PDR

MEMORANDUM

Date: August 23, 1995

To: Mr. John Austin
U.S.NRC
Washington, DC 20005

Through: Mr. Carl Johnson
Technical Director
Nevada Nuclear Project Office
Carson City, Nevada

From: Linda Lehman
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Dear Mr. Austin,

The purpose of this letter is to inform you of a number of concerns which the State of Nevada has about Ground Water Travel Time (GWTT) and its calculation, which were voiced at the NRC/DOE Technical Exchange on this topic in March of 1995. As you know these exchanges are considered to be informal and therefore minutes are not kept. Because there is no official record, we are concerned that the comments offered by the State of Nevada may not be remembered or considered. Therefore, we have elected to put them in writing so that they may become part of the official record.

In addition to specific comments dealing with GWTT, we would also like to comment on the Advisory Committee on Nuclear Waste (ACNW) meeting presentations of March 10, 1995, on future hydrology studies for Site Characterization. Finally, we would like to make a recommendation for a different approach to calculating GWTT which is more physically consistent with the geologic structures and hydrogeology as conceptualized at Yucca Mountain. We hope you will consider these comments and alternative approaches as constructive and that you will respond as appropriate or ask us for further explanation if necessary.

I. Comments

1. There is major concern that little actual field data are being utilized in the overall modeling effort or in the exercises used to calculate GWTT. Verification of model assumptions must be supported and take place via actual field testing to the maximum extent possible.

2. During the discussion by Jim Duguid of INTERA, Inc., he stated that GWTT and model results would utilize matric potential and moisture content as verification parameters, reasoning

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that if these parameters were matched by the models, then the calculation of travel time would be verified.

In contrast, our research has shown model verification to require more information. During the period 1990 - 1993 we participated in the INTRAVAL study aimed at model validation. Our group consisted of five modeling sub-groups who each developed independent models of the unsaturated zone at Yucca Mountain (Brown et al, 1994). The goal of the project was to validate a model based on matrix measured water contents. The group concluded that this could not be done due to the non-uniqueness of model solutions. That is, many different model formulation, including different conceptual models, matched the measured water contents equally well in part due to boundary condition and parameter uncertainty. This would also hold with the addition of matric potential, realizing that in most models the two are linked via the so-called water retention functions. It was clear to us that additional, then unavailable, measurements of other parameters would be needed to validate models.

Kwicklis, et al (1993) came to a similar conclusion in attempting to solve for flux in the unsaturated zone. Important here was the uncertainty in water retention properties and the total lack of information from fractures themselves. It is just not possible to validate a single model based on matrix water contents and matric potential alone, especially when fractures play an important or dominant role.

Verification of GWTT against the above parameters along with other parameters which can yield a time history of the fluid, such as isotope geochemistry, will be required. It must be stressed however, that any model results used for GWTT must be consistent with, and be able to explain the known data. This includes saturated zone data such as water table oscillation distributions. These oscillations hold valuable information about potential recharge and their significance must be considered in concepts used by modelers. The saturated and unsaturated zones are connected and DOE must start viewing the system as the sum of its parts. See Lehman and Brown, 1995a and 1995b.

Temperature is also an important parameter to match in flow modeling in both the saturated and unsaturated zones. Figure 1 is a map of the temperature contours at the water table in the vicinity of Yucca Mountain. As can be seen, a cold temperature spike appears to be coincident with the strike of the Ghost Dance Fault. This may indicate that colder water is moving across the steep hydrologic gradient, which exists in the northern part of the site, via fracture zones and is transmitted to the south. A high temperature area can be seen to the west of the mountain and occurs in close proximity to the volcano area and seems to also parallel the Solitario Canyon Fault zone. Any modeling of the saturated zone flow field should be able to account for this temperature field.

3. An early version of the potentiometric surface was published by the USGS in Robison, 1984 and is shown as Figure 2. This map indicates two embayments in the 730 meter contour of

