BWIP SITE TECHNICAL POSITION NO. 1.1:

HYDROGEOLOGIC TESTING STRATEGY

FOR THE BWIP SITE

Division of Waste Management
U. S. Nuclear Regulatory Commission
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1.0 BACKGROUND

1.1 Purpose

At the time of licensing for a proposed deep geologic repository for high-level nuclear waste, the Department of Energy (DOE) has the reponsibility to present and defend a complete licensing/performance assessment of the geologic repository system. As part of its responsibilities, the NRC staff will be required to perform an independent assessment of the groundwater flow system with respect to the technical criteria of 10 CFR Part 60. Specifically, the staff expects to use mathematical models to predict pre-and post-emplacement groundwater flow paths and travel times. These predictive assessments will be used to reach findings on compliance with the proposed EPA Standards (10 CFR 60.112), which apply to post-emplacement conditions, and with the criterion for minimum pre-emplacement groundwater travel time along the path of likely radionuclide travel (10 CFR 60. 113(2)).

Predictive modeling of groundwater flow will require defensible conceptual models of the flow system, defensible boundary conditions, and defensible values of hydraulic parameters. The purpose of this technical position is to provide guidance to DOE on an approach that the NRC staff considers acceptable in determining what hydrogeologic testing (including types of tests, scale of tests and number of tests) at the Hanford site will be required to produce the hydraulic data necessary and sufficient to perform rigorous, quantitative modeling. The site technical position is aimed at developing a testing strategy that would yield sufficient defensible hydraulic data to support predictions of repository performance.

A highly prescriptive approach by the NRC staff to guidance on groundwater testing strategy is not appropriate. Given the existing data on the groundwater flow system at Hanford, a range of feasible hydrogeologic conceptual models exists. In light of the current levels of uncertainty about the groundwater flow system and of the dynamic nature of the site characterization process, the NRC staff considers that the guidance should provide an "envelope" of approaches broad enough to help guide the detailed decisions that must be made in the future by DOE. Therefore, the technical position presents a logical progression of alternative testing scenarios that can be implemented at the BWIP for the full range of feasible hydrogeologic conceptual models. The focus of the technical position is the hydraulic testing of the groundwater flow system at the site. The testing strategy emphasizes the primary importance of hydraulic testing near the repository horizon, which is assumed to be well below the top of the Grande Ronde Formation. (The main horizons being considered at the time of this draft are the Umtanum and Cohasset units.) The technical position also describes how the testing approach would be expanded to characterize possible flow paths in formations above the Grande Ronde in order to develop an adequate and defensible data base for determining compliance with respect to the criterion for minimum pre-emplacement groundwater travel time from the disturbed zone to the accessible environment.

In the Draft Site Characterization Analysis (NUREG-0960) the NRC staff identified several areas of the BWIP hydrogeology that require further investigation, but which are not addressed in detail in this technical position. These include the regional hydrologic setting (i.e., the development of defensible boundary conditions), the measurement of key solute transport parameters, and the appropriate use of hydrochemistry in flow system interpretation. Each of these topics, particularly the development of defensible boundary conditions, also must be addressed comprehensively by DOE in the site characterization process. Although these issues are not covered in detail in this technical position, the approach described provides a vehicle by which other testing can be performed to address critical questions about effective porosity, hydrochemistry, and long-term measurements of hydraulic head.

Recognizing that DOE is already formulating major program plans, the NRC staff has developed this site technical position on hydrogeologic testing before receiving the DOE Site Characterization Plan for BWIP in order to provide timely guidance to the Department on an aspect of the site characterization investigations which has major programmatic impact, both in terms of schedule and cost.

1.2 Basic Approach

The basic approach of this site technical position is that the hydrogeologic characterization of the Hanford site should rely to the maximum extent possible on direct testing of the hydraulic response of the site to an induced hydraulic stress.

The principal goal of this approach is to provide the hydraulic data required to formulate, apply and interpret defensible performance analysis models at a variety of scales in support of licensing assessments. The approach recognizes that direct testing of the groundwater flow system's hydraulic performance subsequently extrapolated to spatial and temporal scales appropriate to licensing assessments, is more convincing than is performance modeling without direct testing of the site's hydraulic response. In addition, the approach recognizes that the final results of performance assessment modeling will be most reliable when reliance on extrapolation, both is space and time, is minimized, to the extent practicable. Furthermore, the NRC staff considers that direct testing of the hydrogeologic systems should be performed at locations which are expected to be most affected by repository operations and waste emplacement, to the extent practicable. This means that some tests should be performed as near to the proposed repository location as possible, both in elevation and plan, and some along the most important potential pathways for radionuclide transport from the repository to the accessible environment. Specifically, the hydraulic testing program for the Hanford site should begin by testing the Grande Ronde Formation. Testing of the Wanapum and

Saddle Mountains Basalts should follow testing of the Grande Ronde and should be concentrated along important potential pathways that have been suggested by earlier stages of the testing program.

Finally, if predictive numerical modeling is used in DOE's licensing performance assessments to demonstrate compliance with EPA and NRC regulations, hydrogeologic testing of the Hanford Site must be integrated with a coherent and comprehensive program designed to establish defensible boundary conditions for the groundwater flow systems. Only when defensible boundary conditions have been determined will it be possible to apply the hydraulic data collected under the type of approach proposed in this site technical position in defensible predictive assessments for compliance with the numerical criteria of 10 CFR Part 60.

1.3 Summary of Testing to Date

The testing of the groundwater flow systems at the Hanford site has been summarized in various reports (RHO, 1979; DOE, 1982). The testing reported in the SCR has included:

- single-hole tests of horizontal hydraulic conductivity of the basalts (primarily the flow tops);
- temporary spot completions of holes for head measurements;
- water sampling by pumping for hydrochemical analysis;
- one two-well test at one depth (DC-7/8); the distance between boreholes was approximately 20m.
- permanently completed, deep piezometers at one location (DC-1).

