Reprint: The RadioActivist Campaign September 2004
7312 NE North Shore Rd., Belfair, WA 98528 <www.radioactivist.org>

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

Hanford Reach Project

SPRING 1986 DATA REPORT

by
Norm Buske
Linda Josephson

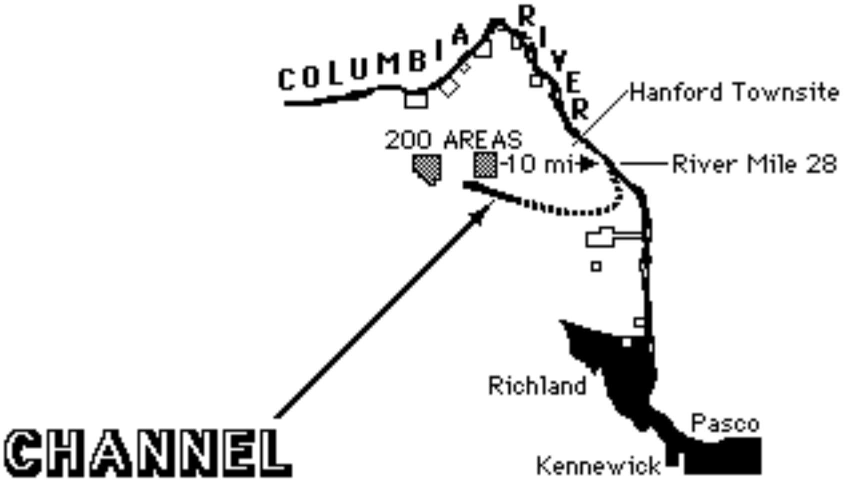
in the public interest

27 April 1986

CONTENTS **page**

SUMMARY

The average discharge from 852 feet of Columbia River shoreline has been measured to be greater than 6 cubic feet per second. This is twice the flow predicted by PNL's computer model for all of 31,680 feet of shoreline and 11 times PNL's maximum estimate of seepage per foot of shoreline for the Hanford Townsite stretch of the river. This measurement conflicts with a seepage model of groundwater flow but supports the concept of a boulder-filled channel connecting the 200 Areas to the river, as sketched below.



The calculated groundwater travel time for this channel is 3 years, replacing seepage model estimates of about 30 years.

The glaciofluvial boulders filling this channel expose much less surface area to the rapidly moving groundwater than do the Ringold sediments previously modeled. The effects of reduced sorption on the boulders together with the reduced travel time imply possible discharges of certain contaminants into the Columbia River up to 10,000 times as large as previously estimated. This result adversely affects the suitability of Hanford as a site for future waste storage. This measurement adversely affects the credibility of ongoing technical, management, and public information programs at Hanford. This measurement does not imply obvious public health effects.

DISCLAIMER

The results and conclusions expressed in this data report are the opinion of **SEARCH Technical Services** which is solely responsible for their content. Comments or corrections are solicited.

ACKNOWLEDGEMENTS

The contributions of the following parties made this investigation possible: Warren Buske, an independent consultant, developed an underwater, spring locating TV system. Tim Connor, HEAL, provided reports and references on groundwater and geology and very stimulating discussion. Don Elle, DOE, coordinated sample submission to USDOE and permitted encampment at River Mile 28. Russ George and Erlyn Kruger, US Army Corps of Engineers, and Roger Schiewe, BPA, arranged and coordinated river level control. Robert Gribble, Grant County PUD, regulated Priest Rapids Dam. Walt Haerer, PNL, provided water table data and proposed tests of the channel theory. The Lord provided calm winds and pleasant weather.

DOE provides laboratory analyses of samples collected by HRP and submitted blind, that is, without location information. At the time at which the lab results are available, HRP provides collection location and time in exchange for concentration values for specified radionuclides and/or chemicals. Greenpeace provided a Zodiac with motor, funded the nitrate sampling instrument and $500. Contributions to HRP from interested parties and the general public total $200. Remaining time and expenses have been provided by **SEARCH Technical Services**.

LIST OF FIGURES AND TABLES

INTRODUCTION

Hanford Reservation is the world's largest nuclear waste storage facility. To assure public confidence in the management of Hanford Operations, the US Department of Energy (DOE) and its predecessors have conducted health and environmental studies. There has been almost no nongovernmental review of Hanford operations, so the public mostly has had to accept DOE evaluations of its own operations.

However, Hanford's candidacy as the site of the nation's first high-level radioactive waste repository has raised questions of the ability of Hanford site to contain wastes, the willingness of Hanford management to admit problems to the impacted public, and the viability of DOE self-monitoring. Most of those questions have concerned the effects of airborne releases on *downwinders*, and the discharge of contaminated groundwater to the Columbia River which is a major resource of the region.

In 1985, **SEARCH Technical Services**, a Washington consulting firm, began independent study - the Hanford Reach Project (HRP) - of groundwater intrusion from Hanford into the Columbia River. After reviewing some of the geological background, shoreline spring and water table data, monitoring well histories and sections, and calculations of tritium entry, HRP proposed a boulder-filled, groundwater channel connecting 200 East Area to the river near Hanford Townsite on 31 January 1986. This proposal was to be tested by the study which is described in this data report.

For this study, means of identifying, sampling, and measuring the flow of underwater springs had to be devised. These springs were expected to account for most of the groundwater discharge into the river. The identification and sampling of nearshore underwater springs had been accomplished in September 1985. Flow rate measurement is the critical part of determining whether the groundwater springs are seepage-type of channel-type. If the groundwater flow is too great and too localized to be described as seepage, then the flow is described as channel-type.

In March, HRP identified a candidate channel discharge into the river and obtained underwater video images of an underwater spring, which were aired by KREM-2 News in Spokane. The critical measurement of channel flow rate was postponed because of rising river levels which block spring flow. In April, the Corps of Engineers arranged to hold the daily average river flow from Priest Rapids Dam to about 112,000 cubic feet per second (cfs) for three consecutive days to allow this study which involved real time measurement of 200 water samples to investigate 852 feet of shoreline.

BACKGROUND

Since the 1950's, channels in the Ringold sediments, backfilled with glaciofluvial Pasco gravels and boulders, have been known to exist both near 200 East Area and at the Hanford Townsite (R.E. Brown, **An Introduction to the Surface of the Ringold Formation Beneath the Hanford Works Area**, HW-66289, August 1, 1960). Many of these channels were known to "bottom beneath the current ground water table" allowing flow toward the Columbia River at potentially "rapid rates [p.2]." Considered to be old river beds, these channels were expected to be continuous.

