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Riverbank Seepage of Groundwater Along the 100 Areas Shoreline, Hanford Site

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RIVERBANK SEEPAGE OF GROUNDWATER ALONG THE 100 AREAS SHORELINE, HANFORD SITE

R. E. Peterson
V. G. Johnson

ABSTRACT

Chemical and radiological data are described for samples of riverbank seepage, nearshore river water, and sediment associated with seepage. Sampling locations are along the right bank (generally southern shoreline) of the Columbia River on the Hanford Site. Locations extend from the 100-B Area approximately 26 miles downstream to the northern edge of the Hanford Townsite. The data were obtained during (1) environmental surveillance activities and (2) remedial investigations to characterize the influence of contaminated groundwater on the Columbia River.

Data for seepage samples collected during September and October 1991 are compared with earlier data sets (1984 and 1988) to portray temporal trends. Concentrations of nitrate, a chemical waste indicator, show a distinct decrease in the most recent results. Chromium, a common 100 Areas contaminant, is present in many seepage samples. Historical data do not exist, so temporal trends cannot yet be discerned.[1] *Tritium, gross beta, and strontium-90 do not show clear temporal trends. Drinking water standards are generally not exceeded in recent seepage, with exceptions for (1) chromium at 100-K, -D, and -H; (2) tritium at 100-B and -N; (3) gross beta at 100-N and -H; and (4) strontium-90 at 100-N, -H, and -F.*

---

[1]Insufficient historical data exist for chromium to discern temporal trends.

Seepage data for 1991 are also compared to estimates for groundwater conditions within one-half mile of the shoreline. Samples from monitoring wells were not obtained simultaneously with samples from the riverbank, so estimates for groundwater constituent concentrations were derived by projecting historical trends in the wells to October 1991. Riverbank seepage concentrations of contamination indicators tend to be intermediate between groundwater and nearshore river water concentrations. Electrical conductivity reveals this relationship most clearly, since natural conditions for groundwater and river water contrast sharply.

Hourly samples from a riverbank seep and nearby monitoring well were obtained to investigate the influence of diurnal changes in river stage on riverbank seepage. Seepage concentrations tend to be intermediate between well and nearshore river values. The results suggest that the timing of sample collection relative to river characteristics prior to sampling strongly influences observed concentrations. The height and duration of river stage fluctuations are important influences on the water quality of bank seepage. Interpretation of waste indicator constituent concentrations in riverbank seepage should consider the riverbank storage of river water. Bank seepage data are probably not the most representative data to use in modeling groundwater contaminant flux to the Columbia River.

Chemical data for sediment from bank seepage sampling locations suggest that there are upstream as well as Hanford Site sources for observed concentrations of some metals. Radionuclides are present in sediments at reactor areas, most notably strontium-90 at 100-N and 100-F Areas.

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Further interpretation of metal and radionuclide concentrations in river sediments requires more complete information on contaminant distribution in various size fractions.

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1.0 INTRODUCTION

During September and October 1991, an extensive sampling project was completed along the Columbia River shoreline adjacent to the retired production reactor areas--the "100 Areas." Samples were collected during moderately low river stage and included riverbank seepage, sediments associated with the seepage, and nearshore river water. The following report provides a summary of the results and compares them with historical data on riverbank seepage and data from groundwater wells located near the river.

1.1 PURPOSE AND SCOPE

This report expands the initial interpretations of analytical results from the 1991 sampling project that was conducted along the 100 Areas shoreline (DOE-RL 1992a). It is intended to support the objectives of a *Hanford Federal Facility Consent and Agreement Order* (Tri-Party Agreement) (Ecology et al. 1990) milestone that pertains to the impact of contaminated groundwater from the Hanford Site entering the Columbia River through shoreline seepage.

The interpretations presented discuss Hanford Site contamination indicators in three different contexts. First, riverbank seepage water quality data obtained in 1991 are compared to previously collected data. Second, riverbank seepage water quality is compared to groundwater quality observed in wells located along the shoreline. Third, selected chemical and radiological characteristics of sediments associated with riverbank seepage are described.

1.2 PREVIOUS SHORELINE SAMPLING EFFORTS

Most of the data that exist for conditions prior to 1991 are the result of the Sitewide Environmental Surveillance program. This program is conducted by Pacific Northwest Laboratory (PNL) for the U.S. Department of Energy (DOE) (Woodruff and Hanf 1991). One of its principal objectives is to identify offsite migration of Hanford radionuclides via numerous pathways, including groundwater. The program thus far has produced two reports that specifically address riverbank seepage: McCormack and Carlile (1984) and Dirkes (1990). Some additional data on riverbank seepage are presented in a report published by SEARCH, Incorporated for sampling conducted in 1988 (Buske and Josephson 1988). All three of these sampling efforts were oriented towards radionuclides, although some measurements of nitrate were obtained during each project and also of metals, anions, and other chemical constituents during the 1988 project. Monitoring associated with the 100-N Area reactor operations also has included sampling shoreline seepage and analyzing for radionuclides (e.g., Perkins 1989).

1.3 100 AREAS CERCLA SHORELINE SAMPLING DURING 1991

Shoreline sampling conducted during September and October 1991 as part of the 100 Areas CERCLA remedial investigations focused on chemical contaminants

as well as radionuclides (DOE-RL 1992a). The sampling attempted to cover as many seepage areas along the 100 Areas as practical. It produced new data for many chemical indicators of Hanford Site contaminants, more widespread observations of chemical and radionuclide distributions, and an additional data set from which trend information can be derived. The locations of seepage areas sampled are shown in Figure 1-1. Additional details for each sample location are presented in DOE-RL (1992a, App. F).

In planning the 1991 field program, an attempt was made to improve the documentation for locations of previously collected seep samples. Using recently developed, 1:2000 scale topographic maps, Hanford Site staff who were involved in the earlier sampling efforts helped identify previously known seepage locations. A reconnaissance survey of the entire shoreline verified these locations when possible and identified seepage areas for sampling during the 1991 program. These maps were then used as base maps for the 1991 sampling. The results of the effort to improve seepage area locations are tabulated in Appendix A.

The shoreline sampling locations previously identified in the Sitewide Environmental Surveillance program reports are described relative to a Hanford River Mile (HRM) system. River mile markers, consisting of white signs on steel posts, are present along the Hanford Site shoreline of the river. The HRM system starts at Vernita Bridge and proceeds downstream along the southern shoreline. To the authors' knowledge, no surveying or other accurate locating method was used to record the earlier sampling efforts. However, most of the seepage areas can be identified in the field from the published descriptions.

The HRM markers are not consistently located at 1-mile intervals along the river. Attempts to reconcile the descriptions of previously sampled locations with the 1991 mapping of the shoreline are not always conclusive. As an interim measure for this report, a consistent reference system using the unsurveyed HRM signposts that can be located in the field has been established (Figure 1-1). These were plotted on U.S. Geological Survey 7 1/2 minute quadrangle maps and used to establish a HRM reference scale for describing seepage locations. Previous sampling locations are described in this report relative to the revised HRM system (Figure 1-1 and Appendix A).

Future shoreline sampling activities should utilize global positioning system technology to document locations. Geographic coordinates in a standard reference grid, such as the Washington State plane coordinate system, would facilitate use of the data in geographic information systems.

The analytical results from the 1991 shoreline sampling activities currently reside in GeoDat, a database that is maintained by the Westinghouse Hanford Company Geosciences organization. GeoDat operates using Paradox™ software (a trademark of Borland International). These data will ultimately reside in the Hanford Environmental Information System (WHC 1991). Data from earlier sampling efforts currently are available only in the hard-copy reports previously referenced.

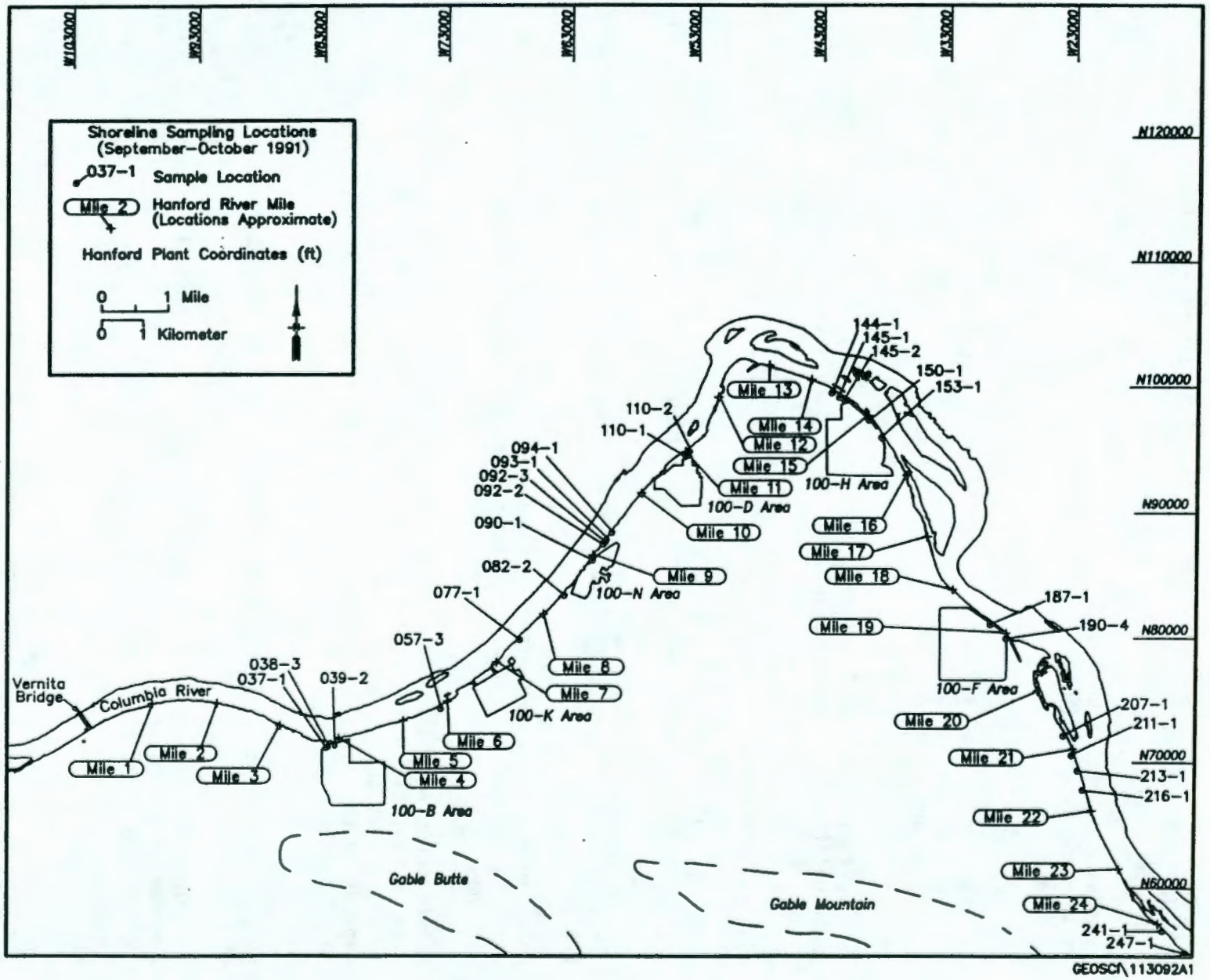

Figure 1-1. Location Map Showing 1991 Shoreline Sampling Locations.

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1.4 RELATIONSHIP TO WORK PLAN TASKS AND TRI-PARTY AGREEMENT MILESTONES

The 1991 shoreline sampling project and the subsequent interpretive effort described in this report have been conducted under tasks described in Appendix D-1, "Surface Water/Sediment Investigation," of the 100 Areas groundwater operable unit work plans (e.g., DOE-RL 1992b). One objective of the Surface Water/Sediment Investigation is to:

> *" . . . identify and characterize, to the extent possible, the current distribution and levels of contaminants present in Columbia River water and sediment as a result of . . . seepage of contaminated groundwater into the river occurring along the river banks and from spring discharges and seeps of the 100 Areas."* (DOE-RL 1992b, p. D1-2).

Work plan Task D3.4, "Spring and Seep Sampling--Water and Sediment," describes the field sampling intended to produce data to help meet this objective. A secondary document containing the results of the sampling and analysis activities, along with an initial interpretation of the results, was published in May 1992 (DOE-RL 1992a). Interpretation of these data, along with other data on groundwater conditions along the shoreline, has continued under work plan Task D3.7, "Data Evaluation." This report reflects progress in interpreting the new data since publication of the initial report.

The data collected under the spring and seep sampling task contribute towards meeting the objectives of Tri-Party Agreement milestone M-30-01, which states:

> *"Submit a report (secondary document) to the EPA and Ecology evaluating the impact to the Columbia River from contaminated springs and seeps, as described in the operable unit work plans . . . "*

A report containing the results of the sampling and analysis activities, along with an initial interpretation of the results, was submitted in February 1992 in support of this milestone (DOE-RL 1992a). The following information expands on the initial interpretations presented in that report.

2.0 TRENDS IN RIVERBANK SEEPAGE WATER QUALITY

This chapter compares the results from the 1991 shoreline sampling program to previously collected data on shoreline seepage water quality. Typical 100 Areas contamination indicators are used to demonstrate trends over time, as well as the spatial distribution of contamination along the shoreline.

2.1 100 AREAS CONTAMINATION INDICATORS

Typical 100 Areas groundwater contamination indicators include chemical constituents such as nitrate and chromium; radioactive indicators such as

tritium, gross alpha, and gross beta; and radionuclides resulting from reactor operations, such as cobalt-60 and strontium-90. Elevated nitrate concentrations have resulted from disposal of nitric acid solutions, although sanitary water drain fields also may have been a source. Chromium has two potential sources--disposal of (1) sodium dichromate, a reactor coolant water additive, and (2) chromic acid solutions used in decontamination activities. Other metals may have been introduced to the environment via coolant water disposal, particularly when coolant water was contaminated with debris from ruptured fuel rods.

Gross alpha activity in 100 Areas groundwater is frequently associated with uranium; gross beta is associated with technetium-99 and strontium-90. Activity levels for these indicators are typically higher than natural background in the vicinity of retention basins and liquid waste disposal trenches, both of which received coolant water. Radionuclides generated by reactor operations may have been present in any waste stream, but probably were most commonly introduced to the environment via disposal of reactor coolant water.

2.2 COMPARISON OF RECENT AND HISTORICAL DATA

This report focuses on the distribution of nitrate, chromium, tritium, gross beta, strontium-90, and chloride to portray both temporal and spatial trends in seepage water quality. Chloride, although not a hazardous waste, is an excellent indicator for distinguishing groundwater from river water and has been included here for that reason.

Scatter diagrams have been prepared that show the concentrations of these constituents relative to their location along the shoreline and to the various reactor areas. The data sources listed in the figures' legend boxes are as follows: PNL 84 (McCormack and Carlile 1984), PNL 88 (Dirkes 1990), SEARCH 88 (Buske and Josephson 1988), and IT 91 (DOE-RL 1992b).

Constituent concentrations in riverbank seepage are highly dependent on river stage and discharge prior to collecting seepage samples. (This is discussed in Chapter 3.0.) No attempt has been made in this report to compensate for the influence of river stage on the measured concentrations. The data presented should not be interpreted as either best-case or worst-case depictions of contaminant exposure at the shoreline. The results do, however, provide a synoptic view of (1) changes in concentrations with time (a general decrease), and (2) the distribution along the shoreline, relative to reactor areas.

When interpreting temporal trends in riverbank seepage data, several scenarios need to be considered. If a decreasing trend with time is present, it may be explained by the passage of a contaminant plume that was introduced to groundwater well before the early 1980's. This is probably a common scenario, because most liquid waste and coolant water disposal occurred during reactor operations (1950's) and during the shutdown period of the mid-1960's. As a result, September/October 1991 seepage data may represent the "tail ends" of plumes whose main body has already migrated into the river channel. The effect would be greater for contaminants that do not move at the same rate as groundwater flow, because of some retardation process.

Another scenario involves plumes that have not yet reached the shoreline, due either to more recent disposal of liquid wastes or to retardation of waste indicator constituents relative to groundwater flow. In these instances, an increasing trend with time may be present. This may be occurring in the 100-N Area, where strontium-90 and its associated beta activity are only moderately lower in the 1991 data than the 1988 data, and possibly higher than in 1984. At 100-K, highly elevated tritium exists in a groundwater monitoring well, yet only slightly elevated levels are present in seepage. At 100-D, chromium is highly elevated in a monitoring well and moderately elevated in seepage, although there are no historical data from which to infer a seepage trend. The examples cited for these three reactor areas all suggest the potential for future increases in seepage concentrations of contamination indicators.

2.3 RIVERBANK SEEPAGE WATER QUALITY

Analytical results from the September/October 1991 shoreline sampling program, along with data collected from earlier sampling episodes, are presented as a function of location along the shoreline.

2.3.1 Nitrate

A common constituent in groundwater around the 100 Areas, concentrations of nitrate in all seepage data collected during 1991 are well below the drinking water standard of 45,000 ppb (Figure 2-1). Previous seepage data suggested that nitrate is elevated above drinking water standards only at 100-N, and then only slightly. Current nitrate data show a slightly increasing trend with downstream distance. This may reflect a general increase in background level for groundwater nitrate, which is consistent with Sitewide nitrate distribution maps (Woodruff and Hanf 1991, Fig. 5.15).

Groundwater plumes containing nitrate concentrations above drinking water standards exist at several reactor areas. The most prominent nitrate plume is associated with the 183-H Solar Evaporation Basins in the 100-H Area. Dilution of these plumes by (1) river water held in bank storage and (2) possible consumption of nitrogen by biological activity in the shoreline ecosystem combine to reduce the concentration observed in seepage samples.

2.3.2 Chromium

The 1991 sampling effort provided the first comprehensive data set for chromium in riverbank seepage, seepage sediment, and nearshore river water (Figure 2-2). Total chromium was measured in these samples using the inductively coupled plasma (ICP) metals analysis method. The drinking water standard for total chromium was raised as of July 30, 1992, from 50 ppb to 100 ppb (40 CFR 141.62, Phase II Rule, effective July 30, 1992). Using the earlier 50 ppb reference, chromium is significantly elevated in seepage at the 100-D Area and slightly elevated at 100-B, 100-K, and 100-H Areas. In the absence of sufficient historical data, a description of temporal trends in chromium concentrations is not yet possible.

Figure 2-1. Nitrate in Riverbank Seepage. A drinking water standard for nitrate is 45,000 ppb.

