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TRITIUM CONCENTRATIONS IN THE COLUMBIA RIVER AT RICHLAND

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ABSTRACT

The concentrations of tritium in the Columbia River, which are measurable using special analytical techniques, have been decreasing during recent years. Tritium levels are significantly greater at the Richland Pumphouse downstream of the Hanford Site than upstream at Priest Rapids Dam. Tritium is known to enter the river along the Hanford Site as direct effluent discharges, which have been virtually eliminated, and through the seepage of ground water contaminated as a result of past operations. The seepage of contaminated ground water has continued, expanding over time to encompass a larger portion of the Hanford shoreline nearer to the downstream Columbia River monitoring station.

Cross-sectional sampling of the river was conducted to determine the distribution of tritium across the river and evaluate the relationship between average tritium concentrations in the river and those measured by the downstream river sampling system. Under certain flow conditions, tritium concentrations were highest near the Benton County shoreline, decreasing with distance across the river. Likewise, average tritium concentrations observed in the water sampling system were elevated when compared with average river concentrations. Understanding the representativeness of the data is imperative in accurately characterizing the river environment and evaluating potential impacts attributable to Hanford operations.

INTRODUCTION

The Hanford Site, established in 1943, is located in southeastern Washington State, occupying an area of approximately 560 square miles. The Site lies approximately 170 miles southeast of Seattle, Washington; 125 miles southwest of Spokane, Washington; and 200 miles northeast of Portland, Oregon (Figure 1). The Columbia River, which originates in the mountains of eastern British Columbia, Canada, flows through the northern edge of the Hanford Site and forms part of the Site's eastern boundary. The flow of the Columbia River is regulated by 11 dams within the United States, seven upstream and four downstream of the Site. Priest Rapids is the nearest dam upstream of the Site, and McNary is the nearest dam

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downstream. The Hanford Reach of the Columbia River extends from Priest Rapids Dam to the head of Lake Wallula (created by McNary Dam) near Richland. This stretch of the Columbia River is the last above Bonneville Dam within the United States that remains unimpounded.

Columbia River discharges fluctuate significantly as a result of the relatively small storage capacities and operational practices of the upstream dams. Flows through the Reach are dictated primarily by operations at Priest Rapids Dam. Annual average flows at Priest Rapids Dam over the last 68 years have averaged nearly 120,000 cubic feet per second (cfs) (McGavock et al. 1987). Daily average flows range from 36,000 cfs to 450,000 cfs. Monthly mean flows typically peak from April through June and are lowest from September through October. As a result of the fluctuations in discharges, the depth of the river varies significantly over time. Fluctuations of greater than 5 vertical feet are not uncommon along the Reach.

The primary uses of the Columbia River include the production of hydroelectric power and extensive irrigation of nearby farmland. Several communities located on the Columbia River rely on the river as their source of drinking water. Water from the Columbia River along the Hanford Reach is also used as a source of drinking water by several onsite facilities and for industrial uses. In addition, the Columbia is used extensively for recreational activities such as fishing, hunting, boating, sailboarding, and swimming.

The state of Washington has designated the Columbia River along this stretch as Class A, Excellent (WDOE 1982). Water quality criteria have been established and water use guidelines provided for this class designation. As such, the water is to be suitable for essentially all uses, including raw drinking water, recreation, and wildlife habitat.

Sources of radionuclides entering the river, which have changed significantly over the years, include primarily worldwide fallout from atmospheric testing of nuclear weapons and discharges from the eight single pass cooling production reactors, both of which have been discontinued for some time. Most recently, the discharge of ground water, contaminated as a result of past operating practices, into the river along the Hanford shoreline contributes to the current concentrations of radionuclides in the river downstream of Hanford.

GROUND-WATER MONITORING AT HANFORD

The Ground-Water Protection and Monitoring Project, operated by the Pacific Northwest Laboratory (PNL) for the U.S. Department of Energy (DOE), is responsible for monitoring the ground water beneath the Hanford Site. Monitoring is performed via a network of sampling wells located throughout the Site. Monitoring data have shown several contaminants to be present in the ground water beneath waste disposal sites. The data also indicate that several of these contaminants are mobile in the ground water system and travel at various rates through the unconfined aquifer, eventually to discharge to the Columbia River.

Tritium and nitrate are the primary constituents used in determining the extent of the contaminated ground water onsite since they are present in easily measurable quantities and they move through the ground water virtually unimpeded. Figure 2 shows tritium concentrations in the unconfined aquifer resulting from 200 Area operations during the years 1980 through 1990, illustrating the migration of contaminants away from waste disposal areas towards the Columbia River. This figure also defines the extent of the contaminated ground-water discharge into the Columbia River, which has expanded over time in a southern direction. Currently, the plume encompasses a larger portion of the Hanford shoreline, nearer the routine river water sampling location at the Richland Pumphouse.

