitive pressure transducers and thermistors to monitor downhole conditions and packer integrity.

The latter instrumentation is monitored at the surface using compatible recording devices.

3.1.2 Groundwater Circulation System

(1) Submersible pump capable of operating at a constant rate against a prescribed dynamic head for the duration of the test. These parameters are determined during pre-tracer injection testing.

(2) Filtration system capable of removing particulates in excess of 5μm-diameter.

(3) Recording propeller-type flow meter capable of maintaining a ±5% accuracy. This instrument should be capable of monitoring the cumulative flow volume, instantaneous flow volume, and the instantaneous flow rate.

(4) Flow controller (regulator) capable of maintaining steady flows (±5%) at the target flow rate.

(5) Calibrated well-head pressure gauge.

(6) Plumbing equipment (valves, pipe, fittings, etc.) as required.

3.1.3 Continuous Tracer Monitoring System

Specific design varies according to the type of tracer being used; however, basic apparatus consists of:

(1) A valve leading from the primary circulation loop to the sample line (see Figure 10).

(2) Appropriate diameter tubing

(3) Appropriate filters and apparatus to protect in-line equipment.

(4) A continuous tracer detection device (e.g., UV-absorption detector or scintillation detector.)

(5) Appropriate recording devices and readouts (e.g., strip chart recorder, digital data recorder, LED, etc.) to monitor tracer concentration at the pumped borehole and to provide a permanent record for documentation.

(6) A metering pump, if required, to maintain back pressure within the sample loop.

(7) Appropriate sample collection apparatus including bottles, and if necessary, a fraction collector.

A schematic for a continuous tracer monitoring and sample collection system employing a UV-absorption detector is shown as a typical example in Figure 11.

4.0 PROCEDURE

4.1 HYDRAULICS

(1) Perform initial formation testing and development to ascertain specific hydrologic properties (static head, hydraulic conductivity, and storativity) of the test interval. The procedures for such testing are detailed in Appendix A, B, and E, respectively.

(2) Estimate breakthrough times and other relevant design data using the values obtained above in step (1) and the general theory presented by Gelhar (1982).

(3) Begin groundwater recirculation between boreholes to determine an optimal flow rate for the test. Concurrent with this, perform other preliminary evaluations, including collection and analysis of reference groundwater samples, and testing and calibration of analytical equipment. A minimum of six to eight hours is required to evaluate the baseline and to perform the above-mentioned tests.

(4) Introduce the tracer into the injection well by the method determined by the type tracer and onsite equipment used.

(5) Monitor tracer concentrations at the discharge well. Monitoring involves the continuous measurement with the onsite detector calibrated during step (2). If appropriate, take discrete samples at specified intervals for verification of the continuous by standard analytical methods in accordance with BOP C-2.4.

(6) Continue recirculation, monitoring, and sampling until termination of the test. The following conditions represent circumstances under which the test should be terminated:

a. Sufficient results have been obtained to satisfy the test objectives. It is desirable to observe at least two tracer "peaks" at the monitoring station.

b. Recirculation failure occur (e.g., the injection well or the formation becomes clogged to the point that water is spilled onto the ground surface).

c. Equipment compliance problems arise (e.g., packer failure).

4.2 RECORD OF MEASUREMENTS

(1) Record general hydrologic information, identification of equipment, and measurement data on the BWIP Hydrologic Information form, Figure 2.

(2) Record continuous tracer monitoring results on a mechanical recording device (e.g., strip chart recorder, punch tape, magnetic tape, magnetic disk, or an appropriate combination). Label and annotate the record to facilitate identification, calibration, and interpretation during the analysis. Report discrete sample analyses on approprite forms as described in BOP C-2.4.

(3) Record pumping data such as water level and flow measurements on the hydrologic test form entitled Constant Discharge-Drawdown Pumping Test (Figure 3).

(4) Record water-level recovery data on the hydrologic test form entitled Constant Discharge-Recovery Pumping Test (Figure 4).

BASALT OPERATING PROCEDURE

5.3 DATA ANALYSIS

The results of dual-borehole recirculating tracer tests can be translated into numerical values of effective porosity and dispersivity for the test interval. Analysis is based upon the general theory for longitudinal dispersion in non-uniform flow along stream lines (Gelhar and Collins, 1971). Results of tracer-concentration data as observed at the discharge borehole are evaluated against dimensionless type curves to obtain parameter values. These types of curves and a detailed explanation of their theory and use are contained in Gelhar (1982).