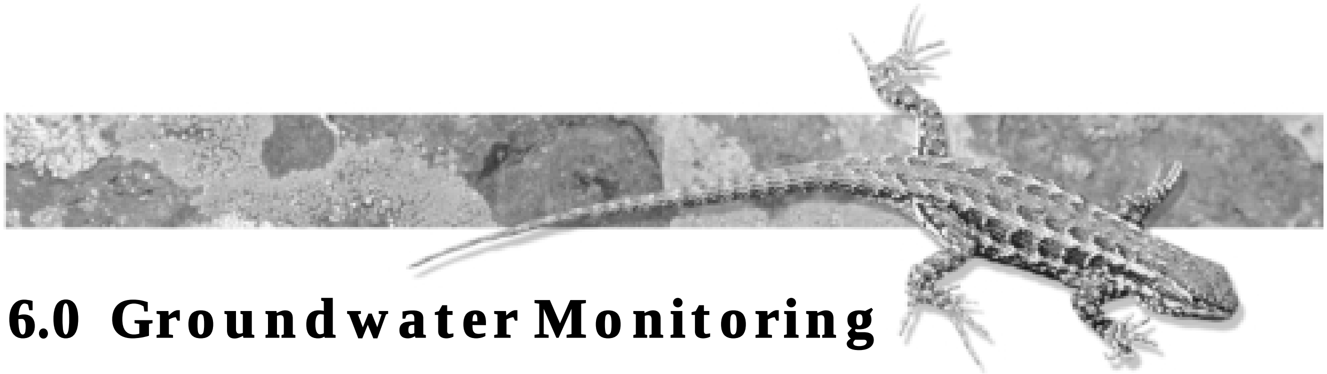

6.0 Groundwater Monitoring

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The strategy for managing and protecting groundwater resources at the Hanford Site focuses on protecting the Columbia River, human health, and the environment; treating groundwater contamination; and limiting the migration of contaminants from the 200 Areas (see DOE/RL-98-48 and DOE/RL-98-56). To support this strategy, the Hanford Groundwater Monitoring Project continues to monitor the quality of groundwater. The project, which is conducted by staff of the Pacific Northwest National Laboratory, is designed to detect and characterize new groundwater contamination and to document the distribution and movement of existing contaminant plumes. Monitoring provides the historical baseline to evaluate current and future risk from exposure to groundwater contamination and to decide on remedial options.

The Hanford Groundwater Monitoring Project includes sitewide groundwater monitoring mandated by U.S. Department of Energy (DOE) Orders and near-field groundwater monitoring conducted to assure that operations in and around specific waste disposal facilities comply with applicable regulations.

Collection and analysis of groundwater samples to determine the distribution of radiological and chemical constituents were major parts of the groundwater monitoring effort. In addition, hydrogeologic characterization and modeling of the groundwater flow system were used to assess the monitoring network and to evaluate potential effects of Hanford Site groundwater contamination. Other work included data management, interpretation, and reporting. The purpose of this section is to provide an overall summary of groundwater monitoring during 2001. Additional details concerning the Hanford Groundwater Monitoring Project are available in PNNL-13788, *Hanford Site Groundwater Monitoring for Fiscal Year 2001*.

Groundwater monitoring was conducted to accomplish the following tasks:

- assess the impact of radiological and hazardous chemicals on groundwater as a result of Hanford Site operations
- evaluate potential offsite effects from the groundwater pathway
- verify compliance with applicable environmental laws and regulations
- evaluate effectiveness of groundwater remediation
- identify and characterize new or existing groundwater quality problems
- evaluate the potential human exposure to contaminants in groundwater.

Background conditions, or the quality of groundwater on the site unaffected by operations, must be known to assess the effect of Hanford Site operations on groundwater quality. Data on the concentration of contaminants of concern in groundwater that existed before site operations began are not available. Therefore, concentrations of naturally occurring chemical and radiological constituents in groundwater sampled from wells located in areas unaffected by site operations, including upgradient locations, provide the best estimate of pre-Hanford groundwater quality. Summaries of background conditions are tabulated in several reports (PNL-6886; PNL-7120; DOE/RL-96-61; and Appendix A of WHC-EP-0595).

