BASALT OPERATING PROCEDURE

Approved By	Subject	Classification
	GENERAL HYDROLOGIC FIELD TESTING PROCEDURES	HYDROLOGY

1.0 SCOPE

These basalt operating procedures apply to determining hydrologic properties and collecting groundwater samples by Basalt Waste Isolation Project (BWIP) personnel or to sub-contractors and consultants when specified in applicable procurement/contract documents.

2.0 APPLICABLE DOCUMENTS

The latest issue of the following documents shall apply to the extent specified herein:

Document No.	Title	BOP No.
RHO-BWI-MA-4	Field Work	C-1.2
RHO-BWI-MA-4	Ground Water Sampling And Analyses	C-2.4

The following references shall apply to the extent specified herein:

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

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

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

4. R. C. Earlougher, "Advances in Well Test Analysis," Society of Petroleum Engineers of AIME, 2nd Edition, Monograph Series (1977) 264 p.

*Reissued with date changes only

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

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

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

8. C. V. Theis, "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 (1935) pp. 519-524.

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

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

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

3.0 INTRODUCTION

Hydrologic tests are performed in boreholes to determine hydrologic properties and to obtain water samples from a selected geologic horizon. These results are 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. 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 RHO-BWI-MA-4, BOP C-2.4.

3.1 APPLICABILITY

Section 2.0 through 6.0 of this BOP apply to the Appendices listed in Section 5.0.

4.0 SAFETY

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

5.0 REQUIREMENTS

The procedures and requirements for hydrologic testing shall be contained in the following appendices:

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 Injection/Withdrawal Test

The basic hydrologic parameters obtained directly from the various types of test are summarized on next page:

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HYDROLOGIC PARAMETER
(single well)

Test Type	Transmissivity	Storage Coefficient
Air-Lift	X	
Constant Rate Pumping	X	estimated*
Constant Drawdown	X	estimated*
Instantaneous Injection/ Withdrawal	X	estimated*

*In general, the determination of storage coefficient using test data obtained from a single well is not highly reliable.

5.1 HYDROLOGIC TESTING FUNCTIONAL RESPONSIBILITY

Functional responsibilities shall be in accordance with RHO-BWI-MA-4, BOP C-2.2, Section 5.2.

6.0 QUALITY ASSURANCE

Quality assurance shall be in accordance with RHO-BWI-MA-4, BOP C-1.2, Section 6.0.

6.1 FIELD NOTES

In addition to the applicable requirements in RHO-BWI-MA-4, BOP C-1.2, Section 6.2 shall include the following information to be recorded by the field hydrologist in assigned notebooks or data forms.

1. The hydrologist shall record daily field hydrological testing activities.

2. The hydrologist shall record hydrologic data on appropriate data forms as described in the appendices to

Section 5.0 of this BOP.

3. Each data entry on the data forms shall be documented as to who obtained the measurement.

6.3 CONTROL OF TEST EQUIPMENT

Calibration of Test Equipment shall be in accordance with BOP C-1.3.

