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Hanford Sitewide Ground Water Remediation Strategy

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EXECUTIVE SUMMARY

This document fulfills the requirements of the *Hanford Federal Facility Agreement and Consent Order*, Milestone M-13-81[1], to develop a concise statement of strategy that describes how the Hanford Site ground water remediation will be accomplished. The strategy addresses objectives and goals, prioritization of activities, and technical approaches for ground water cleanup.

The strategy establishes that the overall goal of ground water remediation on the Hanford Site is to restore ground water to its beneficial uses in terms of protecting human health and the environment, and its use as a natural resource. The Hanford Future Site Uses Working Group[2] established two categories for ground water commensurate with various proposed land uses: (1) restricted use or access to ground water in the Central Plateau and in a buffer zone surrounding it; and (2) unrestricted use or access to ground water for all other areas.

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[1] Ecology, EPA, and DOE, 1992, *Hanford Federal Facility Agreement and Consent Order*, 2 vols., as amended, Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy, Olympia, Washington. Since the publication of the Draft of this document, DOE-RL has decided to incorporate and publish updates to the strategy in the annual "Hanford Site Ground Water Protection Management Plan" (DOE-RL-89-12). This strategy documents the baseline approach originally developed in 1994. Appendix A has been added to summarize major accomplishments and changes to the original approach as a convenience to the reader.

[2] Hanford Future Site Uses Working Group, 1992, *The Final Report of the Hanford Future Site Use Group.*

In recognition of the Hanford Future Site Uses Working Group and public values, the strategy establishes that the sitewide approach to ground water cleanup is to remediate[3] the major plumes found in the reactor areas that enter the reactor areas and to contain the spread and reduce[4] the mass of the major plumes found in the Central Plateau. Specifically, for the reactor areas, the following plumes are to be remediated: ^{90}Sr in the N Reactor area, and chromium in the 100-K, 100-D, and 100-H Reactor areas. In the Central Plateau, an approach of containment and mass reduction is taken for the organic contamination associated with Plutonium Finishing Plant past operations, the combined ^{99}Tc and uranium plumes associated with the Uranium-Trioxide Plant, and the combined ^{99}Tc and ^{60}Co plumes associated with the BY Cribs.

The approach to remediate each major plume is presented. Each approach is based on the general remediation principles to (1) define the extent of contamination, (2) identify and gain control of continuing sources of contamination, and (3) implement containment/remediation of the plumes. Major information needs were revealed, including the following: in the 100 Areas, the geographic extent of chromium contamination at the 100-D and 100-K Reactors, and the method to control the source of ^{90}Sr contamination at N Reactor; in the 200 West Area, the vertical distribution of organic, uranium, and ^{99}Tc contamination; and in the 200 East Area, the extent and source of ^{99}Tc and ^{60}Co contamination.

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[3] Ground water remediation refers to the reduction, elimination, or control of contaminants in the ground water or soil matrix to restore ground water to its intended beneficial use.

[4] Containment and mass reduction refers to controlling the movement of ground water contamination for the purpose of treatment.

A coordinating group is proposed to provide continuing direction, adjust priorities, and to respond to new information as it is developed. Cleanup is presented as a phased process consisting of expedited, interim, and final actions. Succeeding phases of remedial actions are oriented toward implementing the Record of Decision that, in turn, will satisfy broader cleanup objectives than found in the initial approach presented here.

The reduction of operations-derived liquid effluent to the soil is deemed an integral element of this document. Protecting the Columbia River, reducing the spread of contamination, maintaining a bias for action, and using available technology are all public values that are recognized in the strategy and incorporated into the approaches. Qualitative estimates of technical feasibility are incorporated into the remediation approach described for each plume.

Nitrate and tritium plumes contaminate wide areas of the aquifer under the Hanford Site. The strategy identifies the need for a detailed evaluation of practicable methods to reduce the flux of nitrate and tritium to the Columbia River.

Key regulatory issues must be resolved to accelerate remediation; e.g., criteria for discharging treated ground water back to the soil. This treated ground water, from which the primary contaminants have been removed, may still contain elevated levels of cocontaminants[5]. Additional

[5] Cocontaminant refers to those chemical species and radionuclides that are found in addition to the contaminants of primary concern.

treatment for cocontaminants is identified as a major factor in determining the scope and feasibility of many of the ground water cleanup projects on the Hanford Site.

Ground water remediation will affect portions of the existing monitoring well networks. These effects must be identified and resolved. Refinement of the existing monitoring networks and better coordination with the monitoring effort of the ground water remediation is needed to better define the extent of plumes, their movement, and the effect of cleanup on ground water contamination.

The strategy identifies the following areas of technology development that may significantly improve cleanup: barriers to flow, dense nonaqueous phase liquid identification and recovery, stabilization methods, and improved ion-specific water treatment methods. Furthermore, the strategy identifies the ^{90}Sr, ^{137}Cs, and plutonium contamination identified with the B-5 reverse well as an area for technology demonstration.

This remediation strategy is an integral part of the *Hanford Site Ground Water Protection Management Program*[6]. Coordination of ground water remediation within the broader Hanford Site program of ground water protection is necessary. Continuing the development and evaluation of contingency cleanup strategies is needed should the existing approaches prove infeasible.

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[6] DOE-RL, 1993, *Hanford Site Ground Water Protection Management Program*, DOE/RL-89-12, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington.

This strategy establishes an approach to remediation that emphasizes early and aggressive field programs while simultaneously collecting and evaluating information leading to a final Record of Decision. The approaches will be refined as the remediation proceeds and a record of the cleanup results develops. The development of site- and contaminant-specific ground water remediation goals and final remediation alternatives remains a product of risk assessment, technical feasibility, and cost considerations. The development of this information remains at the operable unit level.

Refinement of the strategy will be the responsibility of a U.S. Department of Energy, Richland Operations Office-chaired group consisting of both internal and external groups, including stakeholders who play a role in liquid effluent management and cleanup activities at the Hanford Site. The Environmental Restoration Contractor, with support from the Operations and Maintenance contractor for the U.S. Department of Energy, has the primary responsibility to carry out the strategy.

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ACRONYMS

ARAR	applicable or relevant and appropriate requirement
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
CFR	*Code of Federal Regulations*
DOE	U.S. Department of Energy
DWS	drinking water standard
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
ERA	expedited response action
ETF	Effluent Treatment Facility
FS	feasibility study
GPMP	*Hanford Site Ground water Protection Management Program*
HPPS	*Hanford Past Practice Strategy*
IRM	interim response measure
OU	operable unit
RA	remedial action
RCRA	*Resource Conservation and Recovery Act of 1976*
RI	remedial investigation
RL	U. S. Department of Energy, Richland Operations Office
ROD	Record of Decision
TEDF	Treated Effluent Disposal Facility
Tri-Party Agreement	*Hanford Federal Facility Agreement and Consent Order*
TSD	treatment, storage, and/or disposal
WAC	*Washington Administrative Code*

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1.0 INTRODUCTION

1.1 PURPOSE

This document establishes the basis for managing remediation of contaminated ground water at the Hanford Site. The strategy is an integral part of the refocused environmental restoration program. This document provides the following:

- Direction for developing sitewide cleanup objectives for ground water remediation
- A basis for informed decision making and future planning related to ground water remediation
- A means to prioritize cleanup actions to optimize technical, administrative, and financial resources for effective remediation of ground water
- A means for facilitating involvement of the stakeholders.

A sitewide perspective is used in describing the strategy. Contamination problems are discussed at a broad, geographic scale and reflect the major ground water issues facing the U.S. Department of Energy (DOE). Current stakeholder values, as well as existing *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) milestones are incorporated in the strategy (Ecology et al. 1989). Future ground water remediation milestones will be an outgrowth of this strategy. Key technical, institutional, and regulatory issues are identified.

This strategy provides direction to decisions affecting sitewide cleanup. Determination of operable unit (OU)-specific remediation goals (applicable or relevant and appropriate requirements [ARAR]) should reflect this strategy. However, interim and final remediation goals are site specific and will be developed at the OU level.

Since the publication of this document, DOE-RL has decided to incorporate and publish updates to the strategy in the annual "Hanford Site Ground Water Protection Management Plan" (DOE/RL-89-12). This strategy document now describes the baseline approach originally developed in 1994. An appendix has been incorporated that provides a status of the ground water remediation activities.

1.2 CONTEXT FOR STRATEGY DEVELOPMENT

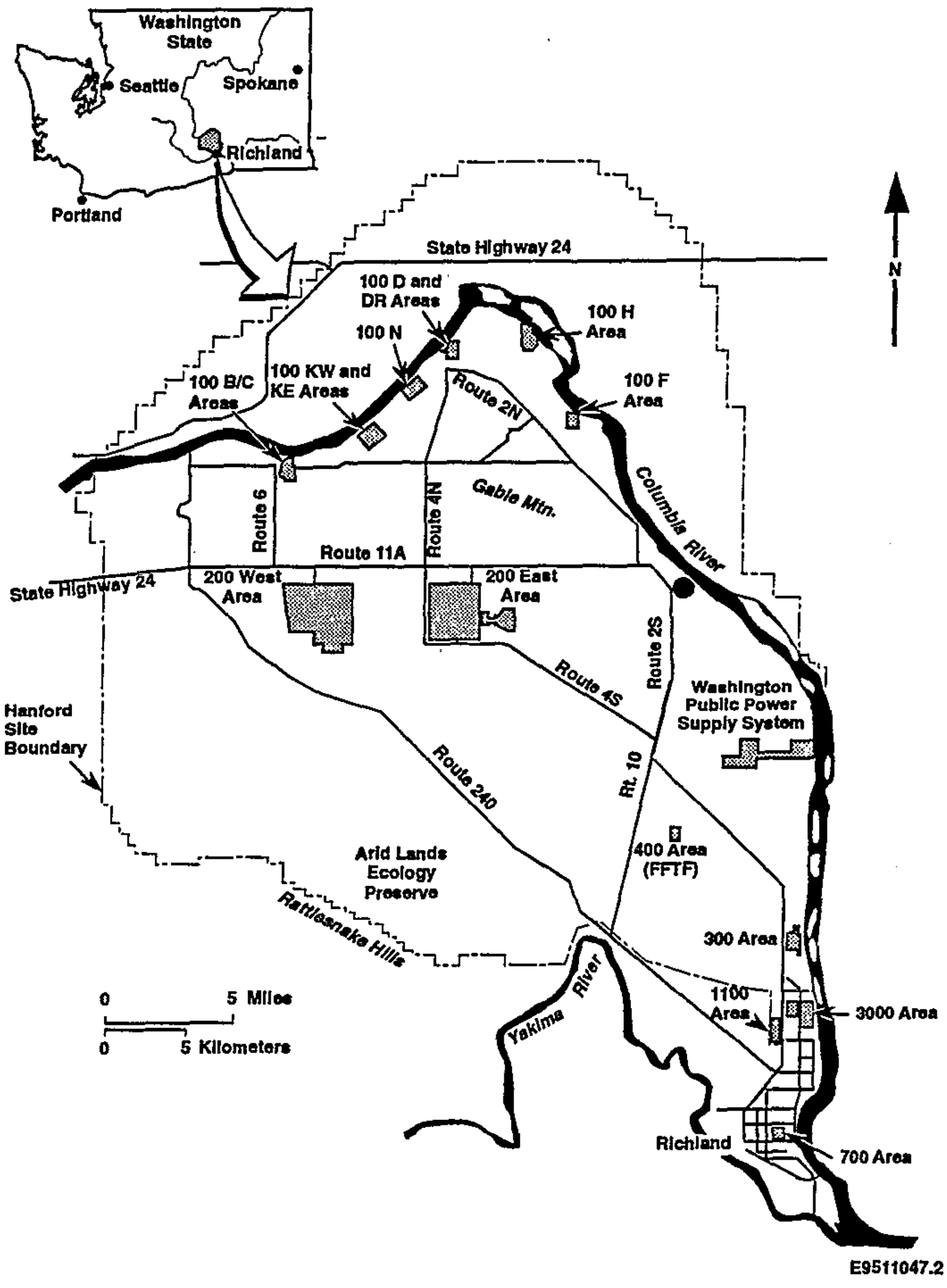
Over 220 km^2 (85 mi^2) of ground water beneath the 1,450-km^2 (560-mi^2) Hanford Site are contaminated by hazardous and radioactive waste to levels above federal drinking water standards (DWS) (40 *Code of Federal Regulations* [CFR] 141) and Washington State ground water quality criteria (*Washington Administrative Code* [WAC] 173-200). Restoring the ground water resource beneath the Hanford Site, reducing contaminant transport offsite via the ground water pathway, and understanding the risks posed by contamination, are all objectives of the environmental restoration program. Ground water remediation at the Hanford Site is likely to be a complex, long-term, and potentially costly endeavor.

Contamination affects a substantial volume of ground water, which ultimately discharges to the Columbia River. The public has expressed a high degree of interest in the consequences of this discharge, and the outcome of the efforts to protect this valuable resource. Cleanup control and direction are established under the Tri-Party Agreement (Ecology et al. 1989). This agreement between the DOE, the U.S. Environmental Protection Agency (EPA), and the Washington State Department of Ecology (Ecology) is legally binding for the DOE and is enforceable by the Ecology and the EPA.

The magnitude of the environmental restoration challenge is revealed by the number of hazardous waste sites. The Hanford Site has been subdivided into four subareas that are included on the National Priorities List (40 CFR 300, Appendix B) of hazardous waste sites. These subareas contain over 1,000 past practice sites as defined by either the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA), or the *Resource Conservation and Recovery Act of 1976* (RCRA). These sites have been grouped into over 75 OUs and 8 ground water OUs associated with geographic regions and specific facilities. A location map showing the commonly cited names of operational areas is presented in Figure 1-1.

As environmental restoration progresses from the assessment phase to active cleanup, it is essential to maintain a balanced and consistent approach. The large number of individual remediation decisions and cleanup activities poses a substantial challenge to the DOE, state and federal regulators, and the contractors performing the work. Furthermore, it is evident that the outcome of remediation for a particular OU may be dependent on actions taken at other OUs within the same ground water flow system. Thus, the need for a comprehensive, sitewide ground water remediation strategy has been recognized and included as Tri-Party Agreement Milestone (M-13-81) (Ecology et al. 1989). The milestone requires a concise, documented strategy that describes how ground water cleanup will be conducted at the Hanford Site. The strategy is to include objectives and goals, and the technical approaches to address each major plume.

Figure 1-1. Hanford Location Map.



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2.0 INSTITUTIONAL AND REGULATORY FRAMEWORK FOR REMEDIATING GROUND WATER

This chapter describes the institutional and regulatory framework in which ground water remediation is to be implemented under CERCLA. A unique process for applying CERCLA actions has evolved due to the complexity of administrating cleanup for the large number of individual OUs at the Hanford Site. Other important programs at the Hanford Site that have a bearing on ground water cleanup are also summarized in this section.

2.1 TRI-PARTY AGREEMENT

In May 1989, the EPA, Ecology, and DOE entered into an interagency agreement, the Tri-Party Agreement (Ecology et al. 1989). The Tri-Party Agreement provides the legal and procedural basis for cleanup and regulatory compliance at the numerous hazardous waste sites on the Hanford Site. It identifies timetables for waste cleanup and a series of "milestones" by which certain actions must be implemented or completed.