Contaminants are known to enter the river via the discharge of contaminated ground water along the Hanford Reach (Dirkes 1990; McCormack and Carlile 1984; Rokkan 1988). Special studies conducted during the past ten years have confirmed the discharge of the contaminated 200 Area ground-water plume into the river and the expansion of the plume towards the 300 Area, nearer to the Richland Pumphouse Columbia River water sampling location (Dirkes 1990; McCormack and Carlile 1984). Radionuclide concentrations found during these special studies were indicative of those observed in ground water near the seep sampling sites.

COLUMBIA RIVER MONITORING

The Surface Environmental Surveillance Project (SESP), also conducted by PNL for the DOE, is responsible for monitoring Site surface waters, including the Columbia River and the riverbank springs entering the river along the Hanford Reach. Results of environmental surveillance activities were reported in quarterly status reports from 1946 through 1957. Since 1957, results of the monitoring programs have been documented in annual Hanford Site Environmental Reports, the latest of which was issued in 1992 (Woodruff, Hanf and Lundgren 1992).

Columbia River monitoring has been performed at Hanford since 1945, shortly after the start-up of the original plutonium production reactors. Samples have been collected routinely from several locations over the years including stations upstream of the Site, along the Hanford Reach, and downstream of the Site. The primary emphasis of the Columbia River monitoring program has been the evaluation of the potential radiation dose to those persons living near to and using the river. Concern as to how representative river sampling locations were with respect to the overall river were expressed very early in the monitoring effort. In addition to the routine sample locations, cross-sectional sampling at numerous transect locations was conducted during the years of peak liquid effluent discharges to observe the channeling of reactor effluent within the river, to better understand the dispersion characteristics of the river, and accurately interpret data obtained from single point monitoring stations located on the river (Soldat 1962).

Numerous studies have investigated the mixing characteristics of the river and the dispersion of contaminants entering the river along the Hanford Reach (Backman 1962; Haney 1957; Honstead 1954; Honstead 1957; Honstead et al. 1951; Norton 1957; Sonnichsen, Jr. et al. 1970). Soldat

(1962) published the data relating to dispersion studies and measurements of radioactivity made on the Columbia River in the vicinity of the Hanford Site from 1946 through early 1961. Results of these studies indicated that contaminant plumes entering the river along the shoreline tend to remain near the shore for several miles downstream of the discharge point. Backman (1962) concluded that effluent discharged from the 300 Area was nearly completely mixed by the time it reached the Pasco water treatment pumping station, approximately 16 miles downstream. Contaminants discharged in the 300 Areas were not expected to be completely mixed 5 miles downstream at the City of Richland water intake (Richland Pumphouse). Based on the above studies, it is apparent that the contaminants entering the river via the 200 Area ground-water plume near the 300 Area are not likely to be completely mixed at the Richland Pumphouse, located approximately 6 miles downstream of the most southerly discharge point of the contaminated 200 Area ground water.

TRITIUM IN COLUMBIA RIVER WATER

Tritium concentrations in the river have been steadily decreasing over the years as a result of the termination of atmospheric testing of nuclear weapons and the shutdown of the production reactors along the river. Annual average tritium concentrations ranged from approximately 2200 pCi/L to less than 840 pCi/L during the years 1966 to 1970. From 1971 to 1980 annual averages continued to decrease, ranging from less than 1100 pCi/L to less than 265 pCi/L. "Less than" values are reported during this time period because some of the samples were below the analytical detection level. The decrease in tritium concentrations has continued during the 1980s with the 1989 annual average tritium concentration at Priest Rapids Dam, upstream of Hanford, being 63 $\pm$ 5 pCi/L.

As the concentrations of tritium continued to decrease, improvements in standard analytical methods were made, lowering the detection levels. Detection levels dropped from 1000 pCi/L during the 1960s to approximately 300 pCi/L by 1980. Even with the improvements in analytical techniques, the standard methods used for tritium analysis became inadequate as the tritium concentrations continued to decrease. Consequently, the contractual detection level for tritium in Columbia River water samples was established at 50 pCi/L in 1981. The increased sensitivity in the analytical method allowed for the identification of a statistical difference between the tritium concentrations at Priest Rapids Dam and the Richland Pumphouse, upstream and downstream of the Hanford Site. Further investigation into the distribution of tritium within the river and the representativeness of the routine sampling locations revealed that additional improvement in the sensitivity of the analytical method was desired. Subsequently, the contractual detection level was reduced to 10 pCi/L during 1991.

