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HANFORD SITE GROUND-WATER MONITORING FOR 1991

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SUMMARY

The Pacific Northwest Laboratory monitors ground-water quality across the Hanford Site for the U.S. Department of Energy (DOE) to assess the impact of Site operations on the environment. Monitoring activities were conducted to determine the distribution of radionuclides and hazardous chemicals present in ground water as a result of site operations and, whenever possible, relate the distribution of these constituents to Site operations. To comply with the Resource Conservation and Recovery Act, additional monitoring was conducted at individual waste sites by the Site Operating Contractor, Westinghouse Hanford Company, to assess the impact that specific facilities have had on ground-water quality. A total of 528 wells were sampled during 1991 by all Hanford ground-water monitoring activities.

Radiological monitoring results indicated that gross alpha, gross beta, tritium, cobalt-60, strontium-90, technetium-99, iodine-129, and cesium-137 concentrations in wells in or near operating areas were at levels above the U.S. Environmental Protection Agency (EPA) or the Washington State standard for drinking water (DWS). Concentrations of uranium in the 200-West Area were above the derived concentration guide (DCG). Concentrations of tritium in the 200 Areas and strontium-90 in the 100-N and 200-East areas were also above the DCG (2,000,000 pCi/L for tritium and 1,000 pCi/L for ^{90}Sr) specified by DOE Order 5400.5 (DOE 1990b). No radionuclides were detected at levels more than ten times any of the appropriate DCGs. Iodine-131, ruthenium-103, and other short-lived radionuclides remained below detectable levels in ground water as a direct consequence of the cessation of nuclear production operations on the Site.

Certain chemicals regulated by the EPA and the State of Washington were also present in Hanford ground water near operating areas. Nitrate concentrations exceeded the DWS at isolated locations in the 100, 200, 300 areas and in several 600 Area locations. Chromium concentrations were above the DWS at 100-D, 100-H, and 100-K areas, and the surrounding areas. Chromium concentrations above the DWS were also found in the 200-East and 200-West areas. High concentrations of carbon tetrachloride were found in wells in the

200-West Area. Trichloroethylene was found at levels exceeding the DWS at wells in and near the 100-F Area and 300 Area. Trichloroethylene concentrations dropped to just below the DWS at the Solid Waste Landfill; however, tetrachloroethylene levels remained slightly above the DWS at that location.

ACKNOWLEDGMENTS

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ABBREVIATIONS

CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CFR	Code of Federal Regulations
DCE	dichloroethylene
DCG	derived concentration guide
DOE	U.S. Department of Energy
DWS	drinking water standard
EPA	U.S. Environmental Protection Agency
ITC	International Technology Corporation
LWDF	liquid waste disposal facility
MCL	maximum contaminant level
NRDW	nonradioactive dangerous waste
PNL	Pacific Northwest Laboratory
PUREX	Plutonium-Uranium Extraction (Plant)
QA/QC	quality assurance/quality control
RCRA	Resource Conservation and Recovery Act
REDOX	Reduction/Oxidation (Plant)
SARA	Superfund Amendments and Reauthorization Act
SWL	Solid Waste Landfill
TCE	trichloroethylene
UST	United States Testing Company
WAC	Washington Administrative Code
WHC	Westinghouse Hanford Company

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TABLES

1.0 INTRODUCTION

The Pacific Northwest Laboratory (PNL)[a] monitors the distribution of radionuclides and other hazardous materials in ground water at the Hanford Site (Figure 1.1) for the U.S. Department of Energy (DOE). This work is performed through the Ground-Water Surveillance Project and is designed to meet the requirements of DOE Order 5400.1 that apply to environmental surveillance and ground-water monitoring (DOE 1988).

DOE Order 5400.1 was issued November 9, 1988, to establish direction for environmental protection programs at DOE facilities. This order requires the use of an environmental surveillance program at DOE facilities. Environmental surveillance activities are conducted to monitor the effects, if any, of DOE activities at Hanford to onsite and offsite environmental and natural resources. The Ground-Water Surveillance Project is designed to satisfy one or more of the following program objectives as identified in the DOE order:

- verify compliance with applicable environmental laws and regulations
- verify compliance with environmental commitments made in environmental impact statements, environmental assessments, safety analysis reports, or other official DOE documents
- characterize and define trends in the physical, chemical, and biological condition of the environment
- establish baselines of environmental quality
- provide a continuing assessment of pollution abatement programs
- identify and quantify new or existing environmental quality problems.

In addition to the Ground-Water Surveillance Project, which monitors contaminant distribution across the Site, two ground-water monitoring activities are being conducted at Hanford by Westinghouse Hanford Company (WHC). Ground-water samples are collected for operational monitoring in and

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(a) The Pacific Northwest Laboratory is operated for the U.S. Department of Energy by Battelle Memorial Institute.

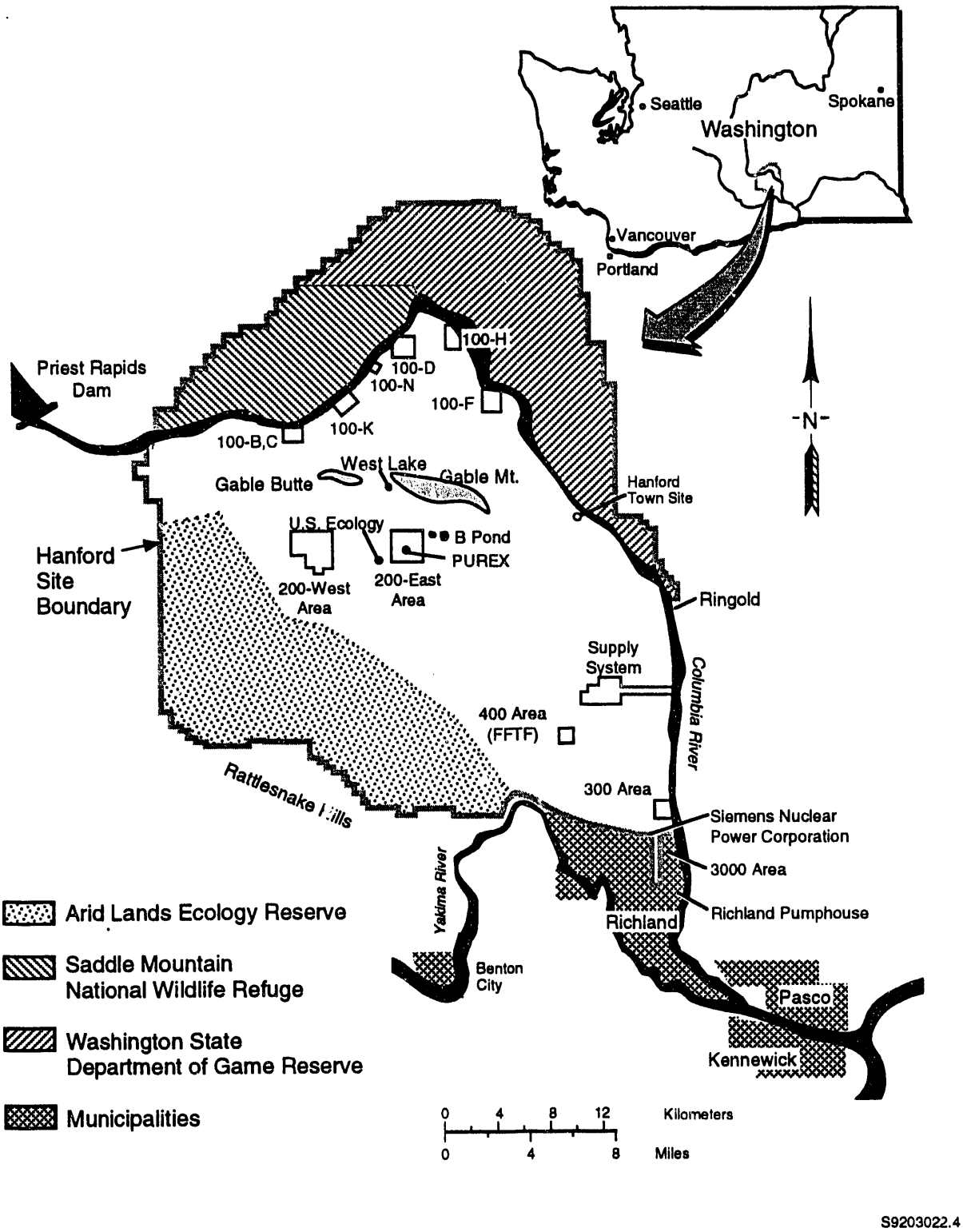

FIGURE 1.1. Hanford Site Location Map

around the 200 Areas for compliance with DOE orders and for facility-specific monitoring for compliance with the Resource Conservation and Recovery Act (RCRA) (40 CFR 265) and Washington Administrative Code (WAC 173-303 and -304). The facility-specific activities include sampling programs at facilities listed in Table 1.1. The results of some of these activities are discussed briefly in this report and are reported in more detail elsewhere (DOE 1992). The compliance monitoring results (primarily for chemicals) are valuable in determining the total impact of Site operations on ground water and, therefore, are used by the Ground-Water Surveillance Project to meet its objectives.

This annual report discusses results of ground-water monitoring at the Hanford Site during 1991. In addition to the general discussion, the following topics are discussed in detail: 1) carbon tetrachloride in the 200-West Area; 2) cyanide in and north of the 200-East and the 200-West areas; 3) hexavalent chromium contamination in the 100, 200, and 600 areas; 4) trichloroethylene in the vicinity of the Solid Waste Landfill, 100-F Area, and 300 Area; 5) nitrate across the Site; 6) tritium across the Site; and 7) other radionuclide contamination throughout the Site, including gross alpha, gross beta, cobalt-60, strontium-90, technetium-99, iodine-129, cesium-137, uranium, and plutonium. Water-level monitoring results for 1991 are discussed in a separate report (Newcomer et al. 1992). Additional discussions of the hydrology and geology of the Site, operational activities, and sampling, analysis, and distributions of average constituent concentrations during 1991 are included in PNL's annual environmental report (Woodruff and Hanf 1992). The RCRA monitoring results are documented in annual reports (e.g., DOE 1992).

TABLE 1.1. Waste Disposal Facilities with Ongoing Sampling Projects

100-D Pond
1301-N Crib
1324-N/NA Ponds
1325-N Crib
183-H Solar Evaporation Basins

216-A-10 Crib
216-A-29 Ditch
216-A-36B Crib
216-B-3 Pond
Grout Treatment Facility
Liquid Retention Facility (200 Area)

Solid Waste Landfill (SWL)
Nonradioactive Dangerous Waste (NRDW) Landfill

216-B-63 Ditch
216-S-10 Pond
216-U-12 Crib
Single-Shell Tanks
200 Area Low-Level Burial Grounds
2101-M Pond

300 Area Process Trenches

2.0 RADIOLOGICAL AND CHEMICAL GROUND-WATER MONITORING

2.1 DATA COLLECTION

The well network used for the Ground-Water Surveillance Project is a combination of several networks that have been designed for facility-specific, operational, and site-wide environmental surveillance activities. The basis for selecting wells, the sampling frequencies, and the constituents analyzed are different for each of these projects and are determined by individual project objectives. The sampling schedules for the operational and facility-specific networks (RCRA monitoring) are reviewed in the context of environmental surveillance needs. A supplemental monitoring network is developed to meet the surveillance objectives (Bisping 1992).

Analytical results discussed in this report were produced by United States Testing Company (UST) in Richland, Washington, International Technology Corporation (ITC), and PNL. Pacific Northwest Laboratory terminated the analytical services contract with UST on June 1, 1990, citing irregularities in contractual performance revealed by a PNL audit. An intensive review of data quality was initiated by PNL following the termination. A report detailing results of that evaluation is being prepared. United States Testing Company data on blind interlaboratory comparison samples showed excellent overall performance for organic, inorganic, and radiological analytes.

Negotiations for a temporary replacement contract with ITC were successfully concluded in October 1990. The ITC began accepting samples for radiochemical analysis in their Richland facility mid-February 1991. The ITC-San Jose, California, laboratory began analysis for a limited suite of hazardous chemicals in June 1991. The PNL in-house laboratories were used during 1991 to augment the limited resources available from the commercial laboratories. Analyses conducted by PNL laboratories in 1991 included trace metals by induction coupled argon plasma emission spectroscopy, common anions by ion chromatography, and volatile organics by gas chromatography. All PNL in-house analyses were conducted according to documented quality assurance/quality control (QA/QC) procedures. On October 23, 1991, long-term analytical support service contracts were awarded to ITC (Richland, Washington) and DataChem,

Inc. (Salt Lake City, Utah) for radiochemical and hazardous chemical analysis respectively. DataChem began receiving samples immediately for chemical analysis. Following startup of the DataChem contract, the in-house PNL laboratories resumed operating as QC functions, with the exception of the PNL gas chromatography laboratory, which has continued to analyze all available ground-water samples generated by the Ground-Water Surveillance Project.

2.1.1 Facility-Specific Monitoring

Well networks have been established for WHC around specific waste-disposal facilities to comply with RCRA requirements. Facility-specific projects are listed in Table 1.1. The requirements for monitoring-well design and location, constituents to be sampled, and sampling frequencies are specified in RCRA regulations (40 CFR 265) and by Washington Administration Code (WAC 173-303 and -304). Ground-water monitoring systems at each site must consist of at least one monitoring well hydraulically upgradient and at least three monitoring wells downgradient of the facility. The location, depth, and number of wells included in the network must ensure that results obtained to evaluate the migration of contaminants to the uppermost aquifer are statistically significant. The RCRA regulations require that ground water be sampled and analyzed for 1) drinking water parameters, 2) parameters that establish ground-water quality, and 3) parameters used as indicators of ground-water contamination. Samples are also analyzed for contaminants known to have been disposed of at the facility being monitored. The frequency of sampling for each parameter is also specified in the RCRA regulations, based on the permitting status of the facility (e.g., interim status, permitted status). Annual reports (DOE 1992) document monitoring networks and analytical plans for these RCRA sites.

2.1.2 Operational Monitoring

Operational monitoring near waste facilities in the 200 Areas is conducted by WHC to allow the performance of waste disposal and storage sites to be evaluated and to assess the impact of specific sites on ground water. The operational monitoring program was significantly redesigned in 1989 to reflect the diminishing importance of Site production operations. A highly focused study entitled "Liquids Effluents Study" (WHC 1990a,b) was performed in 1989

and 1990, which aimed at very intensive characterization of ground water associated with key operational areas of remaining concern. The study involved 90 wells in both the 200 Areas. Some of the wells were specially remediated for the purposes of the study, thus providing new sampling locations not previously (or at least not recently) sampled. All wells were sampled for a base set of Environmental Protection Agency (EPA) RCRA Appendix 9 chemical constituents as well as gross alpha, gross beta, and tritium. In addition, some selected radiological constituents such as technetium-99, uranium, and plutonium were included on a discretionary basis if operational information suggested contamination potential by those species. Results of that study have been published in two reports by WHC (1990a,b). The role of the operational monitoring program continued to decrease in 1991, with less than 50 wells sampled during the year.

2.1.3 Environmental Surveillance

The objective of environmental surveillance is to monitor the distribution and movement of radionuclides and other hazardous materials in ground water at the Hanford Site. The work is performed to satisfy the environmental surveillance requirements identified in DOE Order 5400.1 as it applies to ground water. The selection of wells, constituents for which samples are collected and analyzed, and sampling frequency are based on knowledge of waste disposal practices and inventories, regulatory requirements, contaminant mobility, and the site hydrogeology.

2.1.3.1 Radiological Monitoring

The radiological monitoring network was developed to monitor the extent of contamination, identify new instances of contaminant release to the ground water, and sample for selected radionuclides that may contribute to radiation dose. Wells and constituents near operational and facility-specific networks were selected to complement monitoring under these programs. For example, some wells in the 200 Areas monitored by WHC to evaluate facility operation are sampled for additional constituents to meet the objectives of the Ground-Water Surveillance Project.

Tritium, gross alpha, gross beta, gamma scans, and beta counting for radiochemical separates (i.e., strontium-90 and technetium-99) are the primary radiological analyses performed on ground-water samples. The maximum extent of radionuclide contamination in the ground water beneath the Hanford Site is defined using tritium because nearly all radioactive waste disposed of at Hanford contains tritium. Tritium exists as part of the water molecule and as such moves with the ground water virtually unretarded by chemical and physical interaction with dissolved constituents and aquifer materials. Tritium was also concentrated in certain large-volume wastes, such as reactor coolant in the 100 Areas and process condensates in the 200 Areas.

Gross alpha and gross beta analyses and gamma scans are used to identify potential new releases of radionuclides in a cost-effective manner at certain locations. These techniques are used to survey wells throughout the Site for a wide variety of alpha-, beta-, and gamma-emitting radionuclides. If measurable quantities of alpha, beta, or gamma radiation are found, samples may be collected and analyzed for individual radionuclides. Subsequent analyses are chosen on the basis of radionuclide inventories, radionuclide mobilities, and concern of the potential dose to humans.

Gross alpha concentrations above background may indicate the sample contains uranium or plutonium. Uranium is an alpha-emitting radionuclide that is mobile in ground water and is commonly the radionuclide responsible for elevated gross alpha concentrations at the Hanford Site. Uranium is also a potential concern in terms of its dose to humans. Plutonium is another alpha emitter that may contribute to gross alpha activity. Past monitoring for plutonium suggests that it is immobile in ground water and hence it has in past years been monitored in only a few wells near facilities suspected of receiving plutonium. These wells are all located within the 200 Areas. A major expansion of the plutonium monitoring effort in 1990 and 1991 confirmed this assessment.

Elevated gross beta concentrations are more difficult to associate with individual radionuclides because of the relatively large number of beta-emitting radionuclides that have been discharged in Hanford liquid wastes. Of the beta-emitting radionuclides discharged on Site, strontium-90 has been a

common contributor to elevated gross beta concentrations in ground water. Strontium-90 is monitored in ground-water samples collected throughout the Hanford Site, with emphasis on the operating areas. Other relatively mobile beta emitters of potential dose concern in the ground water are technetium-99 and iodine-129. Radioactive decay products of uranium also contribute to gross beta concentrations in areas with elevated uranium.

Gamma scans provide a quantitative assay for a large number of gamma-emitting isotopes with a range of half-lives. Because these assays are performed by high-resolution counting techniques, it is possible to identify isotopes of interest with a high degree of confidence. In addition, a software library search can be used to identify unknowns. Isotopes routinely reported include cesium-137, cobalt-60, antimony-125, and numerous other short-lived fission and activation products, as well as some naturally occurring isotopes such as potassium-40.

2.1.3.2 Chemical Monitoring

A subset of both the PNL ground-water surveillance and the WHC operational radiological monitoring networks is used for environmental surveillance chemical sampling (in addition to nitrate) by PNL. Wells selected for chemical analysis are chosen primarily for their proximity to known active and inactive chemical disposal areas in the 100, 200, and 600 areas, and on the basis of the compiled waste inventories (Stenner et al. 1988). During 1991, 528 wells were sampled for selected chemical constituents (i.e., nitrate at a minimum) as part of the Hanford ground-water surveillance projects.

Nitrate is monitored in most of the wells sampled. Nitrate, which is mobile in ground water, was present in many of the waste streams disposed of to the ground and, like tritium, can be used to help define the extent of contamination in Hanford aquifers. Extensive historical records also exist for nitrate. Other chemicals and radionuclides related to Site operations that are potential ground-water contaminants are listed in Table 2.1. Ground-water samples collected from wells located in or near areas of known or suspected ground-water contamination are analyzed for appropriate hazardous constituents. In addition, geochemical indicator parameters such as pH, major

TABLE 2.1. Major Chemical and Radiological Ground-Water Contaminants and Their Link to Site Operations

Facilities Type	Area	Constituents
Reactor Operations	100	^{3}H, ^{60}Co, ^{90}Sr, Cr^{6+}, SO_4^{2-}
Irradiated Fuel Processing	200	^{3}H, ^{137}Cs, ^{90}Sr, ^{129}I, ^{99}Tc, NO_3^-, Cr^{6+}, CN^-, F^-, uranium, plutonium
Plutonium Purification	200	CCl_4, $CHCl_3$, plutonium
Uranium Recovery	200	uranium, ^{99}Tc, NO_3^-
Fuel Fabrication	300	uranium, ^{99}Tc, Cr^{6+}, NO_3^-, trichloroethylene

cations, and major anions are typically also analyzed in the same samples as an aid to interpretation and for use in constructing ion balances needed for quality control checks on analytical data.

2.1.4 Sample Collection for 1991

During 1991, the PNL environmental surveillance radiological sampling network consisted of 528 wells, including those cosampled with other projects. Wells were monitored with frequencies ranging from weekly to annually. The majority of the wells were monitored on a semiannual basis.

The unconfined aquifer ground-water surveillance network for 1991 is shown in Figure 2.1. Wells from which samples were collected from the uppermost confined aquifer are shown in Figure 2.2. Detailed maps of monitoring well locations for the 100-B, 100-D, 100-F, 100-H, 100-K, 100-N, 200-East, 200-West, 300, 400, and 1100 areas are included in Appendix A.

2.1.5 Monitoring Well Design

Most monitoring wells on the Hanford Site are 10, 15, or 20 cm (4, 6, or 8 in.) in diameter and are constructed of steel casing. Several small-diameter [5-cm (2-in.)] piezometers are sampled for radionuclides only. Monitoring wells for the unconfined aquifer are completed with well screens or perforated casing in the upper 3 to 6 m (10 to 20 ft) of the aquifer.