In 1963, D.J. Brown and W.A. Haney estimated that tritium-contaminated groundwater reached the Columbia River in 6-7 years after discharge was begun from PUREX (**Chemical Effluents Technology Waste Disposal Investigations -- July-December, 1983 -- The Movement of Contaminated Ground Water from the 200 Areas to the Columbia River**, HW-80909). Their conclusion was based on 1963 data from a few monitoring wells, as shown in the copy of their Fig. 5, which is Fig. 1, below. Notice how few monitoring wells there were in the tritium plume near the Columbia River. The outside edge of the plume was contoured at $2 \bullet 10^{-6}$ μC/cc (microCurie per cubic centimeter) which is 2000 pCi/L (picoCurie per liter).

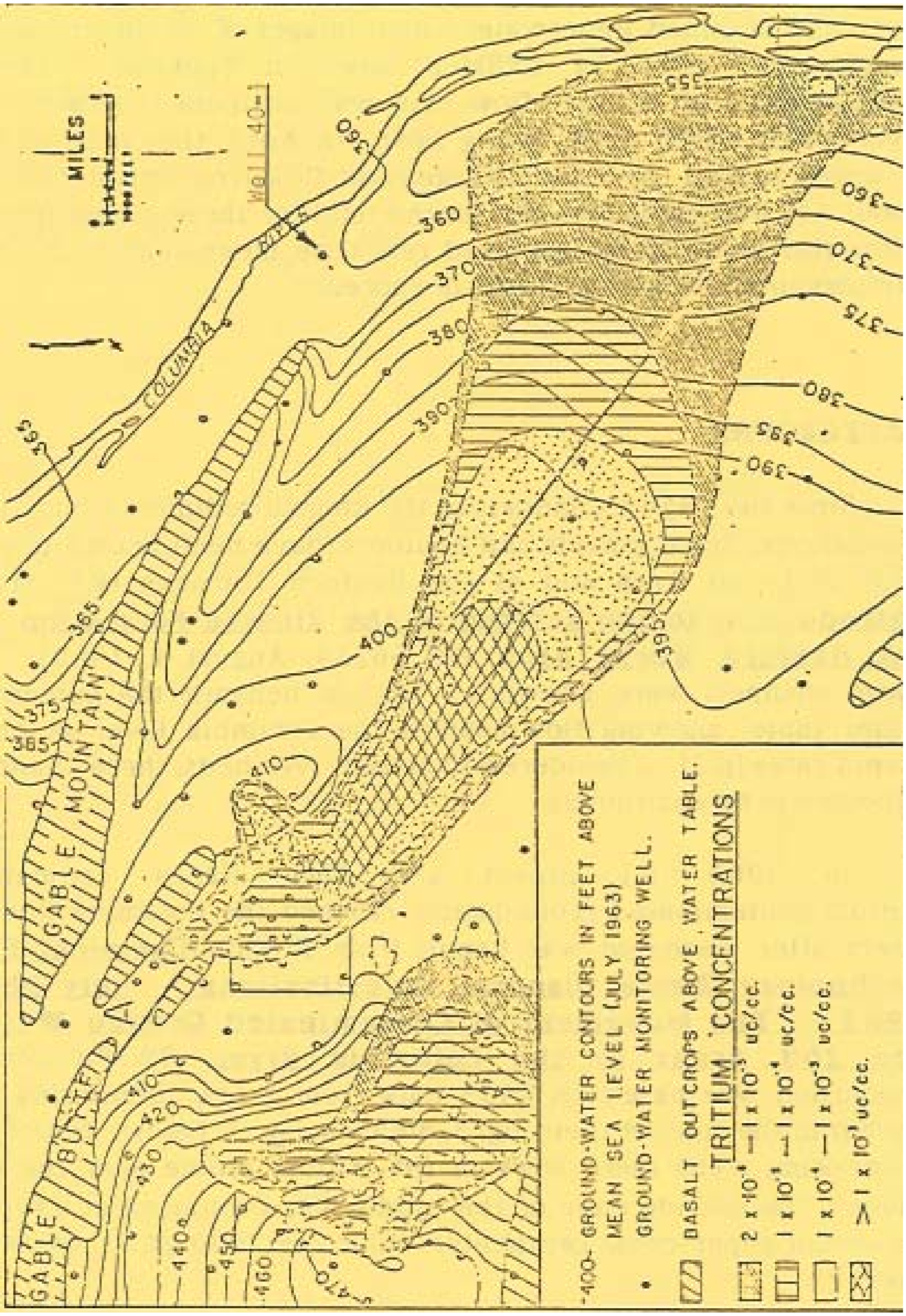


Figure 1. GROUNDWATER TRITIUM CONTAMINATION – 1963

Well 40-1 is marked on Fig. 1 to show its location near the Columbia River, about two miles north of the presumed edge of the tritium plume. However, Well 40-1 actually showed initial, erratic tritium contamination as high as 40,000 pCi/L in 1963, as may be seen in Fig. 2, below.