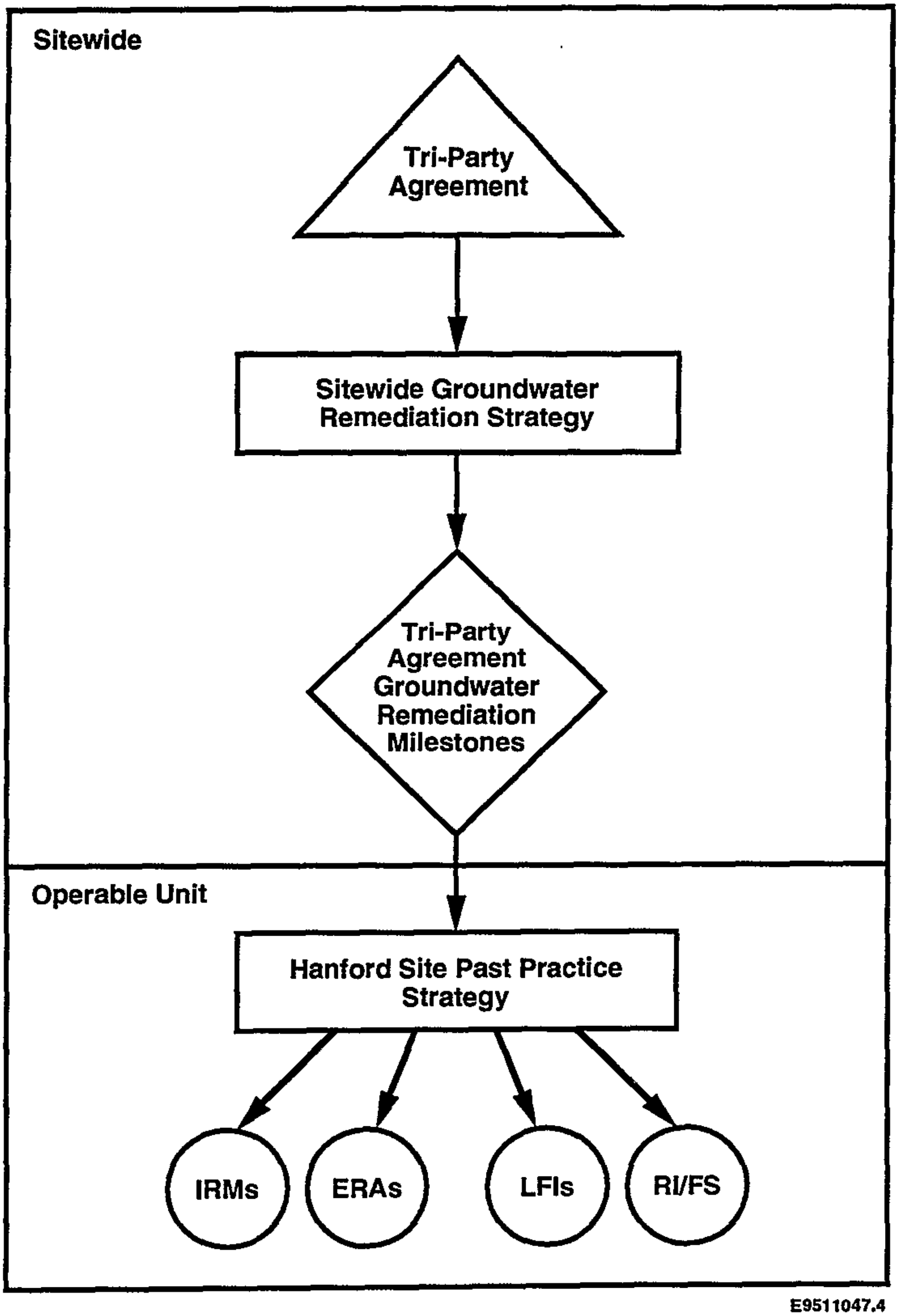
The Tri-Party Agreement coordinates two important regulatory programs: RCRA and CERCLA. The EPA has the lead role in administering CERCLA. Four subareas of the Hanford Site, the 100, 200, 300, and 1100 Areas, are included on the EPA's National Priorities List (40 CFR 300, Appendix B).

Ecology has the lead role in administering RCRA under provisions of Washington State's WAC 173-303, "Dangerous Waste Regulations." Under the Tri-Party Agreement, there are more than 50 RCRA treatment, storage, and/or disposal (TSD) units that will be closed or permitted to operate. Most of the TSDs are located within OUs.

2.2 APPLICABILITY OF SITEWIDE GROUND WATER REMEDIATION STRATEGY

This document provides a means of addressing issues of sitewide significance, and a broader perspective for planning remediation at the OU level. Future Tri-Party Agreement milestones will be developed on the basis of this strategy (Ecology et al. 1989). Decision making at the OU level is driven by regulations and should be compatible with the strategy outlined in this document. Figure 2-1 illustrates the relationship of the ground water remediation strategy to the *Hanford Past Practice Strategy* (HPPS) (Thompson 1991).

Figure 2-1. Relationship of the Sitewide Ground Water Remediation Strategy to the Hanford SitePast Practice Strategy.



2.3 CERCLA REMEDIAL INVESTIGATION/FEASIBILITY STUDY PROCESS FOR THE OPERABLE UNIT

Within this document, ground water remediation refers to those CERCLA restoration activities that return contaminated ground waters to their beneficial uses wherever practicable. Potential beneficial uses of ground water are (in part) dependent on the quality of the resource. In general, restoration cleanup levels in the CERCLA program are established by ARARs.

The CERCLA regulatory process typically involves establishing preliminary remediation goals for individual OUs, which are modified on the basis of the remedial investigation (RI) and feasibility study (FS). Preliminary remediation goals for OUs are based on readily available information and ARARs. Goals may be modified as characterization and cleanup activities are implemented. However, final remediation goals are determined when specific remedies are selected and a Record of Decision (ROD) is reached. Preliminary and final remediation goals are generally numeric and are set at the OU level.

A significant portion of the effort in reaching a ROD leading to implementing remedial actions (RA) occurs under the RI and FS process. The RI is a process to determine the nature and extent of the problem represented by the release. The RI emphasizes data collection and site characterization and is generally performed concurrently and in an interactive fashion with the FS. The RI includes sampling and monitoring, as necessary, and the gathering of sufficient information to determine the necessity for RA, and to support the evaluation of remedial alternatives. The RI and the FS are collectively referred to as the RI/FS.

An FS develops and evaluates options for RA. The FS emphasizes data analysis using data gathered during the RI. The RI data are used in the FS to define the objectives of the response action, to develop remedial alternatives, and to undertake an initial screening and detailed analysis of the alternatives. Each alternative (viable approach to an RA) is assessed with respect to the following set of evaluation criteria:

- Overall protection of human health and the environment
- Compliance with ARARs
- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, or volume through treatment
- Short-term effectiveness
- Implementability
- Cost
- State acceptance
- Community acceptance.

Risk assessment evaluations are also incorporated into the decision process at this time.

Once the RI/FS is completed, the EPA in conjunction with Ecology selects the appropriate cleanup option. This important step is documented by a ROD. Following the ROD, the remedial design is the technical analysis that follows selection of a remedy and results in detailed plans and specifications for implementation of the RA. An RA follows the remedial design and involves actual construction or implementation of a cleanup. A period of operation and maintenance may follow RA activities.

2.4 HANFORD PAST PRACTICE STRATEGY

The HPPS (Thompson 1991) was developed for the purpose of streamlining the past practice corrective action process. Although investigations and studies remain important for meeting long-term goals, a significant portion of the near-term funding resources can be dedicated to that remedial work for which there is sufficient information to plan and implement interim measures. The HPPS allows for the following:

- Accelerating decision making by maximizing the use of existing data
- Undertaking expedited response actions (ERA) or interim response measures (IRM), as appropriate to either remove threats to human health and welfare and the environment; or to reduce risk by reducing toxicity, mobility, or volume of contaminants.

There are three paths for decision making under the HPPS. A limited field investigation refers to the collection of limited additional site data that are sufficient to support a decision on conducting an ERA or an IRM. An ERA may be implemented for situations requiring an immediate onsite response action to abate a threat to human health or welfare or the environment. For situations in which extensive information may not be necessary to initiate some cleanup action, an IRM may be implemented before a final remediation action.

2.5 OTHER RELEVANT DOE PROGRAM ACTIVITIES

There are several other ongoing programs at the Hanford Site that relate to or affect ground water and are described in the following sections. Planning and implementation of CERCLA ground water remediation should be integrated with these other DOE program activities.

2.5.1 Ground Water Protection Management Plan

In accordance with DOE Order 5400.1, *General Environmental Protection Program* (DOE 1988a), the *Hanford Site Ground Water Protection Management Program* (GPMP) has been formulated (DOE-RL 1993c). The intent of this program is to protect the ground water resources of the Hanford Site. With several DOE programs (e.g., waste management, environmental protection, and environmental restoration) engaged in activities that affect ground water, there are circumstances where coordination of these programs is necessary to prevent duplication of effort, resolve potentially conflicting objectives, and make optimal use of resources.

In January 1994, a new Tri-Party Agreement milestone, M-13-81A, was negotiated (Ecology et al. 1994). This milestone stipulates the revision of the existing Hanford Site GPMP document (DOE-RL 1993c) to incorporate cleanup goals, Tri-Party Agreement requirements concerning discharge to the ground, ground water withdrawal and treatment, and the treatment of liquid effluent discharged to the soil column. This document will be an integral part of the GPMP defining the approach to address current ground water contamination problems. The revised GPMP will be used to coordinate these efforts and to manage Hanford Site ground water resources. This will widen the purview of the document, which will serve as a vehicle for coordinating issues that cross institutional and regulatory program boundaries.

2.5.2 RCRA Waste Management Facilities

Under the direction of DOE, the U.S. Department of Energy, Richland Operations Office (RL), there also is a major effort to comply with EPA and state regulatory requirements at TSD units. The RCRA program involves application for permits to operate regulated TSD units, compliance monitoring of ground water to detect and assess possible contamination from the TSD units, and corrective measures including development of TSD closure plans and cleanup actions. Ground water monitoring at a TSD facility is designed to distinguish upgradient ground water conditions from conditions downgradient of the TSD (Geosciences 1994). Ground water remediation activities that involve pumping and reintroducing treated ground water will affect ground water flow and quality, and will have significant impacts on portions of the RCRA monitoring program. These impacts need to be identified and resolved.

2.5.3 Liquid Effluent Program

In December 1991, Ecology and DOE signed Consent Order No. DE 91NM-177, also known as the Liquid Effluent Consent Order. The Consent Order, together with Tri-Party Agreement Milestone M-17-00, commits the DOE to an aggressive schedule for completion of effluent disposal facility upgrades and to secure permits. Under this order, permits administered for WAC 173-216, "State Waste Discharge Permit Program" requirements are applicable to certain liquid effluent streams (Ecology and DOE 1992). The Permit (WAC 173-216) requires best available technology or all known and reasonable methods of prevention, control, and treatment for those waste streams. As directed by Ecology and DOE (1992) and the Tri-Party Agreement (Ecology et al. 1989), for interim compliance purposes, ground water impact assessments were performed for a number of effluent disposal facilities (Tyler 1991). Most of these disposal facilities are also located in CERCLA OUs.

Under RL, a liquid effluent program is being conducted to bring facilities that discharge liquid effluent into compliance with environmental regulations. The focus is to reduce liquid effluent volumes generated, expand and improve treatment capacities, and to cease discharge of contaminated effluent to the ground. These efforts to reduce effluent discharges will lead to reducing the rate of spread of many contaminants, most notably beneath the 200 West Area.

RL has constructed the 200 Areas Effluent Treatment Facility (ETF) to provide effluent treatment and disposal capability for the Central Plateau. The initial mission of the 200 Areas ETF (Project C-018H) is to provide treatment of process condensate from the 242-A Evaporator. Treated effluent from the 200 Areas ETF will be disposed to a crib-type discharge facility called the State-Approved Land Disposal Site, which is being constructed north of the 200 West Area. A second liquid effluent program project, the 200 Areas Treated Effluent Disposal Facility (TEDF) (Project W-049H), will provide a network of piping in both the 200 East and 200 West Areas. The 200 Areas TEDF will discharge the treated effluent to a new pond located in the 200 East Area.

Disposal of treated effluent from these facilities to the ground will likely result in some localized changes in ground water flow directions. Of greater significance to ground water remediation is the presence of potentially high concentrations (maximum 6,000,000 pCi/L of tritiated water in the treated effluent to be disposed to the soil column from the 200 Areas ETF. Tritium cannot be practically removed by treatment (DOE-RL 1994). This will result in the introduction of a new tritium contaminant plume to the unconfined aquifer.

2.5.4 Operational and Sitewide Monitoring

Operational ground water monitoring and sitewide surveillance monitoring of ground water have been conducted by the DOE for a number of years. Operational monitoring is oriented toward evaluating the effects of operational facilities (mostly related to liquid effluent disposal) on "near-field" ground water conditions, but also examines resultant sitewide effects of operations (Johnson 1993). The sitewide program is a broad monitoring effort primarily oriented toward evaluating "far-field" sitewide conditions and offsite exposure to Hanford Site activities (Woodruff and Hanff 1993).

2.5.5 Hanford Remedial Action Environmental Impact Statement

The DOE has interpreted the *National Environmental Policy Act of 1969* requirements to be applicable to environmental restoration program activities. The Hanford Remedial Action Environmental Impact Statement is being prepared and will examine remediation alternatives and decisions germane to overall cleanup of the Hanford Site.

2.6 REGULATORY OVERLAP

Several federal and state regulations are applicable to activities affecting ground water. Because these regulations are applied to facilities and activities often situated in the same location, there are overlapping regulatory programs with potentially conflicting requirements and conditions to be satisfied. Some of the issues raised by this overlap of regulatory programs are described below:

- Liquid effluent disposed under a WAC 173-216 permit (Washington State regulation used to permit liquid discharges to surface and/or ground water) may affect ground water quality or movement in a manner that is incompatible with CERCLA remediation objectives. For example, the 200 Areas ETF (Project C-018H) will dispose treated waste containing tritiated effluent to a proposed State-Approved Land Disposal Site and, as a result, there will be a new tritium plume contaminating the unconfined aquifer.

- RCRA "derived-from" and "mixture" rules for listed waste as administered by Ecology under WAC 173-303 could result in additional regulatory requirements for CERCLA cleanup actions. This would delay the start of remediation efforts if substantive requirements of RCRA are imposed.

Effective and expedient implementation of ground water remediation depends on clarification and resolution of potentially conflicting regulatory issues.

2.7 CERCLA MONITORING NETWORK

Existing Hanford Site monitoring networks were not designed to meet the needs of the environmental restoration mission. RCRA and operational monitoring networks, and CERCLA ground water investigations are typically designed to evaluate ground water conditions at individual facilities or in a limited geographic area. Implementing multiple, concurrent ground water remediation efforts will affect large areas and impact many of the localized networks, significantly reducing their effectiveness.

To support the refocused environmental restoration program, it is recommended that a CERCLA monitoring network be developed based mostly on existing wells that address the following:

1. The effectiveness of RAs
2. The movement of plumes
3. Early notification of increasing contamination
4. Compliance with selected standards in areas away from the plumes.

RCRA-related and other ground water monitoring programs would not be compromised. Coordination of ground water data collection among the systems is required to maintain an efficient, cost-effective operation.

To better align with the regulatory framework of remediation, the CERCLA network should consist of four categories of monitoring wells:

- Treatability test monitoring wells
- RA assessment wells
- Plume periphery monitoring wells
- Compliance monitoring wells.

A remediation effort would include wells that fit each category; e.g., nesting from centers of highest contaminant concentrations (treatability test and RA wells), to lower concentration (plumes periphery wells), to areas of no contamination (compliance wells). The area of coverage for each well category, sampling, and reporting requirements would be established to meet the objectives of the well category.