In NUREG-0960 the NRC staff identified several important weaknesses in the testing:

- Hydraulic heads measured using packer technology during the drill-and-test sequence are subject to large uncertainties due to (a) systematic errors associated with the open borehole above the packers and (b) transient pressure effects associated with the drilling of the boreholes;
- Small-scale, single-hole tests of horizontal hydraulic conductivity do not produce values that are representative of significant volumes of rock and do not test the hydraulic continuity of the unit tested;
- Vertical hydraulic conductivity, effective porosity, and the storage characteristics of the basalts and interbeds have not been tested significantly;

- Because of these inadequancies in basic hydrogeologic investigations and the lack of a well integrated regional modeling effort, defensible external and internal hydrogeologic boundaries have not been defined;

- Hydrochemical data have not been related systematically to hydraulic data to support interpretations of flow systems (NUREG-0960, Chapter 3).

Based on the testing to date, a variety of conceptual models of the flow system at the BWIP site can be developed. A selection of such models is shown in Figure 1. The conceptual models are geologically similar to the extent that each incorporates a sequence of layered basalt flows intercalated with sedimentary interbeds. However, due to variable intra- and inter-flow structures, the models are dissimilar from the point of view of their hydrogeologic performance when acting as a host rock for a nuclear waste repository (NUREG-0960, Appendix D).

On the basis of the weaknesses in the testing program to date, the NRC staff considers that neither the appropriate conceptual models of the flow system nor the representative values of its governing parameters are known at present. In order to develop models supported by the hydrogeologic data necessary and sufficient for licensing assessment, the NRC staff considers that a modified approach is required to define what the groundwater system is, how it behaves now, and how it can be expected to respond to perturbations induced by the repository.

1.4 Large-Scale, Multiple-Well Pump Tests

The importance of large-scale, multiple-well pump tests was stated in NUREG-0960. "Such tests would facilitate objective verification of any conceptual model, provide bulk values of hydraulic parameters including vertical hydraulic conductivity, improve hydraulic head data, provide information on hydrogeologic boundaries, and permit calibration of the numerical model so that defensible travel times can be estimated" (NUREG-0960 p. 3-11). In addition to these reasons, large-scale tests are required at the BWIP for the following reasons:

a) minimization of drilling mud effects on hydraulic property measurements (NUREG-0960, Appendix I);

b) hydraulic boundary detection, location and characterization (NUREG-0960, Appendices E and H);

c) demonstration of the presence or absence of hydraulic continuity of flow tops (NUREG-0960, Appendices E and L);

d) investigation of the degree of vertical hydraulic isolation of flow tops (NUREG-0960, Appendix E).

Large-scale tests can minimize the adverse effects of drilling mud on hydraulic property testing. Small-scale tests, such as "slug" tests, can be affected significantly by drilling mud, as noted in NUREG-0960, Appendix I. The drilling mud can, in fact, affect the measurement of hydraulic conductivity by "slug" tests although the effect on the raw data may not be detectable. This assertion has been verified by Lester, Thomas and Faust (1983). Large-scale tests with multiple wells minimize, if not eliminate, the adverse effects of drilling mud so that reliable measurements of hydraulic conductivity can be obtained.

Large-scale tests using multiple wells facilitate the detection and location of hydrogeologic boundary conditions at depth that may not be detectable by any other means. The water-level response in the multiple wells permits the evaluation system of the type of hydrogeologic boundary encountered as well as the location of the boundary. Boundary detection is important to the selection of the appropriate conceptual model and to the prediction of travel time.

Hydraulic continuity can be determined with a large-scale test using multiple observation wells. Monitoring the water-level response in the observation wells to pumping provides a direct method of determining aquifer continuity within the radius of influence of the pump test. The differences in hydraulic response between continuous and discontinuous systems are significant. If observation wells in a flow top that is being pumped do not respond to the pumping, then more careful evaluation of the hydraulics of the flow system is required, because the values of the hydraulic properties control the areal extent of the cone of depression. The existence of hydraulic continuity at the scale or scales of interest must be ascertained prior to the adoption of a layered aquifer system as a conceptual model.

Vertical hydraulic isolation of the units can be determined via large-scale tests using appropriately located observation wells that are located within the unit being pumped or that are isolated in units underlying and overlying the pumped unit. Large-scale tests can be used to measure vertical hydraulic conductivity and to determine the degree of vertical isolation. The effects of anisotropic and heterogeneous conditions which are not located within the limited area of influence of a small-scale, single-well test often can be detected by large-scale tests.

The large-scale, multiple-well pump tests proposed in this technical position would be used to determine hydraulic parameters that integrate the effects of hydrogeologic discontinuities at a variety of scales over relativey large volumes characterized by the radial distance between the pumping well and the observation wells (NUREG-0960, Chapter 3 and Appendix E). This approach to collecting hydraulic data is appropriate for defining the groundwater flow system at spatial scales of tens of meters to kilometers, including the spatial scale of the distance from the repository to the accessible environment. If more detailed knowledge of the properties of discontinuities is required (e.g., information on the dual-porosity nature of fractured basalt), specialized methods of analyzing test results may be required (e.g., Earlougher, 1977, Chapter 10). To produce defensible hydraulic data at spatial scales appropriate to processes within the repository, which will require highly site-specific and detailed information, it will be necessary to integrate the testing approach presented in this technical postion with tests and measurements performed in the exploratory shaft and in-situ test facilities.

2.0 A TESTING STRATEGY FOR THE GROUNDWATER FLOW SYSTEM AT THE BWIP SITE

2.1 Constraints

The strategy presented in this site technical position has been developed in light of the following constraints and objectives:

1. The existing work should be utilized to the fullest extent possible, both with respect to the available data and to the available facilities.

2. The strategy should be flexible, so that it can be adjusted in response to the results of on-going testing and modeling at any time during the program.

