SITE TECHNICAL POSITION (STP)

Groundwater Issues
for the Basalt Waste Isolation Project (BWIP)

BWIP STP 1.0

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Site Technical Position - Groundwater Issues For

The Basalt Waste Isolation Project

Background

In review of an application for Construction Authorization for a high-level waste geologic repository, the NRC staff is required to make a determination as to whether the site and design meet the Technical Criteria of 10 CFR Part 60 (Subpart E). The NRC staff determination will be based on the answers to, and supporting analyses of, technical questions concerning the geologic setting and the engineered barrier system. During the process of Site Characterization, the Department of Energy (DOE) performs the laboratory and field investigations that develop the information needed to address these basic technical questions.

Investigations needed to characterize a geologic repository are complex and involve long lead times. The Nuclear Waste Policy Act of 1982 (The Act) has established a schedule for site characterization and selection. Specifically, The Act requires publication of Site Characterization Plans (SCP's) by DOE at an early stage of the process. Subsequent to the receipt of an SCP the NRC must prepare a formal Site Characterization Analysis (SCA) for each site. Documented site reviews, technical meetings, and single-issue site technical position papers will precede and supplement the SCA's.

Because of the complexity and long lead times for site characterization investigations, it is essential that activities be organized to make possible an NRC determination regarding site acceptability. Proper organization necessitates early identification of technical questions relevant to the specific site. Therefore, this document establishes the NRC position as to the essential technical questions (specific issues) relevant to groundwater at the Basalt Waste Isolation Project (BWIP) site. Other Site Technical Positions relevant to groundwater will address both NRC staff concerns regarding selected specific issues and acceptable technical approaches for addressing those specific issues.

Terminology used by NRC staff to describe issues is as follows:

Site issues are defined as questions about a specific site that must be answered or resolved to complete licensing assessments of the geologic setting and engineered barrier system design suitability in terms of 10 CFR 60. Site

issues are not necessarily controversial questions. Site issues can be divided into performance issues and specific issues.

Performance Issues are broad questions concerning both the operational and long-term performance of the various elements of the overall geologic repository system (i.e., engineered barrier subsystems, geologic setting). Performance issues are derived directly from performance objectives in 10 CFR 60 (including environmental objectives of 10 CFR 51). Performance issues include the integration of numerous specific issues.

Specific Issues generally are questions about conditions and processes (information needed) that must be considered in assessing the performance issues. Performance issues establish the relationship between specific issues discussed in this Site Technical Position and the performance objectives of 10 CFR 60.

Performance issues for a geologic repository, as developed in NUREG-0960 are:

1. How does the conceptual design address releases of radioactive materials to unrestricted areas within the limits specified in 10 CFR 20?

2. How does the conceptual design accomodate the retrievability option?

3. When and how does water contact the backfill?

4. When and how does water contact the waste package?

5. When and how does water contact the waste form?

6. When, how, and at what rate are radionuclides released from the waste form?

7. When, how, and at what rate are radionuclides released from the waste package?

8. When, how, and at what rate are radionuclides released from the backfill?

9. When, how, and at what rate are radionuclides released from the disturbed zone?

10. When, how and at what rate are radionuclides released to the accessible environment?

11. What is the pre-waste emplacement groundwater travel time along the fastest path of radionuclide travel from the disturbed zone to the accessible environment?

12. Have the NEPA Environmental/Institutional/Siting requirements for nuclear facilities been met?

Because groundwater is a primary transporting agent for radionuclide migration, information on the groundwater system collected during site characterization at BWIP will be part of the total repository system information needs of the NRC staff required to assess the performance issues. Specific issues identified in the following section delineate information on groundwater at BWIP needed by the NRC staff to adequately assess the performance issues. The sequential order in which issues are identified should not be interpreted as the order of relative importance.

Technical Position

It is the position of the NRC staff that, based on our current level of knowledge of the BWIP site, assessment of compliance with the relevant technical criteria of 10 CFR 60 and 10 CFR 51 requires that, at a minimum, the following specific issues concerning groundwater be addressed.

1.0 Groundwater

1.1 What is the nature of the present groundwater system?

1.1.1 What is the nature of the present regional groundwater system?

1.1.1.1 What is (are) the conceptual model(s) of the present regional groundwater system?

1.1.1.1.1 What are the regional hydrogeologic boundaries, boundary conditions, recharge and discharge locations, mechanisms and amounts?

1.1.1.1.2 What are the distributions of measured and interpolated hydraulic parameters that affect groundwater flow in the region?

1.1.1.1.3 What are the hydrostratigraphic units and structures within the regional groundwater system, and how and to what extent do they affect groundwater flow?