The strategy recommends development of a compliance monitoring network that would surround the Central Plateau. Figure 4-3 shows an approximate location for such a network. This recommended boundary closely approximates the Hanford Future Site Uses Working Group's waste management area boundary for the Central Plateau. Sufficient wells currently exist to implement such a network.

3.0 STAKEHOLDER VALUES TO GUIDE REMEDIATION

Successful remediation of ground water necessitates public, tribal, and regulatory acceptance of both the process and outcome. That acceptance is more likely to occur when an informed public is provided meaningful opportunities to participate in the process and help determine the outcome. This strategy was developed with recognition that stakeholder values should shape cleanup objectives and aid in prioritizing the sequence of cleanup actions. While there is a great diversity of viewpoints among the stakeholders in cleanup of the Hanford Site, there are values shared by many that may serve as themes for building consensus and providing direction to ground water remediation. It is necessary to have a vision for what must be accomplished in the cleanup of the Hanford Site. The desired future uses for the land and resources of the Hanford Site provide the basis for determining the goals of environmental restoration. This section presents stakeholder values and describes proposed future uses of the Hanford Site.

3.1 VALUES

Values to guide ground water remediation are based on comments and statements expressed by the public, Indian Tribal Nations, and stakeholders in a variety of public forums. Initial information for this section was derived primarily from public commentary to recent revisions of Tri-Party Agreement milestones (Ecology et al. 1989), from Hanford Site cleanup stakeholders and Indian Tribal Nations that participated in the Future Site Use Working Group (Hanford Future Site Uses Working Group 1992), and the Hanford Tank Waste Task Force (Tank Waste Task Force 1993). Subsequent refinement of this document will incorporate, as appropriate, public and Indian Tribal Nation perspectives expressed during workshops for ground water remediation and the Hanford Advisory Board perspectives.

Commonly held values to guide ground water remediation are as follows:

- Protect human health, worker safety, and the environment
- Protect the Columbia River
- Use available technology and start remediation
- Develop new technologies to clean up contaminants less amenable to remediation with available technologies
- Reduce the mobility, toxicity, and quantity of ground water contaminants
- Do nothing to make ground water protection and remediation efforts less effective

- Comply with applicable federal, state, and local laws/regulations, and Indian Tribal Nation treaty rights
- Eliminate the disposal of liquid waste to the soil column
- Clean up ground water on a geographic basis, to the level necessary to enable the future land use option to occur
- Facilitate the efforts by DOE to relinquish control of parts of the Hanford Site
- Use funding wisely and effectively
- Minimize the amount of land area that will be impacted by waste management efforts
- Reintroduce treated and partially treated ground water to the aquifer only in areas already contaminated.

3.2 EXTENT OF CLEANUP TO ENABLE FUTURE USES

For the purpose of identifying a range of potential future uses for the Hanford Site, the Future Site Use Working Group was convened (Hanford Future Site Uses Working Group 1992). The group was composed of representatives from relevant federal, Indian Tribal Nations, state, and local governments, as well as representatives from constituencies for labor, environmental, agricultural, economic development, and citizen interest groups, all with an interest in the cleanup and future uses of the Hanford Site. Generic proposals for how an area of the site might be used in the future, called "future use options" were developed. The following types of future use options were considered:

- Agriculture
- Wildlife
- Indian Tribal Nation (Native American) uses
- Industry
- Waste management
- Research/office
- Recreational/related commercial
- Recreation.

In devising cleanup scenarios for the various future use options, the group addressed the issue of "how clean is clean" in general, nonregulatory terms. Cleanup scenarios identify distinct levels of access necessary to allow various future land use options, which are based on the presence of contamination to the air, surface, subsurface, and ground water. Potential beneficial uses for ground water are therein linked to future use options. The following levels of access have been defined by the group:

- Exclusive--an area where access is restricted to personnel who are trained and monitored for working with radioactive or hazardous materials
- Buffer--the part of the Hanford Site that surrounds an exclusive area. It is treated like an exclusive area because of potential risks from the exclusive area, in which environmental restoration activities (but not waste management area activities) may occur
- Restricted--an area where access is limited because of contamination, with the exception that the ground water may be restricted on an interim basis and ultimately cleaned up to unrestricted status
- Unrestricted--an area where there is no access restriction.

3.3 CLEANUP SCENARIOS AND PRIORITIES

The Future Site Use Working Group devised cleanup scenarios for six geographic study areas (Figure 3-1). The group then recommended general priorities or criteria that could be considered for focusing cleanup activities. Cleanup scenarios relevant to ground water remediation are presented in the following sections.

3.3.1 Reactors on the Columbia River

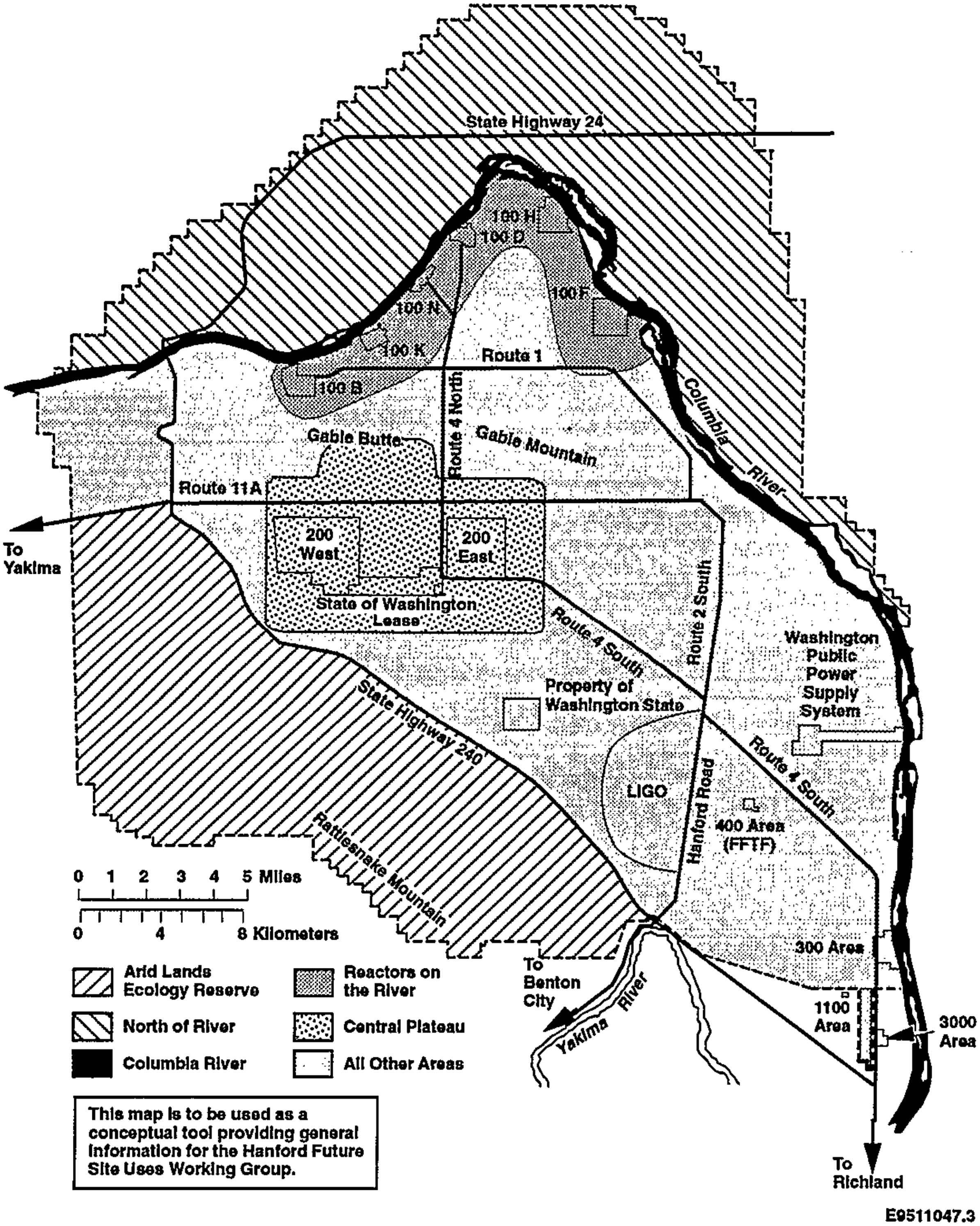
The Reactors on the Columbia River area is an aggregation of all 100 Areas OUs and includes reactors and associated facilities within a 68.8-km^2 (26.6-mi^2) area. For all cleanup scenarios, ground water would be remediated to an unrestricted status for the entire area. Cleaning up flows of contaminated ground water to the Columbia River is the most immediate and highest priority. Both the Hanford Advisory Board and the Hanford Future Site Uses Working Group have established this area as a priority for cleanup activities. The following specific areas are identified as the most important for cleanup of ground water:

- 100-N Reactor area with associated springs and seeps
- 100-K Basins
- Ground water contamination flowing into the Columbia River.

3.3.2 Central Plateau

The Central Plateau encompasses approximately 116 km^2 (45 mi^2) at the center of the Hanford Site, and includes the 200 East and 200 West Areas and an area informally known as the 200 North Area. The cleanup scenario for the Central Plateau assumes that future use of the

Figure 3-1. Hanford Future Site Uses Geographic Areas.



surface, subsurface, and ground water in and immediately surrounding the Central Plateau would be an exclusive waste management area. Surrounding the exclusive area would be a temporary surface and subsurface buffer zone to reduce risks associated with ongoing activities in the Central Plateau. Environmental restoration, but not waste management activities, would occur in the buffer zone to clean up existing contamination. The cleanup target for the buffer zone is to remediate and restore contaminated areas (including ground water) for ultimate availability for unrestricted use.

For the exclusive zone, the cleanup target is to reduce risk outside the zone sufficient to minimize the size of the buffer zone or restrictions posed by contaminants coming from the Central Plateau. Periodically, the size of the buffer zone would be decreased commensurate to the decrease in risks associated with waste management activities. It is important that cleanup efforts seek to prevent the spread of ground water contaminants to other areas of the Hanford Site. Localized ground water cleanup within the Central Plateau should be quickly pursued for those actions that prevent the migration of contamination. In the foreseeable future, the waste management area would remain an exclusive zone. Depending on technical capabilities, it is desirable to ultimately achieve cleanup sufficient to allow future uses other than waste management.

3.3.3 Columbia River

A total of 82 km (51 mi) of the Columbia River flow through or border the Hanford Site. Cleanup of contaminated ground water that discharges into the Columbia River is an immediate priority. Cleanup of sediments in the Columbia River or of contaminants in the riparian zone should be undertaken only if the cleanup can occur without causing more harm than good. There should be no dam construction or dredging in the Hanford Reach. Class A water quality should be maintained over the long term, with reasonable efforts to improve the water quality over time.

3.3.4 North of the River

The "North of the River" (Wahluke Slope) subarea refers to 363 km^2 (140 mi^2) of land north of the Columbia River that is relatively undisturbed or is returning to shrub-steppe habitat. Potential uses of the subarea North of the River would be unrestricted and would not be constrained by the presence of contamination on the surface or in the ground water. It is assumed that cleanup can be performed relatively quickly and at a low cost using existing technology; i.e., cleanup could begin immediately. This priority for early cleanup should not detract from cleaning up areas that pose an imminent health risk. It was also assumed that cleanup costs for this area are a relatively small percentage of the overall cleanup budget. Early cleanup would allow conversion of the site to future use options and show tangible progress in cleanup.

3.3.5 Arid Lands Ecology Reserve

The Arid Lands Ecology Reserve is 311 km^2 (120 mi^2) of a relatively undisturbed habitat/wildlife reserve south of Highway 240 and west of the Yakima River. Use of ground water would be restricted where ground water is contaminated or where withdrawal of ground water would spread contamination. No future use options for the Arid Lands Ecology Reserve require the use of the ground water beneath that area. Following DOE direction, cleanup of the Arid Lands Ecology Reserve has been completed.

3.3.6 All Other Areas

This geographic area of 627 km^2 (242 mi^2), incorporates the 300, 400, and 1100 Areas, and all of the Hanford Site not included in the five other geographic areas described by the group. Future use options defined for "all other areas" assume no migration of contaminants from the Central Plateau, except existing ground water plumes. Key cleanup priorities would be threats to drinking water supply well fields and areas where there is existing public access to the river. Where cleanup activities would threaten wildlife species and/or habitat, the benefits of ground water remediation should be compared to the potential harm. The guiding principle is to "do no harm."

Two cleanup scenarios were proposed. For one scenario, ground water beneath the 1100 Area would be unrestricted, because of the proximity to the city of Richland's water supply well fields and residential areas. Elsewhere, ground water use would be restricted where it is contaminated or where withdrawal of ground water would spread contamination.

The second scenario suggests that access to ground water within the 300 Area should be restricted and the other areas remediated to unrestricted status. Within 100 years, after which it is assumed that there would no longer be institutional controls, the entire geographic unit should be restored to attain unrestricted status.

4.0 CONTAMINANT HYDROGEOLOGY

This section presents the geologic and hydrologic features that control the direction and rate of ground water flow. The major plumes on the Hanford Site are tabulated and described relative to the quantity and extent of contaminants. Distribution patterns are also discussed. A detailed description of Hanford Site geology and hydrology is provided in DOE-RL 1993c and Johnson 1993.

The physical, chemical, and hydraulic characteristics of stratigraphic units determine contaminant flowpaths and migration rates. These features also influence the capability to intercept and remediate a contaminant plume. Knowing these characteristics, along with a history of wastewater disposal, the basis for selecting appropriate methods to remediate ground water and/or restrict the spread of contamination is formed.

4.1 HYDROLOGIC CHARACTERISTICS

The Hanford Site is located in the Pasco Basin, a broad sediment-filled depression that lies within the larger Columbia Basin physiographic province. The Hanford Site is noted for its thick sedimentary fill, wide areal variability in water and contaminant movement, deep unconfined aquifer, and limited natural recharge to the aquifers.

4.1.1 Vadose Zone

The soil column above the water table is dominated by unconsolidated sandy gravels (Hanford formation) that were deposited during glacial activity during the last one million years. These sediments are highly transmissive to water. The downward movement of moisture is slowed wherever fine-textured soils or sediments occur. In the eastern side of the Hanford Site, the water table resides in these sediments. Evapotranspiration prevents most of the precipitation from reaching ground water. The thickness of the vadose zone ranges from 0 m (0 ft) near the Columbia River to over 106 m (348 ft) in the south-central portion of the Hanford Site (Dirkes 1994)

The stratigraphy above the water table in the Central Plateau and other areas has a profound influence on the movement of liquid effluent through the soil column beneath many waste disposal sites. Layers of fine-textured sediment slow the downward movement of water, resulting in saturated water zones above and separated from the top of the unconfined aquifer ("perched" water zones). This condition expands the source area beyond the physical dimensions of a disposal facility. It also significantly influences the time required for contaminants to reach the water table. Extended drainage periods may persist following termination of wastewater disposal operations. The interplay between stratigraphy and disposal operations is an important element in planning ground water remediation.

4.1.2 Aquifers

The unconfined aquifer generally occurs in unconsolidated to semi-consolidated silts, sands, and gravels of the Ringold Formation. These sediments were deposited by the Columbia River as it meandered across the central Pasco Basin during the past several million years. The Ringold Formation is less transmissive to water than Hanford Site sediments. Ground water flow rates are highly variable due to aquifer heterogeneity, but generally range from less than 0.30 m/day (1 ft/day) to several meters/day (feet/day) (Freshley and Graham 1988). The highest rates are in the unconsolidated gravelly sands of the Hanford formation, and similar deposits in the Ringold Formation. The aquifer ranges in saturated thickness from 0 m (0 ft) near the margins of the Pasco Basin to approximately 60 m (197 ft) near the center of the Basin (DOE-RL 1994b).