3. The strategy proposed should use conventional techniques and proven equipment, to the extent practicable.

4. The time schedule of NWPA must be adhered to, to the extent practicable.

5. The cost of the testing strategy must be reasonable in light of the limited resources and time of the project.

In addition, the proposed testing strategy has been developed by the NRC staff on the assumption that the repository horizon will be within the Grande Ronde Formation. If the final selection of the repository horizon is outside the Grande Ronde, then changes to the details of this strategy would be necessary. However, the NRC staff considers that the philosophical framework and the logic of the approach presented in this site technical position can be adapted readily to any potential repository horizon in the basalts at the Hanford site.

Additionally, this site technical position was developed on the basis of information available to the NRC staff from the BWIP Site Characterization Report (SCR) and the July, 1983 Hydrogeology workshop concerning site conditions and facilities.

Finally, this site technical position assumes that the EPA standard as applied to 10 CFR 60.112 is in a form consistent with the Final 10 CFR Part 60. If significant changes are made to the EPA standard, the NRC staff may wish to revise this site technical position.

2.2 Approach

The approach to investigation described in this site technical position paper is based on the following steps:

1. <u>Preliminary Activities</u>

   - installation of a trial piezometer string;
   - installation of a piezometric and hydrochemical monitoring network in selected existing and new boreholes;
   - installation of continuous water-level-monitoring recorders in all other deep, open boreholes at the BWIP site;
   - performance of a head and hydrochemistry survey of the site.
   - development of a technical consensus that the piezometric baseline has been established.

2. <u>Large-Scale Pump Test</u>

   - design, installation and performance of large-scale, long-term pump test in at least one location near the RRL (e.g., at DC-16C);
   - evaluation of need for further testing using appropriate performance assessment methodology (see Figure 5 and discussion in Appendix A).

3. <u>Additional Large Scale Testing (if needed)</u>

   - design, installation of wells, and performance of long-term pump tests at other sites adjacent to or on the RRL (e.g., DC-4/5, DC-3, RRL-2, and possibly the McGee well);
   - evaluation of the need for further testing using performance assessment methodology.

4. <u>Additional Local Scale Testing (if needed)</u>

   - design, installation of wells, and performance of local-scale tests (pump tests, dual-well tests) adjacent to existing or new monitored boreholes on or near the RRL (e.g., RRL-4, RRL-6, RRL-14, DC-1/2, DC-X (a new hole southwest of the repository), DC-18 and the McGee well).

In each case, the length of the test and the rate of pumping of the well should be as large as possible within the constraints of equipment and aquifer performance (e.g., achieve maximum drawdown and maximum cone of depression) in the host rock.

Details of the testing program are given in Appendix A; graphical representations of the logic of the program are given in Figures 2 to 5. The program generally uses boreholes which are open in the Grande Ronde Formation for observation of hydraulic head in the Grande Ronde. New wells are anticipated for most of the pumping locations and for most of the head-monitoring locations in units above the Grande Ronde Formation (Figure 2). The NRC staff considers that, to the extent practicable, new boreholes should be drilled using air-rotary technology in order to avoid the potential effects of mud on hydraulic test results.

At several points in the flow diagram of Figure 4, there is a notation of need for consultation between NRC and DOE. These are critical programmatic decision points, and the NRC staff considers that further consultation would be prudent.

2.3 Schedule and Cost

One of the criteria considered in the development of this site technical position is that the cost and schedule for any revised program be acceptable within the relevant constraints (Section 2.1.4). Rough estimates, based on industry cost experience for drilling, equipment, and testing, suggest that the cost of the revised program should fall within the range of $3 million to $10 million, exclusive of administrative overhead. The final preliminary activity is the development of a technical consensus that a piezometric baseline has been established, based on the results of the hydraulic-head survey of the site. Large-scale hydraulic testing would not begin until consensus has been reached (see Figures 3 and 4). A rough estimate of the elapsed time for completion of the testing program, exclusive of time needed to mobilize equipment, is estimated at between one and two years, depending on the outcome of the large-scale tests and on the time required to demonstrate the existence of steady-state or long-term trending, transient-state hydraulic conditions.

The staff considers that it would be prudent for BWIP to avoid major perturbations to the groundwater system during the period of hydraulic testing. If major perturbations do occur, for example, from the sinking of the exploratory shaft, it will be necessary for BWIP to determine the effects on the groundwater system or to demonstrate again that a piezometric baseline exists before continuing with hydraulic testing.

2.4 Relationship of this Program to Other Hydrogeologic Field Investigations

This site technical position addresses in detail only the investigations of the hydraulics of the groundwater system at the Hanford site. However, NUREG-0960 identified other areas in the BWIP program for hydrogeologic characterization of the site that require additional testing to address remaining key issues. These areas include evaluation of solute transport parameters (dispersivity, retardation, and effective porosity), long-term hydraulic head conditions, and long-term hydrochemical conditions. Many of the facilities which would be installed under the program described in this site technical position also are appropriate for testing required to address these areas.

2.4.1 Solute Transport Parameters

The standard method of evaluating solute transport parameters is to perform tracer tests between boreholes that are spaced a relatively short distance apart (e.g., DC 7/8). If sensitivity studies indicate that characterization of fractures is important for modeling radionuclide transport, detailed analyses of hydraulic and tracer tests in paried boreholes can be used to assess the fractured media (e.g., Earlougher, 1977; Grisak and Cherry, 1975; Grove and Beetem, 1971; Hsieh et al., 1983). If still more detailed information is required, e.g., for very-near-field transport modeling, hydraulic and tracer test data can be coupled with data on fracture parameters collected in the in-situ test facility or through the use of borehole logging techniques such as acoustical televiewers (e.g., USGS, 1983). In addition to the paired boreholes already in place, the program described in this site technical position, if carried out to stages 3 or 4, would provide a considerable number of such pairs of boreholes open to each horizon of potential interest. If hydraulic testing is completed after stage 2, then boreholes for tracer testing may have to be drilled at critical locations because additional test probably will be needed to develop an adequate data base for transport modeling. The number and exact location of additional paired boreholes for tracer testing should be determined after analyzing results of the hydraulic testing.