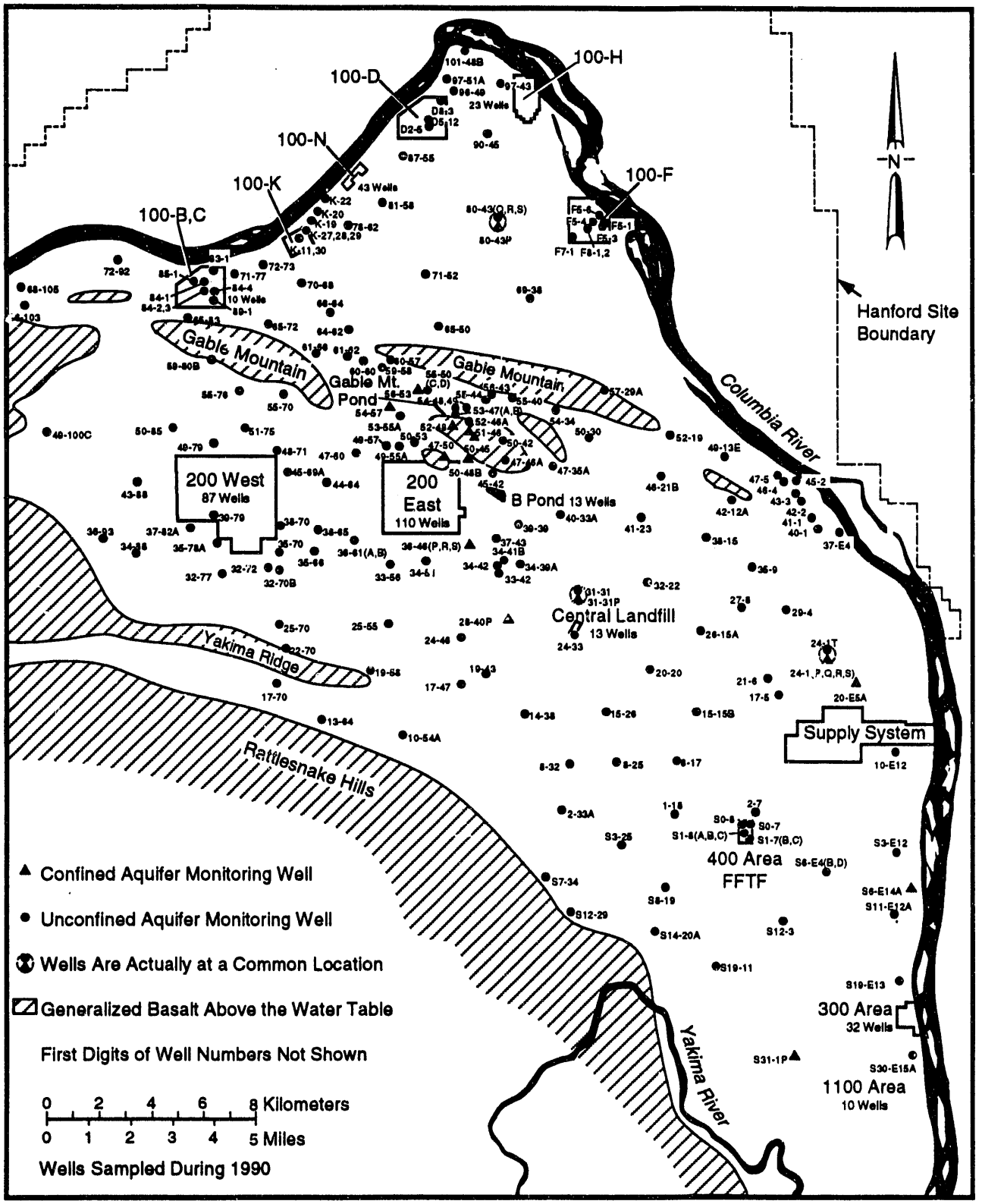

FIGURE 2.1. Location of Hanford Site Unconfined Aquifer Ground-Water Monitoring Wells

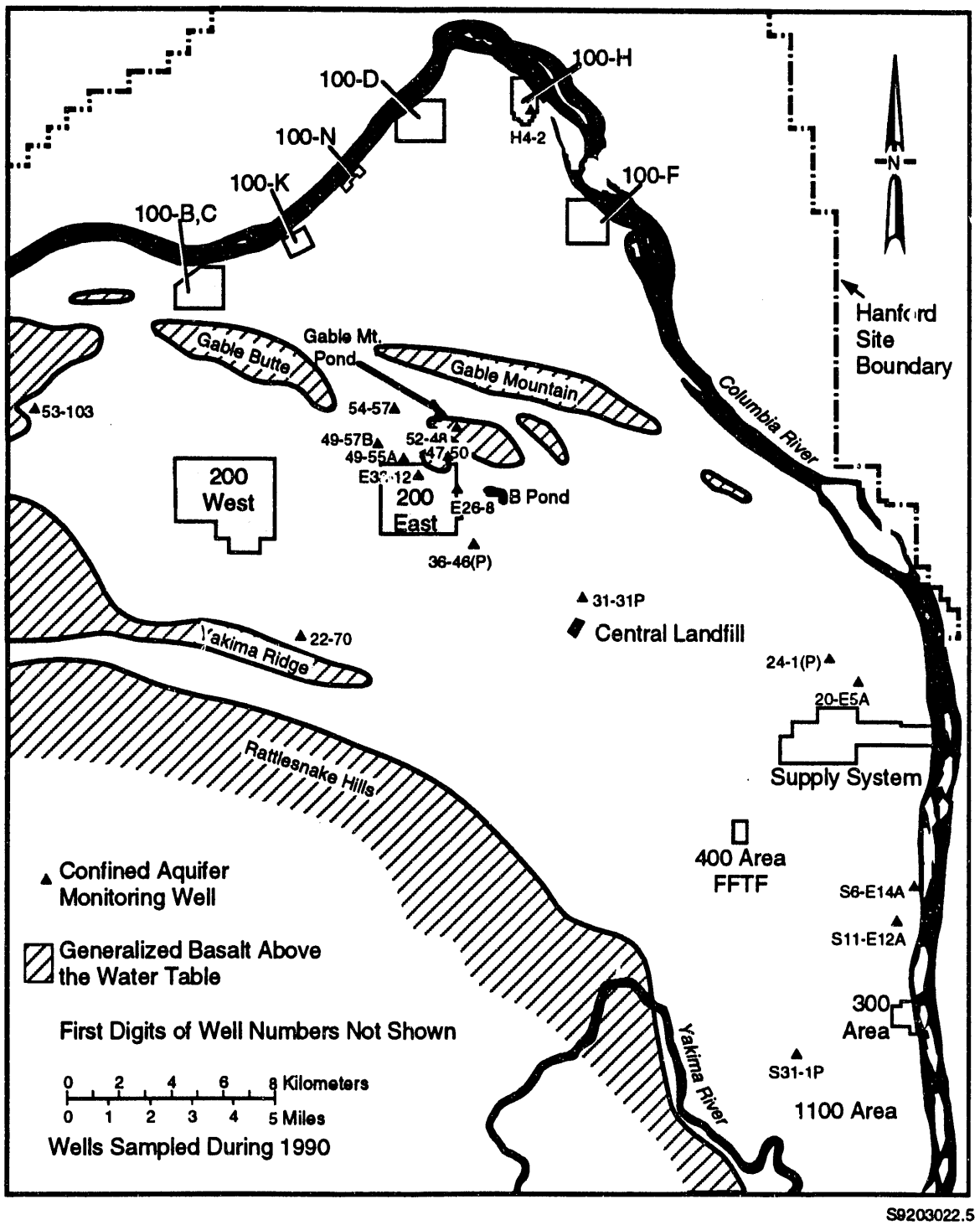

FIGURE 2.2. Location of Hanford Site Confined Aquifer Ground-Water Monitoring Wells

Completion at the water table allows samples to be collected near the top of the aquifer where maximum concentrations for some radionuclides were measured at a few locations on the Hanford Site (Eddy et al. 1978). Confined aquifer monitoring wells have screens, perforated casing, or an open hole within the monitored horizon. Only wells containing submersible pumps were chosen for chemical sampling to allow sufficient purging of wells prior to sampling.

2.1.6 Sampling Methods

Samples are collected using internally documented sampling procedures (PNL 1989) that follow formal, established guidelines (EPA 1986). Wells fitted with submersible pumps are sampled after pumping for a sufficient time (at least 20 min) to allow ground-water temperature, pH, and specific conductivity to stabilize. The purging process removes any stagnant water in the well, allowing collection of a sample that is representative of the ground water in the aquifer near the well.

Samples for volatile organic analyses were taken with zero head space and sealed immediately with a septum-sealed cap. A disposable, 0.45-micron pore-sized filter pack was connected to the Teflon sampling line for sampling filtered trace metals. The filter was purged with 500 mL (0.13 gal) of well water, then a sample was collected in the appropriate sample bottle. Trace metal samples and some radiochemical samples were preserved by acidification at the time of collection. All samples were placed on ice in ice chests immediately after sampling for transport to the analytical laboratory or sample storage facility. Prior to October 23, 1991, samples for nitrate, metals, and volatile organic analyses were promptly submitted to PNL laboratories. Samples for radionuclide analyses were archived until October 23, 1992, at which time an analytical services contract with ITC was established. Samples were then delivered to the Richland facility on a daily basis. After October 23, 1991, most chemical samples were shipped by air freight to DataChem, Inc. in Salt Lake City. Samples were shipped in cooled ice chests. Species with short holding times, such as nitrate, were measured immediately following receipt and logging in. Samples were in all cases stored at 4°C (39°F) from the time of sampling until they were analyzed. All samples were tracked using

chain-of-custody procedures from sampling through analysis and disposal. Procedures for analyzing samples have been described elsewhere (Jaquish and Bryce 1990, Appendix B).

2.2 RADIOLOGICAL AND CHEMICAL MONITORING RESULTS FOR THE UNCONFINED AQUIFER

Results of the Ground-Water Surveillance, operational, and facility-specific ground-water monitoring projects are discussed in this section. Information on contaminants can be found in past environmental monitoring reports by PNL and the operating contractor (WHC). The most recent reports are Woodruff and Hanf (1992); Evans et al. (1992); WHC (1990a,b). Evans et al. (1992) discussed in detail the following contaminants in Hanford Site ground water: 1) carbon tetrachloride in the 200-West Area; 2) cyanide in and north of the 200-East and 200-West areas; 3) hexavalent chromium in the 100 Areas and extended environs, 200-West Area, and 200-East Area; 4) chlorinated hydrocarbons near the Hanford Solid Waste Landfill (SWL), 300 Area, and 100-F Area; 5) nitrate across the Site; and 6) tritium and other radionuclides across the Site. This report provides an update to that information, including data that became available during 1991 and in a few cases early 1992. Other observations of chemical and radiological contaminants are also briefly discussed.

Results are discussed relative to the maximum contaminant level (MCL), and/or derived concentration guide (DCG) appropriate for each constituent and to background concentrations. The MCLs for radionuclides are more restrictive than the DCGs because the MCLs are based on an annual dose to the affected organ of 4 mrem/yr, while the DCGs are based on an effective whole body dose of 100 mrem/yr. The DCGs are only relevant to radionuclides. Derived concentration guides are presented in DOE Order 5400.5 (DOE 1990b).

Tritium and nitrate plume maps were prepared by modifying the 1990 maps to reflect changes indicated by data collected during 1991.

Most major ground-water contaminant plumes on the Site are now believed to be identified and well characterized; however, there are still some uncertainties. The most serious limitation comes from the nature of the well network itself, in which the wells are irregularly distributed and in general

provide insufficient spatial density for optimal contouring. Areas with insufficient well density for accurate plume definition include 1) the area north of the BY Cribs in the 200-East Area; 2) the area south of the BC Cribs near the 200-East Area; 3) the area between the 200-East and 200-West areas; 4) the eastern portion of the plumes originating in the U1/U2 Cribs in the 200-West Area; 5) essentially all of the 100 Areas. Concerning the last point, 100-B, 100-D, 100-K, and 100-F areas only have a few usable monitoring wells each. 100-H Area has a good well network close to the 183-H Solar Evaporation Basins, but little information is available for the rest of that site. Similarly, 100-N Area now has an extensive network of wells near compliance facilities, but has very limited well distribution in the area of maximum radiological contamination by strontium-90. Since most of the existing ground-water contamination on the Site appears to be associated with past practices, well-drilling activities that have targeted operating facilities have contributed only minimally to improving the situation in either the 100 Areas or other parts of the Site. With the recent onset of drilling activities associated with the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), this situation is improving, and eventually sufficient wells will exist to characterize at least some of these areas.

2.2.1 Cyanide

Cyanide has been detected in six widely spaced wells in the 200-West Area: 299-W12-1, 299-W14-2, 299-W15-8, 299-W18-7, 299-W19-25, and 299-W19-28. The highest level reported in 1991 was 70 μg/L in well 299-W14-2, essentially identical to the measurement made in 1988. Two separate areas of concentration are present. The northern lobe is centered near the 216-T-26 Crib, which received a total estimated inventory of 6000 kg of ferrocyanide in the period 1955 to 1956 (Stenner et al. 1988). The source of the other concentration maximum is not obvious.

Cyanide was detected in samples collected from wells in and directly north of the 200-East Area (Figure 2.3). The cyanide source is believed to be wastes containing ferrocyanide disposed to the BY cribs. Samples taken in January 1989 had an average cyanide concentration of 580 ± 110 μg/L in well 699-50-53 (six replicate measurements). Lesser amounts of cyanide have been

found in four other wells in or near the northern side of the 200-East Area. Unfortunately, continuing purge water disposal problems coupled with lack of comprehensive analytical support prevented sampling of well 699-50-53 for cyanide again until mid-1991 when a concentration of 760 μg/L was reported. Wells containing cyanide also contained concentrations of several radionuclides, including cobalt-60. Although cobalt-60 is normally immobile in the subsurface, it appears to be chemically complexed and mobilized by cyanide or ferrocyanide.

The EPA has proposed a drinking water standard (DWS) for cyanide of 200 μg/L pending public review. Ferrocyanide is not explicitly regulated but is currently considered to be indistinguishable from cyanide because of the nature of the specified analytical test used, which responds equally to both free and complexed forms of cyanide.

2.2.2 Fluoride

Fluoride concentrations above the DWS have been observed in a few wells in the 200-West Area between T Plant and Z Plant. The maximum concentration in 1988 was 12.8 mg/L in well 299-W15-4. None of the 200-West Area wells in the fluoride plume were sampled in 1989 or 1990. Well 299-W15-4 showed a fluoride concentration of 7.0 mg/L in 1991, somewhat lower than the previous maximum. Two areas of concentration appear to be indicated; however, this may be an artifact of the well distribution. The source of fluoride is believed to be several liquid waste disposal facilities (LWDFs) associated with Z Plant. For example, the 216-Z-9 Crib received 210,000 kg of aluminum fluoride nitrate (Stenner et al. 1988) during the course of its operation from 1955 to 1962. A similar amount of aluminum fluoride nitrate was disposed to the 216-Z-18 Crib during its operation from 1969 to 1973. However, the fact that the plume is some distance from those two cribs makes identification of the source somewhat questionable. All wells sampled outside the 200-West Area contained fluoride levels below the DWS, which for fluoride is 2.0 mg/L. The location of the fluoride plume is shown on Figure 2.3.

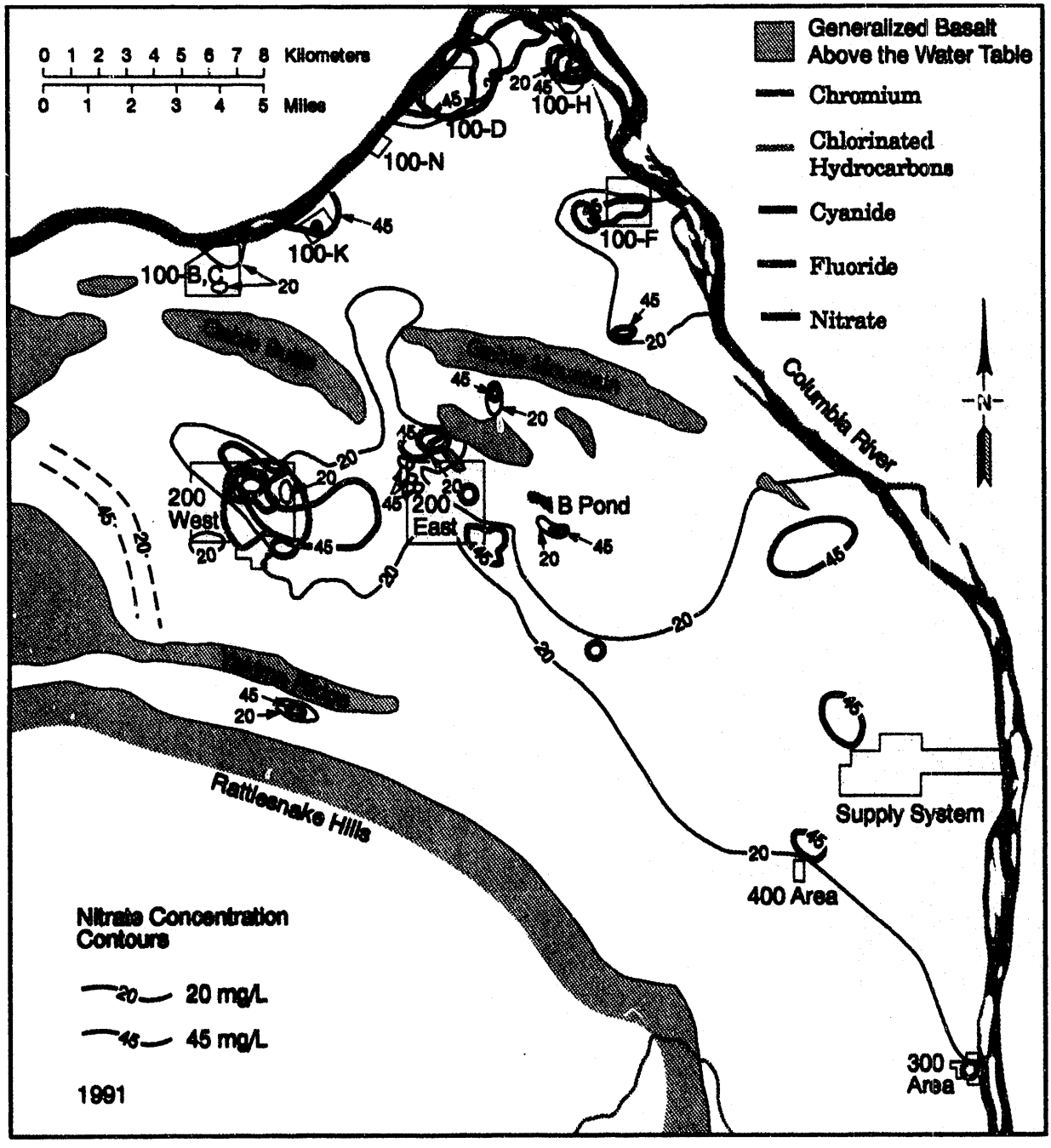

FIGURE 2.3. Hazardous Chemicals in Ground Water at Concentrations Above the Drinking Water Standard

2.2.3 Hexavalent Chromium

Chromium has been found in ground water from wells in the 100-B, 100-D, 100-H, and 100-K areas. In addition, at least one well in the 100-F Area had detectable hexavalent chromium.

The highest measured chromium concentrations on the Site have been found in well 199-D5-12. The concentration of chromium in that well dropped to a low point of 464 μg/L in March 1990. No new measurements were available in 1991 because of reductions in the operational monitoring program. A measurement by the Ground-Water Surveillance Project in early 1992 shows that the trend appears to have reversed reaching 1000 μg/L. A trend plot showing the concentration of chromium as a function of time in ground-water samples collected from well 199-D5-12 is shown in Figure 2.4. The chromium plume in the 100-D Area is centered near the reactor. The probable sources of the chromium contamination are the 116-D-1A and 116-D-1 trenches, which received large inventories of chromium during the 1950s and 1960s (Stenner et al. 1988). As there is no major water use currently in the 100-D Area, the origin of the concentration changes is not evident.

A sizable chromium ground-water plume is located in the 100-H Area. The center of the plume is located just south of the 183-H Solar Evaporation-Basins. The evaporator basins were used for volume reduction of decontamination wastes originating from the 300 Area Fuel Fabrications Facility. Leakage from at least one of the basins is believed to be the major contamination source. Other chromium sources exist around the upgradient 100-H reactor (Hall 1989). A trend plot showing the concentration of chromium in two 100-H Area ground-water wells (199-H4-3 and 199-H4-4) as a function of time since mid-1985 is shown in Figure 2.5. Well 199-H4-4 is located near the bank of the Columbia River. The large cyclic variation visible in the data from the well is associated with river stage, which can cause dilution through bank storage. The overall trend in both this well and well 199-H4-3, which is farther from the river and near the leaking basin, has been a continuous decrease that now appears to have leveled off somewhat above or (for 199-H4-4) just below the DWS depending on the degree of river influence at the time of sample collection.