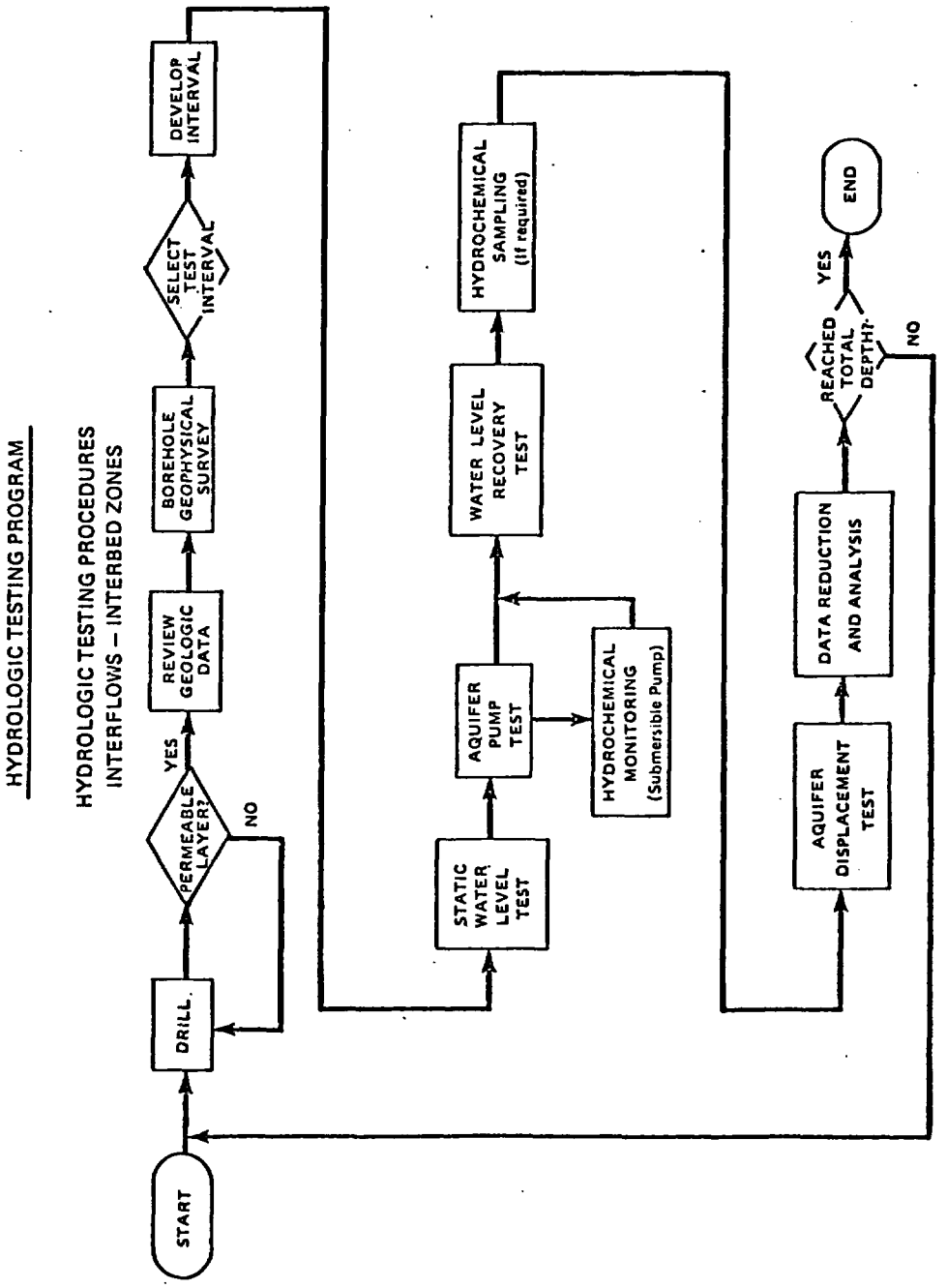

FIGURE 1. Flow Chart Showing Generalized Hydrologic Testing Procedures.

BASALT OPERATING PROCEDURE

BWIP HYDROLOGIC TEST INFORMATION

WELL _____ HANFORD COORDINATES _____

TEST TYPE _____ TEST DATE _____

AQUIFER _____ AQUIFER DEPTH _____

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 INFORMATION

BASALT OPERATING PROCEDURE

DRAWDOWN PUMPING TEST DATA SHEET

WELL _____ AQUIFER _____ TEST INTERVAL _____

TEST TYPE _____

PAGE _____ OF _____

DATE	HOURS	TIME, T, SINCE PUMP STARTED-MINUTES	WATER LEVEL DATA		DISCHARGE MEASUREMENTS					REMARKS
			DEPTH TO WATER BELOW MEASURING POINT (FEET)		FLOW CUMULATOR, GALLONS	CUMULATIVE AVERAGE-GPM	INSTANTANEOUS FLOW-GPM	FLOW RATE WEIR IN	FLOW RATE GPM	TEMPERATURE °C	

SITE HYDROLOGIST _____

FIGURE 3. Constant Discharge - Drawdown Pumping Test Data

RECOVERY PUMPING TEST DATA SHEET

WELL _____ AQUIFER _____ TEST INTERVAL _____

TEST TYPE _____

PAGE ____ OF ____

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
					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