2.4.2 Long-Term Measurements of Hydraulic Heads

An essential objective of this hydraulic test program is to obtain a detailed three-dimensional, temporal record of hydraulic head over the controlled area. This record would provide an initial data base for pre-development piezometric conditions, including calibration of the external boundary conditions, and a record of the hydraulic effects of all subsequent drilling, testing, and subsurface exploration. In addition to monitoring the pre-emplacement activities, the head-monitoring system would be capable of monitoring long-term activities at the site.

2.4.3 Long-Term Data on Hydrochemistry

The extensive network of depth-specific sampling points proposed in this program would allow periodic sampling of groundwater from each geologic unit. Such a sampling program would facilitate further evaluation of groundwater chemistry by providing for repeated collection of pressurized samples and by preventing mixing of waters from different elevations within each borehole.

3.0 CONCLUSION

This site technical position provides a broad summary of an approach that the NRC staff would find acceptable for developing and then evaluating the hydrogeolgic investigation program at the BWIP site. The proposed approach takes advantage of the existing facilities and previous experience at Hanford, including the geological characterization of the site and the existence of boreholes open in the Grande Ronde Formation. In addition, the physical installations needed to implement this program also could be used in testing to obtain the data needed to address the areas of solute transport, long-term measurements of hydraulic head, and hydrochemistry.

The hydraulic testing strategy which is described in this document is not necessarily the only approach which would lead to an acceptable hydraulic data base and performance assessment; nor is it intended to be a blueprint for the DOE or its contractors. However, the method of arriving at a testing strategy for site characterization is intended to be representative of the type of strategy expected prior to license application. Because of the dynamic nature of this kind of testing program, the NRC staff considers that continuing consultation between NRC and DOE will be required over the full period of site characterization. This strategy specifically delineates stages at which such consultation would be appropriate. Finally, the staff also wishes to reemphasize the importance of developing defensible boundary conditions and conceptual models for the groundwater flow systems.

APPPENDIX A - DETAILS OF APPROACH

A1 STAGE 1. PRELIMINARY ACTIVITIES

1A. Complete one hole in the Grande Ronde Formation.

This completion would serve to test the effectiveness of the selected completion technique. The completion method which probably would be of greatest utility in this program would be a temporary piezometer string with multiple ports completed in the Grande Ronde in order to obtain data on each flow top and each dense interior of the formation. Each completion interval would be equipped to allow the water pressure to be read using a down-hole tool and also to allow a water sample to be taken under pressure. At least one commercial piezometer system is currently available for this purpose, and it has been used successfully at the depths contemplated at the BWIP site. If such a system were not successful at BWIP, then more conventional completion approaches would have to be used.

1B. Install continuous water level recorders

In order to monitor water levels in all boreholes on a continuous basis, water-level recorders would be installed in all boreholes open to the Wanapum or Grande Ronde units. These boreholes currently include the following: DC-1, DC-2, DC-3, DC-4, DC-5, DC-6, DC-7, DC-8, DC-12, RRL-4, RRL-6, RRL-14, DC-16A, and C and all of the wells in the McGee cluster. These monitoring wells would record the temporal variation of the composite water levels in the entire deep basalt rock mass. They would be capable of recording the effects of any testing on any part of the site. (Note that as the rest of this program progresses, it will be necessary to remove some of the recorders to allow completion of some holes). There are a variety of commercially available recorders which are capable of being used for this purpose.

1C. Install head and hydrochemistry monitoring system

The installation of the area-wide piezometer and hydrochemistry monitoring network would begin immediately. A possible network is shown in Figure 2, although other networks also are feasible.

The suggested network includes a total of ten new holes, of which six would be drilled to below the Umtanum unit (DC-18, DC-X, DC-19, DC-20, DC-22, 57-83) and four would be drilled to the base of the Wanapum unit (at the locations of DC-4/5, DC-3, DC-16, and RRL-2). Each of the boreholes would then be completed with piezometers using the technology proven in Stage 1A. It is considered that the arrangement shown would provide adequate investigation of the currently proposed controlled area and of depths to below the Umtanum unit.

1D. Perform head and hydrochemistry survey of site.

A full suite of head measurements and water quality samples (if feasible) would be taken from the installations described above after the completion of drilling and the decay of the major transients caused by the closure of the existing vertical flow conduits. This survey would produce the first time-coincident head and water quality survey of the site; it also would provide needed information on the pre-emplacement head gradients and water quality. After the inital survey, a regular (e.g., monthly) monitoring survey of heads would be maintained through the remainder of the site characterization program.

1E. Develop a technical consensus that piezometric baseline has been established.

Before large-scale pump tests can be performed and successfully analyzed, a piezometric baseline must be established that shows the existence of steady-state or predictable, long-term trending, transient-state hydraulic conditions. This is a critical decision point in the testing strategy, and decisions on existence of an adequate piezometric baseline will be based on expert technical judgment. The NRC staff considers that it would be prudent for DOE to solicit review by NRC and others as an approach to developing a technical consensus that a piezometric baseline which is adequate for use in defensible assessments with respect to 10 CFR Part 60 has been established.

Additionally, the staff considers that it would be prudent for BWIP to avoid major perturbations to the groundwater system during the period of hydraulic testing. If major perturbations do occur, for example, from the sinking of the exploratory shaft, it will be necessary for BWIP to reestablish that piezometric baseline conditions exist or to determine quantitatively the effects of the perturbation on the groundwater flow system before continuing with hydraulic testing.

