Department of Energy
Washington, DC 20585

MAR 3 1 1995

Mr. Joseph J. Holonich, Chief
High-Level Waste and Uranium
Recovery Projects Branch
Division of Waste Management
Office of Nuclear Material Safety
and Safeguards
U.S. Nuclear Regulatory Commission
Washington, DC 20555

References: (1) Ltr, Federline to Milner, dtd 10/6/94
(2) Ltr, Bernero to Dreyfus, dtd 10/13/94
(3) Ltr, Dreyfus to Bernero, dtd 11/14/94
(4) Ltr, Dreyfus to Bernero, dtd 3/14/95

Dear Mr. Holonich:

In a letter dated October 6, 1994 (Reference 1), the U.S. Nuclear Regulatory Commission requested additional information to address the State of Nevada's concern regarding the study of pneumatic pathways at Yucca Mountain, Nevada, their role and importance in the characterization of the site, and assurance that this data would be collected (if important to site characterization) prior to any potential compromise posed by the current Exploratory Studies Facility construction schedule. The U.S. Nuclear Regulatory Commission also requested a description of the conceptual models of air flow through the mountain used to develop the Accelerated Surface Based Testing Plan and a discussion of how the U.S. Department of Energy will determine if the Paintbrush Tuff nonwelded unit over the site, the Topopah Spring unit outcrop in Solitario Canyon, and the Solitario Canyon fault are pneumatic barriers.

The Nuclear Regulatory Commission reiterated their concern that operation of the Tunnel Boring Machine can potentially impact site characterization in a letter dated October 13, 1994 (Reference 2). In a letter dated November 14, 1994 (Reference 3), the Department agreed to respond to the concerns in Reference 1 and to apply a "hold" on the Tunnel Boring Machine operations beyond the upper Paintbrush Tuff nonwelded unit contact to provide additional confidence that adequate data would be collected. In a letter dated March 14, 1995 (Reference 4), the Department committed to provide this information prior to April 1, 1995.

Enclosure 1 provides the requested information as well as additional information. The Department believes the enclosed information addresses the State of Nevada's concerns on this subject. Additionally, Enclosure 2 shows the existing borehole locations. Enclosure 3 lists the commitments the Department has made in this letter.

102.8
WM-11
NH03

If you have any questions regarding this subject, please call Chris Einberg of my staff at (202) 586-8869.

Sincerely,

Ronald A. Milner

Ronald A. Milner, Director
Office of Program Management and
  Integration
Office of Civilian Radioactive
  Waste Management

Enclosures:
1. Pneumatic Pathway Information
2. Map of Borehole Locations
3. List of Commitments

cc w/encl:
R. Loux, State of Nevada
R. Price, NV Legislative Committee, NV
J. Meder, NV Legislative Counsel Bureau, NV
M. Murphy, Nye County, NV
D. Bechtel, Clark County, NV
P. Niedzielski-Eichner, Nye County, NV
B. Mettam, Inyo County, CA
V. Poe, Mineral County, NV
F. Mariani, White Pine County, NV
R. Williams, Lander County, NV
L. Fiorenzi, Eureka County, NV
J. Hoffman, Esmeralda County, NV
C. Schank, Churchill County, NV
L. Bradshaw, Nye County, NV
W. Barnard, NWTRB, Washington, DC
E. Lowry, NV Indian Environmental Coalition, NV
R. Holden, National Congress of American Indians
M. Knapp, USNRC, Bethesda, MD

ENCLOSURE 1

PNEUMATIC PATHWAY INFORMATION

INTRODUCTION

By letter (Federline to Milner, dtd October 6, 1994) the U.S. Nuclear Regulatory Commission (NRC) requested additional information regarding the studies of pneumatic pathways at Yucca Mountain, their role and importance in the characterization of the site, and assurance that these data would be collected (if important to site characterization) prior to any potential compromise posed by the current Exploratory Studies Facility (ESF) construction schedule. The letter also included requests for a description of the conceptual model(s) of air flow through the mountain used to guide the planned testing program, and a discussion of the relevance of the testing program to a determination of the existence of pneumatic barriers at the site.