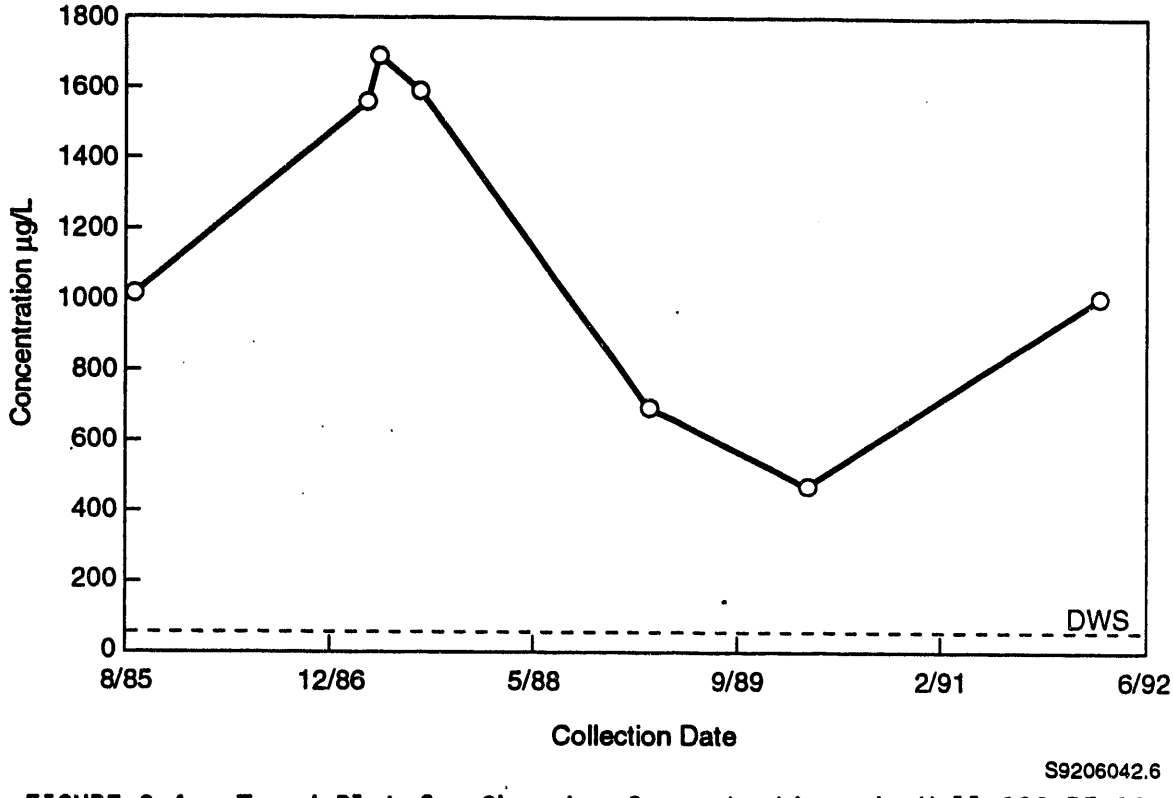

FIGURE 2.4. Trend Plot for Chromium Concentrations in Well 199-D5-12

Detectable chromium was also found in various parts of the 600 Area, particularly near the 100-D and 100-H Areas. In 1991, the highest concentration was found in well 699-97-43 (approximately 1 km west of the 100-H Area) at 160 µg/L, more than three times the DWS. Chromium concentrations in that area have remained relatively constant for the past 5 years.

Chromium contamination was found at several locations in the 200-West Area. The 1991 concentration in well 299-W10-9 (135 µg/L) was similar to earlier measurements. The maximum chromium concentration found in the 200-West Area during 1991 was 350 µg/L in well 299-W22-20, also very similar to previous measurements. Ground-water samples from at least 10 other 200-West Area wells have shown detectable chromium. The origin of the plume at the southern end of the 200-West Area is attributed to past waste disposal at the 216-S-13 Crib, which was retired in July 1972 after receiving an estimated 10,000 kg of sodium dichromate over a 20-year period (Stenner et al. 1988).

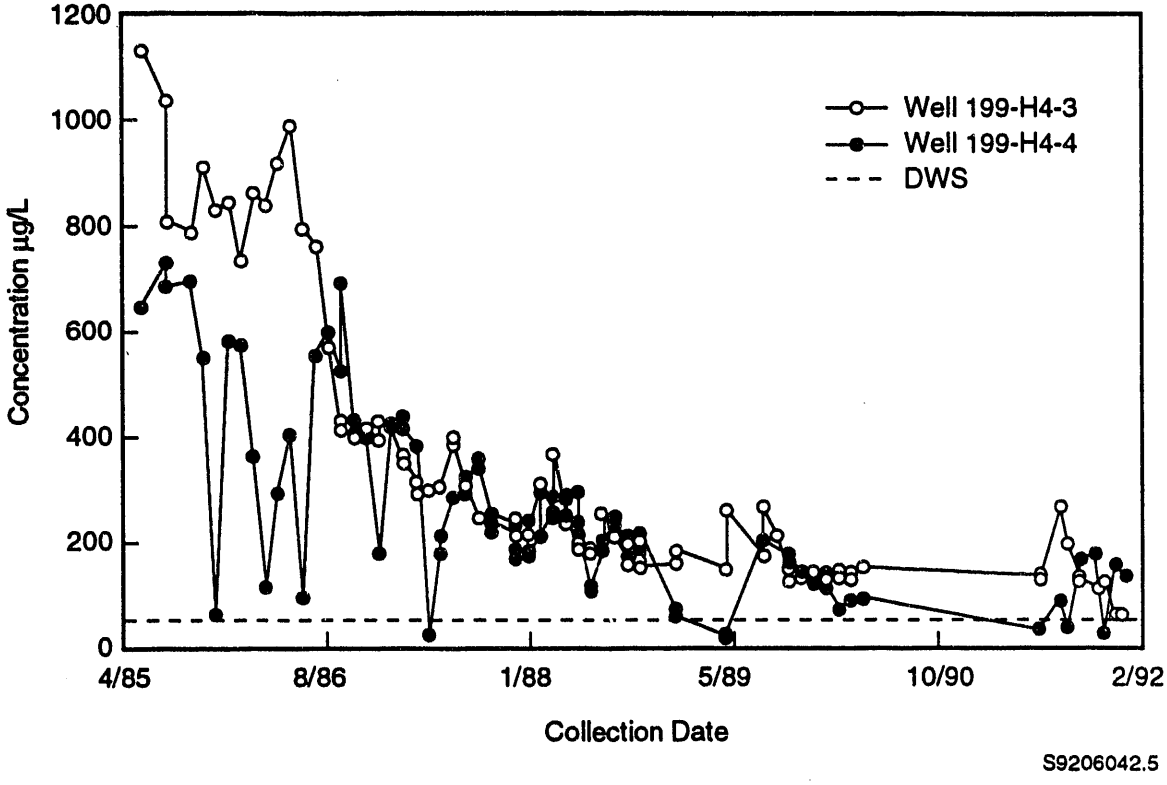

FIGURE 2.5. Trend Plot for Chromium Concentrations in Two Wells near the 183-H Solar Evaporation Basins

The origin of the chromium plume at the north end of the site is less obvious. The most likely candidate is the 216-T-28 Crib, which had been used for disposal of decontamination wastes from T Plant in the early 1960s. Chromium has commonly been associated with decontamination waste on the Site.

A few wells in the 200-East Area also showed evidence of minor chromium contamination. The highest level found was in well 299-E13-14, with a chromium concentration of 73 µg/L in August 1991, essentially identical to the last previous measurement, taken in 1988. Figure 2.3 shows the areas of chromium contamination on the Site.

2.2.4 Volatile Organic Compounds

2.2.4.1 Carbon Tetrachloride and Chloroform in the 200-West Area

Extensive carbon tetrachloride contamination has been found in the unconfined aquifer beneath much of the 200-West Area. The contamination is believed to be from waste disposal operations associated with Z Plant

(particularly the 216-Z-18 Crib, 216-Z-1A Tile Field, and 216-Z-9 Trench) before 1973. A concentration of 8,100 μg/L was found in a well near Z Plant first monitored in October 1988 (well 299-W15-16). Carbon tetrachloride concentrations in well 299-W15-16 were similar in 1989 and 1990, reaching a maximum of 8,700 μg/L in March 1990. In 1991 the maximum concentration reported for that well had dropped to 5400 μg/L; however, because of the change in analytical laboratories it is not entirely clear if the difference is significant. Previous intercomparison studies performed on samples from that well have shown significant analytical scatter apparently resulting from difficulties associated with analysis of exceptionally high-level samples that require dilution.

Figure 2.6 shows the carbon tetrachloride trends in wells at the east (699-38-70), west (699-39-79), north (299-W6-2) and south (299-W19-15) edges of the ground-water plume. The trends at the east, north, and south edges appear to indicate a relatively static, or at least a diffuse, nature to the plume at those locations, while the data from the western edge show a rapid increase since late 1985 followed by a leveling or slight decrease in 1989 and continuing through 1991. This behavior suggests there is some plume movement to the west with the leading edge of the plume now just past the well. Except for 699-39-79, wells in that area are rather sparse and represent a significant data gap. The MCL, or target concentration, of carbon tetrachloride for remediation under CERCLA and the Superfund Amendments and Reauthorization Act (SARA) of 1986 is 5 μg/L. The DWS is also 5 μg/L.

In addition to carbon tetrachloride, a chloroform plume of more limited extent was also observed in the 200-West Area near Z Plant. The origin of the chloroform is not clear; however, it is probably a degradation product of carbon tetrachloride either through radiolytic processes prior to disposal or through natural transformation processes (i.e., microbial degradation) in the subsurface. The chloroform plume is more limited in extent than the carbon tetrachloride plume and is similar, but not identical, to it in location. The highest chloroform levels on the Site in the previous year were found in wells 299-W15-9 and 299-W15-8 (1550 and 1540 μg/L respectively). Those wells are located near the 216-Z-9 Trench and actually have higher levels of chloroform

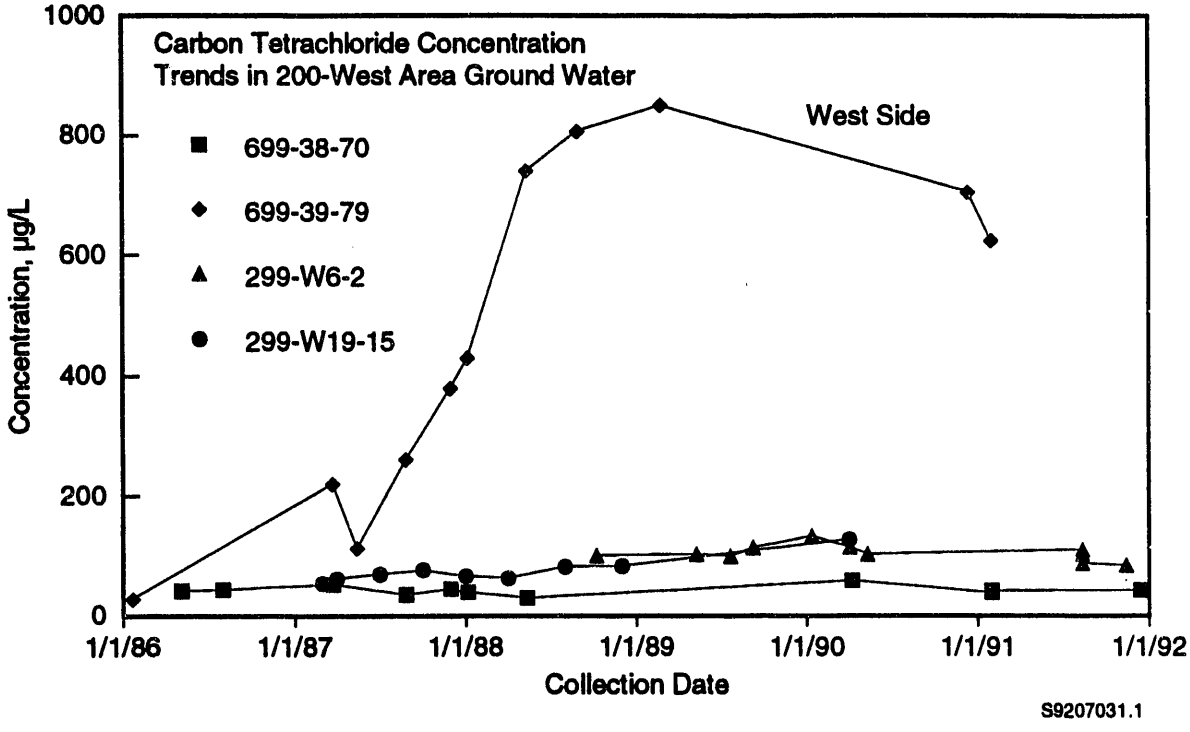

FIGURE 2.6. Trend Plot for Carbon Tetrachloride Concentrations in Four Wells near the Margins of the Z Plant Ground-Water Plume

than carbon tetrachloride. Neither well was resampled in 1991. A second high concentration of chloroform is associated with well 299-W18-4 (last sampled in 1989; 632 µg/L). The second concentration maximum appears to be distinct and is likely to be associated with one of the other LWDFs in that area, either 216-Z-1A or 216-Z-18. The DWS for chloroform is 100 µg/L (total trihalomethanes).

2.2.4.2 Trichloroethylene Contamination

Trichloroethylene (TCE) contamination in excess of the 5-µg/L DWS was found in ground water at several sites in 1991. Trichloroethylene was found in 600 Area wells on the west side of the 100-F Area. The highest level reported in 1991 was 30 µg/L in well 699-77-36. Trichloroethylene concentrations in that well appear to be constant with time based on 12 previous measurements. The concentration of TCE in well 199-F7-1 has been somewhat variable, rising to 35 µg/L early in 1990 after remaining relatively constant for several years but decreasing to 19 µg/L in 1991. The source of the TCE at that location is not known.

Several wells at the SWL contained TCE close to but slightly below the DWS. Solid Waste Landfill wells had shown TCE concentrations above the DWS in 1987 and 1988. The highest level of TCE reported for any of the monitoring wells in the vicinity of the SWL during 1991 was 5.6 μg/L in well 699-23-34. Several other wells in the same area showed TCE concentrations in the range of 3 to 4 μg/L. Trichloroethylene and several chlorinated hydrocarbon constituents are attributed to waste water from the vehicle maintenance area. The waste water contained small amounts of solvents and was discharged to three trenches on the west side of the SWL between January 1985 and January 1987. A soil gas survey of the landfill performed in 1989 (Evans et al. 1989) confirmed the presence and documented the distribution of TCE and other chlorinated hydrocarbons in the landfill. Other chlorinated hydrocarbons detected in the ground water and soil gas include 1,1,1 TCE and perchloroethylene.

Trichloroethylene and some of its degradation products [i.e., cis-dichloroethylene (1,2-DCE)] were found in wells monitoring the lower portion of the unconfined aquifer in the 300 Area near the North Process Pond. Maximum concentrations in 1990 were 12 μg/L TCE and 110 μg/L DCE in well 399-1-16B, similar to the levels observed in 1989. Similar levels were found in nearby well 399-1-16C, which monitors the upper portion of the confined aquifer. Trichloroethylene had not previously been observed in well 399-1-16A, which monitors the upper portion of the unconfined aquifer; however, a TCE concentration of 2.5 μg/L was found in well 399-1-16A in 1991. Stenner et al. (1988) show large inventories of TCE disposed to both the North and South Process Ponds. These ponds are the likely source of the contamination. The vertical distribution of the TCE and DCE is consistent with its high density, which would tend to cause it to sink to the bottom of the aquifer in its liquid phase. Dichloroethylene is commonly found as a degradation product of TCE. The relatively high (and increasing with time) ratio of DCE to TCE suggests that the source is some distance from the monitoring well cluster.

Trichloroethylene contamination has been detected at levels exceeding the DWS in two locations inside the 200-West Area. Two regions of minor TCE contamination are indicated, one near the Reduction/Oxidation (REDOX) facility

and the other west of T Plant near the T Tank Farm. Neither areas are known sources of TCE discharge. Neither plume region showed any significant change during 1991. The highest TCE level measured in 1991 in the 200-West Area was 50 μg/L in well 299-W22-20, representing a small increase over previous years.

Trichloroethylene contamination was found in several recently installed ground-water wells in the Horn Rapids Landfill located southeast of the 300 Area. The contamination was originally detected during a soil gas survey conducted during the preliminary phase of the 1100 EM-1 CERCLA investigation and was subsequently confirmed through well drilling. Concentrations range up to 110 μg/L in well 699-S31-E10A. The source of the contamination is not clearly established at this time; however, the distribution of the soil gas plume combined with the best information currently available on ground-water flow direction at that site suggests that the contaminant plume may originate from outside the boundaries of the landfill and DOE-controlled land.

2.2.5 Nitrate

Most ground-water samples collected in 1991 were analyzed for NO_3^-. Nitrate was measured at concentrations greater than the DWS (45 mg/L as NO_3^- ion) in wells in all operational areas except the 400 Area.

Although NO_3^- is associated primarily with process condensate liquid wastes, other liquids discharged to ground also contain NO_3^-. Nitrate contamination in the unconfined aquifer reflects the extensive use of nitric acid in decontamination and chemical reprocessing operations. Nitrate, like tritium, can be used to define the extent of contamination because NO_3^- is present in many waste streams and is mobile in ground water. The distribution of nitrate in Hanford Site ground water is similar, but not identical, to the tritium distribution. The distribution of NO_3^- on the Hanford Site is shown in Figure 2.3. Although most nitrate observed onsite is the result of Hanford operations, elevated nitrate concentrations in wells to the west of the Site appear to be the result of increasing agricultural activity in Cold Creek Valley. There is no known source of nitrate in that area associated with Site operations and wells located between well 699-36-93 and Hanford waste disposal facilities show no evidence of plume passage. A trend plot of nitrate data associated with well 699-36-93 located near the Yakima Ridge is shown in

Figure 2.7. Nitrate levels have been near or above the DWS in that well since 1985. Past versions of the plume map have, for reasons of conservatism, assumed a Hanford origin and combined these measurements as part of a single plume emanating from the southwest corner of the 200-West Area. That interpretation is now believed to be inconsistent with the known hydrology of that part of the Site. The nitrate plume map was first modified in 1990 to reflect this difference in interpretation. The plume map shown in Figure 2.3 continues to employ that interpretation.

The highest NO_3^- concentrations in the 200-East Area continued to be found near LWDFs that received effluent from Plutonium-Uranium Extraction (PUREX) Plant operations. Nitrate concentrations in wells near the 216-A-10 and 216-A-36B cribs continued to decrease during 1991 but remained above the DWS, even though these facilities were removed from service in 1987. There is also a large nitrate plume north of the 200-East Area. This plume is clearly associated with the BY Cribs waste disposal operation, which is evidenced by several other constituents in the same plume including cyanide, tritium, cobalt-60, and technetium-99.

The configuration of the NO_3^- plume emanating from the 200-East Area shows the influence of two periods of PUREX operation and recent changes in the operation of B Pond. The location of B Pond is shown in Figure 1.1. Increases in the volume of process cooling water discharged to B Pond may have resulted in expanding the area of lower NO_3^- concentrations in ground water to the east and south of that facility (see Figure 2.3).

Nitrate concentrations above the DWS were widespread in ground water beneath the 200-West Area. Highest concentrations are centered in three locations: 1) wells near U Plant, 2) wells in the northwestern part of the 200-West Area, one well near the 216-Z-9 Trench, and 4) wells near the 216-S-25 Crib. The highest NO_3^- concentrations across the Site continued to be found in wells east of U Plant near the 216-U-17 Crib. The presence of nitrate in wells near this crib was observed before February 1988 when the crib went into operation. The source of NO_3^- is believed to be wastes disposed of in the 216-U-1 and 216-U-2 cribs. These cribs received over

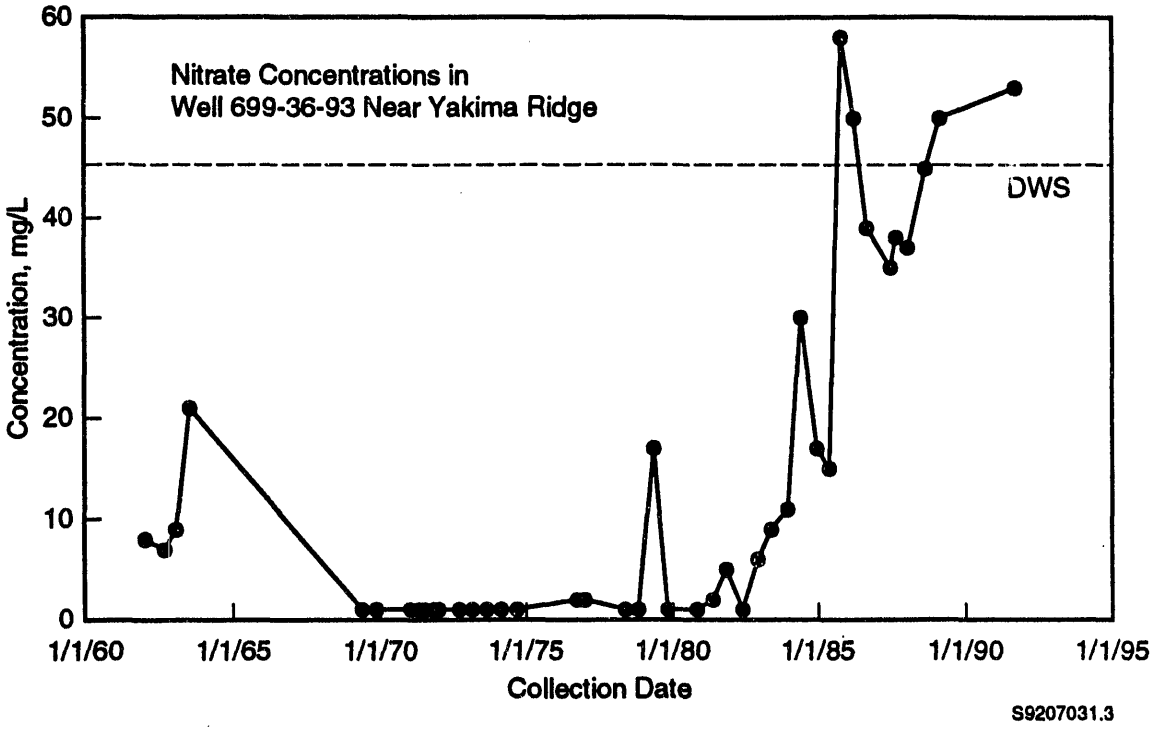

FIGURE 2.7. Trend Plot for Nitrate Concentrations in Ground-Water Wells near the Western Margin of the Hanford Site near Yakima Ridge

1 million kg of NO_3^- during their operation from 1951 to 1967 (Stenner et al. 1988). A maximum NO_3^- concentration of 1360 mg/L was measured in 1989 in a newly installed well (299-W19-26) and similar concentrations were seen in other nearby wells. No nitrate measurements are available for that well in 1990 or 1991; however, other nearby wells showed no significant change from 1989. Nitrate concentrations in wells located near the 216-U-1 and 216-U-2 cribs west of U Plant continued to decrease in 1991, with concentrations in most of the wells below the DWS. For example, the nitrate concentration in well 299-W19-18 located near U Plant has dropped below the DWS as shown in Figure 2.8.