Figure 3 illustrates the decrease in annual average concentrations of tritium in Columbia River water at Priest Rapids Dam and the Richland Pumphouse during 1982 through 1990. This downward trend, evident both upstream and downstream of Hanford, is not consistent at both locations. The differences between tritium concentrations observed at the Richland Pumphouse and Priest Rapids Dam have been variable, apparently increasing slightly in recent years. This could be a result of lower river flows during recent years resulting in less dilution or may reflect a non-uniform distribution of tritium across the river as a result of the location of ground-water discharges relative to the sample location.

A special study was conducted during 1987 and 1988 to determine the distribution of tritium within the Columbia River at Richland, Washington. The investigation was also designed to evaluate the relationship between the average tritium concentrations in the river water at Richland and in water collected from the monitoring system located at the city of Richland drinking water intake (Richland Pumphouse). This study supplemented the routine monitoring program and fulfilled recommendations provided in applicable monitoring guidance (DOE 1991).

A number of factors played a part in the selection of tritium for the purposes of this investigation. Tritium is a major constituent in the ground water entering the river along the Hanford Reach as a result of past operations and is known to be a primary constituent in the ground-water plume nearing the routine river sampling location. There is a reported difference in the tritium concentrations observed at Priest Rapids Dam and the Richland Pumphouse, indicating a contribution due to Hanford. Analytical techniques, using special procedures, are sensitive enough to detect tritium at the levels present in the river, allowing meaningful comparisons of the data from the river and the routine sampling system. The costs associated with tritium analysis are not prohibitive. Finally, significant public and political interest and concern in the source, quantity, and impact of tritium entering the river has been expressed.

Figure 4 presents the tritium concentrations observed during each of the 1987 Richland Ferry Landing cross-sections. Apparent in these figures is the relatively large uncertainty, approximately 30%, associated with each of the results. The variability in the tritium concentrations and the uncertainties associated with the individual results make it difficult to draw any meaningful conclusions relative to the distribution of tritium across the river. Tritium concentrations were highly variable during the August 27, 1987 cross-section, with no apparent gradient present. There appears to be a slight decline in tritium concentrations as you proceed across the river from west to east during the August 31 cross-section, although the tritium concentrations level off after the first approximately 100 to 200 yards of the cross-section. The results of the September 10, 1987 traverse were similar to those observed during the August 27, 1987 sampling, highly variable tritium concentrations across the river with no readily apparent gradient.

Several stations were identified during the August 27, 1987 traverse from which water samples were collected from multiple depths. At these stations samples were collected from depths 0.2, 0.6 and 0.8 times the river depth, measured from the water surface (Figure 5). There is no consistent relationship apparent between tritium concentrations and depth. The insensitivity of the analytical method used in 1987 precludes conclusive discussion relative to the vertical distribution of tritium in the Columbia River at the Richland Pumphouse. The uncertainties associated with the sample results overlap in all cases, as is evident in the figure. In addition, the cross-section sample results indicate that the influence of the ground-water contaminants entering the river are limited to near-shore samples, within approximately 100 to 200 yards of the shoreline. Only one of the stations sampled at multiple depths falls within this region of the river. Further study of the vertical distribution of tritium within the zone of influence of the ground-water may be warranted. However, the low tritium concentrations present at any station within the river at the Richland Pumphouse minimize the benefit of further study.

The 1988 Richland Pumphouse cross-section tritium concentrations are displayed in Figure 6. Improvements in the sensitivity of the analytical method reduced the uncertainties associated with each sample result and allowed for meaningful interpretations of the data. Tritium concentrations across the river remained relatively constant during the June 23, 1988 (high flow) sampling traverse. Similarly, with the exception of the near shore sample, tritium concentrations were stable during near-average flow conditions on August 5, 1988. The data clearly indicate a concentration gradient as you proceed across the river from the west bank to the east bank under low flow (September 29, 1988) conditions. The elevated tritium concentrations appear to remain within approximately 100 yards of the shoreline, consistent with past shoreline discharge dispersion studies and the findings of the 1987 sampling activities. Tritium concentrations at stations further from the shoreline (greater than 100 yards) approach typical background (upstream) concentrations.

The average tritium concentrations in Columbia River water as measured along cross-sections near the Richland Pumphouse and with the Richland Pumphouse monitoring system during 1987 and 1988 are shown in Figure 7. The average tritium concentrations measured using the routine monitoring system were consistently higher than the average river tritium concentration measured along the cross-section. The difference in the averages was determined to be statistically significant (t-test, 0.05). It is apparent that sampling results obtained using the routine monitoring system overestimate the average radionuclide concentrations in Columbia River water at the Richland Pumphouse. Dose estimates, based on the measured contaminant concentrations at the Richland Pumphouse, are therefore conservative and overestimate the actual potential dose, due to tritium and associated shoreline discharge contaminants, received by the public as a result of living near and using the Columbia River.

