BWIP'S TURN



United States Nuclear Regulatory Commission
Geotechnical Branch

# Site Technical Position - Geologic Issues For The Basalt Waste Isolation Project

## Background

In reviewing a license application for a high-level waste geologic repository, the NRC staff is required to determine if the site and design meet the criteria of 10 CFR Part 60. The NRC staff determination will be based on analyses of technical questions in the fields of geology, groundwater flow, geochemical retardation, waste form and waste package and facility design. During site characterization, the Department of Energy (DOE) will perform laboratory and field investigations to develop the information needed to address these basic technical questions.

Investigations to characterize a geologic repository are complex and involve long lead times. The Nuclear Waste Policy Act of 1983 (NWPA) has established a schedule for site characterization and selection. Specifically, NWPA requires publication of Site Characterization Plans (SCPs) 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 techncial position papers will precede and supplement the SCA's.

This document establishes the NRC position as to the geologic technical issues at the Basalt Waste Isolation Project Site. Future Site Technical Positions will address both NRC staff concerns regarding selected site specific issues and acceptable technical approaches for addressing those issues.

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

Site issues are questions about a site that must be resolved to complete licensing assessments of site and design suitability to meet the requirements of 10 CFR Part 60. 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 (e.g., waste form, container, geologic setting). Performance issues are derived directly from performance objectives in 10 CFR Part 60 (including environmental objectives of 10 CFR Part 51). Development of generic performance issues for a geologic repository is explained in detail in Appendix

C of NUREG-0960, "Draft Site Characterization Analysis of the Site Characterization Report for the Basalt Waste Isolation Project," March 1983.

Specific Issues are questions about conditions and processes (information needs) that must be considered to assess performance issues. Performance issues include the integration of numerous specific issues.

Appendix C of NUREG-0960 identifies 12 performance issues which the NRC has determined must be resolved prior to licensing of a high-level waste geologic repository. These issues are as follows:

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

2. How does the design criteria and conceptual design accommodate 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 from the far field 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?

To resolve these issues requires knowledge of the geologic setting at the Basalt Waste Isolation Project.

In order to provide a framework that will allow all sites to be considered equally, five first order specific issues and 15 second order sub-issues have been developed. The issues identified in the following section identify the generic geologic questions that need to be resolved and information needs required so that the NRC staff can adequately assess the performance issues.

Generally, the Umbrella Site Technical Positions are divided into five technical areas (1.0 Groundwater, 2.0 Waste Form/Waste Package, 3.0 Geochemistry, 4.0 Repository Design and 5.0 Geology). The site issues developed under each STP are numbered and listed by the technical areas designated above.

The order of these issues should not be interpreted as the order of relative importance.

Technical Position

It is the position of the NRC staff that, based on the current level of the Basalt Waste Isolation Project Investigations, assessment of the technical criteria in 10 CFR Part 60 requires that, at a minimum, the following geologic issues should be addressed for the Basalt Waste Isolation Project Site:

5.1 How does the geomorphic setting affect waste isolation?

- 5.1.1. What is the present geomorphic setting?
- 5.1.2. What are the nature and rates of present or projected geomorphic processes?
- 5.1.3. What would be the effect on the site of the projected geomorphic processes?

5.2. How does the stratigraphic setting affect waste isolation?

- 5.2.1. What is the present stratigraphic setting?
- 5.2.2. What anticipated and unanticipated processes and events could change the stratigraphic setting?
- 5.2.3 What would be the effect on waste isolation of the projected changes in the stratigraphic units?

5.3. How does the structural/tectonic setting affect waste isolation?

- 5.3.1. What is the present structural/tectonic setting?
- 5.3.2. What are the nature and rates of present and projected

tectonic processes?