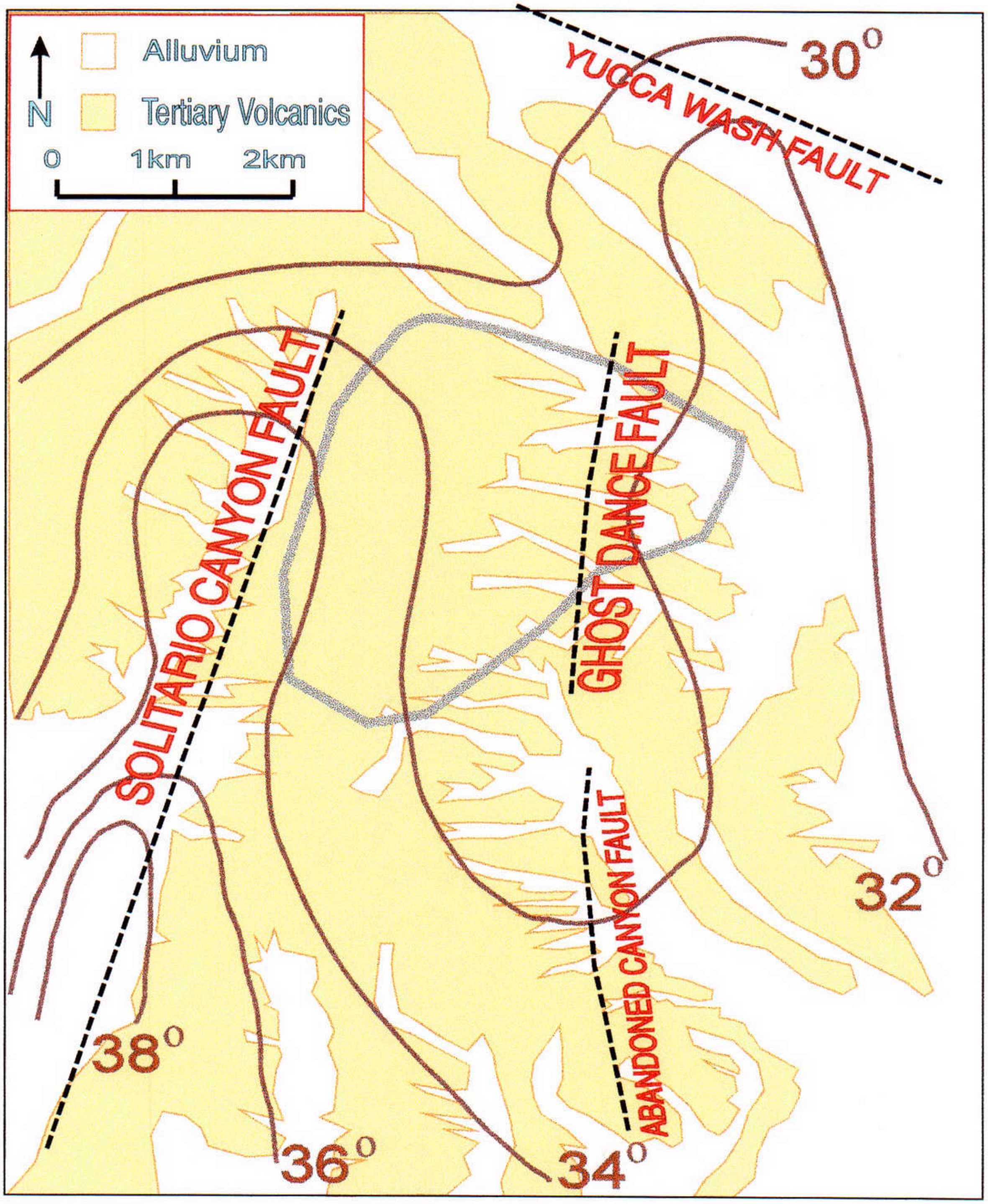

Figure 1. Water table temperature contours in degrees C (Sass et al 1988).

