SEARCH technical services
(509) 725-6666
STAR ROUTE BOX 17, DAVENPORT WA 99122

WM DOCKET CONTROL
CENTER

'85 MAR 20 P2:25

~~WM Record File~~ 101.5

WM Project 10
Docket No.
PDR ✓
LPDR ✓ (B)

Distribution:
Justus
Kennedy
Wright
(Return to WM, 623-SS)
To: Justus

14 March 1985

U.S. Department of Energy
Attention: Comments—EA
1000 Independence Avenue, SW
Washington, DC 20585

REFERENCE: Technical Review Comment on
DRAFT EA: REFERENCE REPOSITORY LOCATION,
HANFORD SITE, WASHINGTON, December 1984.
SEARCH : 5545

CONCLUSION: The Hanford Site fails the Geohydrology Disqualifying Condition and therefore should be eliminated from further consideration as a potential repository site according to DOE guidelines. Available data indicate a pre-waste-emplacement ground-water travel time from the disturbed zone to the Columbia River of 300 years.

BACKGROUND: According to DOE guidelines, potentially acceptable repository sites are first evaluated in the Draft Environmental Assessment (DEA) against 12 specified Disqualifying Conditions. If the Hanford Site is shown to fail any one of these Disqualifying Conditions, then the site is automatically eliminated from further consideration.

This Technical Review Comment evaluates the Hanford Site in regard to the Geohydrology Disqualifying Condition [1] which is defined as follows:

> "A site shall be disqualified if the pre-waste-emplacement ground-water travel time from the disturbed zone to the accessible environment is expected to be less than 1,000 years, along any pathway of likely and significant radionuclide travel."

In other words, Hanford is eliminated as a possible site if much of a sample of water placed where the repository would be situated would be expected to enter the Columbia River within the next 1,000 years.

8504090028 850314
PDR WASTE
WM-10 PDR

1286

Ideally, one would actually like to carry out the experiment of timing the spread of a suitably tagged water sample. But repository site selection cannot await a thousand-year demonstration of site qualification. Instead, one examines possible pathways and measures appropriate flow velocities to calculate an expected ground-water travel time to the accessible environment. If these measurements and calculations are performed properly, the calculated travel times should be close to the results which would be found from the actual experiment.

The scientific problem is to select the appropriate pathway of <u>significant</u> radionuclide travel and to assign appropriate flow velocities to the various legs of that pathway. The "travel time" along this critical pathway is the sum of the following: the length of each leg divided by the flow velocity along it.

Another technical term of interest is "hydraulic conductivity" which is the flow velocity divided by the "hydraulic gradient." A hydraulic gradient is the slope of an equivalent ground-water surface, which drives the flow. Our interest in these technical terms is that hydraulic conductivity is a physical property of a particular geologic structure, and the hydraulic gradient can be measured from bore-holes. Thus, the flow velocity of each leg of a critical pathway can be calculated as the product of the measured hydraulic conductivity and hydraulic gradient. Such calculations form the basis for travel time predictions.

This review assumes that the repository is emplaced within the Cohassett Flow of basalt at a depth of about 3,000 feet, Fig. 1 [2]. This review further represents that accessible environment to be the Columbia River which is about 60,000 feet to the east of the reference repository location, Fig. 2 [3]. Corresponding to these vertical and horizontal scales, any significant pathway