A2. STAGE 2. LARGE-SCALE PUMP TEST

2A. Design and pre-analyze the large-scale pump test

After completing the preliminary activities, a large-scale pump test would be designed and pre-analyzed. The general arrangement of the pump test facilities could be as follows:

- a piezometer with multiple completions in a number of the permeable horizons in the Grande Ronde and Wanapum Formations;

- a pumping well which is open to the entire Grande Ronde down to the base of the Umtanum unit; the well would be capable of pumping from any selected horizon by use of bridge packers or other, similiar devices;

- other nearby piezometer strings installed during Stage 1.

The location of the test well and associated piezometers would be chosen on the basis of existing hydraulic test data. The NRC staff considers that a location in or near the RRL would provide the greatest amount of information (e.g., near RRL-2 or DC-16).

2B Prepare and perform the large-scale pump test

The large-scale pump test would be either from the entire Grande Ronde unit or from a portion of it, depending on the results of the pre-analysis. Pump testing in units above the Grande Ronde also may be required to characterize potential pathways. Each test would run for as long as it takes for conditions to approach steady state. If the effects are extensive, the test might continue in excess of three months; if the effects are local, a few weeks may suffice. Monitoring would be conducted in all piezometers on site, as part of the regular monitoring program initiated in Step 1C, augmented by more frequent monitoring of selected piezometers.

2C. Analyze test and evaluate results

The analysis of the test would be performed using both appropriate closed-form analytical solutions and numerical paramater-matching methods. The results of the testing would provide two, fundamentally different sets of information:

1. A perturbation/response data set for use in validation of computer modeling and direct demonstration of the flow systems.

2. A parameter data set relating to the behavior of the material involved at the scale of the testing, for use in future modeling.

Both sets are needed for site characterization, performance assessment, and preparation for the licensing process.

2D. Decision on the need for additional information

Once all the results of the analysis of the large-scale pump testing and the testing of head and hydrochemistry are complete, a new data base will exist for performance assessment and for conceptual understanding of the site. The decision to continue with hydraulic testing must be made at this point, based upon the results of performance analyses. The process is described below:

1. Perform sensitivity studies of performance using the updated data base. Both the models tested and range of values used to test the sensitivity of specific parameters should consider the updated understanding of levels of uncertainity.

2. Establish the sensitivity of performance to key hydrologic parameters.

3. Is performance clearly acceptable under the EPA/NRC regulations? If so, cease testing for hydrologic parameters. If not, go to the next step.

4. Is performance clearly unacceptable under EPA/NRC regulations? If so, cease testing for all purposes. If not, go to the next step.

5. Will further testing reduce uncertainties sufficiently to allow performance to be defined to required limits for decision making? If so, proceed to next test level. If not, cease testing for hydrologic parameters.

This process is shown schematically in Figure 3.

A3. Stage 3. Additional Large-Scale Pump Testing

If the large-scale pump test described above perturbs only a small volume of basalt, it is likely that additional testing may be needed. The next stage of testing would then be implemented. This stage would involve large-scale tests at up to four locations on or close to the RRL (e.g., near DC-4/5, DC-3, RRL-2, and possibly the McGee wells).

The test design would be similar to that used for Stage 2. A large-diameter well open to the entire Grande Ronde Formation would be drilled adjacent to the piezometer string already completed at each site; selected intervals in this well would be pumped in order to stress the surrounding rock-mass. The response (if any) to this pumping would be measured in all piezometers on the site. In addition, a flow velocity profile would be taken during pumping to define where the water was being produced in the well. Test duration would be until steady-state conditions are approached, which is expected to be between one week and several months.

For each of these tests, the process of design, pre-analysis, preparation, performance, analysis and evaluation would be identical to the process described for Stage 2. At the end of this stage, a minimum of two areas would have been tested to the same degree using large-scale technology.

Additional testing of the overlying units, particularly the Wanapum, may be required for site characterization if a clear hydraulic connection were identified during the testing of the Grande Ronde. In this case, a second test, pumping from a new well open to all or part of the Wanapum, would be designed, performed and evaluated using the same procedures proposed for the testing of the Grande Ronde. Note that many of the piezometers needed for such a test would be in place already.

A4. Stage 4 - Additional Local Tests

It is possible that the testing performed to this point will have characterized only a small volume of rock surrounding the test wells, such that the data collected represent values of hydraulic properties only in the vicinity of the test locations. If this occurs, then the decision process may show that further values of the key parameters are needed. In order to obtain these values, the fourth stage of the testing program would be implemented. Local-scale tests would be conducted at various sites (e.g., near RRL-4, RRL-6, RRL-14, DC-1/2, DC-12, DC-X, DC-18, and the McGee wells, if not tested previously).

These tests would involve the drilling of a pumping well adjacent to the existing piezometer strings at these locations and pumping from it in a manner similar to that used for previous tests (e.g., at DC-16B). If this stage of testing is needed, the head effects created by this pumping will be localized, so it is likely that monitoring will only be effective at the adjacent piezometer well. Consequently, the tests will be of short duration (1-4 weeks), and it may be advantageous to perform additional, detailed two-hole tests to determine parameter values in key locations (see, for example, Hsieh et al., 1983) using the existing pairs of wells and piezometers.

Again, the general process of design, pre-analysis, preparation, preformance, analysis and evaluation for these tests would be similar to that used in previous tests. Testing would cease when adequate definition was obtained, as defined by the logic of Figure 3.

A5. Stage 5 - Single Hole-Testing

In the event that no response to well-pumping could be felt in piezometers as little as 50 meters away, then the only viable exploratory technique available would be single-hole testing. Single-well technology has been used extensively on the site already, and it would appear that little more could be learned about the site by further testing of this sort. If site characterization depended on this type of testing alone, the testing program probably will not provide the hydrogeologic data necessary and sufficient for licensing assessments under 10 CFR Part 60 unless a very large number of small-scale tests are performed. Given the wide range of values of hydraulic parameters and the current inability to integrate those values into a defensible three-dimensional distribution of parameters for numerical modeling, the staff considers that small-scale hydrogeologic testing of a statistically significant number of single boreholes to determine representative values for defensible performance analysis of the site is virtually impossible in light of limited resources and the schedule imposed by NWPA. However, if BWIP chooses to pursue a site characterization program based on single-hole testing, then heavy dependence would have to be placed upon model calibration using the accurate temporal head and geochemical data collected from the multiple piezometer strings in the deep holes. Even in this case, the installation of piezometer strings and the hydraulic heads and hydrochemical data monitored in them would be an integral part of the test strategy.