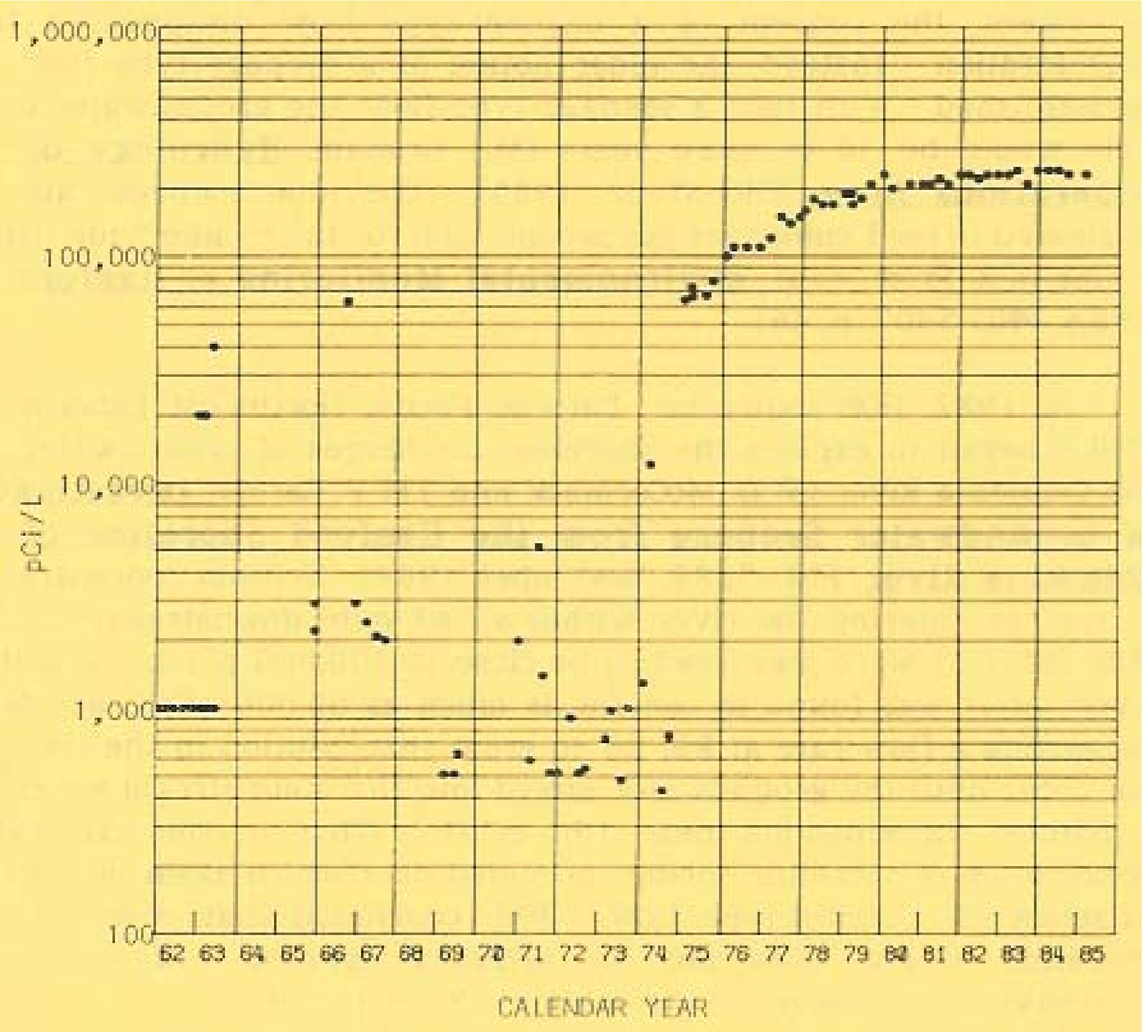


Fig. 2. TRITIUM CONCENTRATION HISTORY FOR WELL 40-1

The northward bend of the tritium path, close to Well 40-1, was missed although the data were available. Thus by 1963, the monitoring well data permitted approximate mapping of the backfilled channel carrying tritium-contaminated groundwater from 200 East Area to the Columbia River and reasonable estimation of the travel time.

Knowledge of this continuous, backfilled channel from 200 East Area to the Columbia River was more or less lost after 1963. Even with a huge increase in the number of monitored wells and seismic profiles, and the development of sophisticated computer models of groundwater movement, the concept of a channel-type flow disappeared from consideration. Instead, the older notion of a seepage-type flow was reestablished. With such a seepage-type flow, the groundwater travel time would be 30 or more years (M.J. Graham, **Hydrology of the Separations Area,** RHO-ST-42, 1985). The total seepage rate was estimated to be 3 cubic feet per second (cfs) for the 6-mile wide tritium plume (K.R. Price, et al., **Environmental Monitoring at Hanford for 1984**, PNL-5407, p. 46).

In 1982, DOE contractor, Battelle Pacific Northwest Laboratories (PNL), began to explore the shoreline discharges of groundwater into the Columbia River (W.D. McCormack and J.M.V. Carlile, **Investigation of Groundwater Seepage from the Hanford Shoreline of the Columbia River**, PNL-5289, November 1984). Tritium concentrations in springs entering the river within a half-mile downstream of River Mile (RM) 28 were measured to be close to 100,000 pCi/L. Nearshore river water was found to contain as much as 60,000 pCi/L at RM 28, suggesting a flow rate at RM 28 so great that dilution in the river did not occur until the groundwater mixed into the main stream which has a tritium concentration near 130 pCi/L. That is, the exploratory observation of shoreline springs provided data which again implied the existence of channel-type flow. PNL concluded that observing the shoreline springs was not an *effective method* of monitoring groundwater discharges to the Columbia River (p.19).

CONCEPTS and METHODS

Since the Columbia River is open to public access and contamination of the Columbia River is of public concern, a river-based method of testing the channel hypothesis was devised. This method is based on the idea that a channel-type flow can be identified by a localized flow rate (cfs) per length of shoreline which is much greater than can be accounted by seepage-type flow.

An estimate of the maximum seepage-type flow in the area was obtained from PNL's calculation of 21.4 cfs for 6 miles of shoreline (Mark Freshley, PNL Calculation No. HANGW-1, January 22, 1986, p. 3). That is, if there is a channel-type flow, the discharge of groundwater into the river must be much greater than 21.4 cfs/6 miles = $6.76 \cdot 10^{-4}$ cfs/ft (= ft^2/sec).

In order to measure groundwater discharge into the river, the groundwater has to be tagged to readily distinguish that groundwater from river water so that the concentration of even much diluted groundwater can be measured after it has mixed with river water. The groundwater entering the river near RM 28 is contaminated with several chemicals, including nitrate and several radionuclides. Nitrate was selected as the primary tag for this test because its concentration in the groundwater [about 4 parts per million (ppm)] is well above the river water concentration (about 0.2 ppm) and because nitrate is easily measured with a field instrument to an accuracy of about 0.01 ppm. This means that nitrate-contaminated groundwater can be detected after it has been diluted over a hundred fold with river water.

The next part of the problem is to measure the amount of nitrate which enters the river along a stretch of shoreline. This is accomplished by means of hydrographic sections. One section, consisting of a fixed line of locations, or *stations,* is established upstream of the area of suspected channel discharge into the river. Similarly, a fixed downstream section is established downstream of the stretch of shore where the channel flow is suspected to enter the river. Target flags are located along the shore to survey these sections.

The survey is accomplished by means of a nautical instrument, a *sextant,* which measures angles. From each station, angles are measured between target flags. A simple program on a pocket microcomputer then reads out the local coordinates of each station relative to the target flags. Those flags are surveyed with respect to fixed features and structures in the vicinity. The pieces of the problem are sketched in Fig. 3, below.