STRATIGRAPHY OF REFERENCE REPOSITORY LOCATION

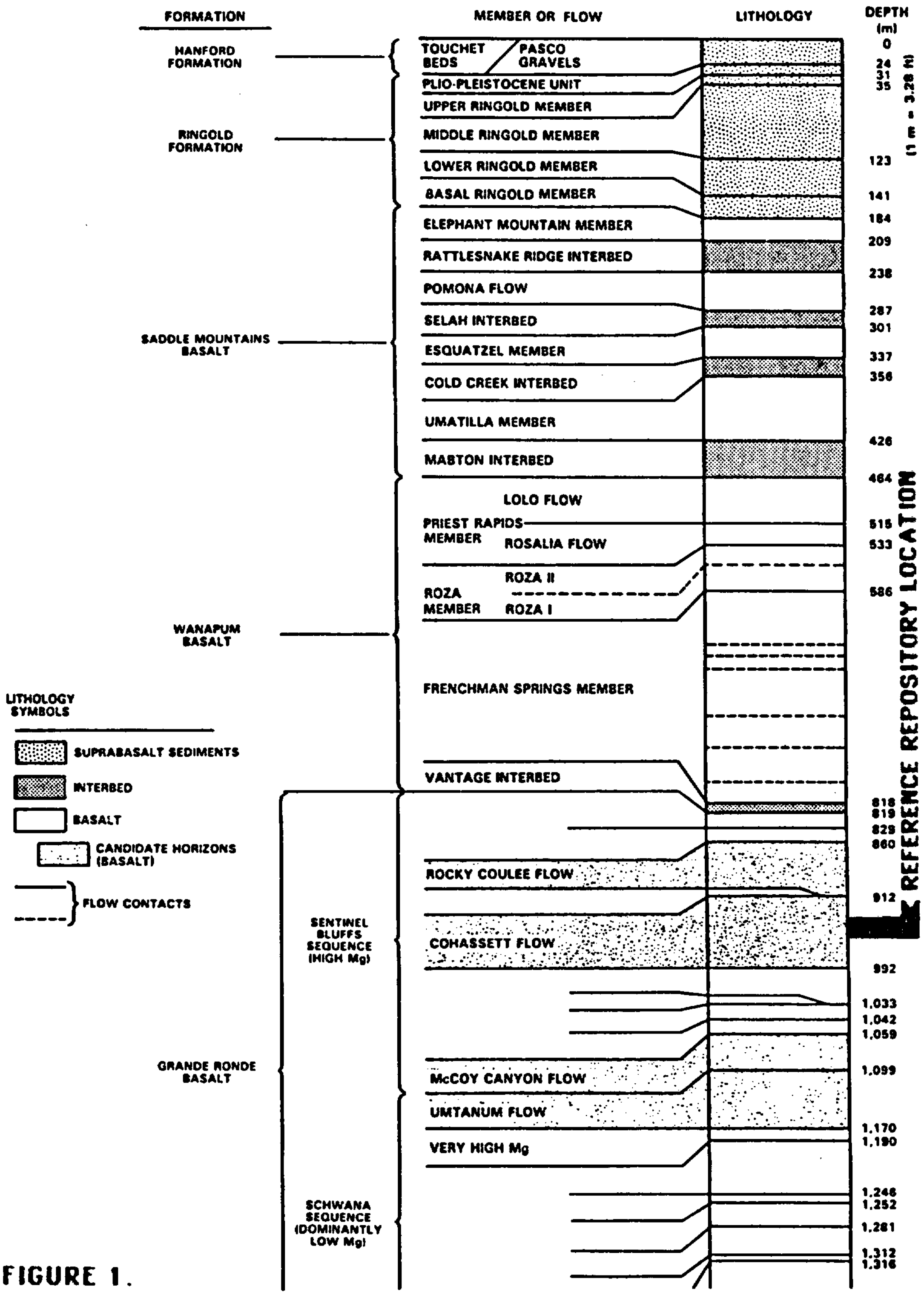


FIGURE 1.

SEARCH.

REFERENCE REPOSITORY LOCATION
WITH NEARBY EARTHQUAKE CENTERS SINCE 1969

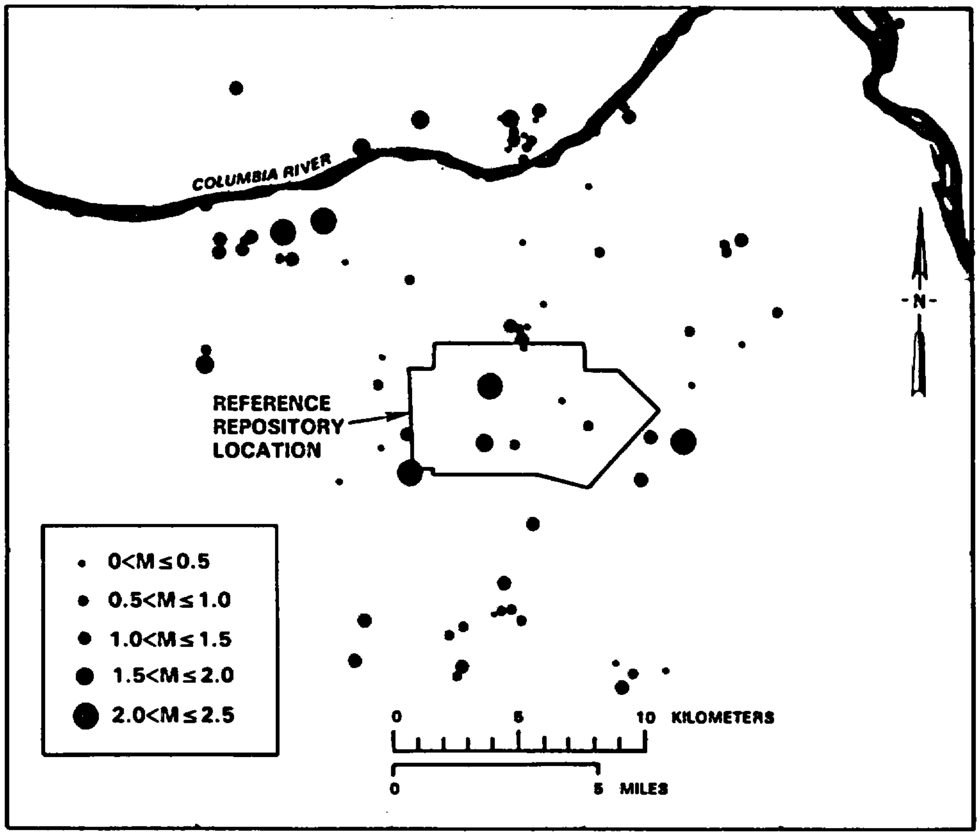


FIGURE 2.

connecting the repository to the Columbia River can be expected to have vertical and horizontal legs.

This review seeks vertical and horizontal structural pathways which can be expected to provide the least resistance to ground-water flow from the reference repository location to the Columbia River. With such pathways of least resistance identified, travel times are calculated from the available data for each leg, and the travel times are summed for the pathway. These calculated travel times must be less than 1,000 years in order for the Hanford Site to pass the Geohydrology Disqualifying Condition.

To obtain a rough idea of expected horizontal ground-water travel times in the area, one may examine the tritium plume released (beginning in 1944 or later) from the 200 East Area which lies just east of the reference repository location. The <u>surface</u> aquifer plume from the 200 East Area reached Well 699-2-3 in

21 years,

Fig. 3 [4]. The site map in Fig. 3 shows that Well 699-2-3 is about as far east of the 200 East Area as the Columbia River is east of the reference repository location. That is, this 21-year period is a crude estimate of the travel time which might be expected for the horizontal leg of a sedimentary pathway connecting the repository to the Columbia River.