1.1.1.2 What are the groundwater flow paths and velocities for the regional groundwater system?

1.1.1.3 What are the uncertainties associated with each of the issues and sub-issues in sections 1.1.1.1 and 1.1.1.2?

1.1.2 What is the nature of the present sub-regional groundwater system?

1.1.2.1 What is (are) the conceptual model(s) of the present sub-regional groundwater system (including the near-field)?

1.1.2.1.1 What are the hydrogeologic boundaries, recharge and discharge locations, mechanisms and amounts for the sub-region?

1.1.2.1.2 What are the distributions of measured and interpolated hydraulic parameters affecting groundwater flow for the sub-region?

1.1.2.1.3 What is the hydrochemistry of the sub-regional groundwater system?

1.1.2.1.4 What are the hydrostratigraphic units and structures within the sub-regional groundwater system, and how and to what extent do they affect sub-regional groundwater flow?

1.1.2.2 What are the groundwater flow paths and velocities for the sub-regional groundwater system?

1.1.2.3 What are the uncertainties associated with each of the issues and subissues listed in sections 1.1.2.1 and 1.1.2.2?

1.1.3 What mathematical models are used to predict groundwater flow in the region and sub-region?

1.2 What are the types, probabilities, and natures of changes that would affect groundwater flow in the region or sub-region?

1.2.1 What are the types, probabilities, and expected effects over time on groundwater flow paths, velocities and/or fluxes, discharge rates and travel times, of repository-induced changes (including underground facility construction, borehole and/or shaft seal failure, thermal effects upon hydraulic gradients, hydrologic properties, and long-term stability and alteration of matrix- and fracture-filling minerals)?

1.2.2 What are the types, probabilities, and expected effects over time on groundwater flow paths, velocities and/or fluxes, discharge rates and travel times, of human-induced changes, excepting repository-induced changes (including water resource development, exploratory drilling, mine development for resources or other human activities)?

1.2.3 What are the types, probabilities, and expected effects over time on groundwater flow paths, velocities and/or fluxes, discharge rates and travel times, of natural changes (including those changes caused by future climatic, structural and tectonic events and processes)?

1.2.4 What are the uncertainties associated with each of the items in sections 1.2.1 through 1.2.3?

The rationale for each issue is described in the following discussion.

<u>Discussion</u>

1.0 Groundwater

The groundwater issues identified below will need to be addressed in order to address each of the twelve performance issues listed on page 2.

1.1 What is the nature of the present groundwater system?

Groundwater is the primary transporting agent for radionuclide migration from a geologic high-level waste (HLW) repository. The NRC Rule (10 CFR 60) requires:

- That radionuclide releases conform to such generally applicable standards established by the EPA (10 CFR 60.112).
- A specified pre-waste-emplacement groundwater travel time from the accessible environment (10 CFR 60.113(a)(2)).
- That the favorable and potentially adverse conditions identified in 10 CFR Parts 60.122 (b) and (c), respectively, be considered in repository siting.

The groundwater system should also be understood to some degree in order to satisfy the design criteria related to control of water intrusion to the underground facility (§60.133 (d)), and to rock excavation techniques (§60.134).

1.1.1 What is the nature of the present regional groundwater system?

The nature of the present regional groundwater system should be known in order to address performance issues 9 through 12, as listed on page 2. The nature of the regional groundwater system is defined by the conceptual model(s) of the system, and resultant predictions of system behavior based on the conceptual model(s). The level of quantitative and qualitative detail necessary for the conceptual models and performance predictions is dictated by the objectives and requirements of each model application.

1.1.1.1 What is (are) the conceptual model(s) of the present regional groundwater system?

The conceptual model of the regional groundwater system provides the hydrogeologic framework for evaluating the nature and significance of the hydrogeologic processes in the region that may affect repository performance. A conceptual model for a given application consists of a characterization of those features of the real system needed to define the relevant behavior of the system. For the purposes of 10 CFR 60.112 and 60.113 compliance assessments, a conceptual regional hydrogeologic model would include, at a minimum, such components as hydrostratigraphic units, recharge and discharge areas, major

structures and discontinuities, distribution of groundwater hydraulic parameters, locations of hydrologic stresses, and degree of transience.

The level of spatial and temporal detail necessary for a regional model would likely be lower than for a sub-regional model. The appropriate level of detail for each conceptual model application should be identified through sensitivity studies (of the appropriate level of sophistication).

A range of defensible conceptual models of the regional groundwater system should be developed that brackets all reasonable interpretations of data.

1.1.1.1.1 What are the regional hydrogeologic boundaries, boundary conditions, recharge and discharge locations, mechanisms and amounts?