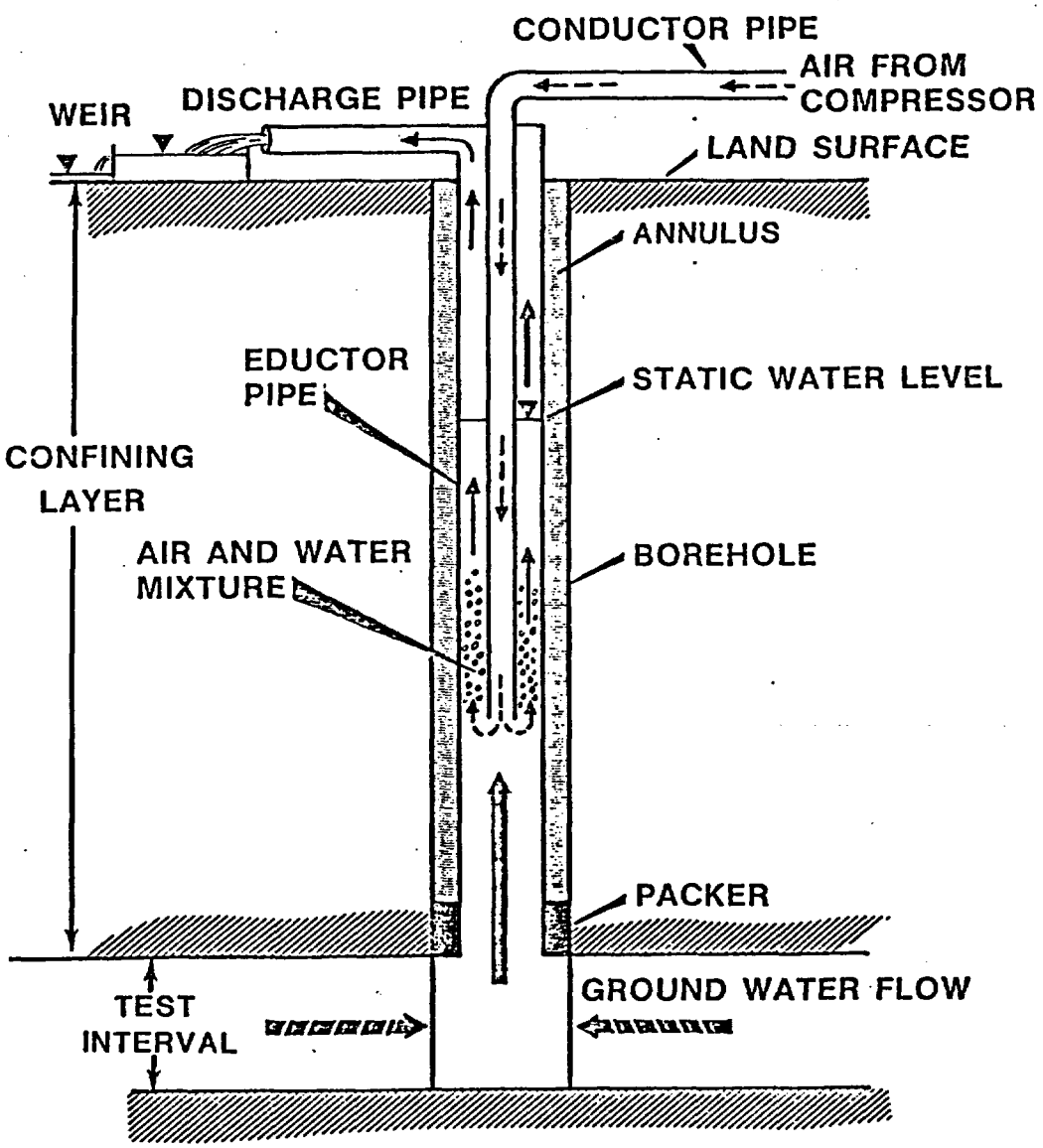

FIGURE 5. Air-lift Pumping and Isolation Packer Arrangement.