Several wells in the northwestern part of the 200-West Area continued to contain NO_3^- at concentrations greater than the DWS. These wells are located near several inactive LWDFs that received waste from early T Plant operations. Maximum concentrations in these wells in 1991 ranged up to 791 mg/L in well 299-W15-4, a small increase from earlier years. The highest levels in the 200-West Area in 1991 or anywhere else on the Site was found in well 299-W15-8

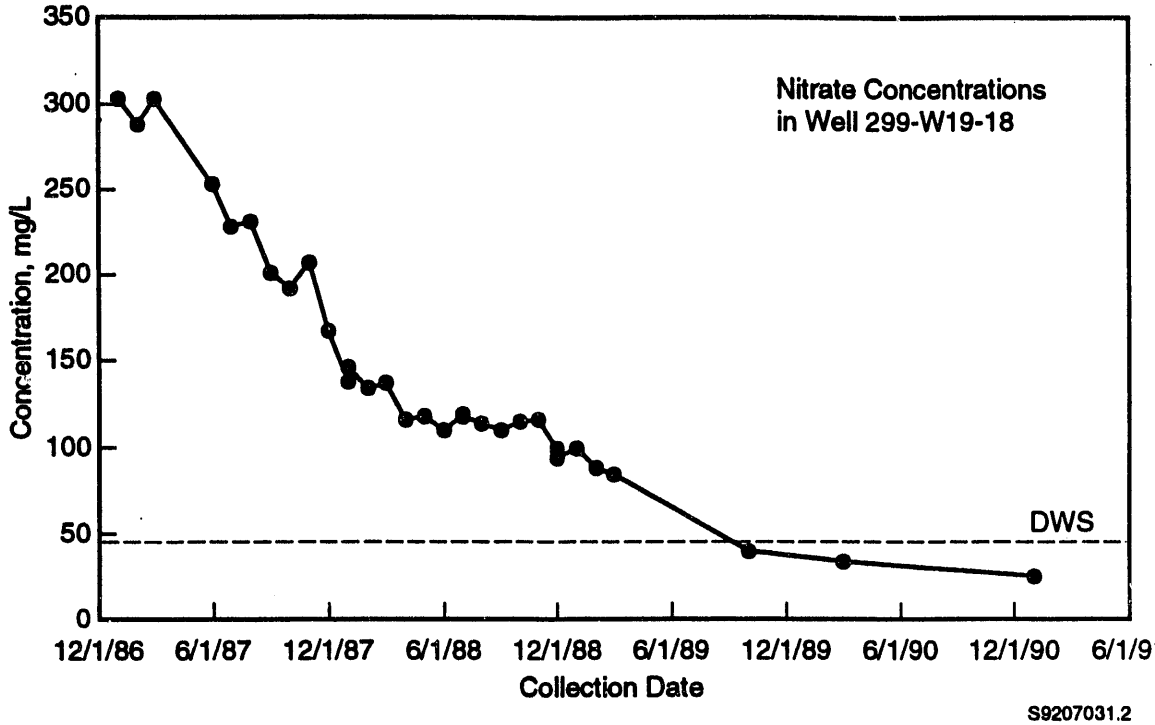

FIGURE 2.8. Trend Plot for Nitrate Concentrations in Well 299-W19-18

(1530 mg/L). Past NO_3^- levels in that well have been considerably lower (139 mg/L in 1988 and 71 mg/L in 1990); however, no measurements are available before 1988. Well 299-W15-8 is located on the south side of the 216-Z-9 Trench, which had received an estimated 500,000 kg of NO_3^- during its operational life from 1955 to 1962. The sudden increase in NO_3^- in that well may be evidence for some recent breakthrough of older crib effluents. Plutonium and americium contamination has also been recently confirmed in that well (see Section 2.2.18).

2.2.6 Tritium

Tritium is present in many waste streams discharged to the soil column and is the most mobile radionuclide on Site. As a result, tritium reflects the extent of contamination in the ground water from Site operations and is the radionuclide most frequently monitored at the Hanford Site. Figure 2.9 shows the current distribution of tritium in the unconfined aquifer resulting from over 46 years of Site operations. An average of all available tritium measurements for 1991 was used for each well. In some areas, where 1991 data

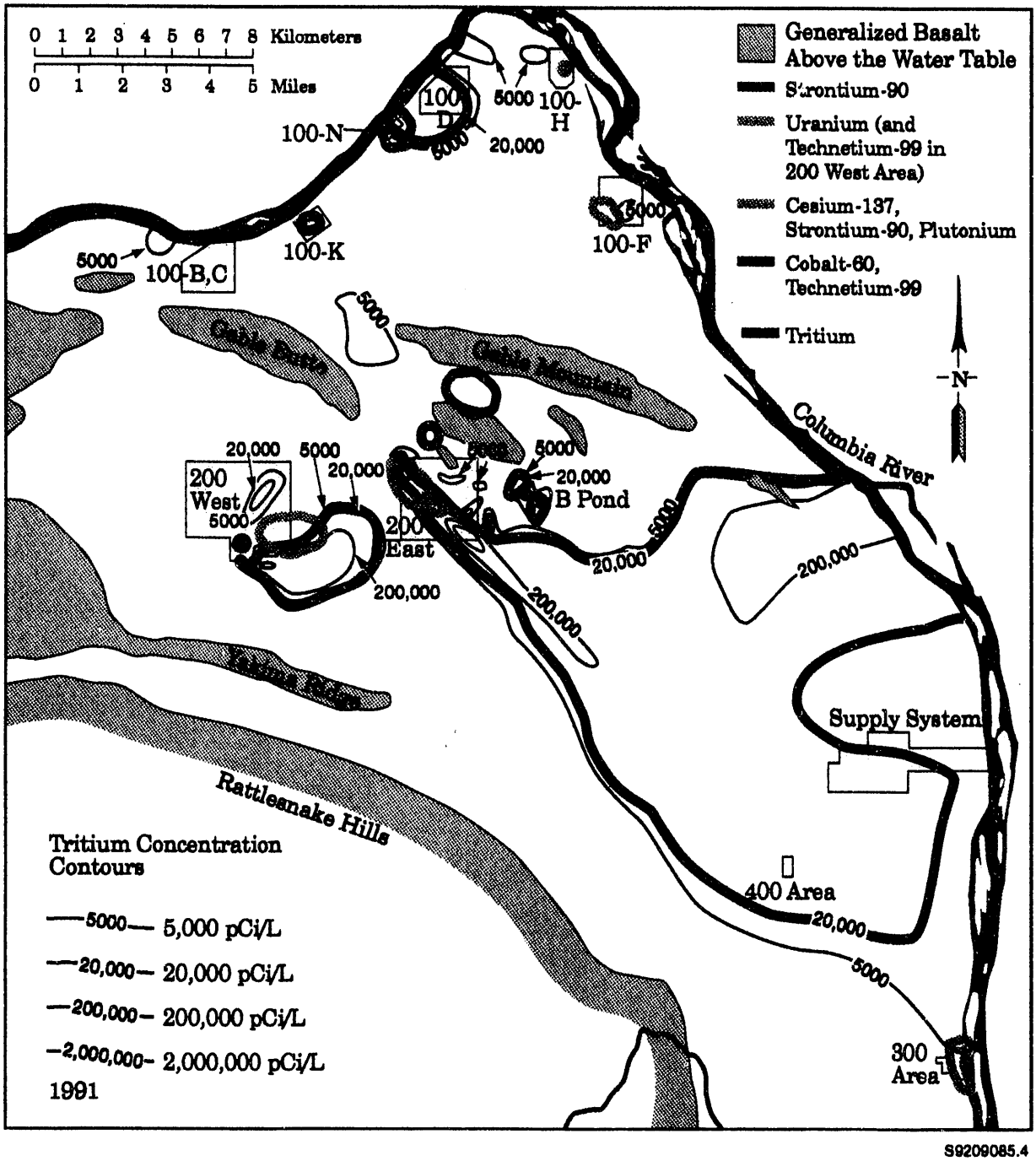

FIGURE 2.9. Extended Radionuclide Plume in Ground Water at Concentrations Above the Drinking Water Standard

were not available and concentrations have changed little in the recent past, data collected during 1989 or 1990 were used.

Tritium concentrations greater than the 20,000-pCi/L DWS were detected in portions of the 100-B, 100-D, 100-K, 100-N, 200-East, 200-West, 400, and 600 areas. Well 199-K-30 continued to contain the highest tritium concentration within the 100 Areas with a maximum concentration of 798,000 pCi/L, similar to the high for 1990, but lower than the maximum of 1,220,000 pCi/L in 1988. Well 199-K-27 showed a large decrease in tritium concentrations, down to 40,400 pCi/L in April 1991 from a high of 134,000 pCi/L in 1990. Wells 199-K-28 and 199-K-29, located between and near the other two wells, remained at relatively low tritium concentrations (2000 and 6000 pCi/L, respectively). The reason for the changes in tritium concentration in 100-K Area ground water is not known. The nearby K-East Basins contain irradiated fuel elements and, as a result, water in the basins contains tritium at a concentration of 3,700,000 pCi/L. DOE (1991a) indicates this basin has leaked in the past and that there may be several unidentified tritium sources in the area.

Concentrations greater than the 2,000,000-pCi/L DCG were detected in four wells in the 200-East Area. The highest tritium concentrations in the 200-East Area, and throughout the Hanford Site, continued to be in wells near cribs that have received effluents from the PUREX Plant. Tritium concentrations greater than the DCG were present in eight wells near the 216-A-10, 216-A-36B, 216-A-37-1, and 216-A-45 cribs. The ground-water tritium concentration measured in well 299-E25-19 was 2,140,000 pCi/L in 1991. That concentration is approximately half that measured in 1990. The highest ground-water tritium concentration measured in 1991 was 3,360,000 pCi/L in well 299-E17-20. Tritium concentrations exceeding the DWS continued to occur in most other wells affected by these cribs.

The movement of the widespread tritium plume (see Figure 2.9) extending from the southeastern portion of the 200-East Area to the Columbia River was consistent with patterns noted earlier (Woodruff and Hanf 1992; Evans et al. 1992). Separate tritium pulses associated with the two episodes of PUREX operations can be distinguished in the plume. The 200,000- to 2,000,000-pCi/L lobe east of the 200-East Area near the Columbia River is a result of

discharges to ground water during the operation of the PUREX Plant from 1956 to 1972. Following an 11-year shutdown, plant operation began again in 1983 and ceased in December 1988. Elevated tritium concentrations measured in several wells (e.g., wells 699-32-43, 699-33-42, 699-36-46 and 699-24-33) downgradient from the 200-East Area represent the formation of a second pulse of tritium moving away from PUREX waste disposal facilities. Large-scale movement of the leading edge of this plume is best observed in well 699-24-33, which clearly shows the arrival of the plume in early 1987 followed by passage of the plume from the earlier campaign. The first plume had reached much higher levels in the mid 1960s. A trend plot of the tritium concentrations in well 699-24-33 is shown in Figure 2.10. By contrast, a trend plot of the tritium concentrations in well 699-40-1 located near the shore of the Columbia River, shows the arrival in the early 1970s of the plume from the first campaign with no discernable effect from the second plume (Figure 2.11).

The eastern portion of the plume continues to move to the east-southeast and discharge into the Columbia River. Migration of the plume continued farther to the south, as indicated by increased tritium concentrations in wells in and near the 300 Area. Figure 2.12 shows the trend of tritium concentrations in well 699-S19-E13, located just north of the 300 Area. In recent years, this well has shown a steady increase in tritium, having reached a new maximum value of 9110 pCi/L in December 1991. The plume is not expected to move much farther south because of the influence of the Yakima River on ground-water flow in this area. The Yakima River is at a higher elevation than the ground water in this area, which is in turn at a higher elevation than the Columbia River (Newcomer et al. 1991). As a result, ground water flows from west to east, limiting the extent of southward movement of the contaminant plume. The recent increase in agricultural activity just southwest of the Site also should reinforce this trend through extensive artificial recharge with irrigation water. In addition, plume spread is also balanced to some extent by radioactive decay of the tritium, which has a half-life of 12.3 years.

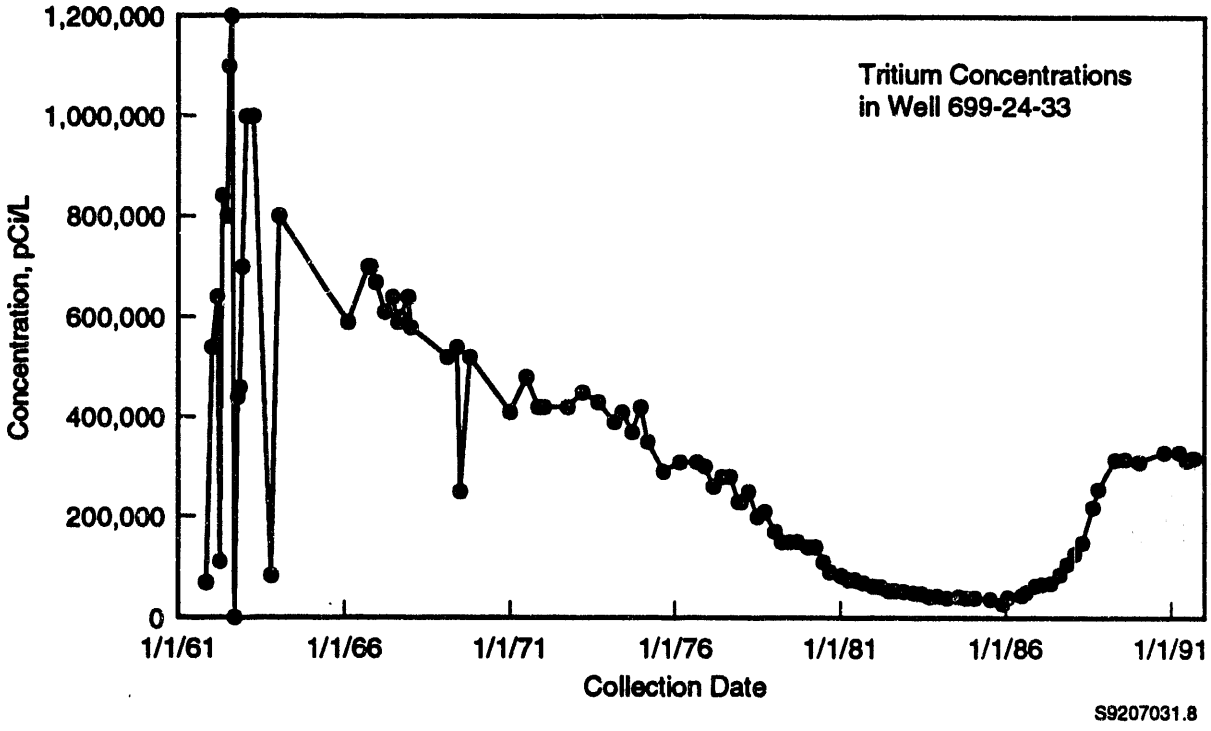

FIGURE 2.10. Trend Plot for Tritium Concentrations in Well 699-24-33

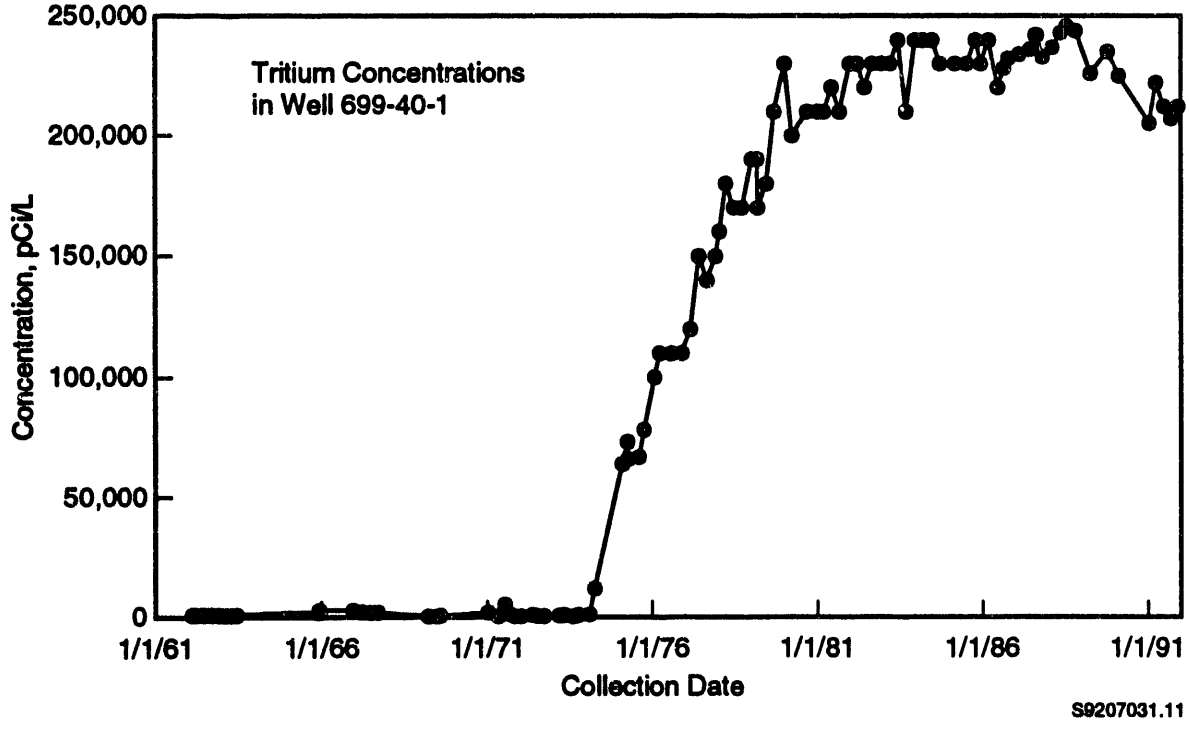

FIGURE 2.11. Trend Plot for Tritium Concentrations in Well 699-40-1

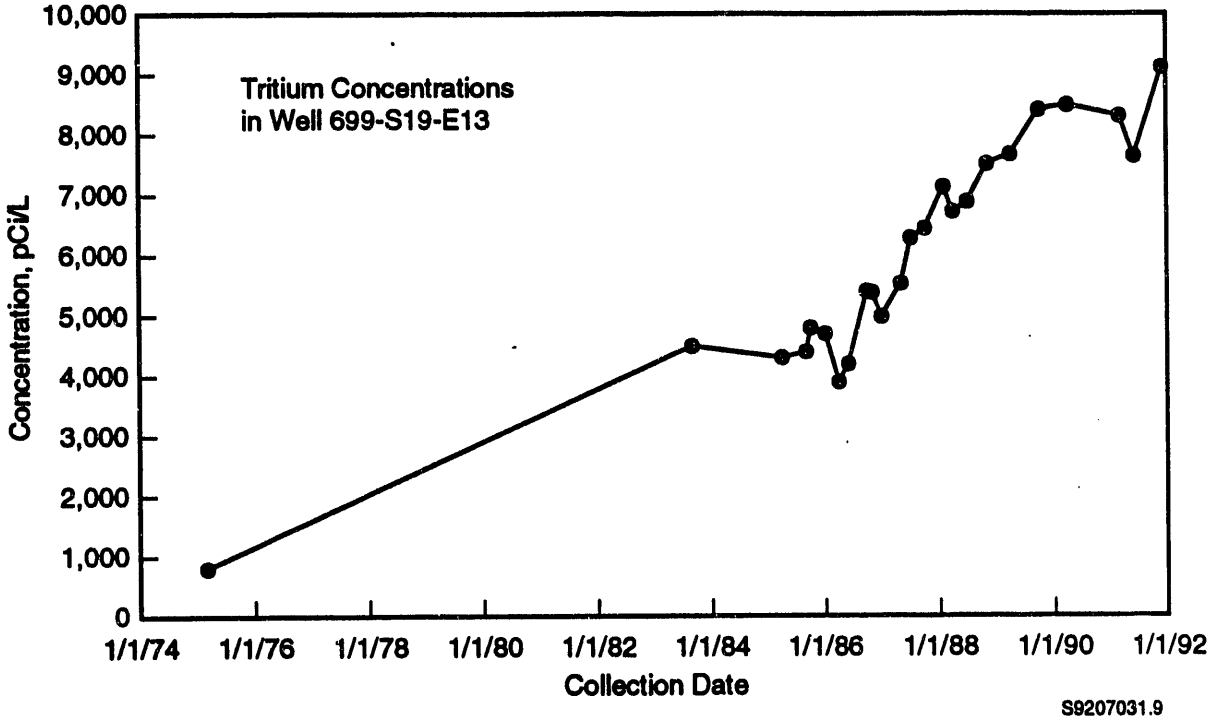

FIGURE 2.12. Trend Plot for Tritium Concentrations in Well 699-S19-E13

The configuration of the western portion of the plume closely matches previous predictions of the direction of contaminant movement from the 200-East Area (Freshley and Graham 1988). Movement to the south may be enhanced by the spreading ground-water mound beneath B Pond. This mound is spreading as a result of increased discharge of steam condensate and process cooling water to B Pond since 1984 when Gable Mountain Pond was deactivated.

The movement of tritium plumes in the 200-West Area was also consistent with previous observations. The plume extending from near the REDOX Plant in the southern part of the 200-West Area continued to move slowly to the east and north. Only one well in the 200-West Area (299-W22-9) continues to show tritium levels in excess of the DCG. Ground water sampled from that well contains one of the highest tritium concentrations on the Hanford Site, reaching a maximum of 5,880,000 pCi/L in 1990. That well was not sampled in 1991; however, results from early 1992 indicate that the tritium level is decreasing slowly but remains very high (4,450,000 pCi/L).