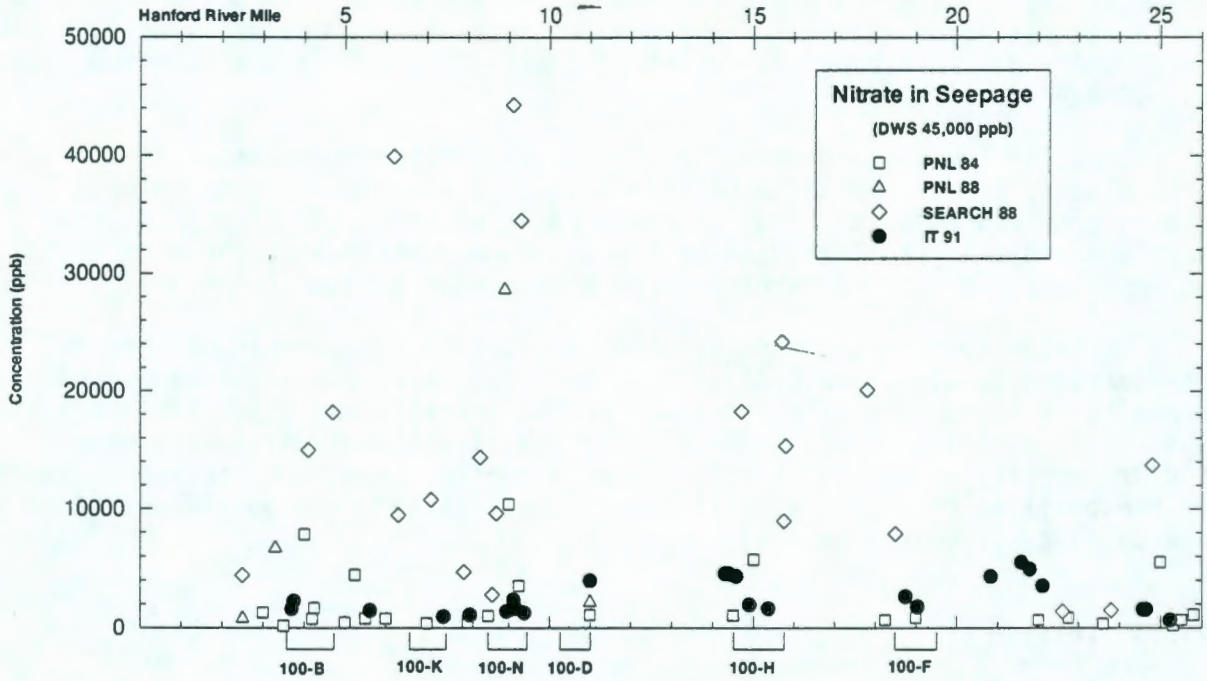
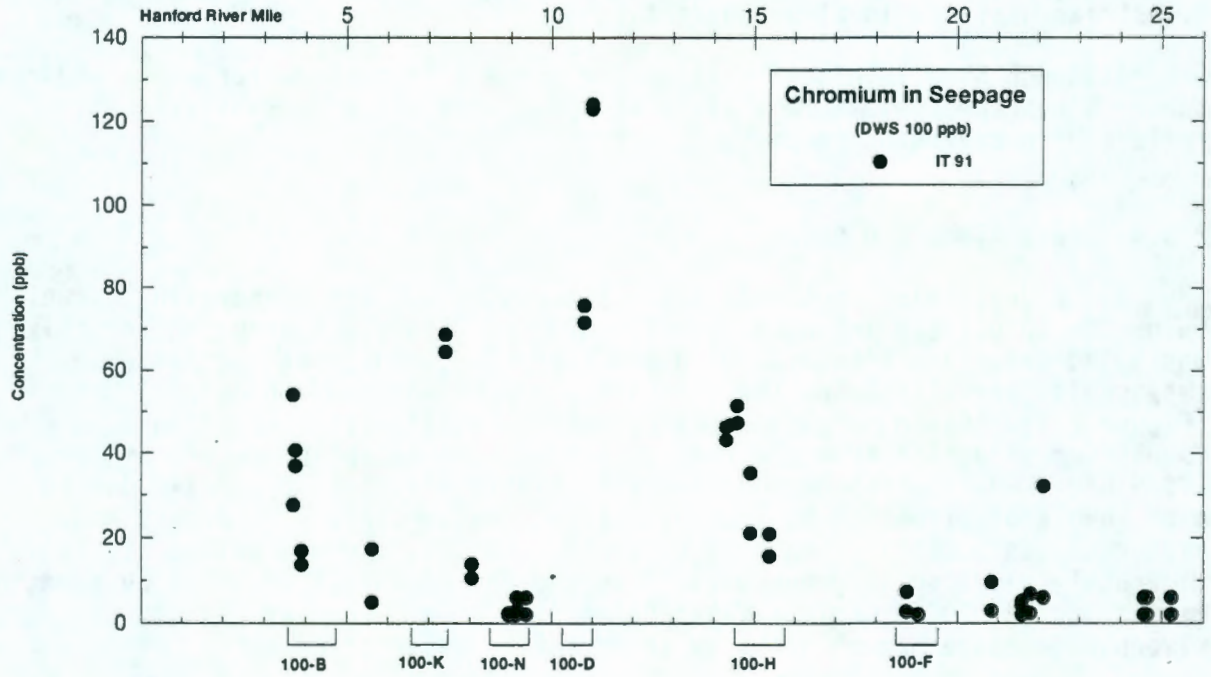


Figure 2-2. Chromium in Riverbank Seepage. The drinking water standard was raised from 50 to 100 ppb as of July 30, 1992.



A well-defined chromium plume is present in groundwater at the 100-H Area (Peterson 1991, Peterson and Connelly 1992). A similar plume is inferred to exist at 100-D, although monitoring well coverage there does not permit a good definition of plume extent. Water quality results from new wells drilled for both RCRA and CERCLA programs during 1992 will help define the chromium plume at 100-D Area.

In water samples, chromium in the hexavalent form (chromate) is predominant, because of its mobility in aqueous solution. Other valence states are less soluble. Thus, a measurement of total chromium in a water sample essentially reflects the hexavalent form. Hexavalent chromium is toxic to organisms and a known carcinogen to humans when inhaled (EPA 1992).

Chromium transported via riverbank seepage of groundwater may become concentrated in algal and bacterial slimes that exist along the shoreline. Since these slimes are often coatings on the gravelly and sandy sediments of the beach, planning future remediation activities that involve excavation and/or dredging along the shoreline should consider the potential consequences of remobilizing chromium, as well as other metals and radionuclides, stored in the coatings (see Section 4.4).

2.3.3 Tritium

Tritium, a radioactive isotope of water with a half-life of about 12 years, has a drinking water standard of 20,000 pCi/L, which is slightly exceeded in riverbank seepage at 100-B and 100-N Areas (Figure 2-3). At 100-B, the tritium level has apparently increased since 1984, while at 100-N, a decrease is indicated. A general decrease in tritium levels with increasing downstream distance is also apparent.

Although high levels of tritium are present in groundwater wells adjacent to the N Reactor fuel storage basin at 100-K Area, this currently is not reflected in riverbank seepage.

2.3.4 Gross Alpha and Beta

Since gross alpha activity along the entire 100 Areas shoreline is well below the 15 pCi/L drinking water standard, no figure was prepared for this waste indicator constituent. With one exception, gross beta activity in seepage is generally below the drinking water standard of 50 pCi/L (Figure 2-4). Again, a general decrease in activity is observed in a downstream direction from the reactor areas. The exception occurs at 100-N Area, where gross beta activity is highly elevated, primarily due to high levels of strontium-90 from past liquid waste disposal. Recent and historical data confirm these high levels. At 100-H, gross beta activity is moderately elevated in groundwater downgradient of the 183-H Solar Evaporation Basins and the 107-H Coolant Water Retention Basin. However, levels in riverbank seepage are at or below the drinking water standard.

Figure 2-3. Tritium (^3H) in Seepage. A drinking water standard for tritium is 20,000 pCi/L. Note logarithmic scale.

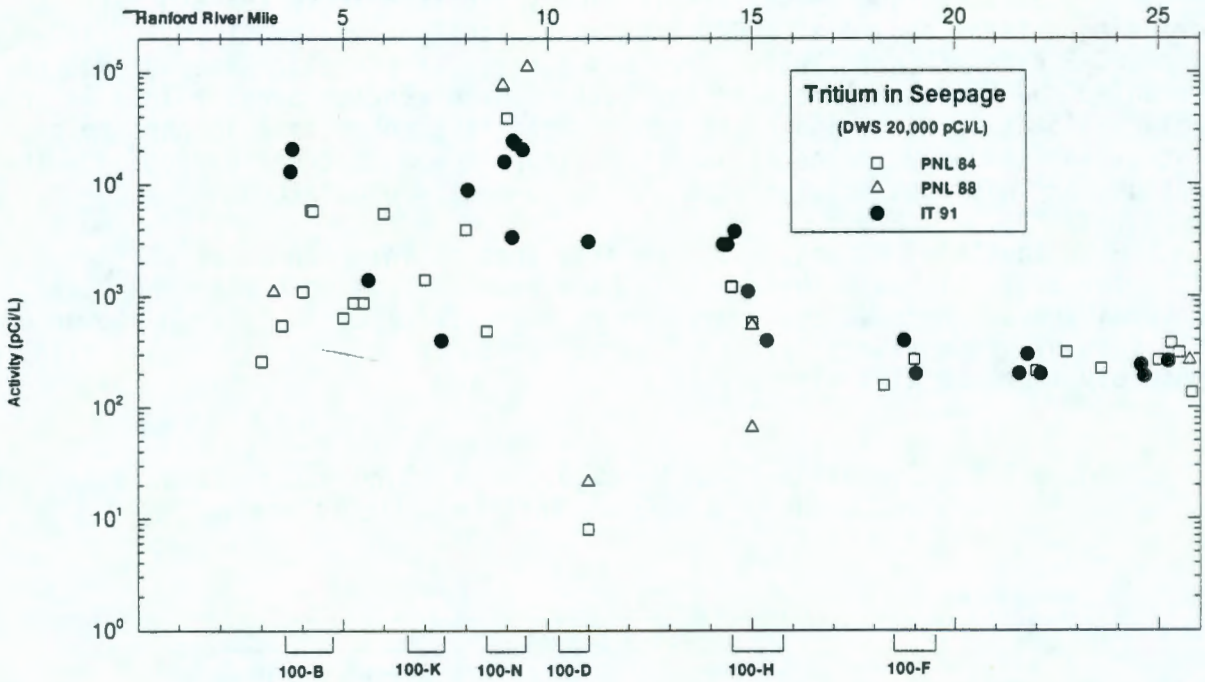
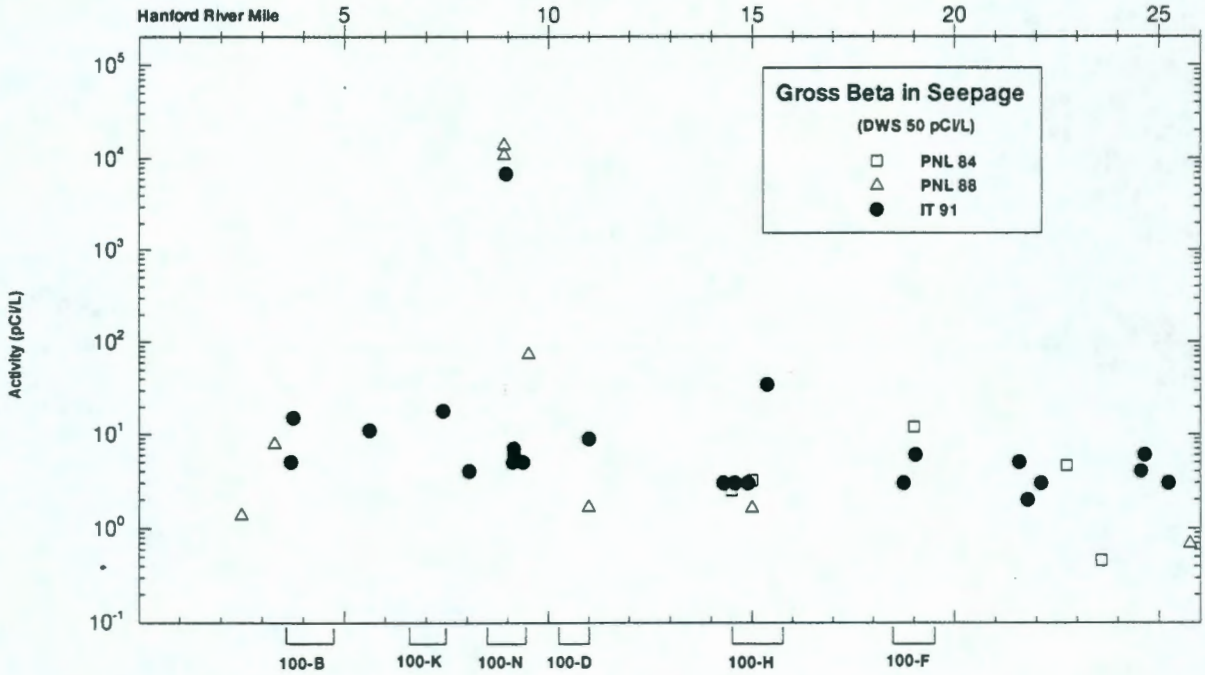


Figure 2-4. Gross Beta Activity in Seepage. A drinking water standard for gross beta is 50 pCi/L. Note logarithmic scale.

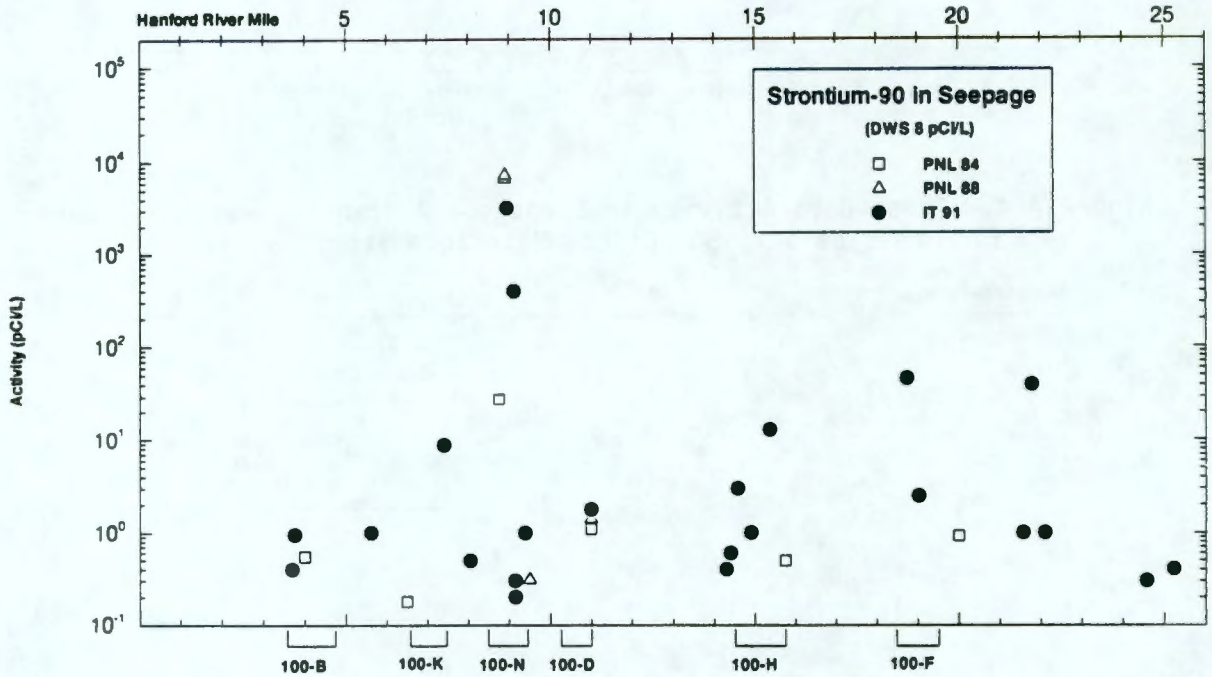


2.3.5 Strontium-90

This radionuclide in seepage is highly elevated above the 8 pCi/L drinking water standard at 100-N Area and slightly elevated at 100-K, 100-H, and 100-F Areas (Figure 2-5). Previous surveys of shoreline seepage had not revealed the elevated levels at the latter three reactor areas. This is the only radioactive waste indicator constituent in seepage that appears to be increasing slightly, rather than decreasing, in a downstream direction. The reason for this apparent increase is not currently understood.

High levels of strontium-90 are also present in groundwater wells (Chapter 3.0), although these levels have been decreasing during the last several years. Because the migration rate of strontium-90 is much slower than the flow of groundwater, levels of strontium-90 in seepage may remain high, or possibly increase with time.

Figure 2-5. Strontium-90 in Seepage. A drinking water standard for strontium-90 is 8 pCi/L. Note logarithmic scale.



3.0 RIVERBANK SEEPAGE AND GROUNDWATER

Seepage observed along the Columbia River shoreline during low river levels has two components. The first is groundwater that flows from the unconfined aquifer on the Hanford Site into the river channel. The second is river water that has been placed in bank storage as the result of high river levels, which also drains back into the river channel. As a result, the water quality of bank seepage is not completely representative of groundwater migrating towards the river. This chapter describes the relationship between riverbank seepage water quality and that of nearby groundwater.

3.1 INTERACTION BETWEEN GROUNDWATER AND COLUMBIA RIVER WATER

During high river stage, river water moves into the riverbank where it either overlies groundwater and/or mixes with groundwater. As the river stage falls, the bank storage water flows back towards the river channel via seepage (Newcomb and Brown 1961, Cooper and Rorabaugh 1963). Thus, the concentration of contamination indicators in riverbank seepage is generally lower than that observed in groundwater wells adjacent to the shoreline.

The water quality of riverbank seepage for a specific sampling event is highly dependent on the stage history of the river prior to obtaining seepage samples. Two significant variables are how high the river stage rose and how long it stayed elevated. This influence on seepage water quality has not been considered in the following analysis, because a quantitative relationship has not been developed to describe the interaction between groundwater and river water held in bank storage. As a result, interpretations made from the data presented in the figures are primarily qualitative, although some limits can be set.

To better describe quantitatively the interaction between river water and groundwater in the riverbank, field experiments involving continuous monitoring of water quality parameters and physical characteristics are needed. Data collection should occur over multiple daily cycles of river stage fluctuations, as well as seasonal cycles, if the phenomenon is to be fully characterized.

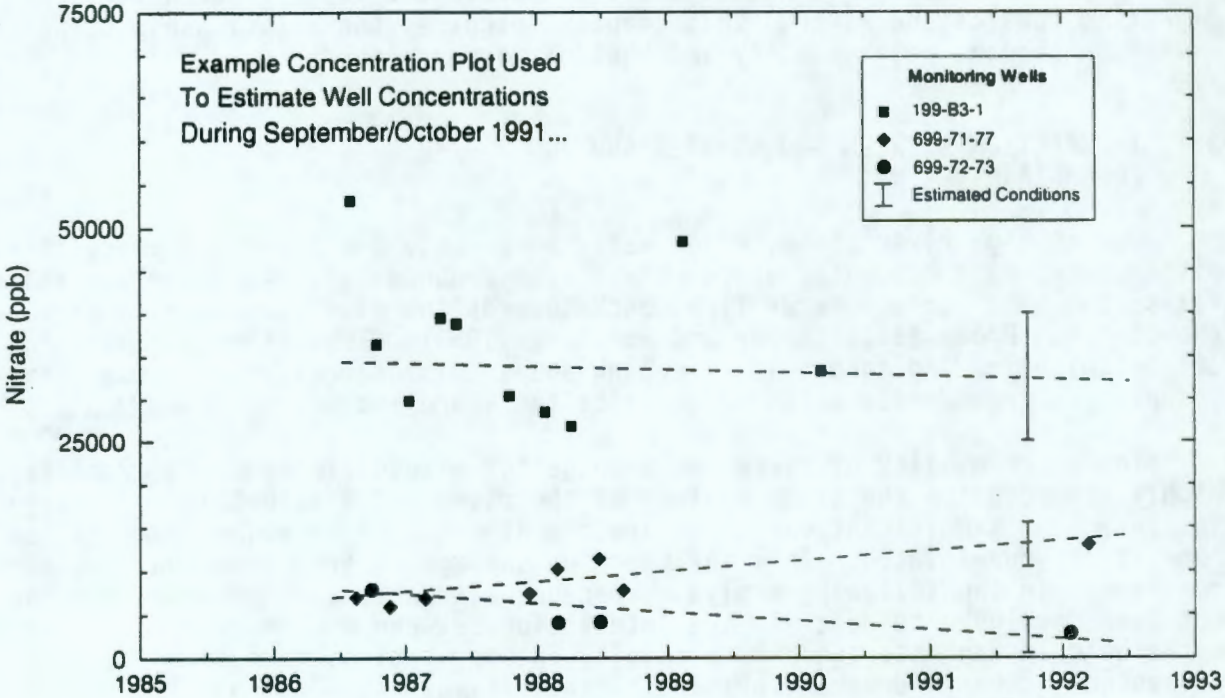
3.2 GROUNDWATER QUALITY ALONG THE 100 AREAS SHORELINE

An analysis of historical data from monitoring wells was conducted as a first step in comparing riverbank seepage to nearby groundwater. This was necessary since simultaneous observations in nearby monitoring wells were not obtained at the time of the 1991 seepage sampling. Consequently, estimates for groundwater were derived from previous trends established in the wells.