5.3.3. What would be the effect on the site of the projected tectonic activity?

5.4 How does seismic activity affect waste isolation?

5.4.1. What is the nature of seismic activity which has occurred and is occurring in the site region?

5.4.2. What is the rate of seismic activity which has occurred and is occurring in the site region?

5.4.3. What would be the effect of the postulated seismic events at the site?

5.5 How does human intrusion affect waste isolation?

5.5.1. What is the nature of human intrusion activities which have occurred in the site vicinity?

5.5.2. What is the nature of human intrusion activites which could be projected to occur in the site vicinity?

5.5.3 What would be the effect on the site of the potential human intrusion activities?

The relationship between the geological issues and performance issues is presented in Table 1.

DISCUSSION

The rationale for each issue is presented in the following sections:

5.1 How does the geomorphic setting affect waste isolation?

The investigation of geomorphology provides evidence not only of the geomorphic processes and features which may affect waste isolation, but also provides evidence of the nature and age of tectonic features which could compromise the ability of the site to isolate waste. Certain geomorphic features are highly important for long term waste isolation, i.e., dissolution features and evidence of active tectonic activity. However, the nature and rate of all processes must be shown to have no major adverse affect on waste isolation to the extent required by 60.122(a)(2). The geomorphic features and processes shown to be important in the operational phase must serve as input into the design requirements and therefore will provide information which will be required primarily to satisfy 10 CFR 60.131 and 60.132, and to a lesser extent, 60.133, 60.134 and 60.135. The three second order issues under Geomorphology are organized to assure that the setting is described, the nature and rates of

processes which have or could affect the site are known and the effect on the site has been addressed.

5.1.1. What is the present geomorphic setting?

To understand the geomorphology of a site, it is necessary that a description of the setting be provided. While 10 CFR 60 emphasizes dissolution and erosion (60.122(c)(10) and 60.122(c)(16)), sufficient detail on the geomorphic regime of the site must be demonstrated such that the requirements of 60.122(a)(2) (i) have been met. The specific information needs include:

- 0 Characteristics of the physiographic province in which the site is located.
- 0 Characteristics of the physiographic/geomorphic units within the site vicinity.
- 0 Characteristics of geomorphic features in the site vicinity.
- 0 Relationships between the geomorphic features and structural/tectonic features.

5.1.2. What are the nature and rates of present or projected geomorphic processes?

While the major emphasis on understanding geomorphic processes and rates must rely on projection of Quaternary processes and events as reflected in 60.122(b)(1), the effect of man's activities such as flood plain occupation or dam construction and the secondary effects of increases in carbon dioxide in the atmosphere can drastically alter these processes and rates, as can potential natural events such as variations in the Earth's orbit. In addition, the effects of the repository, such as how construction, excavation and waste emplacement modifies the setting and thereby locally effects the geomorphic processes, must be addressed. The information needs include:

- 0 The present nature and rates of geomorphic processes including:
  - erosion and deposition in the site vicinity.
  - mass wasting in the site vicinity.
- 0 The nature and rates of paleogeomorphic processes with emphasis on the Quaternary including:
  - the climatic regime during the Quaternary.
  - paleofluvial erosional and depositional processes.
  - paleoclimate.
  - glaciation within the site vicinity.
  - pluvial lakes and streams within the site vicinity.
  - mass wasting during the Quaternary.
- 0 The nature of natural events, such as surface faulting which

could modify or change the geomorphic processes.

- 0 The nature of man's activities, such as dam construction, which could modify the geomorphic processes.
- 0 The effects of repository construction, operation and closure on the geomorphic processes.

5.1.3. What would be the effect on the site of the projected geomorphic processes?

The effects of the geomorphic processes shown to be most significant during the operational phase must be accommodated by proper design and therefore must be adequately evaluated (See 60.122(a)(ii) and 60.122(a)(iii)). The post closure concerns must be addressed in sufficient detail so that a clear distinction can be made between those processes which could affect waste isolation, and therefore require additional investigation, and processes which can be shown to have little or no effect on waste isolation. Information needs include:

- 0 The probability of erosion changing the surface water flow regime thereby modifying erosional and depositional processes.
- 0 The probability of erosion exhuming the waste.
- 0 The probability of flooding of the operations area due to geomorphic processes.
- 0 The probability of geomorphic processes changing the surface or groundwater flow regime.
- 0 The probability and nature of glacial effects (both primary and secondary) which could modify the geomorphic regime.
- 0 The probability of loading from glacial ice or melt waters changing the stress regime.
- 0 The potential for change in the climatic regime.
- 0 The probability of human activities modifying the geomorphic regime.