Underlying the Ringold Formation are the Columbia River Basalts, which are extensive layers of flood basalt. The basalts contain numerous confined aquifers, some of which are regional water sources. Vertical movement of water between aquifers may occur along fractures or faults in some areas (Early et al. 1988).

4.1.3 Aquifer Recharge

Both natural and artificial sources of water recharge the aquifers within the Pasco Basin. The most significant volume source is irrigation water from the Columbia Basin Project, although the influence is limited to the area north of the Columbia River, because the river acts as a ground water flow divide for the unconfined aquifer.

Irrigation in the upper Cold Creek valley to the west of the Hanford Site may contribute a portion of the recharge to the unconfined aquifer beneath the Central Plateau. The volume of recharge is uncertain, because much of the irrigation water is lost to evaporation. Artificial recharge caused by Hanford Site operations historically has produced major ground water mounds in the 200 East and 200 West Areas. The reduction or cessation of waste disposal has resulted in declines in water table elevations across much of the 200 Areas. The disappearance of mounds and changes in water table elevations have changed contaminant plume characteristics. At the southern end of the Hanford Site, the city of Richland maintains a ground water storage "reservoir" that creates a ground water mound, which influences ground water flow directions in the 1100 Area.

4.1.4 River/Ground Water Interaction

The interaction between the Hanford Site aquifer and the Columbia River is an important element in assessing contaminant impacts on the river system. River water moves in and out of the banks during daily stage fluctuations, causing variable water quality characteristics in shoreline monitoring wells. Also, the interface zone between the river and the aquifer has characteristics that may retard or modify contaminants being transported by ground water (Peterson and Johnson 1992).

4.1.5 Direction and Rate of Ground Water Movement

Contaminant plumes move in directions that are approximately perpendicular to the water table elevation contours. Plume maps that represent typical chemical and radiological waste indicators are shown in Figures 4-1 and 4-2. During the operating history, changes in the volume of liquid waste disposed to the soil column have changed the shape of the water table, resulting in alterations to migration patterns.

In the 100 Areas, the rate of flow toward the Columbia River is variable, ranging up to 4.6 m/day (15 ft/day). The rate is strongly influenced by river stage within several hundred meters of the shoreline. During extended periods of high river stage, flow is temporarily inland from the river, resulting in bank storage of Columbia River water. An upward hydraulic gradient is often present from deeper, confined aquifers, which works against downward migration of contamination.

On the Central Plateau, average rates of movement in the upper unconfined aquifer are about 0.15 m/day (0.5 ft/day) in the 200 West Area and 0.3 to 0.61 m/day (1 to 2 ft/day) elsewhere; however, locally flow rates may reach as high as 6 m/day (20 ft/day). Flow rates in the confined aquifers are much slower (<0.003 m/day [<0.01 ft/day]). The potential for downward vertical movement of ground water from the unconfined aquifer into the upper confined system in some areas beneath the Central Plateau exists, as revealed by the decrease in hydraulic head with depth (Johnson et al. 1993).

Ground water monitoring results indicate the occurrence of mobile (^{129}I and ^{99}Tc) contaminants in the confined aquifers (Early et al. 1988). This occurs where natural, fracture-controlled inter-communication exists (e.g., Gable Gap area) and where preferential pathways may have been created due to unsealed wells connecting upper and lower aquifer systems (e.g., old wells drilled into the upper basalt aquifers near waste disposal sites). Where contaminants have reached the confined system, the areal extent or movement is currently assumed to be very limited as compared to the upper unconfined aquifer where most of the ground water contamination occurs. Limited information in the confined aquifer is available to evaluate this assumption at the present time.

Marked variations in permeability occur within the unconfined aquifer, especially in the 200 West Area. Variable cementing of the aquifer sediments accounts for most of the differential permeability in the 200 West Area. Within the 200 East Area, the major source of variability is whether the water table is located within the Ringold Formation or the more permeable Hanford formation.

Figure 4-1. Areal Distribution of Chemical Contaminants in Relation to Current Water Table Contours.

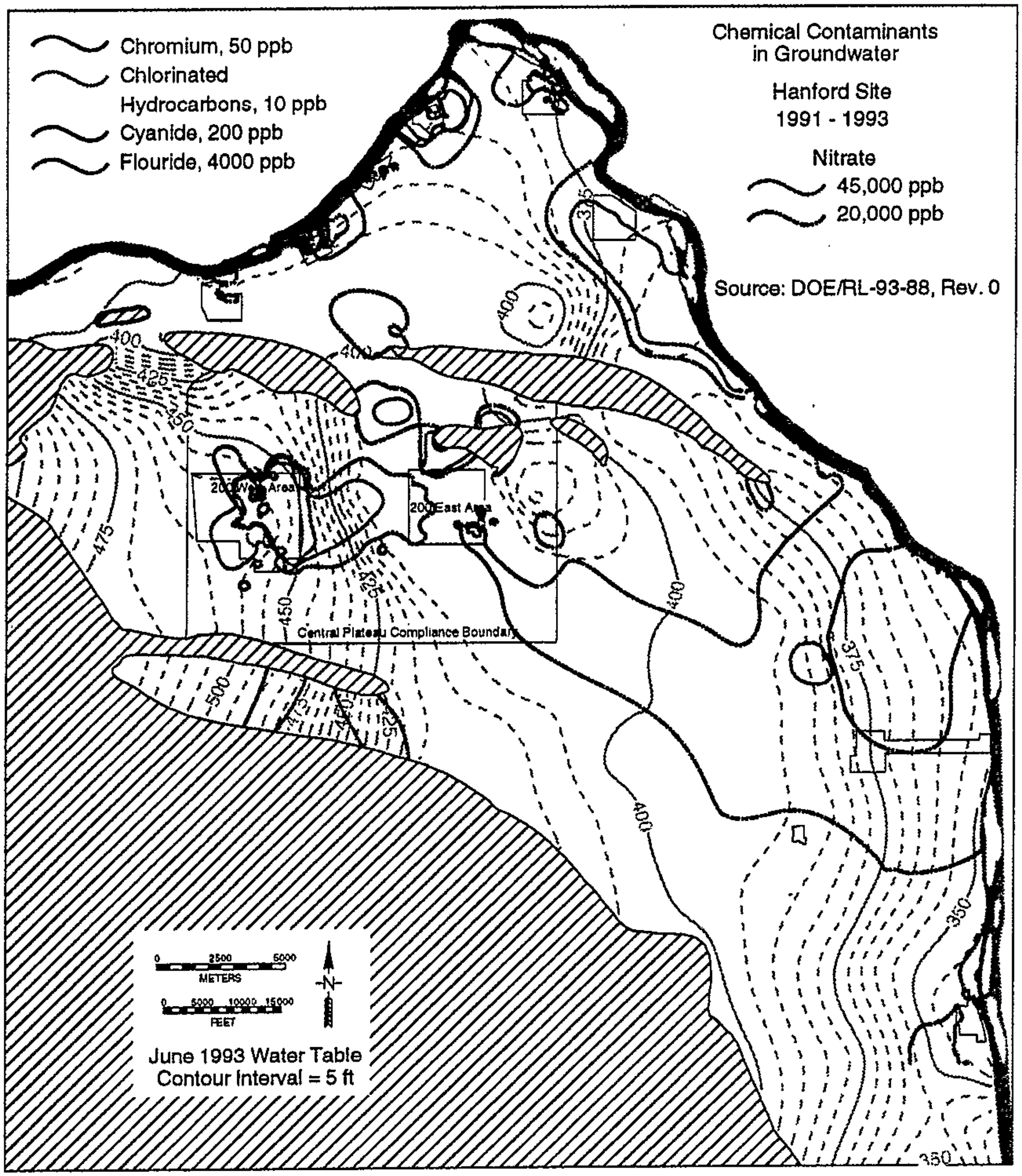
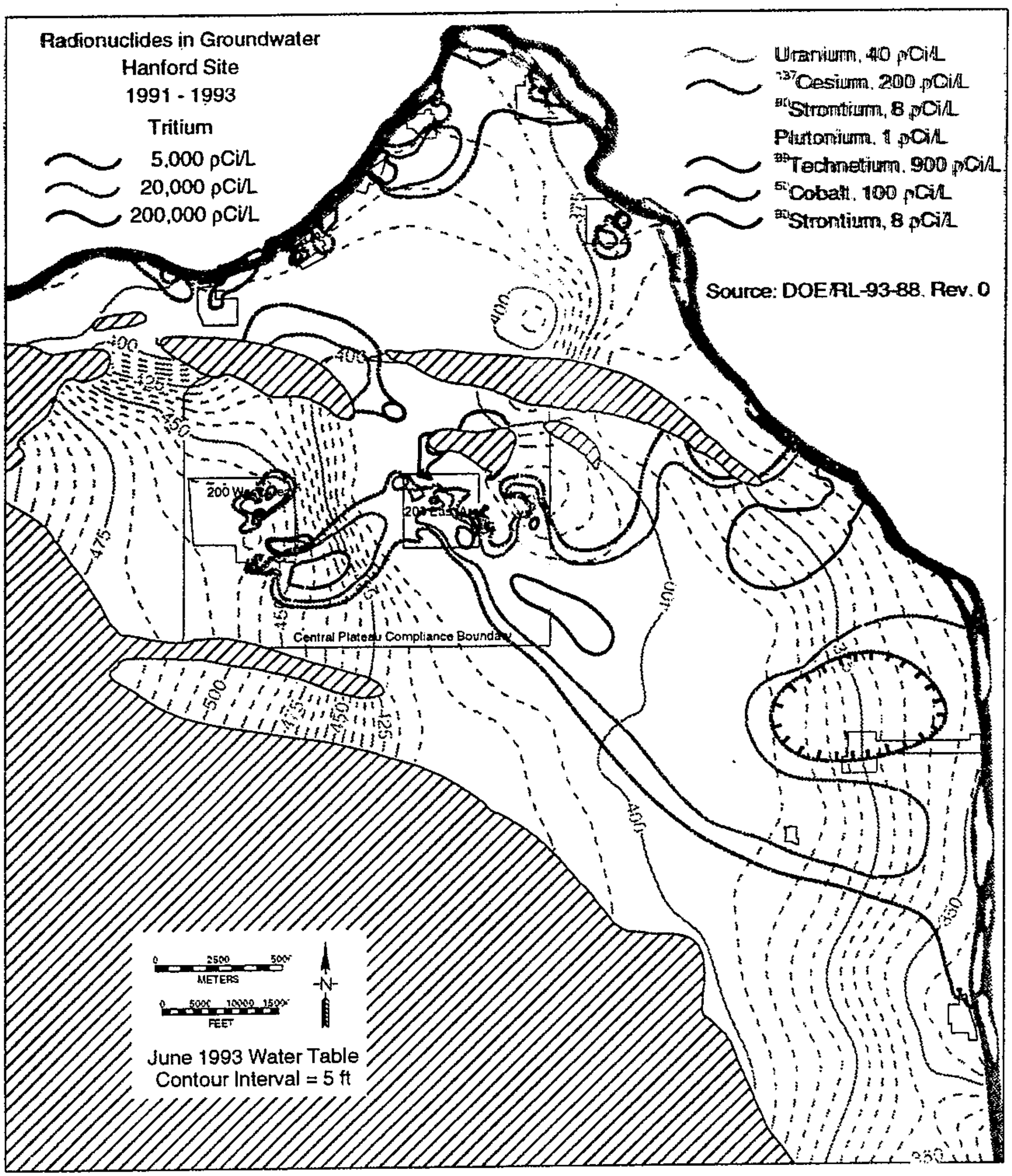


Figure 4-2. Areal Distribution of Radioactive Contaminants in Relation to Current Water Table Contours.



The interaction of natural and artificial recharge sources with the variation in aquifer permeability across the Central Plateau controls the direction and rate of movement of contaminant plumes that originate from past practice disposal sites within the 200 West and 200 East waste management areas. The rate of movement is also influenced by the chemical reactivity of the contaminant in the environment.

Two general flow directions are observed for the major contaminant plumes originating in the Central Plateau: (1) to the southeast with discharge to the Columbia River between the old Hanford townsite and the 300 Area, and (2) through Gable Gap with discharge to the river between the 100-B and 100-D Reactor areas (Figure 4-3). Based on current water table elevations and known aquifer transmissivities, mobile contaminants from the 200 West Area are expected to take about 100 years to reach the Gable Gap area, followed by a much shorter travel time from Gable Gap to the river. Travel times from the 200 East Area are expected to be on the order of 10 to 20 years because of the very high aquifer transmissivities downgradient from this waste management area. Mobile contaminants from past operations conducted in the 200 East Area have already reached the river. The observed rates of movement of the tritium and carbon tetrachloride (CCl_4) plumes are consistent with these estimates. As water table gradients decrease as a result of significantly reduced wastewater discharges, the travel times will become longer than the estimates noted above. Flow paths may also be altered to some extent, especially as discharges to B Pond subside.

4.1.6 Contaminant/Soil Interactions

Contaminants found in aquifers generally move in the direction of the water. However, the rate of contaminant movement is often less than the rate of water movement due to fixation and adsorption reactions. Fixation will remove a contaminant from water and affix it within the structure of the mineral. Adsorption also removes a contaminant from water and accumulates it on the surface of a mineral. The affinity of a contaminant for a soil is defined by its equilibrium coefficient. Generally, the higher the value of the distribution coefficient, the greater is the affinity of the contaminant for soil and the slower it moves in the aquifer.

Table 4-1 presents values of the distribution coefficient considered representative of Hanford Site soils for each major contaminant. A value greater than five is considered immobile. For each radionuclide, radioactivity decay half-lives are also provided in Table 4-1. A half-life is the interval of time for a radionuclide to decay to one-half of its original quantity. A contaminant with a short half-life will decrease more rapidly than one with a long half-life.

4.2 CONTAMINANT PLUME DISTRIBUTION PATTERNS AND VOLUMES

The major contaminant plume boundaries in the unconfined aquifer, as defined by exceedance of DWSs, Washington State Water Quality Standards, or equivalent concentrations, are shown in Figures 4-1 and 4-2. The directions and distribution patterns reflect the interaction of

Figure 4-3. Ground Water Streamlines for the Central Plateau.