Scatter plots were constructed for each contamination indicator for numerous wells located along the shoreline. When groundwater data were not available in a well during the September/October 1991 sampling period, historical trends in the scatter plots were visually projected to obtain an

estimated range for the well. Figure 3-1 is an example scatter plot for nitrate in several 100-B Area wells. It shows typical distributions of historical data from which subjective estimates were made regarding groundwater conditions.

Figure 3-1. Example Scatter Plot for Estimating Well Concentrations.



Selection of wells to compare with seepage locations was also subjective, since monitoring well coverage is uneven among the various reactor areas. For this report, wells located within approximately 800 m of the river were considered. This distance approximates the inland distance to which river stage fluctuations are easily observed in monitoring wells. Significant mixing or layering of river water with groundwater probably occurs only at much closer distances, perhaps within 150 m or less, depending on the degree of change in river stage. The inland distance of river influence also varies with location along the 100 Areas shoreline.

At some areas, such as 100-H and 100-N, numerous wells are located fairly close to the shoreline, thus providing more representative information on groundwater discharging as seepage. At other areas, such as 100-D and 100-K, wells are farther from the river, thus making the correlation with seepage more tenuous. Other influences on the correlation include contaminant plumes in some reactor areas that have not yet reached the river and groundwater conditions that are not homogeneous between a particular well and the shoreline.

For all these reasons, the groundwater monitoring well values that are presented in this chapter should be used only as a guide. The data provide a synoptic view of water quality along the 100 Areas shoreline, creating at least a generalized background, or reference level, for evaluating the water quality of shoreline seepage.

3.3 COMPARISON OF SEEPAGE AND ESTIMATED GROUNDWATER CONDITIONS

Riverbank seepage results for typical Hanford Site contamination indicators are compared to nearby groundwater quality using scatter plots, where concentration is plotted as a function of location along the shoreline. Estimates for groundwater are presented as range bars, to emphasize the uncertainty in values determined by projecting historical trends.

Values for samples taken from the Columbia River adjacent to the seepage locations are also presented. Given the very low discharge rates of the seepage, it is unlikely that these river samples have been significantly influenced by the seepage that was sampled. Consequently, the data for river samples should be viewed as river background values.

3.3.1 Nitrate

In nearly all locations, nitrate levels in seepage appear considerably lower than values estimated for nearby groundwater, the latter occasionally exceeding a drinking water standard of 45,000 ppb (Figure 3-2). Even at 100-H Area, where nitrate levels associated with the 183-H Solar Evaporation Basins may reach several hundred thousand parts per billion, the seepage data do not reflect such high levels. Bank storage of river water may be largely responsible for this. An additional process that may be contributing to consistently lower levels of nitrate in seepage might be biological utilization of nitrate in the shore zone ecosystem.

3.3.2 Chromium

Seepage concentrations of chromium generally are less than the values for groundwater, but not by the same margin as nitrate (Figure 3-3). At 100-B, 100-K, 100-D, and 100-H Areas, chromium in seepage is at or slightly above the former drinking water standard of 50 ppb.

Elevated chromium in groundwater has been previously described in the 100-H Area (Peterson 1991) and 100-D Areas (Hartman and Peterson 1992). The elevated levels in the 100-K Area have not been previously described in detail and very few historical data exist to describe groundwater levels in the 100-B Area. Based on the somewhat elevated levels in seepage, elevated chromium in 100-B Area wells should be anticipated. Initial sampling of 100-B Area wells under the CERCLA program is under way and results will become available in late 1992.

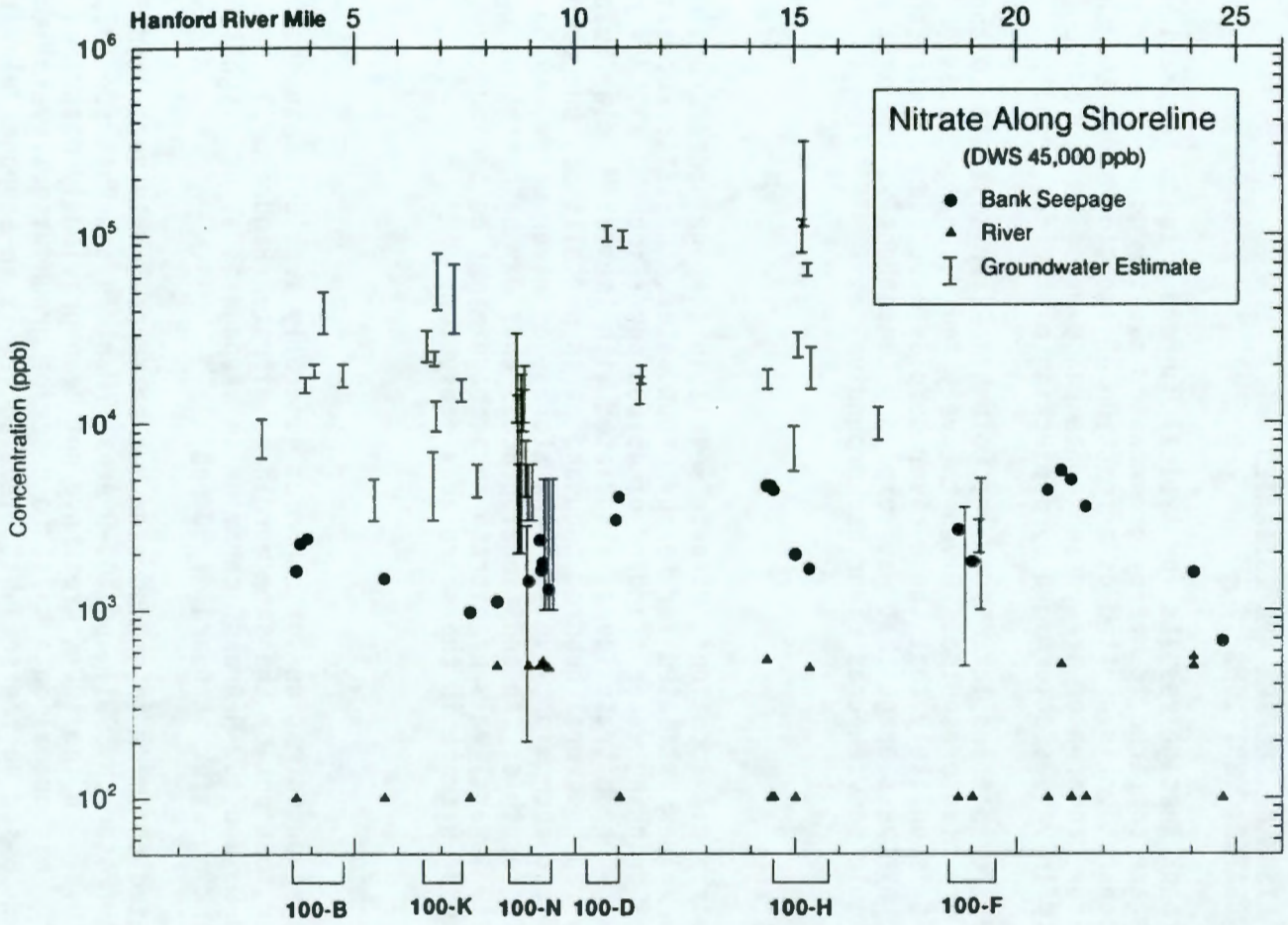


Figure 3-2. Nitrate in Seepage, River, and Shoreline Wells.

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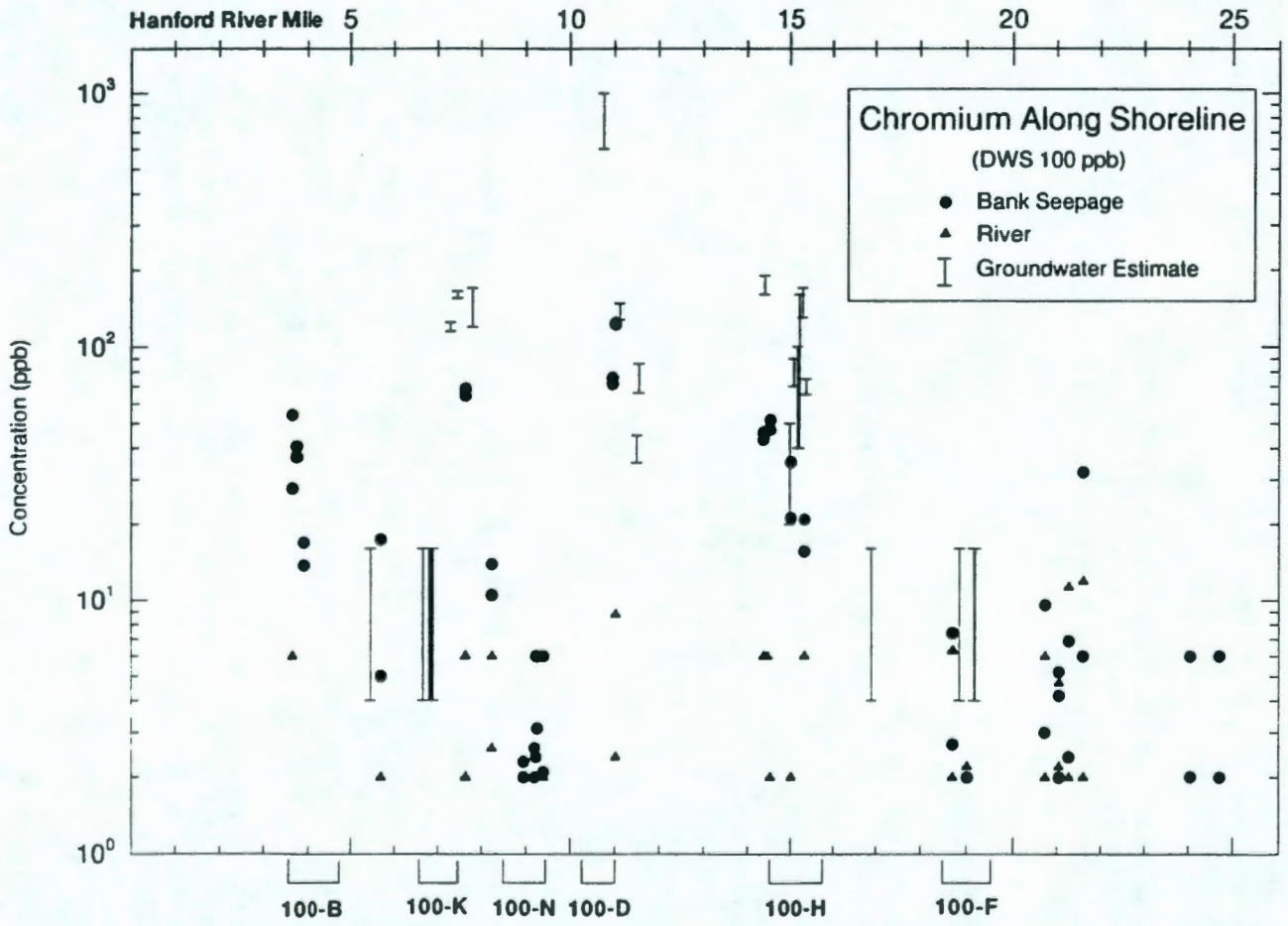

Figure 3-3. Chromium in Seepage, River, and Shoreline Wells.

3.3.3 Tritium

Tritium concentrations in seepage are generally lower than nearby monitoring well concentrations (Figure 3-4). The 20,000 pCi/L drinking water standard is exceeded in seepage at 100-B and 100-N Areas by a small margin. It is exceeded in groundwater at 100-B, 100-K, 100-N, and 100-D by larger margins. The highest tritium values in groundwater are found at the 100-K Area and may be associated with the storage basin used for spent fuel from the N Reactor.

Tritium levels in seepage and groundwater appear to decrease in a downstream direction from the 100-N Area. The elevated levels in 100-D Area are probably the result of a plume emanating from the 100-N Area. This plume is described in Woodruff and Hanf (1991, Fig. 5.5).

3.3.4 Gross Beta

An exception to the general trend of seepage being intermediate in quality between groundwater and river water occurs at the 100-N Area. Here, gross beta activity at the 100-N Area springs equals or exceeds nearby groundwater values (Figure 3-5). Drinking water standards are exceeded in both seepage and groundwater. The cause for the anomalously high values in seepage may be an as yet undefined process for concentrating strong beta radiation emitters, such as strontium-90, at the seepage locations. At 100-B and 100-H Areas, gross beta activity in seepage is also near the drinking water standard.

3.3.5 Strontium-90

High levels of strontium-90 are present in seepage at the 100-N Area springs. Strontium-90 is also slightly elevated above the 8 pCi/L drinking water standard at 100-K and 100-H Areas, and moderately elevated at 100-F (Figure 3-6). The levels at 100-H and 100-F are difficult to explain, since they are not consistent with gross beta levels for the same seeps. Other than at 100-N, very few groundwater values are available to compare with seepage data. New data from wells will become available in late 1992.

The nearshore river water sample taken adjacent to 100-N Area springs also has a strontium-90 level that is elevated to the drinking water standard. This river sample even exceeds values in nearby monitoring wells.

3.3.6 Electrical Conductivity

Conductivity is included in this analysis to demonstrate the contrast between Columbia River water and Hanford Site groundwater. Figure 3-7 readily shows the intermediate position held by seepage conductivity, which is influenced by contaminant plumes or waste water disposal in only a few areas. Conductivity, as well as chloride content which mimics conductivity, are excellent variables to use in describing the interaction between river water held in bank storage and groundwater.

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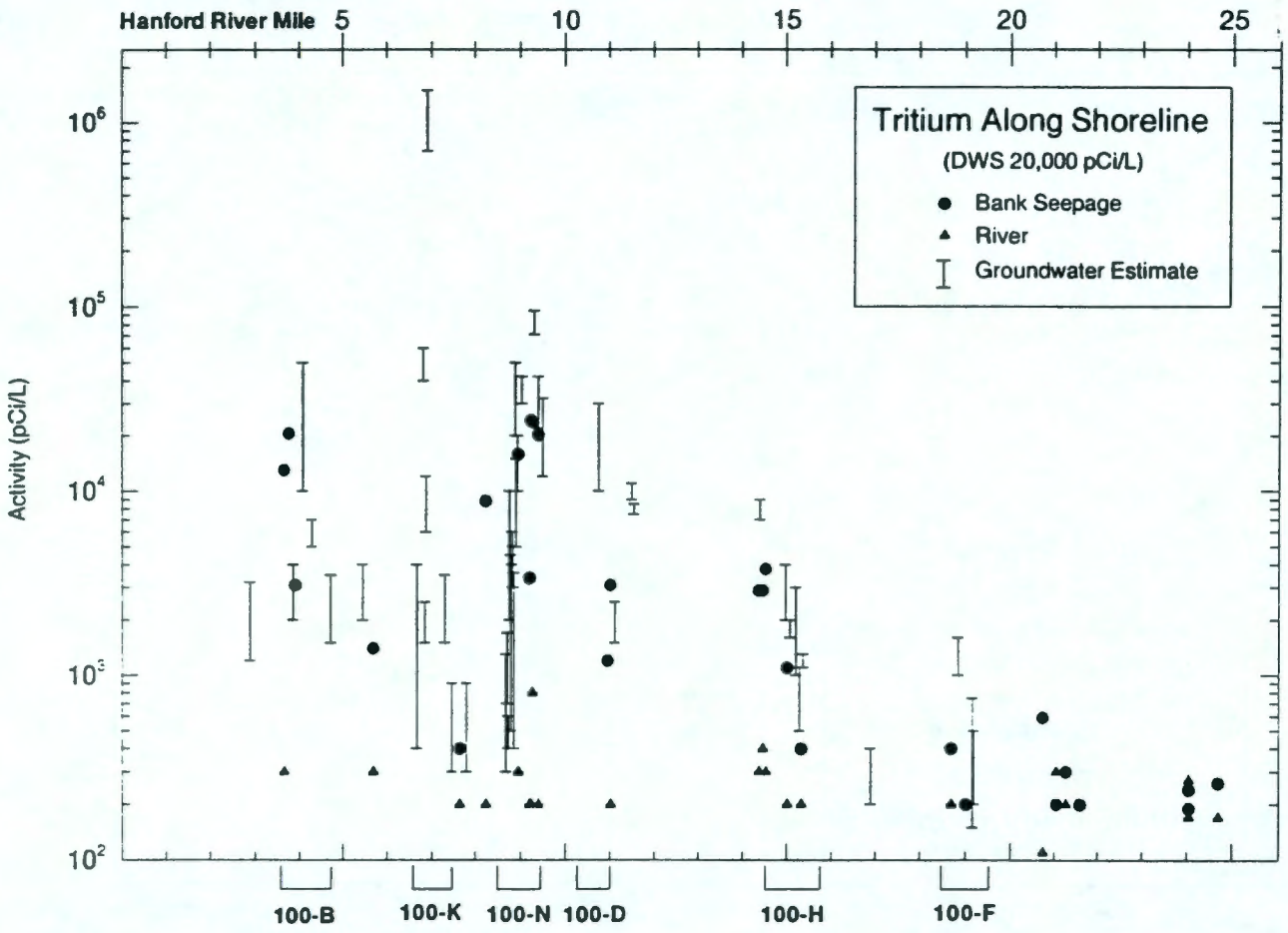

Figure 3-4. Tritium in Seepage, River, and Shoreline Wells.

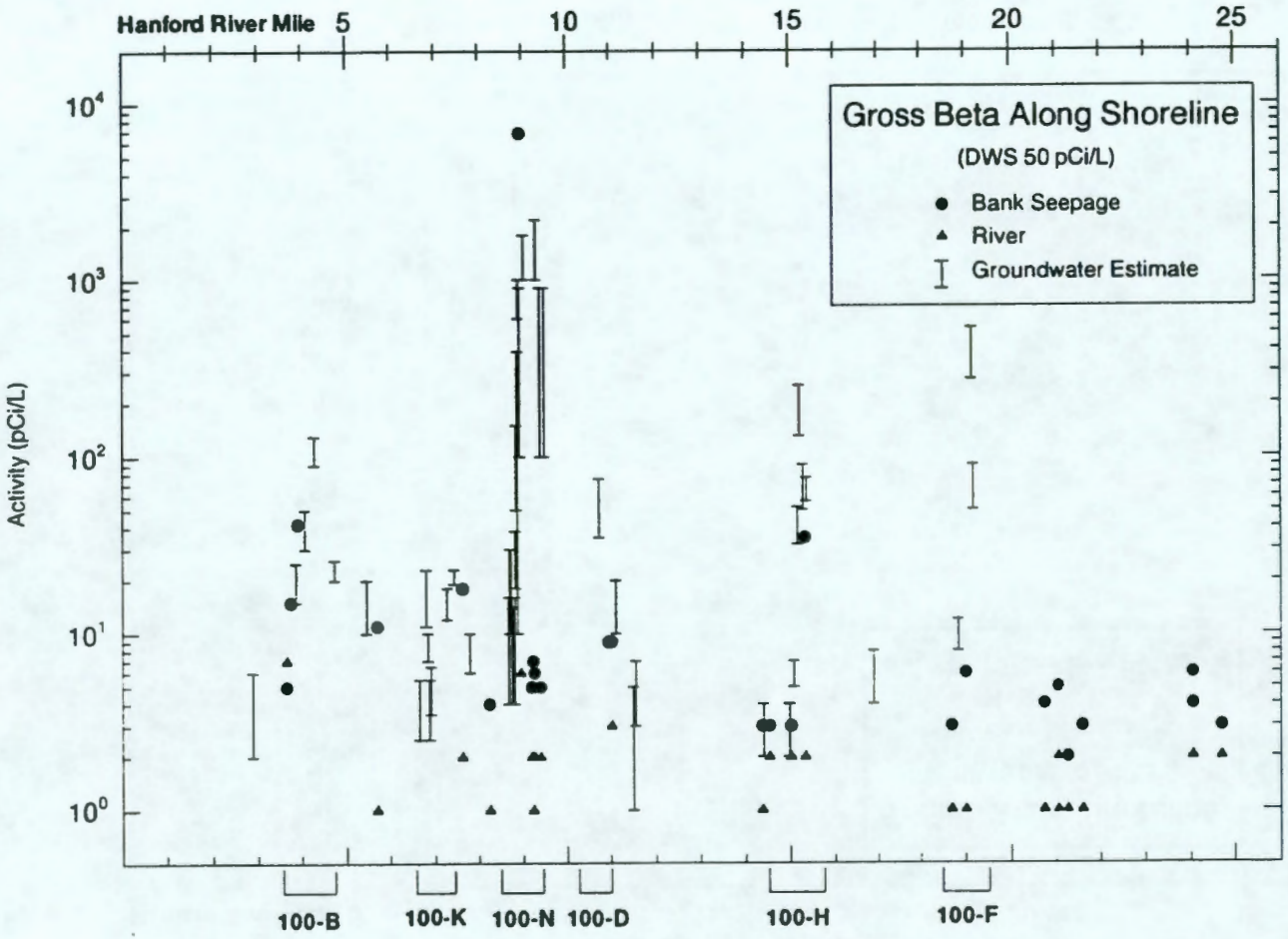

Figure 3-5. Gross Beta in Seepage, River, and Shoreline Wells.