This information is necessary to define the conceptual model of regional groundwater flow in terms of general flow direction and volume. The boundaries will define the scale of the regional groundwater system, which is expected to be roughly of the scale of the Pasco Basin.

1.1.1.1.2 What are the distributions of measured and interpolated hydraulic parameters affecting groundwater flow in the region?

Defensible interpretations of the three-dimensional spatial and temporal distribution of hydraulic parameters affecting groundwater flow are necessary to make quantitative determinations regarding compliance with 10 CFR 60.112 and 60.113 and presence of favorable and potentially adverse conditions related to groundwater noted in section 1.1. The parameters for which information is necessary to make these determinations include but are not necessarily limited to hydraulic conductivity, storativity, total porosity, effective porosity, and hydraulic head.

1.1.1.1.3 What are the hydrostratigraphic units and structures within the regional groundwater system, and how and to what extent do they affect groundwater flow?

The lithology and stratigraphy of the Pasco Basin basalts, interbeds, and suprabasalt sediments are likely to have a controlling effect on groundwater flow in the region. Identification of the units and structures controlling regional groundwater flow, and of their degree of spatial continuity, is a necessary component of a regional groundwater flow model. The effect that these structures and hydrostratigraphic units, and associated structural and

stratigraphic discontinuities, have on the regional groundwater system should be assessed in order to evaluate compliance with the performance objectives of 10 CFR 60.

1.1.1.2 What are the groundwater flow paths and velocities for the present regional groundwater system?

The conceptual model of the regional groundwater system will be combined with appropriate mathematical models of groundwater flow to identify and calculate potential groundwater flow paths and velocities. This information will be used to assess compliance with the criteria of 10 CFR 60.112 and 60.113, as well as to identify favorable and potentially adverse siting conditions. The spatial and temporal scales at which the calculations are carried out must be relevant to the nature of the problem studied (i.e., radionuclide transport, general groundwater flow, etc.)

1.1.1.3 What are the uncertainties associated with each of the issues and sub-issues in sections 1.1.1.1 and 1.1.1.2?

The conceptual model of the regional groundwater system, including its associated hydrogeologic parameter values, and the resultant predicted flow paths and velocities, can never be identified with complete accuracy due to measurement errors, incomplete sampling or testing within the spatial or temporal domains, alternative testing interpretations, etc. The degree and nature of uncertainty in individual parameters and in the resultant conceptual model(s) should be identified and characterized in terms of probabilistic distributions (with confidence levels reflecting the amount of data which supports the chosen distribution) or bounding values. Uncertainty in data and conceptual models for the regional groundwater system will contribute to uncertainty in evaluations of compliance with the requirements of 10 CFR 60. An acceptable level of uncertainty is that which will permit the licensing review board to make a finding as to the existence of reasonable assurance of compliance with the regulatory criteria.

1.1.2 What is the nature of the present sub-regional groundwater system?

THe nature of the present sub-regional groundwater system should be known in order to address each of the twelve performance issues listed on page 2. The nature of the sub-regional groundwater system is defined by the conceptual model(s) of the system, and resultant predictions of system behavior based on the conceptual model. The level of quantitative and qualitative detail

necessary for the conceptual models and performance predictions is dictated by the objectives and requirements of each model application.

1.1.2.1 What is (are) the conceptual model(s) of the present sub-regional groundwater system (including the near-field)?

The conceptual model of the sub-regional groundwater system provides the hydrogeologic framework for evaluating the nature and significance of the hydrogeologic processes that may affect repository performance. As noted in section 1.1.1, a conceptual model consists of a characterization of those features of the real system needed to define the relevant behavior of the system. For the purposes of 10 CFR 60.112 and 60.113 compliance assessments, a conceptual sub-regional hydrogeologic model would include, at a minimum, such components as hydrostratigraphic units, local inflow and outflow (or recharge and discharge) areas, local structures and discontinuities, distribution of hydraulic parameters, locations of hydrologic stresses, and degree of transience. For evaluations of the degree of transience, the impact of Hanford site activities, such as drilling, pumping, injecting, and waste disposal, on the sub-regional groundwater system should be assessed.

The level of spatial and temporal detail necessary for a sub-regional model would likely be higher than for a regional model, depending on the precise application of the model. For example, to characterize the sub-regional groundwater system for analyses of compliance with 10 CFR 60.112, it may be necessary to obtain detailed information about individual fracture systems that may provide hydraulic connectivity in the deep basalts. The appropriate level of detail should be identified for each given application of the conceptual model through parametric sensitivity studies (of the appropriate level of sophistication).