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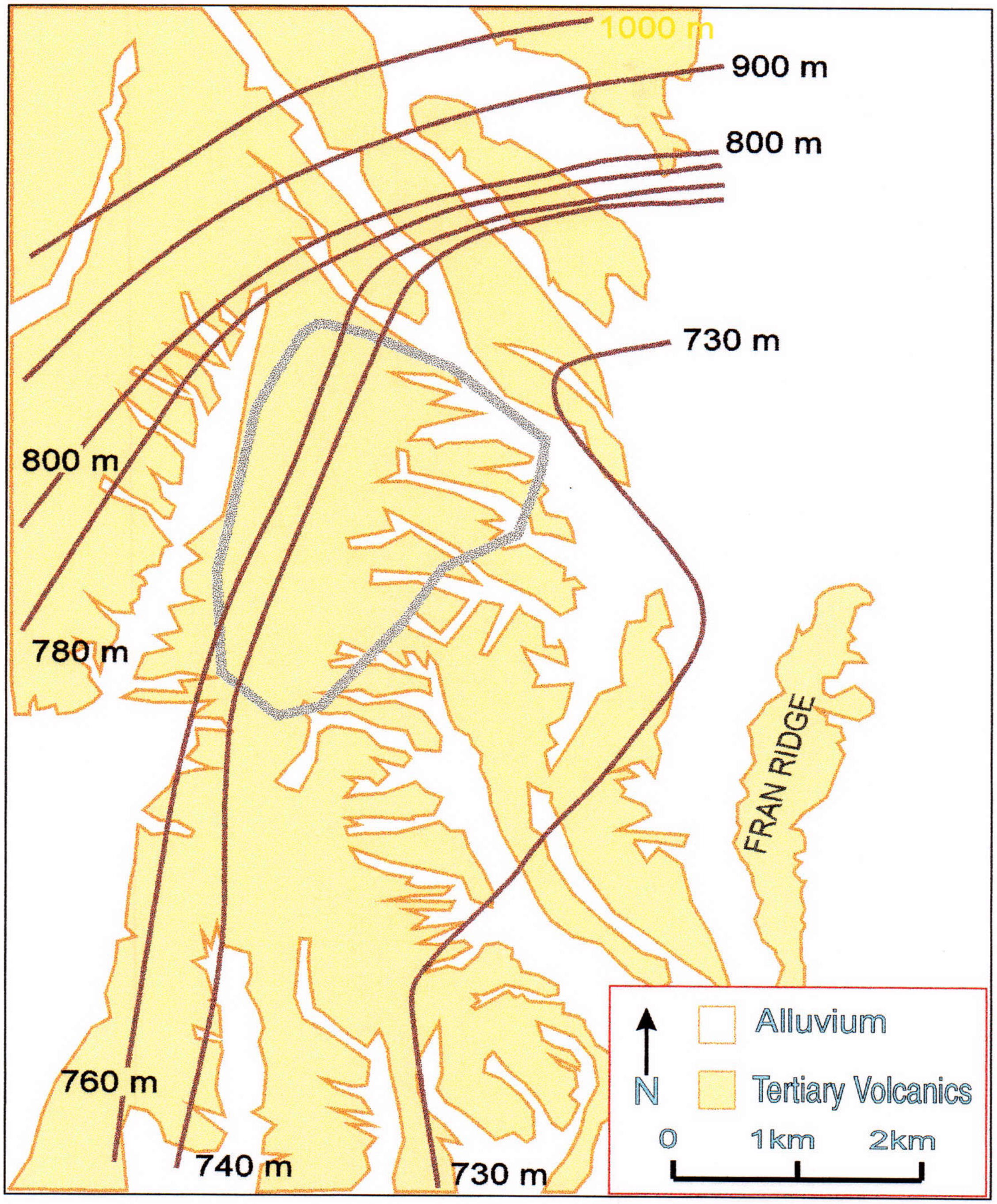

Figure 2. USGS preliminary saturated zone potentiometric surface (Robison, 1984).

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the potentiometric surface: one in the location of the Drill hole Wash Fault, a known fault zone, and the other embayment to the south of the repository footprint. This map was subsequently revised by the USGS in 1994, after making corrections for temperature, elevation and density. This revised map from Erwin, et al 1994 is shown as Figure 3. As can be seen the sharp embayment near the Drill Hole Wash fault has disappeared and two other small embayments exist closer into the repository. They can be seen primarily in the 730.5 meter contour line. Checking data from which this figure was constructed (listed on page 15 of Erwin et al, 1994) it can be seen that all the revised data were not used in the revised potentiometric surface map. Figure 3 shows the revised data labeled in red which were not used and are not consistent with the mapped potentiometric surface. The authors reasons for not including these revised head data were stated on page 14, paragraph 2 as follows:

> "Adjustments for wells UE25 b-1, USW H-4, UE 25 c2, and UE 25 c3 produced lower water levels and when plotted created an apparent water level low in the middle of the revised potentiometric-surface map. No physical reason could be found for this feature. Thus, none of the adjusted water level values were used in the revised potentiometric-surface map."

Rather than discard field data, L. Lehman & Associates subsequently re-plotted the complete set of revised head data and the result is shown as Figure 4. As can be seen, there are now three embayments, two of which are coincident with two known fault zones: the Drill Hole Wash Fault and the recently discovered Sundance Fault. These embayments suggest that the faults are hydraulically significant. These faults may be acting as either conduits or channels for groundwater flow or as less permeable features which are displacing the 730 meter contour. Based on the assumption that the fracture patterns at Yucca Mountain are fractal (Barton and Larsen, 1985) and therefore would be self-similar and repeating, another northwest trending fault can be predicted to exist at the location of the third and lower most embayment. This embayment is quite deep and may stretch to the Solitario Canyon fault zone. As such it may be indicating a pathway for interbasin flow, just south of the repository footprint. This area remains largely unmapped. The eastward bulges in the 730 meter contour line of Figure 4 may alternatively be indicating areas of recharge (recharge mounds) down the extensional zone of the Ghost Dance Fault.

The flow field interpretations just described are quite different from interpretations which would result from utilizing the Erwin et al., 1994 USGS potentiometric surface map. We feel that this saturated zone potentiometric map is not accurate and does not include adjusted data points which we believe are crucial to the interpretation of ground water flow paths and therefore GWTT. These data need to be examined by the NRC in detail before accepting the potentiometric surface or using it for calibration of ground water models. We urge the NRC to make their own investigations into the potentiometric surface interpretation, as conceptual models are often the primary cause of model uncertainty in GWTT and transport calculations.