Well 699-2-3 was selected for this travel time estimate because its tritium record is particularly simple: There is an abrupt breakthorough of tritium-bearing water in 1965, followed by an exponential increase in concentration, followed by near attainment of saturation concentration in 1976.

Although the horizontal leg of the surface aquifer, extending from 3,000 feet over the reference repository location to the Columbia River, has a travel time of only 21 years to breakthrough, there is no similarly conductive vertical leg connecting the repository

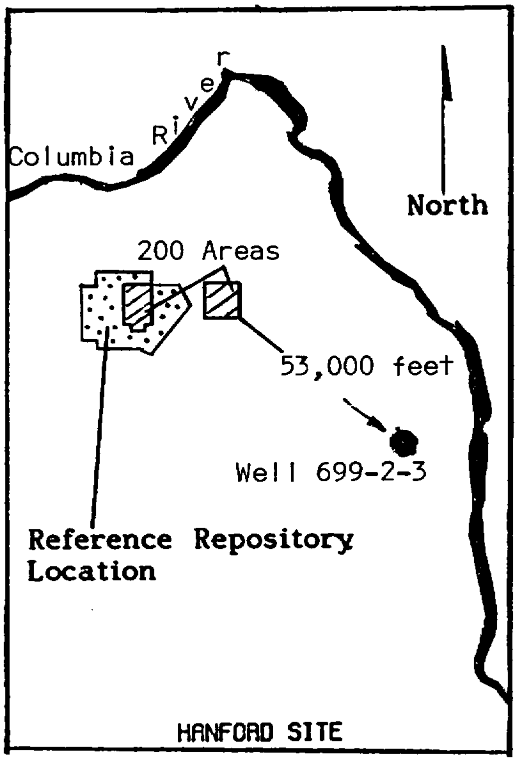
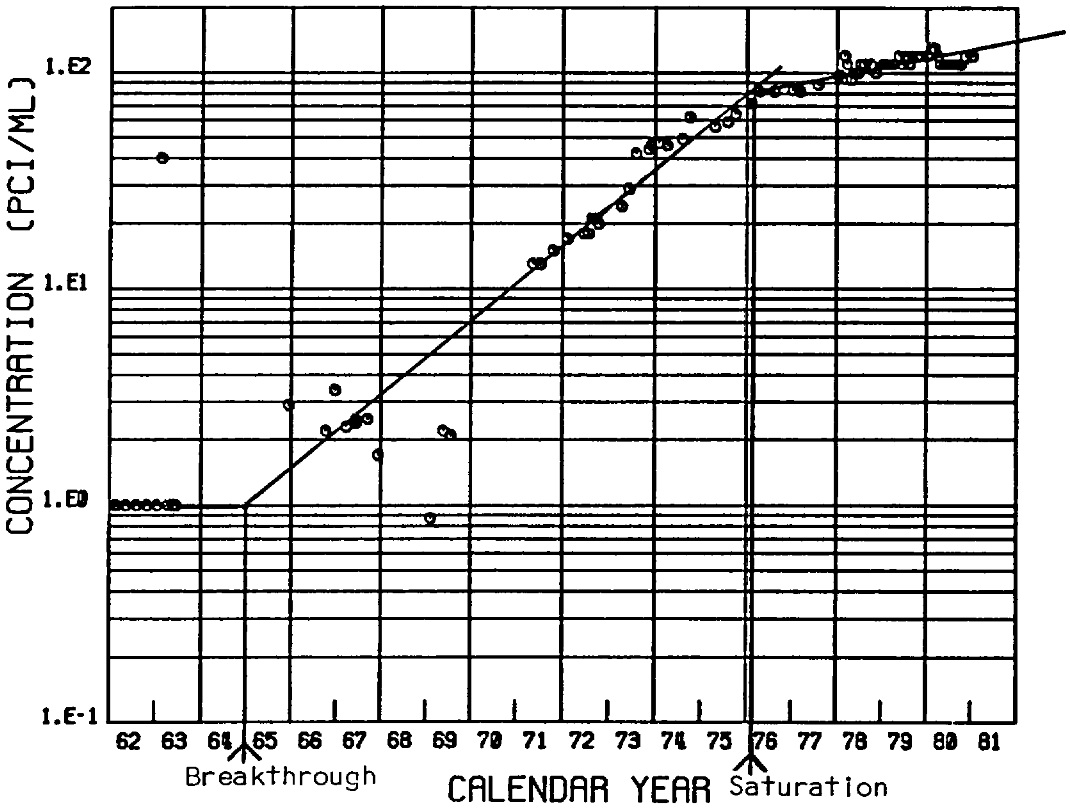


FIGURE 3. TRITIUM HISTORY OF WELL 699-2-3



location to the unconfined surface aquifer in which the flow of Fig. 3 was measured. One may suspect that the presumedly local recharging of the deep aquifers at Hanford would imply reciprocal, upward flows to the surface aquifer as well. But any such pathways are not identified in the DEA. If such vertical legs do exist over the reference repository location, the travel time to the Columbia River might be as low as 21 years. However, in the absence of supporting data, the review turns to other, better identified pathways.