Tritium concentrations in well 299-W23-4 increased rapidly, reaching a maximum of 5,450,000 pCi/L in February 1988, followed by a rapid decrease to below the DCG during the remainder of the year. That trend continued up to the present, with concentration down to 3360 pCi/L by December 1991. The explanation of this very rapid decrease in tritium concentration remains unclear. Well 299-W23-4 had shown negligible tritium levels during 1987.

Tritium concentrations in nearby wells within the 200-West Area and in the adjacent 600 Area remained above the DWS and were relatively constant throughout 1991 with the exception of tritium concentrations in well 299-W23-9, which dropped by nearly an order of magnitude in 1990 after remaining nearly constant for several years. The tritium concentration in well 299-W23-9 rose again in 1991 to 454,000 pCi/L but still remains well below the high for 1989 of 1,520,000 pCi/L.

Movement of the tritium plume extending north and east from the REDOX Plant was indicated by changes in the tritium concentrations in several wells in the plume. Concentrations in well 699-35-70 continued to decrease slightly, suggesting that peak concentrations may have moved beyond this well. Figure 2.13 shows the tritium concentrations in well 699-35-70 since the mid-1970s with the passage of the tritium plume in evidence. The current tritium concentration in the well is about fivefold below the peak concentration corrected for radioactive decay since the peak occurred in 1976. Plume movement in that area is very slow because of low hydraulic conductivity in the unconfined aquifer in that region; however, some perceptible movement is still occurring. Concentrations in wells near the center of the plume remained relatively constant. The northernmost extent of the plume appeared to be near well 699-40-62. Well 699-44-64, north of well 699-40-62, has shown a small but steady increase over the last 24 months, reaching a new high of 1150 pCi/L in December 1991.

2.2.7 Gross Alpha Activity

In general, the Ground-Water Surveillance Project has, in recent years, opted to use more specific analytical techniques rather than the relatively nonspecific gross alpha method. Gross alpha measurements have thus been made primarily by the operational and compliance monitoring projects. Elevated

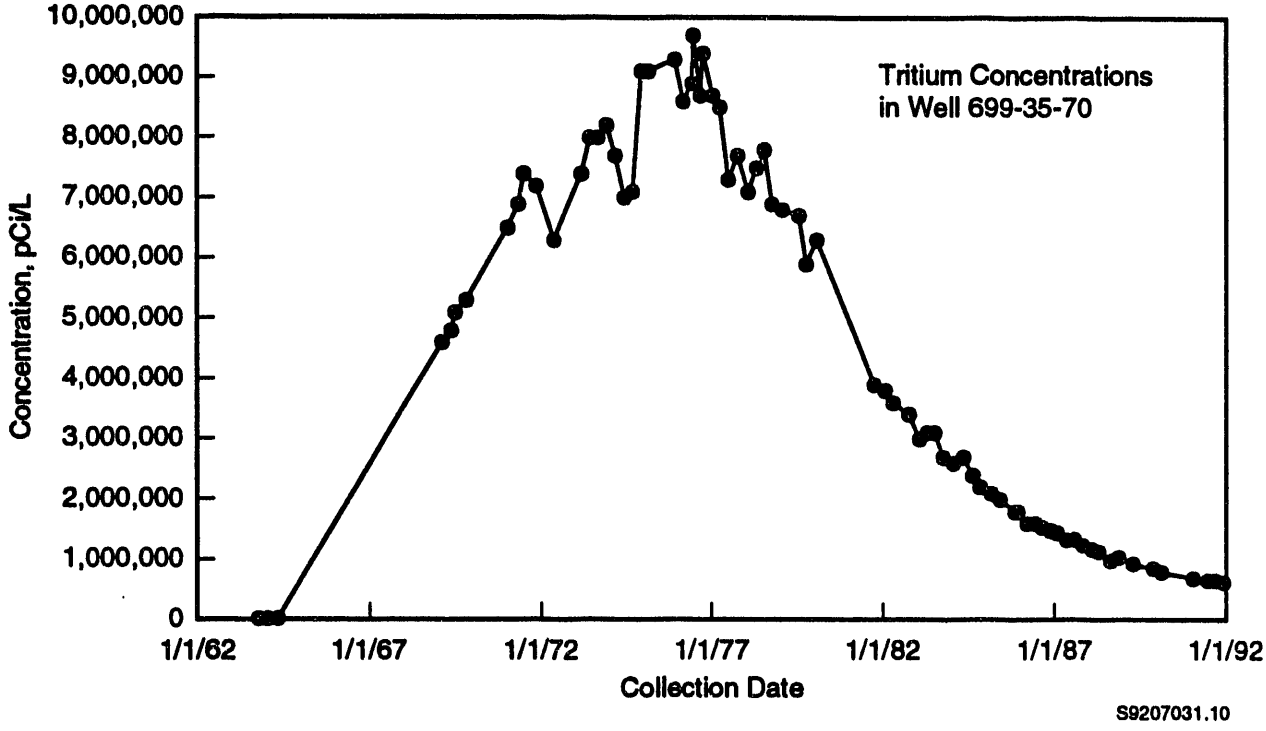

FIGURE 2.13. Trend Plot for Tritium Concentrations in Well 699-35-70

gross alpha concentrations have been detected in ground water from wells in several areas and may be attributable to the presence of isotopes of plutonium and/or uranium; however, plutonium (and other transuranic isotopes) concentrations in all but four wells were below the detection limit attainable by the analytical laboratory. The DWS for gross alpha is 15 pCi/L, not including uranium. Wells in the 100-F, 200, and 300 areas where gross alpha has routinely exceeded 15 pCi/L have been shown to contain uranium at levels that would account for the gross alpha level detected. Several wells in the 100-H Area also contained gross alpha levels exceeding the DWS. Levels of gross alpha in ground-water samples were generally quite low throughout the 200-East Area with the exception of a few wells near the northwest corner that are located in areas of known uranium contamination. Gross alpha levels in those wells remain near or slightly above the 15 pCi/L DWS (i.e., 299-32-3, 16.3 pCi/L gross alpha in March 1991). The highest gross alpha levels measured on Site were found in wells adjacent to the inactive 216-U-1 and 216-U-2 cribs. Wells adjacent to these cribs contained uranium levels that would account for the gross alpha levels detected.

2.2.8 Gross Beta Activity

Gross beta concentrations greater than the 50-pCi/L DWS have been found in wells throughout the Site. Gross beta levels can be attributed to one or more of the following radionuclides in ground water: potassium-40 (naturally occurring), cobalt-60, strontium-90, technetium-99, ruthenium-106, antimony-125, cesium-137, thorium-234, and protactinium-234 (uranium radioactive decay products), and to a lesser extent iodine-129. During past Site operations, some shorter-lived beta emitters (such as ruthenium-103, ruthenium-106, or iodine-131) were also occasionally present. Tritium is not detected by the method used for assay of gross beta. Gross beta activity associated with Hanford activities in most cases derives from a combination of uranium and technetium-99 activity. Known exceptions include some wells in the 100-N Area and a few wells in the 200-East Area that contain strontium-90 at concentrations high enough to be detected with the gross beta technique.

Although gross beta levels greater than the DWS have in the past been widespread, the highest levels were typically found in wells near several waste disposal facilities in the 100-N, 200-East, and 200-West areas, and in the 600 Area adjacent to the 200 Areas. Many of those wells were not analyzed for gross beta in 1991 because of reductions in the operational monitoring program. Wells in the 200-East Area with the highest gross beta levels in 1990 reflected past disposal of liquid waste to the inactive 216-B-5 Injection Well, BY Cribs, and cribs near the PUREX Plant. Gross beta levels in wells 299-E28-23 (12,900 pCi/L) and 299-E28-25 (12,000 pCi/L) near the 216-B-5 Injection Well were some of the highest measured onsite in 1990. All wells near this injection well contained elevated levels of strontium-90, and three wells also contained measurable cesium-137. During its operational life, the 216-B-5 Injection Well received an estimated 24 Ci of strontium-90 and 28 Ci of cesium-137 (decay corrected to mid 1991) when used from 1945 to 1947 (Stenner et al. 1988). The BY Cribs received waste scavenged from U Plant. Wells monitoring the BY Cribs (located at the north end of the 200-East Area) showed gross beta levels greater than the DWS, ranging up to 3130 pCi/L (well

699-50-53) in 1991. The BY Crib monitoring wells showed the presence of cobalt-60 and technetium-99 accounting for the majority of the gross beta activity.

The highest gross beta levels in the 200-West Area in 1990 were found in wells near U Plant. Gross beta levels in wells near the 216-U-1 and 216-U-2 cribs remained above the DWS but are generally decreasing. Gross beta levels in these wells are dominated by uranium radioactive decay products. None of these wells were sampled in 1991 because of reductions in the operational monitoring program.

Highest gross beta levels were found in wells monitoring the 1301-N LWDF. Well 199-N-67 showed a gross beta concentration of 7850 pCi/L in November 1991. The observed concentrations at this location are primarily due to strontium-90. Gross beta and strontium-90 levels in that well have dropped about fivefold since the first measurements were reported in December 1988 more than a year after shutdown of the N Reactor.

Gross beta levels exceeding the DWS have been found in wells down-gradient of Siemens Power Corporation and the Horn Rapids Landfill. The highest levels reported in 1990 were from well 699-S31-10A (91 p/CiL). Similar levels of technetium-99 were found in wells in the same area. For example, a ground-water sample collected from well 699-S31-10A in March 1992 showed 81 pCi/L of technetium-99. This is well below the action level of 3790 pCi/L defined in EPA's Proposed Primary Drinking Water Standard (EPA 1991). A comprehensive radiological analysis of ground-water samples collected from the Horn Rapids Landfill wells in late 1991 for WHC and the U.S.. Army Corps of Engineers was performed by PNL laboratories. Data reported at that time is still undergoing validation; however, preliminary results from that study show that the gross beta activity is attributable solely to technetium-99 contamination with no strontium-90, gamma emitting radionuclides, or excess uranium present. The plume appears to originate from the nearby area of the fuel fabrications facility operated by Siemens Power Corporation. A gross alpha (uranium) plume has also been identified originating from the same location (see Figure 2.20) but does not extend quite as far to the northeast. Technetium-99 is commonly associated with the use of recycled uranium as part

of the fuel cycle. Technetium has typically exhibited a greater mobility than uranium on other areas of the Hanford Site so the behavior of the plumes at the Horn Rapids Landfill is entirely consistent with other observations.

2.2.9 Cobalt-60

All cobalt-60 concentrations were consistently near or below the detection limit (20 pCi/L) for wells monitored in 1991 except in a region north of the 200 Areas affected by waste disposed of in the BY cribs (Figure 2.9). The highest concentrations of cobalt-60 in Hanford Site ground water during 1991 was in well 699-50-53 (449 pCi/L). Cobalt-60 in this well appears to be highly mobile, probably because of the presence of a soluble cobalt-cyanide (or ferrocyanide) complex associated with the plume originating from the BY Cribs. This effect was first observed as far back as the late 1950s and was the main reason that disposal to the BY Cribs was discontinued. Concentrations of cobalt-60 have in the past been above detection in a number of 100-N Area wells near the 1325-N LWDF, but dropped below detection in 1990.

2.2.10 Strontium-90

Concentrations of strontium-90 were above the 8-pCi/L DWS in wells in the 100-B, 100-D, 100-F, 100-K, 100-N, 200-East, 200-West, and 600 areas. Concentrations of strontium-90 were greater than the 1000-pCi/L DCG in the 100-N and 200-East areas, ranging up to 6060 pCi/L in the 100-N Area near the 1301-N LWDF (well 199-N-67), significantly reduced from the maximum of 23,400 pCi/L reached in March of 1989. A trend plot of strontium-90 concentrations in two of the 100-N Area wells is given in Figure 2.14 showing the continuous decrease of strontium-90 in that well. A contour plot showing strontium-90 ground-water plume distribution is given in Figure 2.15. The plot is based on ground-water well data collected in 1991. Also included on the plot are data from spring-sampling locations near the shoreline[a]. These measurements were all made in December 1991 at relatively low river stage in order to minimize the effect of bank storage.

(a) Craig Perkins, Environmental Engineer, WHC, personal communication, 1992.

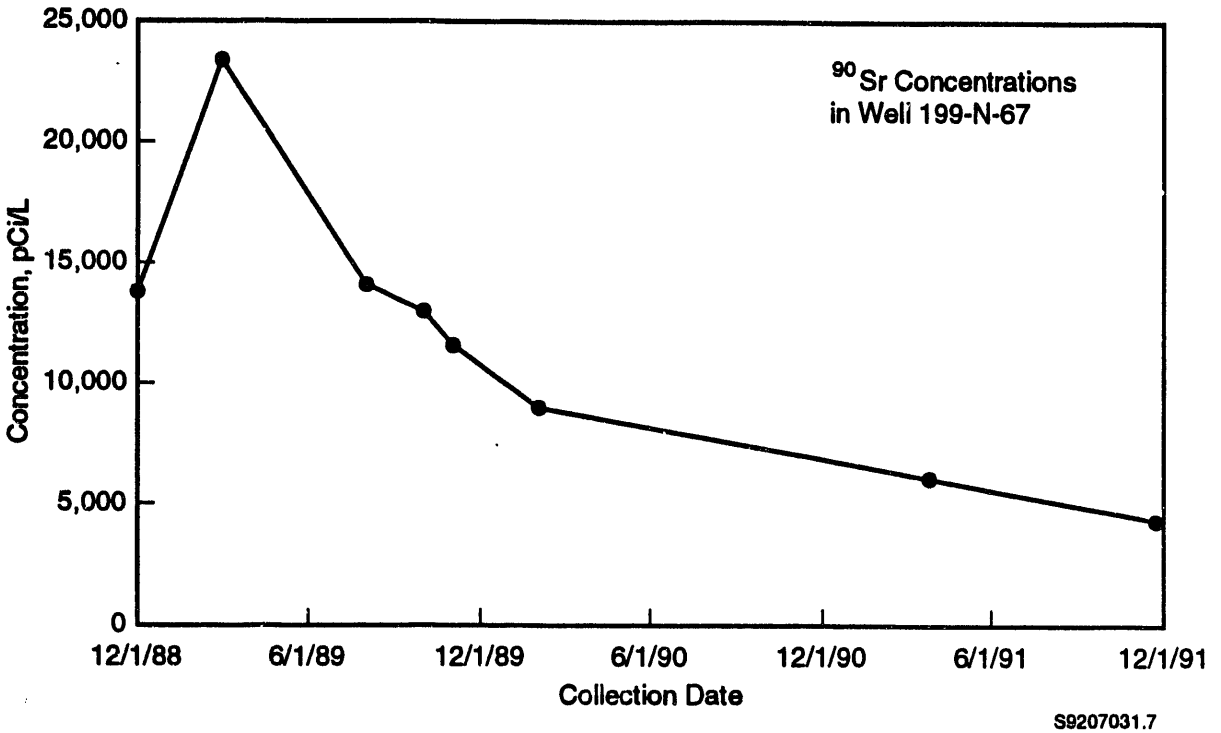

FIGURE 2.14. Trend Plot for Strontium-90 Concentrations in Well 199-N-67

Concentrations of strontium-90 ranged up to 3150 pCi/L in the 200-East Area near the 216-B-5 Injection Well (see Figure 2.20). Concentrations of strontium-90 above the DWS (maximum of 171 pCi/L in well 699-53-48B) but less than the DCG were detected in several wells near Gable Mountain Pond. Strontium-90 contamination in that area resulted from accidental discharge of waste to Gable Mountain Pond during its early use. Strontium-90 has since migrated through the sedimentary column to the ground water, which is relatively close to the surface at that location. Initial breakthrough occurred in 1980 in some areas and later in others. Trend plots showing strontium-90 breakthrough for several representative Gable Mountain Pond monitoring wells is shown in Figure 2.16. Well 699-53-47B appears to show a slightly increasing trend. Locations of areas of strontium-90 ground-water contamination exceeding the DWS are shown on Figure 2.9.

2.2.11 Technetium-99

Concentrations of technetium-99 greater than the 3790-pCi/L DWS proposed by EPA (EPA 1991) were detected in wells in the 100-H, 200-East, and 200-West

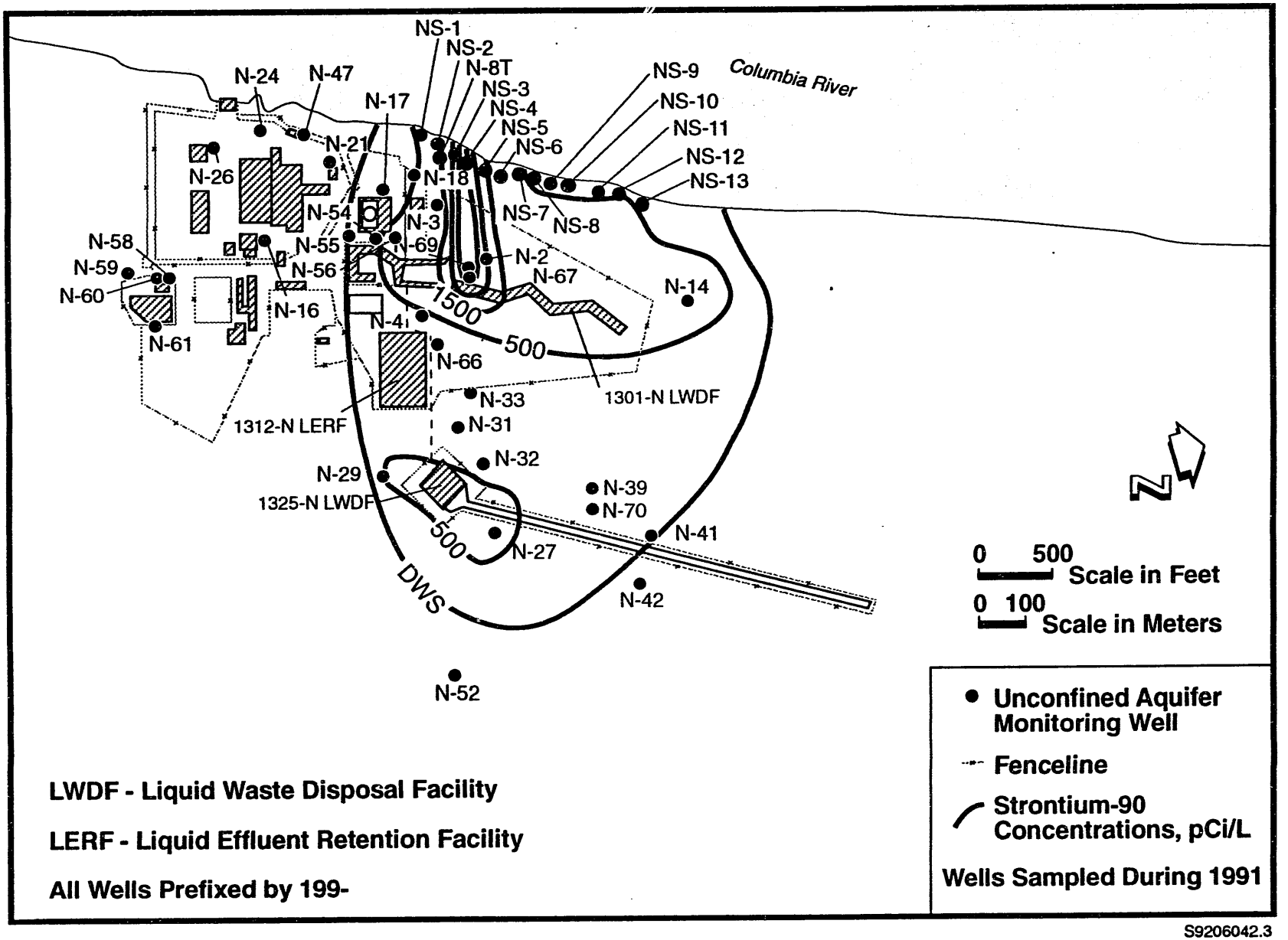

FIGURE 2.15. Contour Plot for Strontium-90 in 100-N Area Ground Water [1989-1990 data. Minimum contour is set at DWS (8 pCi/L). Maximum contour is 4500 pCi/L.]

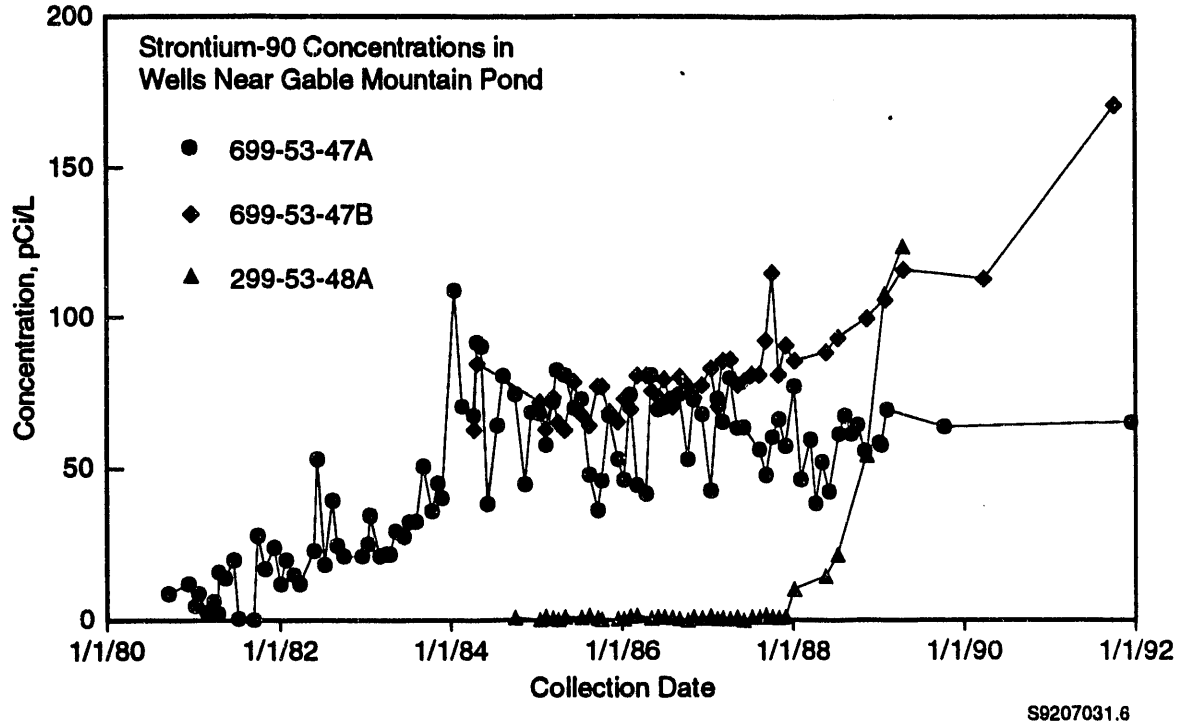

FIGURE 2.16. Trend Plot for Strontium-90 Concentrations in Wells near Gable Mountain Pond

areas and in portions of the 600 Area. These locations are identified on Figure 2.9. Concentrations did not exceed the 100,000-pCi/L DCG in any well sampled in 1991.