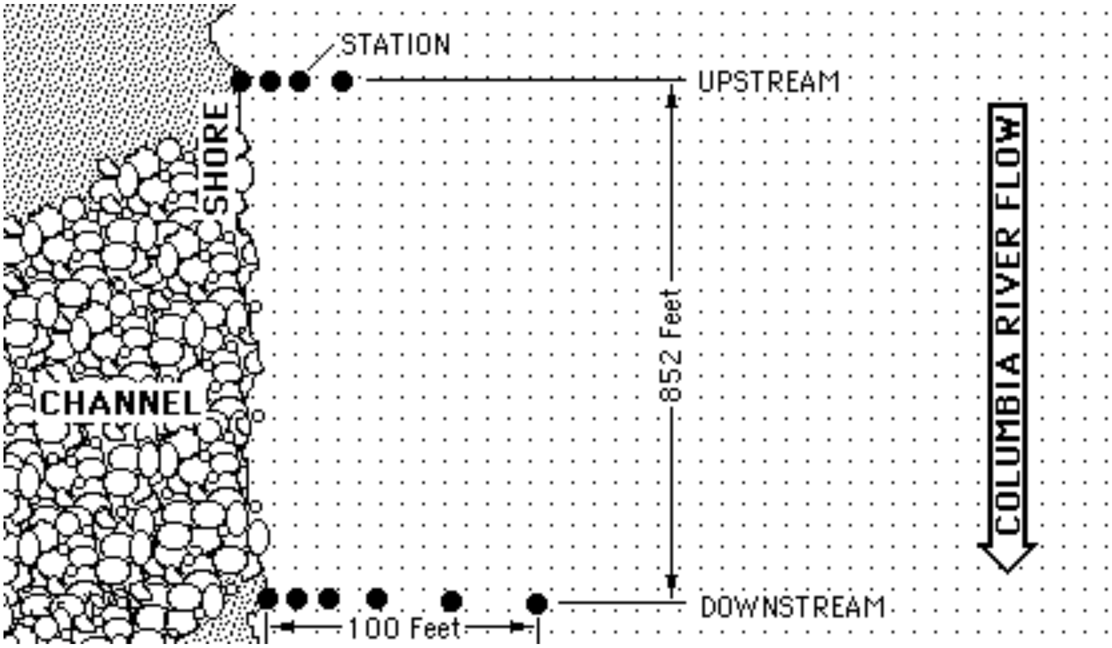


Figure 3. SKETCH OF MEASURING CONCEPT

The idea, then, is to measure the following quantities at each station in each section, at one instant in time:

nitrate concentration (ppm above river background)
current speed in the river (ft/sec)
water depth (ft)
distance between stations (ft)

The product of these four quantities, summed over each section, is the amount of nitrate (expressed as ppm•ft^3/sec) crossing that section. The difference between the amount of nitrate crossing the downstream section and the amount crossing the upstream section is the amount of nitrate (per unit time) which is entering the river between the two sections.

That amount of nitrate entering between the sections equals the product of the concentration of nitrate contamination (ppm) in the springs and the total flow rate (cfs) of those springs. Thus, by measuring the nitrate concentration of the springs, their total flow rate may be calculated. Nitrate concentrations are very near background values at the riverward ends of the sections.

Likely channel location is chosen by means of visual identification of underwater springs and by approximating nitrate entries along stretches of the shoreline. Visual identification is by means of a diver using a hookah air compressor and a squeeze-bottle sampler. Nitrate entry is explored by establishing temporary hydrographic sections perpendicular from the river shore. Other technical considerations are described in the Errors Section of this report.

PROCEDURES

Section locations were decided on the basis of apparent land forms, locations of observed underwater springs, informal sampling of nearshore nitrate values, flows and nitrate values of shoreline springs, stability and simplicity of observed river currents, and evaluation of offshore mixing between sections.

Station data were collected in 30 minutes when only nitrates were sampled. When depth, current speed and locations were measured, 120 minutes were required.

- **Current.** Kahl, Price AA current meter. Standard measurements were for 60 seconds with fractional counts interpolated where necessary.
- **Navigation.** Navy sextant angles input into HP-41CV, 3-arm protractor program. RM 28 mile post surveyed as reference. Baseline surveyed on mile post and compass bearing.
- **Nitrate.** Orion SA 270 with nitrate electrode and automatic temperature compensator. In variance with standard procedure, 1 ml ionic strength adjustor was used instead of 2 ml because of the low nitrate concentrations.
- **Spring finding.** Negatively buoyant diver with custom *hookah* compressor towed.
- **Stations**. Stations (except **#0** and **#0.5**) marked by anchored floats with lines about three times water depth. Metzler 12' inflatable with 5HP Honda motor as station boat On alternate sampling runs, when only nitrates were sampled, the boat nudged up to the stations from downstream. For the other runs, the boat was anchored at each station.
- **Water sampling**. Surface river samples collected directly into rinsed analysis or lab container. Shoreline spring sampled with rinsed squeeze bottle. Underwater springs sampled with rinsed squeeze bottle and *hula* skirted weight with plastic hose and JackRabbit hand pump.
- **Water depth**. Steel tape with weighted end at stations, stake leveled to reference boulder for river level.

RESULTS

FLOW RATE. Flow rates of groundwater between the two hydrographic sections, 852 ft apart, were calculated for each of five measurement runs, Fig. 4, below.

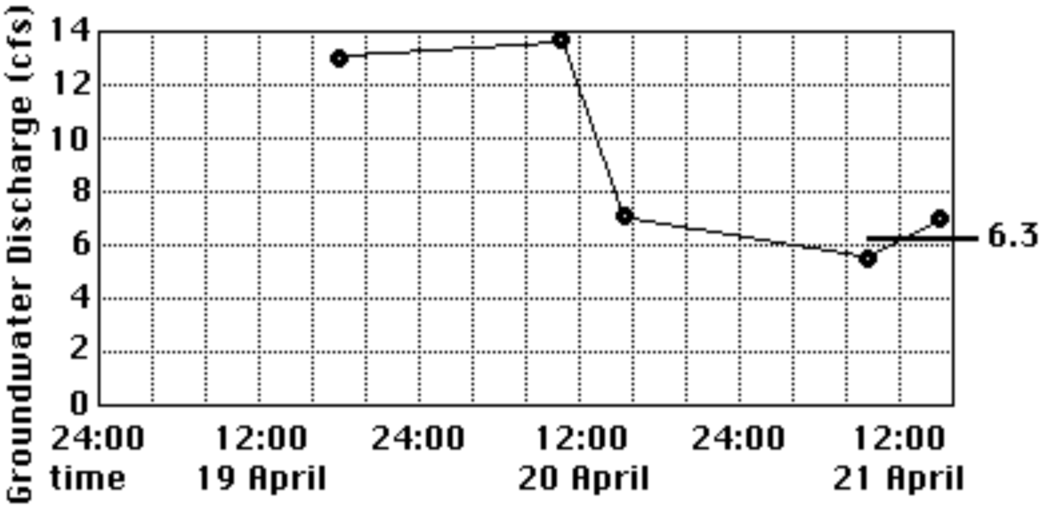


Figure 4. GROUNDWATER ENTERING 852 FT OF SHORELINE

Apparent discharges from shoreline springs decreased markedly after 12:00 on 20 April, suggesting that shoreline storage was nearly discharged. By 12:00 on 21 April, observation of shoreline springs between RM 28.5 and 30 failed to reveal any flow. Therefore, the last two measurement runs are considered to represent the equilibrium condition of groundwater discharge into mean river flow.

Although short-term groundwater flow into the Columbia River is affected by river level, the long-term discharge depends only on the amount of groundwater flowing through the system. Therefore, the equilibrium condition, described by the last two measurement runs estimates the mean annual groundwater discharge into the Columbia River between these two sections 852 ft apart. The average of the last two runs is

6.3 cfs .