5.2. How does the stratigraphic setting affect waste isolation?

The primary concern of stratigraphy is to assure that a host unit of the proper depth, thickness and lateral extent exists in which the waste can be isolated. The description of geometric relationships of the various units and the properties of these units provides the basic information to determine ground water flow and transport, engineering design parameters and waste package design parameters. The information should include a description of the type, quantity, extent and purpose of all explorations undertaken to determine these parameters.

5.2.1. What is the present stratigraphic setting?

The stratigraphic setting of the site must be sufficiently well understood and described so that the requirements of 60.111, 60.131, 60.132, 60.133, 60.134, and 60.135 can be met. Characteristics of the units which affect fluid flow and transport, and therefore determine compliance with 60.112 and 60.113, should be emphasized. The information must be presented so that a clear relationship between rock stratigraphic, hydrostratigraphic, engineering stratigraphic and lithotectonic units and properties can be shown. The information needs for stratigraphy include:

- 0 The nature of the regional stratigraphic setting of the flows, interbeds and suprabasalt and sub-basalt units including:
  - the 3-dimensional geometry of each unit.
  - the lateral variations and discontinuities which occur within these units.
  - the depositional/emplacement history of these units.
  - post and syndepositional alterations which have occurred in these units:
  - the physical and chemical properties of these units, such as mineralogy, petrology, foliation, jointing, vesicle distribution, etc.
- 0 The nature of the stratigraphic setting of the site including:
  - the 3-dimensional geometry of the various units.
  - the lateral variations and discontinuities which occur in these units.
  - the depositional history of these units.
  - post and syndepositional alterations which have occurred in these units:
  - the static and dynamic physical properties of these units.
  - the type, nature and static and dynamic physical properties of surfical materials at the site.
  - the groundwater conditions within the various units which can affect soil and rock response.
  - the nature of the bedrock surface, depth of significant weathering and potential for unrelieved residual stress in the bedrock.
- 0 The nature of the repository horizon including:
  - the thickness and lateral extent of the repository horizon.
  - the depth of the proposed horizon.
  - lateral variations in the repository horizon.
  - the static and dynamic physical, index and chemical properties of the main rock units and of significant interbed material within the repository horizon.

  - the nature of discontinuities within the repository horizon with emphasis on zones of structural weakness.
  - the petrology/mineralogy of the repository horizon.

- 0 The stratigraphy along the proposed shafts including:
  - the static and dynamic physical, index and chemical properties of the lithological units along the proposed shafts.
  - the nature of stratigraphic discontinuities along the shafts.

5.2.2 What anticipated and unanticipated processes and events could change the stratigraphic setting?

A description and evaluation of the potential responses of the various units under anticipated loading conditions must be presented. A description of mineral assemblages, not only within the main unit but present as interbeds and joint fillings, must be presented. Both the potential for physical and chemical changes must be understood. Information needs include:

- 0 The response of units to ambient conditions.
- 0 The response of units to anticipated and unanticipated processes and events.
- 0 The response of units under anticipated repository loading conditions.

5.2.3 What would be the effect on waste isolation of the projected changes in the stratigraphic units?

Mineral assemblages susceptible to shrinking, slaking, solution, phase changes and other physical and chemical alterations due to the projected loading conditions may require special design considerations or change groundwater flow and transport conditions. The information needs include:

- 0 Areas [interbeds, joint filling, units] of minerals subject to physical and chemical alterations under anticipated loading conditions.
- 0 Nature of expected alterations

5.3. How does the structural/tectonic setting affect waste isolation?

The structural/tectonic setting not only affects design and flow/transport phenomena, but provides input into the major disruptive events which could affect the site. Knowledege of the structural/tectonic setting provides basic information such that compliance with the requirements of 60.131, 60.132, 60.133 and 60.134 can be accomplished, and therefore the performance objectives in 60.111, will be met. Compliance with the performance objectives of 60.112 and 60.113 requires knowledge of credible flow paths and disruptive events and

therefore knowledge of locations of structures, discontinuities and potential disruptive events. Sufficient detail on the structural/tectonic setting must be given such that the requirements of 60.122(a)(2)(i), (ii) and (iii) can be demonstrated.