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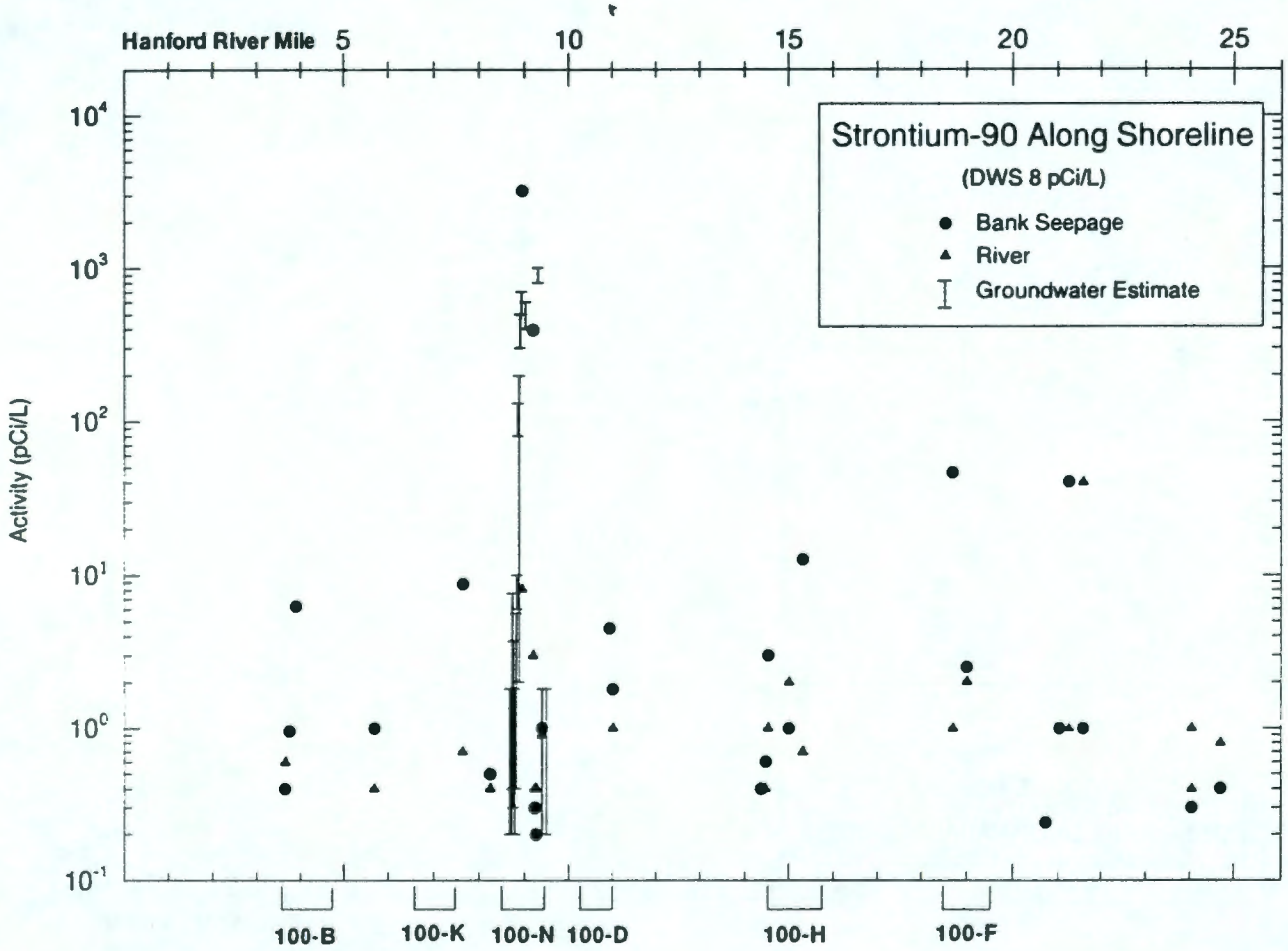


Figure 3-6. Strontium-90 in Seepage, River, and Shoreline Wells.

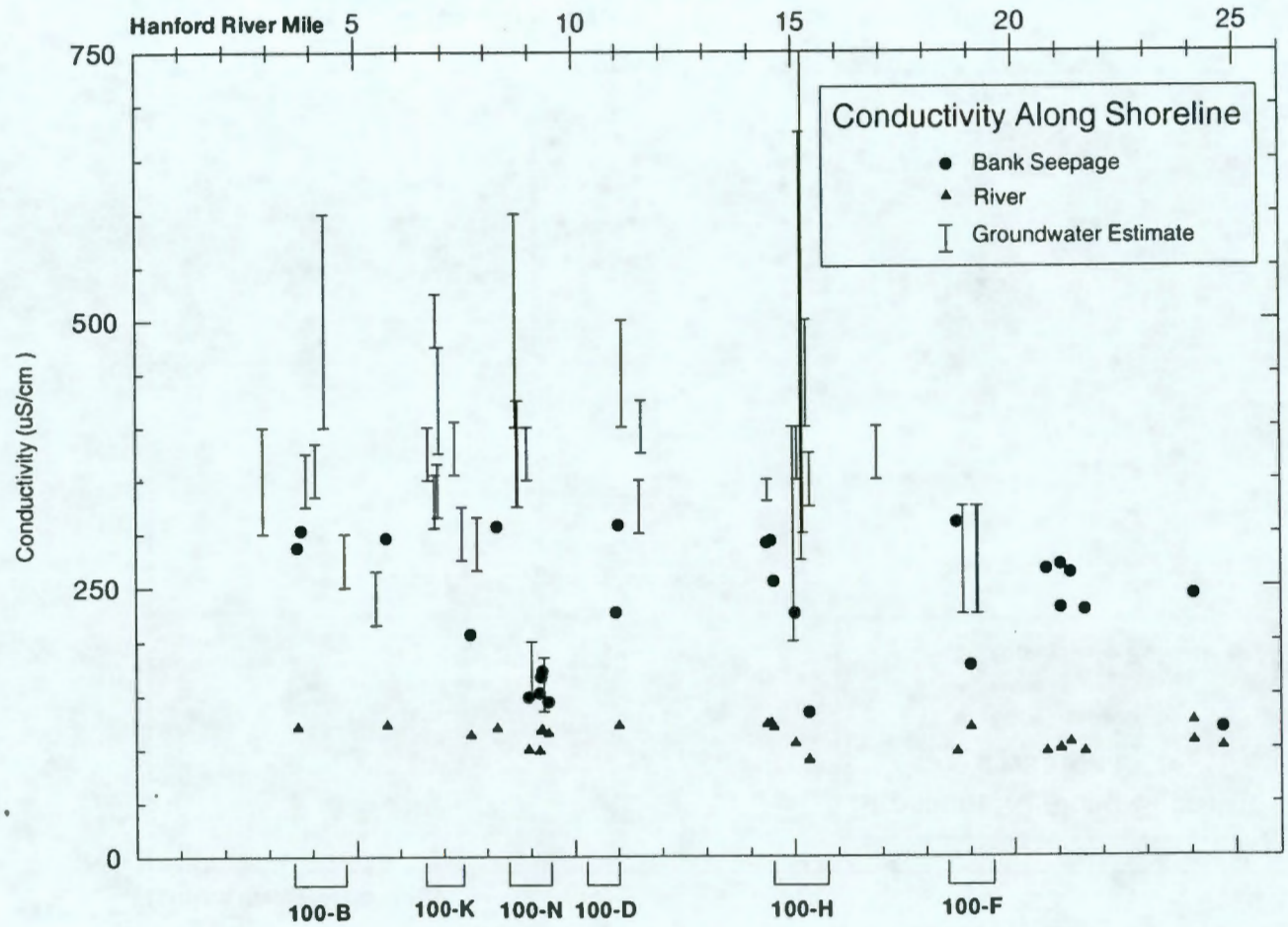


Figure 3-7. Conductivity in Seepage, River, and Shoreline Wells.

3.4 SHORT-TERM VARIABILITY BETWEEN SHORELINE SEEPAGE AND GROUNDWATER

One objective of the 100 Areas characterization effort is an improved understanding of the interaction between groundwater and the Columbia River. Seasonal changes in groundwater wells located along the shoreline are correlated with seasonal changes in river discharge, as shown by existing monthly and quarterly water samples. However, shorter term changes in groundwater quality are not well described by existing data. This section presents the results of an initial effort to obtain data to describe the daily changes that occur in groundwater near the river, as it fluctuates through its daily rise and fall.

3.4.1 Interaction Between Groundwater and River Water

As groundwater moves towards the river, it encounters river water that has entered the banks of the river channel during periods of high river stage, the latter referred to as bank storage of river water (Newcomb and Brown 1961). River water held in bank storage may overlie the groundwater and/or it may mix with groundwater, causing a dilution in the concentrations of certain groundwater constituents. This natural interaction mitigates health and environmental risks associated with contaminated groundwater seepage along the shoreline.

The dilution of contaminated groundwater prior to its emergence as riverbank seepage is only partially understood. The water quality of seepage potentially can vary between pure river water draining back into the river channel after periods of high river stage, to nearly undiluted groundwater after extended periods of low river stage. The timing of compositional changes in riverbank seepage relative to the rise and fall of river stage is not well documented with field data.

A typical river stage cycle along the 100 Areas consists of a rise and fall once a day, with a change in elevation of 2 to 2.5 m in the river and 0.3 to 0.6 m in nearby groundwater wells. Order-of-magnitude changes in the concentration of selected groundwater constituents are not unusual in wells located near the riverbank. This variability is attributed to either preferential sampling in the well of river water, which may overlie the groundwater, or to dilution of groundwater in the well by river water, during periods of high river stage.

Since wells are sampled monthly, quarterly, or annually, and without regard to river stage at the time of sampling, it is not possible to interpret the short-term timing of these concentration changes relative to the bank storage of river water. Seasonal changes, however, can be fairly well described using existing data.

3.4.2 Sampling Strategy

A riverbank seepage location was selected in the 100-H Area that has a groundwater monitoring well located nearby. Water samples from both the seep and the well were collected simultaneously at 1-hour intervals during daylight

hours on November 25 and 26, 1991. Water samples from the well were obtained using a portable submersible pump. Samples from the seep and river were collected using stainless steel sampling cups, following procedures established during the 1991 seep sampling conducted by IT Corporation (DOE-RL 1992a).

Temperature, pH, and specific conductance were recorded for each sample using field instruments. Nitrate and hexavalent chromium analyses were performed using a portable water analysis kit (Model DR/2000 photometer, Hach Company, Loveland, Colorado). The well's water level was measured with a steel tape. A nearby well contained a pressure transducer and temperature probe, which produced data at 1-hour intervals. A river stage recorder for the 100-H Area was in operation and also produced 1-hour data.

3.4.3 Riverbank Seepage and Well Sampling Locations

Seep number 153-1, which was sampled during 1991, was selected for this project. It is located along the shoreline adjacent to the 107-H Coolant Water Retention Basin (Figure 3-8). Well 199-H4-11 was used for groundwater samples. It is located adjacent to the northeast corner of the 107-H Basin, just outside the fence, and is approximately 50 m from the river's edge and 100 m upstream of seep 153-1. The well is constructed to RCRA standards and is sampled regularly as part of the 183-H Solar Evaporation Basins RCRA monitoring program. Historical water levels, nitrate, and chromium concentrations for the well are shown in Figure 3-9.

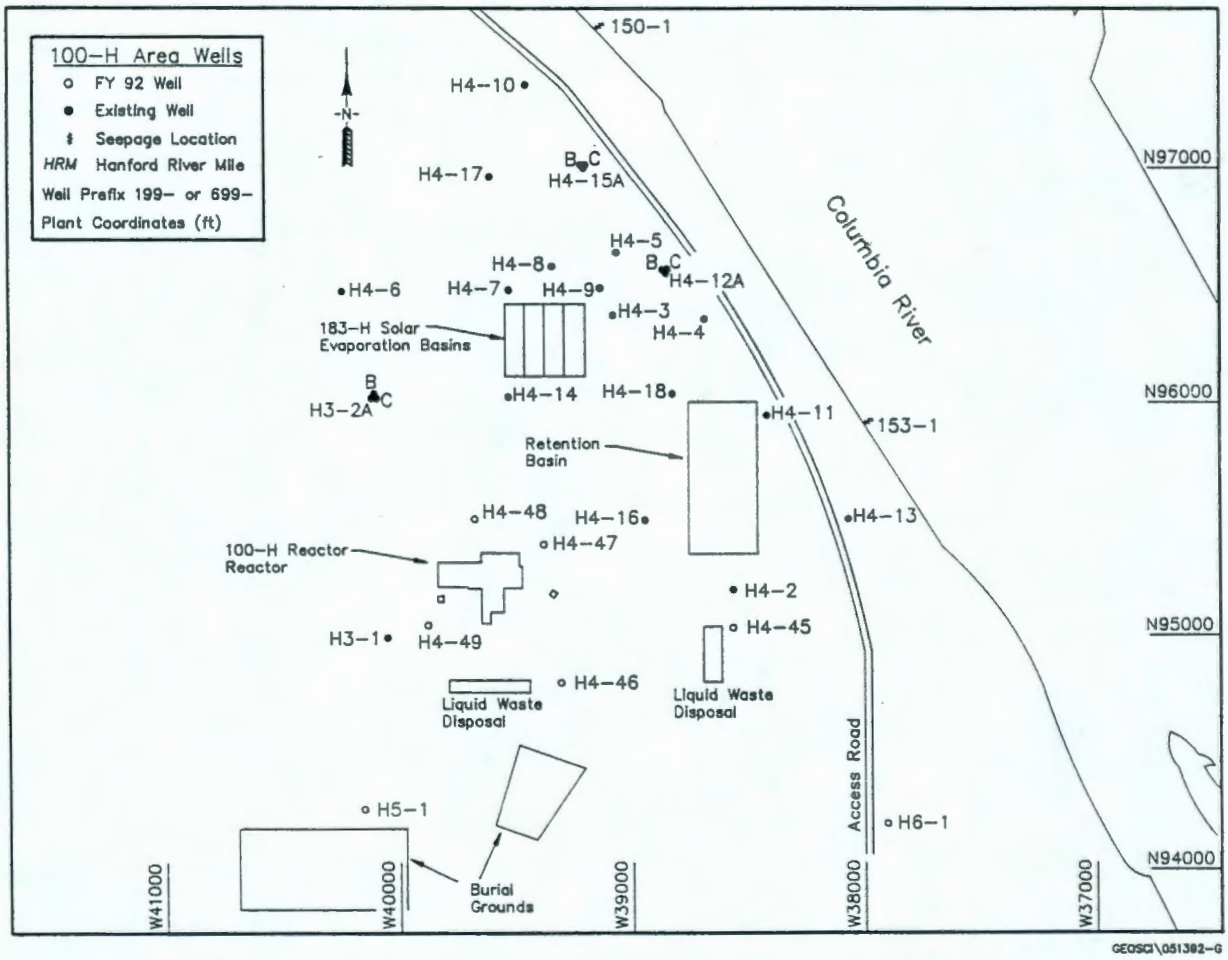
3.4.4 Analytical Results

The field data obtained during the project are compiled in Appendix B. Water level fluctuations recorded by data loggers for the river at 100-H and a monitoring well (199-H4-12A) located 200 m northwest of well 199-H4-11, as well as the steel tape measurements made in the sampled well, are shown in Figure 3-10. On November 25, the river was moderately high during the night and dropped to its daily low during the sampling interval. On November 26, the night river stage was higher than the previous night; the river was still falling at the beginning of the sampling time interval. The seep became submerged when the river rose during the day, thus stopping sampling activities.

During both days, the water level recorder in well 199-H4-12A showed a continuous decrease of approximately 0.25 ft during the sampling activity. This decrease is consistent with the steel tape measurements made at sampled well 199-H4-11. Note also that the changes in the wells' water level lag the change in river stage by approximately several hours.

Temperature data for well 199-H4-11, riverbank seepage, and the river near the seep are shown in Figure 3-11. On both days, the seep showed an increase in temperature as the day progressed; this is particularly evident in the second sequence. The increase may reflect the flow of relatively warmer groundwater through the riverbank. That is, during the preceding night,

Figure 3-8. Location Map for Wells and Seeps in the 100-H Area.



relatively cooler river water moved into the bank. The following morning, it flowed back towards the river. Changes in conductivity, shown in Figure 3-12, can be interpreted in an analogous way. Temperature and conductivity in seepage both display an intermediate position between groundwater and river water end members.

An exception to this pattern is present in the pH data, shown in Figure 3-13, where the seepage pH appears to have the lowest value. The pH values for the river appear anomalously high, and measurement error, possibly due to temperature effects on instrument calibration, is suspected. River pH should typically fall in the range of 8.0 to 8.2. If pH is to be used in the future to describe groundwater/river interaction, special consideration in taking field measurements is appropriate.

Nitrate and hexavalent chromium concentrations in the well and the seep (Figures 3-14 and 3-15) also demonstrate the change in water quality that occurs when river water held in bank storage drains back toward the river. (Field logistics precluded measuring nitrate and chromium in river samples.)

Figure 3-9. Historical Water Levels, Nitrate, and Chromium in Well 199-H4-11.