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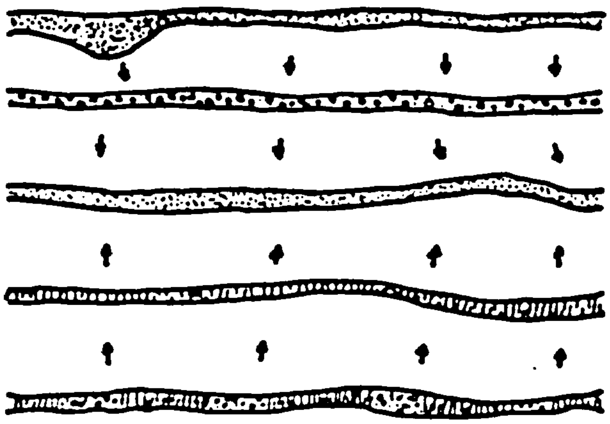
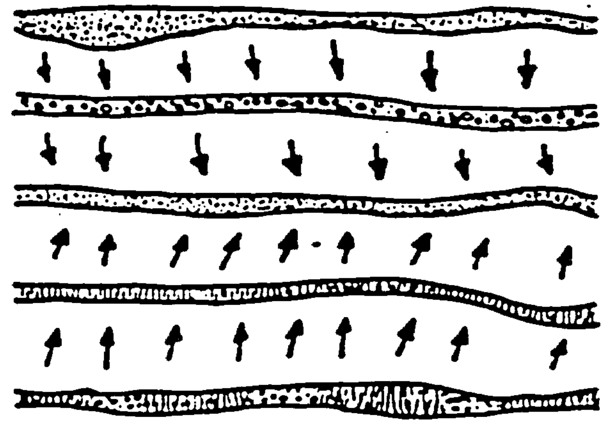
ALTERNATIVE CONCEPTUAL MODELS