A range of defensible conceptual models of the sub-regional groundwater flow system should be developed that brackets all reasonable interpretations of data.

1.1.2.1.1 What are the hydrogeologic boundaries, recharge and discharge locations, mechanisms and amounts for the sub-region?

This information is necessary to define the conceptual model of sub-regional groundwater flow in terms of general flow direction and volume. The boundaries will define the scale of the sub-regional groundwater system, which is expected to be roughly of the scale of the Hanford site.

1.1.2.1.2 What are the distributions of measured and interpolated hydraulic parameters affecting groundwater flow for the sub-region?

Defensible interpretations of the three-dimensional spatial and temporal distribution of groundwater hydraulic parameters are necessary to make quantitative determinations regarding compliance with 10 CFR 60.112 and 60.113, and presence of favorable and potentially adverse conditions related to groundwater noted in section 1.1. The parameters for which information in necessary to make these determinations include but are not necessarily limited to hydraulic conductivity, storativity, total porosity, effective porosity, and hydraulic head.

1.1.2.1.3 What is the hydrochemistry of the sub-regional groundwater system?

Hydrochemical data may assist in the development of sub-regional conceptual flow models by providing, for example, verification of the existence of chemically distinct hydrostratigraphic units, or by providing support for hypothetical flow paths in the sub-region based on hydrochemical transport considerations. Information regarding the hydrochemistry will also be valuable for radionuclide transport analyses, a topic which is discussed in more detail in BWIP Site Technical Position 3.0: Geochemistry Issues for the Basalt Waste Isolation Project.

1.1.2.1.4 What are the hydrostratigraphic units and structures within the sub-regional groundwater system, and how and to what extent do they affect sub-regional groundwater flow?

The lithology, stratigraphy, interflow and intraflow structure of the Hanford site basalts, interbeds, and suprabasalt sediments are likely to have a controlling effect on sub-regional groundwater flow. Identification of the units and structures controlling regional groundwater flow, their hydraulic properties and characteristics, and their degree of spatial continuity, is a necessary component of a sub-regional groundwater flow model. The effect that these structures and hydrostratigraphic units, and associated structural and stratigraphic discontinuities (including individual fractures and fracture sets) have on the sub-regional groundwater system, and on the near-field groundwater flow characteristics which govern radionuclide transport, should be assessed in order to evaluate compliance with the performance objectives of 10 CFR 60.112 and 60.113.

1.1.2.2 What are the groundwater flow paths and velocities for the sub-regional groundwater system?

The conceptual model of the sub-regional groundwater system will be combined with appropriate mathematical models of groundwater flow to identify and calculate potential groundwater flow paths and velocities. This information will be used to assess compliance with the criteria of 10 CFR 60.112 and 60.113, as well as to identify favorable and potentially adverse siting conditions. The spatial and temporal scales at which the calculations are carried out must be relevant to the nature of the problem studied (i.e., radionuclide transport, general groundwater flow, etc.)

1.1.2.3 What are the uncertainties associated with each of the issues and subissues listed in section 1.1.2.1 and 1.1.2.2?

The conceptual model of the sub-regional groundwater system, including its associated hydrogeologic parameter values, and the resultant predicted flow paths and velocities, can never be identified with complete accuracy due to measurement errors, incomplete sampling or testing within the spatial or temporal domains, alternative testing interpretations, etc. The degree and nature of uncertainty in individual parameters and in the resultant conceptual model should be identified and characterized in terms of probabilistic distributions (with confidence levels reflecting the amount of data which supports the chosen distribution) or bounding values. Uncertainty in data and conceptual models for the sub-regional groundwater system will contribute to uncertainty in evaluations of compliance with the requirements of 10 CFR 60. An acceptable level of uncertainty is that which will permit the licensing review board to make a finding as to the existence of reasonable assurance of compliance with the regulatory criteria.

1.1.3 What mathematical models are used to predict groundwater flow in the region and sub-region?

A mathematical model is the translation of the conceptual understanding of the groundwater flow system into mathematical expressions describing physical processes. In general, mathematical models are either solved analytically or converted to a set of algebraic equations that are solved numerically. Mathematical models might be used to verify the compatibility of conceptual models with field measurements, and they might be used to predict groundwater and radionuclide travel paths and travel times. It is necessary to show that the mathematical models used are representative of the physics of the

hydrogeological processes being described. For example, if a mathematical model based on the equations of flow through porous media is utilized for a particular application describing flow or transport through fractured basalt, it must be shown that the idealization of the fractured medium as a porous medium for that particular application is a reasonable approximation of the true physical system.