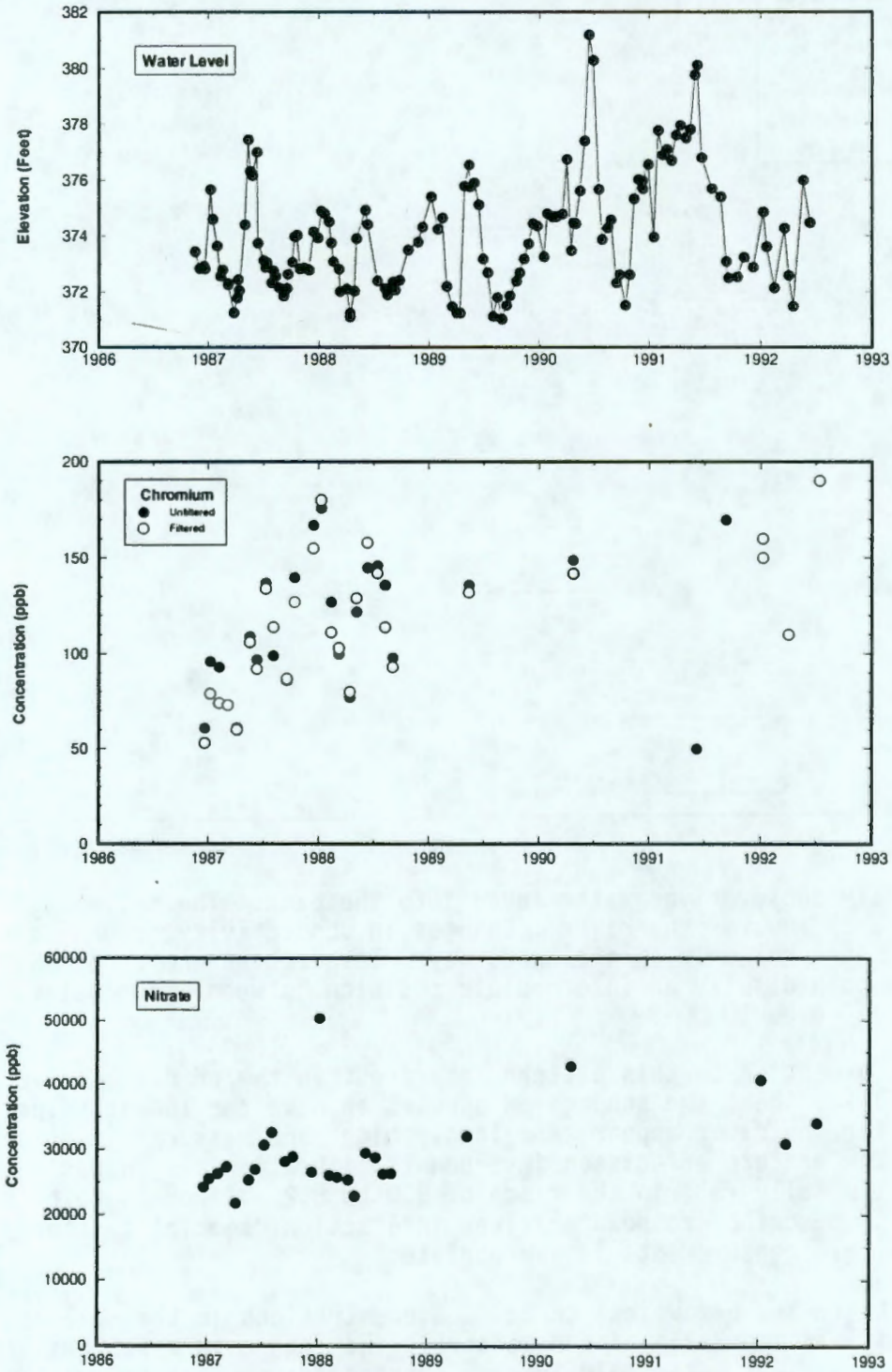


Figure 3-10. River Stage and Well Water Levels During Sampling Period.

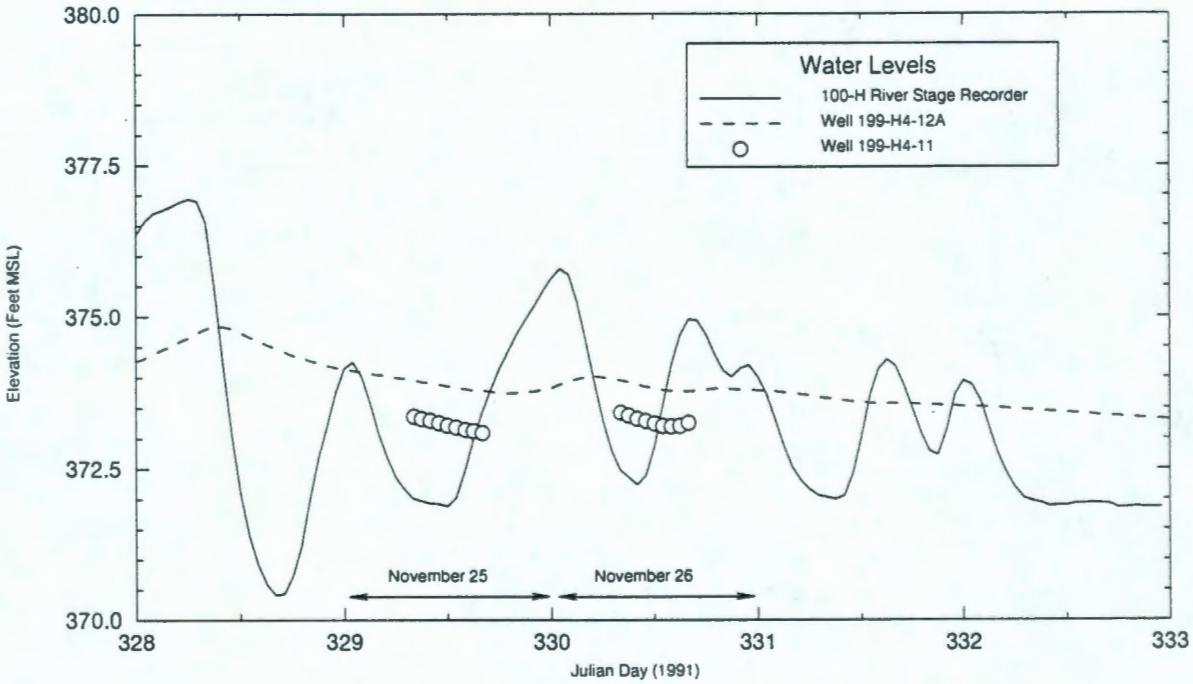


Figure 3-11. Temperature in Well, Seepage, and River.

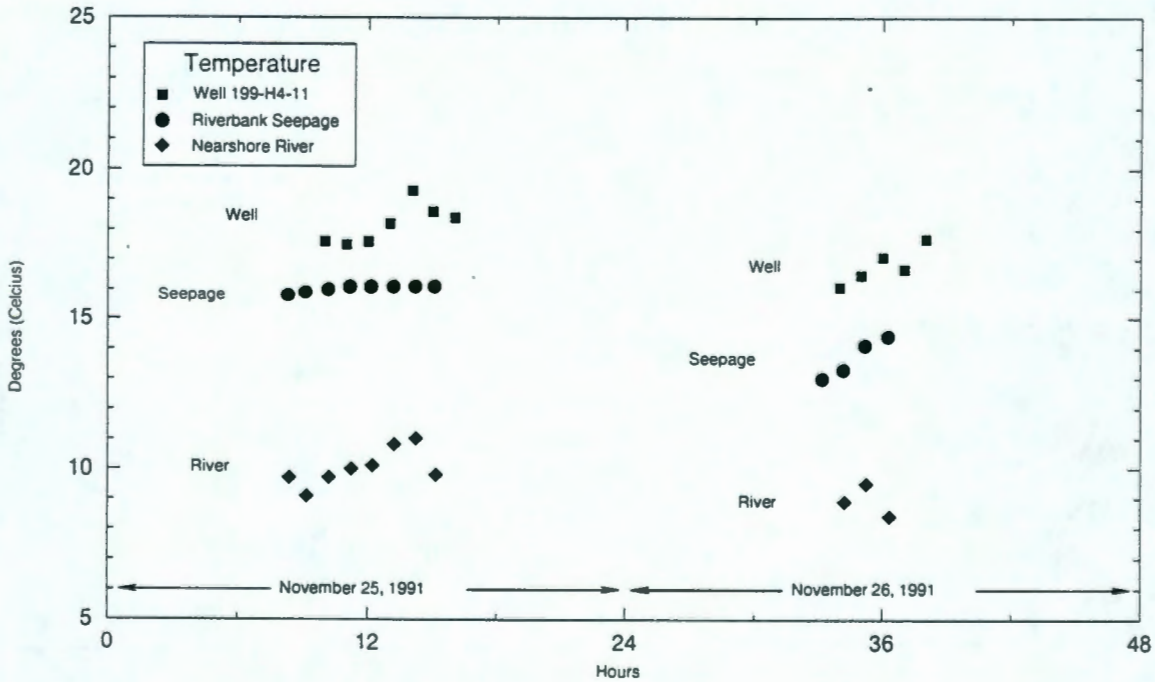


Figure 3-12. Conductivity in Well, Seepage, and River.

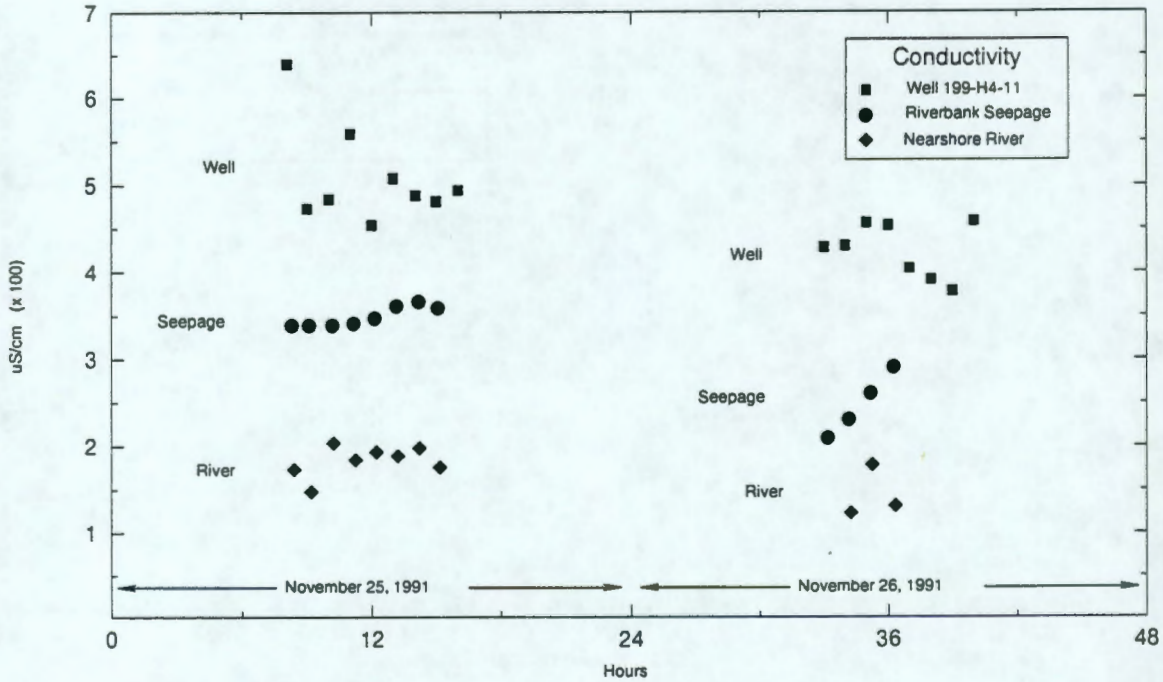


Figure 3-13. pH in Well, Seepage, and River.

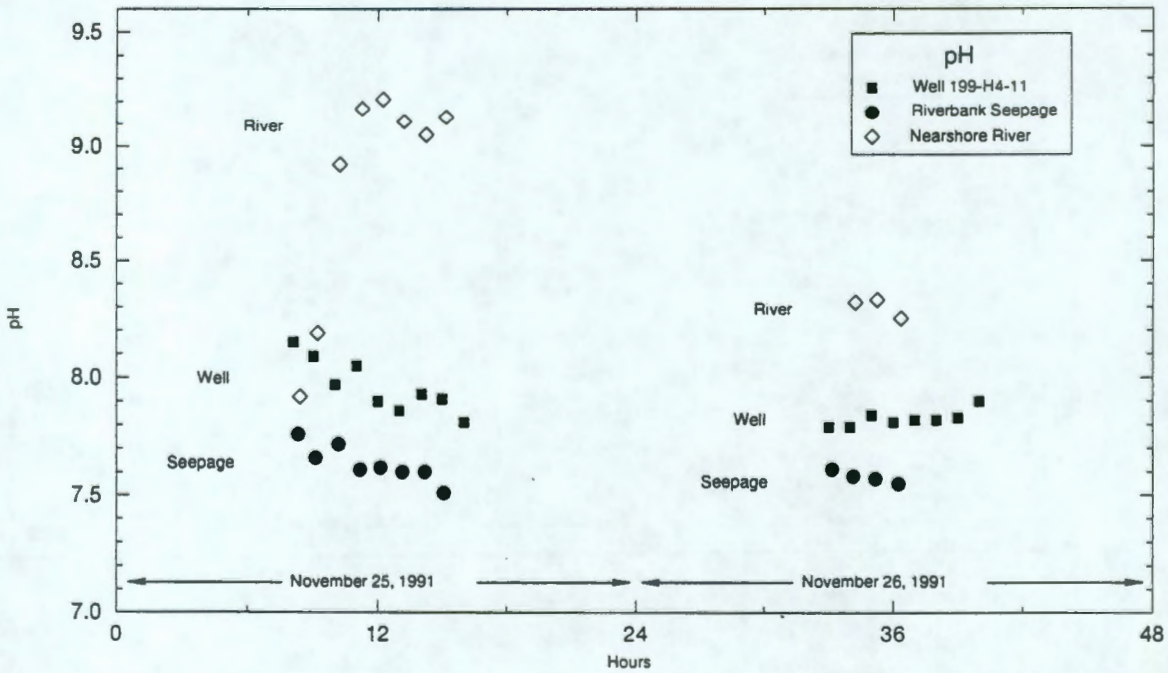


Figure 3-14. Nitrate in Well and Riverbank Seepage.

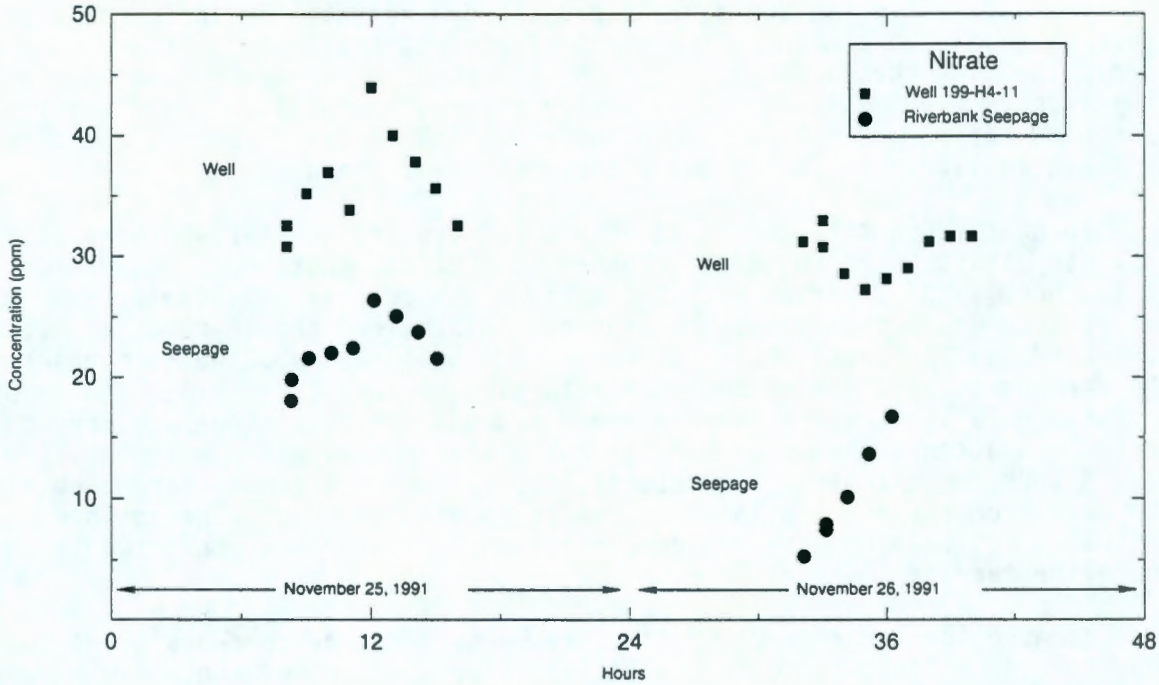
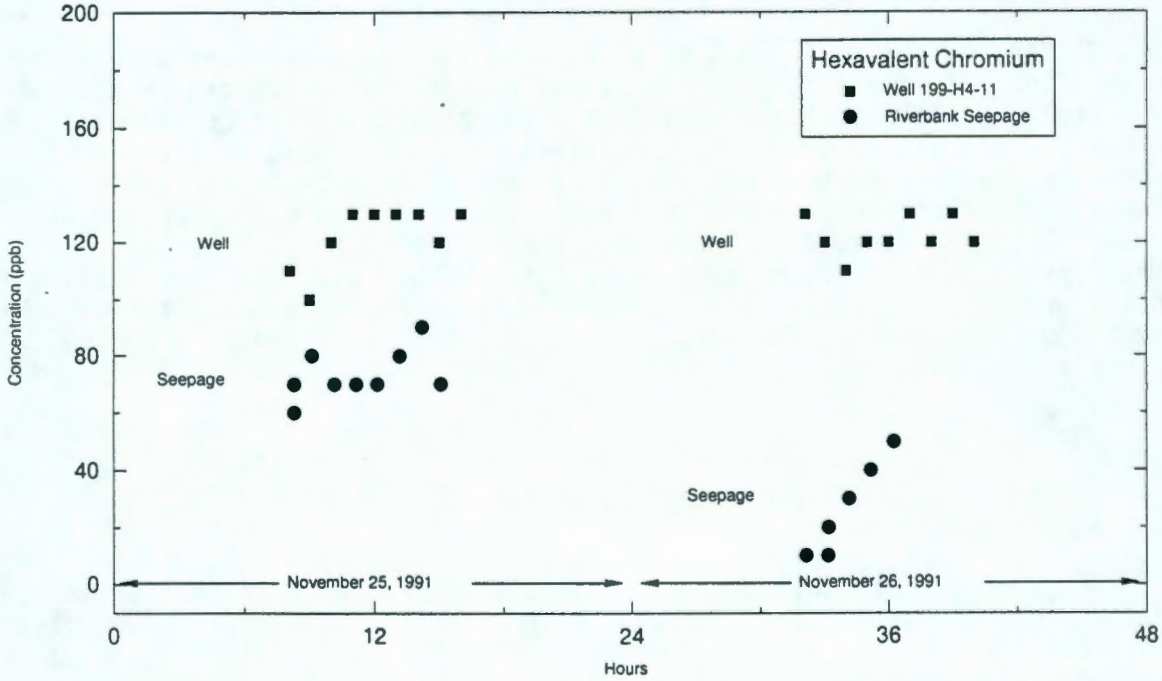


Figure 3-15. Hexavalent Chromium in Well and Riverbank Seepage.



3.4.5 Discussion

The data collected during this project demonstrate the influence that river stage has on the characteristics of riverbank seepage. At any particular time that a seep is exposed, the observed concentrations of certain constituents are highly dependent on the river stage history immediately preceding the seep sampling. Both the elevation of the river and the duration of elevated levels influence the water quality of seepage.

To better quantify the relationship between groundwater and bank storage, expanded data sets in two areas are needed. First, short-term measurements (e.g., hourly) of a variable that clearly distinguishes groundwater from river water, such as conductivity, are needed. This record should cover at least several daily fluctuations in the river and should be repeated to characterize the various seasons during the year. In situ measuring equipment and remotely operated data loggers are the preferred methods for obtaining such records. Second, an attempt should be made to correlate previous seep water quality data with river discharge characteristics, if the latter data can be obtained. The data from these investigations can be modeled to provide defensible estimates for maximum expected concentrations of hazardous constituents in shoreline seepage.

Because aquifer characteristics are by no means homogeneous along the 100 Areas shoreline, the data collection efforts described above may have to occur at each area where information on contaminant flux to the river is needed. A single groundwater/river interaction relationship probably will not be adequate to predict the future characteristics of individual groundwater plumes.

Monitoring the water quality of riverbank seepage provides important information for assessing the risk to the public and environment posed by exposure to radiological and hazardous chemical groundwater constituents. However, these data are not representative of the contaminant flux and total volume of groundwater that ultimately discharges into the river system. Observed riverbank seepage probably accounts for only a small portion of Hanford Site groundwater that discharges into the river (Dirkes 1990, p. 4). Other investigative methods must be used to produce data that are applicable to (1) modeling the total flow of contaminated groundwater into the Columbia River and (2) assessing the cumulative impact and resulting risk to the Columbia River system.