CONCLUSIONS

The concentrations of tritium in Columbia River water, which are well below drinking water standards, have been decreasing during recent years. Tritium levels are significantly greater at the routine river monitoring station located at the Richland Pumphouse, downstream of the Hanford Site, than upstream at Priest Rapids Dam. In addition, the difference between concentrations observed at Priest Rapids Dam and the Richland Pumphouse has been increasing over the past few years.

Tritium is known to have entered the river along the Hanford Reach as direct effluent discharges, which have been virtually eliminated during recent years, and through the seepage of ground water contaminated as a result of past operations. The seepage of contaminated ground water has continued, expanding over time and encompassing a larger portion of the Hanford shoreline nearer to the Richland Pumphouse river monitoring location.

Sampling was conducted along cross-sections located at or near the Richland Pumphouse monitoring station to determine the distribution of tritium across the river and evaluate the relationship between average tritium concentrations in the river and in the routine river sampling system. Under certain river flow conditions, tritium concentrations were highest near the Benton County shoreline on the Hanford side of the river, decreasing with distance across the river. Tritium concentrations in samples collected from the routine monitoring system at the Richland Pumphouse were consistently elevated when compared with average river concentrations as determined through cross-sectional sampling. As expected, impacts were greatest during low river flow conditions.

Understanding the representativeness of the data is imperative in accurately characterizing the river environment and evaluating potential impacts attributable to Hanford operations. This study confirms that sampling at the Richland Pumphouse, the nearest point of water withdrawal for a public drinking water supply downstream of Hanford, provides an upper estimate of the potential dose received by the public through this pathway. The results also verify the conservative nature of impact assessments based on the river monitoring data, which tend to overestimate some radionuclide concentrations as a result of the proximity of the contaminant source with the sampling location.

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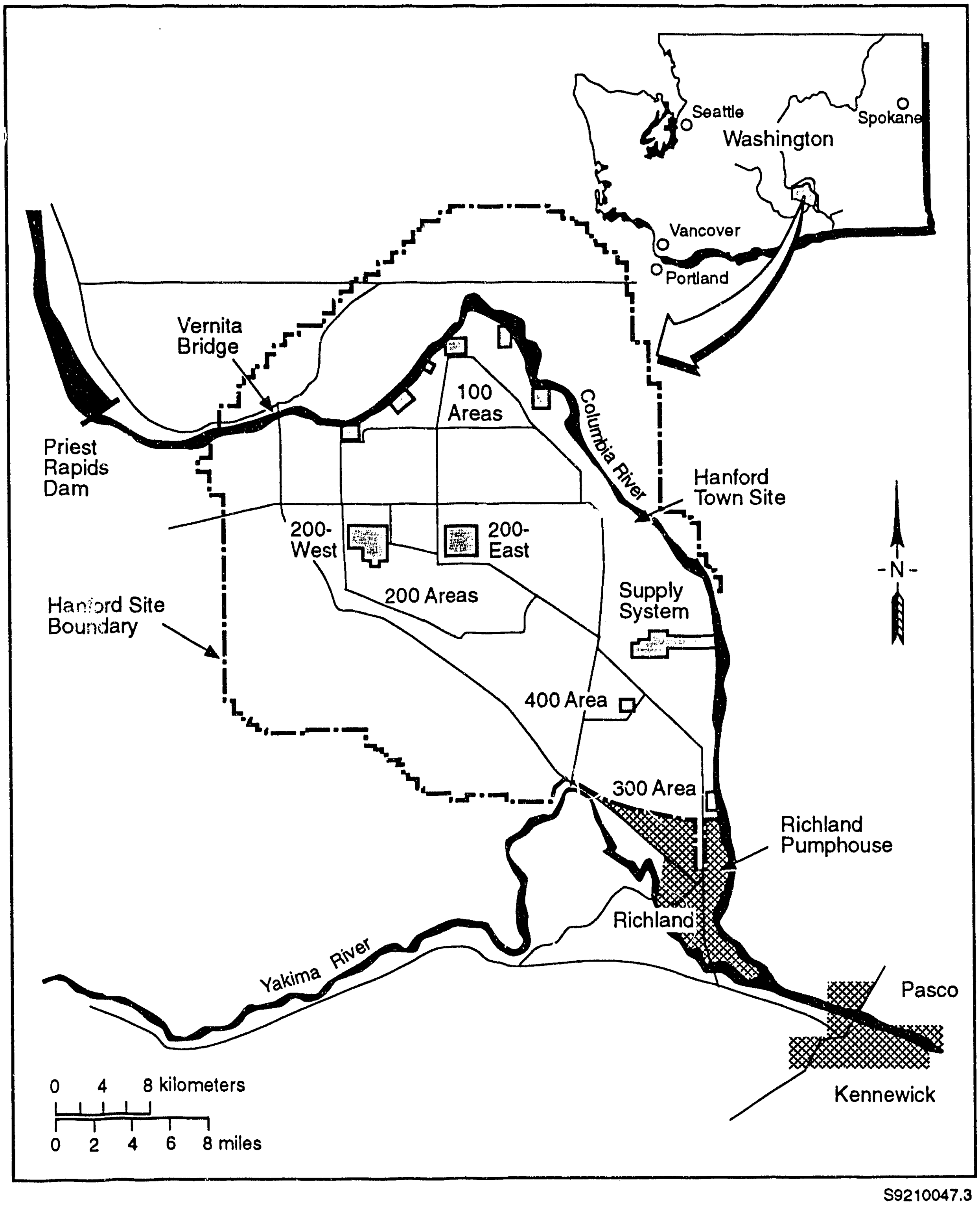