2.2.12 Ruthenium-106

Because of its short half-life (367 days), ruthenium-106 was detected in the past principally in wells located in areas near operating reactors and active fuel reprocessing facilities. Past examples have included the 100-N Area and the 200-East Area near the PUREX Plant. Concentrations in wells in the 100-N Area were at most marginally detectable in 1987 and continued to decline in 1988 because the N Reactor was in cold standby status. Ruthenium-106 was undetectable by routine methods in the 100-N Area after 1989. Concentrations of ruthenium-106 in wells near LWDFs receiving effluents from the PUREX Plant generally increased in 1988, with well 299-E24-12 reaching a maximum of 547 pCi/L (DWS is 30 pCi/L) in April 1988. That trend reversed in 1989 as a result of interruption in the operation of PUREX, with the ruthenium-106 concentrations in well 299-E24-12 dropping to below detectable levels. A

ruthenium-106 concentration of 257 pCi/L was found in well 299-E17-15 in September 1989. The concentration of ruthenium-106 dropped to below the detection limit (20 pCi/L) in that well in 1990. Ruthenium-106 has, thus, not been detectable by routine methods after 1989 in any Hanford groundwater.

2.2.13 Antimony-125

Antimony-125, a gamma emitter, has been measured in the past in a few wells in 100-N and 100-K areas. Concentrations measured in samples from these two areas have been as high as 305 pCi/L near the 1325-N LWDF in 1987. In 1991, however, the maximum concentrations observed were 103 pCi/L in samples collected from one 100-K Area well and 30 pCi/L in samples from several 100-N Area wells. The half-life of antimony-125 is 2.76 years. It has thus tended to decay rapidly following cessation of nuclear production operations. The DWS for antimony-125 is 300 pCi/L and the DCG is 60,00 pCi/L.

2.2.14 Iodine-129

The presence of iodine-129 in ground water is significant because of its relatively low DWS (1 pCi/L), its potential for accumulation in the environment as a result of long-term releases from nuclear fuel reprocessing facilities (Soldat 1976), and its relatively long half-life (16 million years). At Hanford, the main contributor of iodine-129 to ground water has been liquid discharges to cribs in the 200 Areas. Assay of that isotope by high-sensitivity, direct-counting methods requires long counting times with correspondingly low analytical throughput. The highest concentrations observed on site are downgradient from the REDOX and PUREX plants. The highest iodine-129 concentration observed in 1991 in Hanford ground water was 44 pCi/L found in well 699-35-70. Many wells sampled in the 200-West, 200-East, and 600 areas had concentrations somewhat above the DWS (Figure 2.17); however, none were above the DCG (500 pCi/L).

Figure 2.17 shows an I-129 plume that is considerably more extensive than previously shown (e.g., Woodruff and Hanf 1992). This change in plume configuration is the result of additional data being available at the time this report was prepared. It does not indicate movement of the plume since completion of the previous report. Comparison of Figure 2.17 with the tritium

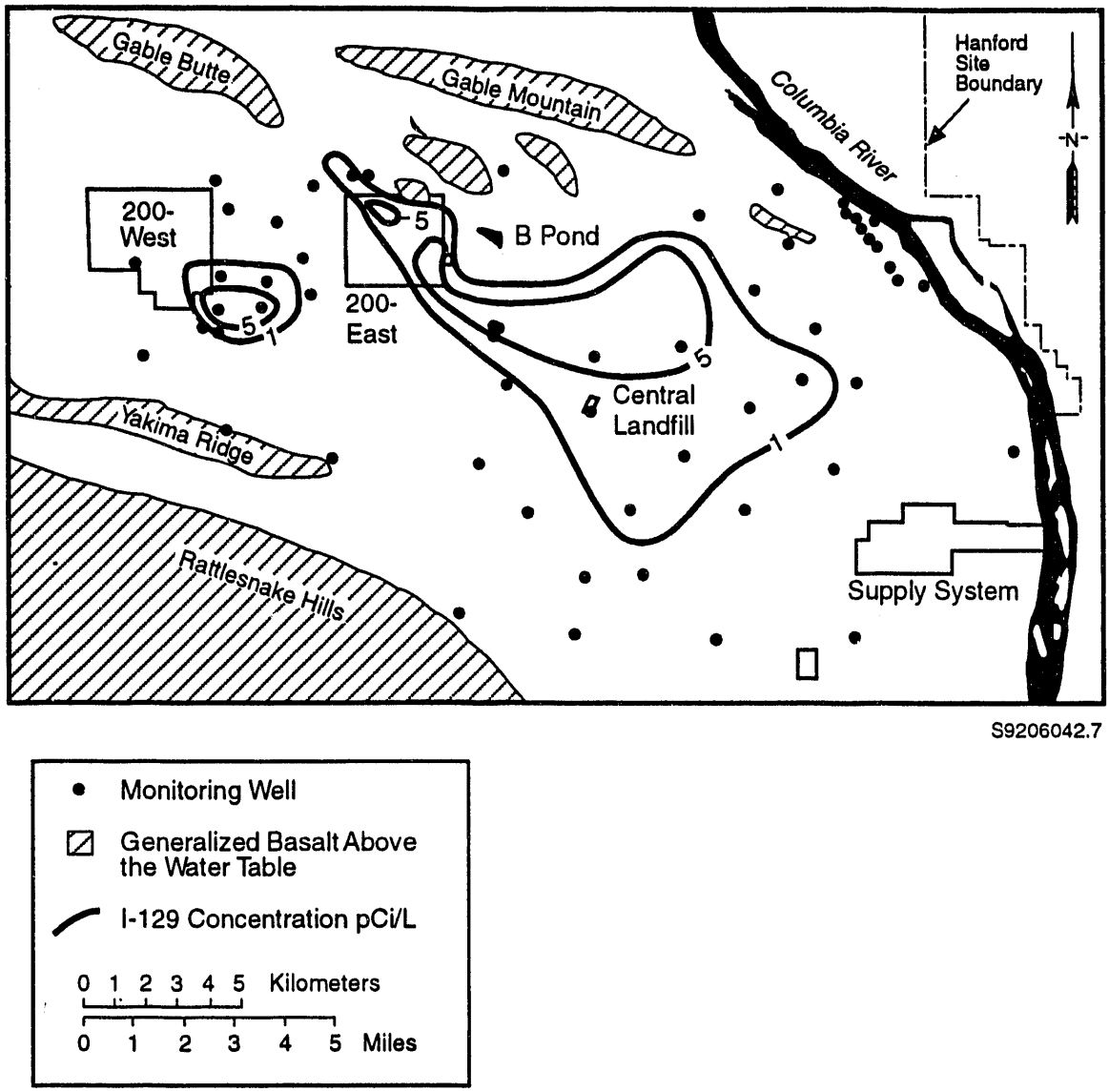

FIGURE 2.17. Contour Plot for Iodine-129 in the 200 and 600 Areas' Ground Water

distribution on the Hanford Site (Figure 2.9) indicates that these two constituents have similar distribution, although the area of the 1-129 plume above the DWS is less extensive than the area of the tritium plume above the DWS.

2.2.15 Iodine-131

Because iodine-131 has a short half-life (8.04 days), it typically has been detected only in ground water near known waste-water discharge facilities

(100-N Area wells). Iodine-131 was not detected in any Hanford Site wells during 1991 because the N Reactor was in cold standby status and iodine-131 was not discharged to ground water.

2.2.16 Cesium-137

Concentrations of cesium-137 were below the detection limit (23 pCi/L) except in three wells located near the 216-B-5 Injection Well. The 216-B-5 Injection Well received an estimated 28 Ci of cesium-137 (decay corrected to mid 1991) during its operation from 1945 to 1947 (Stenner et al. 1988). The DWS for cesium-137 is 200 pCi/L, and the DCG is 3000 pCi/L. The area with cesium-137 above the DWS is depicted in Figure 2.9. Most of the wells located near the 216-B-5 Injection Well were not-sampled in 1991 because of newly implemented restrictions on entry to radiation protection zones.

2.2.17 Uranium

The highest uranium levels in Hanford ground water occur in wells adjacent to the inactive 216-U-1 and 216-U-2 cribs. Uranium concentrations in these wells have been decreasing over the last 4 years following remediation activities associated with those cribs. The total uranium concentration in well 299-W19-3 dropped from 11,500 pCi/L[(a)] in January 1987 to 737 pCi/L in April 1990. Well 299-W19-3 and several other key wells near the 216-U-1 and 216-U-2 cribs were not sampled for uranium in 1991 because of programmatic reductions in the operational ground-water monitoring program administered by WHC; however, well 299-W19-18, which is located downgradient of the cribs showed a maximum of 897 pCi/L in early 1991. Uranium levels in that well and others nearby appear to have stabilized. A trend plot of uranium concentration for well 299-W19-18 is shown in Figure 2.18. In addition, a newly installed well further downgradient from the cribs near U Plant itself (299-W19-29) was sampled for the first time in 1991, with a maximum value of

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(a) Uranium concentration is determined by fluorometric measurement of total elemental uranium. These values (μg/L) are converted to activity units (pCi/L) using a factor of 0.6905 pCi/μg. This value was calculated assuming secular equilibrium between uranium-234 and uranium-238 and a normal isotopic abundance of uranium-235. It also agrees with isotopic ratios observed in ground-water samples where the isotopic analyses were performed.

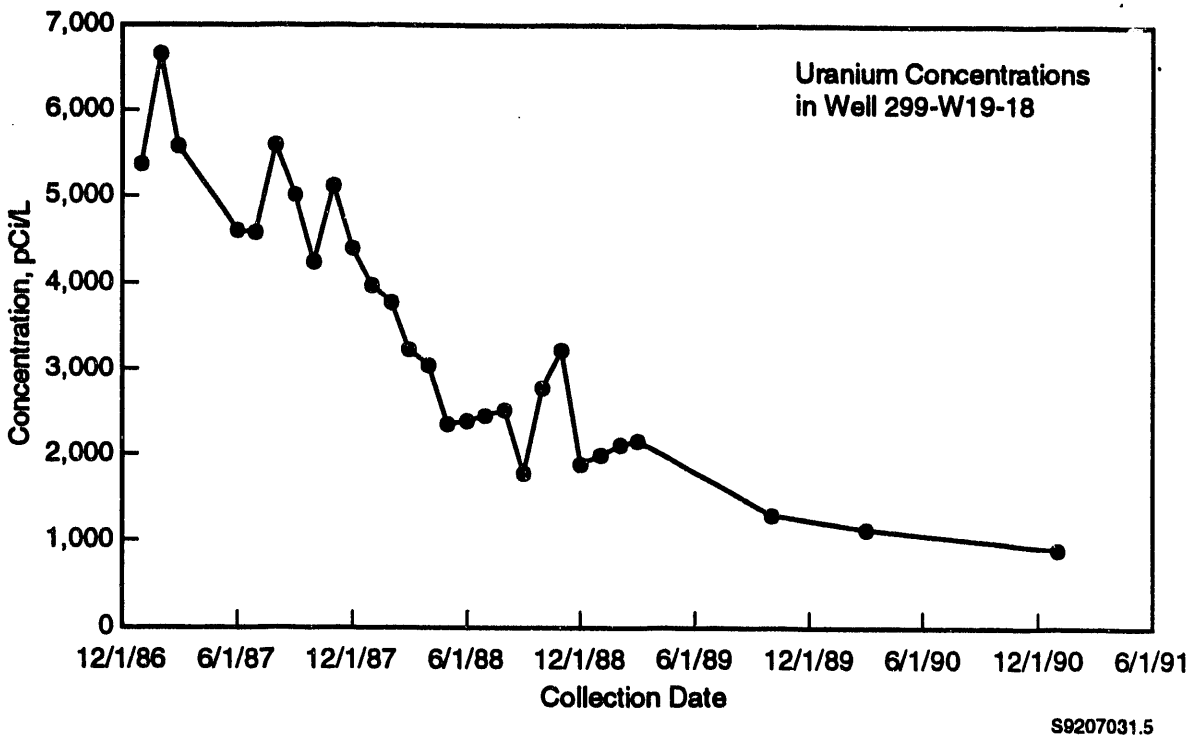

FIGURE 2.18. Trend Plot for Uranium Concentration in Well 299-W19-18

2240 pCi/L reported. It thus appears that the plume center has shifted somewhat to the east, which is consistent with known ground-water flow in that part of the Site.

There is a small uranium plume in the northwest corner of the 200-East Area downgradient of B Plant. The source of the plume is believed to be the 216-B-12 Crib, which received an estimated 7 Ci or 20,700 kg of uranium (Stenner et al. 1988) during its operation between 1957 and 1973. Uranium levels in this well have been decreasing slowly over the past few years. For example, the uranium concentration in well 299-E28-21 decreased from 52.1 pCi/L in 1987 to 19.1 pCi/L in early 1990. That well was not sampled in 1991.

Uranium levels increased sharply in two 100-F Area wells in 1987. Levels in well 199-F8-1 reached a maximum of 414 pCi/L in January 1988 and generally have decreased thereafter, dropping to a low of 72 pCi/L in April 1990. No additional measurements were available in 1991.

A uranium plume exists in the 100-H Area near the 183-H Solar Evaporation Basins. The maximum uranium concentration during 1991 in the 100-H Area ground water was 122 pCi/L in well 199-H4-3.

A plume of uranium also exists in the unconfined aquifer beneath the 300 Area in the vicinity of uranium fuel fabrication facilities and inactive waste sites known to have received uranium waste. The extent of the plume was limited to an area downgradient from active and inactive LWDFs. Uranium concentrations in wells in and adjacent to the 300 Area ranged up to 362 pCi/L during 1991. This observation was for well 399-1-17A in March and is similar to concentrations measured in previous years. An expedited response action performed on the 300 Area Process Trench in mid-1991 was aimed at reducing the uranium source term in that area. Use of the trench was resumed following completion of the remedial action. Uranium levels in well 399-1-17A appear to have been reduced following that action, having apparently stabilized about a factor of ten below the maximum values seen in 1990. A trend plot showing the uranium concentration in that well is shown in Figure 2.19. Well 399-1-17A is located near the downgradient discharge point for the 300 Area Process Trench. That well has shown cyclic variations in the uranium level in the past, and it is thus too early to conclusively ascertain if the remedial action was completely effective. Figure 2.20 shows the distribution of uranium contamination in ground-water in the 300 Area and alpha near the Horn Rapids Landfill. Uranium concentrations in ground water above 15 pCi/L were observed over a much smaller portion of the 300 Area than in past years. This may be attributable to the expedited response action. Alpha data for wells at Siemens Nuclear Power Corporation Facilities reported by Geraghty and Miller (1991) were plotted along with alpha data collected by the Ground-Water Surveillance Project in the vicinity of the Horn Rapids Landfill. The configuration of this plume would suggest that the contamination did not originate at a DOE facility.

2.2.18 Plutonium

A survey of plutonium in ground water was continued during 1991. The survey covered 132 wells including most of the usable wells in the 200 Areas and a few selected 600 Area wells. Concentrations of plutonium-239/240 were

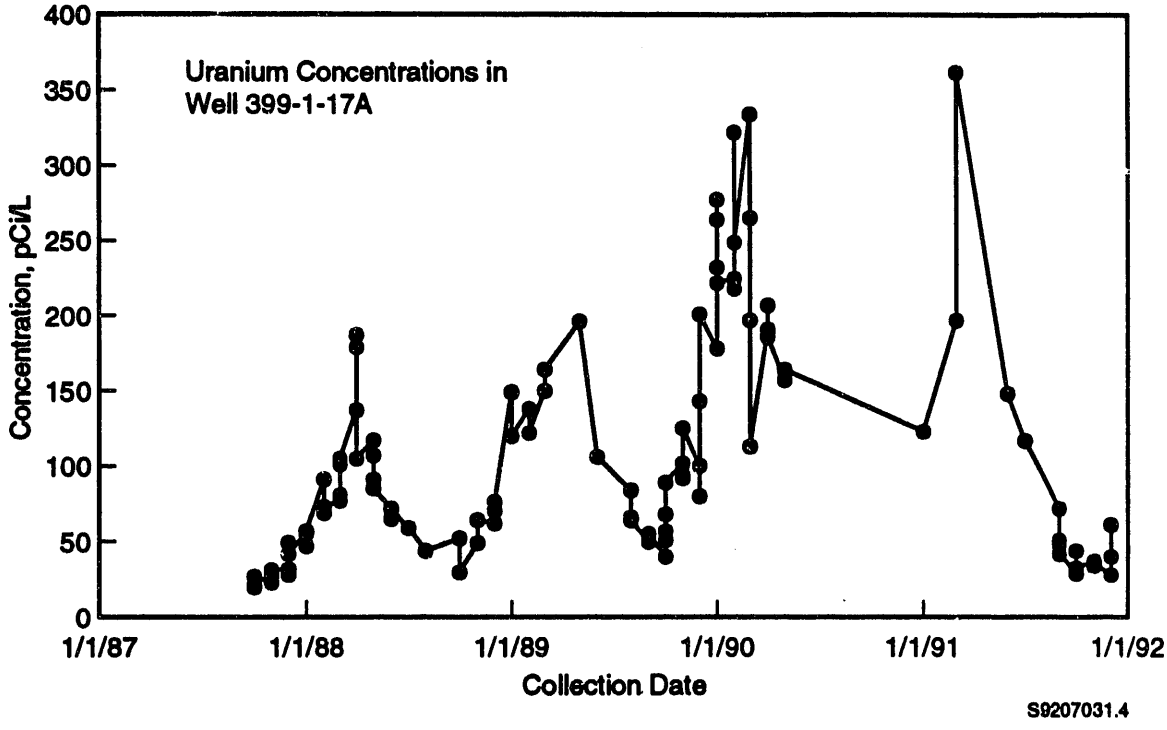

FIGURE 2.19. Trend Plot for Uranium Concentrations in Well 399-1-17A

below the detection limit in all wells, except for one well located near the 216-B-5 Injection Well and one well in the 200-West Area near the 216-Z-9 Trench. Plutonium is generally considered to bind strongly to sediments and thus has limited mobility in the aquifer. Ground water sampled at well 299-E28-23 contained 21.7 pCi/L of plutonium-239/240 in 1990. That well could not be sampled in 1991 because of newly implemented restrictions on entry to radiation protection zones. Ground water at well 299-E28-25 contained 13.3 pCi/L in 1991, similar to the levels seen in the past 2 years. Plutonium was detected for the first time in 1989 in another nearby well, 299-E28-24, ranging up to 144 pCi/L in 1990. That well was not sampled in 1991.

Plutonium-238 has also been detected at much lower levels in all three wells. The 216-B-5 Injection Well received an estimated 244 Ci of plutonium-239/240 during its operation from 1945 to 1947 (Stenner et al. 1988). The DCG for plutonium-239 is 30 pCi/L. There is no explicit DWS for plutonium-239; however, the gross alpha DWS of 15 pCi/L would be applicable at a minimum.