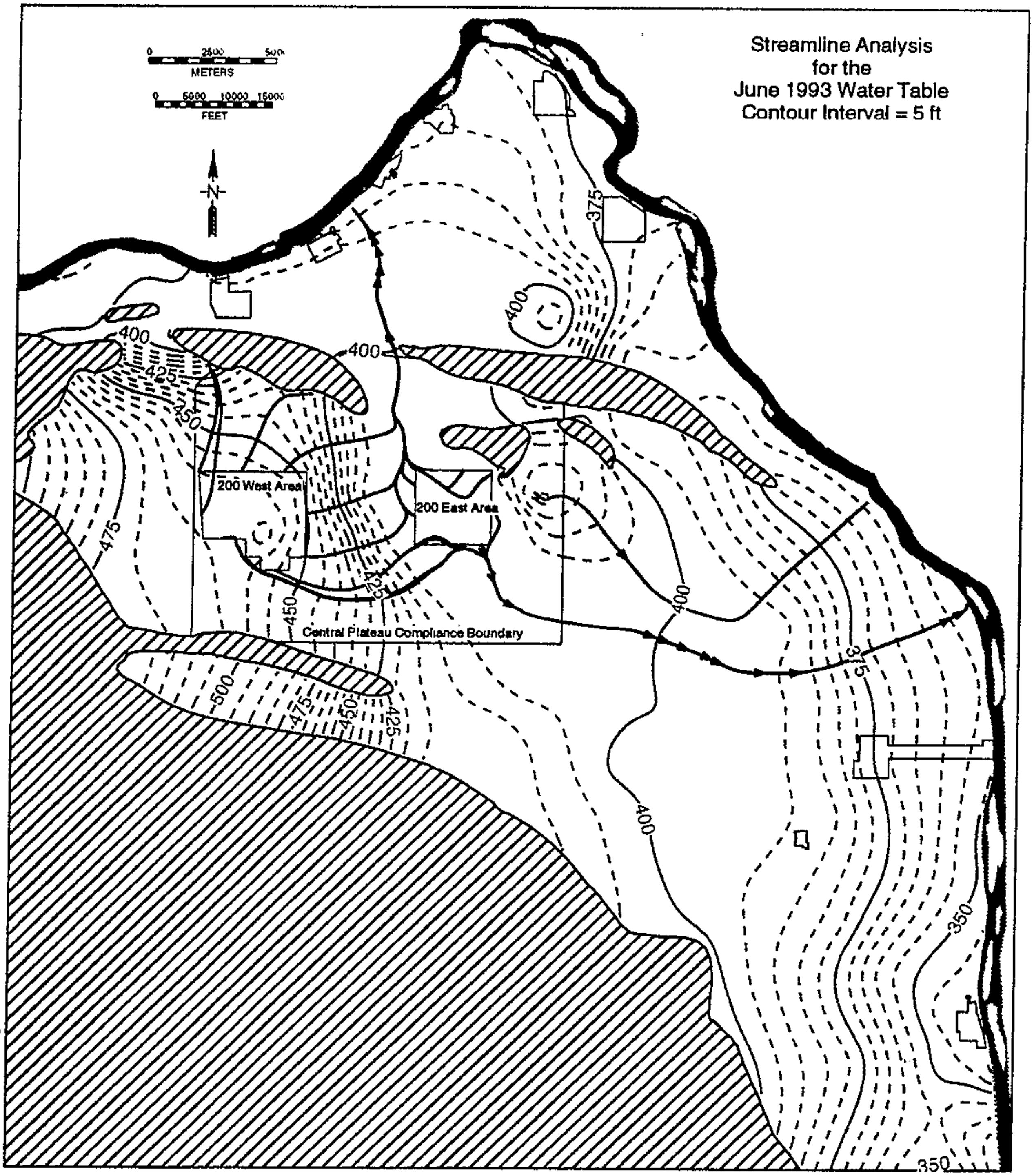


Table 4-1. Soil Distribution Coefficients and Radioactivity Decay Half-Lives.

Contaminant	Representative Distribution Coefficient (ml/g)	Half-Life (years)
$^{234,235,238}U$	0.1-2	2.47 E5, 7.1 E8, and 4.51 E9
^{99}Tc	0	2.12 E5
Carbon tetrachloride	0-2	N/A
$^{239,240}Pu$	200	24390
^{137}Cs	50	30.2
^{60}Co	50	5.25
^{90}Sr	25	28.9
Chromium	0	N/A
Tritium	0	12.3
^{129}I	0	1.7 E7
Nitrate	0	N/A

N/A = not applicable.

hydrogeologic conditions, disposal chronologies, and contaminant chemistry. For descriptive purposes, most of these plumes have been grouped into the Central Plateau and 100 Areas reactor sites geographic regions. Three contaminants (nitrate, tritium, and ^{129}I) are discussed as sitewide plumes.

Several contaminant plumes overlap because of either merging of separate plumes from different sources, or because they were released as cocontaminants. The lateral extent of plume movement is influenced by the chemical reactivity or tendency of the contaminant to adhere to aquifer sediments, especially fine-grained material. Constituents such as tritium, nitrate, and ^{99}Tc do not interact with aquifer solids and are therefore the most widely distributed. Chlorinated hydrocarbons are only slightly adsorbed and are thus expected to be minimally influenced by aquifer solids. Strontium-90, ^{137}Cs, and plutonium are highly reactive and/or form insoluble solid phases in ground water, and are thus very limited in areal extent.

4.2.1 100 and 200 Areas Plumes

Table 4-2 provides estimates for individual contaminant masses and volumes within the plume boundaries shown in Figures 4-1 and 4-2. The volume estimates assume that the sampling depths of the monitoring wells upon which the plume contours are based represent the average

Table 4-2. Contaminant Plume Dimensions and Volumes (2 sheets).

Project	Target contaminants	Quantity				Extent of contamination		
		In pore fluid		On aquifer solids		Area		Pore fluid volume
		(Ci)	(g)	(Ci)	(g)	(m^2)	(mi^2)	(L)
200 West Area								
200-UP-1[a]	Uranium	9.1E-2	1.3E+5	0.2	2.4E+5	4.6E+5	1.7E-1	4.6E+8
	^{99}Tc	2.8	1.6E+2	0	0	7.5E+5	2.8E-1	7.5E+8
200-ZP-1[a]	Carbon tetrachloride	N/A	5.8E+6	N/A	-[d]	1.1E+7	4.2	1.1E+10
	Chloroform	N/A	1.1E+5	N/A	-[d]	3.4E+6	1.3	3.4E+9
	Trichloroethylene	N/A	9.8E+3	N/A	-[d]	8.5E+5	3.3E-1	8.5E+8
200 East Area								
B-5 Reverse Well[a]	^{239}Pu	1.0E-1	1.6	2.4E+2	4.3E+3	3.1E+2	1.2E-4	7.8E+5
	^{137}Cs	8.1E-4	9.3E-6	2.4E-1	9.3E-6	3.1E+2	1.2E-4	7.8E+5
	^{90}Sr	4.1E-2	2.9E-4	6.2	4.4E-2	6.6E+4	2.5E-2	1.7E+8
50-53A[a]	Cyanide	N/A	4.8E+4	N/A	0	7.8E+4	3.0E-2	2.0E+8
	^{99}Tc	5.0	2.8E+2	0	0	7.5E+5	2.9E-1	1.9E+9
	^{60}Co	3.7E-2	3.3E-5	0	0	9.3E+4	3.6E-2	2.3E+8
Reactor areas								
100K Area[b]	Chromium	N/A	1.1E+5	N/A	0	5.6E+5	2.2E-1	7.1E+8
	^{90}Sr	1.7E-2	1.2E-2	2.5	1.8E-2	2.6E+5	1.0E-1	6.5E+8
100D Area[b]	Chromium	N/A	1.4E+5	N/A	0	7.4E+5	2.8E-1	9.3E+8
	^{90}Sr	1.3E-3	8.5E-6	1.9E-1	1.3E-3	2.3E+4	8.5E-3	5.5E+7
100H Area[b]	Chromium	N/A	3.6E+5	N/A	0	9.1E+5	3.5E-1	1.1E+9
	^{90}Sr	6.5E-3	4.6E-5	1.0	7.0E-3	1.4E+5	5.5E-2	3.5E+8
100F Area[b]	Chromium	N/A	0	N/A	0	0	0	0
	^{90}Sr	2.5E-2	1.8E-4	3.8	2.7E-2	1.3E+5	5.0E-2	3.2E+8

Table 4-2. Contaminant Plume Dimensions and Volumes (2 sheets).

Project	Target contaminants	Quantity				Extent of contamination		
		In pore fluid		On aquifer solids		Area		Pore fluid volume
		(Ci)	(g)	(Ci)	(g)	(m^2)	(mi^2)	(L)
100N Area[b]	Chromium	N/A	0	N/A	0	0	0	0
	^{90}Sr	5.0E-1	3.6E-3	7.5E+1	6.0E-1	4.3E+5	1.7E-1	1.1E+9
100B/C Area[b]	Chromium	N/A	0	N/A	0	0	0	0
	^{90}Sr	1.0E-1	6.5E-4	1.4E+1	1.0E-1	5.5E+5	2.2E-1	1.4E+9
Sitewide								
Sitewide[c]	Tritium	2.1E+5	2.2E+1	0	0	1.8E+8	6.9E+1	8.9E+11
	^{129}I	1.7E+0	1.0E+4	0	0	8.5E+7	3.3E+1	1.7E+12
	Nitrate	N/A	2.5E+10	N/A	0	4.1E+7	1.6E+1	1.4E+11
Other Areas								
1100	Trichloroethylene (TCE)	N/A	41.4 E+3	N/A	-d	4.8 E+5	2.0 E-1	1.2 E+9
300[b]	Uranium (DOE-RL 1995b)	.04	6.1E+4	0.47	6.7E+5	5.6E+5	2.2E-1	0.8E+9

[a]Assumes that plumes have an average thickness of 10 m (32 ft).
[b]Assumes that plumes have an average thickness of 5 m (16 ft).
[c]Assumes plume thickness as described in Section 4.2.2.
[d]No estimates available.

concentration over an assumed maximum depth of 10 m (32.8 ft). In some cases, significant concentrations have been observed to a depth of 30 m (98 ft). Depth distribution is clearly an important factor that can significantly impact remediation strategy and the likelihood of success. The lack of definition of vertical contaminant distribution in the unconfined aquifer is a major issue that must be resolved.

The quantities or masses associated with aquifer solids listed in Table 4-2 were calculated using the pore fluid quantities (columns 3 and 4) and published distribution coefficients for Hanford Site soils (Ames and Serne 1991).

The amount associated with aquifer solids can be much greater than the amount that occurs in pore fluid (e.g., ^{90}Sr, ^{137}Cs, and plutonium). Additionally, the total amount associated with pore fluid and aquifer solids relative to the total released is an important factor in assessing the fate of contaminants discharged to the soil column. For example, the total quantity of ^{90}Sr, shown in Table 4-2, is less than 10% of the reported amount discharged. This suggests a large fraction is still contained in the vadose zone.

4.2.2 Sitewide Contamination

Three plumes in the Central Plateau extend well beyond existing CERCLA OU boundaries. These plumes have concentrations that fall both above and below accepted ground water standards. The waste constituents are tritium, ^{129}I, and nitrate. Reference is made to Section 5.10 for a description of an approach to remediation. The plumes have the following elements in common:

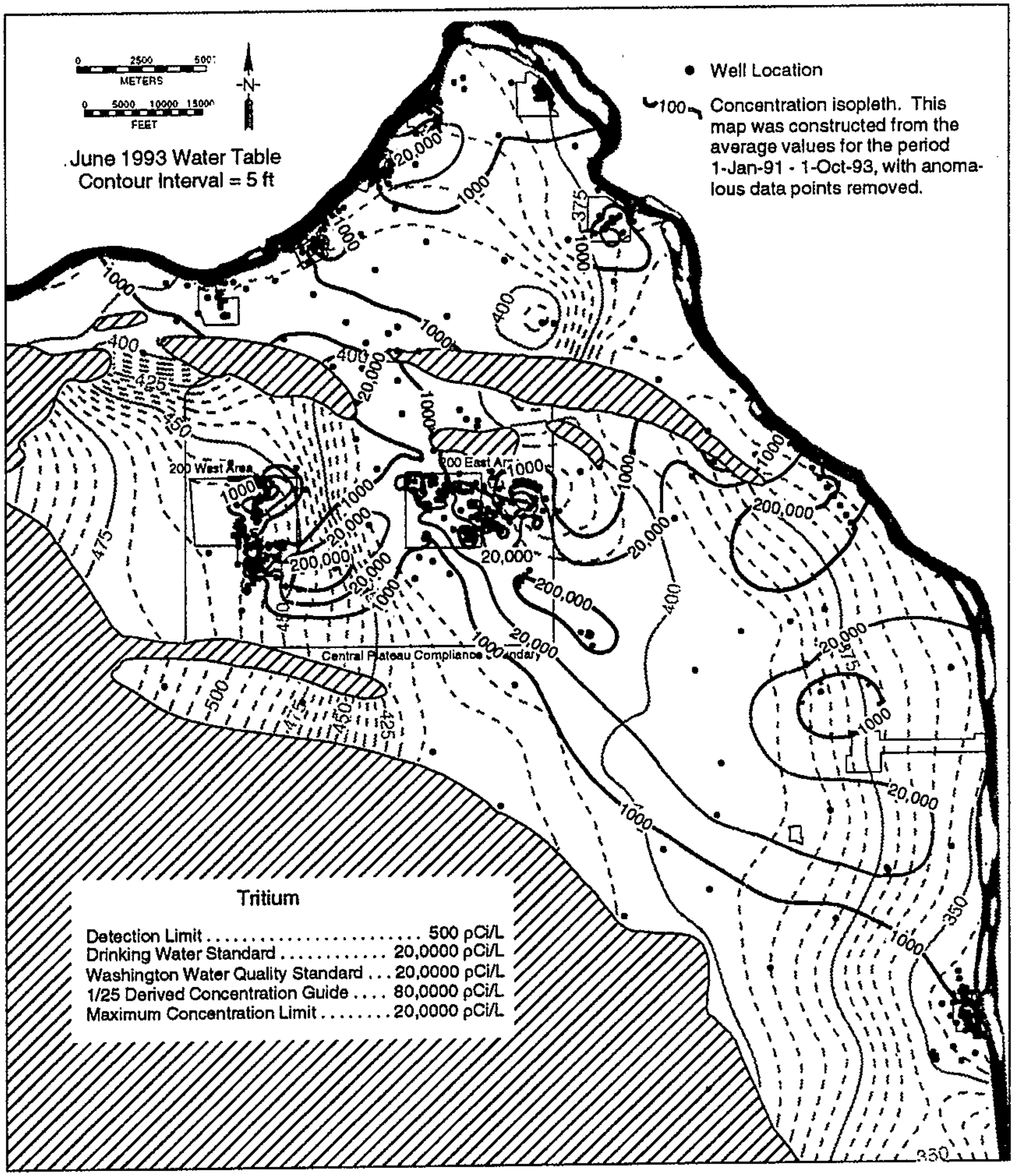
- Widespread, covering tens of square miles
- Limited areas of high concentrations.

4.2.2.1 Tritium. This waste constituent has been introduced to ground water at a number of locations as a result of irradiated fuel processing. Tritium was produced primarily as a fission product during reactor operations. Processing records indicate that the quantity of tritium discharged on the Hanford Site is approximately 220,000 Ci (decay corrected to December 31, 1992). Estimates for tritium based on ground water sampling information yields a roughly comparable estimate of 210,000 Ci. The distribution of tritium on the Hanford Site is shown in Figure 4-4.

Tritium (^{3}H) is an isotope of hydrogen. It replaces or exchanges with nonradioactive hydrogen in water molecules and thus becomes part of the water molecule. In the environment it is indistinguishable from nontritiated water and moves with the same characteristics. The only attenuation mechanism for tritium, other than dilution, is radioactive decay with a half-life of 12.3 years.

4.2.2.1.1 Tritium Discharge to the Columbia River. Data from the Pacific Northwest Laboratory environmental reports from 1984 through 1992 have been used to estimate the Hanford Site discharge of tritium into the Columbia River. Before 1984, reported differences between upstream and downstream measurements were not statistically significant. Tritium migration into the Columbia River ranged from 3,800 to 8,400 Ci/yr during this period. The highest value occurred in 1991, with a drop to 4,600 Ci/yr in 1992. The peak in 1991 may correspond to the entry of the higher concentration portions of the Hanford townsite plume into the river. Data indicate the first arrival of significant quantities of tritium at the Columbia River near the Hanford townsite in either 1975 or 1976.

Figure 4-4. Map of the Hanford Site Showing Areal Extent of Major Tritium Plumes.