5.3.1. What is the present structural/tectonic setting?

Evaluation of the present structural/tectonic setting of the site requires that the static conditions and the mechanism by which the elements formed can be understood. This information is required for design and flow/transport modeling and for the evaluation of disruptive scenarios and anticipated repository performance. The studies must be responsive to the requirements of 60.122(a)(2). The information include:

- The tectonic models for the site region which include:
  - the Cold Creek Syncline and associated features
  - the Rattlesnake-Wallula Alignment and associated features.
- The compatibility of these models with global models emphasizing:
  - plate motions in the Pacific Northwest.
  - plate motions in the Pacific Ocean Basin.
  - absolute hot-spot movement..
- The nature of the major regional tectonic elements (basins, lineaments, fold belts, etc.) with emphasis on the Pasco Basin and adjacent terrain.
- The nature of the structural framework of the region and site area.
- The geometric interrelationship of the regional and site elements including:
  - the Rattlesnake-Wallula Alignment (RAW).
  - the Gable Mt. anticline
  - thrust faults
- The tectonic processes which formed structures.
- The possibility that the style of tectonic deformation has changed in the last 13,000 years.
- The geomorphic expression of structures.
- The probability of undetected faulting in the site region including:
  - listric faulting
  - thrust faulting in the Cold Creek Syncline area.
  - east-west trending faulting
  - north-west to south-east trending faulting and conjugate faults
  - local or regional decollements.
- The relative age relationship of all structural elements.
- The absolute ages of the structural elements.
- The geological anomalies present including:

  - aeromagnetic and gravity anomalies that define intact blocks in the Cold Creek Syncline.
  - the N-96 and N-84 anomalies.
- 0 The isostatic adjustment, uplift, tilting and subsidence which has occured in the site region.
- 0 The cause and orientation of tectonic breccias, such as those found in boreholes in the Cold Creek Syncline
- 0 The nature of non-tectonic deformation which has occured in the site region.
- 0 The nature of structural features and their interrelation at the repository horizon.
- 0 The nature of structural discontinuities along shafts.

5.3.2. What are the nature and rates of present and projected tectonic processes?

To evaluate potential disruptive events and therefore potential changes in flow/transport modeling, both due to changes in the flow regime and the creation of new pathways for radionuclide migration, it is necessary to understand the active driving forces of the tectonic system. This issue is primarily in response to 60.122(b)(1), however, it provides input into all tectonic adverse conditions. The information include:

- 0 The relationship of the regional stress field to the tectonic/structural features.
- 0 The magnitude, orientation and distribution of stress in the site area.
- 0 The variation in stress with depth.
- 0 The in situ stress at the repository horizon.
- 0 The cause of core disking.
- 0 The nature and rates of tectonic deformation.
- 0 The relationship of active faults in the site region to the stress field.
- 0 The nature and rates of isostatic adjustment, uplift, tilting and subsidence occurring in the site area.
- 0 The direction and rate of deformation occurring both at the surface and in the subsurface which includes resolution of inconsistencies regarding:
  - east-west shortening or,
  - north-south shortening.
- 0 The nature and rates of non-tectonic deformation occurring in the site region.
- 0 Nature and rates of volcanism and heat flow in the site region.

- Ambient temperature of the repository horizon.
- Geothermal gradient of the site area.