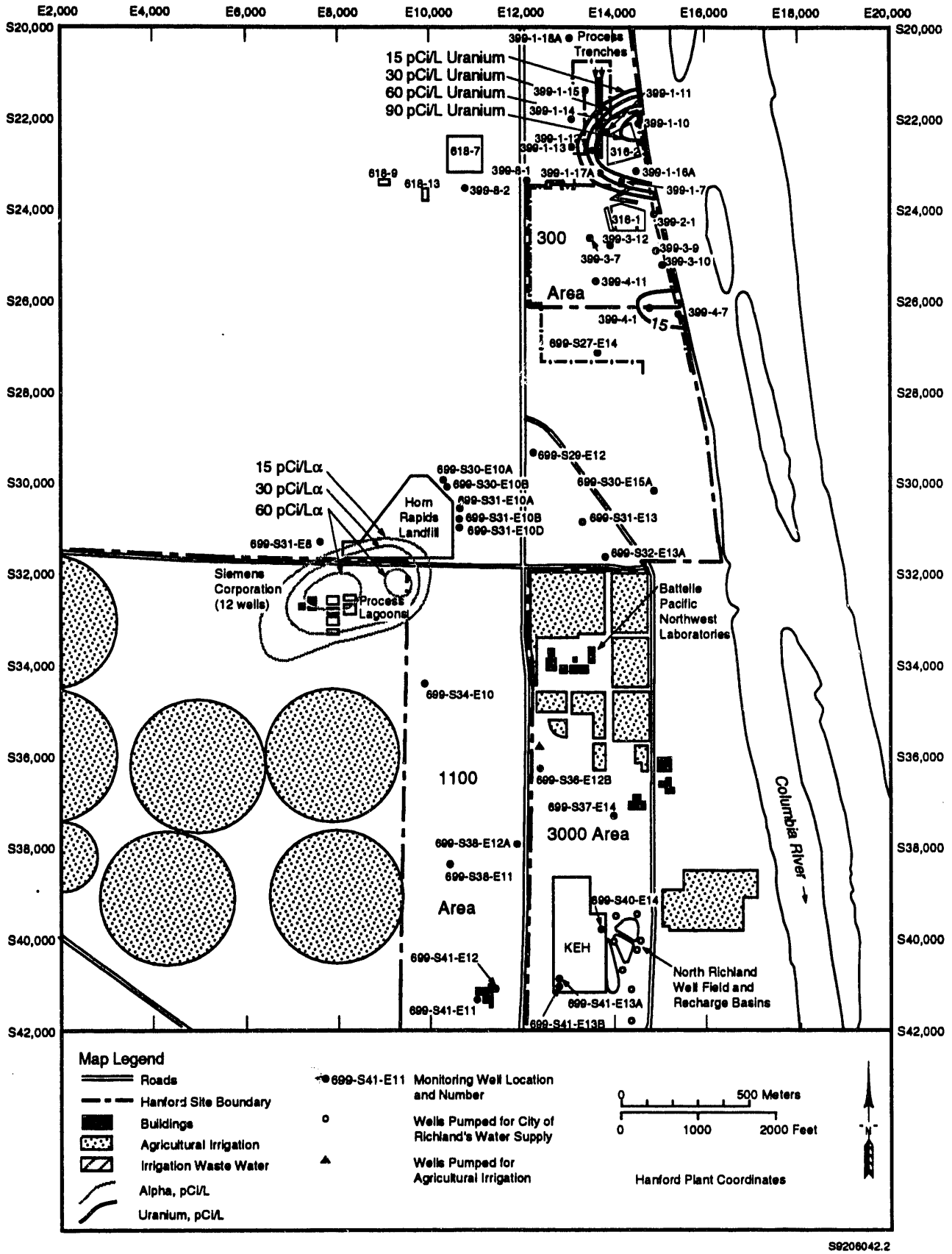

FIGURE 2.20. Contour Plots for Uranium in the 300 Area and Alpha in the Horn Rapids Landfill

Alternately, if the DCG (which is based on a 100-mrem dose standard) is converted to the 4-mrem dose equivalent used for the DWS, 1.2 pCi/L would be the relevant guideline.

Plutonium-239/240 was detected for the first time in May 1990 in a well located in the 200-West Area (299-W15-8). That well monitors the 216-Z-9 Trench, which received a large burden of plutonium and americium from Z Plant liquid effluent streams. No previous transuranic measurements were available for this well. Because the data were received just prior to termination of the analytical contract with UST, it was not possible to verify the observation in 1990. The measured concentration of plutonium-239/240 was 8.3 pCi/L. Plutonium-238 was also detected in the same sample (0.14 pCi/L). The well was resampled on November 14, 1991. Unfiltered, acidified samples were collected in the normal manner for transuranic analysis. In addition, a filtered, acidified sample was collected for plutonium assay. The unfiltered samples confirmed the presence of plutonium-239/240 (1.9 pCi/L), plutonium-238 (0.03 pCi/L), and americium-241 (5.9 pCi/L). No plutonium was found in the filtered samples confirming that the transuranic fraction is associated with particulate material.

2.3 RADIOLOGICAL AND CHEMICAL MONITORING RESULTS FOR THE CONFINED AQUIFER

The uppermost (Rattlesnake Ridge) confined aquifer was monitored to determine the extent of ground-water interaction between the confined and unconfined aquifers. Intercommunication between aquifers was identified by Graham et al. (1984). Ground-water samples from the confined aquifer were analyzed for a variety of radionuclides and hazardous chemicals. In most cases no indication of contamination was observed. Detection of radionuclides in well 299-E33-12 in the past is attributed to contamination by high-salt waste that migrated by density flow into the borehole when it was open to both the unconfined and the confined aquifer during drilling (Graham et al. 1984). Samples were not collected from this well during 1990 or 1991 as a result of various programmatic interruptions.

Intercommunication between the Rattlesnake Ridge confined aquifer and the unconfined aquifer north of the 200-East Area was indicated in the past by

the concentrations of NO_3^- in well 699-47-50. This well is located near an erosional window (i.e., near an area where the confining layer is absent) in the confining basalt flow (Graham et al. 1984). Elevated levels of tritium (3830 pCi/L) have been measured in ground water from the Rattlesnake Ridge interbed in well 699-42-40C. Elevated levels of iodine-129 (0.15 pCi/L) have previously been observed in the same well. Well 699-47-50 and 699-42-40C were not sampled in 1990 or 1991 because of a variety of programmatic interruptions.

2.4 GROUND-WATER QUALITY NEAR RICHLAND WATER SUPPLY WELLS

During 1991, ground water from monitoring wells in the southern portion of the Hanford Site was sampled and analyzed for hazardous chemicals and radiological constituents. This region currently is being characterized through a remedial investigation under CERCLA. Tetrachloroethene was detected at low concentrations in ground water in a well near one of the sites being investigated. In the vicinity of the Horn Rapids Landfill, elevated levels of nitrate, sulfate, trichloroethylene, uranium, and technetium-99 have been observed in ground-water samples. Data collected indicate that the presence of these contaminants cannot be attributed to the Horn Rapids Landfill (DOE 1990a, 1991b). No contaminants were observed in concentrations above the DWS in the vicinity of the Richland water supply wells.

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APPENDIX

MAPS OF OPERATIONAL AND FACILITY-SPECIFIC MONITORING WELL NETWORKS

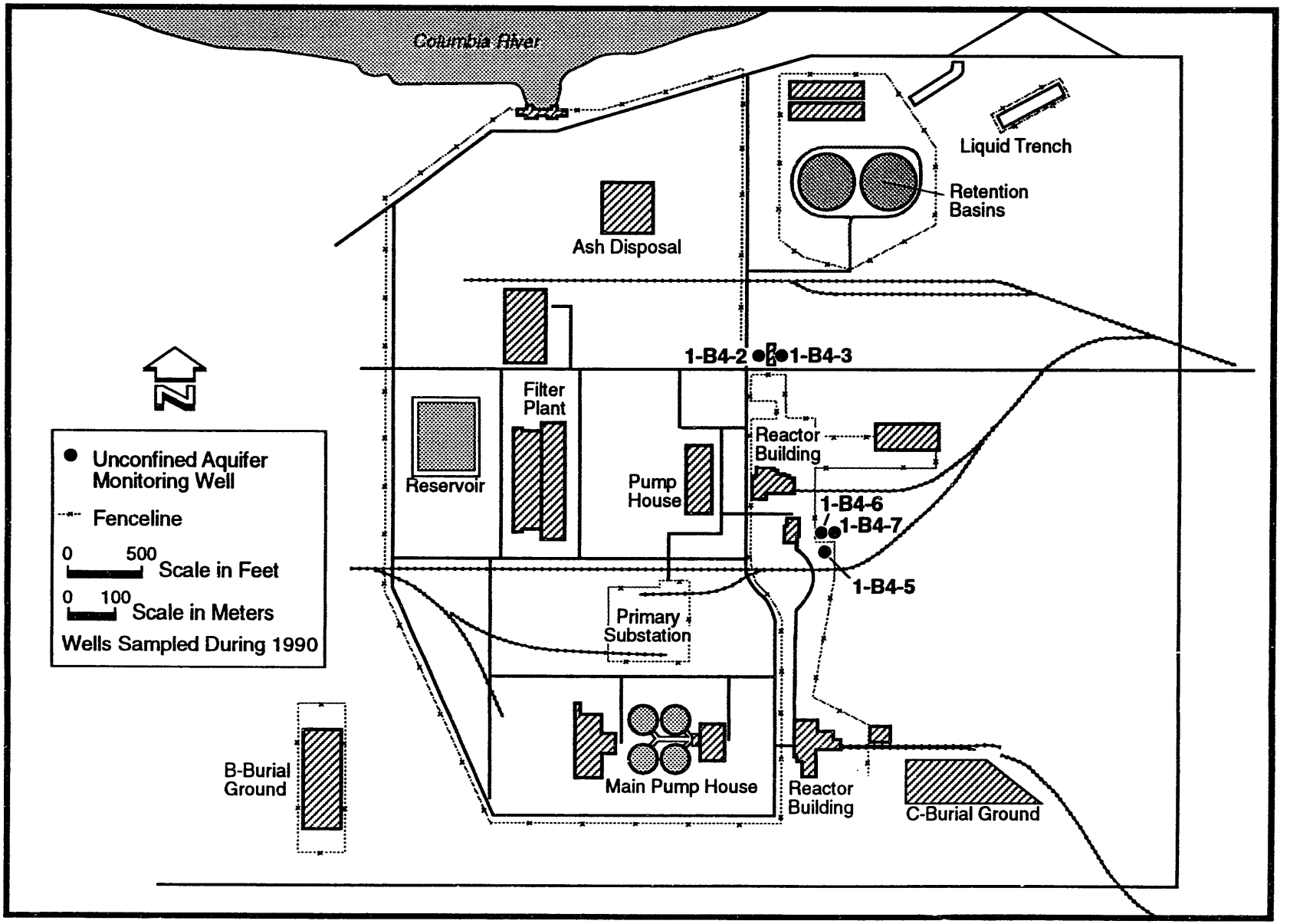

FIGURE A.1. Well Location Map for the 100-B Area

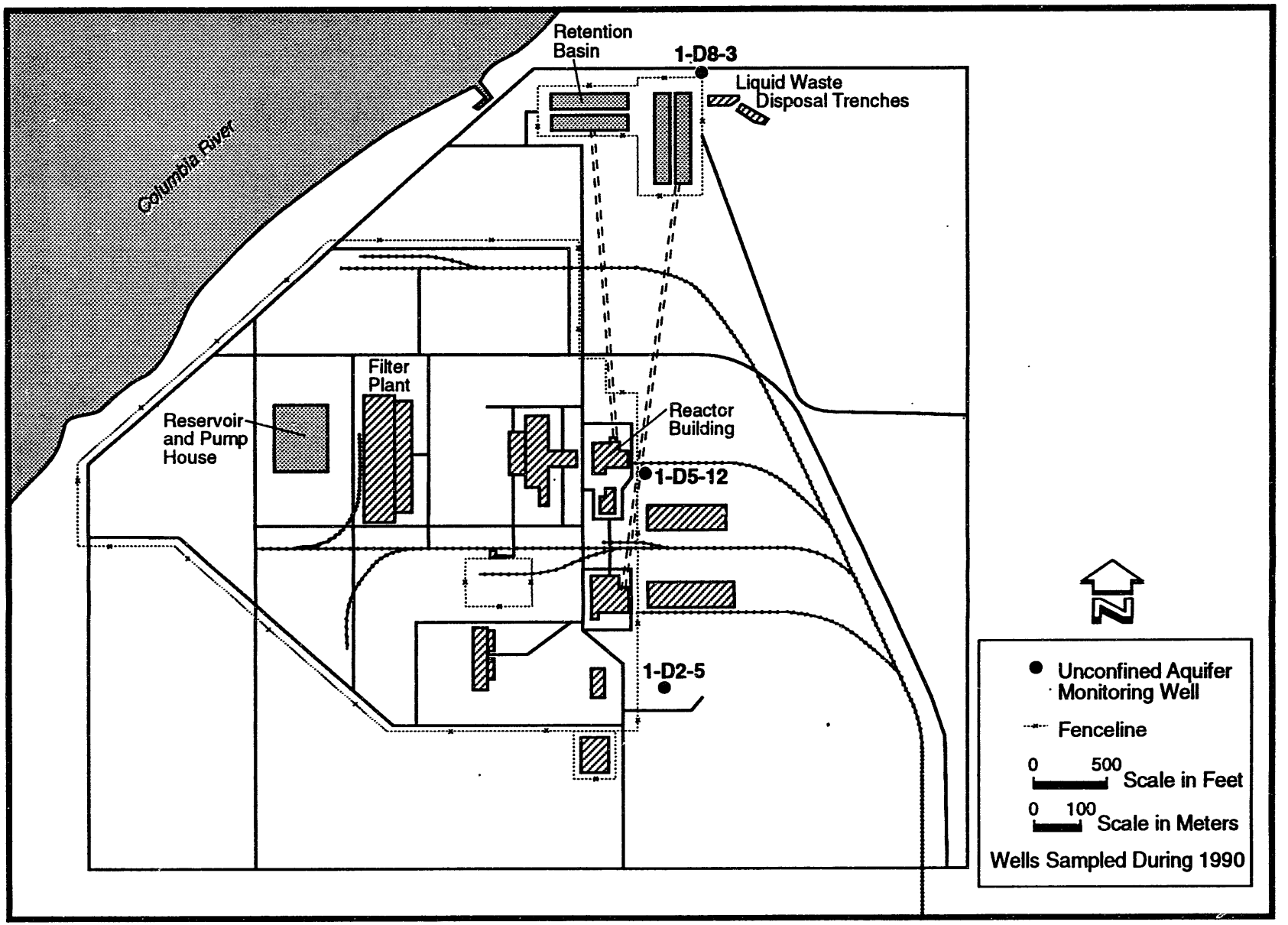

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FIGURE A.2. Well Location Map for the 100-D Area

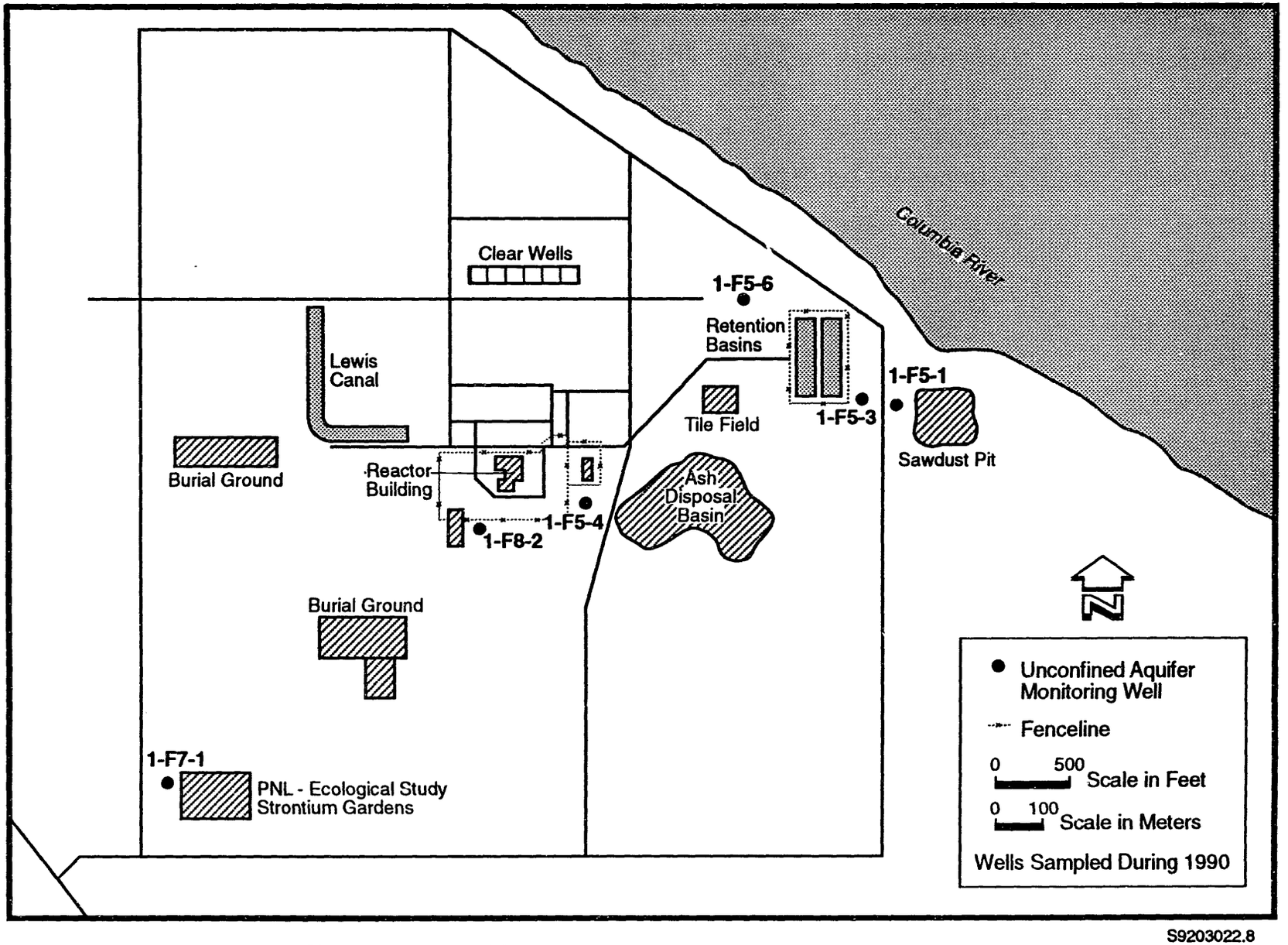

FIGURE A.3. Well Location Map for the 100-F Area

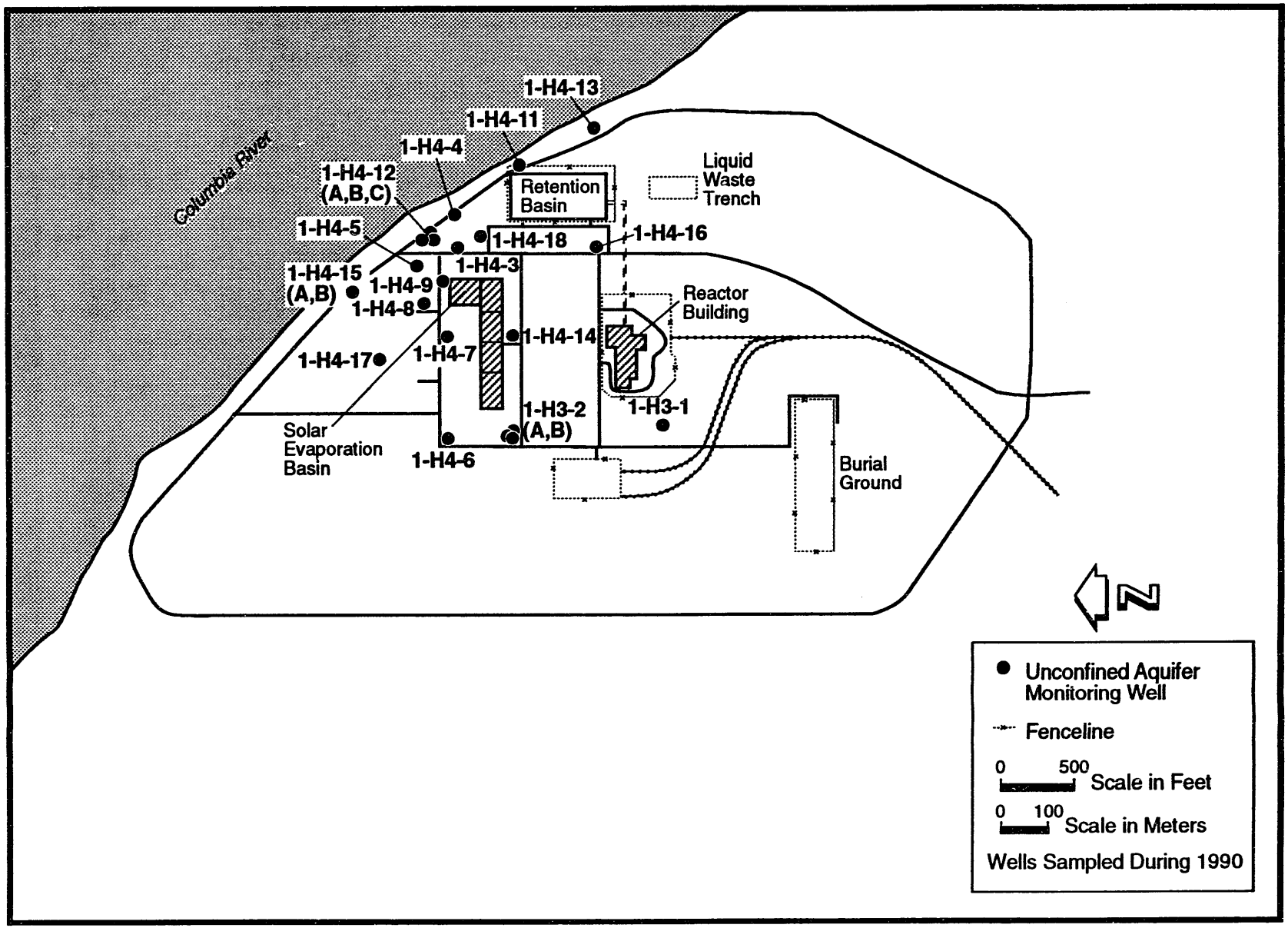

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FIGURE A.4. Well Location Map for the 100-H Area