FIGURE 1. U.S. Department of Energy's Hanford Site

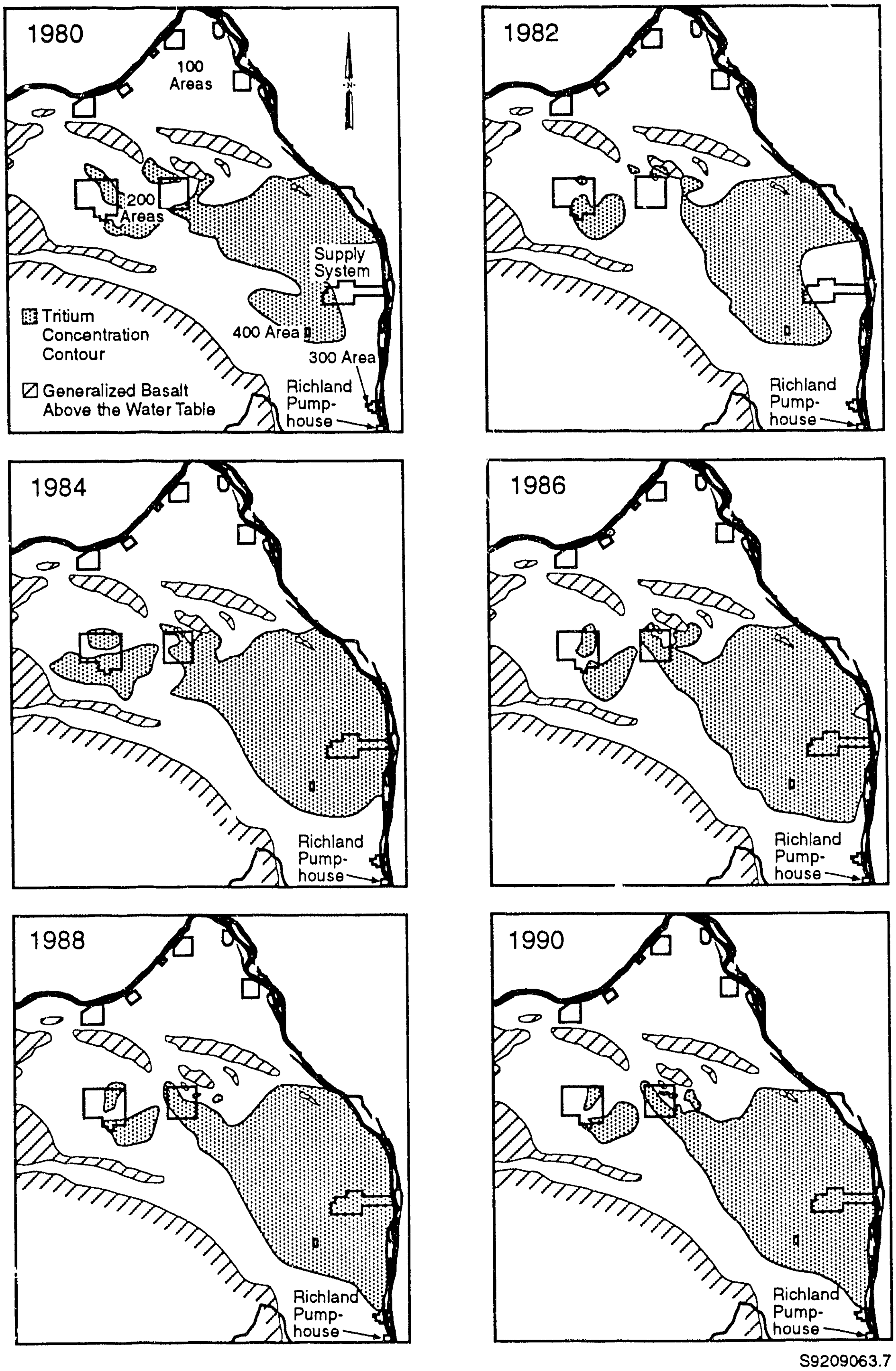

FIGURE 2. Tritium Distribution in Unconfined Ground Water Resulting From 200 Area Operations at Hanford, 1980 through 1990