The study of the role of pneumatic pathways in the context of performance of a repository at Yucca Mountain has been underway for several years. The ESF will be an integral part of the study of this issue. The schedule for installing downhole instrumentation in the vicinity of the planned ESF excavation is closely tied to the ESF construction schedule. When the ESF schedule was accelerated, the testing schedule was modified to ensure the collection of relevant data.

The geologic disposal concept assumes that openings will be developed and waste will be emplaced in a volume of rock whose behavioral characteristics are reasonably predictable with respect to maintaining isolation of that waste from the accessible environment. To understand the behavioral characteristics of this rock under repository conditions, the role of present-day pneumatic pathways are helpful in understanding the eventual role of such pathways in coupled heat, water, and gas flow systems.

The study of the role of pneumatic pathways is addressed through a variety of specific activities. These study activities have been and are being conducted under various Study Plans (e.g., Study Plan 8.3.1.2.2.1, "Characterization of the Unsaturated-Zone Infiltration"; Study Plan 8.3.1.2.2.3, "Characterization of the Percolation in the Unsaturated Zone-Surfaced-Based Study"; Study Plan 8.3.1.2.2.4, "Characterization of the Yucca Mountain Unsaturated Zone in the Exploratory Studies Facility"; Study Plan 8.3.1.2.2.6, "Characterization of the Yucca Mountain Unsaturated-Zone Gaseous Phase Movement"; and Study Plan 8.3.1.2.2.9, "Site Unsaturated Zone Modeling and Synthesis," that are identified in the Site Characterization Plan developed for Yucca Mountain. In addition, the use of the natural system response to external stimuli has been identified as a potential method of evaluating large-scale behavior of the gaseous flow system.

CONCEPTUAL MODEL OF AIR FLOW

Prior to the large scale *in situ* testing program utilizing the ESF itself, a conceptual model of moisture and gas flow within the unsaturated zone has been postulated. A numerical model, discussed below in the context of the decision framework, is also being completed that describes anticipated behavior. The pneumatic-pathways data collection has been planned based on a conceptual model that assumes a two- or three-layer system, where the fractured and relatively permeable units are separated by lower-permeability, bedded units that act as barriers to pneumatic flow.

The upper zone includes the Tiva Canyon member (TCw), a welded unit which is highly permeable and well-connected to the atmosphere. Gas movement in the Tiva Canyon member appears to be barometrically and thermally/topographically driven. Therefore, convection is probably the dominant mechanism by which bulk movement of the gas phase occurs.

The second zone is comprised of the welded units of the Topopah Spring Member (TSw), which appear to be isolated from the Tiva Canyon Member by the Paintbrush Tuff non-welded unit (PTn) and/or the Topopah Spring vitric caprock. This zone also seems to be highly permeable to gas flow, but the barometric responses below the PTn are significantly attenuated and time-lagged with respect to the atmospheric signal. Significantly, gas-pressure fluctuations throughout the vertical extent of the TSw appear to be in phase, suggesting a lateral propagation of the atmospheric signal. If the signal were propagating vertically downward, as appears to be the case with the TCw, the barometric responses would be increasingly time-lagged and attenuated with depth. These preliminary results, which were presented in poster form at the Technical Program Review in February of 1995, suggest that: (1) a pneumatic pathway appears to connect the atmosphere and the TSw in the vicinity of Drill Hole Wash, essentially short-circuiting the PTn, but (2) in the TSw <u>net</u> gas flow seems to be much slower than in the TCw, with diffusion the dominant mechanism by which bulk movement of the gas phase occurs. Ten years of monitoring carbon-14 activities in the gas phase at borehole USW UZ-1 (enclosure 2, Map of Borehole Locations) have indicated a systematic increase of apparent age with depth in the TSw that is consistent with the interpretation of diffusion-dominated flow.