4.2.2.1.2 Extent of Tritium Contamination. An approximation to the quantity of tritium in Hanford Site ground water, based on limited data concerning the deep occurrences of tritium, assumes that the tritium plume concentration in the Central Plateau extends to depths of 60 m (197 ft) in the 200 West Area and 20 m (66 ft) in the 200 East Area, and to depths of 20 m (66 ft) in the 600 Area, east and southeast of the 200 East Area, and in the Gable Gap. This approximation yields a total tritium ground water inventory of 210,000 Ci. This value is approximately 5% less than the estimated quantity discharged; however, when added to the 45,000 Ci (decay corrected) estimated for river discharge, there is an indication that there is a discrepancy of approximately 15%. The estimate is in reasonable agreement with the discharge estimates, particularly in consideration of the uncertainties in both the quantity of tritium produced and in estimates of the deep distribution of tritium.

4.2.2.2 Iodine-129. Iodine-129 is a ground water contaminant concern because of its relatively long half-life (16 million years) and low regulatory standard (DWS = 20 pCi/L). Three extensive plumes of ^{129}I contamination originated from Central Plateau liquid waste disposal facilities that received process wastewater (Figure 4-5).

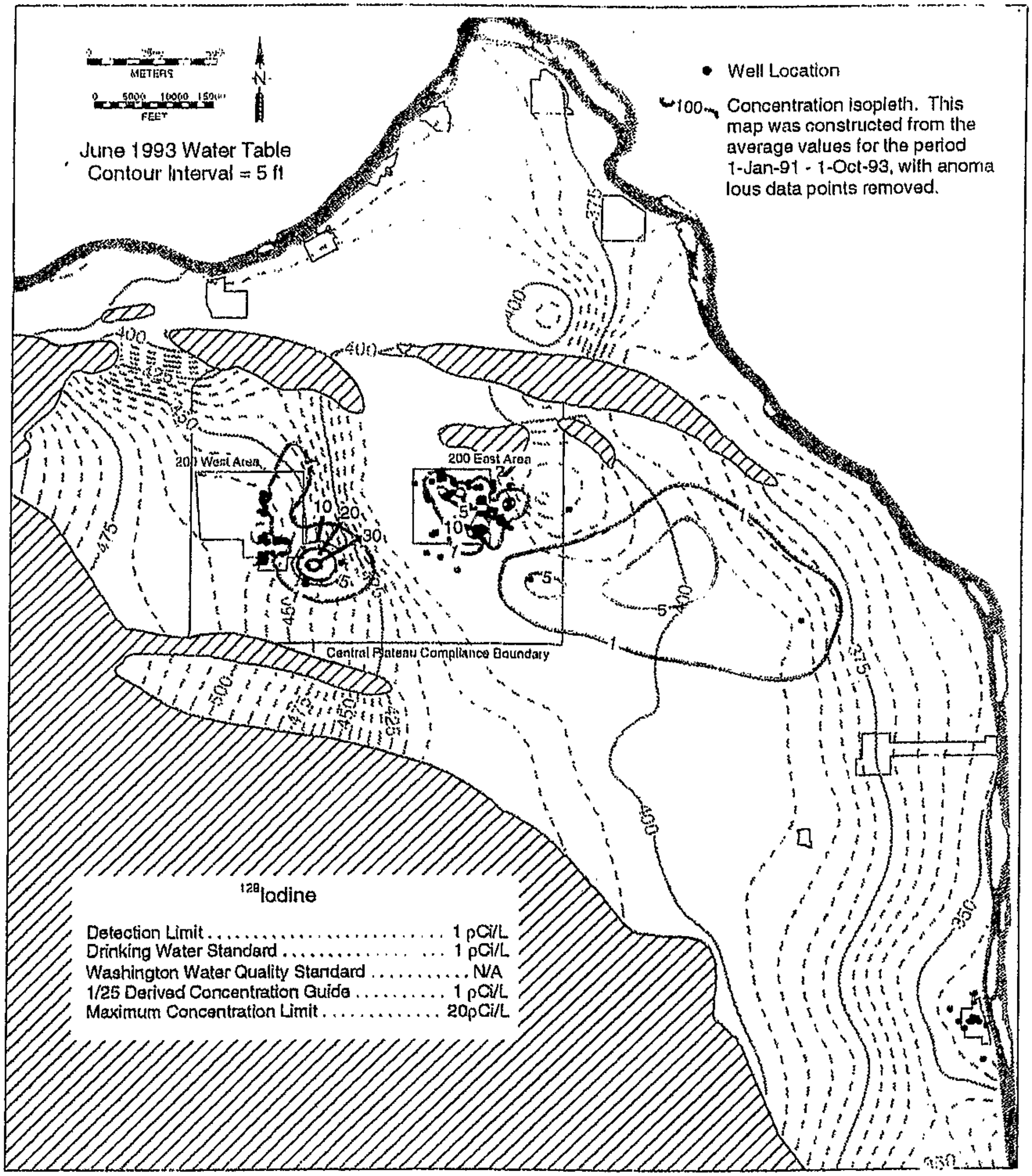
4.2.2.2.1 Iodine-129 Plume Migration. Iodine-129 occurs in wastewater and ground water as mobile anionic species (I^- or IO^-) and generally travels at the same velocity as ground water. Its distribution and centers of highest concentration roughly coincide with the tritium contaminant plumes that underlie the Central Plateau. There is no analytical data indicating that ^{129}I in concentrations exceeding the DWS have entered the Columbia River. The edge of the plume appears to be 2.5 to 3 km (1.6 to 1.9 mi) from the Columbia River in the vicinity of the Hanford townsite.

4.2.2.2.2 Extent of Iodine-129 Contamination. Iodine-129 contamination is present in the unconfined aquifer, over 84.5×10^6 m^2 (33 mi^2) of the central portion of the Hanford Site. Because ^{129}I is a cocontaminant with tritium in the Central Plateau and has the same mobility as tritium, its distribution at depth in the aquifer should be similar. Iodine-129 may be present to depths of 60 m (197 ft) beneath the 200 West Area and 20 m (66 ft) beneath the 200 East Area and the 600 Area east and southeast of the Central Plateau. A total volume of 1.7×10^9 m^3 (4.5×10^{11} gal) of ground water is estimated to be contaminated with ^{129}I in excess of the DWS.

4.2.2.3 Nitrate. Nitrate contamination is present in all operational areas, as well as in significant portions of the 600 Area. Nitric acid was used in numerous site processes related to decontamination and fuel reprocessing activities. Acid waste solutions are the primary contributor to nitrate plumes currently observed in ground water. The distribution of nitrate is shown in Figure 4-6.

Nitrate is an extremely mobile anion that moves at the same velocity as the ground water. The anion is not retarded by sorption. The only attenuation mechanisms for nitrate are denitrification or biological assimilation that are assumed to be of minimal importance in Hanford Site aquifers.

Figure 4-5. Hanford Site Map Showing Areal Distribution of Iodine-129 Plumes.



4.2.2.3.1 Nitrate Discharge to the Columbia River. Nitrate is currently being discharged at concentrations exceeding the DWS to at least four stretches of shoreline along the 100 Areas of the Columbia River. A significant stretch of shoreline adjacent to the Hanford townsite is the locus of nitrate discharge from 200 East Area sources at concentrations slightly below the DWS. It appears that the arrival of the nitrate plume at the Hanford townsite was coincidental with the tritium plume. Both tritium and nitrate show marked increases in well 699-40-1 beginning in 1975 to 1976. Nitrate concentrations exceeded the DWSs beginning in 1984 and remained elevated for 2.5 to 3 years. Concentrations in the well have remained slightly below the DWS from 1986 to the present.

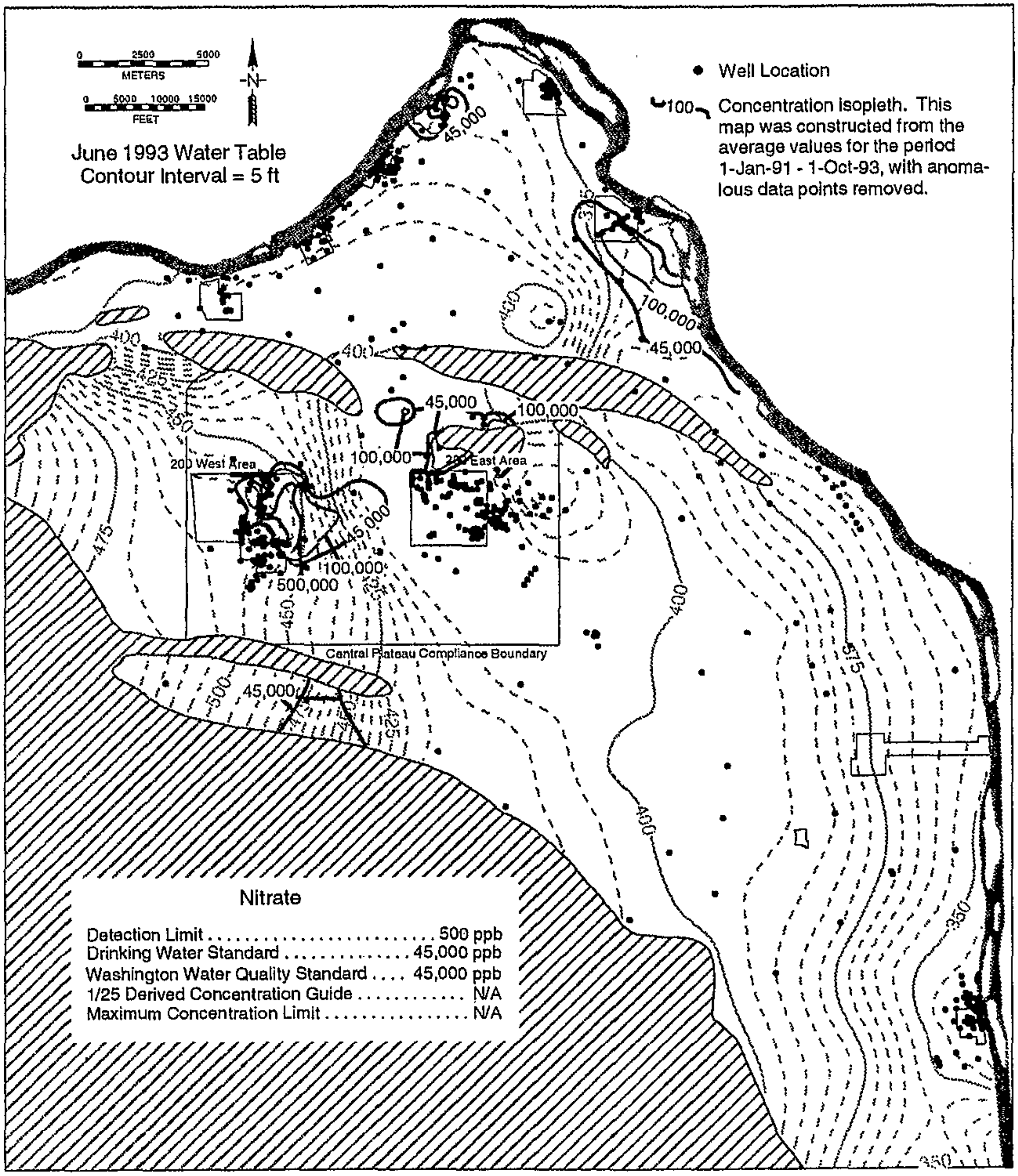
4.2.2.3.2 Extent of Nitrate Contamination. The net area of nitrate contamination that exceeds the DWS for the Hanford Site as a whole is 40.7 x 10^6 m^2 (15.7 mi^2). As nitrate appears to have moved as a cocontaminant with tritium, it seems reasonable that a similar depth distribution profile is probable for plumes emanating from the Central Plateau as described in the tritium plume volume discussion (Section 4.2.2.1.2). With the assumption that nitrate contamination extends to depths of 60 m (197 ft) in the 200 West Area, to depths of 20 m (66 ft) in the 200 East Area and in the 600 Area east and southeast of the 200 East Area and in Gable Gap, and to 10 m (33 ft) elsewhere on the Hanford Site, the total volume of nitrate-contaminated ground water beneath the Hanford Site is estimated to be 1.4 x 10^8 m^3 (3.7 x 10^{10} gal).

4.2.2.4 Other Areas (300 and 1100 Areas)

The 1100 Area ground water is relatively uncontaminated. The only contaminant that comprises a plume is trichloroethylene. The plume is dissipating as it moves slowly to the northeast with concentrations up to 58 parts per billion (ppb). The plume is estimated to cover 0.2 square miles and contain approximately 41 kilograms of contaminant (based on a porosity of 0.25 and an assumed depth of contamination of 10 meters).

Ground water contamination within and near the 300 Area is described by Dresel et al. (1994). Contaminants identified in this area are uranium, trichloroethylene, and tritium. Both uranium and trichloroethylene occur above federal drinking water standards and are the result of fuel fabrication previously conducted in the area. Tritium contamination is from past process activities found in the 200 Areas and has not been detected in the 300 Area at levels above drinking water standards (DOE/RL 1995).

Figure 4-6. Hanford Site Map Showing Areal Distribution of Nitrate Plumes.



5.0 SITEWIDE GROUND WATER REMEDIATION STRATEGY

The goal of ground water remediation is to restore ground water to its intended beneficial uses in terms of protecting human health and the environment. This strategy provides a common, sitewide perspective to guide the development of remediation activities for individual OUs. Guiding principles for a comprehensive ground water remediation approach are summarized below. These principles are developed within the context of existing ground water conditions, the institutional and regulatory framework for remediation, and stakeholder values described in previous sections of the document. Details of specific strategy elements are addressed in the following sections.

5.1 GUIDANCE

This strategy is a geographic and plume-specific approach to ground water remediation. It is oriented to reflect public and tribal values and priorities. The following are key elements of this strategy:

- Place a high priority on actions that protect the Columbia River and near-shore environment from degradation caused by the inflow of contaminated ground water
- Reduce the contamination entering the ground water from existing sources
- Control the migration of plumes that threaten or continue to further degrade ground water quality beyond the boundaries of the Central Plateau.

5.1.1 Initial Remediation Efforts

Ground water remediation efforts are already underway on the Hanford Site. These initial efforts will ensure the following:

- Maintain a bias toward field remediation activities by employing the HPPS (Thompson 1991) to accelerate interim RAs
- Continue implementation of accelerated ground water remediation projects to control plume expansion, reduce contaminant mass, and better characterize aquifer response to RAs
- Identify and control sources of contaminants in the vadose zone that impede efforts to remediate ground water.

5.1.2 Final Remediation Efforts

Succeeding phases of RAs are oriented toward implementing the final ROD, which in turn will satisfy broader cleanup objectives; for example:

- Achieve ARARs with respect to the value of current and potential future beneficial uses for the ground water resource
- Develop alternative containment and remediation strategies if currently available ground water restoration technologies prove inadequate or impracticable
- Restore ground water adjacent to the Columbia River for unrestricted beneficial use
- Prevent further degradation of ground water quality beyond the boundaries of the Central Plateau, and ultimately restore unrestricted beneficial use of ground water beyond that boundary.

5.1.3 Resource Optimization

An important element in the ground water remediation strategy is optimizing the use of available resources. The following are key considerations:

- Balance the sequencing and scale of RAs to achieve efficient use of technical and monetary resources
- Incorporate existing and/or proposed treatment and disposal infrastructure
- Implement currently available technology and foster demonstrations of developing technology, where appropriate, for meeting remediation objectives
- Improve the integration of the existing ground water monitoring networks and sampling schedules, to better characterize the contamination problem and to measure the effectiveness of remediation efforts.