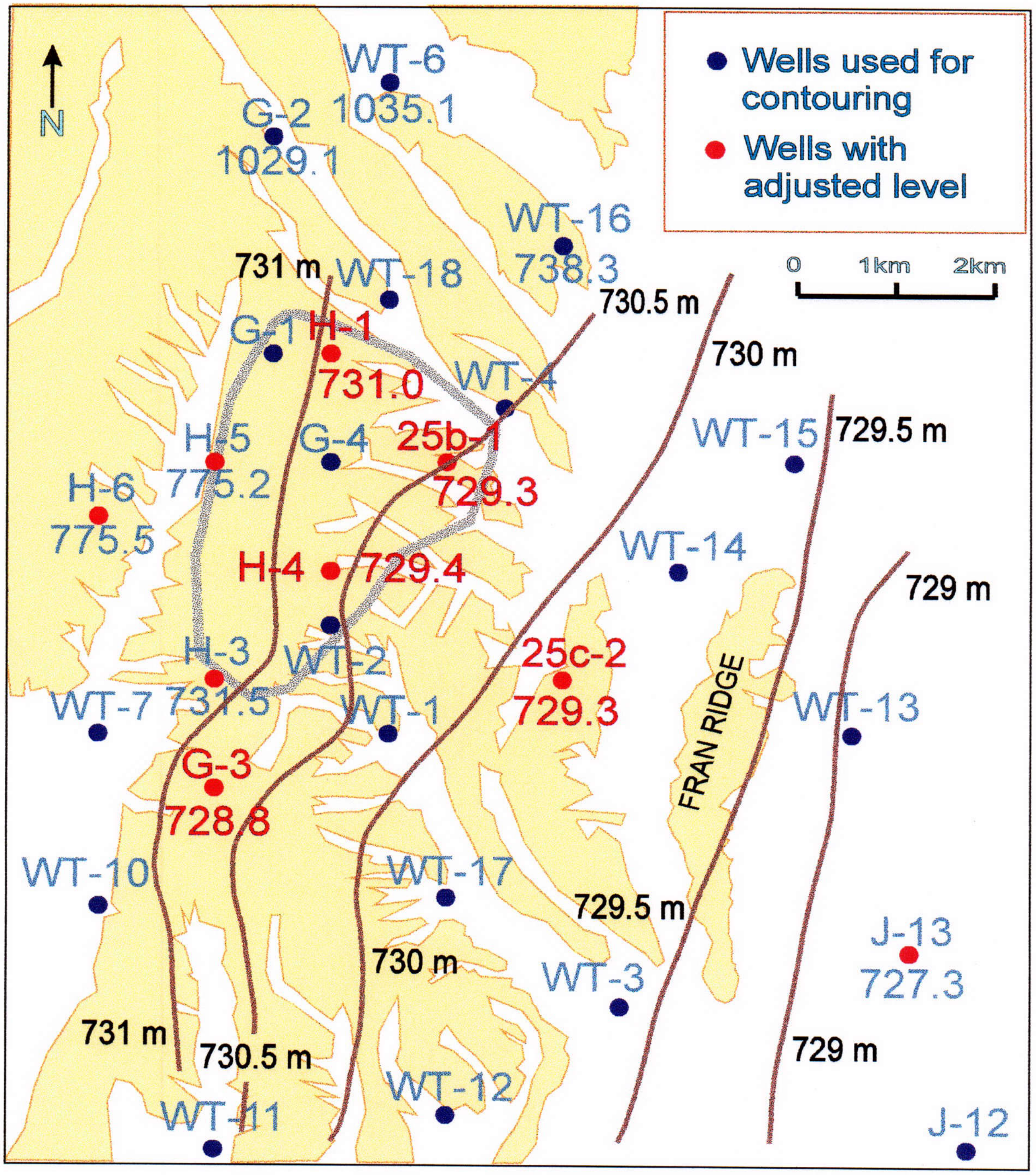

Figure 3. USGS Revised saturated zone potentiometric surface (Ervin, Luckey and Burkhardt, 1994). Red labels indicate adjusted data inconsistant with surface.