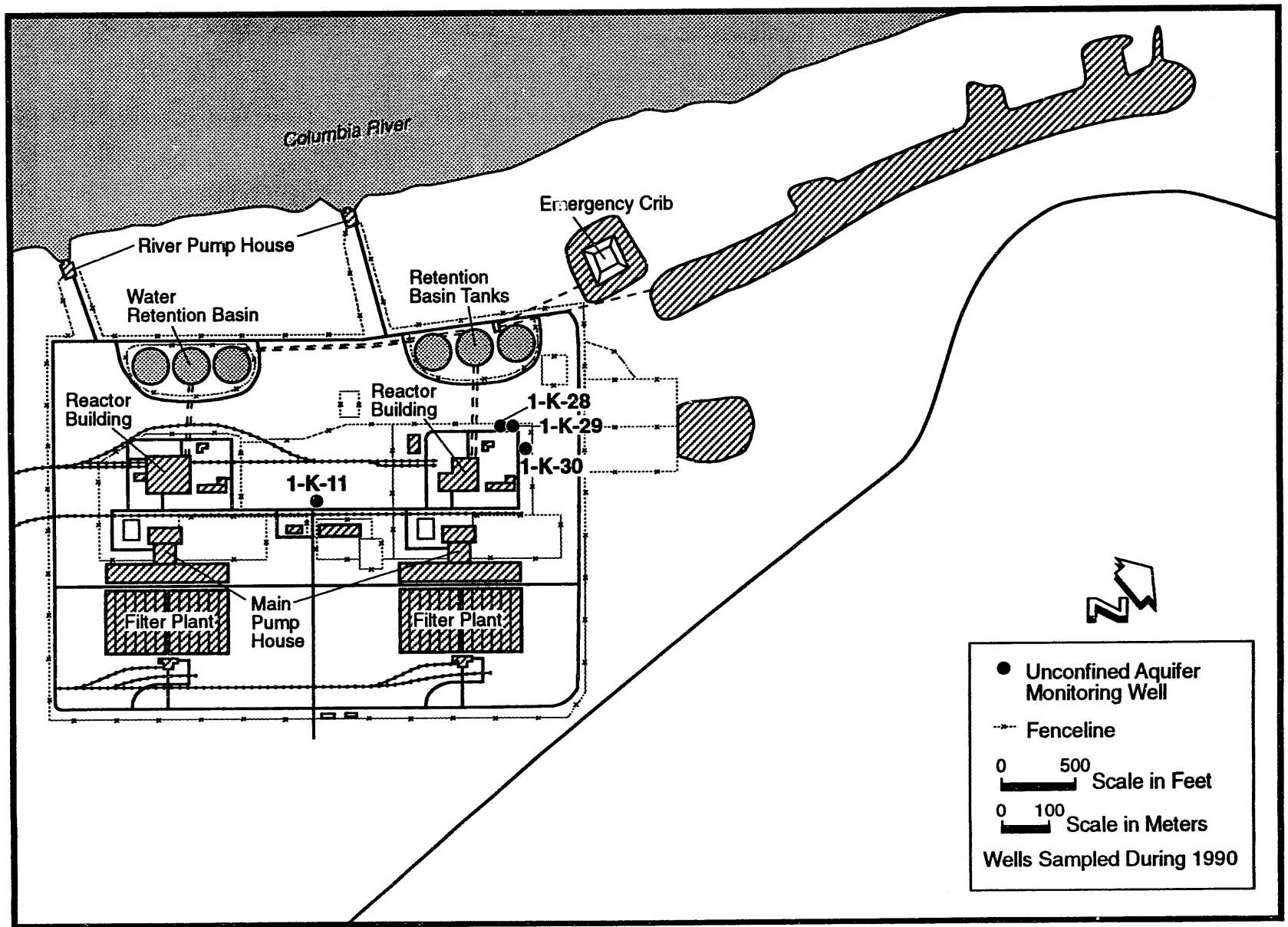
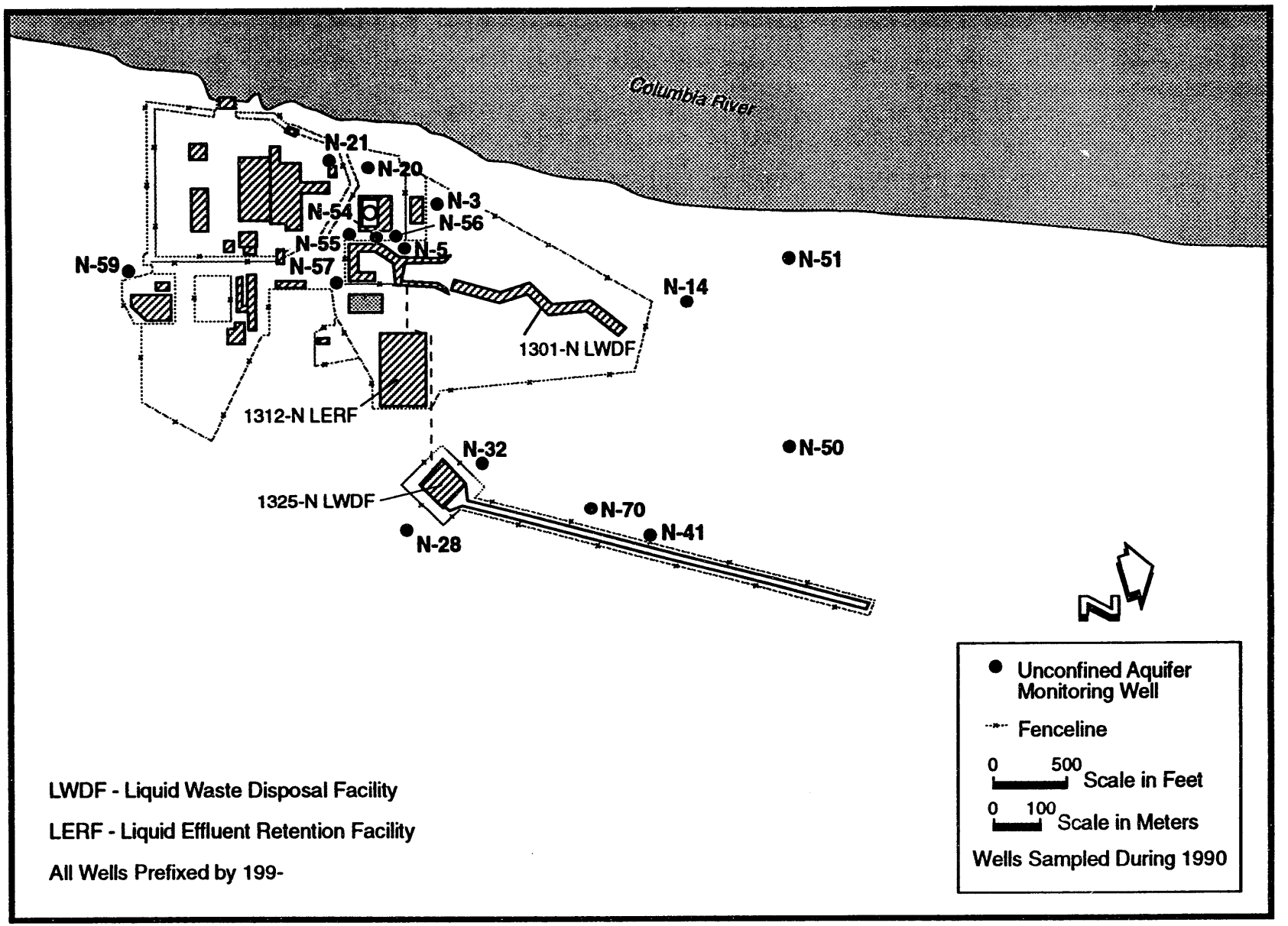


FIGURE A.5. Well Location Map for the 100-K Area



S9207031.14

FIGURE A.6. Well Location Map for the 100-N Area

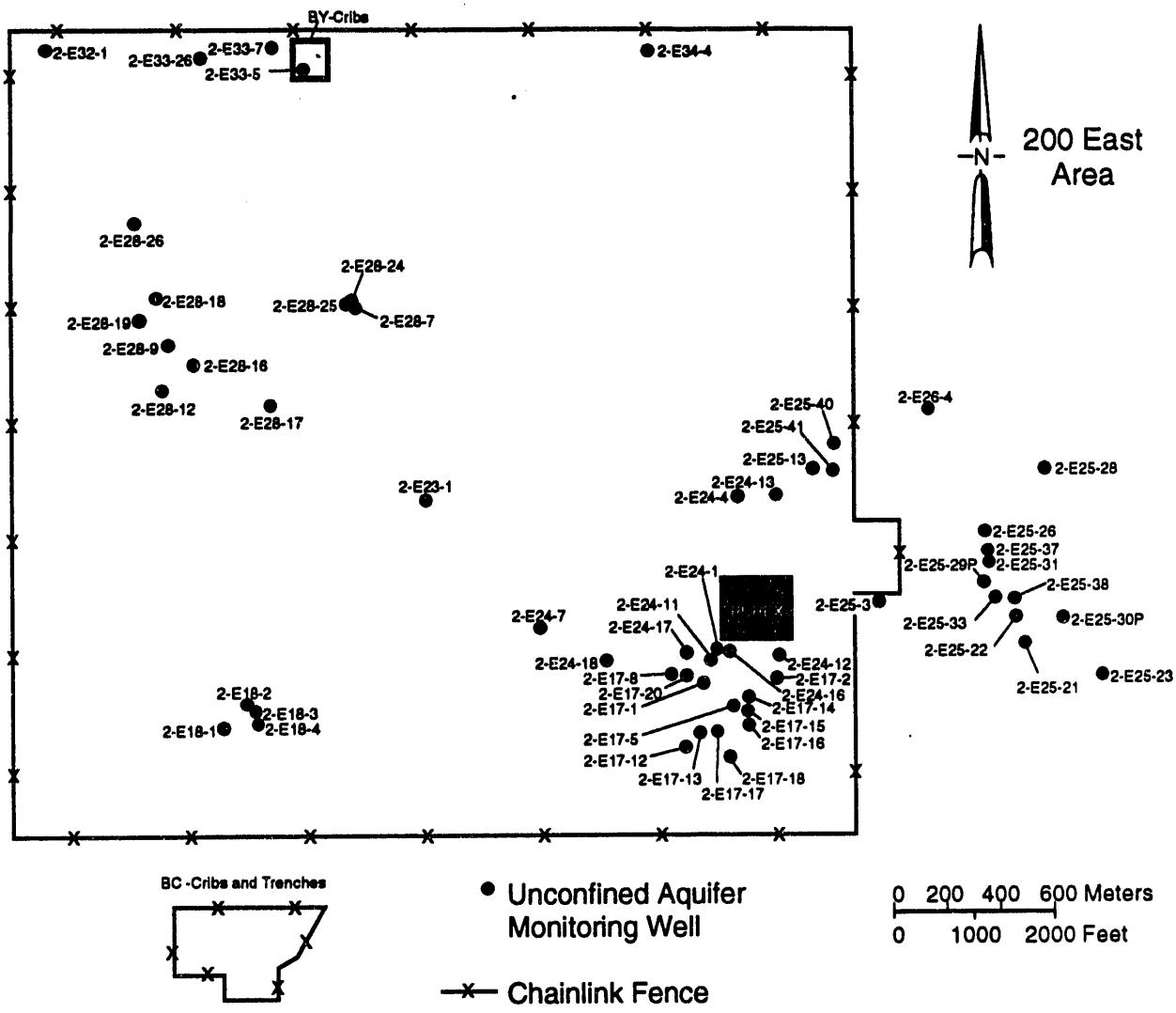


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FIGURE A.7. Well Location Map for the 200 East Area

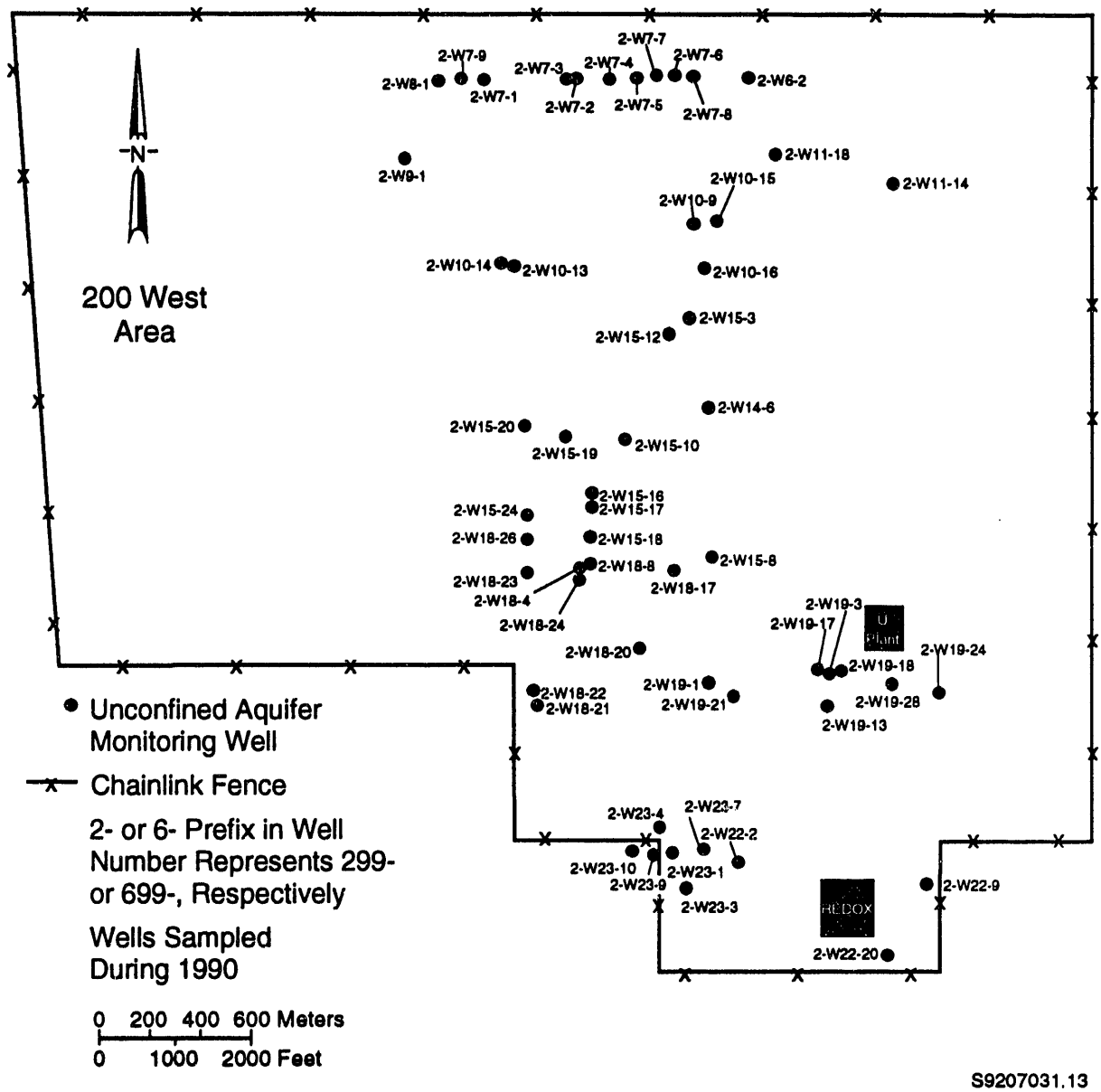

FIGURE A.8. Well Location Map for the 200 West Area

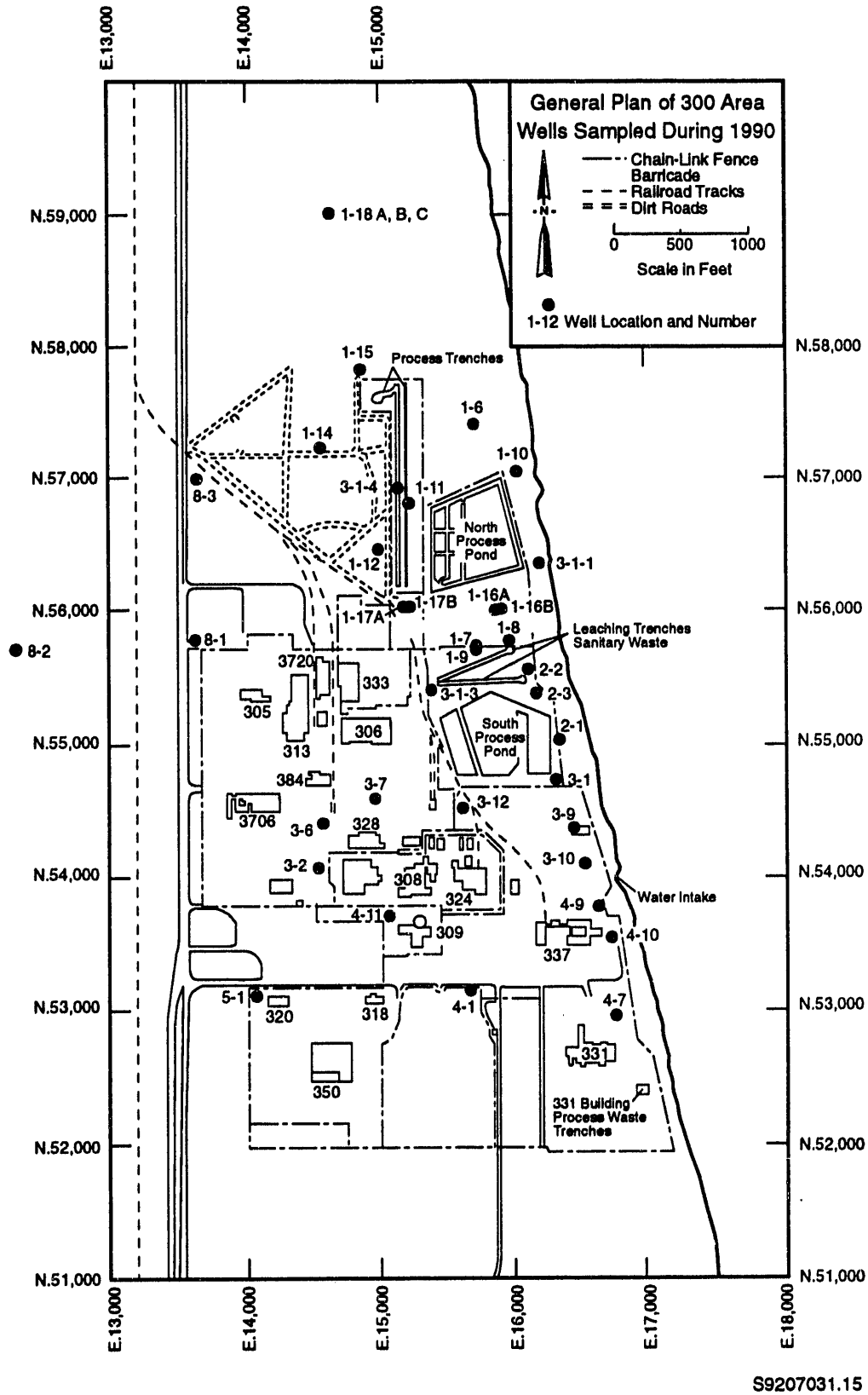

FIGURE A.9. General Plan of 300 Area

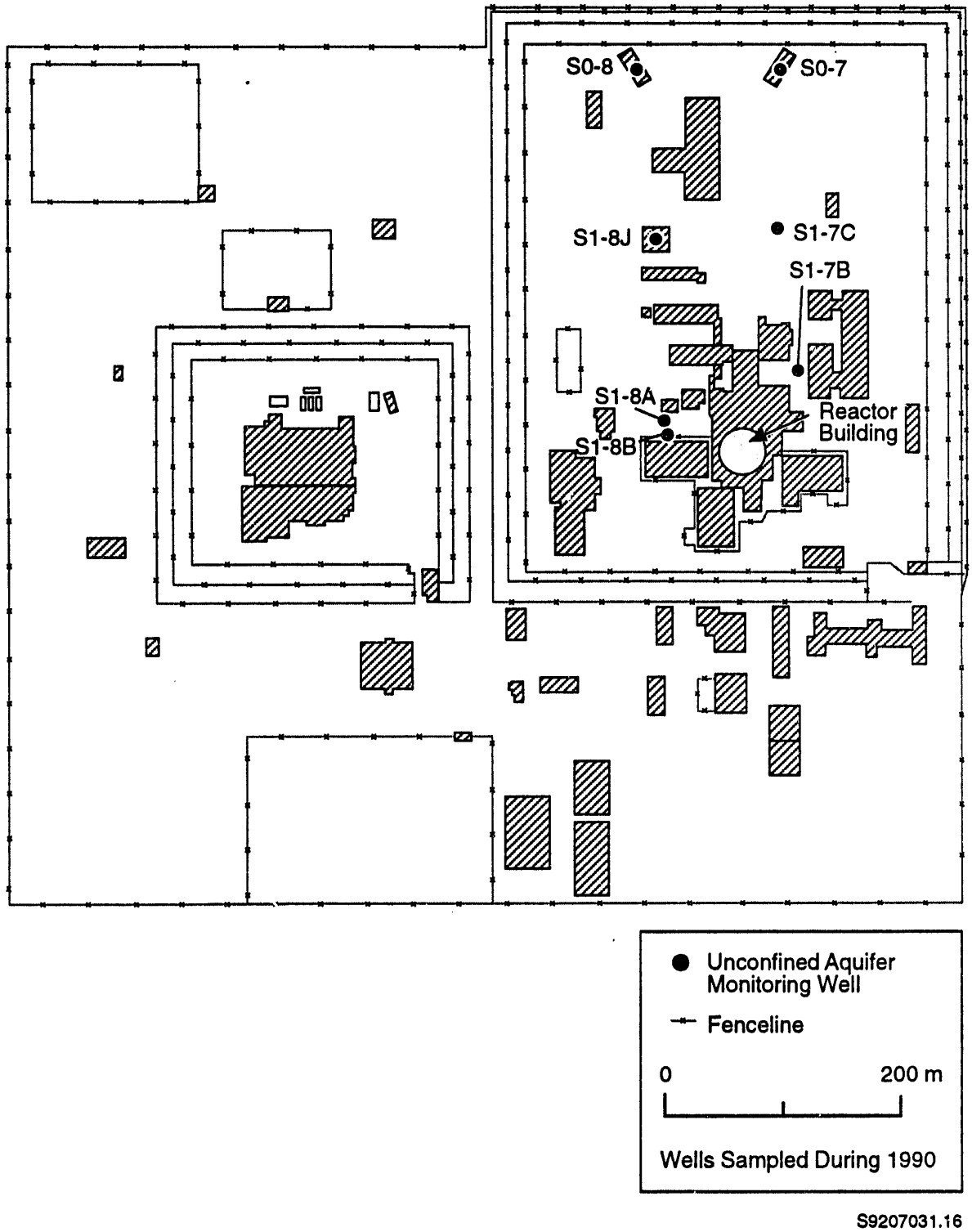

FIGURE A.10. Well Location Map for the 400 Area

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