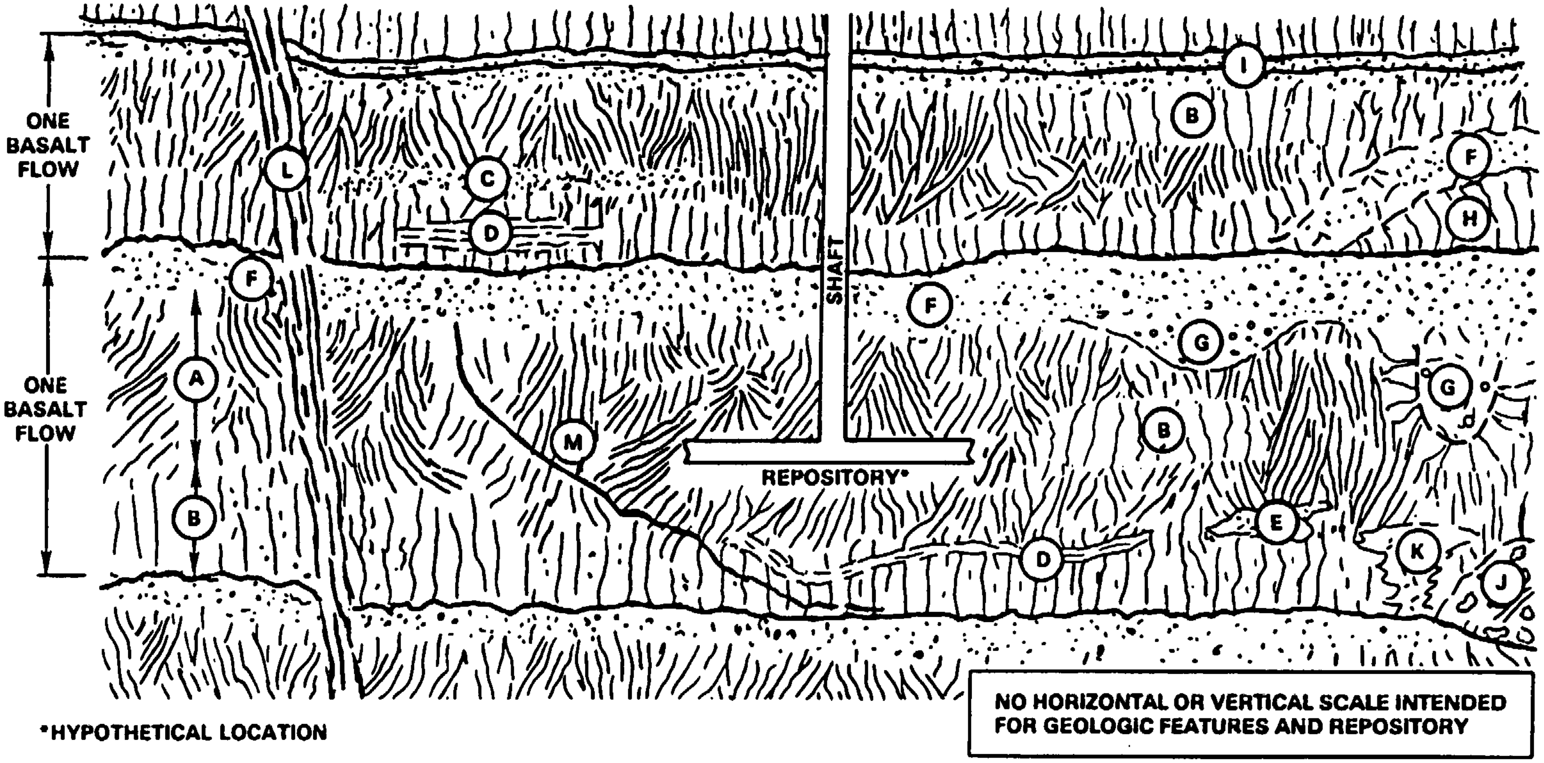
FLOW PATHS: This section identifies a ground-water pathway to the Columbia River, composed of one vertical leg and one horizontal leg. Then in the following section, the conceptual basis for this identification will be explored.

Begin with the observation that ground-water travels quite rapidly, horizontally, in sedimentary units such as the surface aquifer at Hanford. Thus, the stratigraphy of Fig. 1 may be reexamined for a sedimentary "interbed" which might have hydraulic conductivity similar to the surface aquifer but would not require such a lengthy vertical leg between the reference repository and that interbed.

Figure 4, taken from the DEA, provides a hypothetical, composite cross section of possible geologic features in a layered basalt sequence with the repository sketched [4]. This figure shows an interbed situated one basalt flow above the basalt flow in which the repository is located. Furthermore, Fig. 4 shows a major fault or fracture which connects the level of the repository with the level of the interbed. That is, Fig. 4 presents hypothetical vertical and horizontal legs of a pathway which might connect the repository to the Columbia River.

As a first step twoard evaluating this hypothetical pathway, the approximate scales of the reference repository [5] and the

GEOLOGIC FEATURES IN A LAYERED BASALT SEQUENCE



*HYPOTHETICAL LOCATION

	FLOW INTERIOR DISCONTINUITIES		FLOW CONTACT		BEDROCK STRUCTURAL DISCONTINUITIES
A	ENTABLATURE JOINTS	F	FLOW TOP	L	FAULT OR FRACTURE ZONE, HINGE OF FOLD, OR SHEAR ZONE
B	COLONNADE JOINTS	G	LOCAL THICKENING OF FLOW-TOP BRECCIA	M	LOCALIZED TECTONIC FRACTURE
C	VESICULAR ZONE	H	FLOW TERMINATION		
D	PLATY ZONE	I	SEDIMENTARY INTERBED		
E	LOCAL FRACTURED ZONE	J	PILLOW BRECCIA		
		K	SPIRACLE OR SPIRACLE-LIKE FEATURE		

FIGURE 4.

stratigraphy (Fig. 1) may be combined with the hypothetical geologic features of Fig. 4 to allow some appreciation of possible spatial relationships. Figure 5 is the diagrammatic result, with the repository shown in the Cohassett Flow which the DEA finds to be most geologically promising [6].