4.0 SEDIMENTS ASSOCIATED WITH RIVERBANK SEEPAGE

Sediment samples collected from the actively flowing seepage areas were analyzed using standard soil analysis methods on the bulk sediment sample. This chapter discusses potential sources for metals and radionuclides in river sediments, reference or background values, and the results of the 1991 sampling activity.

4.1 SOURCES FOR METALS AND RADIONUCLIDES IN SEDIMENT

To help evaluate the significance of analytical results for seepage sediment samples, a review of potential upstream sources is provided as an aid for interpreting the concentrations observed along the Hanford Reach of the Columbia River.

4.1.1 Metals

Concentrations of certain metals in sediment samples collected near the spring sampling sites may be influenced by upstream sources as well as by former Hanford Site operations. For example, mining and related refining activities in the upper Columbia River drainage basin (Figure 4-1) may contribute to above-background occurrences of zinc, copper, lead, cadmium, and other metals. These metals are associated with secondary ore minerals from the silver, lead, and zinc mining districts in northern Idaho and southern British Columbia (Maxfield et al. 1974; Johnson 1991, 1979; Rember et al. 1991; Robbins 1978; Silker 1964; Miller et al. 1975). Other metals associated with British Columbia mining activities may include antimony, tin, indium, thallium, arsenic, manganese, and mercury (Hoy et al. 1985).

Previous studies have described the potential effect of mining activities on selected metal concentrations in river sediment both upstream and downstream of the Hanford Site. Johnson (1979) showed that zinc concentrations in fine-textured sediments (<64-μm particle diameter) behind Priest Rapids and McNary Dams were approximately eight to five times higher, respectively, than natural background. Similar patterns were observed for lead, cadmium, and copper (Whetten et al. 1969). Concentrations in riverbed sediment decrease with downstream distance from Priest Rapids Dam to the mouth of the Columbia River and appear to decline in proportion to sediment loads added to the Columbia River by major tributaries (Johnson 1979, 1991).

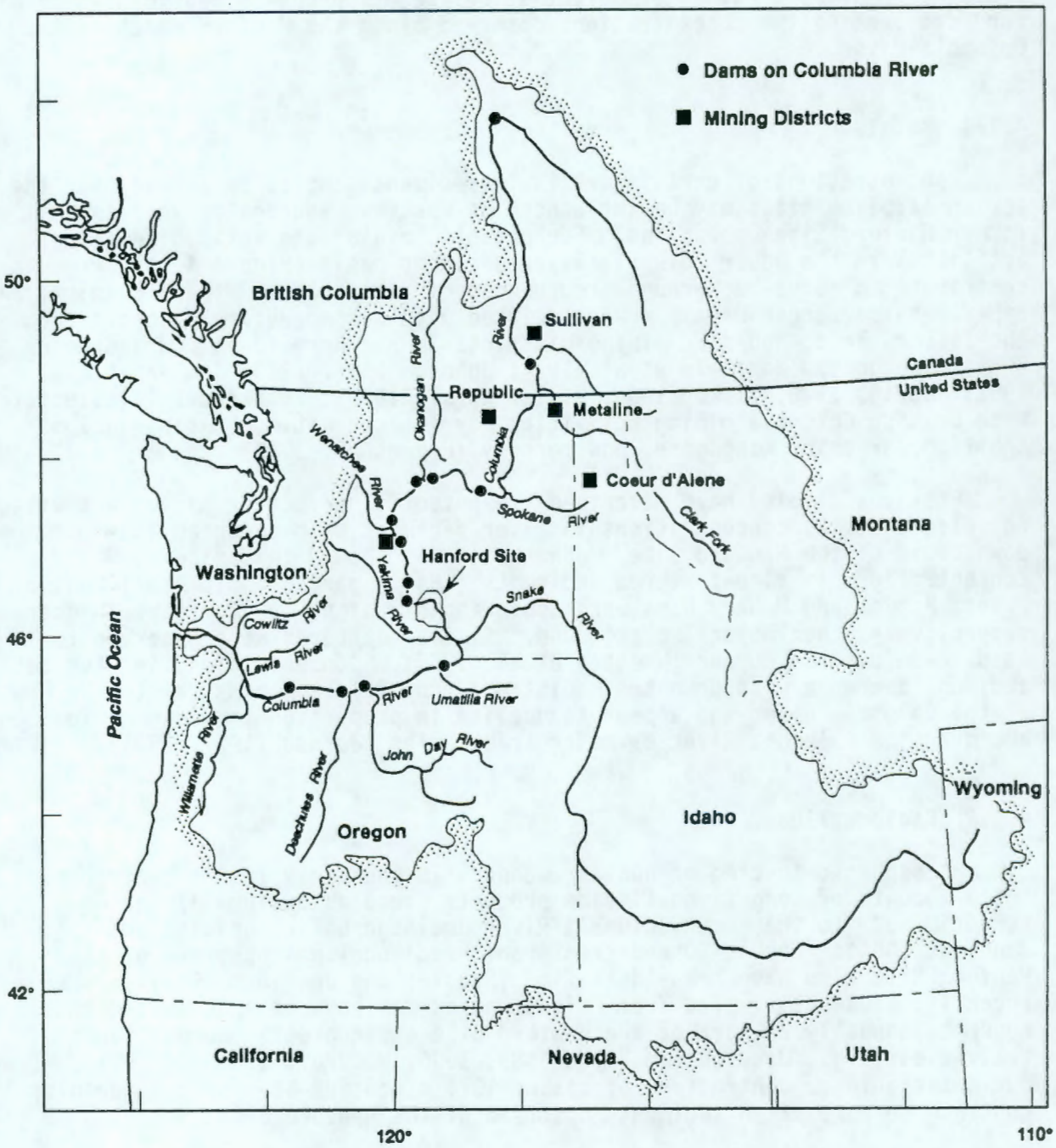
4.1.2 Radionuclides

Atmospheric testing of nuclear weapons in the early 1960's contributed trace amounts of long-lived fission products, such as cesium-137 and strontium-90, to the upper Columbia River drainage basin (Beasley and Jennings 1984). Cobalt-60 and transuranic radionuclides upstream of the Hanford Site also have been identified (Beasley and Jennings 1984). More recently, sediment samples from Priest Rapids Dam have been collected and reported annually as part of the Hanford Site environmental surveillance activities (e.g., Jaquish and Bryce 1989, 1990; Woodruff and Hanf 1991). Low-but-detectable concentrations of cesium-137, strontium-90, and transuranics continue to persist in sediments upstream of the Hanford Site.

4.2 REFERENCE AND BACKGROUND VALUES

Reference and background values are used to put the observed sediment concentrations from the 1991 seepage survey in perspective. Existing data for radionuclide concentrations in sediment samples from Priest Rapids Dam are ideal for this purpose. Unfortunately, similar data for heavy metals are not

Figure 4-1. Location Map for Mining Activities Within the Columbia River Drainage Basin.



available. In lieu of river sediment background values from upstream of Hanford, local Hanford Site soil/sediment background threshold values are used as preliminary reference values (Hoover and Legore 1991). "World average shale" (Bowen 1966) serves as a third reference scale. The latter is a very generalized reference for metals associated with fine-grained sediments (<64-μm particle diameter). The reference values used in this report, along with the average seep sediment results, are summarized in Tables 4-1 and 4-2.

Natural variations, such as the positioning of various constituents in different particle size fractions and mineralogical suites, provide an underlying justification for the maximum or threshold value approach proposed by Hoover and Legore (1991) for Hanford Site soil background levels. In this approach, a wide variety of Hanford sediments or soils are sampled and analyzed, ensuring inclusion of both fine- and coarse-textured materials. The maximum naturally occurring concentration for each metal of interest is then established (with 95% confidence) from this range of samples.

4.3 SEEPAGE SEDIMENT ANALYTICAL RESULTS

Comparison of the metal results from the 1991 sampling program with the reference levels (Table 4-1) suggests that antimony, cadmium, silver, and zinc are above the soil background or worldwide average shale reference values. Marginal or possible exceedances include copper and chromium. Strontium-90 exceeds reference values established for sediments above Priest Rapids Dam. Gross beta and strontium-90 concentrations are highly elevated near the 100-N Area (Table 4-2). Distribution patterns for those constituents that appear to be above reference concentrations shown in Tables 4-1 and 4-2 are discussed below. A summary of all analytical results as reported in DOE-RL (1992a) is presented in Table 4-3.

4.3.1 Distribution of Metals (Figures 4-2 through 4-5)

No obvious correlation of potential Hanford Site sources (i.e., contaminant plumes and/or reactor sites) is evident in the plots of metal concentrations as a function of location along the 100 Areas shoreline, with the exception of chromium at 100-D and 100-H Areas. At those areas, the elevated chromium concentration in seepage sediment is most likely the result of past liquid waste disposal practices associated with reactor operations. Circumstantial evidence suggests the cadmium, zinc, and silver may be related to solute and/or colloidal transport of metals from mine tailings leachate and refinery effluent from upstream sources (e.g., Pita and Hyne 1975). However, additional sediment analyses are needed to confirm this hypothesis and to account for variations due to variable grain size of the bulk sediment samples. The bulk sediment samples that were analyzed consist predominantly of sand with small but highly variable amounts of silt- and clay-sized material.

Antimony is also a potential mining-related metal that is elevated above the worldwide average shale reference. However, antimony does not exhibit the same distribution pattern as silver, cadmium, and zinc. This may be related in part to the more complex chemistry of antimony.

Table 4-1. Metal Reference Values and Seepage Sediment Results.

Constituent	Hanford soil background[1] (mg/kg)	World average shale[2] (mg/kg)	Seep sediment average value[3] (mg/kg)
Aluminum	16,600	82,000	6,288 ± 1,167 (28)
Antimony	N/Av	1.5	9.8 ± 4.4 (25)
Arsenic	4	13	N/An
Barium	169	580	68 ± 16 (28)
Beryllium	2	3	0.3 ± 0.1 (16)
Cadmium	N/Av	0.3	0.9 ± 0.5 (24)
Calcium	11,200	22,100	4,048 ± 1,425 (27)
Chromium	20	90	31 ± 27 (28)
Cobalt	16	19	7.5 ± 1.5 (20)
Copper	21	45	20 ± 5 (28)
Iron	29,800	47,200	22,400 ± 28,900 (26)
Lead	10	20	N/An
Magnesium	6,480	15,000	3,733 ± 533 (26)
Manganese	424	850	312 ± 104 (27)
Mercury	N/Av	0.4	N/An
Nickel	18	68	12 ± 2.7 (24)
Potassium	2,740	26,600	787 ± 211 (27)
Silver	N/Av	0.1	1.1 ± 0.4 (16)
Sodium	N/Av	9,600	194 ± 53 (24)
Strontium	43	300	N/An
Vanadium	82	130	38 ± 14 (26)
Zinc	50	95	173 ± 80 (28)

[1]Provisional threshold values based on acid leach--U.S. Environmental Protection Agency (EPA) Method 6010 (Hoover and Legore 1991).

[2]Total bulk sample concentrations for world average shale (Bowen 1966).

[3]Acid leach--EPA Method 6010. Total digestion would yield higher values. Values shown are averages, plus or minus one standard deviation, with number of samples in parentheses. Analytical uncertainties restrict the number of significant figures to less than three.

N/Av = Not available.

N/An = Not analyzed.

Table 4-2. Selected Radionuclide Reference Values and Seepage Sediment Results.

Radionuclide	Priest Rapids Dam[1] average value (pCi/g)	Seep sediment average value[2] (pCi/g)
Gross beta	N/Av	31 ± 110 (15)
Cesium-137	0.26 ± 0.02	0.24 ± 0.28 (28)
Cobalt-60	0.003 ± 0.012	0.5 ± 2.0 (28)
Potassium-40	N/Av	12.8 ± 3.2 (27)
Radium-226	N/Av	0.79 ± 0.38 (28)
Strontium-90	0.026 ± 0.031	10.9 ± 78 (15)
Technetium-99	N/Av	0.28 ± 0.22 (5)
Thorium-232	N/Av	1.1 ± 0.6 (28)
Uranium-238[3]	0.73 ± 0.05	0.79 ± 0.38 (28)

[1]Average values for four sites, plus or minus two standard deviations (Jaquish and Bryce 1989).

[2]Average values, plus or minus two standard deviations, for number of samples shown in parentheses.

[3]Based on results reported for radium-226.

N/Av = Not available.

Table 4-3. Summary of All Reported Analytical Results (DOE-RL 1992a) for Seep Sediment Samples. (sheet 1 of 2)

Constituent*		Minimum value	Maximum value	Average value	Standard deviation
Metals (mg/kg)					
Aluminum	(28)	4,800	9,350	6,287.9	1,167.1
Antimony	(25)	1.9	22.2	9.84	4.40
Barium	(28)	45.4	111.0	67.79	16.41
Beryllium	(16)	0.20	0.63	0.309	0.112
Cadmium	(24)	0.22	2.70	0.921	0.543
Calcium	(27)	2,550	10,000	4,048.2	1,424.9
Chromium	(28)	9.1	122.0	30.76	26.68
Cobalt	(20)	5.1	11.5	7.51	1.51
Copper	(28)	11.0	31.6	19.55	5.09
Iron	(26)	11,500	171,000	22,400	28,894
Magnesium	(26)	2,870	4,890	3,732.8	532.6
Manganese	(27)	135	578	312.2	103.8
Nickel	(24)	9.1	19.7	12.33	2.72
Potassium	(27)	551	1,300	787.1	210.8
Silver	(16)	0.47	2.5	1.128	0.443
Sodium	(24)	117	311	194.1	52.7
Vanadium	(26)	23.2	82.2	38.35	13.96
Zinc	(28)	58.9	364	172.65	80.23
Radionuclides (pCi/g)					
Gross alpha	(13)	0	16	7.3	3.8
Gross beta	(15)	10	317	31.5	55.4
Antimony-124	(5)	0.0622	1.238	0.4269	0.4603
Cerium-141	(1)	--	--	0.1507	--
Cobalt-60	(28)	0.02252	4.973	0.4746	1.0369
Chromium-51	(28)	0.6844	86.09	6.2507	16.5158
Cesium-134	(28)	0.02426	0.2999	0.04934	0.04976
Cesium-137	(28)	0.0331	0.5897	0.2401	0.1415

Table 4-3. Summary of All Reported Analytical Results (DOE-RL 1992a) for Seep Sediment Samples. (sheet 2 of 2)

Constituent*		Minimum value	Maximum value	Average value	Standard deviation
Radionuclides (pCi/g) (cont)					
Europium-152	(16)	0.1004	0.7582	0.3522	0.2295
Europium-154	(3)	0.08792	0.1637	0.1148	0.0347
Europium-155	(10)	0.04961	0.3257	0.0985	0.0766
Manganese-54	(1)	--	--	0.02639	--
Potassium-40	(27)	7.927	15.6	12.81	1.54
Radium-226	(28)	0.4206	1.273	0.7862	0.1911
Strontium-90	(15)	-0.2	207	10.9	38.8
Technetium-99	(5)	0.2	0.5	0.28	0.11
Thorium-228	(28)	0.6557	1.913	1.1126	0.3439
Thorium-232	(28)	0.5844	1.708	1.0460	0.3105
Uranium-235	(3)	0.08449	0.1084	0.0999	0.0109
Zinc-65	(28)	0.05262	0.2445	0.0954	0.0429

*Number of samples analyzed is in parentheses. Analytical uncertainties restrict the number of significant figures to less than three.

Figure 4-2. Cadmium in Seepage Sediment.

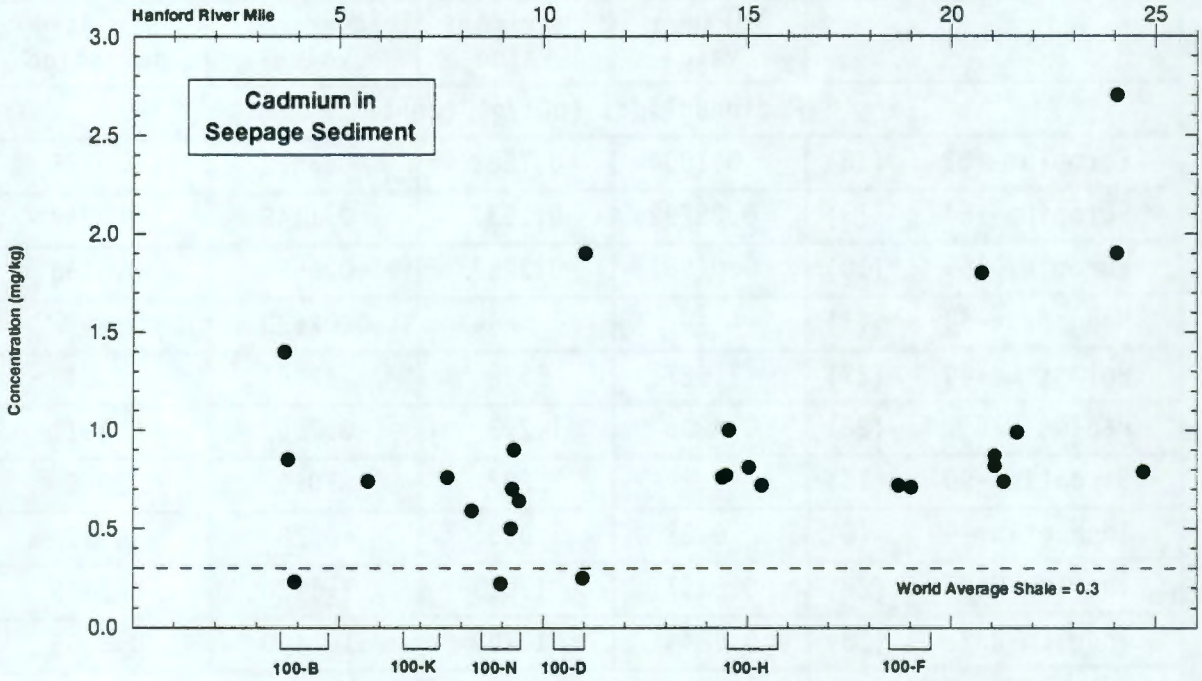


Figure 4-3. Silver in Seepage Sediment.

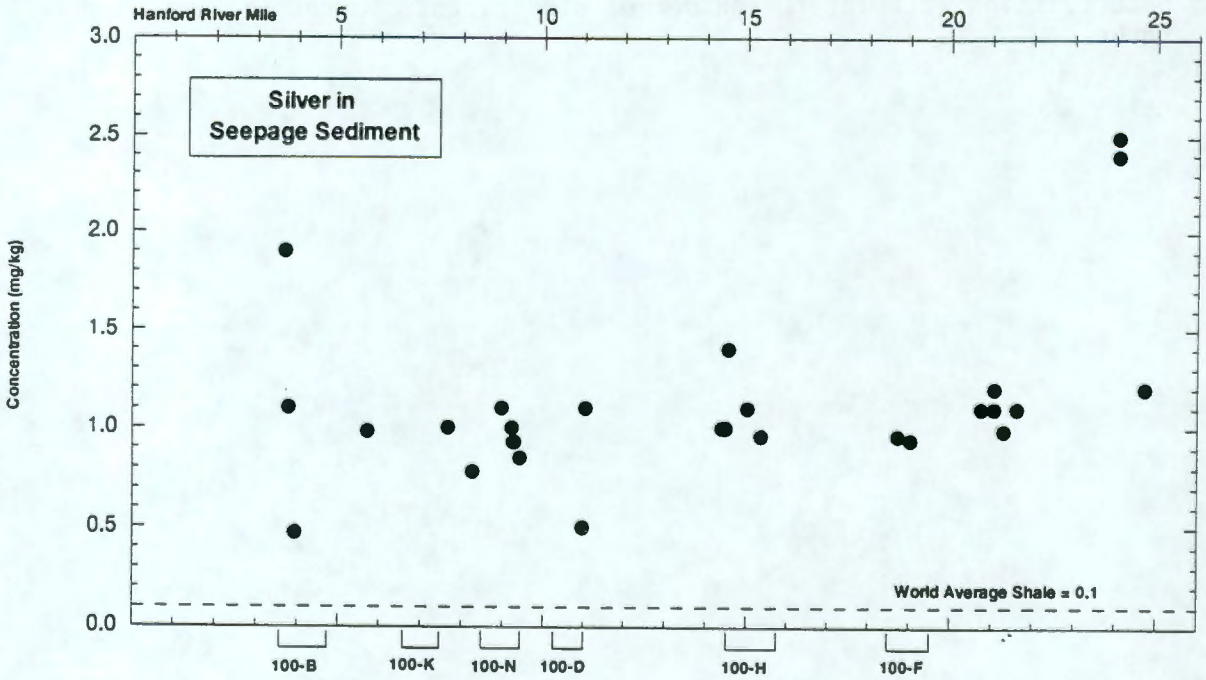


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Figure 4-4. Zinc in Seepage Sediment.