1.2 What are the types, probabilities, and natures of changes that would affect groundwater flow in the region or sub-region?

The long time period for which high-level radioactive wastes (HLW) must be isolated from the accessible environment requires that potential future changes in the groundwater system be considered for possible impacts on HLW isolation. The NRC Rule requires that the geologic setting and engineered barrier system conform to the EPA Standard with respect to both anticipated and unanticipated events and processes, and that the engineered barrier system conform to NRC's technical performance criteria with respect to anticipated processes and events. Therefore both anticipated and unanticipated processes and events affecting groundwater flow over the next 10,000 years (according to the currently proposed EPA Standard) must be identified and considered in demonstrations of compliance with 10 CFR 60. The probabilities of these changes should be identified in order that their significance be properly weighted in demonstrations of compliance with the NRC Rule as a whole, and the EPA Standard in particular. This issue and the following sub-issues are directly related to performance issues 3 through 11 identified on page 2.

1.2.1 What are the types, probabilities, and expected effects over time on groundwater flow paths, velocities and/or fluxes, discharge rates and travel times, of repository-induced changes (including underground facility construction, borehole and/or shaft seal failure, thermal effects upon hydraulic gradients, hydrologic properties, and long-term stability, and alteration of matrix- and fracture-filling minerals)?

During repository construction physical changes such as fracturing will occur in the repository block. During and after waste emplacement, shaft seal failure could provide a means to quicken resaturation of the repository and/or provide a pathway for radionuclide transport. Additional changes during and after waste emplacement will include lithostatic and pore repressurization of the repository and surrounding geologic units. In addition, after waste emplacement the thermal load generated by the wastes may have an effect upon

the hydraulic gradient, and upon material properties affecting hydraulic parameters. For example, the potential for hydrofracturing due to thermal fluid expansion should be considered with respect to potential impacts on groundwater flow and radionuclide transport. Also, the effect of thermal fluid buoyancy on radionuclide transport must be considered in assessments of compliance with 10 CFR 60 performance objectives.

1.2.2 What are the types, probabilities, and expected effects over time on groundwater flow paths, velocities and/or fluxes, discharge rates and travel times of human-induced changes, excepting repository-induced changes (including water resource development, exploratory drilling, mine development for resources or other human activities)?

Human-induced changes that would affect groundwater flow need to be considered in assessing long-term repository performance. Identification of the types of changes, probabilities of occurrence, and descriptions of the nature of changes are necessary. Among the changes that should be considered with respect to hydrogeology of the Hanford site and Pasco Basin include changes caused by the potential development of water resources in the area for future irrigation, drinking and recreational purposes; present and future (non-HLW) waste injection practices in the area; potential exploration for mineral resources; and potential exploration for coal, gas or oil resources. In considering these changes, the value of resources relative to values in surrounding areas of similar size, the probability of resource exploration and/or development, and the potential impacts of these activities on groundwater flow and radionuclide transport should be evaluated.

1.2.3 What are the types, probabilities, and expected effects over time on groundwater flow paths, velocities and/or fluxes, discharge rates and travel times of natural changes (including those changes caused by future climatic, structural and tectonic events and processes)?

Natural processes and events which may change regional and sub-regional conditions and the existing groundwater system need to be considered in determining whether long-term performance of the repository will comply with radionuclide release standards. Geologic changes which could affect groundwater flow include regional tectonic movements and associated local faulting, folding and fracturing. Climatic variations, such as glaciation, are known to have occured during the Quaternary Period and therefore any such changes should be identified and evaluated with respect to groundwater flow and radionuclide transport. The potential for volcanic and seismic events within

or adjacent to the Pasco Basin or Columbia Plateau should also be identified and evaluated with respect to changes in the groundwater system. Other natural changes that should be considered are those resulting from, as examples, land surface and river morphology changes, and flooding.

1.2.4 What are the uncertainties associated with each of the items in sections 1.2.1 through 1.2.3?

The identification and consequence assessment of potential future events and processes over the long time periods required for HLW isolation is an unprecedented consideration in waste disposal technology. The identification and the assignment of occurrence probabilities to such future events and processes is subject to a large measure of uncertainty, as are the predictions of repository behavior resulting from the various scenarios identified. The degree and nature of the uncertainties in future events, processes and potential consequences should be carefully identified and characterized, where possible, in terms of probabilistic distributions or by scenarios which bracket the extremes of potential behavior. Uncertainties in future events and processes will contribute to uncertainty in evaluations of compliance with the requirements of 10 CFR 60. An acceptable level of uncertainty is that which will permit the licensing review board to make a finding as to the existence of reasonable assurance of compliance with the regulatory criteria.