Total nitrate measured entering the river between the sections, expressed as concentration times flow rate (ppm•cfs) is shown in Fig. 5., below.

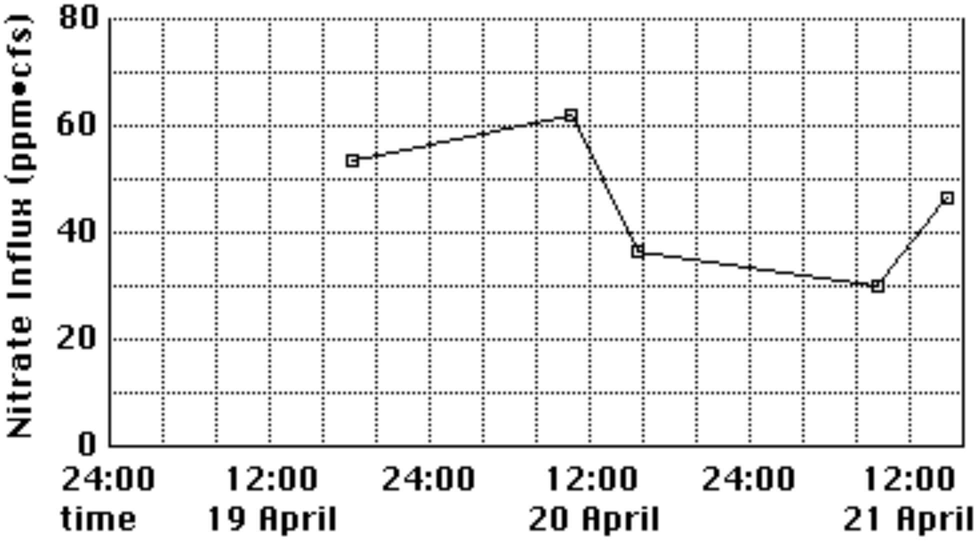


Figure 5. NITRATE ENTERING 852 FT OF SHORELINE

The rise in nitrate entering the river at the end of the study is mostly attributed to rising nitrate concentration in the groundwater entering the river. While the flow rate (Fig. 4) had apparently reached equilibrium, the nitrate concentration continued to rise almost linearly. This implies that bank storage pressure was relieved before the stored river water was flushed out. A much longer term study would be required to estimate the equilibrium concentration of contaminants in groundwater entering the river and the amount of contaminants entering. Figure 5 provides a lower bound estimate of about 50 ppm•cfs nitrate as the average for this 852 ft of shoreline.

TRAVEL TIME. The time required for water to travel from the 200 Areas to the Columbia River is much less for a channel-type flow than for a seepage-type flow as used in PNL's VTT computer model. If we assume that the smoothed water table contours and aquifer thicknesses used in the VTT model are correct, then the VTT model's predicted travel time differs from the travel time down a channel by the following factor:

$$(\text{relative path length}) \times (\text{relative porosity}) / (\text{relative flow rate}) = \frac{\text{channel travel time}}{\text{seepage travel time}}$$

The available data on channel location suggests that the channel is about 1.5 times as long as the VTT model seepage path, Fig. 6.

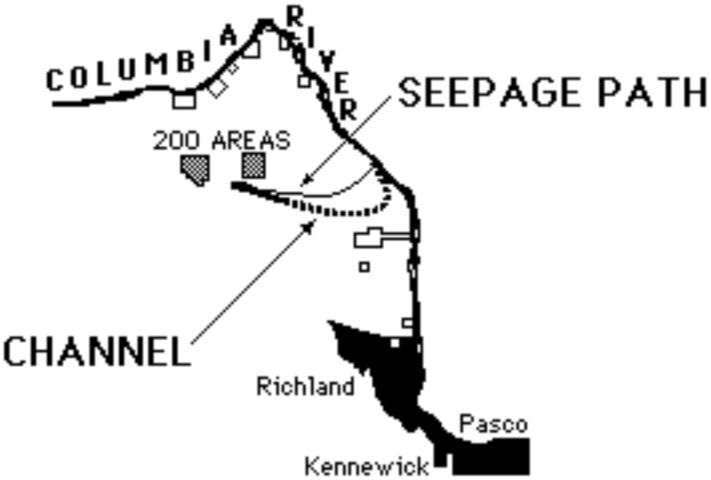


Figure 6. APPROXIMATE PATH COMPARISON

In March 1986, a 40-gallon garbage can was filled with Pasco gravel (mostly cobbles and boulders) from the shore at RM 28.0. The volume of water added to fill this can was 41% of the volume required to fill the garbage can without the rocks. This experiment overestimates the porosity of Pasco gravels because of surface effects of the garbage can and imperfect packing.. The VTT computer model employs a constant porosity of 0.10, which would be more representative of the Ringold sediments than of the Pasco gravels which fill the channel. Based on the above, the porosity of the channel fill is estimated to be 0.25.

The relative flow rate is (6.3 cfs / 852 ft) / (3.03 cfs / 6 mi) = 77.

Finally, the mean travel time for the 6-mile stretch of the VTT model is estimated to be about 50 years (interpolated and weighted for flow, based on D.R. Friedrichs, et al., **Hanford Pathline Calculational Program - Theory, Error Analysis and Applications**, ARH-ST-149, Fig. E-6, 1977). The resulting, calculated flow time for the channel is

2.5 years .

SORPTION. Radionuclides and chemicals in the contaminated groundwater which is discharged near the 200 Areas. are partly removed as the groundwater passes around the gravels and boulders which are observed to fill the channel. These gravels and boulders are typically about 1000 times as large as the sand and clay particles of the Ringold formation. Figure 7 shows the Pasco gravels exposed at low water near RM 28.3.

Figure 7. PASCO GRAVELS

Therefore, there is roughly 1/1000 as much surface exposed to the passing water in the channel as is exposed to water passing through an equal distance of Ringold sediments. Further, the voids in the gravels and boulders allow some of the passing contaminant ions to remain somewhat distant from the active surfaces of the rock.

From these considerations, we see that the channel-type flow provides thousands of times less sorptive capacity than does a seepage-type flow. Although we know of no water analyses from the channel proper, Spring 28-2 is only a few hundred feet from the downstream edge of the channel. Spring 28-2 water contains 400 times as much Iodine-129 and 900 times as much Technetium-99 as do other shoreline springs (McCormack and Carlile, op cit., Tables B.2 and B.4).

For contaminants which are easily removed by sorption, this reduction in sorptive capacity makes no difference; they are removed anyway. For contaminants - such as tritium - which are essentially unaffected by sorption, this reduction in sorptive capacity makes no difference; they are not removed, regardless. The reduced sorptive capacity is important for contaminants having lifetimes longer than a few months, which are somewhat subject to sorption. The identification of these contaminants is, unfortunately, beyond the scope of HRP.