The striking feature of this scaling of the actual structures is the great horizontal extent--about 11,000 feet [7]--of the repository.

APPROXIMATELY SCALED CROSS-SECTION
AND
CRITICAL FLOW PATH FOR DEA PREFERRED LOCATION

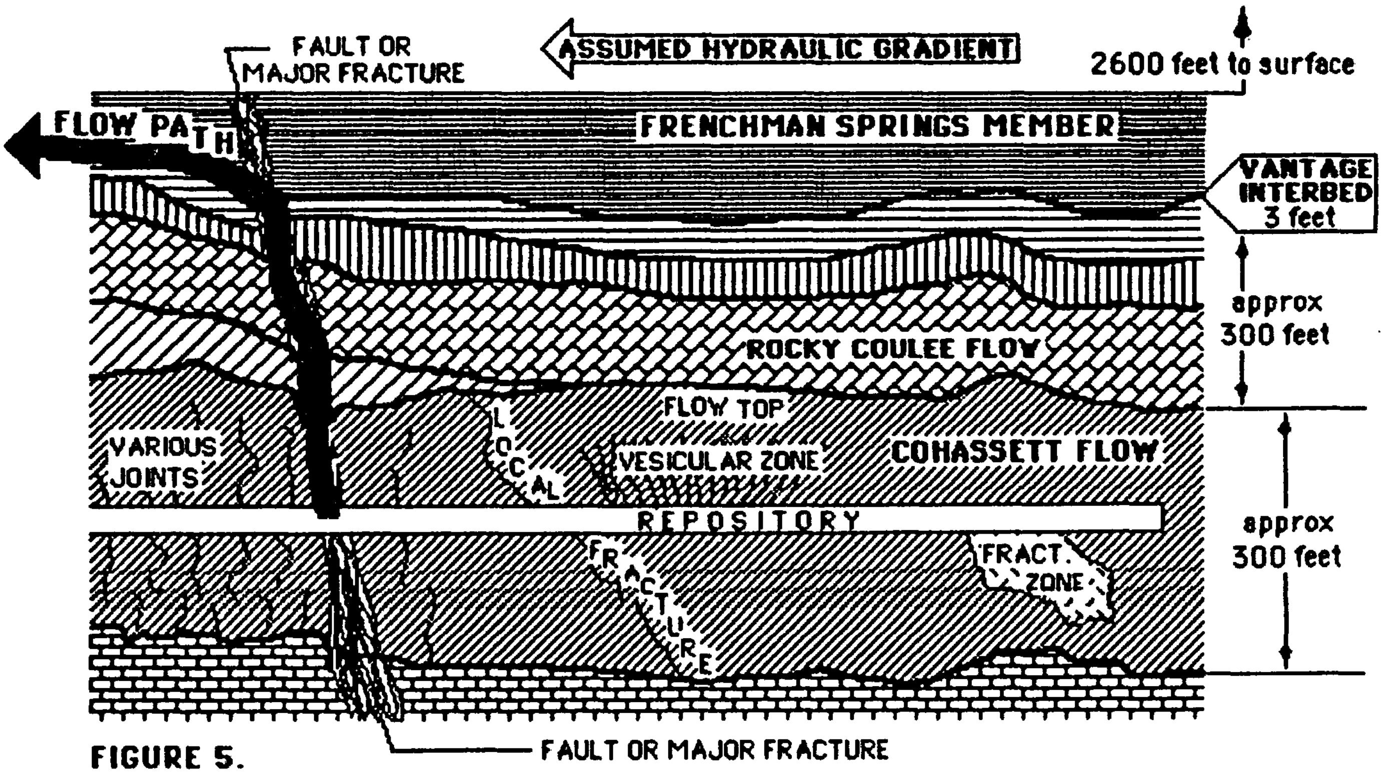


FIGURE 5.

Figure 5 shows this scaled repository to cross several vertical discontinuities in the Cohassett Flow. The most severe of these discontinuities, a fault or major fracture, is shown as connecting the repository to the Vantage Interbed, some 400 feet above it.

The next step is to estimate how likely it is that the 120,000,000 square-foot repository will actually intersect such a fault or major fracture. Three lines of inquiry suggest that such intersection is very likely: (1) One major discontinuity, the "Cold Creek Barrier," is already identified next to the reference repository location, in DEA Fig. 3-1. (2) General descriptions of Central Basin basalt outcropping [8] and easily made observations from roadways reveal major vertical discontinuities with horizontal scales much less than the repository scale. (3) General consideration of quasi-static plate failures suggests fracture spacing on the order of plate thickness, in this case less than 1,000 feet. On this basis, an arrow is drawn into Fig. 5 to depict the probable, significant flow pathway for the reference repository location in the Cohassett Flow.

Once the ground-water has reached the Vantage Interbed, rapid horizontal migration can be expected to expose that water to other vertical discontinuities over a wide area, allowing migration to other interbeds or the surface aquifer.

MODELING CONCEPTS: The evaluation of this repository-fracture-interbed-river pathway requires an understanding of both sampling and modeling biases. Consider an example which is more intuitive and familiar than ground-water flow:

Suppose that the steel-hulled S.S. Cohassett, shown in Fig. 6 has been torpedoed and that the captain asks a geologist (who happens to be aboard) to estimate the time before the ship will sink. The geologist probes the 88 plates on each side of the hull at random points to locate holes which would cause the ship to leak. Figure 6 shows the torpedo hole to have an area equal to about four plates, so the chance that any one probing of the hull will reveal the torpedo hole is only 4/176=2.3%.

SINKING OF THE S.S. COHASSETT

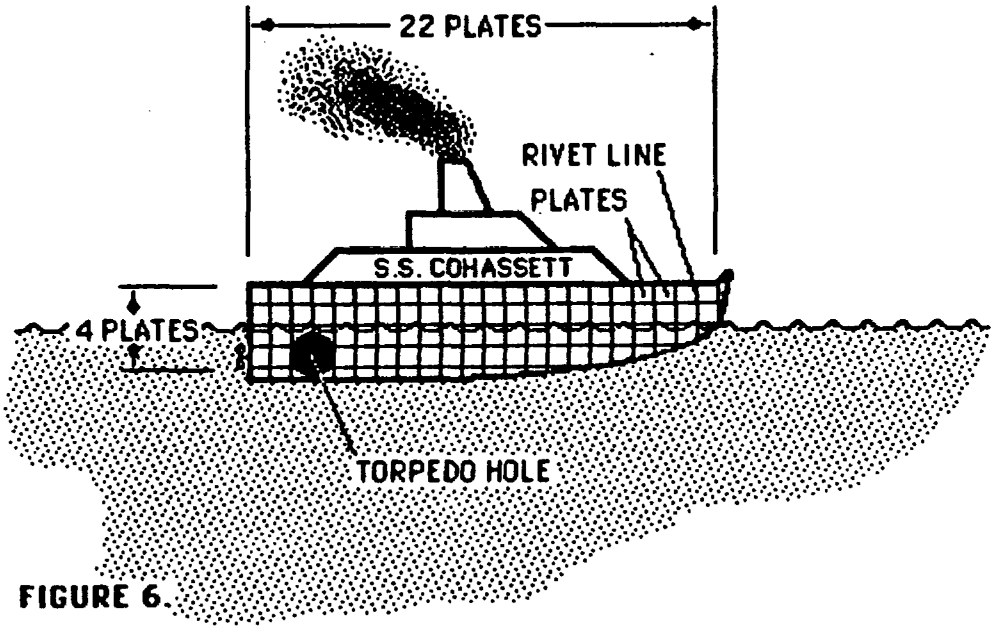


FIGURE 6.

Many random probings are required to achieve any confidence of finding the torpedo hole. For example, 10 random probings would have only a 21% chance of finding the hole. Even 50 random probings provide only a 78% chance of finding the hole. But if the geologist's probe does not enter the torpedo hole, his data can only reveal small rivet leaks which could not sink the S.S. Cohassett. That is, with a limited sampling program, the geologist is likely to report back to the captain that the Cohassett will not sink! The point of this example is that sampling programs underestimate the severity of leaks, whether into the S.S. Cohassett or out of the Cohassett Flow at Hanford. This inherent sampling bias is exacerbated as the number of samples is reduced. In the limit, there are no (reported) leaks if there are no samples taken.

> Now take the example a bit further. Suppose the geologist conducts 50 probings with the following outcomes: 42 probings reveal solid hull plates; 7 probings reveal slightly leaking rivets; and one probing reveals the torpedo hole. With the torpedo hole found, it can then be measured. The geologist can then calculate the sinking rate of the ship. But in order to do so, the geologist must recognize that the torpedo hole is **the only significant datum** he has.
>
> If instead the geologist applies usual data processing techniques to determine an "effective" hole size, he may be misled: The mean hole size is 1/50 of the torpedo hole size while the median and modal hole sizes are each zero. The point of this further development of the example is that usual data processing techniques may inadvertently bias the calculation toward unrealistically low leakage rates.
>
> From this example of the sinking of the S.S. Cohassett, the reader may appreciate the care that is necessary to assure that ground-water travel time from the repository location to the Columbia River is not grossly overestimated.

CALCULATION: With this awareness of biases toward exaggerated travel time estimates, the review proceeds to assignment of representative travel times to the legs of the repository-fracture-interbed-river pathway. The upward direction of flow in the vertical fault or fracture leg is supported by

> ...measurements across the deep basalts indicate either a slight upward gradient or essentially no gradient [9].

The upward flow is also driven by the buoyancy effect of ground-water heating by radioactive decay of the contained waste. This "chimney effect" depends on the extent of ground-water heating, which has not yet been characterized by DOE [10].

In lieu of final DOE characterization, leaching temperature studies for a variety of potential waste containment media suggest an expected temperature near 194°F [11]. If ground-water ambient is about 54°F, the leach water may be assumed to be heated 140°F above ambient. Its density would then be decreased about 3.5% due to this heating. This would introduce a vertical hydraulic gradient of 3.5%. Applying this gradient to the only hydraulic conductivity data (10 feet/day) given for a (localized) fracture zone near the site [12], the travel time for the vertical leg of the flow path is calculated to be two years.

As an alternative model for the vertical leg travel time, consider a major structural discontinuity which exhibits an abrupt change in hydraulic head. The most extreme measurement for the area shows a "hydraulic head" drop of 500 feet [13]. (Hydraulic head is the hydraulic gradient multiplied by the distance over which it occurs.) If either this horizontal change in hydraulic head does not occur in each stratigraphic member or if the discontinuity is not exactly vertical, then an equal, local vertical head is developed. In the absence of other data, such a 500 foot vertical head may be presumed to apply to the 400 foot-high, assumed fault or fracture connecting the repository location to the Vantage Interbed. If this vertical hydraulic gradient of 500 feet/400 feet = 1.25 is multiplied by the above fracture conductivity (10 feet/day), the critical travel time up the fracture is calculated to be 50 days.

From either this model of a structural discontinuity or the previous model of buoyancy, one concludes that the vertical leg of the flow path can be expected to have a travel time which is trivial compared to the 1,000-year requirement of the Geohydrology Disqualifying Condition. Therefore, this required 1,000-year travel time must be provided by the horizontal leg if the Hanford Site is not to be disqualified.

The preview of this horizontal leg travel time provided by the tritium plume in the surface aquifer is not encouraging. However, one may still hope that travel times for interbeds above the Cohassett Flow might be drastically greater. Unfortunately, the only DEA data relevant to the horizontal leg travel time are the following:

> ...the hydraulic conductivities of most individual flow tops and interbeds range between approximately 10^{-4} and 10^{7} meter per second [$=10^{4}$ to 10^{1} feet/year, emphasis added, 14]....

As the example of the sinking of the S.S. Cohassett demonstrated, "most" values are irrelevant for the calculation of leakage rate. The largest hydraulic conductivity paths generally dominate the leakage. Thus, one wants to know, What is the hydraulic conductivity of the interbed with the highest conductivity?

In the absence of a published value of this critical datum, a representatively large conductivity for an interbed may be estimated from the observation that hydraulic transmissivity data for the basalt-flow tops in the Grande Ronde Basalt are log-normally distributed. Then if one also applies this probability distribution to hydraulic conductivities for the 12 major stratigraphic features within 1,000 feet over the Cohassett Flow reference repository location (Fig. 1), the maximum feature conductivity--presumably of the Vantage Interbed--may be estimated. For this estimation, the meaning of "most" individual flow tops and interbeds is equated to 51% of those flow tops and interbeds. For the log-normal distribution, this 51% range corresponds to 0.69 standard deviations from the log-mean. Also for the log-normal distribution of hydraulic conductivities, the conductivity of the most conductive stratum of 12 strata is expected to occur at 1.39 standard deviations about the log-mean. Figure 7 diagrams the analysis. According to this calculation, the most conductive stratum of the 12 strata above the repository would have an expected hydraulic conductivity of $3X10^{5}$ feet/year. (If this extrapolation is incorrect, DOE will presumably publish data demonstrating that no interbed hydraulic conductivity measurements have values this large.)

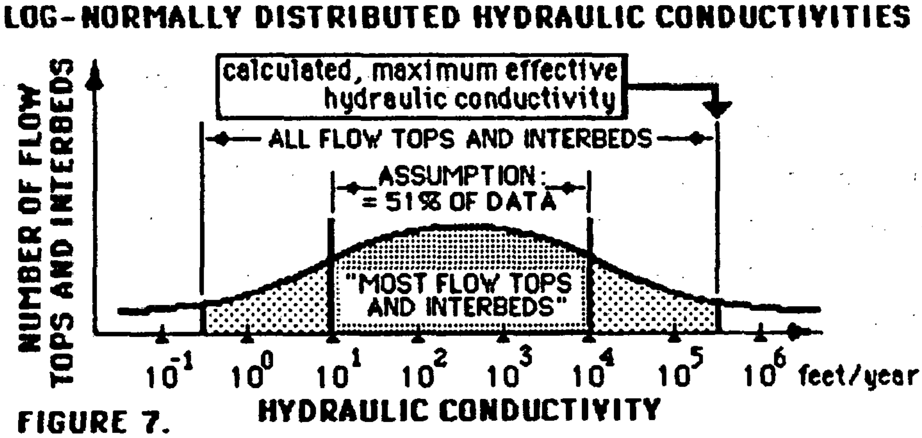


FIGURE 7.

The effective hydraulic gradient must also be determined in order to calculate the travel time for the horizontal leg of the interbed flow. The "deterministic regional hydraulic gradient" used in the DEA is 10^{-3} [<u>16</u>]. This is a factor of 10 greater than the regional average for the Cold Creek syncline [<u>9</u>]. Still, the use of this seemingly conservative value is justified from the same considerations as were explored in the "sinking of the S.S. Cohassett:" that is, the flow is expected to travel the shortest, high conductivity pathway to the lowest surface available (the Columbia River channel). Multiplying the effective hydraulic conductivity ($3X10^5$ feet/year) by the effective hydraulic gradient (10^{-3}), the effective flow velocity is obtained:

300 feet/year.

This is 17% of the easterly component of the breakthrough flow velocity to Well 699-2-3 in the unconfined surface aquifer, implying that the Vantage Interbed is expected to be much more compact than the surface aquifer. The 300 foot/year flow velocity implies a breakthrough travel time to the Columbia River of 60,000 feet / 300 feet/year =

200 years (to breakthrough).

Breakthrough, however, does not imply a significant release of radionuclides to the Columbia River. As Fig. 3 shows, the breakthrough concentration of radionuclides is negligible: The maximum concentration of radionuclides released to the Columbia River requires about 50% more time. That is, the expected travel time for significant radionuclide travel to the Columbia River is

300 years.

The ground-water from the repository disturbed zone is expected to emerge from one or more of the nearly 115 springs which enter the Hanford Reach of the Columbia River [17]. At least one of these springs is already demonstrated to be contaminated beyond Washington State drinking water standards [18].

SUMMARY: The 300-year travel time to the Columbia River predicted in this review is dramatically different from the DEA prediction of an 81,000-year travel time. This difference is attributable to the following:

This review and the DEA use different pathway assumptions. This review employs an interbed flow path on the basis that it is expected to be the most significant flow path. The DEA employs the basalt flow top that overlies the repository horizon on the basis that this "most direct groundwater pathway" is

> **one plausible hydrologic conceptual model** [emphasis added, 15].