5.3.3 What would be the affect on the site of the projected tectonic activity?

The effects of tectonic activity can adversely affect the flow/transport of radionuclides and, as such, is directly responsive to information needs required by 60.122(c)(3),60.122(c)(4), 60.122(c)(5) and 60.122(c)(20). In addition, tectonic activity must be considered as input into most design related issues. The information needs include:

- 0 The potential - based on the structures, fault geometry, known zones of relative weakness and the stress field- for the formation of new faults or for the reactivation of present faults in the site area including:
  - the Cold Creek Syncline area
  - the RAW area.
- 0 The potential for renewed volcanic activity in or near the Pasco Basin including:
  - flood basalt emplacement
  - air fall tephra deposition
  - ash flows
  - the potential for changes in geothermal activity in the site area.
- 0 The probability of flooding of the site area due to tectonic or volcanic activity.
- 0 The probability of non-tectonic deformation at the site.
- 0 The stability of the repository horizon in relationship to the in situ stress field.
- 0 The probability of changes in the groundwater regime due to tectonic activity.
- 0 The evaluation of credible and bounding natural disruptive event scenarios.

5.4 How does seismic activity affect waste isolation?

Seismic activity is only a direct concern during the operational phase, and knowledge of its effects is required by 10 CFR 60.131, 60.132 and 60.133. Additionally, a number of potentially adverse conditions (10 CFR 60.122(c)) are attributed to the nature of seismic activity in the vicinity of the site. Indirectly, seismic activity helps define the tectonic regime of the site area and aids in locating structures along which disruptive movement may occur. Disruptive movement could, in turn, alter or destroy anticipated pathways for

radionuclide migration. The relationship of seismic activity to the tectonic regime is discussed in section 5.3 above.

5.4.1. What is the nature of seismic activity which has occurred and is occurring in the the site region?

To make projections on the type and size of seismic events which could affect the site, it is necessary to first develop a historic data base of seismic activity. It is also necessary to define zones which include subsets of the seismic activity that are spatially related and exhibit similar characteristics. This issue is directly responsive to 10 CFR 60.122(c)(12) and provides the framework for determination of the parameters for 60.122(c)(13) and 60.122(c)(14). The information needs include:

- 0 A complete seismic history of the site region, including both natural and induced seismicity and earthquake swarms, with descriptions of the effects of earthquakes which have disrupted the geologic setting.
- 0 Models of seismic velocities in the crust.
- 0 Definition of seismic source areas and seismogenic structures.
- 0 Source mechanisms of earthquakes and earthquake swarms with supporting data.

5.4.2. What is the rate of seismic activity which has occurred and is occurring in the site region.

In order to more clearly understand the effect of seismicity on the performance objectives of the site, it is necessary to establish the rates of seismic activity in the site region. These rates can be derived from instrumental seismic history as well as from geologic evidence. The information needs include:

- 0 Datable evidence of large earthquakes within the region, such as surface ruptures and sand blows.
- 0 Recurrence rates from regional historical data.
- 0 Variations of recurrence rates among regional seismic sources and structures.

5.4.3. What would be the effect of postulated seismic events at the site?

Knowledge of appropriate postulated seismic events,along with a knowledge of areas subject to undesirable responses to these events, can provide the information required to accomodate or mitigate these effects. Most seismic

activity, either natural or induced by various forms of human activity, can be accomodated by utilizing appropriate design parameters. Certain effects, however, such as ground rupture, liquefaction and landsliding may require mitigation by avoidance. The information needs for determining the effects of these postulated events include:

- 0 The maximum credible earthquake(s) expected to affect the site.
- 0 The maximum expected ground motion at the site, resulting from the maximum credible earthquake(s), examined as a function of depth to at least the depth of the repository including:
  - ray paths from the MCE(s) to the site.
  - attenuation characteristics of these paths.
  - mechanisms or structures which may focus seismic energy resulting in abnormal ground motion.
- 0 Postulated catastrophic coseismic events, such as landslides, liquefaction or ground rupture that could affect the site or site region.
- 0 The ground motion and point of application of induced seismicity including:.
- 0 The nature of human activities which could induce seismicity.
  - injection of fluids into the confined aquifer at the 200W area.
  - effects of construction of Ben Franklin Dam and other future and existing dam structures.
  - groundwater withdrawals for irrigation.