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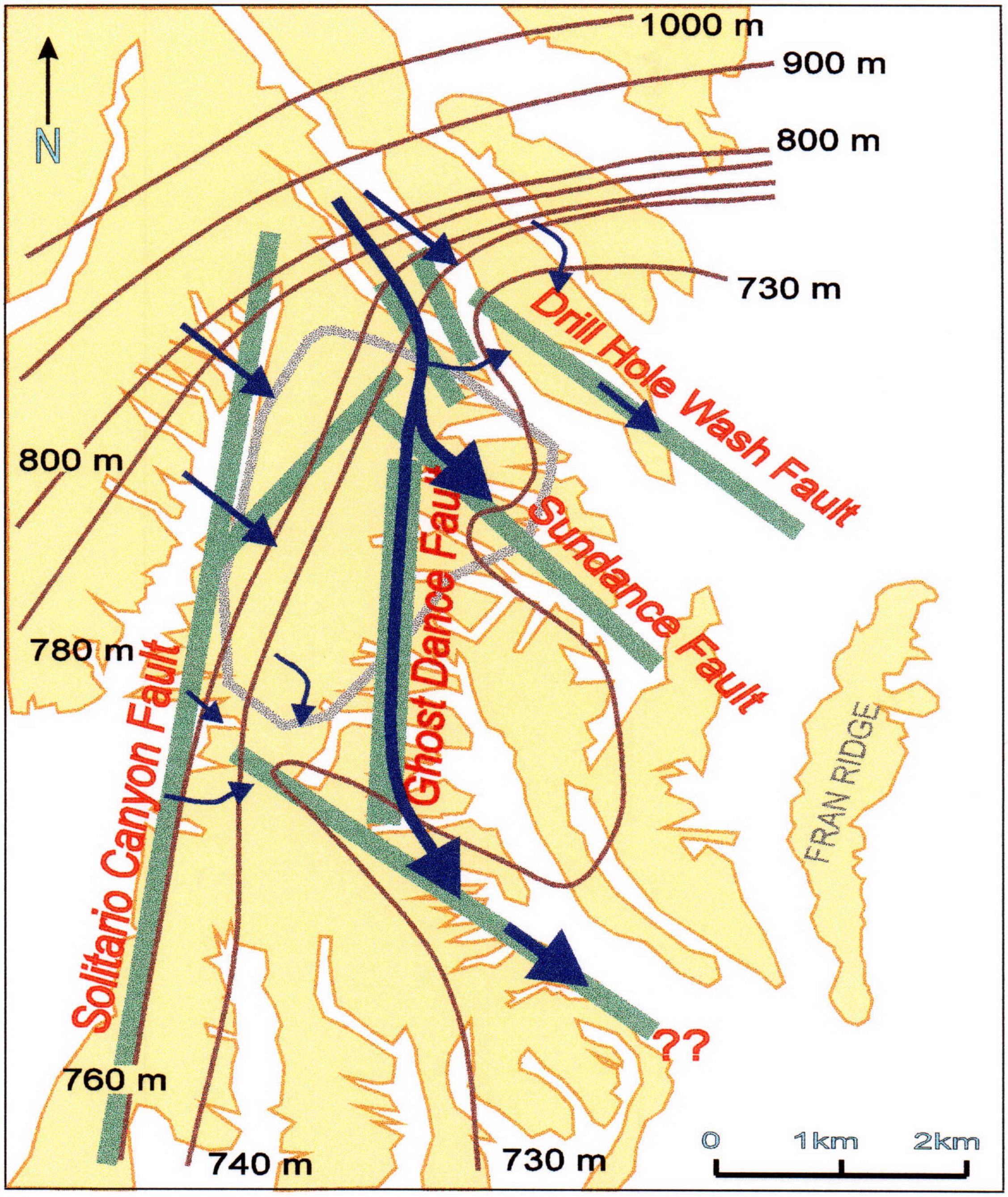

Figure 4. Alternative potentiometric surface with fault locartions and resulting flow pathways.

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4. The basis for the GWTT calculations will be Bodvarsson's 3-dimensional site ground water flow model. This model utilizes matrix flow and faults are currently being modeled as equivalent porous media. Boundary conditions currently assume the Solitario Canyon Fault to be a no flow boundary condition and in general fault zones are considered to be dry or drier than the surrounding matrix blocks. Bodvarsson is currently calibrating his model to water content or saturation. We feel that a lot of other concepts need to be tested with this model before the model is accepted. Current field work is indicating that fracture flow and focused recharge is occurring in amounts which have been assessed at higher than 14 mm per year with some reported values reaching rates of 100 mm per year. Such high flux rates have been observed for several weeks (Flint, 1995). None of these flux rates are possible through the matrix of any tuff units at Yucca Mountain with the possible exception of the Paintbrush Tuff nonwelded unit (PTn). Currently, matrix flow models yield travel times which are in the range of 10s to 100s of thousands of years. Links to the 2.5 year water table oscillation frequencies have yet to be attempted, though Bodvarsson thinks it is possible to incorporate this into the modeling exercises. Our feeling is that matrix flow models will not be able to account for the short time scale phenomenon being observed. Unless these linkages are provided and the higher observed flux rates accounted for, we cannot accept GWTTs based on this model.

During the meeting Cliff Ho of Sandia explained that 2-dimensional models were being developed to do calculations of GWTT along cross sections of the Bodvarsson 3-dimensional model. We hope that the NRC or CNWRA will be examining these 2-dimensional models rigorously. We also hope the assumptions used and the calculations will be available to the State of Nevada for critical review before they become thoroughly entrenched into the performance assessment system.