5.1.4 Stewardship

The stewardship responsibility for remediating and protecting ground water resources beneath the Hanford Site will be met by the following:

- Maintaining consistency with the Hanford Site GPMP
- Coordinating RAs, whenever feasible, at CERCLA OUs with adjacent OUs, with RCRA facilities undergoing closure, and with state-permitted waste discharge facilities

- Coordinating RAs that require disposal of treated ground water with ongoing waste management and liquid effluent programs.

5.2 GEOGRAPHIC AND PLUME-SPECIFIC APPROACH

Previous studies of Hanford Site ground water have screened and "targeted" the major ground water contamination plumes by geographic area. Contaminant species that are widespread and/or present serious environmental concerns are addressed in the following sections. By implementing Section 5.1 and stakeholder values (see Section 3.0), a cleanup approach of containment and mass reduction is assigned to the major contaminant plumes identified in the Central Plateau. Similarly, contaminant plumes found in the reactor areas are assigned a cleanup approach of remediation. Table 5-1 lists the major contaminant plumes and their cleanup approach. These site specific approaches are based on an initial evaluation of available data. More detailed evaluations will subsequently be conducted in accordance with CERCLA or other appropriate regulatory requirements.

Table 5-1. Major Contaminant Plumes and Cleanup Approach.

Plume	Facility	Location	Cleanup approach
Uranium and ^{99}Tc	UO_3 Plant	Central Plateau (200 West Area)	Containment and mass reduction
Organic (CCl_4, trichloroethylene, and chloroform)	PFP	Central Plateau (200 West Area)	Containment and mass reduction
Combined plutonium, ^{137}Cs, and ^{90}Sr	B Plant (B-5 reverse well)	Central Plateau (200 East Area)	Technology development
^{99}Tc and ^{60}Co	BY Cribs	Central Plateau (200 East Area)	Containment and mass reduction
^{90}Sr	N Reactor	Reactor areas (100-N)	Remediation[a]
Chromium	D Reactor H Reactor K Reactor	Reactor areas (100-D, 100-H, and 100-K)	Remediation

PFP = Plutonium Finishing Plant.
UO_3 = Uranium Trioxide (Plant).

a Ground water remediation refers to the reduction, elimination, or control of contaminants in the ground water or soil matrix to restore ground water to its intended beneficial use.

The cleanup approaches reflect the public values of protecting the Columbia River, controlling the spread of contamination, and eliminating recontamination of cleaned areas of ground water. The assigned approach is intended to guide the initial approach to cleanup and is not intended to limit additional cleanup, should it prove feasible.

Contamination associated with past discharges to the B-5 reverse well has an approach called "technology development." Remediation of this contamination currently requires technology development activities and may not be completely amenable to pump-and-treat methods. As described in later sections, this contamination is virtually immobile within the aquifer. The ground water remediation strategy designates the B-5 reverse well-combined plumes to serve as a testing center for the purpose of technology development, leading to the reduction of the contaminant mass or its further stabilization within the aquifer.

The ground water remediation strategy also selects one plume in the reactor areas and the Central Plateau as having higher priority over others in their respective areas. The ^{90}Sr plume, located at N Reactor, is selected in the reactor areas and the CCl_4 plume is selected in the Central Plateau. Both contaminants are found at levels well over state DWSs. Strontium-90 is discharging directly to the Columbia River and is the highest source of waterborne radioactivity accessible to the public. Carbon tetrachloride is a suspected carcinogen and is the largest of the targeted plumes; it has the potential to contaminate still larger areas. Beyond these two plumes, prioritization is given to contamination found in the 100 Area, followed by contamination of limited areal extent found anywhere on the site where immediate action would prove beneficial.

For each area and plume, an overview of hydrochemical conditions is provided, followed by a brief description of an approach to cleanup. Major data and information gaps are identified along with areas where technology development would potentially accelerate ground water cleanup.

Three widespread contaminant plumes and their remediation potential are also discussed: radioactive ^{129}I, tritium, and nitrate. Each covers large areas, is often found above ground water standards, and poses significant challenges to remediation. These plumes have not been "targeted" for immediate action.

Contaminants such as fluoride and arsenic that are detected as small, localized plumes or "hot spots" are best addressed on the more detailed level of the OU. Section 5.11 discusses important issues surrounding the disposal of treated and partially treated ground water.

5.3 CENTRAL PLATEAU--200 WEST AREA--URANIUM AND TECHNETIUM-99 CONTAMINATION

5.3.1 Hydrochemical Conceptualization

Uranium and ^{99}Tc plumes associated with the 216-U-1/2 Cribs are expected to continue moving eastward from the 200 West Area and to eventually turn northward through Gable Gap. The rate of contaminant movement will decrease as the water table declines in the 200 West Area and the hydraulic gradient is subsequently reduced. Remediation is complicated by the textural variability and permeability of the geologic formation containing the plume, by the interaction of dissolved uranium with aquifer sediments, and the presence of cocontaminants.

5.3.2 Remediation Approach

Remediation of the uranium and ^{99}Tc plumes requires a combination of source identification and possible control, plume containment, and treatability testing. Although the transport of contamination can be substantially reduced by hydraulic controls, the final level of cleanup is likely to be above current ARARs using existing technologies. Technetium-99 is expected to be more amenable to pump-and-treat methods than uranium.

A multiple-phase approach is recommended that addresses data needed for design, containment, and/or remediation. Phase I should include the following:

- Determining the vertical extent of contamination
- Identifying continuing sources of contamination that would affect the permanence of cleanup efforts
- Treatability testing to evaluate alternatives for removing and treating ground water
- Conducting studies to better define the direction and rate of movement.

Based on the results of Phase I, Phase II would implement the selected alternative. Containing the spread of the contamination is the initial goal while information is collected and analyzed before the implementation of a larger remediation system. Existing site treatment infrastructure (e.g., the 200 Areas ETF) will be considered during the selection of treatment alternatives.

5.3.3 Technology Development

Technology development directed at restricting the movement of uranium in the unsaturated and saturated zones is of particular interest. These would include improved grouts and other flow-restricting additives, chemical agents directed at altering the mobility of the contaminants, and improved application methods. Current technology used for uranium and technetium removal from ground water is ion exchange. Improved and cost-effective physical-chemical ground water treatment technologies for uranium and ^{99}Tc are also needed.

5.4 CENTRAL PLATEAU--200 WEST AREA--ORGANIC CONTAMINATION

5.4.1 Hydrochemical Conceptualization

A CCl_4 plume in the 200 West Area is moving eastward from the vicinity of cribs associated with the Plutonium Finishing Plant. The rate of plume migration will diminish as a result of declining hydraulic gradient in the 200 West Area; however, movement to the east and eventually northward through Gable Gap will likely continue.

The fate of approximately two-thirds of the total quantity of the CCl_4 discharged to the soils is unknown (Last and Rohay 1993). If present in sufficient quantities, CCl_4 can sink vertically and maintain a separate liquid phase within the vadose zone or within the aquifer. The separate liquid phase can act as a continuing source of ground water contamination.

5.4.2 Remediation Approach

A phased approach is needed to address the major data gaps while actively preparing for containment and mass reduction of the more contaminated and the known source areas. Phase I concentrates on defining the existence of and the ability to remediate the potential source areas and pilot-scale treatability tests. Examination of the extent of contamination in the upper confined aquifer in selected locations is also recommended along with remediation of unsealed wells in the area. Based on the results of Phase I, implementation of a pump-and-treat system will be considered for the purpose of containment and mass reduction in the unconfined and upper confined aquifer.

5.4.3 Technology Development

Concurrent with the Phases I and II efforts, additional research is needed on improved treatment systems, containment of large plumes, in situ treatment, and immobilization methods (e.g., bio-remediation, reduction by metallic iron, enhanced natural degradation, enhanced methods to identify and remediate dense nonaqueous phase liquids).

5.5 CENTRAL PLATEAU--200 EAST AREA--TECHNETIUM-99, COBALT-60, CYANIDE, AND NITRATE CONTAMINATION

5.5.1 Hydrochemical Conceptualization

Estimated quantities of the primary contaminants in the liquid effluent disposed to the BY Cribs include 0.45 Ci of ^{60}Co; 18,900 kg (41,670 lb) of ferrocyanide; 5,700,000 kg (12,600,000 lb) of nitrate; and an unknown quantity of ^{99}Tc (DOE-RL 1993a, 1993b). These liquid effluent were dense brines and may have sunk into the aquifer, providing a source of continuing contamination (Kasza 1993). Plumes of ^{99}Tc, ^{60}Co, cyanide, and nitrate occur north of the 200 East Area and are believed to be associated with the BY Cribs. The plumes are moving northward through

Gable Gap and the highest concentrations occur in the vicinity of well 699-50-53A. Technetium-99 and ^{60}Co are the primary contaminants of concern at this location.

5.5.2 Remediation Approach

A phased approach consisting of the following major elements will be implemented:

- Treatability testing using a pilot treatment system to remove ^{99}Tc and ^{60}Co from ground water
- Areal and vertical definition of the plume
- Confirmation of the source of contamination and what potential control measures may be needed, if any
- Implementation of hydraulic controls to contain the plume, reduce the mass of contaminants, and slow its spread.

The key elements of the first phase include treatability testing and the collection of improved geohydrologic information. Based on the results of Phase I, source control and containment of the plumes would be conducted in subsequent phases.

5.5.3 Technology Development

Existing pump and treat technology appears to be adequate to successfully remediate the BY Cribs plume. However, improvements in the ability to remotely determine the elevation of the bottom of the aquifer by geophysical means could prove beneficial for locating any remnants of the dense contaminant mass and for defining any preferential ground water flow paths.

5.6 CENTRAL PLATEAU--200 EAST AREA--PLUTONIUM, STRONTIUM-90, AND CESIUM-137

5.6.1 Hydrochemical Conceptualization

Significant quantities of plutonium, ^{90}Sr, and ^{137}Cs are present in the vadose zone and aquifer material around the 216-B-5 reverse well (injection well) in the 200 East Area (Brown and Rupert 1950; Smith 1980). Because of high sorption coefficients and inclusion in relatively insoluble solid phases, the contaminants do not represent a threat to ground water outside of the 200 East Area. However, because of their high concentrations and long half-lives, the radionuclides, particularly plutonium, represent the potential for long-term contamination of ground water within the 200 East Area.

5.6.2 Remediation Approach

Geochemical considerations make implementation of a pump-and-treat system at this location appear to have little chance to succeed. It is recommended that currently planned treatability testing be directed at determining the geochemical nature of the dissolved and particulate fraction and in examining the time-dependent response of the contamination in the aquifer to treatability testing.

The ground water remediation strategy establishes the area contaminated with the relatively immobile plutonium, ^{90}Sr, and ^{137}Cs as a technology development test site for the purpose of permanently controlling contamination.

5.6.3 Technology Development

Potential technology development opportunities include the following information needed to remediate contamination found at the 216-B-5 reverse well:

- Determination of what geochemical phases are controlling distribution and transport of plutonium and ^{90}Sr
- Bench-scale tests with samples of contaminated sediments
- Development of methods for physical removal of the contaminated sediments
- Development of barrier technology to contain the contamination.

5.7 REACTOR AREAS (100 AREAS)

5.7.1 Hydrochemical Conceptualization

Ground water contaminants in the 100 Areas are important because of their proximity to the Columbia River. Ground water flow is generally northward into the river. Principal contaminants forming plumes in the 100 Areas are ^{90}Sr, tritium, nitrate, and chromium. The most significant of these are ^{90}Sr, particularly in the 100-N Area, and chromium, which is toxic to aquatic organisms.

5.7.2 Remediation Approach

The contaminants considered in the following discussion are limited to those having significant areal extent and are found at levels well above DWSs; i.e., problem areas where major efforts will be extended for remediation and that should be viewed in a sitewide context. Contaminants meeting the above general criteria for the 100 Areas include the radionuclide ^{90}Sr, found in the 100-N Area; and the chemical contaminant chromium, found in the 100-D, 100-H, and 100-K

Areas, respectively (Hartman and Peterson 1992). Strontium-90 is found at levels over 100 times the DWS of 8 pCi/L; chromium is found at levels 10 times over the freshwater fish chronic toxicity criteria of 11 ppb. Both plume types are found in ground water discharging to the Columbia River (Peterson and Johnson 1992). Strontium-90, in sufficient concentrations, represents a potential human health hazard, and chromium is of concern due to its aquatic toxicity.

On September 23, 1994, the U.S. EPA and Ecology issued an Action Memorandum to RL establishing the approach for the remediation of N Springs. The memo included the construction of a barrier to flow of a minimum of 914 m (3,000 ft) in length between the source of contamination and the Columbia River. Additionally, a small-scale treatability test was specified to evaluate the ability of a pump-and-treat system to remove dissolved ^{90}Sr from the ground water. The purpose of the barrier is to reduce the flux of dissolved ^{90}Sr to the Columbia River by increasing the travel time of the strontium to allow radioactive decay to mitigate the problem. It is recommended that remediation be phased and await the results of the initial remediation efforts and decisions on remediation of the contamination held in the soil column below the source (i.e., the 1301-N Crib) of the ^{90}Sr ground water plume.

The commitments made under the Tri-Party Agreement for 100-D and 100-H Reactor areas (HR-3 OU) include the testing of an approximately 189-L/min (50-gal/min) pump-and-treat system to remove chromium. This treatability testing is being conducted in the 100-D Area near a known source of chromium. Should ground water remediation of chromium be needed, hydraulic containment with pump-and-treat systems and/or barriers to flow offers potential remediation alternatives. The high mobility of chromium and its ability to be selectively removed from ground water make its remediation potentially possible using a pump-and-treat system. Better definition of the extent of the contamination at the 100-D Reactor and of potential sources of continuing contamination is needed.

For each of the three chromium plumes located in the 100-D, 100-H, and 100-K Reactor areas, the remediation strategy establishes the goal of remediation for the aquifer. The proposed cleanup approach is either pump-and-treat alone or in combination with cutoff wells. Sources of continuing contamination must be identified and remediated in each area.

Certain activities will be needed in each area. These activities include a detailed description of aquifer hydraulic properties and flow paths in the vicinity of the plume or waste site, treatability testing of contaminant removal systems, and constructability testing of barriers. Additional wells will be drilled for extracting contaminated water and reinjecting treated water. Numerical modeling of ground water flow should be conducted to help the design of pump-and-treat systems and flow barriers.

For most of the 100 Areas, it is recommended to continue characterization of ground water contamination under the HPPS. This includes monitoring during remediation of surface sources; e.g., cribs, underground tanks, and burial grounds. The need for ground water remediation at the

OU level should be reevaluated if undesirable changes occurred during source remedial activities, or if previously undetected contaminant problems are revealed by continued characterization efforts.

5.7.3 Technology Development

The following processes offer areas where technology improvements can greatly accelerate the cleanup of ground water: geochemical fixation of chromium in source areas, passive removal technologies (such as funnel and gate), improved barrier construction technologies, improved leaching/fixative methods for strontium removal/fixation, and improved physical-chemical treatment.

5.8 300 AREA

The CERCLA 300-FF-5 ground water OU in the 300 Area has completed the Phase I RI and Phases I and II FSs. A combined Phase II RI/Phase III FS report has been submitted to the regulatory agencies in January 1995. A ROD for the OU is expected by late summer 1995.

Ground water contamination in the 300 Area occurs in three primary areas. The principle plume is uranium contamination derived from past operations and disposal practices within the 300 Area. The uranium plume intersects with the Columbia River, Tritium is encroaching from the north (originating from the Separations Area) and a plume composed of nitrates and ^{99}Tc is found to the south and east of the 300 Areas that is migrating toward the Columbia River.