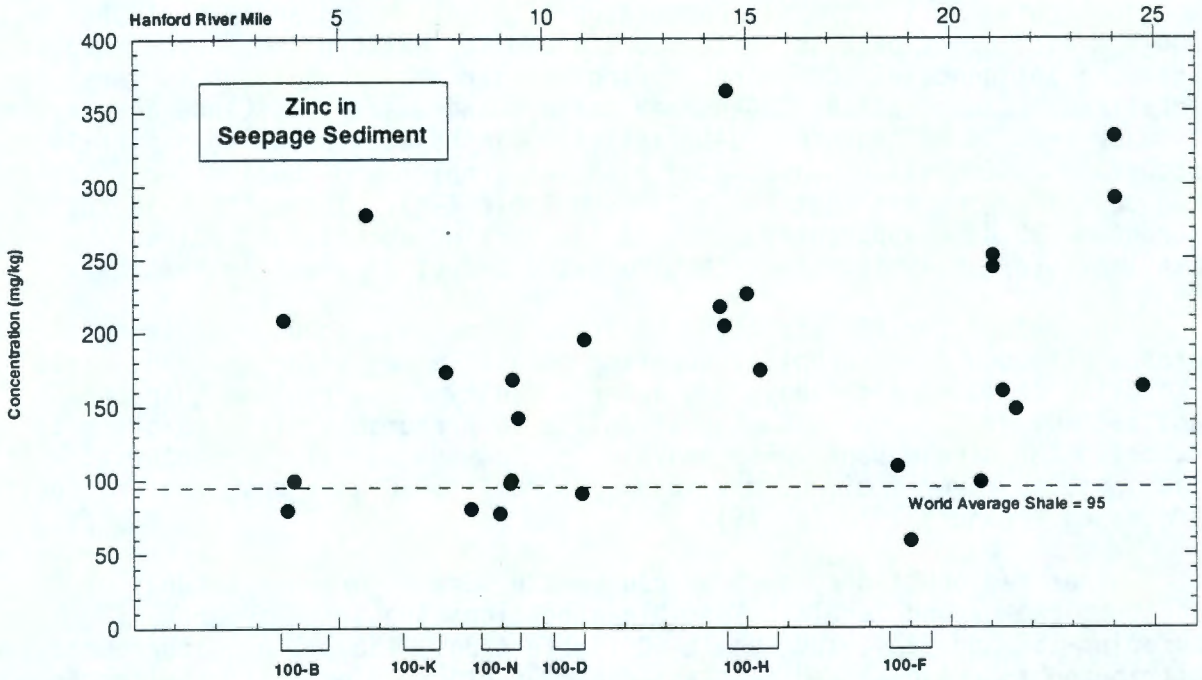
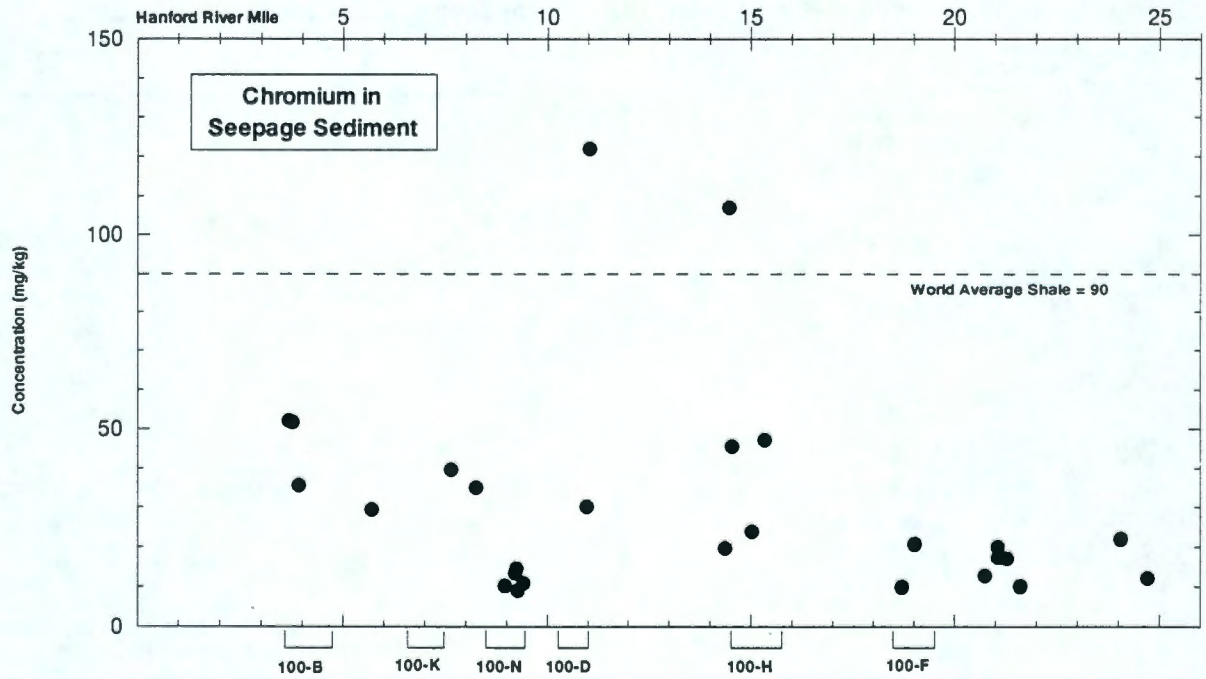


Figure 4-5. Chromium in Seepage Sediment.



4.3.2 Distribution of Radionuclides (Figures 4-6 through 4-8)

Strontium-90 is strongly correlated with well-known sources at the 100-N Area. Gross beta activity shows a similar pattern and further suggests that the influence of 100-N Area springs on streambank sediment is very localized. Except at the 100-N Area springs and a short distance downstream, a major portion of the gross beta activity can be attributed to naturally occurring radionuclides associated with the uranium and thorium decay series radionuclides and with potassium-40 (see Table 4-3). The scatter in the strontium-90 data apparently reflects the varying amounts of sediment available for analysis, since the indicated detection limit is variable.

The reason for the strontium-90 association with seepage sediment is not clear, although a preferential sorption mechanism may offer one explanation. Shoreline sediment might have a greater affinity for strontium than the aquifer solids through which the strontium-90 presumably migrated prior to reaching the stream bank. For example, periphyton (algal and bacterial coatings) on river sediment may take up strontium-90 as a result of metabolic processes (Francis 1978, p. 75).

Other radionuclides, such as radium-226, are at or near natural or upstream background levels. Possible exceptions are trace amounts of europium-152 and -154, and cobalt-60 (Table 4-3). The latter occurrences are attributed to residual sediment-associated contamination that resulted from coolant water discharge to the river during former operation of the "once-through" plutonium production reactors.

Figure 4-6. Strontium-90 in Seepage Sediment.

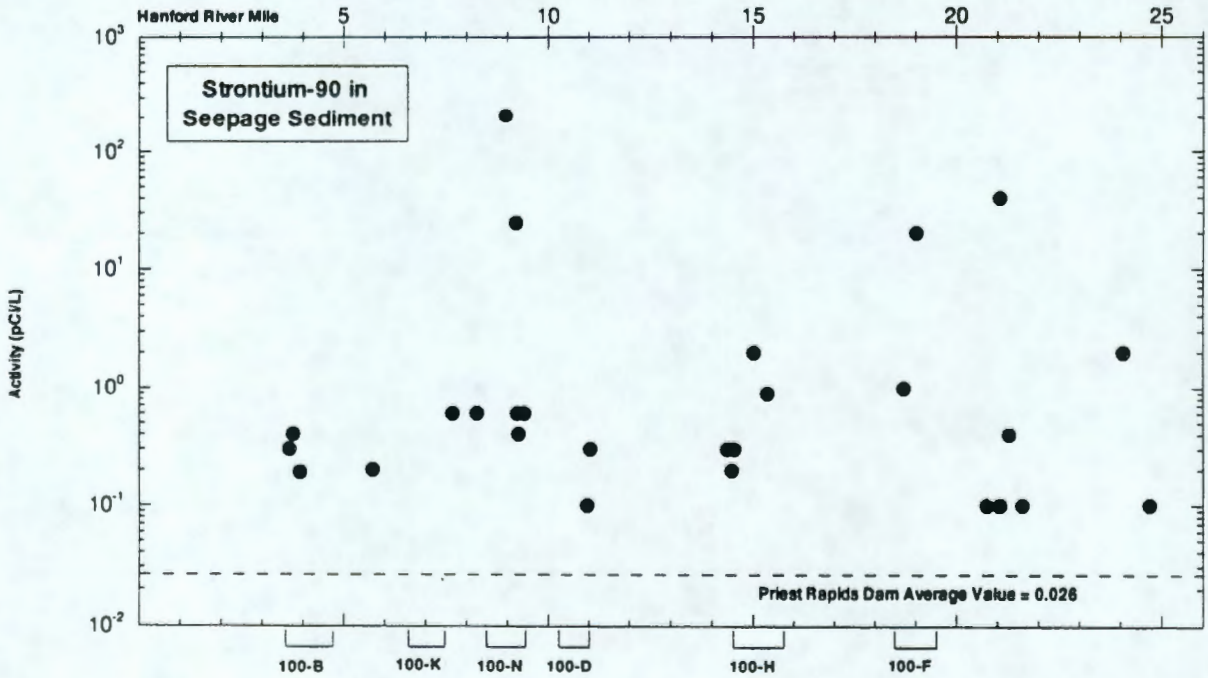


Figure 4-7. Gross Beta in Seepage Sediment.

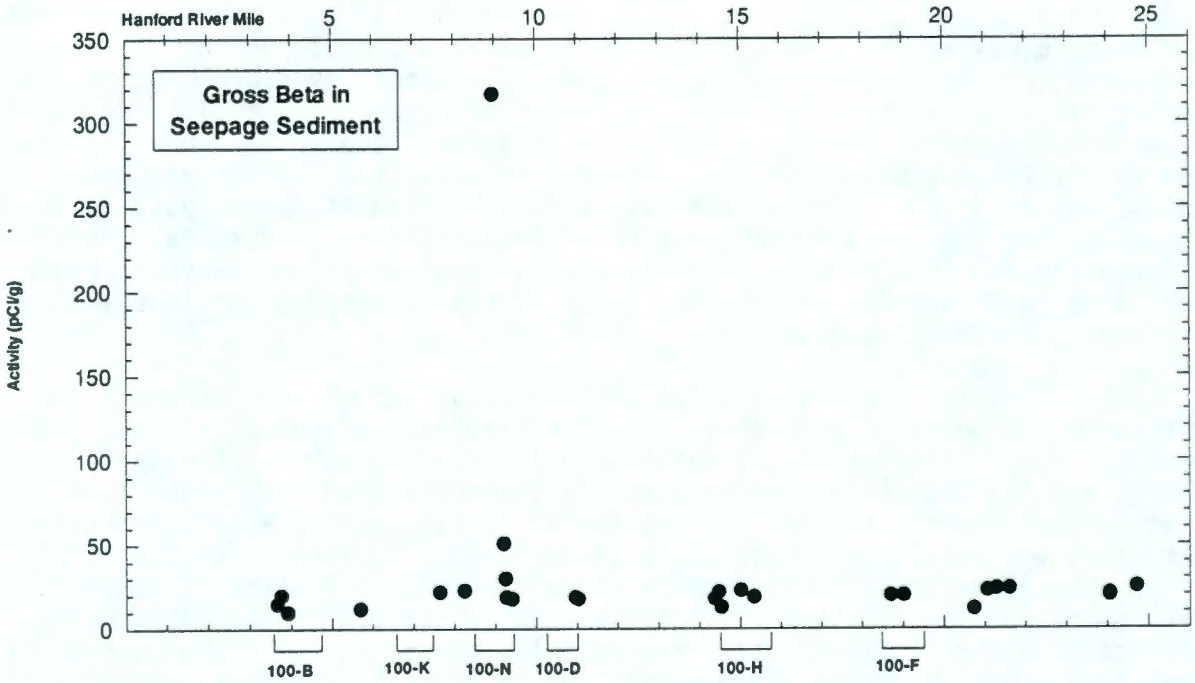
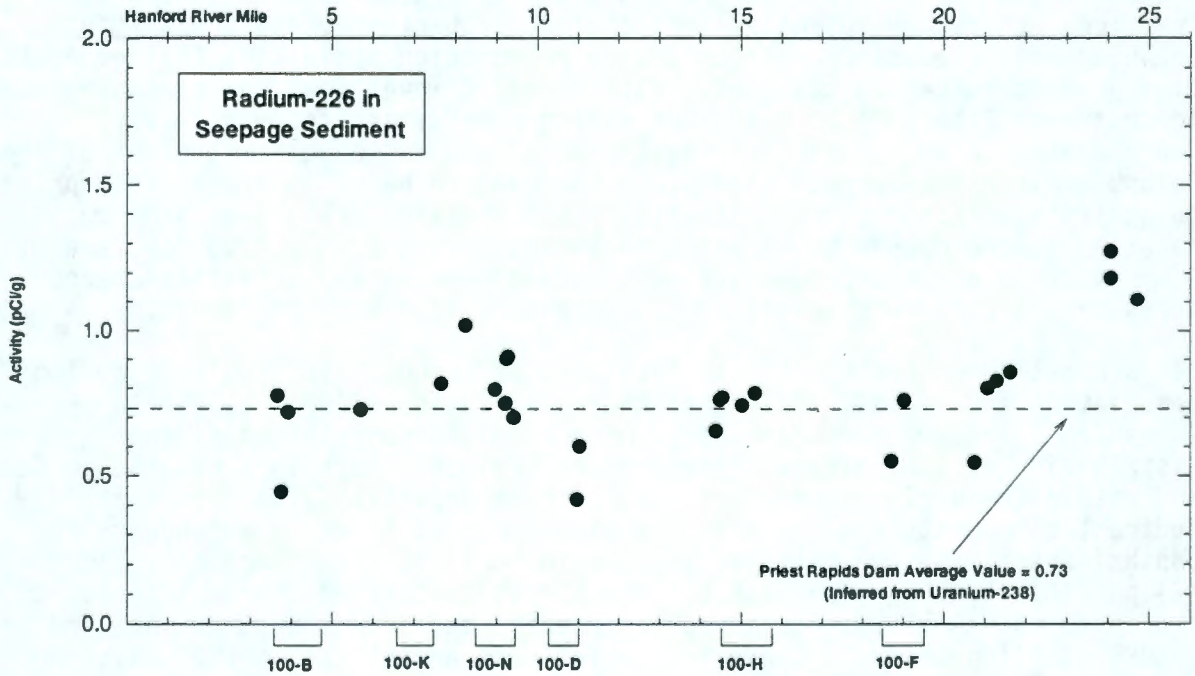


Figure 4-8. Radium-226 in Seepage Sediment.



4.4 IMPLICATIONS OF CONTAMINATION IN SEDIMENT TO REMEDIATION ACTIVITIES

Regardless of the origin for elevated metal and radionuclide concentrations in sediments along the 100 Areas, their presence needs to be considered in assessing the potential impact of remediation activities. Examples of remedial actions where sediment information is relevant include removal of reactor discharge lines, nearshore excavation of contaminated soils, and dredging. Appropriate data should be required to help evaluate the potential for remobilizing sediment-bound metals and radionuclides. This information can then be used to predict the impact of sediment-associated contaminants on aquatic ecosystems, particularly if remedial actions include disturbing sedimentary deposits.

The particle size distribution of a sediment deposit may strongly influence the measured concentrations of contamination indicators. For example, many radionuclide and metal solutes have a greater affinity for the clay-sized fraction (i.e., <4-μm particle diameter) than for larger size fractions. If any preferential sampling of certain particle size fraction occurs as the result of sample collection procedures, such as winnowing of fines, the analytical results may be biased. Figure 4-9 illustrates this dependence on size fraction for the distribution of zinc in Columbia River sediment. Other metals may be preferentially concentrated in the coarser size fractions, where high-density minerals, which typically contain metals, tend to accumulate.

Since toxic metals and radionuclides may be present in significantly higher concentrations in fine-grained sediment fractions than in coarser fractions, there are potential implications to benthic biota and salmon spawning beds (redds) downstream of any remediation activities that generate fine-grained suspended sediment. Site-specific investigations of contaminants in sediments likely to be disturbed during remediation activities are appropriate. Also, characterizing the metal and radionuclide content of the Columbia River's suspended load along the Hanford Reach is appropriate prior to activities that disturb sediments, since the fine-grained suspended material is one mechanism by which contaminants are transported downstream. If monitoring of resuspended sediment during remediation activities becomes necessary, a reference level for the suspended load will be needed.

To better understand the implications of remobilizing sediment during remediation activities, additional characterization efforts appear to warranted. These efforts include a more complete description of the distribution of contaminants in shoreline sediment, both in a geographic sense and within the various components of sediment deposits. Two important sediment components are (1) size fraction, because there is a tendency for contaminants to be concentrated in certain sediment size fractions, and (2) particle coatings, such as biological substrates and inorganic deposits or precipitates. Analyses for mercury, arsenic, and lead should be included in future sampling activities and in any followup analytical work on existing samples. These metals are associated with mining and former agricultural activities, as well as with Hanford Site operations. Site-specific toxicity bioassays may also be needed to help evaluate the significance of elevated metal concentrations in fine-textured sediment.

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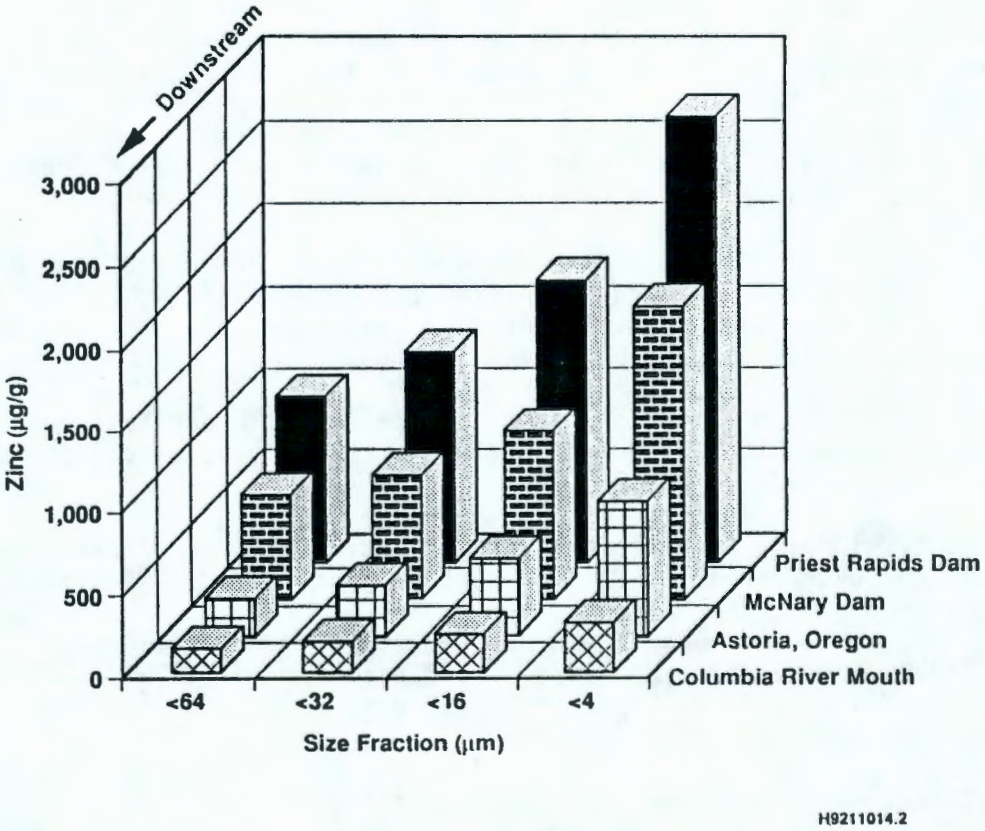
Figure 4-9. Zinc Concentrations in Various Particle Size Fractions. Based on 1976 data.