5. The Site Characterization work is currently not adequate to discriminate between alternative conceptual models. The models which have been developed by State funded research will require changes to the planned site characterization program in order to be verified or ruled out, as the case may be.

One such change should occur within the Systematic Drilling Program. This program was designed when very little was known about the flow system at Yucca Mountain. The initial approach was geared toward developing statistically valid and more uniformly distributed sets of data on which to evaluate flow system mechanics. Much of the work performed on the site utilized the idea of random distributions of hydraulic parameters. This random field concept has dominated the DOE performance assessments as well. However given what we know today, about the correlations within the matrix blocks, the random field idea must give way to other approaches.

The State of Nevada alternative concept of the flow field is not random, but fractal and structurally controlled. Therefore, there are specific sites which should be investigated in order to validate or refute this model, based on the geometry and structure of the site. Much work has been done to date on matrix properties, but what is required is information about fracture properties which control flow and how they are related to the local stress field.

The Large Features Drilling Program approach to site characterization is much superior for locating significant flow pathways. However, to date this program has concentrated primarily on the eastern side of Yucca Mountain, where the picture may be somewhat different than on the western and northwestern sides. Future plans do call for boreholes to be placed in the Solitario Canyon Fault but placements should be re-examined in light of recent data. Well placement is absolutely critical when looking at focusing mechanisms and fracture zones. Specifically, fracture intersections should have highest priority for testing.

The recent unsaturated zone drilling has produced some very useful information while drilling in the northern portion of the repository block, where occurrences of perched water were encountered. While much useful information has been released for well UZ-14, no temperature data have yet been released after 2 years. This is unfortunate because temperature is one of the more sensitive indicators of flow paths. If the temperature of the perched water is cold, its origin could be from the north of the steep hydrologic gradient, implying a natural breach. If it is warm, its origin is likely to be from the west in Solitario Canyon. This is important information and it must be made public, even if it requires caveats as to its accuracy.

The western side of the mountain should be characterized more thoroughly than is currently planned because the repository will, out of necessity for space, be placed as close as possible to the Solitario Canyon Fault. Also, the western edge of the repository will lie at the most shallow position with respect to land surface, perhaps as shallow as 600 feet below the land surface. The potential for recharge along this fault is significant because of the large catchment area, exposures of transmissive soils, and the absence of the PTn unit. Yet this region goes largely ignored to date by the DOE. The tunnel boring machine will not go close to the Solitario Canyon Fault and the northwest ramp extension has not been definitely decided upon and at the moment seems unlikely due to budget constraints. Nye County will be placing a borehole along the Solitario Canyon Fault to investigate its properties, but it is unfortunate that the DOE program to place boreholes in this area is fraught with delays.

6. With respect to statements about the possibility of 10CFR60 being changed: if it is a "silly regulation". We believe this is unnecessary and it should not be changed, as it sets a bad precedent. The 1,000 year GWTT is a reasonable estimate and areas which have such high velocities should be avoided in any case.

II. Future Hydrology Studies for Site Characterization

Russ Paterson of the DOE, presented a description of the future activities of the regional hydrology program at the ACNW meeting on March 10, 1995. The references below are taken directly from Patterson's handout at that meeting. Some specific criticisms of the DOE plan follow.

According to Patterson, Study Plan 8.3.1.2.1.3 entitled Characterization of the Regional Ground Water Flow System will undertake the following work:

- Begin drilling first deep borehole and all of the shallow boreholes for Forty Mile Wash infiltration studies (number of boreholes will be between 10 and 30), complete remaining Forty Mile Wash boreholes and neutron boreholes."

Comment:

This study is not worth this much effort. The Forty Mile Wash infiltration is not going to have much, if any effect on the flow field through the repository (except to provide a boundary effect if significant recharge and rise in water levels occurs). While it may help define infiltration rates in that area, the fact is that most infiltration occurs in the upper reaches of the washes and extensive measurements along the main wash will not be that useful. The money for this effort would be better spent on the western side of Yucca Mountain in the Solitario Canyon Wash up-gradient of the repository. Forty Mile Wash is down-gradient of the repository. Further, more money should be spent on focused recharge locations on the mountain rather than off the mountain.

- "Analyze potentiometric and temperature data from boreholes in the Amargosa Desert and nearby mountain ranges to investigate alternative conceptual models of the flow system."

Comment:

Again, while it is perhaps useful to look at nearby locations, these data gathering efforts should now be narrowed to Yucca Mountain. Focused recharge mechanisms and fracture flow mechanisms on the mountain should have priority, not regional data. If these data collection efforts aren't initiated soon, there will be little actual site data for the License Application.