In 2001, groundwater samples were collected from both the unconfined and upper confined aquifers beneath the Hanford Site. The unconfined aquifer was monitored extensively because it contains contaminants from Hanford Site operations (PNNL-13788) and provides a potential pathway for contaminants to reach points of human exposure (e.g., water supply wells, Columbia River). The upper confined aquifer was monitored, though less extensively and less frequently than the unconfined aquifer, because it also provides a potential pathway for contaminants to migrate off the site. Some sampling also was conducted at the request of the Washington State Department of Health.

Sitewide groundwater monitoring is designed to meet the project objectives stated in DOE Order 5400.1

and the tasks described in the preceding paragraphs. The effects of Hanford Site operations on groundwater have been monitored for more than 50 years under this project and its predecessors. Near-field monitoring of groundwater around specific waste facilities was performed to meet the requirements of the *Resource Conservation and Recovery Act* (RCRA) (40 CFR 265) and Washington Administrative Codes (WAC 173-216; WAC 173-303; WAC 173-304) as well as applicable DOE Orders (e.g., 435.1, 5400.1, 5400.5). Groundwater monitoring was also performed in conjunction with cleanup investigations under the *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA) (40 CFR 300).

To evaluate the effect of remediation efforts on groundwater, groundwater within the contaminant plumes must be monitored to characterize and define flow patterns and trends in the concentrations of radiological or chemical constituents. Monitoring is required to quantify the existing groundwater quality problem and to provide a baseline of environmental conditions against which future changes can be assessed.

Areas that potentially could be a source of contamination also were monitored to characterize and define trends in the condition of the groundwater. These areas were monitored to identify and quantify emerging or potential problems in groundwater quality. Potential source areas included active waste disposal facilities or facilities that had generated or received waste in the past. Most of these facilities are located within the 100, 200, and 300 Areas. However, some sources such as the 618-11 burial ground are located outside these operational areas.

Water supplies on and near the Hanford Site potentially provide the most direct route for human exposure to contaminants in groundwater. In 2001, one of the site's ten DOE-owned, contractor-operated drinking water systems provided groundwater for human consumption on the site. This system supplied water at the Fast Flux Test Facility (see Section 4.3). Water supply wells used by the city of Richland are located near the site's southern boundary. Monitoring wells near these water systems were sampled routinely to assure that any potential water quality problems would be identified long before regulatory limits were reached.

Summary results for groundwater monitoring in 2001 are discussed in Section 6.1.

6.0.1 Groundwater Hydrology

Both confined and unconfined aquifers are present beneath the Hanford Site. An aquifer is a water-saturated geologic interval or unit that has a high permeability, meaning it can transmit significant quantities of water. A confined aquifer is bounded above and below by low-permeability materials that restrict the vertical movement of water. The confining layers may be dense rock, such as the central parts of basalt flows, silt, clay, or well-cemented sediment (i.e., caliche). Extensive, confined aquifers at the site are found primarily within interflows and interbeds of the Columbia River basalts.

An unconfined aquifer, or water-table aquifer, is overlain by unsaturated sediment. The upper surface of the saturated zone in an unconfined aquifer, which is called the water table, rises and falls in response to changes in the volume of water stored in the aquifer. The unconfined aquifer is bounded below either by the basalt surface or, in places, by relatively impervious clays and silts. Laterally, the unconfined aquifer is bounded by basalt ridges and by the Yakima and Columbia Rivers. The basalt ridges have a low permeability and act as a barrier to the lateral flow of groundwater where they rise above the water table (RHO-BWI-ST-5, p. II-116).