5.5 How does human intrusion affect waste isolation?

The human intrusion scenario must consider three aspects: past activities which may have produced a pathway for waste migration, the ongoing and proposed site exploration activities which could compromise the site and the potential for either inadvertent or deliberate penetrations into or through the repository which could allow release of radionuclides. Those human activities that could result in induced seismicity are discussed in section 5.4.3.

5.5.1 What is the nature of human intrusion activities which have occurred in the site vicinity?

The primary emphasis of this issue is to address the concern of 60.122(c)(18) and 60.122(c)(19), therefore providing information which will be used in addressing the performance objectives of 60.112 and 60.113(a)(2). Areas which have shown a complex drilling and mining history are by nature those with the highest probability of future activities especially under the scenario of loss of records and monuments which identify the site. This information therefore

provides a relative basis to start assessing future intrusion scenarios. The information needs include:

- 0 The locations of boreholes and mines in the vicinty of the site.
- 0 The completion procedures used on these boreholes.
- 0 The status of mines in the area.
- 0 Mine and well production histories including:
  - Rattlesnake hills gas field.
- 0 The recorded rates of fluid injection/withdrawal in the vicinity of the site.
- 0 The nature of fluids injected or withdrawn.

5.5.2. What is the nature of human intrusion activities which could be projected to occur in the site vicinity?

This issue is formulated primarily to respond directly to 60.122(c)(17) which in turn is to minimize the potential for creating potential pathways for radionuclide travel. In addition, fluid injection and withdrawal, which by itself could modify the ground water flow path, could modify the local stress field thereby creating seismic activity such as occurred at Rangely, Colorado or producing significant changes such as large scale subsidence. The information needs include:

- 0 The known and potential resources which could be present within the site vicinity with emphasis on the relationship of hydrocarbons with the target formation at depth in the RRL.
- 0 The economic classification of the resources.
- 0 The potential extraction methods.
- 0 The potential of the setting for fluid injection or withdrawal.
- 0 The status and plans for mines in the area.
- 0 The location and nature of proposed site characterization activities.

5.5.3. What would be the effect on the site of the potential human intrusion activities?

To evaluate the consequences of human activity upon the site, it is necessary to understand the probability of these events occurring and the subsequent changes in characteristics caused by these activities. This information can be used as a basis to determine the potential for loss of waste isolation. A preferred site is one in which there is a very low to non-existent possibility of human activity creating changes in the waste isolation characteristics. For those sites in which modifications by human intrusion could occur, an

assessment must be made regarding the nature and effects of such modifications. The information needs include:

- The probability for, and nature of, flow path modification.
- The probability for, and degree of, vertical ground movement.
- The probability for, and nature of, ground cracking.

TABLE 1

RELATIONSHIP OF GEOLOGIC ISSUES TO PERFORMANCE ELEMENTS

| RFORMANCE LEMENTS | GEOLOGIC ISSUES | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 5.1.1 | 5.1.2 | 5.1.3 | 5.2.1 | 5.2.2 | 5.2.3 | 5.3.1 | 5.3.2 | 5.3.3 | 5.4.1 | 5.4.2 | 5.4.3 | 5.5.1 | 5.5.2 | 5.5.3 |
| p. 1 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| p. 2 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| p. 3 | X | X | X | X | X | X | X | X | X | | | | X | X | X |
| P. 4 | | | | | | | | X | X | | | | | X | X |
| p. 5 | | | | | | | | X | X | | | | | X | X |
| p. 6 | | | | X | X | X | | X | X | | | | | X | X |
| p. 7 | | | | X | X | X | | X | X | | | | | | |
| p. 8 | | | | X | X | X | | X | X | | | | | X | X |
| p. 9 | X | X | X | X | X | X | X | X | X | | | | X | X | X |
| p. 10 | X | X | X | X | X | X | X | X | X | | | | X | X | X |
| p. 11 | X | X | X | X | X | X | X | X | X | | | | X | X | X |
| p. 12 | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |