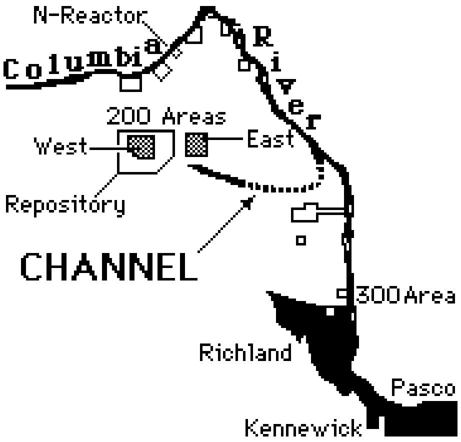


SEARCH Technical Services
HCR 11 - Box 17
Davenport, WA 99122
(509) 725-6666

**Hanford
Reach
Project**

Technical Basis of the Channel Theory

prepared for
Hanford Site Groundwater Monitoring Meeting
- 29 July 1986

Reprinted November 2002

The RadioActivist Campaign
7312 N.E. North Shore Rd.
Belfair, WA 98528

Norm Buske

Summary of Channel Concept

Since 1960, geologists have known that several old Columbia River channels cut the Ringold formation at Hanford. These channels were filled with Pasco gravels as the glaciers receded. Data from Hanford wells showed one such channel at the 200 East Area and another at the old Hanford Townsite. We propose that these are one and the same channel which forms the major groundwater feature at Hanford. This particular channel is partly filled with cobbles and boulders allowing more than 4 million gallons per day of waste water to travel from 200 East Area to the river in only 3 years and providing limited surface area for the sorption of radionuclides.

Implication

Present-day water movement in the unconfined aquifer at Hanford is one of the simplest, most measured, thoroughly modelled, and best understood monitoring problems at Hanford. Battelle Pacific Northwest Laboratory (PNL) annually performs thousands of analyses on samples from hundreds of the available wells and from the Columbia River. These and many other study results are compared with PNL's sophisticated VTT Model of groundwater movement to assure that the model agrees with reality.

In spite of the accuracy which PNL's programs assure that the VTT model can have, the model describes a slow seepage flow with at least a 30-year travel time to the river. This model conflicts with a continuous underground channel from 200 East Area to River Mile 28 [see header on p. 1]. Available evidence shows that the VTT Model improperly omits this largest of Hanford groundwater features.

We conclude that present-day science at Hanford cannot solve the simplest groundwater problem. On this basis, we doubt that present-day science at Hanford can reliably solve vastly more difficult and vastly more important problems of long-term disposal of civilian and defense waste.

In the case of a deep geological repository for either civilian or defense waste, the connection between the failure of the VTT Model and the expected failure of proposed models of the deep, confined aquifers is direct: All involve saturated flows of groundwater down the hydraulic gradient and into the Columbia River. All these modeling efforts employ similar sorts of collected field data, similar laboratory tests of flow media, and similar computer codes. The differences are that the VTT Model is much more accessible to input data; the VTT Model can be verified from observations of the actual transport history of desfense wastes over the last 40 years; and the VTT Model is insensitive to water movement between aquifers. That is, the unconfined aquifer is substantially easier to model accurately than are the confined aquifers at Hanford.

In the case of shallow disposal of defense wastes in the unsaturated zone, a conceptually different kind of model accounts for 99% of DOE calculated radionuclide travel time to the Columbia River [Disposal of Hanford defense high-level, transuranic and tank wastes, DOE/EIS-0113, e.g., Table Q.9]. That different model admittedly "demonstrates a rather high degree of uncertainty" and "is to some extent subjective [p. O.8]." This admitted uncertainty contrasts to the description of the VTT Model as "well documented and its application to the unconfined aquifer underlying the Hanford Site is a matter of record [p. O.24]." From this we conclude that massive failure of the VTT Model eliminates confidence in DOE's model of the unsaturated zone.

DOE's model of the unsaturated zone conceives of radionuclides such as ^{90}Sr being tied to the soils and migrating extremely slowly to the unconfined aquifer below. Even relatively mobile ^{99}Tc would only "reach the Columbia River within a few hundred years after initiation of waste leaching if no barriers to migration intervene [p. R.45]." This conclusion differs from the reality that the channel is already discharging both of these radionuclides into the river at unaccountably high concentrations.

Recommendations

Based on physical evidence which is described in the following sections, I recommend the following:

- Eliminate Hanford as a candidate high-level waste repository because of demonstrated technical nonfeasibility of evaluating groundwater flow from any deep aquifer to the accessible environment.

- Retract the Defense waste DEIS until modeling of Hanford groundwater flows and contaminant transports have become reasonably accurate.

- Rebuild the conceptual and mathematical models of groundwater flow at Hanford so that predicted travel times of important radionuclides can be expected to agree with reality to within a factor of about 3.

- Critically review present Hanford Operations-related safety, health, and environmental programs to assure that the absence of major accidents at Hanford has a technical basis.

Evidence of the channel

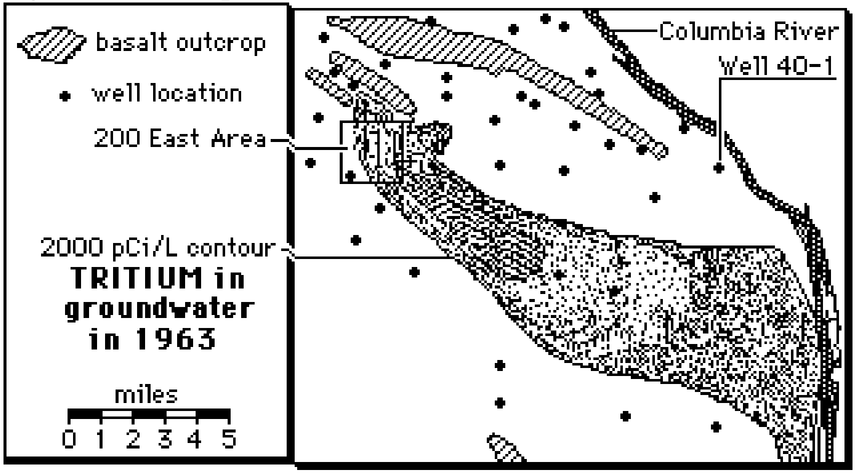
Geology • Randall E. Brown [An introduction to the surface of the Ringold Formation beneath the Hanford Works Area, HW-66289, August 1, 1960] discovered the old river channels at Hanford and described the importance of that discovery as

> . . . the fourth major breakthrough in the solution of the detailed geology of the Hanford region [p.1] . . . evidently continuous . . . old river channels incised into the Ringold sediments and filled with highly permeable Recent fluviatile gravels [p.4]. . . . Many of the channels now bottom beneath the current ground water table. Where this occurs ground water flow toward the Columbia River is at least potentially at quite rapid rates through the highly permeable fluviatile gravels [p.2].
>
> The minimum altitude of the bottom of the channels is imperfectly known, because those few wells that penetrate them measure their depth only at single points [p.5]. . . . Recognition of the presence of the channels permits monitoring wells to be located better where the most rapid ground water flow occurs and where contaminants may be moving rapidly toward the Columbia River (the least desirable situations) [p.2]. . . . The two- to three-mile spacing of wells easily permits geologic features of small extent to remain undetected [p.4]. . . . The exact location, width and depth of the channels is clearly subject to reinterpretation as new information becomes available. The location and indicated depth of the channels in the east central part of the map area, adjacent to the Columbia River where few wells exist, are based more on the need for an exit channel there than upon positive evidence of such a channel [p.6]. . . . Refinement of the channel pattern is necessary to explain still better the observed behavior of the ground waters and containments, and to permit improved predictions of the probable behavior of wastes in the ground. This

> in turn will permit increases in and the further assurance of the safety of disposal at Hanford [p.8].
>
> Accurate delineation of the interface between these two geologic units [the Pasco gravels and the Ringold formation] thus is the **most important single geologic problem at Hanford if the magnitude of the delaying effect of the Hanford geology is to be determined and if the movement of wastes and ground waters is to be reliably predicted for postulated sets of conditions** [emphasis added, p.2].

Early movement • Radioactive waste is a wonderful tracer for study of groundwater movement. It is so diverse that many properties of the medium through which it passes can be calculated from well data. The calculations involve high-school algebra. The numbers used in the calculations are listed in the Handbook of Chemistry and Physics to one-percent accuracy. These calculations are most useful during the first stages of travel before the makeup of the discharged wastes fluctuates.

In 1963, D.J. Brown and W.A. Haney [The movement of contaminated ground water from the 200 Areas to the Columbia River, HW-80909, Chemical effluents technology waste disposal investigations, July-December] examined the tritium which had been discharged at PUREX in 200 East Area since the first half of 1957. The well data available to Brown and Haney in 1963 were few compared to the data available now. But with those scant data, they delineated much of the channel, as suggested by the 2000 pCi/L tritium contour from their Fig. 5 which is digitized and simplified, below:



Perhaps the lower part of their observed channel path represents a leak from the channel into the discontinuous Beverly Interbed near the river. At any rate, the observed tritium travel time from 200 East Area to the river based both on monitoring well samples which were first analyzed for tritium late in1961 and on laboratory sorption tests of soil columns was 6-7 years [p. 10].

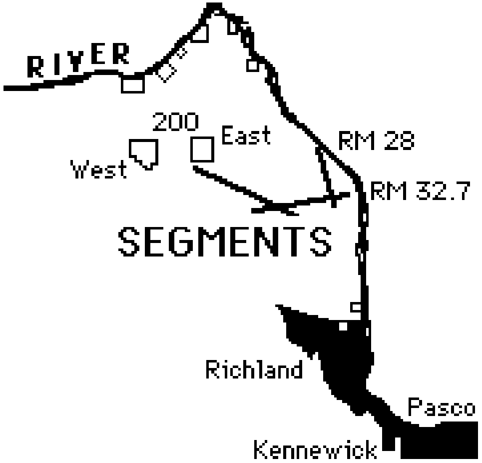
Well 40-1 • Gross beta activity of PUREX discharges to the ground increased rapidly during the first half of 1957 (HW-80909, Fig. 3). Well 40-1, shown in the figure above, began its sporadic rise in tritium, from the previous background level of 100 pCi/L to 20,000 pCi/L by the beginning of 1963 [Ground-water monitoring at the Hanford Site, January-December 1984, PNL-5408, Fig. 10]. This implies a travel time to the river of about 5.5 years.

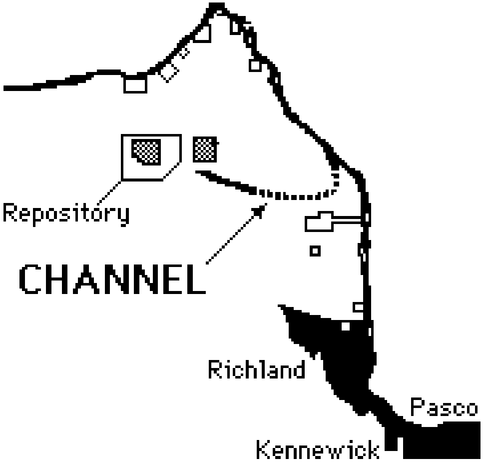
Shoreline springs • PNL examined and sampled shoreline springs along the Hanford Reach between December 1982 and September 1983 [Investigation of Ground-Water Seepage from the Hanford Shoreline of the Columbia River, PNL-5289]. The mouth of the channel has subsequently been identified by HRP as the 200-yard wide Spring #28-1 at River Mile 28.0 which PNL had identified but apparently not sampled. The discharge from this spring both onshore and offshore was so great that the tritium concentrations (49,000 to 61,000 pCi/L, Table C.1) of nearshore river water were reported by PNL at RM 28 at half the maximum concentration (110,000 pCi/L) of any spring sampled by PNL.

PNL's Fig. 5 shows graphically that the bulk of waste-water discharge occurs along one-mile of shoreline rather than the 6-mile stretch suggested by the VTT seepage model which PNL had developed. (The sample locations shown in PNL's Fig. 5 disagree with logged locations in significant ways.)

Furthermore, the major discharge indicated by high tritium concentrations near RM 28 is at the north end of the broader tritium plume which is described by PNL as extending from RM 27 to RM 32.7. This skewing of the apparent discharge to the north end of the tritium plume suggests leakage from the channel into the river where the channel progresses northward quite close to the shoreline as it approaches its mouth at RM 28. That is, the broad plume and contaminated springs, such as Spring 28-2, downriver of RM 28 can be explained as leakage from the down gradient side of the channel.

According to this explanation of the tritium plume near the river in terms of channel leakage, the most southerly excursion of the channel would be close to the southern edge of the plume at RM 32.7. Following that bottom edge of the plume back up the hydraulic gradient [PNL-5408, Fig. 3], one can sketch the connection between the final segment of the channel discharging into the river at RM 28 and the channel path shown by Brown and Haney near 200 East Area. These three approximate segments and the smoothed path are shown, below:





Thus, PNL's study of shoreline springs allows reasonable approximation of the channel path and future detailed mapping as proposed by Brown.

Rather than announcing discovery of the mouth of the channel and setting about the implied revision of the VTT Model, PNL's final conclusion of their study of shoreline springs was, "The results of this study also indicate that monitoring the unconfined aquifer [i.e., wells] is the most effective method of monitoring groundwater discharges to the Columbia River [p.19]." In other words, PNL proposed not to look at groundwater discharges into the river.

Channel tritium • At 1300 hours on 21 April 1986, after river level had been held constant for 53 hours by arrangement with the Corps of Engineers, BPA, and Grant County PUD, a sample (diluted 9:1 with distilled water to form PNL No. 86-47) was collected from Spring 28-1 for analysis. It yielded ^{3}H concentration of 150,000 pCi/L, the highest known concentration of ^{3}H reported to enter the river. Nitrate concentration of that spring was still increasing almost linearly with time [Spring 1986 Data Report, Fig. 11] as river water which had intruded at previous high river stage was still being flushed out.

Tritium concentrations in the Columbia River increase by 40 pCi/L as 1.0×10^{14} L of river water pass the Hanford Reach during the year [=112,000 cubic feet per second (cfs), see PNL-5817, Figs. 25 and 28 and Tables A.13 and A.14]. This implies that Hanford adds 4000 Ci of ^{3}H to the river yearly. Of this, only 270 Ci are accounted by Hanford Operations [PNL-5408, Table F.23]. The total reported Hanford Operations discharge of 36 cfs (=3.2×10^{10} L/year) near the 200 Areas [p. 5] implies that the average ^{3}H concentration of waste water entering the river is 125,000 pCi/L. This is close to the concentration of Spring 28-1 suggesting that the channel discharge is a major fraction of the 36 cfs total discharge.

Once one recognizes that 4000 Ci of ^{3}H and 36 cfs of water are discharged into the river from the 200 Areas, there are few options for a discharge mechanism. To carry the required 4000 Ci of ^{3}H into the river, either almost all of that 36 cfs discharge must be as concentrated as the most concentrated sample ever obtained or some part of the discharge must be much more concentrated. Neither well data nor preliminary near shore reconnaissance by HRP suggest the presence of such a discharge into the river.

Measured flow • Average flow from 852 feet of channel mouth was measured in April 1986 to be 6.3 cfs using very conservative techniques, as described [HRP Spring 1986 Data Report, Fig. 4]. Subsequent refinements (unpublished) suggest a best estimate of the channel discharge near RM 28 close to 10 cfs (=1×10^9 L/year). This is about a third of the reported waste water disposal near 200 Areas. Perhaps HRP is still underestimating the channel flow rate. Alternatively, much of the unaccounted discharge is from the Beverly confined aquifer as suggested by the work of Brown and Haney.

HRP proposed on 31 January 1986 to perform this measurement as a test of both the channel theory and the VTT Model which predicts a broad seepage along

6 miles of river shoreline. PNL did not object to the validity of this test, which is the first test Based on scaling arguments, the travel time from 200 East Area to the river, following this channel, was calculated by HRP to be 2.5 years [Spring 1986 Data Report, p. 16]. Unpublished subsequent refinements in the calculation reduce this estimate to about 2.3 years.

Spring 28-2 strontium • The channel mouth is observed to be filled with cobbles and boulders. Typical diameters of these cobbles and boulders are roughly1000 times typical diameters of Ringold sediments. Since surface area for sorption of radionuclides varies inversely with the length scale of sorpting element, a continuous channel though these cobbles and boulders could allow even readily sorpt radionuclides to enter the Columbia River. ^{90}Sr provides a test of this sorption argument for the existence of a continuous channel-type flow.

On 30 July 1985, Spring 28-2 (which is suggested to be a down river leak from the right side of the channel) yielded ^{3}H concentration of 22,000 pCi/L, ^{90}Sr concentration of 0.28 pCi/L. This ^{90}Sr concentration is an elevation of 0.11 pCi/L above the measured river water concentration of 0.17 pCi/L [PNL-5817, Table A.58].

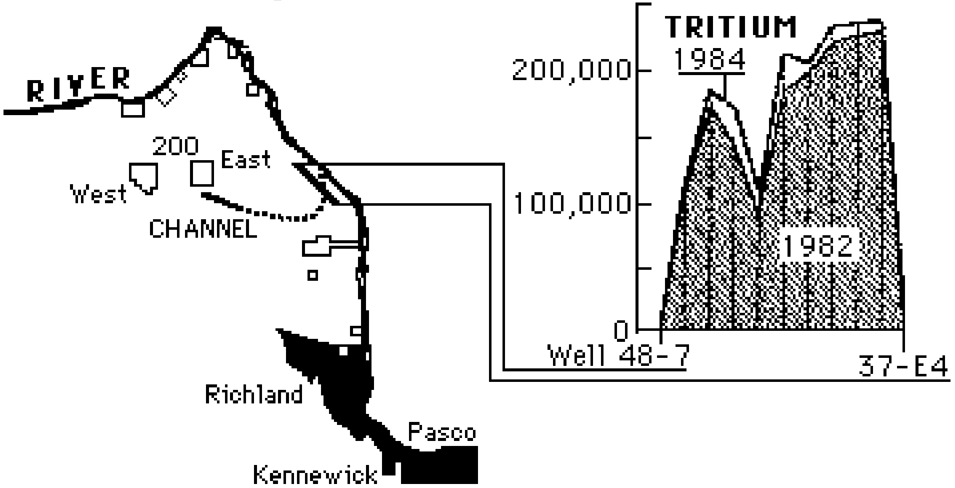
Assuming that this Spring 28-2 sample represents a mixture of channel water (conservatively represented by Spring 28-1 with ^{3}H concentration of 150,000 pCi/L and a nitrate concentration of 22 ppm as nitrate) with river water (represented by a sample from RM 27.5 collected the same day with 115 pCi/L ^{3}H and 0.18 pCi/L ^{90}Sr), then ^{90}Sr concentration of the channel can be calculated as an algebraic mixing problem. Based on the ^{3}H concentrations, Spring 28-2 water was 15% channel water and 85% river water on 30 July 1985. Then the concentration of ^{90}Sr in the channel was about 0.85 pCi/L which is 4.7 times background. This transport of ^{90}Sr is inconsistent with DOE models of radionuclide retention in the unsaturated zone near the 200 Areas [ARH-C-00002, Fig.9].

Spring 28-2 technetium • PNL-5289 lists ^{99}Tc concentration in Spring 28-2 water as 43 pCi/L on 11 September 1983 [Table B.4], at which time nitrate concentration was 4.65 ppm [Table C.1]. Again assuming that prediluted PNL Sample No. 86-47 represents channel water, Spring 28-2 water is calculated to be 20% channel water and 80% river water on 11 September 1983. The concentration of ^{99}Tc in 1983 channel water would then be 215 pCi/L. As Appendix R of DOE/EIS-0113 shows, this level of ^{99}Tc contamination at the river is not expected for several hundred years yet. This major inconsistency with both the unsaturated zone model and the VTT seepage model documents the existence of the channel.

215 pCi/L of ^{99}Tc in a 30 cfs channel flow transports 5.8 Ci of ^{99}Tc into the river yearly. This calculated ^{99}Tc transport into the river is more than 10 times Hanford's total listed release of ^{99}Tc [PNL-5817, Table F.20 lists 0.35 Ci for 1985]. This suggests both that the soil column does not retain radionuclides in the manner which DOE supposes and that a tank leak or spill is contaminating the channel water which enters the river.

Watertable contourability • PNL asked on 31 January 1986 if a channel would appear on contours of the watertable. HRP agreed that the channel should be contourable where the water table data are spaced closely enough to reveal this feature. PNL provided data, and HRP provided contours consistent with the data and other constraints on contouring. The contours clearly show the head of the channel near 200 East Area. Toward the river, the watertable data are consistent with the existence of the channel but do not prove its existence. Additional watertable data have been requested from DOE.

Tritium notch • When HRP first proposed that a single channel connects 200 East Area to the river near RM 28 on 31 January 1986, PNL asked how this might be evidenced in the well data. HRP responded that there would be a notch in the tritium plume associated with the long inactivity of PUREX up to the 1984 restart. That is, a channel would have a lower tritium concentration than the older and broader seepage plume. Figure 7 of PNL-5408, digitized and simplified below, confirms this prediction.



Although this is a striking confirmation of the existence of the channel, HRP subsequently noticed that an *island* of low hydraulic conductivity would also explain a notch in the tritium section. This limits the importance ascribed to the successful prediction.

HRP also suggested that the restart of PUREX in November 1983 would rapidly become apparent down the channel. Rising ^{3}H concentration was obvious before the end of 1983 at Well 33-42 which is a mile ESE of 200 East Area [PNL-5817, Fig. 22].

Channel Direction • R.E. Brown suggested that the Recent channels, of which RM 28 channel is one, ". . .travers the Hanford Works area in a generally southeastward direction crudely paralleling the present-day Columbia River [Hw-66289, p.5]." Interestingly, the Columbia River has a dog-leg toward the northeast, near the eastern boundary of Hanford. That is, the underground channel appears to resemble closely the present adjacent river course.

Other Evidence

VTT Model features • In order to accommodate a channel-type flow into the VTT Model, three modifications are necessary: (1) The channel course must be included as a band of high conductivity. (2) Node spacing for that channel band must be much less than channel width. That is, the modelled channel should be a few nodes wide. The VTT Model already permits the inclusing of finely spaced node grids. (3) In order to avoid conflict with the wide spacing of watertable elevation data which are input to the model, the smoothing routine must be constrained to contour watertable elevation perpendicular to the modelled channel. This assures that modelled flow will follow the channel.

These required modifications are trivial. The only technical reason that the VTT Model does not include the channel to RM 28 is that PNL decided not to input the channel.

Model verification • The VTT Model was largely calibrated against coarsely spaced measurements of watertable elevation. That calibration was much too coarse and insensitive to relate to channel-type flow. In its present form, the VTT Model has not been developed, tested, or verified with respect to flows having a width less than 1000 feet. VTT Model travel times from 200 East Area range from about 30 years to 125 years [Hanford groundwater scenario studies, ARH-SA-292, Fig. 24]. All VTT predictions conflict with the tritium observations by Brown and Haney in 1963.

The VTT Model has been coupled to a radioactive waste concentration model called MMT-DPRW [p. 14]. The coupled model has been used to predict the shape of the tritium contours around the 200 Areas. All of the predictions which I have seen represent the tritium after 1972 [e.g., Fig. 9], by which time the tritium-contaminated groundwater had broadly spread to the river [Waste management operations, ERDA-1538-V1, Fig. II.3-20]. I can find no tritium concentration comparison for the early years, during which time the modelled contours would be obviously inconsistent with Brown and Haney's observations. Since initial condition tests are a usual part of computer model verification, the absence of such tests which would have readily invalidated the VTT Model is conspicuous.

Channel location • Several people have noticed that isometric plots of watertable elevations from the VTT Model, viewed from the southeast, show a pronounced depression of the watertable close to the RM 28 channel [e.g., Variable thickness transient groundwater flow model theory and numerical implementation, BNWL-1703, Fig. 10]. This depression of the watertable is actually along the south flank of Gable Mountain [Fig. 11]. In the VTT Model, this particular depression corresponds to a region of very low conductivity; it is not a channel.

Hydraulic gradient • PNL has suggested that the hydraulic gradient would not be expected to steepen near the Columbia River if a channel exists [Walt Haerer, personal communication, 13 March 1986]. No technical basis for this argument has been provided.