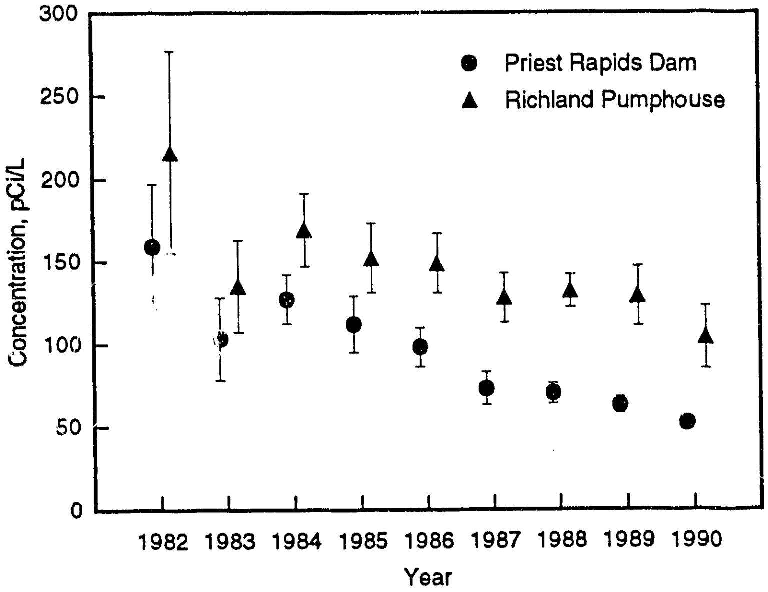

FIGURE 3. Annual Average Tritium Concentrations in Columbia River Water at Priest Rapids Dam and the Richland Pumphouse, 1982 through 1990