Based on the findings of the RI and the remedial alternatives that will be undergoing a detailed analysis during 1994 as part of the Phase III FS, it is anticipated that active remediation could be either selective hydraulic containment or selective slurry wall containment with minimal extraction. However, based on the current contaminant levels identified in ground water, it is probable that only institutional controls with no active remediation will be required.

5.9 1100 AREA

The 1100 Area is located north of the city of Richland in the southernmost portion of the Hanford Site. Investigations leading to a ROD indicated that no significant contamination of the aquifer currently exists. Ground water plumes of trichloroethylene and nitrate plumes, located in the vicinity of the Horn Rapids Landfill, have had ground water concentrations above standards.

The ROD requires continued institutional controls and monitoring of the ground water to ensure that contaminant levels decrease as predicted. If monitoring does not confirm the predicted decrease of contaminant levels, the need for more intrusive remediation will be considered by the Tri-Party Agreement agencies.

5.10 OTHER CONTAMINATION--TRITIUM, IODINE-129, AND NITRATE

Three waste constituent plumes are characterized as sitewide contamination issues: tritium, ^{129}I, and nitrate (Section 4.2.2). Currently no active remediation of these plumes is proposed. The basis for not proposing active remediation is discussed in the following sections.

The total volume of ground water containing greater than 20,000 pCi/L of tritium is approximately 8.9×10^{11} L (2.4×10^{11} gal), spread over approximately 180 km^2 (69 mi^2). The mass of tritium contained in that volume is relatively small, amounting to approximately 22 g (0.78 oz). Separation of tritium from ground water is not practical with current technology. Remediation possibilities are limited to increasing the residence time of tritium to allow for decay and/or intercepting tritium near the area of discharge to the river (or other intermediate location). It is recommended that additional evaluation of alternatives be conducted.

The volume and areal extent of water contaminated with ^{129}I places severe constraints on the ability of current technology to effectively remediate this ground water problem. Current calculations indicate that a treatment system would have to operate continuously for 3,000 years at 3,785 L/min (1,000 gal/min) to effect a 90% reduction in observed concentrations. Iodine removal will be limited due to competing ion effects from anions in ground water. The development and testing of innovative iodine removal technology is recommended.

Nitrate occurs as a cocontaminant that is marginally over standards with nearly every other plume of concern on the Hanford Site. The only areas in which this is not the case is the relatively large plume found in the 100-F Area. The strategy recommends that alternatives for nitrate remediation be combined into the analysis of remediation alternatives for tritium previously discussed.

In summary, each of these large plumes needs to be examined in detail before an approach can be specified. However, individual segments of each plume offer some opportunity for aggressive action. It is recommended that the decision to remediate portions of these plumes be based on the following two criteria, in addition to regulatory and legal requirements:

1. The contaminant can be shown to a) pose a real or potential adverse impact to Columbia River water quality or the ecosystem; or b) compromise a current or potential beneficial use of the river

2. The remediation effort, if conducted immediately, should reduce or eliminate the spread of contamination to uncontaminated parts of the ground water system.

Finally, opportunities should not be overlooked for cotreatment of sitewide contaminants as part of systems that address the priority contaminant plumes. Treatment for the sitewide contaminants may be technically and economically "added on" to other systems, without significantly altering the ability of the original system to meet its intended purposes.

5.11 TREATMENT AND DISPOSAL OF TREATED GROUND WATER

Aboveground treatment of contaminated ground water must dispose of the treated water. Three alternatives exist:

- Reintroduction to the ground
- Discharge to a stream or Columbia River
- Evaporation.

Evaporation is discounted because of the projected high volumes of water coupled with the expected high energy use and its costs. Ideally, all contaminants can be reduced to levels below regulatory concern. However, in many cases, effective treatment is only feasible for the primary contaminants. The treatment of the remaining cocontaminants is often not possible or would significantly affect the feasibility of conducting the remediation.

It is recommended that treatment of ground water have the objective of reducing both targeted and cocontaminants to levels below regulatory concern. However, should complete removal be judged unnecessary or prove infeasible, the following criteria are recommended to determine a disposal location. The selected location should ensure the following:

- Not spread contamination into uncontaminated areas or impede the current and future cleanup effort

- Facilitate the containment and removal of contaminants, if possible

- Make use of existing liquid treatment and disposal facilities, as feasible

- Facilitate secondary usage of the treated effluent.

Establishing the location for the disposal of partially treated ground water is key to the implementation of effective, large-scale containment and remediation systems and should be the focus of attention in the near future.

There are opportunities to optimize resources for treatment and disposal of effluent generated by CERCLA ground water remediation activities and liquid effluent projects. The 200 Areas ETF and the TEDF are operational infrastructures that will be considered for future effluent treatment and/or disposal needs (Figure 5-1). The 200 Areas ETF is a 568-L/min (150-gal/min) mixed waste (low-level radioactive and RCRA waste) treatment facility and will be available to treat other Hanford Site dilute aqueous waste in support of the Hanford Site environmental restoration mission. To enhance the potential for the future treatment of ground water or other restoration activity waste, a second pipeline was installed along with the 200 Areas TEDF pipeline from the 200 West Area to the 200 East Area. This pipeline could be connected to the 200 Areas ETF for transportation of the effluent across the Central Plateau for treatment. Engineering and geohydrologic studies are necessary to evaluate these opportunities.

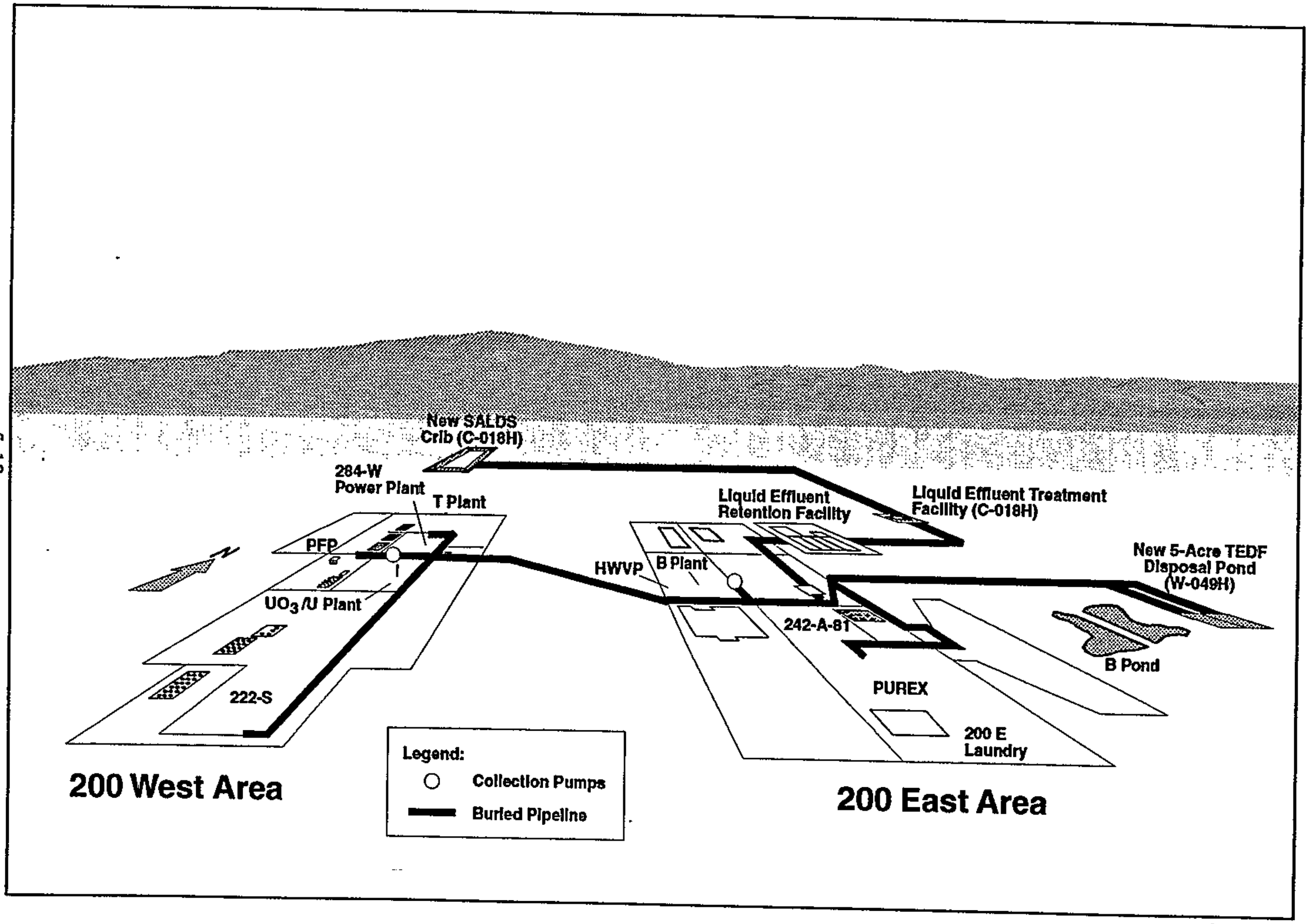


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Figure 5-1. 200 Areas Effluent Treatment Facility, Collection and Disposal Network.

5.12 IMPLEMENTATION OF A GROUND WATER REMEDIATION STRATEGY

The ground water remediation strategy provides direction for cleanup. It purposefully builds on past achievements, commitments, programs, and plans. The strategy direction can be phased in at the OU level at a pace consistent with facilitating remediation, while minimizing disruption of scheduled activities.

The value of this strategy to the implementing program is that it provides an opportunity to assess past achievements and efforts, while refining and proposing a new course of action. To the organizations outside the implementing program, the strategy presents a summary of the remediation program and its direction and thus allows for improved coordination.
A management-level coordinating group should be designated to facilitate the interaction between the remediation program and other program elements involved with liquid and solid waste disposal.

As remediation proceeds, reporting the effectiveness of the ground water remediation effort, changes in approach, and understanding of successes and failures becomes increasingly important. The following three recommendations are made:

1. Nonregulatory, interim goals be established to allow evaluation of progress

2. Preparation of an annual report summarizing and evaluating program progress

3. Prioritization of remediation efforts be coordinated by a group consisting of internal and external organizations and stakeholders impacting and being impacted by liquid effluent management and cleanup activities at the Hanford Site.

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APPENDIX

SUMMARY OF GROUND WATER REMEDIATION FIELD ACTIVITIES

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1.0 INTRODUCTION

The DOE-RL has committed to eight interim remedial and expedited response actions. These commitments were made to gain important information on the feasibility of ground water pump and treat systems to contain and clean up ground water on the Hanford Site. The following sections status the progress made in implementing the initial remediation approach described in Section 5.0 of this document. Project status is for July 1995, and all quantities are approximate. Section 4.0 of this document provides maps showing the location of each plume described in the following sections.

1.1 URANIUM AND TECHNETIUM PLUME (200-UP-1 OPERABLE UNIT)

Two existing wells were identified and a treatment system procured to test the feasibility of removing uranium and technetium from ground water. One well was used for extraction and the other for injection. The system was located near the 216-U-17 crib, southeast of the UO_3 plant. The test began in March, 1994 and continues. Since it started, the system has removed 13.8 kg of uranium and 10 kg of technetium , respectively, from 3.5 million gal of ground water. The DOE-RL has agreed to expand and redesign this pump-and-treat system to contain the plume. The new design calls for two new extraction wells and two new injection wells. The new system is scheduled to become operational by October 1995.

1.2 ORGANIC PLUME (200-ZP-1 OPERABLE UNIT)

Similarly to Section 1.1 of this Appendix, two wells were identified and a treatment system installed to also test the feasibility of removing organic contaminants from ground water. The system was located near the 216-Z-12 crib, south of the Plutonium Finishing Plant. The test began in August 1994 and continues today. It has removed 27.3 kg of CCl_4 from approximately 3 million gal of ground water. The DOE-RL has agreed to expand to a 19-well system for the purpose of containing the high concentration area of the plume. The treatment system will have a nominal capacity to treat up to 500 gal/hr of ground water. The new system is planned to become operational in stages with the initial stage starting by March 1996.

1.3 COMBINED PLUTONIUM, CESIUM-137, AND STRONTIUM-90 PLUME (200-BP-5 OPERABLE UNIT)

A pumping well was identified in the center of this very small plume along with a second nearby well to receive treated ground water. The system was located at the 216-B-5 reverse well, east of B-plant. The purpose of the test was to evaluate the feasibility of removing the above contaminants from ground water. The test was conducted from August 1994 to May 1995 and removed 6.5×10^{-4} g of plutonium, 5.7×10^{-5} g of ^{137}Cs and 8.7×10^{-5} g of ^{90}Sr from 986,000 gal of water. The DOE-RL, in conjunction with EPA and Ecology, has agreed to discontinue the pump-and-treat system for these contaminants. The limited extent of this plume, its relative immobility, coupled with its location far from the Columbia River were assumed to have sufficient information to support this conclusion.

1.4 TECHNETIUM-99 AND COBALT-60 (200-BP-5 OPERABLE UNIT)

Data collected during the construction of the ground water pump-and-treat test system indicated that the previously identified plume has decreased in concentration and may be dispersing and decaying as it moves toward the Columbia River through the Gable Mountain/Gable Butte Gap. A small pump-and-treat system was implemented to evaluate the feasibility of removing ^{90}Tc and ^{60}Co from ground water. The test was conducted from January to May 1995 and removed 0.73 g of ^{99}Tc and 1.4×10^{-7} g of ^{60}Co from 377,000 gal of water. The DOE-RL, in conjunction with EPA and Ecology, has agreed to discontinue this pump-and-treat system.

1.5 STRONTIUM-90 (N SPRINGS)

A pump-and-treat test is scheduled to begin by September 30, 1995 at N Springs. The system includes 2 injection wells, 4 extraction wells, and an ion exchange treatment system with a nominal capacity of 50 gal/minute. The purpose of the test is to evaluate the feasibility of removing ^{90}Sr from ground water at N Springs, establish cleanup standards, and to evaluate the potential for such a system to reduce the flux of ^{90}Sr to the Columbia River.

The installation of a sheet pile barrier wall using conventional pile driving was attempted between December 2 and December 30, 1994. It was concluded that this installation method would not allow the construction of barrier wall. Other tests are planned in the future.

1.6 CHROMIUM (100-HR-3 OPERABLE UNIT)

A pump-and-treat test system was installed in August 1994 to remove chromium from ground water in the 100-D Reactor Area. The pump-and-treat system continues to operate. The system has removed 13.6 kg of chromium from 3 million gal of water. The DOE-RL has decided to expand the system for the purpose of protecting aquatic species sensitive to chromium.

The DOE-RL has also decided to construct similar pump-and-treat systems in the 100-H and 100-K Reactor areas. The definition of scope and schedules for these two system has just been initiated.

1.7 OTHER ACTIVITIES

The strategy provides a broad approach and general direction for remediation activities at the Hanford Site. Since its original publication significant progress has been made in many areas. These areas include field activities (as described above), technology demonstrations, and engineering studies. A few significant ones are mentioned below:

- Examination of the feasibility of removing contaminants from ground water using barriers permeable to ground water but with the capability to remove selected contaminants.

- Annual review of the development status of tritium contaminated water treatment and control technologies under Milestone M-26-05.

- Feasibility study of the available treatment methods to remove iodine-129 from ground water under Milestone M-15-81B.

- Improved coordination, consolidation and redirection of ground water monitoring activities.

Each of these areas either provide information to make effective decisions or implement changes that allow ground water remediation to more aggressively progress at the Hanford Site.

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