This model is simply "assigned" to the Hanford Site. In other words, the conceptual basis for the DEA model makes no assumption that the model actually represents the travel time that can be expected nor does it even seek to identify "any pathway of likely and significant radionuclide travel," as required by the Disqualifying Condition.

Nonetheless, the DEA model formalism allows a calculation of probabilities according to that model, as carefully stated in the DEA:

> The cumulative distribution of ground-water travel times predicted by the ... model is shown in Figure 6-22....
>
> From this distribution, it is estimated that pre-waste-emplacement ground-water travel time has a probability of approximately 0.95 of exceeding 1,000 years [emphasis added, 20].

Notice that the DEA does not contend that the actual ground-water travel time is likely to exceed 1,000 years.

By careful reading of these DEA statements, one discovers that no technical disagreement between the result of this review (a 300-year travel time) and the DEA calculation (an 81,000-year travel time) exists: The former is an estimate of the condition of physical reality; the latter is a reported output datum of a mathematical model. One further understands the DEA summary statement that

> Based on current knowledge, obvious disqualifying conditions have not been identified that would result in rejecting the reference repository location from further consideration for a nuclear waste repository [emphasis added, 21].

The DEA has avoided identifying pathways of likely and significant radionuclide travel, thereby avoiding necessary elimination of the Hanford Site on the basis of the Geohydrology Disqualifying Condition.

Submitted as a public comment by,
SEARCH Technical Services

Norman Buske
Principal Reviewer

DISTRIBUTION: Unlimited: Parties of interest.

DISCLAIMER: This review was prepared as a public service at the expense of SEARCH Technical Services, a proprietorship registered in Washington State. Responsibility for this review resides exclusively therewith. This review is not copyrighted and may be used for any purpose. Additional copies are available, without charge, subject to supply.

REFERENCES AND NOTES

1. Draft EA: Reference Repository Location, Hanford Site, Washington [DEA], DOE/RW-0017, U.S. Department of Energy, Section 2.3.1.1 (1984).
2. DEA, Fig. 2-29 (p.2-58) is copied as Fig. 1.
3. DEA, Fig. 3-25 (p.3-56) is copied as Fig. 2.
4. The approximate extent of the ground-water tritium plume is shown in Fig. 7 of Environmental Surveillance at Hanford for CY 1982, PNL-4657, Pacific Northwest Laboratory, 24 (1983). Figure 3 is modified from Fig. 13 of Radiological Status of the Ground Water Beneath the Hanford Site, PNL-3768, Pacific Northwest Laboratory, 31 (1981).
5. DEA, Fig. 3-36 (p.3-84) is copied as Fig. 4.
6. DEA, Section 2.2.3.
7. Taken from the scale on DEA Fig. 5-5 (p.5-16). The 5,272-foot height of the underground facility suggested in this figure is assumed to be adjustable downward to fit within the basalt flow site.
8. See Roadside Geology of Washington, D.A. Alt and D.W. Hyndman, Mountain Press, 193-216 (1984) for an excellent introduction to the character of the basalt flows as well as a statement of concern about the radioactive wastes already in hydrogeological retention at Hanford. Another descriptive background is provided by Geology of the Grand Coulee, address before the Northwest Scientific Association, Spokane meeting, December 27, 1928, J.G. McMacken, if you can find a copy. Important structural discontinuities are usually identified and mapped by means of seismic surveys which have become extraordinarily well developed by the petroleum industry. A theoretical introduction is provided in Seismic Filtering, R. Van Nostrand, ed., Society of Exploration Geophysicists (1966). Detailed seismic evaluation of fractures is curiously missing from the DEA.
9. DEA, p.3-89.
10. DEA, p.6-262.
11. Twelve authors presented data for leaching from special containment media for high-level wastes in Scientific Basis for Nuclear Waste Management, S.V. Topp ed., North-Holland. Those authors were Stone, Spitsyn et al., Dosch, Welch et al., Vance et al., Staples et al., Campbell et al., Oversby and Ringwood, Boatner et al., Hayward and Cecchetto, Reeve et al., and Hermansson and Christensen.

The leaching temperatures (^{o}F) they reported were as follows:
72, 77(2), 104(2), 140, 167, 194(8),
203(2), 212(2), 302(2), 392, 1112
The two lowest temperatures provided room-temperature references, and the highest temperature involved consideration of radiation effects. 8/12 of the authors employed 194^{o}F.

12. DEA, p.3-86.
13. DEA, p.3-90.
14. DEA, p.3-88. No reference other than Strait and Mercer (1984) is provided for the 200 single-hole data upon which the quoted range is based. That reference, and the other references with "SD-" prefixes are not available to the public, according to Rockwell Hanford Operations.
15. Stochastic Analysis of Groundwater Traveltime for Long-term Repository Performance Assessment, RHO-BW-SA-323P, P.M. Clifton et al., Rockwell Hanford Operations, 5 (1983). DEA, p.6-265.
16. DEA, p.6-266.
17. Investigation of Ground-Water Seepage from the Hanford Shoreline of the Columbia River, PNL-5289, W.D. McCormack and J.M.V. Carlile, Pacific Northwest Laboratory, vii (1984).
18. A Gross Beta value of 88 pCi/L was reported in Hanford Reach Expedition Report, N. Buske and L.S. Josephson, Search Technical Services, apparently for Spring Designation 15-0 of [16]. That report used Public Health Laboratories Report No. 2308.
19. DEA, p.6-269, 6-271-272.
20 DEA, p.6-268.
21. DEA, p.2-64.

--+--