A possible third zone is comprised of the upper units of the Crater Flat Tuff between the water-table and bedded units of the upper Calico Hills Tuff. The pneumatic barrier may be the basal vitrophyre of the Topopah Spring Member, or the bedded and non-welded units of the Calico Hills Tuff. Little is known about the character of gas flow in the Crater Flat Tuff. At one location, Borehole SD-9, the barometric pressure response in the Crater Flat Tuff is largely attenuated and time-lagged relative to the response seen in the Topopah Spring member. Preliminary carbon dioxide and methane concentrations are also very different when these two zones are compared. The lateral extent of the third zone may be small and primarily related to the presence of perched water in Borehole SD-9.

The conceptual model of air flow does not assume that these zones are continuous over the entire Yucca Mountain area. Instead, it is postulated that the Drill Hole Wash, Bow Ridge, Ghost Dance, and Solitario Canyon faults, and several other sub-vertical structural features, act as gas-flow pathways that divide this two- or three-layer system into a series of flow cells. Each cell may have significantly different gas-transport characteristics, depending upon the spatial distribution of permeabilities in the bounding fault zones.

In addition to the conceptual model described above, the pneumatic-pathways data collection is being driven by the need to establish background data on the pneumatic system in the vicinity of the ESF prior to passage of the Tunnel Boring Machine (TBM).

TESTING PROGRAM OVERVIEW AND SEQUENCE

Tests are underway that sample large volumes of rock and fracture systems within Yucca Mountain such that the role and behavior of existing pneumatic pathways can be observed. Some of these tests involve monitoring barometric pressure changes that occur naturally, and observing their effects at depth. These tests, conducted in existing boreholes, will ultimately utilize the ESF itself to bring atmospheric pressure transients closer to the monitoring boreholes. Such large-scale observations are important to the extrapolation of other test information to the scale of Yucca Mountain.

Concern has been expressed that the scheduled rate of tunnel advancement could preclude the collection of data on ambient conditions. Further, given more rapid advance rates, these data may become otherwise irretrievable. To ensure compliance with the testing plan, a hold was placed on tunnel advancement beyond the upper Ptn contact until data on ambient conditions have been collected in the vicinity of the north ramp. The data collected prior to the penetration of the PTn will prove to be of value in resolving the State of Nevada's concerns (as cited in the letter) with respect to the PTn, TCw, and TSw performing as pneumatic barriers.

The testing program is focused on the observation of barometric pressure changes that accompany weather fronts. The largest weather fronts generally occur in the winter months. The first of the pressure monitoring systems (in NRG-7a) was installed in late October and has been gathering data since the beginning of November 1994. A second system (in NRG-6) was installed in mid-November. These instrument arrays record pressure changes nominally at the surface and at depth (above, within, and below the PTn) in response to atmospheric pressure changes. Once the initial data have been collected, the hold will be lifted (Commitments from Reference 3, letter, Dreyfus to Bernero, dated

November 14, 1994). After the hold is lifted, monitoring will continue to discern any potential effects of ESF excavation as the source of an advancing pressure front change. The hold, as put in place, reads as follows:

> The TBM shall not excavate beyond the TCw/PTn (Tiva Canyon welded/Paintbrush Tuff non-welded) geologic contact until after collection of pneumatic data from monitored boreholes. This hold shall be rescinded when:
>
> * Pneumatic data have been collected from isolated intervals in the Tiva Canyon welded unit (TCw), the Paintbrush non-welded unit (PTn), and the Topopah Spring welded unit (TSw).
> * Data have been collected over a time period equivalent to early to later winter (this period is anticipated to be completed by late February).
> * Data for several barometric pressure changes (weather fronts) have been gathered, or
>
> An alternative testing program that meets the above objectives is developed.

Data sought from the pre-construction pneumatic pathways testing program are considered to be non-critical, but of high value to the characterization of Yucca Mountain. As a consequence, the instrumentation plan and schedule for pneumatic pathways monitoring was integrated with the planned ESF construction schedule to capture pre-construction (ambient) conditions. The current plans provide these data well in advance of the penetration of the Paintbrush Canyon non-welded tuff (PTn). The TBM is not scheduled to reach this unit until approximately July 1995.

Collection of the pneumatic pathways data from monitoring locations adjacent to the planned ESF uses the emplacement of the tunnel itself as part of the overall testing strategy. Tunnel emplacement provides the opportunity for inducing changes in barometric pressure at specific locations underground for purposes of monitoring response within the mountain thereby facilitating an iterative model calibration process.