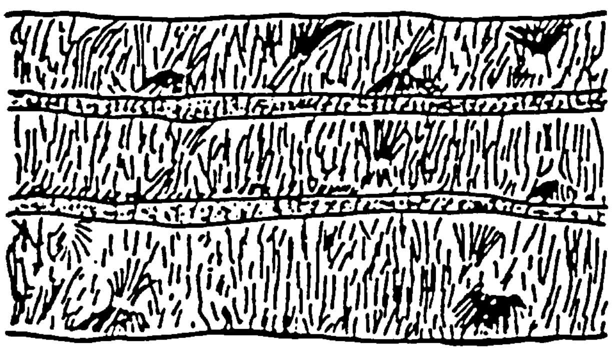
Figure 1



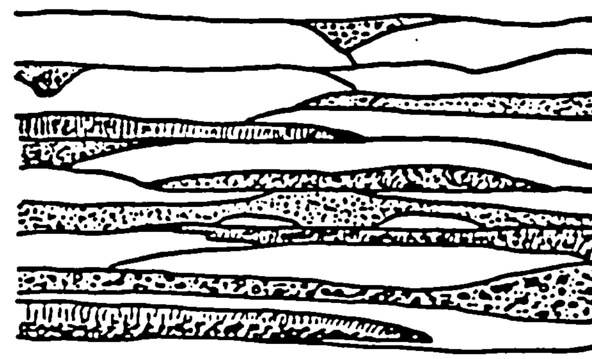
CONTINUOUSLY-LAYERED; LOW K_V



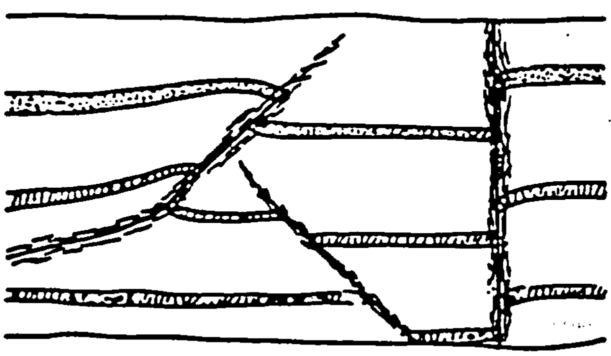
CONTINUOUSLY-LAYERED; HIGH K_V



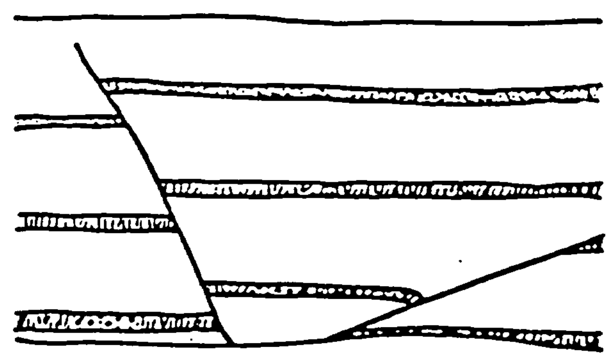
HOMOGENEOUS; ANISOTROPIC



DISCONTINUOUSLY-LAYERED



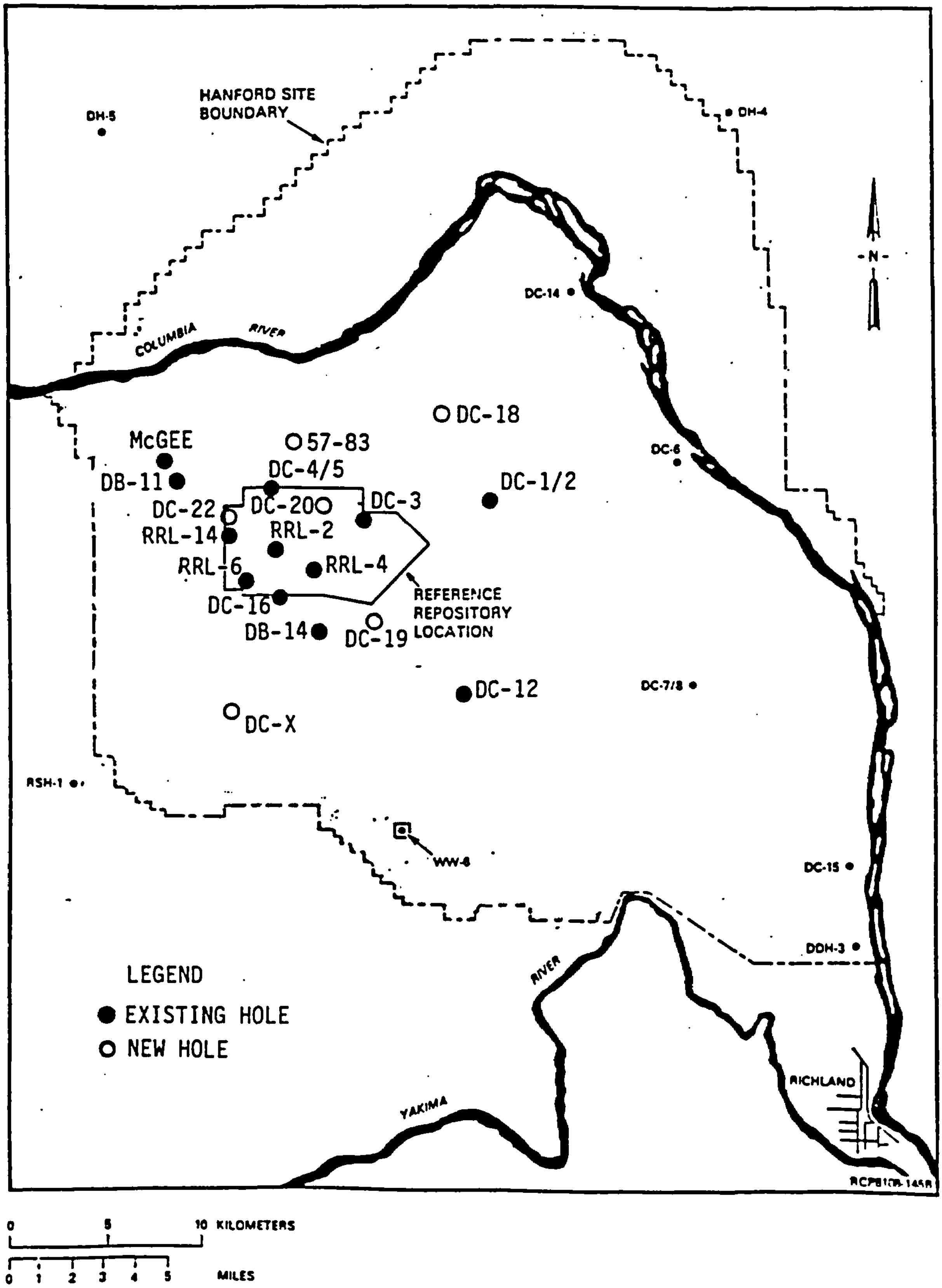
HIGH PERMEABILITY DISCONTINUITIES



LOW PERMEABILITY DISCONTINUITIES