BASALT OPERATING PROCEDURE

CONSTANT DRAWDOWN TEST DATA SHEET

PAGE____ OF_____

WELL_____ AQUIFER_____ TEST INTERVAL_____

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

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

SITE HYDROLOGIST_____

FIGURE 6. Constant Drawdown Test Data.

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INSTANTANEOUS SLUG TEST DATA SHEET

Well _____ Time _____

Aquifer _____ Test Interval _____

Depth To Water _____ Depths To Transducer _____

Date _____

Slug Volume _____ Barometer Reading (beginning) _____ (end) _____

TIME		PRESS. TRANS. READING		TIME		PRESS. TRANS. READING		TIME		PRESS. TRANS. READING	
Min	Sec	Psi	Water(ft)	Min	Sec	Psi	Water(ft)	Min	Sec	Psi	Water(ft)

SITE HYDROLOGIST _____

FIGURE 7. Instantaneous Slug Test Data Sheet.

BASALT OPERATING PROCEDURE

"APPENDIX A"
HYDROLOGIC FORMATION DEVELOPMENT PROCEDURES

1.0 INTRODUCTION

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

2.0 SAFETY

Safety requirements shall be in accordance with RHO-BWI-MA-4, 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. Calibrated water-level equipment and discharge flow measuring devices shall be in general accordance with U. S. Geological Survey - Techniques of Water Resources Investigations, "Methods of Measuring water Levels in Deep Wells."

2. Air compressor shall provide an uphole annulus velocity of about 1,000 to 2,000 feet per minute at a pressure of 125 psig. The submergence of the conductor pipe shall be at least 60 percent initially.

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

3.2 METHOD

The following procedure shall apply 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. General hydrologic information, equipment, and measurement datum shall be recorded on BWIP Hydrologic Information form, Figure 2.

2. During pumping, pertinent measurements such as the discharge rate shall be recorded on the hydrologic test form, Constant Discharge - Drawdown Pumping Test Data, Figure 3. Other pertinent observations such as fluid characteristics shall be recorded in the remark column.

3. After air-lift pumping stops, recovery water-level measurements are obtained until static conditions have been reached. These measurements are recorded on hydrologic form, Constant Discharge - Recovery Pumping Test Data, shown in Figure 4.

4.0 FINAL RESULTS

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

BASALT OPERATING PROCEDURE

"APPENDIX B"
CONSTANT DISCHARGE TEST
AIR-LIFT 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

Safety requirements shall be in accordance with RHO-BWI-MA-4, BOP C-1.2, Section 4.0.

3.0 PROCEDURES

3.1 EQUIPMENT

Equipment shall be 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. This test shall be started after the static head has been determined following hydrologic development as discussed in this BOP's Appendix A.

2. This test shall be conducted for about 24 hours at a constant discharge or until sufficient hydrologic data are obtained to discontinue pumping as recommended by the supervising hydrologist or site representative.

3. Terminate pumping as recommended by the supervising hydrologist or site representative.

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

3.3 RECORD OF MEASUREMENTS

1. General hydrologic information, equipment, and measurement datum shall be recorded on BWIP Hydrologic Information form, Figure 2.

2. During pumping, pertinent measurements such as water level, temperature, and discharge rate shall be recorded on the hydrologic test form, Constant Discharge - Drawdown Pumping Test Data, Figure 3. Other pertinent observations such as fluid characteristics shall be recorded in the remarks column.

3. Water-level measurements obtained in the annulus for geologic horizons above the packer shall be monitored and recorded during hydrologic testing to assess proper packer setting and/or vertical leakage.

4. Recovery water-level data shall be recorded 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.

Static head is obtained prior to pumping and also following the constant rate air-lift test.

Transmissivity is determined by analyzing the drawdown (if available) and the recovery portion of the air-lift pumping test using the straight-line method (Cooper and Jacob, 1946) and the modified Theis recovery method (Theis, 1935). Hydraulic conductivity (K) is computed from the equation: $K=T/m$ where T equals transmissivity, and m equals effective saturated thickness.