PNEUMATIC PATHWAYS TESTING METHODOLOGY

The testing program addressing pneumatic pathways within Yucca Mountain includes both surface-based and underground testing activities. The program uses both direct and indirect observations of rock properties relative to fluid behavior to evaluate the role of pneumatic pathways in the response of the system to expected perturbations.

A subset of activities within the much broader unsaturated-zone hydrologic investigations program has been accelerated to provide baseline information in the vicinity of the ESF and to provide the modeling capability to address ESF effects on the testing program. This program will become fully operational during FY 1995.

The testing program utilizes two approaches to gathering information. The first is the active method of testing, which imposes changes on an existing state and monitors responses to imposed conditions. This part of the program is conceptually analogous to aquifer testing using measurements of pumping rate and associated drawdowns of water levels in wells. This is being accomplished by air-permeability testing of surface-based boreholes and those drilled radially from ESF alcoves; the methodology relies on known rates of air injection and the measured pressure responses. These tests are focused on specific locations and potential features above, in and below the PTn as well as on significant intersecting structures such as major faults.

The second approach is the passive method, which relies on monitoring changes that occur naturally. In surface-based boreholes, the monitoring consists of observing the response to barometric changes that occur seasonally, diurnally, and in association with weather fronts. The methodology is analogous to using tidal methods to evaluate a coastal aquifer. Monitoring locations are selected based on the results of air-permeability testing, and are sited above, within and below the PTn at various distances from Solitario Canyon, from major faults and from the ESF alignment as shown in Enclosure 2.

Direct observations on drill core focus primarily on estimating the water content and saturation-dependent permeability of rock matrix, on the characteristics of small-scale fractures, and on the state of the system with respect to saturation and water potential. These laboratory analyses to help delineate the unsaturated-zone flow system will continue as new boreholes are drilled and samples are obtained. Age dating of borehole gases and water extracted from partially-saturated rock samples leads to pathway recognition by inference from apparent residence times and the geologic conditions that are associated with anomalously "young" water or rock gas. Often, mixing relations or lateral flow must be invoked to explain geochemical observations. Air-permeability tests in specific borehole intervals allow scale effects to be evaluated by comparisons with matrix properties, and once the boreholes are instrumented, monitoring in-situ fluid potentials, temperatures, and pressures becomes possible.

The ESF component of the pneumatic pathways testing program includes physical and chemical information gathered from samples collected within the ESF, radial borehole testing in alcoves constructed at stratigraphic and structural discontinuities (contacts and faults), and monitoring and analysis of the effects of ventilation. The underground testing program is designed to provide estimates of bulk permeability of the densely welded units, fracture connectivity within and between these units, and the capacity of these and the non-welded units to transmit gas phase and liquid phase fluids under present and forecast future conditions.

TEST LOCATIONS

The surface-based component of the pneumatic pathways testing program includes testing and monitoring in a series of boreholes drilled as a part of the ongoing investigation program. The Catalog of Planned Boreholes for Site Characterization Surfaced-Based Testing was transmitted to the NRC (letter, dated August 26, 1994, Brocoum to Holonich). Boreholes located in potential flow regimes along the ESF alignment (ramps and main drift) and several on Yucca Crest that are thought to be affected by the free face along Solitario Canyon are being instrumented. The immediate testing program phase includes open-hole monitoring of air velocity, composition, temperature and humidity in UZ-6, -6s and -13; completed air-k testing and gas phase geochemical sampling in UZ-16 and gas sampling, temperature, air pressure and humidity testing in UZ-1. In fiscal year (FY) 1994, air permeability testing was conducted in UZ-16, NRG-7a and NRG-6. In FY 1995, air permeability testing is planned in boreholes UZ-4, UZ-5, UZ-7a, and SD-12. Monitoring instrumentation is completed in NRG-4, -6 and -7a. In addition, monitoring instrumentation is planned for installation in UZ-4 and UZ-5 by the end of FY 1995 and UZ-7a and SD-12 in FY 1996.