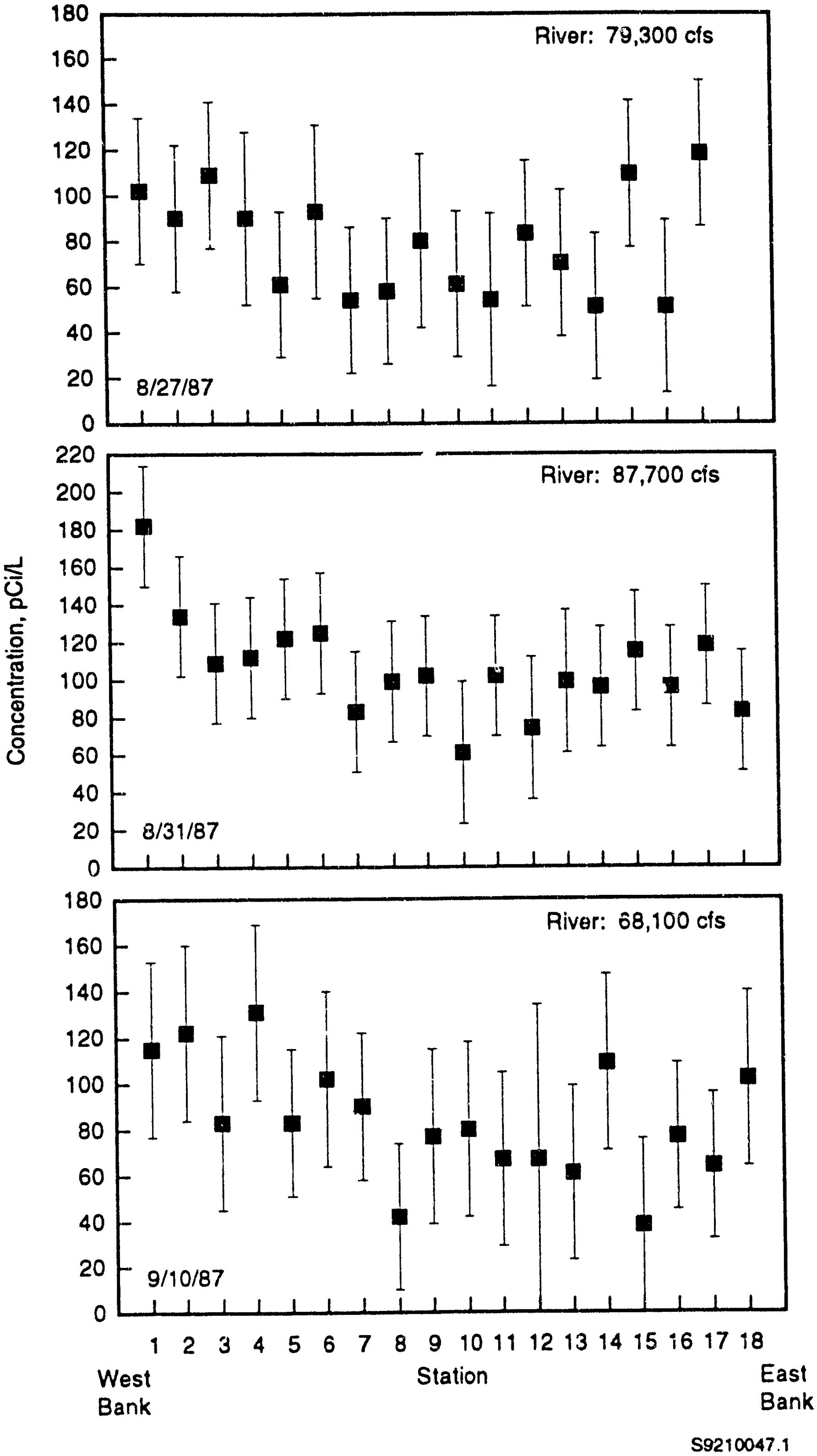

FIGURE 4. Tritium Concentrations Along Richland Ferry Landing Cross Section, 1987

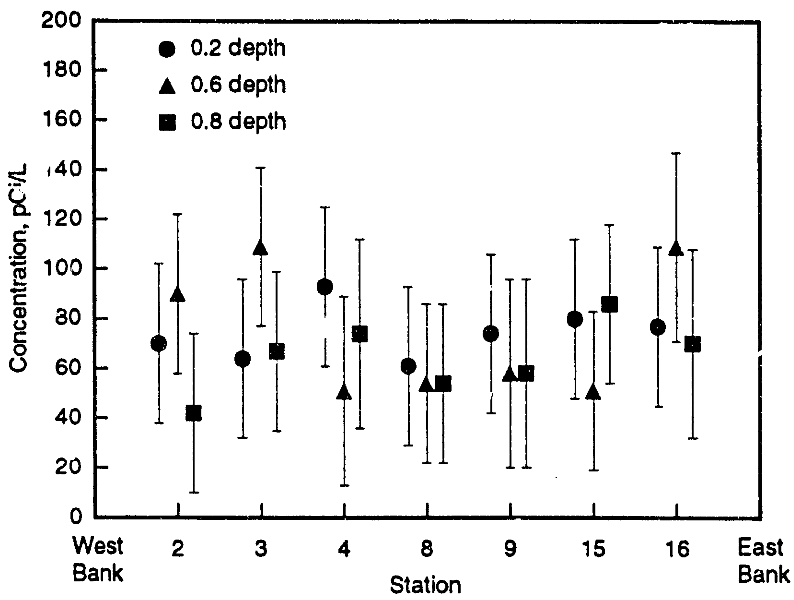

FIGURE 5. Tritium Concentrations With Depth Along the Richland Ferry Landing Cross Section, 8/27/87