DATA

Columbia River flow was controlled from Priest Rapids Dam by arrangement with the US Army Corps of Engineers, bringing the flow rate to nearly 112,000 cfs, the 1984 mean annual flow rate. This controlled river level which was lower than the previous level was achieved at RM 28 at 10:00 Local Time on 19 April 1986, as seen in Fig. 8, below.

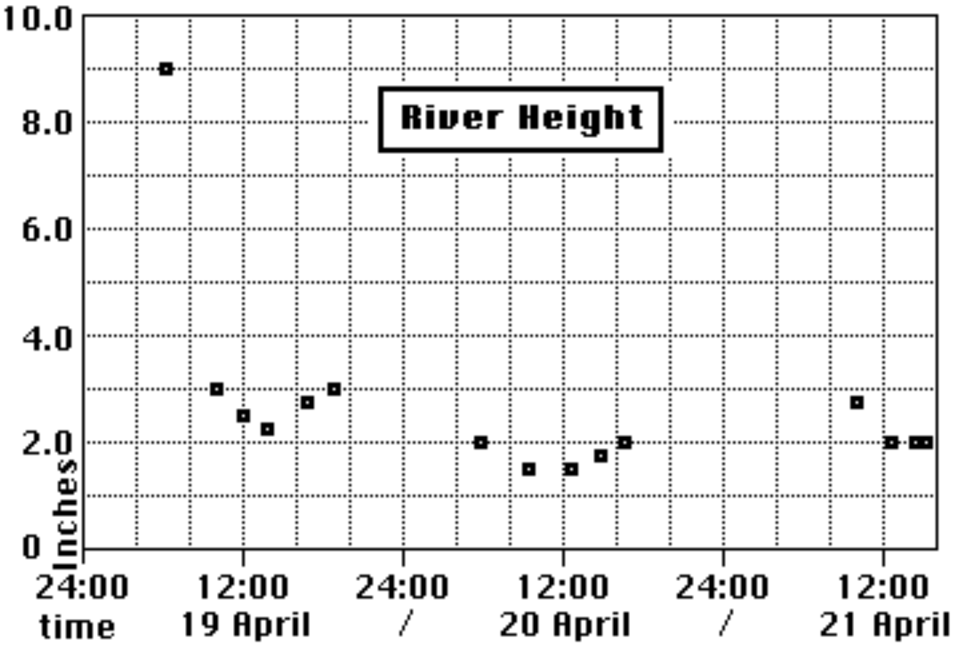


Figure 8. RIVER LEVELS AT RM 28 DURING STUDY.

The reference level in Fig. 28 is arbitrary. Notice that the total measured range of river level variation was only 1.5 inches during the study period.

Two hydrographic sections were established 852 ft apart, perpendicular to a 98° Magnetic baseline. RM Post 28 was 128 ft upstream of the downstream section and 74 ft inland of the baseline. **Station 0** of the upstream (US) section was located 138 ft riverward of this baseline. The upstream section is shown in Fig. 9, below.

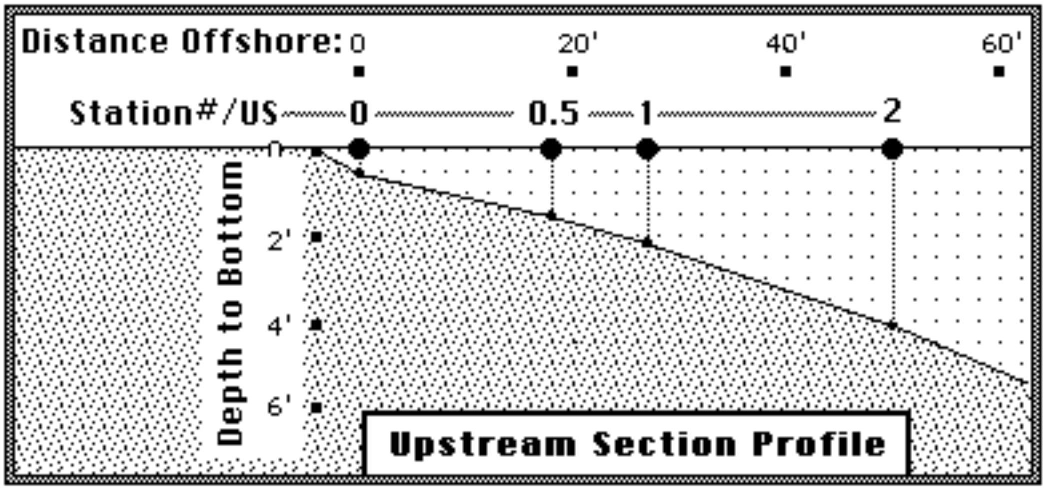


Figure 9. UPSTREAM SECTION

The stations in the sections were marked by long-line tethered floats, except **Stations 0**, next to boulders, and **Stations 0.5** which were visually interpolated between their adjacent stations.

Station 0 of the downstream (DS) section was located 72 ft riverward of the baseline. Figure 10, below, dimensions the downstream section.