III. Alternative Concept for the Evaluation of Ground Water Travel Time

There are a number of ways that the NRC and the DOE can evaluate GWTT in terms of whether or not it becomes a disqualifying condition, or represents an unlicenseable situation. Methods were proposed by NRC in a 1986 Technical Position (TP), and by Jeffrey Pohle at the March 16, 1995 Technical Exchange on GWTT. We would like to propose a variation to the approaches of the 1986 TP and those of Pohle, 1995 for your consideration.

Pohle lists the strengths of the 1986 TP to be as follows:

- Establishes the need to perform an uncertainty evaluation

- Highlights the utility of a probability distribution approach to evaluating uncertainty in determining GWTT.

Pohle, 1995, also describes the weaknesses in this approach which includes the following:

- For repositories in the unsaturated zone, it is unlikely that the single "path" (in a macroscopic sense) could be postulated.

- Definition of "path" is limiting because it:

  - focuses efforts toward simplified analysis along a single "path" (one dimensional perspective) and

  - need to consider such things as outflow locations, inflow and outflow quantities and possibility of water particles changing direction, i.e. multi-dimensional movement.

- This also leaves the unresolved question as to what point on the CDF constitutes reasonable assurance of the GWTT along the fastest path.

To attempt clarification of these troublesome items, Pohle has proposed some ideas for discussion, such as clarification of terms. These terms are listed as follows:

1. Groundwater means all water which occurs below the land surface. The term water refers to liquid water, not water vapor.

2. Groundwater travel time can be defined as the time it takes a "water particle" to travel from the particle's point of origin to the accessible environment.

3. Paths of likely radionuclide travel can be defined as the calculated paths of "water particles".

4. Paths of likely radionuclide travel an be defined as those calculated paths of "water particles" that originate at, or are released from, the location of the underground facility.

Generally we are in agreement with these concepts with the exception of Item 1 under some circumstances. Water vapor travel time for pre-emplacement conditions is probably not significant to the GWTT calculation. However, under thermal loading conditions, it becomes a significant component in the advective cycle. If under these conditions it is shown to have a significant role in transporting radionuclides these pathways must also be considered.

This proposed approach, builds from the June 30, 1986 Draft Technical Position on GWTT and incorporates ideas from Pohle and Dwayne Chesnut, of LLNL. In this variant, the first steps outlined by NRC, 1986 are followed, i.e.:

(1) determine the paths of likely radionuclide travel as can be defined by alternative conceptual models.

(2) calculate a cumulative distribution function (CDF) of travel times for each individual path (based on travel times of "water particles").

We believe that these first steps are the most critical, because in this fashion the importance of geological structures to releases can be assessed. The third step as envisioned by the 1986 TP is the most contentious, as it required the determination of the fastest pathway. Pathway in this case was defined deterministically. We agree that the pathways must be deterministic, yet some probabilistic measure of travel time is required along these pathways.

An alternative to the 1986 TP third step is proposed herein which utilizes the above clarifications and a graphic approach to solving this problem. By way of example, the alternative conceptual ground water flow models proposed by Lehman & Associates is used. The first step would be to determine likely paths of radionuclide travel. A conceptual model might allow recharge to occur along specific geologic structures, and ranges of infiltration could vary and be transient. In this scenario a series of pathways could be defined which would be located coincident with structures such as the major and minor fault zones with higher infiltration rates occurring at fault intersections and areas where highly permeable materials are exposed at the surface and especially in areas where the PTn is absent along the western edge of the repository block.

The GWTT between the repository horizon and accessible environment is the crucial calculation. Site scale models and particle tracking could be used to define these pathways and calculate velocities under pre-emplacement conditions. This would require numerous particles to be released in the rock formation at or just above the repository horizon. These particle traces would represent pathways or zones of likely fast pathways.

These pathways would then be translated to a surface (Chesnut's concept) perhaps a section below the repository or at the water table where each pathway would be a point on this surface. The distributions of points on this surface would form a pattern of GWTTs, for example as in Figure 5. Probabilities of exceeding the EPA standard could then be calculated at this surface. In this fashion zones which exceed the standard are defined. This could lead to the disqualification of zones rather than the disqualification of the entire repository, if some zones are likely to exceed the standard.

This approach would also give the DOE information required to make a suitability determination, in that they could determine if the area which does not exceed the GWTT