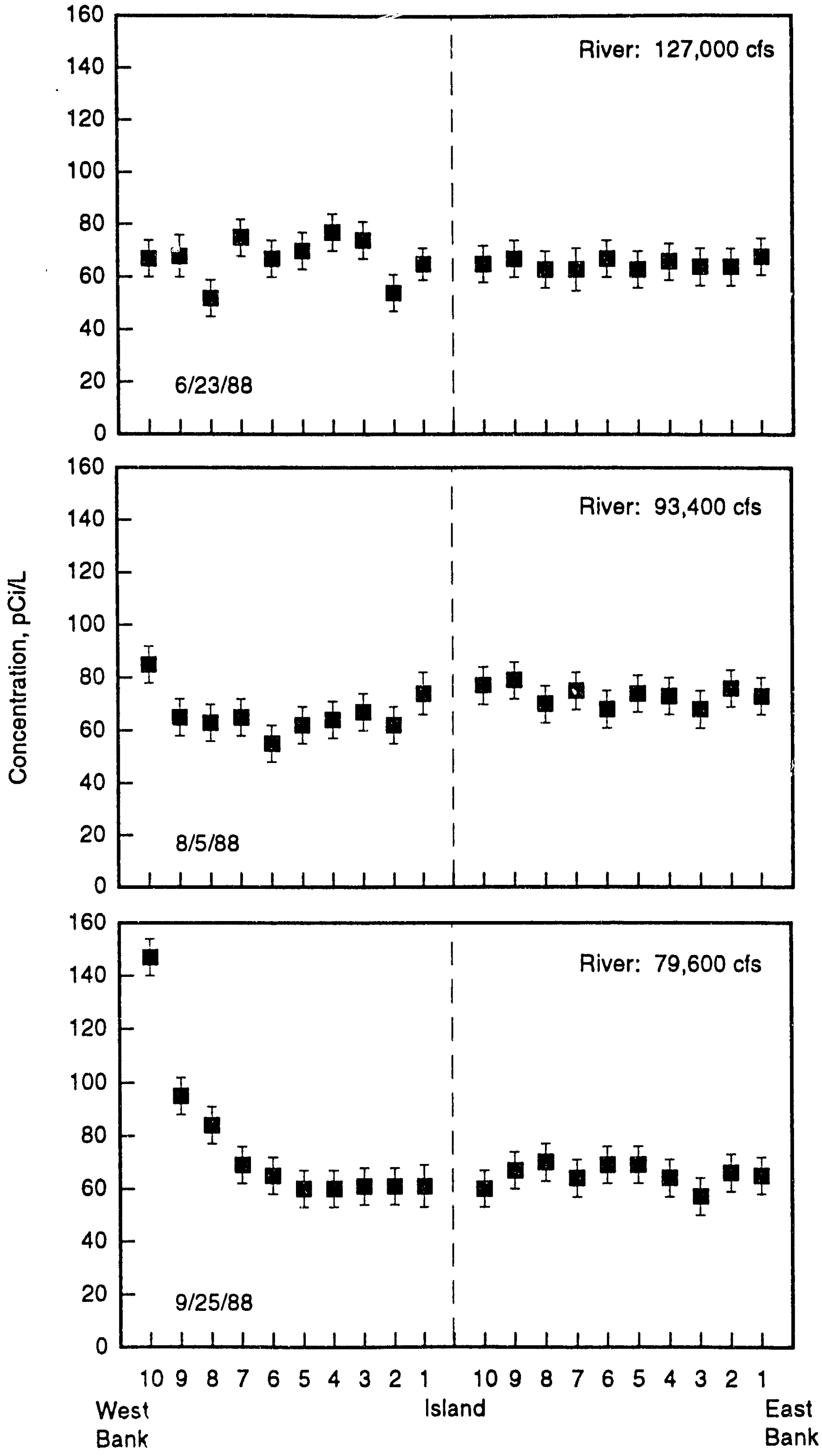

FIGURE 6. Tritium Concentrations Along Richland Pumphouse Cross Section, 1988

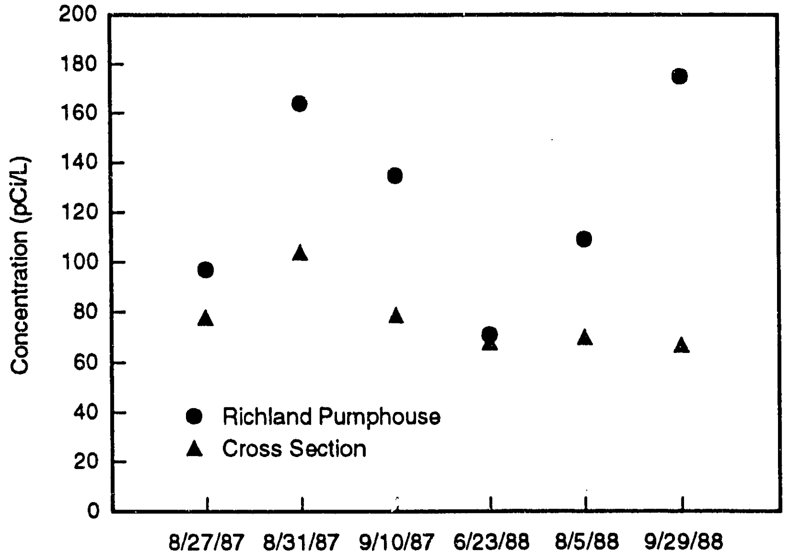

FIGURE 7. Average Cross Section Tritium Concentrations Versus Average Richland Pumphouse Tritium Concentrations, 1987 and 1988

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