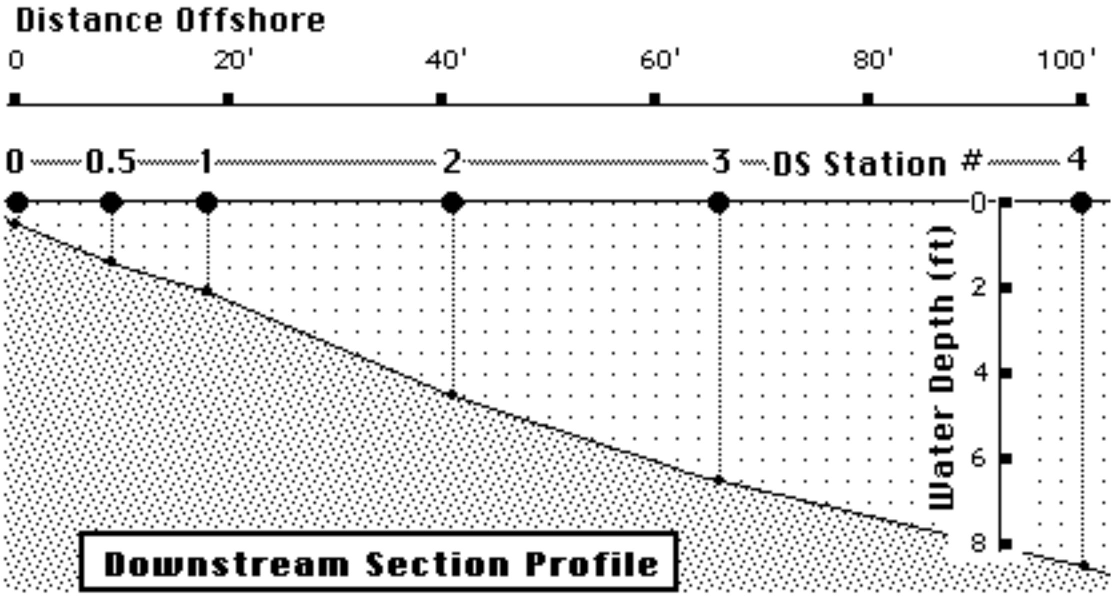


Figure 10. DOWNSTREAM SECTION

In order to minimize eddy diffusion of nitrate into the main stream of the river between the sections, the two sections were located as close together as practical without excluding much of the obvious groundwater channel flow. At the same time, the sections had to be positioned off points of the shoreline to provide a simple river flow regime. To satisfy these requirements, the upstream section was placed where the very nearshore nitrate concentrations just began to increase substantially above background. This placement allowed the use of a shorter upstream section than downstream section.

The concentration of nitrate in shoreline spring S-1, which is believed to correspond to the downstream edge of PNL Spring 28-1 is shown in Fig. 11, below, for the study period.

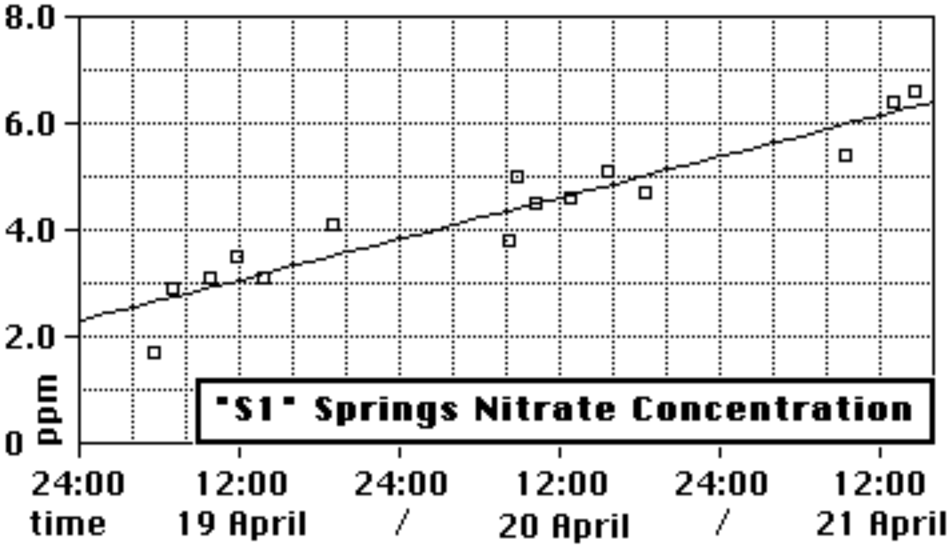


Figure 11. NITRATE DEVELOPMENT AT SITE

These S-1 nitrate data are least-squares fit by a straight line in Fig. 11. There is only a hint of departure from this straight-line increase in nitrates by the end of the study. (A log curve fit is less well correlated.)

An Offshore Spring located in 6 ft of water in the major, observed underwater discharge area, 109 ft upstream of the downstream section, 183 ft riverward of the baseline, was sampled at 14:30 20 April 1986. It yielded 4.7 ppm nitrate, which is almost identical to the simultaneous value of S-1 in Fig. 11. Other spring data collected near the hydrographic section locations are listed in Table 1, below.

Flow rates measured at the stations in the hydrographic sections are listed in Table 2, which follows Table 1.

Table 1. NITRATE AND TEMPERATURE FOR SHORELINE SPRINGS AT SITE

Spring Name-Location	Date	Time	Nitrate(ppm)	Temp.(°C)
S1 – 20' US of DS Section	19 April 1986	05:30	1.7	6.7
		07:30	2.9	9.1
		09:45	3.1	12.1
		11:45	3.5	12.3
		13.45	3.1	12.8
		19:00	4.1	11.6
	20 April 1986	08:10	3.8	14.3
		08:45	4.98	15.4
		08:45	4.7	15.8
		10:12	4.5	14.4
		12:50	4.6	17.9
		15:40	5.1	14.5
		18:19	4.7	15.7
	21 April 1986	09:27	5.39	15.3
		13:00	6.4	18.8
		14.40	6.61	17.2
Campsprings– 260' US of DS Section	19 April 1986	07:45	1.5	9.1
		09:45	1.5	12.6
		11:45	1.5	12.0
		13.45	1.8	14.7
	20 April 1986	08:05	3.2	15.1
		12:35	2.9	22.4
		17:56	3.2	16.0
	21 April 1986	09:50	3.8	20.1
		14:55	2.3	24.7
Lower US Springs– 60' DS of US Section	19 April 1986	12:15	2.9	14.5
	20 April 1986	07:50	3.4	13.2
		10:44	2.5	15.5
		16:17	5.4	15.0
		18:29	5.1	16.2
	21 April 1986	09:35	5.5	16.9
		14:55	5.57	19.2
Upper US Springs– 60' US of US Section	19 April 1986	09:30	2.4	10.4
		18:30	2.8	11.3
	20 April 1986	10:44	3.6	15.2
	21 April 1986	09:35	3.09	17.6
		14:55	4.14	20.4
Underwater Springs– 109' US of DS Section, 183' off baseline	20 April 1986	14:30	3.7	14.2
		14:30	4.0	15.6
		14:30	4.7	14.0
Halfway Springs– Halfway between US and DS Sections	20 April 1986	18:02	2.9	13.9
	21 April 1986	09:55	3.52	16.5
		14:55	3.34	18.0

Table 2. CURRENT MEASUREMENTS AT STATIONS (fps @ depth)

Station#/Section	Run1 19 April 17:20-19:00	Run3 20 April 14:50-16:35
Sta0/US	0.022 @ 0.5'	0
Sta0.5/US	0.213 @ 1.0'	0.202 @ 1.0
Sta1/US	0.601 @ 1.0'	0.428
Sta2/US	1.218 @ 1.0'	1.182 @ 1.0'
	1.037 @ 3.0'	
Sta0/DS	0.224 @ 0.5'	0.372 @ 0.5'
Sta0.5/DS	0.674 @ 0.5'	0.674 @ 1.0'
Sta1/DS	0.783 @ 1.0'	0.946 @ 1.0'
Sta2/DS	1.326 @ 1.0'	1.398 @ 1.0'
	1.254 @ 2.0'	
	1.290 @ 3.0'	1.254 @ 3.0'
Sta3/DS	1.803 @ 1.0'	1.912 @ 1.0'
	1.692 @ 3.0'	1.618 @ 3.0'
Sta4/DS	2.308 @ 1.0'	2.200 @ 1.0'
	1.766 @ 4.0'	2.164 @ 4.0'

Nitrate concentrations in river water at the stations is listed in Table 3, below.