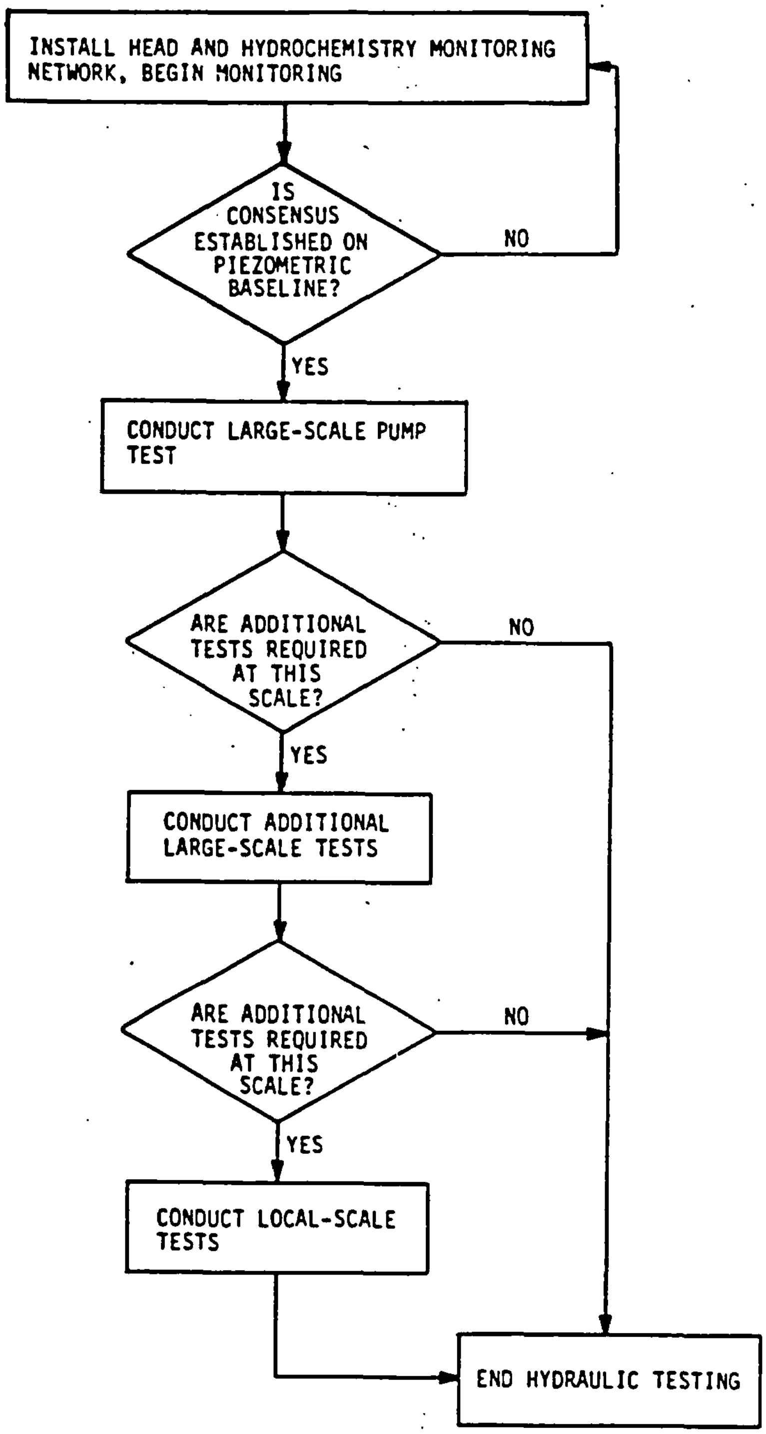
BOREHOLE LOCATIONS

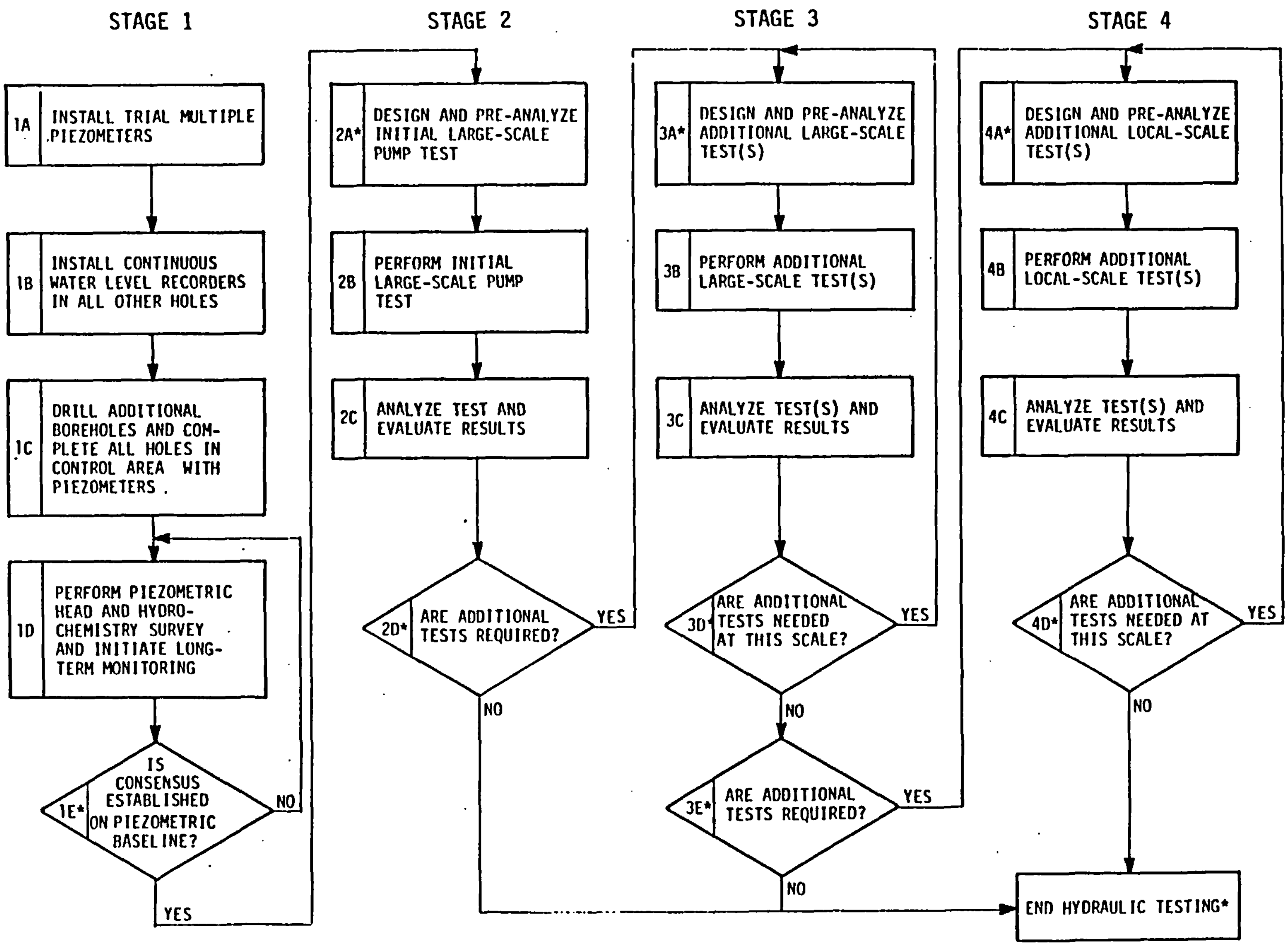
Figure 2



SUMMARY LOGIC CHART FOR A POSSIBLE GROUNDWATER TESTING STRATEGY AT THE BWIP SITE

Figure 3





*NRC CONSULTATION AND REVIEW

DETAILED LOGIC CHART FOR A POSSIBLE GROUNDWATER TESTING STRATEGY AT THE BWIP SITE

Figure 4

DECISION MAKING PROCESS FOR TESTING AT BWIP

Figure 5