BASALT OPERATING PROCEDURE

Field collection and analysis of water samples shall be in accordance with RHO-BWI-MA-4, 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 shall be 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

Safety requirements shall be in accordance with RHO-BWI-MA-4, BOP C-1.2, Section 4.0.

3.0 PROCEDURES

3.1 EQUIPMENT

Equipment shall be in accordance with Appendix B except a submersible or line-shaft turbine pump shall be used to withdraw water from the borehole at a constant discharge rate throughout the pumping period. In addition, the submersible pump shall be of 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. This pumping test shall be started after the static head conditions have been reached following the air-lift test discussed in Appendix B.

2. Groundwater shall be pumped from the test interval at a constant discharge rate for 24 hours or until sufficient hydrologic data have been obtained to discontinue pumping as determined by the supervising hydrologist or site representative.

3. Water samples shall be collected during the test period as determined by the supervising hydrologist or site representative for preliminary hydrochemical analysis. Field collection of water samples shall be in accordance with RHO-BWI-MA-4, BOP C-2.4.

4. The test shall be terminated 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. General hydrologic information, equipment, and measurement datum shall be recorded on BWIP Hydrologic Information form, Figure 2.

2. During pumping, pertinent measurements such as water level, temperature, and discharge rate shall be recorded on the hydrologic test form, Constant Discharge - Drawdown Pumping Test Data form, Figure 3. Other pertinent observations such as fluid characteristics and water sample collection data shall be recorded in the remarks column.

3. Water-level measurements above the packer shall be monitored and recorded during hydrologic testing to assess proper packer setting and/or vertical leakage.

4. Recovery water-level data shall be recorded 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 analysis shall be 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

Safety requirements shall be 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 and sensitive pressure gages, 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 or site representative.

4. Close shut-in valve after sufficient hydrologic data are obtained as determined by the supervising hydrologist or site representative.

5. Monitor recovery pressures following termination of flow period to determine static head.

3.3 RECORD OF MEASUREMENTS

1. General hydrologic information, equipment, and measurement datum shall be recorded on BWIP Hydrologic Information form, Figure 2.

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

3. Water-level measurements above the packer shall be monitored and recorded during hydrologic testing to assess proper packer seats and/or vertical leakage.

4. Recovery water-level measurement shall be recorded on hydrologic form, Constant Discharge-Recovery Pumping Test Data, Figure 4.

5. Field collection of water samples shall be in accordance with RHO-BWI-MA-4, 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 is determined by allowing the pressure to stabilize prior to and following test pumping.

The transmissivity is determined by analyzing discharge-rate data during the test period using analytical solutions by Jacob and Lohman (1952). Transmissivity is also determined by analyzing the recovery portion of the costant drawdown test using the straight-line solution (Cooper and Jacob, 1946) and the Theis modified method (Theis, 1935).

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

Collection of water samples shall be in accordance with RHO-BWI-MA-4, 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 pressure 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 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 shall be in accordance with RHO-BWI-MA-4, BOP C-1.2, Section 4.0.

3.0 PROCEDURES

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

3.1 EQUIPMENT

1. Packer element(s) to isolate test interval.
2. Calibrated and sensitive pressure transducers and recording equipment to monitor pressure changes.

3.2 METHOD

1. Allow the hydraulic head to reach equilibrium prior to conducting tests.

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

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

3.3 RECORD OF MEASUREMENTS

1. General hydrologic information, equipment, and measurement datum shall be recorded on BWIP Hydrologic Information form, Figure 2.

2. Pressure measurements shall be monitored with calibrated and sensitive pressure transducers. These measurements shall be noted on hydrologic form, Instantaneous Slug Test DataSheet, shown in Figure 7. Pressure transducer measurements shall be verified in the field by taking measurements on a selected basis with a calibrated pressure gage or known atmospheric pressure reading.

4.0 DATA ANALYSIS

Slug/withdrawal testing data are obtained to determine transmissivity using analytical solutions by Copper and Others (1967) and Van der Kamp (1976). The hydraulic conductivity (K) is computed from the empirical equation $K = T/m$; where T equals transmissivity, and m equals effective saturated thickness.