Table 3. NITRATE CONCENTRATIONS AT STATIONS (ppm)

	Run1	Run2	Run3	Run4	Run5
	19 April	20 April		21 April	
Station#/Section	17:20-19:00	10:12-10:44	14:50-16:35	08:50-10:00	14:30-14:55
Sta0/US	0.52 0.48	0.50	0.42	0.592	0.484
Sta0.5/US	0.47	0.35	0.30	0.303	0.294
Sta1/US	0.23	0.24	0.23	0.238	0.216
Sta2/US	0.20	0.22	0.23	0.202	0.220
Sta0/DS	2.8	0.92	0.93	1.33	0.854
Sta0.5/DS	0.51	0.40	0.36	0.344	0.386
Sta1/DS	0.34	0.33	0.35	0.330	0.320
Sta2/DS	0.27	0.30 surface 0.34 bottom	0.31 surface 0.30 @ 4'	0.270	0.259
Sta3/DS	0.22	0.26	0.21 surface 0.22 @ 6'	0.209	0.248
Sta4/DS	0.20	0.24 0.20	0.20 surface 0.19 @ 4' 0.19 @ 8'	0.178	0.198
Midstream	0.17 0.17 0.17	0.18	0.18 0.18	0.169 0.179	0.178 0.172

Water temperatures at the stations, measured with the nitrate thermistor at the same time as nitrate concentrations were measured, are listed in Table 4, below.

Table 4. WATER TEMPERATURE AT STATIONS (°C)

Station#/Section	Run1	Run2	Run3	Run4	Run5
	19 April	*20 April*		*21 April*	
	17:20-19:00	*10:12-10:44*	*14:50-16:35*	*08:50-10:00*	*14:30-14:55*
Sta0/US	8.0 8.9	10.2	10.8	10.9	13.0
Sta0.5/US	8.5	9.3	10.0	9.6	11.6
Sta1/US	8.0	8.8	9.3	8.6	10.8
Sta2/US	8.0	8.5	9.2	8.5	10.1
Sta0/DS	10.5	10.3	11.2	10.5	12.5
Sta0.5/DS	8.8	9.3	10.3	11.6	11.5
Sta1/DS	8.3	9.5	9.6	8.7	11.0
Sta2/DS	8.4	8.7 surface 9.3 bottom	9.5 surface 9.9 @ 4'	8.4	10.3
Sta3/DS	8.1	8.8	9.3 surface 9.8 @ 6'	8.3	10.0
Sta4/DS	8.6	9.3 8.6	9.5 surface 10.1 @ 4' 9.6 @ 8'	8.2	10.0
Midstream	8.0 7.6 7.6	7.9	9.5 8.5	8.1 8.2	9.8 9.5

MISC. OBSERVATIONS

After discharge of transient river bank storage, no springs were observed between 0.3 and 5 feet depth. That is, the springs apparently moved offshore.

Winds were calm and the river glassy smooth for the duration of the reported study.

One beaver, swimming upstream.

ERRORS

The major errors which are known to affect the reported measurements of spring water intrusion between upstream and downstream sections are as follows:

LATERAL MIXING. Nitrate is lost to lateral eddies which mix nitrate out beyond the end of the sections. This loss increases as the distance between upstream and downstream sections is increased. Thus, the sections must be as long as practicable and placed as close together as practicable. This error results in underestimate of nitrate entering the river between sections which are farther apart than they are long provided less excess nitrate is spilled around the end of the upstream section than is spilled around the end of the downstream section. This is apparently the situation in the present study.

CHANNEL OVERFLOW. As the channel approaches the river, water is spilled from the lower (river) side of the channel, reducing the flow measured from the channel mouth. In particular, the nitrate entering the river down to Spring 28-4 is likely of channel origin. This error results in underestimation of nitrate entering the river between sections.

PARALLEL FLOW. The described methodology is not suitable for river stretches having substantial cross-channel flow. Between the upstream and downstream sections of the described study, the flow always appeared parallel to the shore. This is accomplished by placing the sections off points in the river and avoiding the bend in the river downstream of RM 28.2.

INSTRUMENT. Nitrate-selective electrodes respond nonlinearly to nitrate concentrations below 0.5 ppm. If this nonlinearity is not explicitly factored out -- as it is not in this study -- the addition of nitrate between sections is underestimated. This error is considered insignificant for the reported test.

TEMPORAL EFFECTS. Temporal changes introduce error which depends on changes in current speed, water depth, in-river nitrate concentration, river bank recharge, and spring nitrate concentration. These errors are minimized by conducting the study during an adequately long period of minimal transients. The established river level cannot differ much from the long-term average to avoid recharge or discharge of river bank storage for periods longer than the study. If significant winds blow, cross-channel and depth-varying flows must be incorporated in the analysis.

Calculations of flow rate were based on reference Spring S-1 which is apparently equivalent to the downstream edge of PNL Spring 28-1. Figure 11 shows that Spring S-1 nitrate concentration did not come to equilibrium during the study period. Since most of the channel mouth is farther along the channel than Spring S-1, the average nitrate concentration of groundwater entering the river at an instant might differ from the value for S-1. However, nitrate measurements of S-1 and the Offshore Spring did not differ. Thus, this effect is expected to slightly underestimate flow rate.

AVERAGING. The estimate of nitrate-above-background passing a hydrographic section is based upon an average obtained from data obtained at each station along the section. For each of two adjacent stations,

(excess nitrate) • (water depth) • (current speed)

is calculated and averaged with the corresponding value for the adjacent station. Then this average is multiplied by the distance between the stations to estimate the excess nitrate passing between the two stations. This method weights the station data by the amount of nitrate they represent and is expected to be nearly unbiased.

For comparison, simple averages of each quantity were obtained between adjacent stations. That simple averaging overestimates flow. Groundwater flows calculated by simple averaging were 18%, 2%, 8%, 14%, and 7% greater than the (reported) flows calculated by the weighting method. This close agreement indicates that the stations were close enough together to provide good estimates of river flow between them.

RECOMMENDATIONS

(1) Obtain shallow seismic sections of the channel and fine-scale water table data from the monitoring wells adequate to map the channel.

(2) Sample Spring 28-1 after depleting river recharge and analyze the sample for heavy metals, hydrocarbons discharged near 200 Areas, and radionuclides having half life >100 days and modest sorption.

(3) Eliminate Hanford as a candidate high-level waste repository.

(4) Separate management and **critical** review of scientific studies of Hanford from parties having an interest in their outcome.

< • = • >