The unconfined aquifer, which forms the uppermost groundwater zone, has been directly affected by wastewater disposal at the Hanford Site. The unconfined aquifer discharges primarily into the Columbia River and is the most thoroughly monitored aquifer beneath the site. Confined aquifers are generally isolated from the unconfined aquifer by dense rock that forms the interior of the basalt flows. However, interflow between the unconfined aquifer and the confined aquifer system is known to occur at faults that bring a water-bearing interbed in contact with other sediments or where the overlying basalt has been eroded to reveal an interbed (Newcomb et al. 1972; RHO-RE-ST-12 P; WHC-MR-0391).

6.0.2 Contaminant Transport

The history of contaminant releases and the physical and chemical principles of mass transport control the distribution of radionuclides and chemicals in groundwater. Processes that control the movement of these contaminants at the Hanford Site are discussed in the following paragraphs.

Most of the groundwater contamination at the Hanford Site resulted from discharge of wastewater from reactor operations, reactor fuel fabrication, and processing of spent reactor fuel. Table 6.0.1 lists the principal contaminants found in each operational area and the type of operation that generated them. In the 100 Areas, discharges included reactor cooling water, fuel storage basin water, filter backwash, and smaller amounts of waste from a variety of other processes. In the 200 Areas, large quantities of wastewater from fuel reprocessing were discharged to the ground. Other contamination sources in the 200 Areas included plutonium purification waste and decontamination waste. The plutonium purification process resulted in the discharge of large amounts of liquid organic chemicals in addition to aqueous solutions. This has produced widespread contaminant plumes. Non-aqueous liquid may also be present, and this would result in a continuing source of contamination that is very difficult to clean up. Groundwater contamination in the 300 Area resulted mainly from discharge of waste from fuel fabrication and laboratory operations.

Liquid effluents discharged to the ground at Hanford Site facilities percolated down through the unsaturated zone toward the water table. Radionuclide and chemical constituents move through the soil column and, in some cases, enter the groundwater. In some locations, sufficient water was discharged to saturate the soil column to the surface. Not all contaminants move at the same rate as the water in the subsurface. Chemical processes such as adsorption onto soil particles, chemical precipitation, and ion exchange slow the movement of some constituents such as strontium-90, cesium-137, and plutonium-239/240. However, these processes may be affected by the chemical characteristics of the waste such as high ionic strength, acidity, or presence of chemical complexants. Other radionuclides, such as technetium-99, iodine-129, and tritium, and chemicals, such as nitrate, are not as readily retained by the soil and move vertically through the soil column at a rate nearly equal to the infiltrating water. When the contaminants reach the water table, their concentrations are reduced by dilution with groundwater. As these dissolved constituents move with the groundwater, many radionuclides and chemicals adhere to sediment particle surfaces (adsorption) or diffuse into the particles (absorption). Radionuclide concentrations are also reduced by radioactive decay.

Outside the source areas (i.e., liquid disposal sites), there is typically little or no downward gradient (driving force or head), so contamination tends to remain in the upper part of the aquifer. In the source areas, where large volumes of wastewater were discharged, a large vertical hydraulic gradient developed that moved contaminants downward in the aquifer. Layers of low-permeability silt and clay within the unconfined aquifer also limit the vertical movement of contaminants. Flow in the unconfined aquifer is generally toward the Columbia River, which acts as a drainage area for the groundwater flow system at Hanford (see Section 6.2.4). Contamination that reaches the river is further diluted by river water.

Table 6.0.1. Chemical and Radiological Groundwater Contaminants and Their Link to Site Operations

Areas	Facilities Type	Contaminants Generated
100	Reactor operations	Tritium, ^{60}Co, ^{90}Sr, hexavalent chromium, sulfate
200	Irradiated fuel processing	Tritium, ^{90}Sr, ^{99}Tc, ^{129}I, ^{137}Cs, Pu, U, cyanide, hexavalent chromium, fluoride, nitrate
200	Plutonium purification	Pu, carbon tetrachloride, chloroform, nitrate
300	Fuel fabrication	^{99}Tc, U, hexavalent chromium, trichloroethene