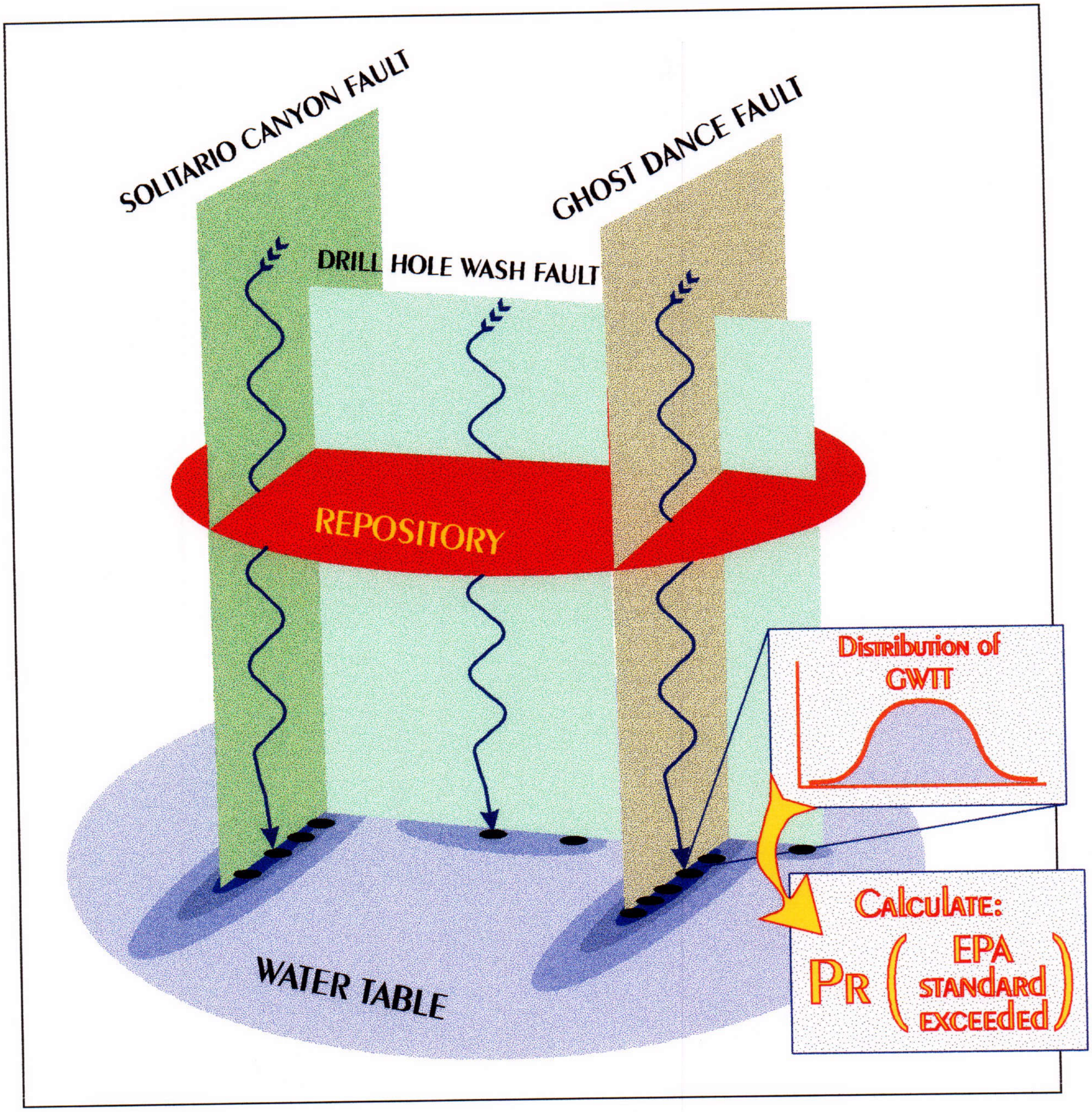

Figure 5. Diagrammatic representation of proposed travel time analysis. First, each pathway has a distribution of particle travel times. Then a probability of exceeding the EPA standard can be calculated. Finally, pathway probabilities are combined to form a map of probability of exceeding the standard at any location.

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criterion is sufficient to make the development of a repository cost effective. When these fast pathways are considered, is there enough repository area available to avoid these regions? If not, then perhaps the repository should not be built. If the areas can be avoided and still manage to dispose of a reasonable amount of fuel, then perhaps it is suitable.

A remaining complication is the concept of the disturbed zone. Since this zone is now entwined in the calculation of travel time, it needs to be addressed in some fashion. It might be approached by changing the location of the release of particles or by changing the position of the surface where the calculation of exceedances is performed. This still remains an open question which is not solved by the above recommendations. However, we think that with some experience in doing these types of analyses, it should be solvable.

Another potential problem would be discriminating between several competing conceptual models. For example, the DOE may urge matrix models over fracture flow models and prefer to analyze as the most probable concept, only matrix models. Some weighting or classifications may be attempted. These things would all tend to skew results.

While the preceding doesn't solve all problems, it is at a minimum, an alternative way to approach the calculation of GWTT and an approach which does not require the disqualification of the entire site, if some GWTT exceedances are observed. Rather, areas or zones could be disqualified and avoided if they have a high probability of exceeding the GWTT criterion.

I hope these comments and suggestions are useful to you and we look forward to a discussion of these ideas.

Sincerely,

L. LEHMAN & ASSOCIATES, INC.

Linda Lehman

Linda Lehman
President

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Enc.

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