Finally, the ability to differentiate the various sources of metals observed in sediment samples would be valuable for planning remediation activities that might influence the river system. It may be possible to define a characteristic distribution pattern, or "fingerprint," for the various metals that reflect either upstream refining of metallic ores or Hanford Site sources. This information could help guide efforts to identify Hanford Site sources and map the extent of contamination derived from those sources. Additional data from within the Hanford Reach and from above Priest Rapids Dam are needed to resolve the current uncertainties regarding the origin of metals observed in shoreline sediments.

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APPENDIX A

RIVERBANK SEEPAGE LOCATIONS ALONG THE 100 AREAS SHORELINE

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APPENDIX A

RIVERBANK SEEPAGE LOCATIONS ALONG THE 100 AREAS SHORELINE

The following table (Table A-1) contains the best available information on the locations of riverbank seepage along the 100 Areas shoreline. To construct the table, seepage locations previously identified in published reports were plotted on 1:2000 scale topographic maps by Hanford Site personnel who had participated in the previous sampling efforts. A field reconnaissance of the shoreline was then conducted to verify as many locations as possible and to select locations for sampling during 1991.

The locations of Hanford River Mile (HRM) signposts that could be located in the field also were plotted on the 1:2000 topo maps. A numbering system for the riverbank seepage locations was established based on these signposts. The seepage identification number consists of its location along the shoreline relative to HRMs, described to the nearest tenth of a mile. If several seeps are located less than a tenth of a mile apart, they are given consecutive numbers as a suffix (e.g., "025-1" indicates a seep located at HRM 2.5, and it is the first seep at that location).

A similar numbering system was used in earlier published reports describing riverbank seepage (McCormack and Carlile 1984, Buske and Josephson 1988, Dirkes 1990). After locating the previously sampled seepage areas on the 1:2000 topo maps, a revised number was assigned to these seeps based on the newly defined HRM reference system. Geographic coordinates, using the North American Datum of 1983, Washington State South Zone grid as it appears on the topo maps, were determined for each seepage area that could be reliably identified on the maps. Further descriptions of the locations sampled in 1991 are presented in DOE-RL (1992)[4].

Future shoreline sampling activities will utilize global positioning system technology to provide geographic coordinates for locations.

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Table A-1. Riverbank Seepage Locations Along the 100 Areas Shoreline. (sheet 1 of 4)

Seep Identifier	Location Type	NAD-83 East (m)	NAD-83 North (m)	HRM	Source Reference	Comments
025-1	Seep			2.50	SEARCH88	Location uncertain, field check
030-1	Seep			3.00	PNL84	3-1A Location uncertain, field check
030-2	Seep			3.00	PNL84	3-1B Locaton uncertain, field check
033-1	Seep			3.30	PNL84	3-2 Location uncertain, field check
033-1	Seep			3.30	PNL88	3-2 Location uncertain, field check
033-2	Seep			3.30	PNL84	3-3 Location uncertain, field check
035-1	Seep			3.50	PNL84	3-4 Location uncertain, field check
035-2	Seep			3.50	PNL84	3-3 Location uncertain, field check
037-1	Seep	564540	145275	3.67	IT91	B06KR3, B06KR4, B06KR7
037-1	Seep	564540	145275	3.67	PNL84	3-5
038-2	Seep	564675	145275	3.76	IT91	B06KR8, B06KR9, B06KS0
038-2	Seep	564675	145275	3.76	PNL84	3-6
039-1	Seep	564940	145350	3.92	IT91	B06KS1, B06KS2, B06KS3
039-1	Seep	564940	145350	3.92	PNL84	4-0
040-1-M	Milepost	565060	145295	4.00	IT91	MP-4
041-1	Seep	565260	145400	4.10	SEARCH88	
042-1	Seep	565283	145400	4.20	PNL84	4-1
042-2	Seep	565430	145443	4.25	PNL84	4-2
047-1	Seep	566633	145817	4.70	SEARCH88	
050-1	Seep	566920	145908	5.00	PNL84	5-1
050-2	Seep	567208	146030	5.00	PNL84	5-2 Location estimated and uncertain
050-2-M	Milepost	566865	145825	5.00	IT91	MP-5
052-1	Seep	567300	146060	5.25	PNL84	5-3 Location estimated and uncertain
052-2	Seep	567339	146088	5.25	PNL84	5-4 Location estimated and uncertain
056-1	Seep	567551	146190	5.60	PNL84	5-4A
057-3	Seep	567585	146210	5.70	IT91	B06KS4, B06KS5, B06KS8
057-3	Seep	567585	146210	5.70	PNL84	5-5
059-1	Seep	567900	146525	5.90	PNL84	5-6
060-1	Seep	568138	146635	6.00	PNL84	6-1
060-1-M	Milepost			6.00	IT91	MP-6 Location uncertain, field check
062-1	Seep	568160	146644	6.20	PNL84	6-2
062-2	Seep	568339	146800	6.20	PNL84	6-3
062-3	Seep	568160	146644	6.20	SEARCH88	
063-1	Seep	568339	146800	6.30	SEARCH88	
068-1	Seep	568986	147250	6.80	PNL84	7-0 Location estimated and uncertain
069-1	Seep	569121	147500	6.90	PNL84	7-1
070-1	Seep	569260	147630	7.00	PNL84	7-1
070-1-M	Milepost	569205	147565	7.00	IT91	MP-7
071-1	Seep	569260	147630	7.10	SEARCH88	
072-1	Seep	569475	147870	7.25	PNL84	7-2
072-2	Seep	569527	147920	7.25	PNL84	7-3
077-1	Seep	569680	148070	7.65	IT91	B06KS9, B06KT0, B06KT3
077-1	Seep	569680	148070	7.65	PNL84	7-4
079-1	Seep	570287	148643	7.90	SEARCH88	
080-1	Seep	570360	148709	8.00	PNL84	8-1

Table A-1. Riverbank Seepage Locations Along the 100 Areas Shoreline. (sheet 2 of 4)

Seep Identifier	Location Type	NAD-83 East (m)	NAD-83 North (m)	HRM	Source Reference	Comments
080-1-M	Milepost				IT91	MP-8 Location uncertain, field check
082-1	Seep	570360	148709	8.25	PNL84	8-1
082-2	Seep	570415	148780	8.25	IT91	B06KT4, B06KT5, B06KT8
082-2	Seep	570415	148780	8.25	PNL84	8.25-1
083-2	Seep	570655	149037	8.30	SEARCH88	
085-1	Seep	571018	149540	8.50	PNL84	8-10
086-1	Seep	571018	149540	8.60	SEARCH88	
087-1	Seep	571073	149600	8.70	SEARCH88	
088-1	Seep	571073	149600	8.75	PNL84	8-11
088-2	Seep	571300	149920	8.75	PNL84	8-12
089-1	Seep	571300	149920	8.90	PNL84	8-13
090-1	Seep	571300	149920	8.96	IT91	B06KT9, B06KV0, B06KV2
090-1-M	Milepost			9.00	IT91	MP-9 Location uncertain, field check
091-1	Seep	571465	150150	9.10	SEARCH88	
092-2	Seep	571465	150150	9.21	IT91	B06KV3, B06KV4, B06KV7
092-3	Seep	571480	150170	9.24	IT91	B06KV8, B06KV9, B06KW2
093-1	Seep	571500	150185	9.27	IT91	B06KW3, B06KW4, B06KW7
093-1	Seep	571575	150185	9.27	PNL84	9-1
093-2	Seep	571618	150350	9.25	PNL84	9-2
093-3	Seep	571575	150185	9.30	PNL84	9-3
093-3	Seep	571575	150185	9.30	PNL84	9-4
093-7	Seep	571575	150185	9.30	SEARCH88	
094-1	Seep	571680	150465	9.41	IT91	B06KW8, B06KW9, B06KX2
095-1	Seep	571720	150155	9.50	PNL88	SPRING
098-1	Seep	571957	150835	9.75	PNL88	N-SPRING
100-1-M	Milepost	572335	151240	10.00	IT91	MP-10
108-1	Seep	573480	152375	10.80	SEARCH88	
110-1	Seep	573480	152375	10.96	IT91	B06KX3, B06KX4, B06KX5
110-1	Seep	573480	152375	11.00	PNL84	11-1
110-1	Seep	573480	152375	11.00	PNL88	11-1
110-2	Seep	571597	152470	11.03	IT91	B06KX6, B06KX7, B06KY0
110-4-M	Milepost	573465	152320	11.00	IT91	MP-11
111-1	Seep	571597	152470	11.10	SEARCH88	
144-1	Seep	577080	153770	14.38	IT91	B06KY1, B06KY2, B06L45
145-1	Seep	577255	153660	14.48	IT91	B06L46, B06L47, B06L50
145-1	Seep	577255	153660	14.48	PNL84	14-4
145-2	Seep	577330	153615	14.54	IT91	B06L51, B06L52, B06L55
145-3	Seep	577400	153580	14.50	PNL84	14-5
145-3	Seep	577400	153580	14.50	PNL88	SPRING
147-1	Seep	577625	153420	14.70	SEARCH88	
150-1	Seep	577885	153160	15.02	IT91	B06L56, B06L57, B06L60
150-1	Seep	577885	153160	15.02	PNL84	15-0
150-1	Seep	577885	153160	15.02	PNL88	15-0
150-1-M	Milepost	577963	153085	15.00	IT91	MP-15
152-1	Seep	578104	152880	15.70	SEARCH88	Location estimated and uncertain
152-2	Seep	578145	152840	15.75	SEARCH88	Location estimated and uncertain

Table A-1. Riverbank Seepage Locations Along the 100 Areas Shoreline. (sheet 3 of 4)

Seep Identifier	Location Type	NAD-83 East (m)	NAD-83 North (m)	HRM	Source Reference	Comments
152-3	Seep	578160	152790	15.25	PNL84	15-4
153-1	Seep	578235	152660	15.34	IT91	B06L61, B06L62, B06L65
153-1	Seep	578235	152660	15.34	PNL84	15-5
158-1	Seep	578372	152266	15.80	SEARCH88	Location estimated and uncertain
178-1	Seep	579837	149066	17.80	SEARCH88	
180-1	Seep	579837	149066	18.00	PNL84	18-0
180-2	Seep	580018	148936	18.00	PNL84	18-1
185-1	Seep	580672	148375	18.50	SEARCH88	
186-1	Seep	580672	148375	18.60	PNL84	18-2
187-1	Seep	580820	148275	18.71	IT91	B06L66, B06L67, B06L70
190-1	Seep	581172	147981	19.00	PNL84	18-3/19-1
190-3-M	Milepost	581172	147981	19.00	IT91	MP-19
190-4	Seep	581230	147940	19.02	IT91	B06L71, B06L72, B06L75
207-1	Seep	582621	145597	20.74	IT91	B06L76, B06L77, B06L80
211-1	Seep	582864	145130	21.06	IT91	B06L81, B06L82, B06L89
211-1	Seep	582864	145130	21.06	IT91	B06L83, B06L84, B06L90
213-1	Seep	582962	144813	21.28	IT91	B06L91, B06L92, B06L95
216-1	Seep	583132	144317	21.61	IT91	B06L96, B06L97, B06LB0
222-1	Seep	583193	144166	22.20	PNL84	22-1
222-2	Seep			22.20	PNL84	22-1A Location uncertain, field check
223-1	Seep			22.25	PNL84	22-2 Location uncertain, field check
225-1	Seep	583267	143935	22.50	PNL84	22-3
226-1	Seep	583303	143764	22.60	SEARCH88	
228-1	Seep	583364	143533	22.75	PNL84	22-4
230-1	Seep	583511	143167	23.00	PNL84	23-1
232-1	Seep	583693	142789	23.25	PNL84	23-2
235-1	Seep	583876	142448	23.50	PNL84	23-3
236-1	Seep	583986	142508	23.60	PNL84	23-4
238-1	Seep	584181	142362	23.75	PNL84	23-4
238-2	Seep	584192	142143	23.80	SEARCH88	
241-1	Seep	584986	140838	24.06	IT91	B06LB1, B06LB2, B06LJ9
241-1	Seep	584986	140838	24.06	IT91	B06LJ3, B06LJ4, B06LK0
247-1	Seep	585729	140070	24.71	IT91	B06LK1, B06LK2, B06LK5
248-1	Seep	584986	140838	24.80	SEARCH88	
250-1	Seep	584876	140924	25.00	PNL84	25-1S
250-2	Seep	584986	140838	25.00	PNL84	25-2S
250-3	Seep			25.00	PNL84	25-2SA Location uncertain, field check
250-4	Seep			25.00	PNL84	25-4S Location uncertain, field check
250-5	Seep			25.00	PNL84	25-5S Location uncertain, field check
253-1	Seep	585473	140271	25.30	PNL84	25-1
255-1	Seep	585632	140192	25.50	PNL84	25-2
255-2	Seep	585729	140070	25.50	PNL84	25-3
258-1	Seep	586339	139582	25.75	PNL84	25-4
258-1	Seep	586339	139582	25.75	PNL88	25-4
258-1	Seep	586687	139546	25.80	PNL84	25-4
258-2	Seep	586687	139546	25.75	PNL84	25-5

Table A-1. Riverbank Seepage Locations Along the 100 Areas Shoreline. (sheet 4 of 4)

Seep Identifier	Location Type	NAD-83 East (m)	NAD-83 North (m)	HRM	Source Reference	Comments
258-3	Seep	586687	139546	25.80	PNL84	25-6

Source References: PNL84 (McCormack and Carlile 1984), PNL88 (Dirkes 1990), SEARCH88 (Buske and Josephson 1988), and IT91 (DOE-RL 1992). See cover page of Appendix A for full citation.

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APPENDIX B

ANALYTICAL RESULTS FROM WELL, SEEPAGE, AND RIVER SAMPLES

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APPENDIX B

ANALYTICAL RESULTS FROM WELL, SEEPAGE, AND RIVER SAMPLES

The following data table contains the analytical results from samples taken on November 25 and 26, 1991 in the 100-H Area. Water samples were collected from well 199-H4-11, riverbank seepage location 153-1, and the Columbia River adjacent to the seep. These samples were collected in support of studies designed to better understand the interaction between Hanford Site groundwater and the Columbia River.

Table B-1. Analytical Results From Well, Seepage, and River Samples. (sheet 1 of 2)

Sample Source	Date	Time	Depth to Water (ft)	Temper. (Deg. C)	pH	Conduct. uS/cm	Chrm-6 (ppb)	Nitro (ppm)	$\overline{NO}$-3 (ppm)
H4-11	11/25/91	805	43.48	10.3	8.15	6.40	.11	7.6	30.8
H4-11	11/25/91	805	43.48	10.3	8.15	6.40	.11	8.0	32.6
SEEP	11/25/91	818		15.8	7.76	3.39	.06	4.7	18.0
SEEP	11/25/91	818		15.8	7.76	3.39	.07	5.1	19.8
RIVER	11/25/91	824		9.7	7.92	1.73			
H4-11	11/25/91	900	43.52	15.2	8.09	4.73	.10	8.6	35.2
SEEP	11/25/91	906		15.9	7.66	3.39	.08	5.5	21.6
RIVER	11/25/91	912		9.1	8.19	1.48			
H4-11	11/25/91	1000	43.55	17.6	7.97	4.84	.12	9.0	37.0
SEEP	11/25/91	1010		16.0	7.72	3.39	.07	5.6	22.0
RIVER	11/25/91	1013		9.7	8.92	2.04			
H4-11	11/25/91	1100	43.59	17.5	8.05	5.59	.13	8.3	33.9
SEEP	11/25/91	1110		16.1	7.61	3.41	.07	5.7	22.4
RIVER	11/25/91	1115		10.0	9.17	1.84			
H4-11	11/25/91	1200	43.63	17.6	7.90	4.54	.13	10.6	44.0
SEEP	11/25/91	1208		16.1	7.62	3.47	.07	6.6	26.4
RIVER	11/25/91	1213		10.1	9.21	1.93			
H4-11	11/25/91	1300	43.66	18.2	7.86	5.08	.13	9.7	40.0
SEEP	11/25/91	1310		16.1	7.60	3.61	.08	6.3	25.1
RIVER	11/25/91	1313		10.8	9.11	1.89			
H4-11	11/25/91	1403	43.70	19.3	7.93	4.88	.13	9.2	37.8
SEEP	11/25/91	1412		16.1	7.60	3.66	.09	6.0	23.8
RIVER	11/25/91	1414		11.0	9.05	1.98			
H4-11	11/25/91	1500	43.72	18.6	7.91	4.81	.12	8.7	35.6
SEEP	11/25/91	1505		16.1	7.51	3.59	.07	5.5	21.6
RIVER	11/25/91	1510		9.8	9.13	1.76			
H4-11	11/25/91	1601	43.75	18.4	7.81	4.94	.13	8.0	32.6
H4-11	11/26/91	805	43.42				.13	7.7	31.2
SEEP	11/26/91	807					.01	1.8	5.3
H4-11	11/26/91	900	43.47	18.8	7.79	4.28	.12	8.1	33.0
H4-11	11/26/91	900	43.47	18.8	7.79	4.28	.12	7.6	30.8
SEEP	11/26/91	910		13.0	7.61	2.09	.02	2.4	7.9
SEEP	11/26/91	910		13.0	7.61	2.09	.01	2.3	7.5
H4-11	11/26/91	1000	43.52	16.1	7.79	4.30	.11	7.1	28.6
SEEP	11/26/91	1009		13.3	7.58	2.30	.03	2.9	10.1
RIVER	11/26/91	1014		8.9	8.32	1.23			
H4-11	11/26/91	1100	43.56	16.5	7.84	4.56	.12	6.8	27.3
SEEP	11/26/91	1110		14.1	7.57	2.60	.04	3.7	13.6
RIVER	11/26/91	1115		9.5	8.33	1.78			
H4-11	11/26/91	1200	43.60	17.1	7.81	4.53	.12	7.0	28.2
SEEP	11/26/91	1215		14.4	7.55	2.90	.05	4.4	16.7
RIVER	11/26/91	1220		8.4	8.25	1.31			
H4-11	11/26/91	1300	43.64	16.7	7.82	4.04	.13	7.2	29.0
H4-11	11/26/91	1400	43.65	17.7	7.82	3.91	.12	7.7	31.2
H4-11	11/26/91	1500	43.64	15.0	7.83	3.78	.13	7.8	31.7

Table B-1. Analytical Results From Well, Seepage, and River Samples. (sheet 2 of 2)

Sample Source	Date	Time	Depth to Water (ft)	Temper. (Deg. C)	pH	Conduct. uS/cm	Chrm-6 (ppb)	Nitro (ppm)	NO-3 (ppm)
H4-11	11/26/91	1600	43.59	11.4	7.90	4.58	.12	7.8	31.7

Notes:

1. "Water Depth" measured in feet from top-of-casing reference point.
2. Temperature, pH, and conductivity all measured using the same instruments at the well, seep, and river. Conductivity units times 100.
3. "NO-3" (nitrate) calculated by subtracting nitrogen reagent blank of 0.6 from nitrogen and multiplying by 4.4.

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