To capture specific information regarding the response to large naturally occurring barometric pressure changes, pneumatic testing and monitoring is planned for Boreholes UZ-4, -5 and -7a and in ESF ramp boreholes NRG-4, -6, and -7a. NRG-6 and -7a have been instrumented by DOE; NRG-4 has been instrumented by the Nye County cooperative study program.

The NRG-hole instrumentation program provides instrument stations above, within, and below the PTn unit. Instrumentation was installed in the NRG boreholes in advance of the winter barometric pressure change. The first ESF-specific monitoring instrument was installed in the TSw in NRG-7a on October 28, 1994, and monitoring began in early November 1994. As the equilibration time for purposes of air pressure monitoring is rapid, data relevant to the pneumatic pathways issue become available almost immediately following installation of the transducers. Approach of the advancing ESF may provide the opportunity to utilize changes in barometric response in the model calibration process, first in the NRG boreholes and subsequently in additional boreholes along the continuation of the tunnel development (e.g., UZ-7a, SD-12, SRG-3) in FY 1996 and later.

Locations of pneumatic testing and monitoring boreholes have been identified in conjunction with the ESF layout. In this way, both the large scale seasonal responses can be monitored as well as any response to the ESF emplacement. It is expected that the ESF will provide an advancing front of barometric pressure proximal to the ramp boreholes that is in phase with and only slightly less than atmospheric pressure (due to ventilation effects). The gas-pressure changes in these boreholes as a function of time and distance from the ESF will provide insight into the role and efficiency of existing fractures as pneumatic pathways within Yucca Mountain. The ESF schedule is not particularly critical to this effort in that several of the monitoring locations are along portions of the tunnel that will not be developed until FY 1996/1997.

DECISION FRAMEWORK

The decision-making framework used to evaluate the testing priorities is included in the site-scale gas flow model which is in an intermediate stage of development. The site-scale gas flow model is an extension of the UZ site-scale moisture model that is currently under development. The gas flow model has been calibrated against data from the relatively well-characterized local gas-flow system at UZ-6/UZ-6s. Over the next few months, the model will be calibrated using meteorological records and associated barometric responses in the NRG boreholes that have been instrumented. The 3-dimensional site-scale model has been modified to include the north ramp of the ESF and various studies of the effects of the ESF on gas flow at Yucca Mountain will be conducted in order to obtain thorough knowledge of ambient conditions of gas flow patterns.

The calibration process will consist of a series of forecasting exercises in which the time lag and attenuation of atmospheric pressure fluctuations reaching each newly-instrumented hole will be predicted. As data are obtained, discrepancies between predicted and observed conditions will be used to refine the gas-flow model. Progressive convergence between the predicted and observed barometric responses will ensure that the probable influence of the ESF on the gas-flow regime is adequately understood. As the bedded tuff is penetrated by the north ramp and the forecasting exercise is continued, NRG-holes that have been instrumented will be used to further compare against the model predictions.

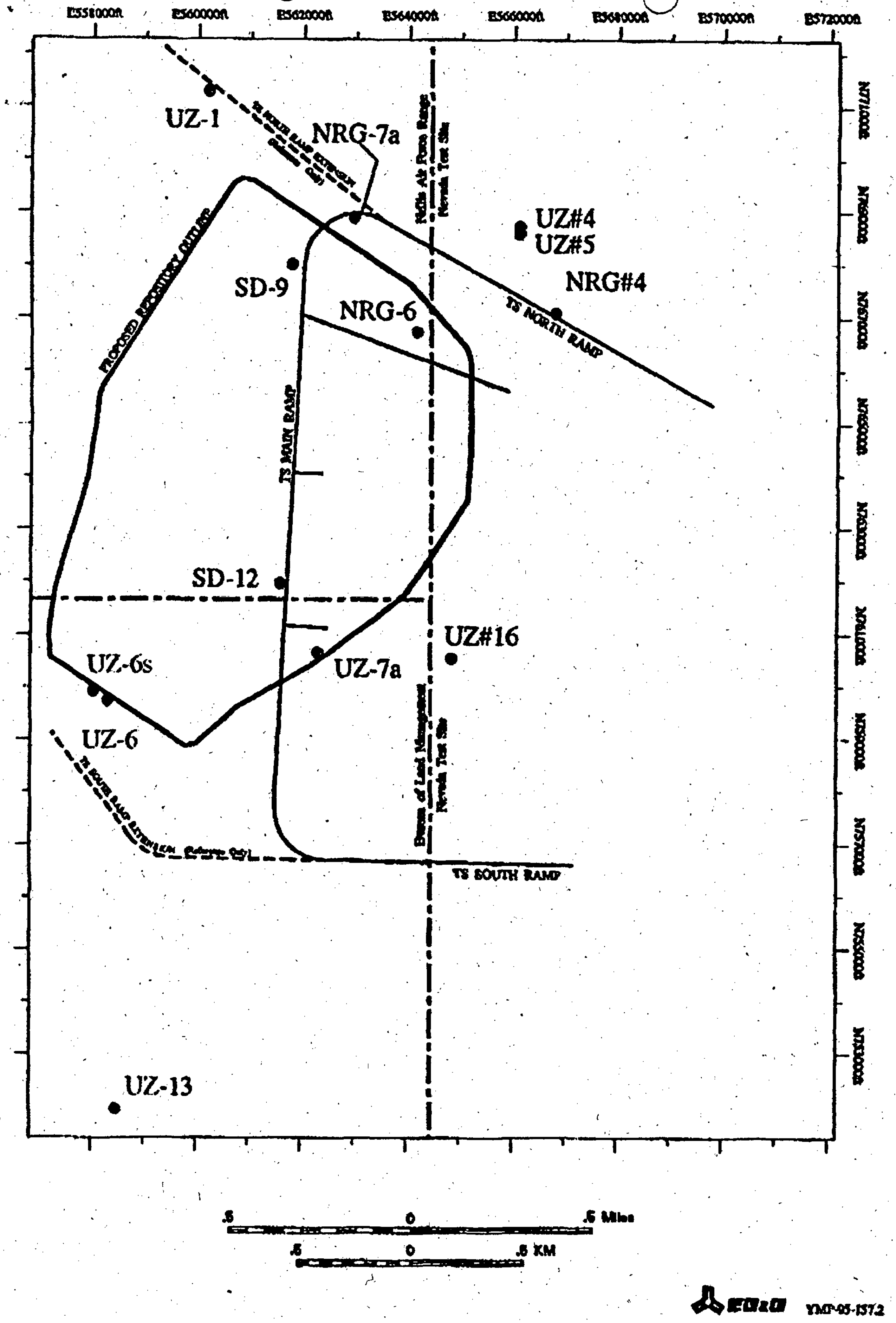
SUMMARY

Characterization of pneumatic pathways is an integral part of the overall testing program underway at Yucca Mountain. The sequencing of testing and ESF construction activities has been considered and plans developed such that the intended sequence of events will occur. While pre-ESF data are not essential to site characterization, they are considered valuable to subsequent analyses of the repository site, and therefore controls on the construction/testing sequencing have been established.

The testing program was developed based on a conceptual model of air flow through Yucca Mountain that identifies potential stratigraphic (e.g., PTn) pneumatic barriers and structural (e.g., faults) pneumatic pathways within the mountain. The testing program currently underway is designed to test the conceptual model(s) and further refine the numerical model used to describe the role and behavior of the pneumatic system within the mountain.

ENCLOSURE 2

MAP OF BOREHOLE LOCATIONS


UZ-1
NRG-7a
UZ#4
UZ#5
SD-9
NRG#4
NRG-6
TS NORTH RAMP
PROPOSED REPOSITORY OUTLINE
TS MAIN RAMP
SD-12
UZ#16
UZ-6s
UZ-7a
UZ-6
TS SOUTH RAMP
UZ-13
.5 0 .5 Miles
.5 0 .5 KM
YMP-95-137.2

ENCLOSURE 3

LIST OF DOE COMMITMENTS

COMMITMENT

1. DOE will use the data obtained from the instrumented NRG holes to compare to the model predictions (enclosure 1, page 6, last paragraph).